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July 28, 1999

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HOLDEN MINE PROJECT
WENATCHEE N.F.

USDA-Forest Service
Wenatchee National Forest
215 Melody Lane
Wenatchee, Washington 98801

Attention: Mr. Norm Day
Remedial Project Manager

Letter of Transmittal
Draft Final Remediation Investigation Report
Holden Mine Site
Chelan County, Washington
Dames & Moore Job No.: 17693-005-019

Dear Mr. Day:

On the behalf of Alumet, Inc. and David E. Jackson, the Alumet Project Coordinator, we are pleased to present for your review the attached Draft Final Remediation Investigation (RI) Report for the Holden Mine Site. The RI report includes the following volumes:

Volumes 1A and 1B - Technical report, Sections 1.0 through 11.0
Volume 4 – Technical appendices M through P

Volume 2 - Technical appendices A through K was provided to all recipients of the Draft RI Report transmitted on April 14, 1998. No changes were made to these appendices due to not receiving Agency comments specific to these portions of the report; therefore, Volume 2 has not been included herein. Volume 3 - Technical appendix L (analytical laboratory data sheets and data validation memoranda) was previously provided to select parties only as requested (Ms. Eileen Burns-Lerum-Alumet, Mr. Theodore Garrett-Covington & Burling, Mr. David Jackson-David E. Jackson & Assoc., Mr. Clay Patmont-Anchor Environmental, and Mr. Michael Bailey-Hart Crowser). Agency comments were also not received specific to this volume; therefore, Volume 3 has not been included herein.

The RI Report was completed in accordance with the current drafts of the Administrative Order on Consent (AOC) and Statement of Work (SOW), and the June 16, 1997 Draft Remedial Investigation/Feasibility Study (RI/FS) Work Plan (which was approved by the Agencies and serves as the final RI Work Plan). In addition, the Draft Final RI Report addresses Agency comments dated July 2, 1998.

Please feel free to contact Dave Jackson at (303) 838-0700 or me at (206) 728-0744 in the event of a question.

Sincerely yours,

Richard R. Langendoen
Dames & Moore Project Manager

Enclosures:
Draft RI Report, Volumes 1, 2 and 4 (4 copies each)

cc: Ms. Eileen Burns Lerum
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(1 copy each)

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DRAFT FINAL
Remedial Investigation Report
Holden Mine Site

Volume 1A – Report

prepared for
Alumet, Inc.

prepared by
Dames & Moore
Seattle, Washington

July 28, 1999

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DRAFT FINAL
Remedial Investigation Report
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EXECUTIVE SUMMARY

INTRODUCTION

The Holden Mine was operated between 1938 and 1957 by Howe Sound Company at a site located approximately 12 miles west of the boat landing at Lucerne on Lake Chelan, situated in Chelan County, Washington. The mine and mill facility processed ore removed from an underground mine on the site for offsite smelting. Since closure of the mine, potential environmental concerns were identified by the USDA-Forest Service (USFS).

The USFS attempted to address the concerns during site construction activities between 1989 and 1991. However, the agencies identified several potential concerns for further evaluation in a Remedial Investigation (RI), the most significant being: (1) the presence of compounds of potential concern in surface water, groundwater, and stream sediments in an adjacent stream (Railroad Creek); (2) the potential release of tailings pile materials into Railroad Creek resulting from erosion and possible earthquake events; (3) affects of the Site on aquatic biota and fisheries populations in Railroad Creek; and (4) wind-blown transport of, or direct exposure to compounds of potential concern in the tailings or other Site materials.

Alumet, a successor to the Howe Sound Company, has since entered into an agreement with the USFS, US Environmental Protection Agency (EPA), and the Washington State Department of Ecology (Ecology) to evaluate the potential environmental concerns.

The purpose of the RI is to:

- Further characterize the environmental setting of the Site
- Define the presence, magnitude, nature and extent of potential environmental concerns determined to be associated with historic mining activities
- Characterize potential pathways and rates of migration of compounds of potential concern on the Site
- Evaluate potential receptors of compounds of potential concern associated with the historic mining at the Site
- Characterize the stream habitat and the presence or absence of natural resource injuries
- Evaluate the analytical data generated from the investigation in terms of applicable, relevant, and appropriate regulations, including both state and federal requirements
- Provide relevant data of sufficient quality so that the Feasibility Study (FS) can evaluate cost-effective remedial alternatives to address significant environmental concerns identified on the Site.

SITE DESCRIPTION AND BACKGROUND

The Holden Mine is situated on the eastern slopes of the Cascade Mountains in the Railroad Creek watershed. The Site is situated at approximately 3,200 feet above sea level (ASL), with surrounding mountain peaks in excess of 9,000 feet ASL. The Site is remote, with access limited to boat or float plane to a boat landing at Lucerne, and to the Site via an unpaved road generally along Railroad Creek. Vegetation consists primarily of coniferous with some deciduous forest with under story. The climate in the region is characterized by warm to hot, dry summers and mild to severe winters. Mean annual precipitation at Holden is 35 inches. Approximately 77 percent of the precipitation falls in the form of snow between the months of November and March.

The geology can be summarized as a glacial, u-shaped valley carved into bedrock. The valley bottom and lower sidewalls have been covered with soil of glacial origin and deposits reworked by Railroad Creek. The mine tailings and primary waste rock piles were placed directly atop the glacial soil and/or alluvium. The general area contains a number of zones of economic mineralization, some of which were mined at the turn of the century.

The Holden Mine ore body was discovered in the late 1800s. The mine property was purchased by Howe Sound Company in the late 1920s. At the time of purchase, the mine consisted of a series of underground workings that were accessed by six portals which were developed in the area of the Site known as Honeymoon Heights. Howe Sound Company constructed two additional tunnels to access the ore body from lower on the slope. The two tunnels were constructed at the same general mine elevation (1500-level) and consisted of one used for ore haul-out and a second used for mine ventilation. Waste rock removed from the development of the 1500-level main and ventilator tunnels, which were advanced through approximately one mile of non-mineralized bedrock, exists in two piles located near the 1500-level main portal.

Approximately 60 miles of underground mine workings were developed during the period of operation. The ore removed from the mine was processed in the onsite mill to produce concentrate of principally copper and lesser amounts of zinc, gold, and silver which was shipped offsite for smelting. During the period of operation, nearly 10 million tons of tailings materials were generated. Approximately 8 million tons of tailings were placed in three piles (from west to east, tailings piles 1, 2, and 3) which cover an area of approximately 90 acres. The remainder of the tailings was backfilled into the mine during the period of mine operation. A majority of the mine openings below the lowermost mine portal near the mill building (1500-level) were backfilled.

The mine closed in 1957 and the mill building was partially salvaged. The patented mining claims were deeded to the Lutheran Bible Institute which became Holden Village, Inc., in 1961 and started an interdenominational retreat that operates to this day. The remainder of the Site outside of the patented mining claims was returned to the Forest Service when the mine closed.

After the mine closed, the lower mine workings eventually filled with groundwater and started flowing out of the lowest mine opening, the 1500-level main portal. Studies were completed by the Forest Service, starting as early as 1964, to characterize potential environmental concerns which became apparent after the mine closed. The studies included the characterization of surface water hydrology and tailings pile chemistry for revegetation, the sampling and analysis of various media, and the development of plans to address the concerns identified.

The Forest Service implemented site reclamation plans between 1989 and 1991 by covering the tailings piles with gravel to address dust generation, regrading the surfaces of the piles to improve surface water drainage, placement of streambank protection to reduce the risk of delivery of tailings materials into Railroad Creek, and the partial removal of cementation in the bottom of the Railroad Creek bed. Water flowing from the underground mine workings, or the portal drainage, was directed around the mill area and into Railroad Creek. A series of 52 groundwater monitoring wells were installed by the Pacific Northwest Laboratories (PNL) and the US Bureau of Mines (USBM) in 1991 and 1995, respectively, within the tailings piles, as well as upgradient and downgradient of the piles.

An excavation within tailings pile 1 was used as a municipal dump and intermittent sewage disposal area by both Howe Sound and Holden Village; the area was filled and covered with tailings and/or soil during the 1989 to 1991 site reclamation effort. Efforts to revegetate the surfaces of the tailings piles were initiated after the reclamation effort was completed. The southern portion of tailings pile 1, which was not disturbed during the 1989 to 1991 effort, has vegetation which dates back to studies completed in the 1960s.

Approximately 50 to 60 full-time staff currently reside in Holden Village. The village receives as many as 400 visitors daily during the summer months. The village uses the maintenance yard, initially established by Howe Sound near the mill building, for operation and maintenance of equipment. A hydroelectric plant is located north of the mill building and utilizes water from a diversion of Copper Creek above the site. Potable water is also provided by a diversion of Copper Creek above the Site. The Glacier Peak Wilderness boundary is about one mile west of the village.

REMEDIAL INVESTIGATION METHODOLOGIES

The scope of work completed during the Phase I through III RI is described in the Draft Work Plan and Sampling and Analysis Plans, and included:

- Review of historical data, including the results of studies completed from the 1960s through 1996
- Sampling and analysis of surface water, groundwater, seeps, soil, and tailings which were performed during four sampling events in April, May/June, July, and September, 1997
- A geophysical survey, including both seismic refraction and electromagnetic (EM) methods
- An assessment of seismic (liquefaction), mass wasting, and erosion potential in terms of the tailings piles
- Ecological surveys to assess the presence or absence and types of terrestrial and aquatic wildlife
- An investigation of the mine-related above-ground and underground features
- An evaluation to identify possible sources of rip rap and granular soil
- An inventory of underground storage tanks in the Winston Home Sites area and excavations to assess the presence or absence of petroleum hydrocarbon fuel products in soil
- Sampling of sediment near the mouth of Railroad Creek in Lake Chelan

- Dye tracer testing in an intermittent surface water drainage near historic mine features to assess potential surface water and groundwater pathways
- A baseline risk assessment to evaluate risk to human and ecological receptors
- Data compilation and report preparation

The nomenclature for the surface water sampling locations in Railroad Creek was developed utilizing a system initially developed by the USFS. The sampling station upstream of the Site was established as RC-1 (Railroad Creek station 1). The sampling station immediately downstream of the Site was designated RC-2, and the station at the mouth of Railroad Creek was noted as RC-3. However, subsequent stations were added during the RI as the need arose for additional data, resulting in a total of eleven Railroad Creek stations (RC-1 through RC-11) which are, therefore, not in sequential order from upstream to downstream.

KEY FINDINGS

A summary of the key findings include the following:

Host Rock Mineralogy

- The Holden Mine ore deposit is hosted by the Buckskin Schist, which is a quartz amphibole schist sequence with at least two horizons of intermittent marble beds and calcareous schists. The dominant silicates are plagioclase and biotite (aluminum-based). The primary sulfide minerals in the Holden Mine ore deposit include pyrite, pyrrhotite, sphalerite and chalcopyrite.

Site Surface Water/Groundwater Interaction and Movement

The data collected during the RI bracketed both high and low flow conditions in Railroad Creek and component inflows:

- All surface water and groundwater at the Site ultimately discharge to Railroad Creek.
- Spring Conditions - The primary component of surface water and groundwater at the Site and in the vicinity during the spring period (approximately April through July) is snowmelt. The source areas for surface water and groundwater originate upslope of the Site and in the upstream portion of Railroad Creek. Water sources flow into Railroad Creek as overland flow, base groundwater flow through the near-surface glacial sands and gravels, overland flows that infiltrates to groundwater from source areas and as groundwater surface or subsurface expressions that represent springs, seeps, or subsurface flow into the bottom of the streambed. Water enters the mine through fractures and joints. Water discharging from the 1500-level main mine portal represents the bedrock groundwater component observed at the Site. As overland flow discharges from the 1500-level main portal to the confluence of Railroad Creek, water also infiltrates to groundwater which eventually flows to Railroad Creek. The tailings pile materials have relatively low permeability; however, some water infiltrates through the surface of the tailings piles during snowmelt, precipitation events, and ponding on the surface of the piles.

- Remainder of Year - After the spring snowmelt, the amount of water flowing into the Railroad Creek from the valley sidewalls decreases significantly. The discharge from the mine portal also decreases. For the remainder of the year, the majority of water coming into contact with the base of the tailings piles is groundwater that flows generally parallel to Railroad Creek within the glacial sands and gravels; however, base groundwater flow beneath the Site continues to discharge to Railroad Creek.
- A Site-specific water balance conducted for the Site accounted for the component inflow sources to Railroad Creek.

Surface Water Quality in Railroad Creek.

- Seasonal fluctuations in the water quality were observed in Railroad Creek and a direct relationship between streamflow rates and concentrations of dissolved metals in Railroad Creek was observed, (i.e., concentrations of metals increase and decrease with increases/decreases in streamflows).
- Dissolved metal concentrations of copper, cadmium, and/or zinc were periodically above State water quality criteria in Railroad Creek adjacent to the Site from RC-4 to RC-5 between April and July 1997. Dissolved copper and/or zinc concentrations at RC-3 were above State water quality criteria in April and May 1997. Dissolved metal concentrations above State water quality criteria in Railroad Creek decline as streamflow rates decline from spring snow melt to fall. By September, State water quality criteria were slightly exceeded for copper only at RC-4 (south bank) and for zinc only at RC-4 (south bank), RC-2 and RC-5.

Component Inflow Sources and Transport Mechanisms to Railroad Creek and Geochemistry Processes

- Component inflow sources to Railroad Creek were identified and the Site geochemistry was characterized.
- Consistent geochemical processes are occurring across the Site including iron sulfide mineral oxidation, oxidation of sphalerite and chalcopyrite, and metal attenuation. Specific processes include the release of metals (iron, copper, zinc, cadmium), the release of metals exerting pH control (iron, aluminum), and differing seep chemistry for different portions of the site reflecting different rock types (mine vs. tailings). This dictates the difference between water chemistry in the east and west parts of the Site. The underground mine, waste rock piles and mill building area are dominated by the effect of residual zinc and copper mineralization, whereas the tailings piles are dominated by concentrated iron sulfides and associated iron alumino-silicates.
- Host rock mineralogy is the primary factor affecting water chemistry at the Site. Weathering of these minerals, especially sulfide minerals, dominates Site water chemistry. Non-sulfide mineralogy of the tailings is expected to be dominated by minerals contained in the ore and in diabase dikes whereas the mine wall rocks are dominated by biotite schist.

- Secondary mineralization and precipitates produced by weathering processes are visibly evident at the Site, including orange brown iron stains (iron oxyhydroxides) on waste rock and tailings, white precipitates (amorphous aluminum hydroxide) in the 1500-level main portal drainage, green stain (copper carbonate) on marble waste rock in the waste rock piles, and efflorescent crusts (metal sulfates) in the mill building and where seepage emerges along the toes of the tailings piles.

- The differences in oxygen availability and water flow in the Site source areas influence the geochemical characteristics of water quality at the Site. Portions of the underground mine are well-oxygenated through the winter months due to airflow induced by temperature differences between the underground mine and the ambient air. Active oxidation occurs in open stopes above the 1500-level of the mine. Random water flow occurs in fractures and dissolves weathering products, some of which are discharged in the 1500-level main portal drainage, and some of which are stored as salts formed by evapo-concentration. The tailings piles are only oxygenated near the surface; therefore, chemical processes leading to the release of metals occur primarily in this zone and not at depth. Acid neutralization occurs at depth in the tailings piles. Groundwater beneath the tailings piles contains reduced iron which rapidly oxidizes upon emergence in seeps, forming ferricrete and flocculent.

- The metal attenuation processes that occur downgradient of source areas prior to entering Railroad Creek include precipitation due to pH increase and aeration, efflorescence (causing seasonal formation of salts), co-precipitation of heavy metals (primarily with iron), and adsorption. Precipitation of iron, aluminum, and copper flocculent probably occurs when seeps mix with slightly alkaline Railroad Creek water and groundwater adjacent to Railroad Creek.

- Comparison of sulfate and aluminum supports the general conclusion of buffering by alumino-silicates.

- The chemical loading analyses completed during the RI accounted for the overland flow and groundwater loading sources of dissolved metals to Railroad Creek.

- Conclusions associated with the water quality and chemical loading of component inflow sources including the portal drainage, groundwater, the waste rock piles, mill building, Copper Creek diversion and seeps SP-12 and SP-23 are provided below.

Portal Drainage

Water quality measured at P-1 (main portal) and P-5 (confluence with Railroad Creek) as overland flow indicates that metals presented in the following table were above regulatory surface and groundwater quality regulatory levels.

	Locations	May 1997	July 1997	September 1997	May 1998
Surface Water Criteria	P-1	Cd, Cu, Pb, Zn, pH	Cd, Cu, Pb, Zn, pH	Cd, Cu, Zn	Cd, Cu, Pb, Zn, pH
	P-5	Cd, Cu, Pb, Zn, pH	Cd, Cu, Pb, Zn, pH	Cd, Zn, pH	Cd, Cu, Pb, Zn, pH
Groundwater Criteria	P-1	As, Be, Cd, Cu, Pb, Zn, SO_4, pH	Cd, Cu, Pb, Zn, SO_4, pH	Cd, SO_4, TDS	Cd, Cu, Fe, Pb, Zn, SO_4, TDS, pH

These dissolved metals concentrations are influenced by seasonal changes in groundwater flow discharging from the main portal. The loading analysis reflects these differences.

- May/June - The portal drainage discharge flows were as high as approximately 3.5 cubic feet per second (cfs) in May 1997 and approximately 1.8 cfs in May 1998, and accounts for more than 65 percent of the load of dissolved cadmium, copper, and zinc to the creek during the spring snowmelt period.
- October/September - Discharge flow rates were measured as low as approximately 0.10 cfs. The drainage accounts for less than 1 percent of the copper load, and approximately one-third of the cadmium and zinc load to Railroad Creek.

The portal drainage overland flow represents the primary source of dissolved copper, cadmium and zinc to Railroad Creek during spring conditions; however during the fall, the concentrations of these metals is greatly reduced.

Groundwater

The groundwater geochemistry in the east and west portions of the Site is different due to the different source rock types (mine ore deposit versus tailings) and differences in oxygen availability and water flow. Groundwater data from monitoring wells and expressed as seeps and springs were used to evaluate groundwater quality associated with the Site, particularly for the west side of the Site. Groundwater underlying the Site is not currently being used as drinking water.

West Portion of the Site

The west portion of the site includes the following source areas: underground mine and Honeymoon Heights, portal drainage, west waste rock piles, and the mill building. Groundwater monitoring wells are not present in these areas; therefore, seep water quality was used to evaluate groundwater quality exceedances, source areas and loading to Railroad Creek. Concentrations of cadmium, copper, and zinc were above the MTCA Method B levels in groundwater in the western portal of the site.

Portal Drainage

Groundwater infiltrating from the portal drainage overland flow is a component of the unaccounted load (groundwater) of copper, cadmium and zinc to Railroad Creek.

Waste Rock Piles

Several seeps flow seasonally from near the base of west and east waste rock piles. Two seeps, SP-6 and SP-15W contain concentrations of cadmium, copper, zinc, beryllium and manganese above the MTCA groundwater levels. Seeps SP-6 and SP-15W account from less than 2 percent of the cadmium, copper and zinc loading to Railroad Creek measured at RC-2. Seep SP-11 contained arsenic and SP-10E contained iron above groundwater threshold levels.

Mill Building

One primary seep, SP-7, flows seasonally from the abandoned mill building and contained cadmium, copper and zinc above MTCA groundwater levels. The seep accounts for less than 2 percent of the cadmium, 4 percent of the copper, and 2 percent of the zinc loading to Railroad Creek as measured at RC-2.

Seeps SP-12 and SP-23

Seeps SP-12 and SP-23 are assumed to represent Honeymoon Heights drainage and flow seasonally from the south bank of Railroad Creek to the west of the portal drainage. These seeps contain copper, cadmium, and zinc concentrations above MTCA groundwater levels. The two seeps combined account for approximately 8 percent of the cadmium, 31 percent of the copper, and 7 percent of the zinc loading to Railroad Creek as measured at RC-2.

The loading analysis further demonstrates that overland flow from the 1500-level main portal is the primary source area contributing dissolved cadmium, copper, and zinc concentrations to Railroad Creek. Source areas including the waste rock piles, mill building, Honeymoon Heights drainage, and groundwater infiltrating from the 1500-level main portal overland flow also contribute metals, primarily copper, cadmium and zinc to Railroad Creek, but represent significantly lower load sources as compared to the overland from the 1500-level main portal. Based on the physical characteristics of the west portion of the site, a high likelihood exists that infiltration of overland flow from the 1500-level main portal contributes to dissolved copper, cadmium and zinc to groundwater in the western portion of the site as well as to groundwater beneath the tailings piles.

East Portion of the Site

The east portion of the Site includes the tailings piles and Copper Creek diversion. The groundwater underlying the portion of the Site east of the Copper Creek diversion, including tailings piles 1, 2, and 3. Groundwater bellow the tailings piles contains concentrations of arsenic, cadmium, beryllium, copper, lead, manganese, zinc, and iron above MTCA groundwater levels. Cadmium, copper and zinc were not identified in water within the tailings which indicates that these constituents most likely originate from the western portion of the site.

Groundwater discharge from the tailings piles into Railroad Creek occurs in the form of springs or seeps and diffuse groundwater flow into the creek substrate.

- The tailings piles are the primary source of dissolved and total iron loading to Railroad Creek throughout the year.
- The precipitation of iron results in the cementing of portions of the Railroad Creek streambank, principally at three of the more prominent seep discharges near the northeast corner of tailings pile 1, and the northwest corner of tailings pile 2.
- Most of the dissolved iron from the tailings piles is converted to a fine precipitate or flocculent after it enters the stream.

Sediment Quality

The sediment in Railroad Creek consists mostly of gravel, cobbles, and boulders. The stream gradient is relatively moderate near the Site and steeper upstream and downstream of the Site; however, the gradient appears to be too steep to allow deposition of sediment. The concentrations of metals in Railroad Creek sediments do not indicated the potential for adverse effects based on Ecology guidance values. Sediment samples were collected from both the Lucerne Bar (near the mouth of Railroad Creek in Lake Chelan) and a reference site near the mouth of the Stehekin River. The results indicated concentrations of zinc slightly above FSQVs for only one sample out of 12 collected and analyzed. The remainder of the results were below the FSQVs. These results suggest a low potential for adverse effects in sediment at Lucerne Bar.

Ecological Conditions

The aquatic survey consisted of the sampling of aquatic insects (benthic macroinvertebrates) and fish at eight locations in Railroad Creek (six station adjacent and downstream of the Site, and two upstream reference or control stations) and three locations in reference streams in the Stehekin River watershed which is outside the Railroad Creek watershed. The sampling was completed during the month of September (safety considerations precluded high flow sampling during the spring melt period). The fish survey included the use of both snorkeling and electrofishing methods. The results of the sampling indicated:

- The populations of benthic macroinvertebrates and fish found adjacent to the upstream and westernmost tailings piles, but outside the area of iron-oxide flocculent, were similar to those found upstream of the Site.. This area is adjacent to the tailings pile but downstream of the portal drainage and the major sources of dissolved cadmium, copper, and zinc loading into Railroad Creek.
- The comparability of fish data collected from two of the three control stations for the mid to lower portions of Railroad Creek is questionable due to stream habitat dissimilarities. The control site for the mid-Railroad Creek segment (Bridge Creek) included a relatively deep pool in which most fish were caught. The control site for the mouth of Railroad Creek (Company Creek) was dissimilar in size and was located immediately adjacent to a salmon spawning ground.

- Benthic macroinvertebrates and fish populations were reduced in Railroad Creek within the segment of the stream with iron-oxide staining and flocculent on the substrate. This extended from the northeast corner of tailings pile 1 to station RC-5, located approximately one-half mile downstream of tailings pile 3.
- At approximately 3 miles downstream of the Site (sampling station RC-10), benthic macroinvertebrate populations were reduced in comparison to the upstream control stations. Fish populations at this station were within the range of data collected at both the control sites outside the watershed and the upstream control sites. Several young fish, which are generally less resistant to dissolved metals than adult fish, were found at this station.
- Fish populations at the mouth of the creek RC-3 were higher than those at the stations upstream of the Site, but lower than those at the Company Creek control site.
- Benthic macroinvertebrate populations near the mouth of Railroad Creek (RC-3) were reduced in comparison to upstream and control stations but had partially recovered in comparison to stations closer to the Site.
- Of the benthic macroinvertebrate species observed in Railroad Creek, "filter feeders" are present throughout Railroad Creek. Filter feeder insects are generally considered to be more sensitive than other macroinvertebrates to dissolved metals in the water column. Benthic macroinvertebrates that are generally absent downstream of the tailings piles (excluding RC-3 at the mouth) are organisms that require a clean upper stone surface (ex. "scrapers") and organisms that require open interstitial spaces for hiding. Bioassays conducted by Ecology using Cladocerans (*Ceriodaphnia*), a sensitive filter feeder, and Railroad Creek water collected from above and below the tailings piles, at RC-10, and at RC-3 indicated no adverse effects.
- The benthic macroinvertebrate species composition, and the finding that fish and macroinvertebrate populations were not reduced downstream of the major sources of dissolved cadmium, copper and zinc loading to Railroad Creek, indicate that the reductions in fish and macroinvertebrate populations adjacent to and downstream of the tailings piles observed appears to be primarily attributable to the lack of suitable habitat or food sources due to the presence of iron flocculent.

Human Health and Ecological Risk Assessment

The human health and ecological risk assessments analyzed potential risks to human and ecological receptors exposed to the compounds of potential concern within soil, surface water, groundwater, sediments, and air at the Site.

- The human health risk assessment found that the risks were acceptable for both residents and visitors to the Site based on reasonable maximum exposure scenarios.

The ecological risk assessment found that:

Trout

- An intermediate potential risk for adverse effects (HQ>1 but <100) to trout may be present due to copper concentrations in surface water in Railroad Creek adjacent to the site under both the worst-case and reasonable exposure scenarios. A small potential risk for adverse effects, downstream of the Site, due to copper was identified using the mainstream Railroad Creek water quality data under both the worst-case and reasonable exposure scenarios.
- Trout may possibly be at risk due to iron concentrations in surface water adjacent to the site under a worst-case scenario; however, no risk was identified using the median mainstream data.
- The combined results of the ERA and ecological survey suggest that reduced trout populations adjacent to the Site near RC-9 to downstream of tailings pile 3 appear to be primarily attributable to the lack of suitable habitat or food items due to the presence of flocculent, although some potential risk for adverse effects due to dissolved metals was noted.
- HQs were less than or equal to 1 for all other metals for trout.

Benthic Invertebrates

- A metals toxicity risk to benthic macroinvertebrates under the worst-case and reasonable exposure scenarios in surface water of Railroad Creek does not exist.
- A small potential risk of adverse effects may be present for benthic macroinvertebrates due to metal concentrations (copper, iron, manganese, and zinc) in sediment from Railroad Creek adjacent to and downstream of the site (HQs ranged from 1.0 to 3.0). Exceedances of sediment quality guidelines have been shown to be unreliable predictors of toxic conditions. Bioassays conducted by Ecology (1997) did not show toxicity due to metals concentrations in Railroad Creek sediment.
- An intermediate potential risk of adverse effects to benthic macroinvertebrates may be present due to metal concentrations (arsenic, cadmium, copper, iron, silver, and zinc) in flocculent adjacent to the site in Railroad Creek. It should be noted that the bioavailability and toxicity of metals in flocculent is unknown. Data from other mine sites suggest that flocculent may not be toxic. The benthic macroinvertebrate community assessment conducted during the RI within Railroad Creek, both upstream and downstream of site influences, exhibited a wide range of conditions. The presence of flocculent on and in the substrate in Railroad Creek from the lower portion of station RC-9 to downstream stations (except RC-3) has influenced the substrate by infilling the interstitial spaces and coating the surface of substrate which generally limits the establishment of periphyton. However, three new genera of pollution sensitive organisms are present at RC-7 and RC-9 and are assumed to be present due to the alteration in habitat. The benthic community at station RC-3 indicates recovering conditions. The combined results of the ERA and the Railroad Creek benthic community evaluation indicate that the reduced benthic community adjacent to the Site near RC-9 to downstream of tailings pile 3 (RC-7) is predominately attributable to the

lack of suitable habitat due to the presence of flocculent, although some potential risk for adverse effects from metal flocculent concentrations was noted.

- Under a reasonable scenario conditions, there is no risk due to metal toxicity to the birds or mammals associated with aquatic habitat near the site.

Terrestrial Exposure Pathway and Receptors of Concern

- Plants may experience toxicity from cadmium, copper, lead, and zinc in Holden Village surface soil and in the surface soils and subsurface soils of tailings piles 1, 2 and 3, the lagoon and the maintenance yard; however, when compared to soil metals concentrations at other mine sites where plants are successfully growing, only copper concentration in subsurface soils, the lagoon, and maintenance yard may present a risk of phytotoxicity.
- Earthworms may be at risk from cadmium, copper, lead and/or zinc in surface and subsurface soils at Holden Village, tailings piles, dust, lagoon and the maintenance yard under the worst-case scenario; however, suitable earthworm habitat may not exist due to the physical qualities of the substrate at the sample locations.
- Robins could be at risk from cadmium in the subsurface tailings, lagoon and maintenance yard, and from zinc in the subsurface soils, tailings pile 3, the lagoon and the maintenance yard, and from lead in the lagoon and maintenance yard based on the worst-case scenario. However, under the reasonable scenario (median concentration), there was no risk from cadmium or zinc. It is highly likely that the input parameters for the robin overestimate the actual exposure conditions because a risk was also shown for robins feeding on earthworms exposed to background concentrations of cadmium and the exposure assessment does not account for the robins relatively large forage range.
- Under normally expected conditions, there is no risk due to metals toxicity to mammals associated with terrestrial habitat near Holden Mine.

Tailings Pile Slope Stability

The slopes adjacent to Railroad Creek vary in height between 50 and 120 feet, and are relatively steep.

- The tailings pile slopes have the potential to release tailings to the creek during an earthquake event with a recurrence interval of approximately 40 years. The event would likely be limited to a maximum depth of approximately 15 feet and include only those slopes of the tailings piles facing Railroad Creek that are steeper than 34 degrees.
- The rock placed as Railroad Creek streambank protection (riprap) during the Site rehabilitation efforts performed by the USFS is weathering relatively rapidly. The height of the rock placement, as well as the size of the rock, appears marginal to protect the base of the tailings piles during a hypothetical 100-year storm event, and is likely not adequate to protect the base of the tailings piles during a hypothetical 500-year storm event.

Windblown Tailings Material

The erosion of the tailings from the piles has resulted in the deposition of the materials on the ground surface adjacent to and downwind of the Site. The majority of the windblown tailings deposits were found to be less than several millimeters in thickness. Concentrations of all metals analyzed, other than iron, were below the regulatory standard for soil. Based on the results of human health and ecological risk assessment, the potential for adverse effects from the iron concentrations was low.

Riprap and Soil Source Evaluation

An evaluation was completed to identify a source of riprap within the Railroad Creek drainage and sources of granular soil that may be needed for remedial actions. The results of the evaluation confirmed that the rock quality within the existing quarry is relatively poor. However, a potential source of higher quality rock exists nearer the Site as a talus deposit (cobble- to boulder-sized rock at the base of a bedrock outcrop). The riprap source had been eliminated by the USFS during the Site work between 1989 and 1991 due to safety considerations; however, it appears feasible to design measures to mitigate the concerns. A potential source of granular soil was identified near tailings pile 3.

Winston Home Sites Fuel Storage Tanks

The results of the evaluation of the Winston Home Sites identified up to 38 underground storage tanks (USTs) remaining in the area. No indications of petroleum hydrocarbons were noted in soils exposed in backhoe test pits excavations completed adjacent to seven of the tank locations. It was reported that some, if not all, of the tanks were pumped during the 1960s in order to supply fuel for Holden Village. All of the tanks appeared to be less than 1000 gallons in size and, therefore, not regulated as USTs. These tanks have been sufficiently evaluated.

POTENTIAL ENVIRONMENTAL CONCERNS

The following potential environmental concerns were identified at the Site:

Seasonal Exceedances of Water Quality Criteria

- The discharge of portal drainage water and Site groundwater in the western portion of the site (represented as seeps) into Railroad Creek results in exceedances of water quality criteria for cadmium, copper, lead, and zinc during the spring snowmelt period at the Site in Railroad Creek. Dissolved metal concentrations decreased as streamflow declined. By September, State water quality criteria were exceeded for copper only in a south bank sample and for zinc only at stations adjacent to and immediately downstream of the site.
- Groundwater concentrations of arsenic, beryllium, cadmium, copper, iron and manganese beneath the tailings piles are above the MTCA groundwater levels in the spring. By fall only iron and manganese are above MTCA levels.

Reduction in Benthic Macroinvertebrate and Fish Populations

- Both benthic macroinvertebrate and fish populations are reduced downstream of tailings pile 1 when compared to the control or reference sites. Fish populations remained low in comparison to reference reaches of RC-7, located adjacent to tailings pile 2, and at RC-5, located approximately one-half mile downstream of the Site. Macroinvertebrate counts were lower than reference reach counts from the Site to the mouth of Railroad Creek, but increased with distance from the Site. However, the presence of unique species of filter feeder aquatic insects in the affected reaches of Railroad Creek suggests that the dissolved metals are not the cause of the reduced macroinvertebrate populations. The reduction in benthic macroinvertebrates and fish populations adjacent to the site appears to be principally from physical effects of iron flocculent in the stream. In addition, bioassays completed by Ecology using Cladocerans (*Ceriodaphnia*), a sensitive filter feeder, and water from Railroad Creek above and below the tailings piles, RC-10 and RC-3 indicated no adverse effects.

- The fish populations at the RC-10 sampling station approximately three miles downstream of the Site are within the range of values collected at the control or reference sites. Young fish were observed at this station.

Tailings Pile Slope Stability

- Based on the results of slope stability analyses, the tailings pile slopes facing Railroad Creek are relatively stable under static conditions. However, the tailings could be released to Railroad Creek in the event of a moderate earthquake. Only the slopes steeper than approximately 34 degrees appear to be at risk. The maximum depth of a failure has been estimated to be 15 feet. The failure of a slope would likely result in the delivery of tailings material to Railroad Creek.
- The base of the tailings piles is at increased risk over time of erosion during storm events due to the continued breakdown and insufficient size of some of the rip-rap streambank protection. The erosion of the toes of the piles during a major storm event may result in the delivery of tailings materials to the creek.

Maintenance Yard

- The surface soil within the maintenance yard area exceeds MTCA levels for arsenic, cadmium, copper, iron, lead, and total petroleum hydrocarbons.
- The subsurface soil within the maintenance yard area exceeds current MTCA levels for total petroleum hydrocarbons only.

Lagoon Soils

- The surface soil within the lagoon exceeds levels for total petroleum hydrocarbons; the subsurface soil exceed MTCA levels for cadmium, copper, lead, and total petroleum hydrocarbons.

RECOMMENDATIONS FOR PHASE III DATA COLLECTION

The following scope of work has been identified by the Agencies as a data need which will require additional sampling and analysis:

Lucerne Bar Sampling

- Additional sediment sampling will be conducted in Lake Chelan near the mouth of Railroad Creek and to the east of the area sampled during the Phase III RI. The objective of the sampling and analysis will be to further characterize the nature and extent of metals concentrations in near-shore sediment. The sampling is scheduled to be completed between August and October 1999.

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ACRONYM AND ABBREVIATION GLOSSARY

ug/kg	micrograms per kilogram (same as ppb)
AOC	Administrative Order of Consent
ARAR	Applicable or Relevant and Appropriate Requirement
ARI	Analytical Resources, Inc.
AST	aboveground storage tank
AWCQ	Acute Water Quality Criteria
bgs	below ground surface
cfs	cubic feet per second
CLP	Contract Laboratory Program
COC	Contaminants of Concern
COPC	Constituents of Potential Concern
CPOM	Coarse Particular Organic Material
CSM	Conceptual Site Model
csz	Cascadia Subduction Zone
CWCQ	Chronic Water Quality Criteria
DQO	Data Quality Objectives
Ecology	Washington State Department of Ecology
EM	electromagnetic
EMSL	Electron Microscopy Services Laboratory, Inc.
EPT	Ephemeroptera, Plecoptera, and Tricoptera
ERA	Ecological Risk Assessment
ER-L	Effects Range-Low
ER-M	Effects Range-Median
FSOV	Freshwater Sediment Quality Values
FSQV	Freshwater Sediment Quality Values
GPS	Global Positioning System
HEC	Hydrologic Engineering Center
HHRA	Human Health Risk Assessment
HI	hazard index
HQ	Hazard quotient
IHS	Indicator Hazardous Substances
LEL	Lowest Effect Level
LOEC	Lowest Effect Concentration
MATC	Maximum Acceptable Toxicant Concentration
MDL	Method Detection Limit
msl	mean sea level
MTCA	Model Toxics Control Act
NAWQC	National Ambient Water Quality Criteria
NOEC	No Observed Effect Concentrations
NOV	Notice of Violation
PA	Preliminary Assessment
PAET	Probable Apparent Effects Threshold
PCB	Polychlorinated Biphenyl
PCOC	Preliminary Contaminants of Concern
PEF	Particulate Emissin Factor
PLM	Polarized Light Microscopy
PNL	Pacific Northwest Laboratory
PQL	Practical Quantitation Limit
QAPP	Quality Assurance Project Plan
RAO	Remedial Action Objectives

RBP	Rapid Bioassessment Protocols
RI/FS	Remedial Investiation/Feasibility
RME	Reasonalbe Maximum Exposure
RBP	Rapid Bioassessment Protocols
RBSL	Risk Based Screening Levels
RME	Reasonable Maximum Exposure
ROC	Receptors of Concern
ROPC	Receptors of Potential Concern
SAP	Sampling and Analysis Plan
SCL	Screening Level Concentration
SCS	Soil Conservation Service
SOW	Statement of Work
SU	standard units
TBC	To Be Considered
TPH	total petroleum hydrocarbons
TRV	Toxicity Reference Values
UCL	Upper Confidence Limit
USBM	United States Bureau of Mines
USEPA	United States Environmental Protection Agency
USFS	USDA Forest Service
USFWS	United States Fish and Wildlife Service
USGS	United States Geological Survey
UST	underground storage tank
UW	University of Washington
VVP	Variable Voltage Pulsator
WAC	Washington Administrative Code
WDFW	Washington Department of Fish & Wildlife
WDNR	Washington Department of Natural Resources
WNF	Wenatchee National Forest
WNHP	Washington Natural Heritage Program

1.0 INTRODUCTION

The Holden Mine is a former underground copper, zinc, gold and silver mine located approximately 11 miles west of the boat landing at Lucerne on Lake Chelan, situated in Chelan County, Washington (Figures 1.1-1 through 1.1-3). The Howe Sound Company operated the mine and mill between 1938 and 1957, and shipped the concentrate produced in the mill offsite for smelting. Since closure of the mine, potential environmental concerns have been identified by relevant agencies. The concerns are primarily related to the leaching of select metals from mine tailings into a nearby surface water body (Railroad Creek), the release of mine portal drainage into Railroad Creek, and the potential release of tailings materials into Railroad Creek due to erosion.

The United States Department of Agriculture-Forest Service (referred to hereafter as USFS) addressed some of the concerns during site activities between 1989 and 1991. However, the agencies continued to have concerns. Alumet, a successor to the Howe Sound Company, has entered into an agreement with the Washington State Department of Ecology (Ecology), the United States Environmental Protection Agency (EPA), and USFS (referred to hereafter as the Agencies) to address the concerns by completing studies to further characterize the Holden Mine site (referred to hereafter as the Site) and develop remedial alternatives.

This report presents the results of a Remedial Investigation (RI) conducted on behalf of Alumet Inc. at the Site. The RI was completed in accordance with:

1. The current drafts of the Administrative Order on Consent (AOC) and Statement of Work (SOW) dated April 11, 1998
2. The April 10, 1997 drafts of the April 1997 Sampling and Analysis Plan (SAP) (Dames & Moore, 1997a), Quality Assurance Project Plan (QAPP) (Dames & Moore, 1997b), and Health and Safety Plan (H&S Plan) (Dames & Moore, 1997c)
3. The May 13, 1997 drafts of the Phase I RI\SAP (Dames & Moore, 1997d), QAPP (Dames & Moore, 1997e), and H&S Plan (Dames & Moore, 1997f)
4. The June 16, 1997 Draft Remedial Investigation/Feasibility Study (RI/FS) Work Plan (Dames & Moore, 1997g)
5. The August 25, 1997 drafts of the Phase II RI SAP (Dames & Moore, 1997h), QAPP (Dames & Moore, 1997i)
6. The April 17, 1998 drafts of the Phase III RI SAP (Dames & Moore, 1998a), QAPP (Dames & Moore, 1998b), and H&S Plan (Dames & Moore, 1998c)
7. The April 27, 1998 draft of the Phase III RI SAP Addendum – Benthic Macroinvertebrates (Dames & Moore, 1998d)
8. The June 5, 1998 draft of the Phase III RI SAP Addendum – Dye Tracer Program (Dames & Moore, 1998e)

9. The August 17, 1998 draft of the Lucerne Bar Sediment Reconnaissance Plan (Dames & Moore, 1998f) and supporting figures (Dames & Moore, 1998k)

10. The August 28, 1998 draft of the Phase III RI Work Plan Addendum – Downloading Groundwater Level Data, Lagoon Area Soil Sampling, Background Soil Sampling (Dames & Moore, 1998g)

11. The September 10, 1998 draft of the Phase III RI Addendum – Stream Flow Measurements and Geologic Mapping (Dames & Moore, 1998h)

12. The October 7, 1998 draft of the Phase III RI Selection of Sediment Sampling Reference Locations (Dames & Moore, 1998j)

The agencies approved the above-mentioned plans in the following documents:

1. The March 26, 1998 Agency Comments on the Draft RI/FS Work Plan (USFS, 1998a)

2. The April 24, 1998 Agency Preliminary Comments – Phase III RI Draft SAP and QAPP (USFS, 1998b)

3. The April 30, 1998 Agency Approval of Alumet's April 27, 1998, Letter Response to Agency's Preliminary Comments – Phase III Draft SAP and QAPP (USFS, 1998c)

4. The May 29, 1998 Agency Consultant Initial Comments on Dye Tracer Program SAP (Patmont, 1998)

5. The September 22, 1998 Agency Comments on Phase III Draft SAPs Dated August 17, 1998, August 28, 1998, September 10, 1998 (USFS, 1998d)

Alumet's formal responses to Agency comments were documented in the following:

1. The April 27, 1998 Alumet Response to April 24, 1998 Agency Comments on Draft Phase III Draft SAP and QAPP (Jackson, 1998)

2. The October 5, 1998 Alumet Responses to September 22, 1998 Agency Comments on Phase III SAPs dated August 17, 1998, August 28, 1998, September 10, 1998 (Dames & Moore, 1998i)

1.1 BACKGROUND

For the purposes of the RI, the "Site" includes the general area within the Railroad Creek valley, in which Holden Mine is situated, between the upstream wilderness boundary to immediately downstream of the eastern end of the tailings piles; the "Railroad Creek watershed" includes the entire watershed area from Lyman Glacier to Lake Chelan; the "aquatic reference reaches" include one stream segment each in Bridge Creek, South Fork of Agnes Creek, and Company Creek which are located to the north of the Railroad Creek Watershed and were sampled for aquatic biota and water quality for comparison to appropriate segments of Railroad Creek; "Lucerne Bar" includes the portion of Lake Chelan near the mouth of Railroad Creek that was sampled for the analysis of sediment quality; and the "Lake Chelan sediment reference location" includes the portion of Lake Chelan near the mouth of the Stehekin River approximately 10 miles north of Lucerne.

The Holden Mine was initially developed in the late 1800s and early 1900s by Mr. J.H. Holden and companies which leased the properties from Mr. Holden. Howe Sound Company took over the assets of the mine in the late 1920s and received approval from state and federal agencies to begin operating the mine in 1938. The mill facility and most of the underground mine workings were developed on patented mining claims. All other mine-related features, including the 1500-level main portal and drainage, tailings piles, and housing, were developed and operated on National Forest System (NFS) land.

Ore materials, consisting primarily of copper, zinc, gold, and silver, were reduced to concentrate in the onsite mill and transported off site for smelting. The processing of the ore resulted in the generation of approximately 10 million tons of tailings material, of which approximately 1.5 million tons were backfilled in the mine, and the remainder was placed in three piles covering approximately 90 acres. Two waste rock piles were also generated near the mill building.

The mine operated until 1957 when economic and other factors resulted in the closure of the mine. The patented mining claims, mill and village structures were deeded by Howe Sound Company to the Lutheran Bible Institute of Seattle, Washington, in 1960, which then formed Holden Village, Incorporated in 1961.

After the mine was closed, the USFS became concerned in the mid-1960s regarding potential releases of tailings materials to the nearby Railroad Creek. Revegetation of the tailings piles was initiated at this time. The mine started filling with groundwater after mine closure and water started flowing out of the lowest mine portal sometime in the mid- to late 1960s.

A number of studies were completed in the 1960s and 1970s by the USFS which identified risks associated with potential mass release of tailings materials as a result of erosion during storm events, and potential impacts to Railroad Creek resulting from the release of mine water. Between 1989 and 1991, the USFS conducted Site activities to rehabilitate the mine tailings piles. The project included the partial regrading of the tailings piles, installation of surface water diversion structures, gravel surfacing, revegetation of the tailings pile surfaces, and other tasks.

The USFS initiated cost recovery efforts by contacting Alumet, Inc., in 1993. The Site has not been listed on the National Priority List (NPL) as a Superfund site. A Remedial Investigation/Feasibility Study (RI/FS) was initiated in 1997 by Alumet. This report summarizes the RI. The Feasibility Study (FS) will be completed subsequent to the RI after an adequate level of Site characterization has been performed to allow development and evaluation of remedial alternatives.

1.2 PURPOSE OF THE RI INVESTIGATION

The purpose of the RI is to:

- Further characterize the environmental setting of the Site
- Define the presence, magnitude, nature and extent of potential environmental concerns determined to be associated with historic mining activities

- Characterize potential pathways and rates of migration of compounds of potential concern on the Site
- Evaluate potential receptors of compounds of potential concern associated with the historic mining at the Site
- Characterize the Site for the presence or absence of natural resource injuries
- Evaluate the analytical data generated from the investigation in terms of applicable, relevant, and appropriate regulations, including both state and federal requirements
- Provide data of sufficient quantity and quality so that the FS can evaluate cost-effective remedial alternatives that will address significant environmental concerns identified on the Site

The preliminary list of remedial alternatives were presented in the Alternative Development and Screening Technical Memorandum which accompanied the Draft RI Report dated April 13, 1998. The results of alternative analyses will be presented in the FS.

1.3 REPORT ORGANIZATION

The scope of work included in this report was specified in the Draft RI/FS Work Plan dated June 1997 (Dames & Moore, 1997g). The format of the report is outlined below, and generally follows EPA guidance (1988). This report is divided into 11 Sections and Appendices as follows:

- Volume I
    - Section 1.0 - Introduction
    - Section 2.0 - Site Description and Background
    - Section 3.0 - Remedial Investigation Methodologies
    - Section 4.0 - Physical Characteristics of the Site
    - Section 5.0 - Nature and Extent of Contamination
    - Section 6.0 - Transport and Fate of Compounds of Potential Concern
    - Section 7.0 - Baseline Risk Assessment
    - Section 8.0 - Discussion and Interpretation of Findings
    - Section 9.0 - Conclusions
    - Section 10.0 - Project Schedule
    - Section 11.0 - References

Each section of the RI Report is summarized below.

Section 1.0 presents a brief history, the purpose of the RI, and highlights the report organization.

Section 2.0 presents the Site description and regulatory and investigatory history of the Site.

Section 3.0 outlines the remedial investigation methodologies used in the investigation.

Section 4.0 discusses the physical characteristics of the Site including the physical setting, geology, soil, hydrology, hydrogeology, mill and mine-related facility conditions, and ecological conditions.

Section 5.0 presents the nature and extent of compounds of potential concern in soil, surface water and sediment in Railroad Creek, relevant tributaries and Lake Chelan, and groundwater/seeps as determined from the Site characterization.

Section 6.0 discusses fate and transport of compounds of potential concern. This section relates the analysis of site-specific characteristics and identifies factors affecting migration and persistence of constituents.

Section 7.0 presents the results of the human health and ecological risk assessments.

Section 8.0 presents the RI summary with a discussion and interpretations of the findings, including the potential injuries to natural resources.

Section 9.0 presents the conclusions, and recommendations to address RI data needs.

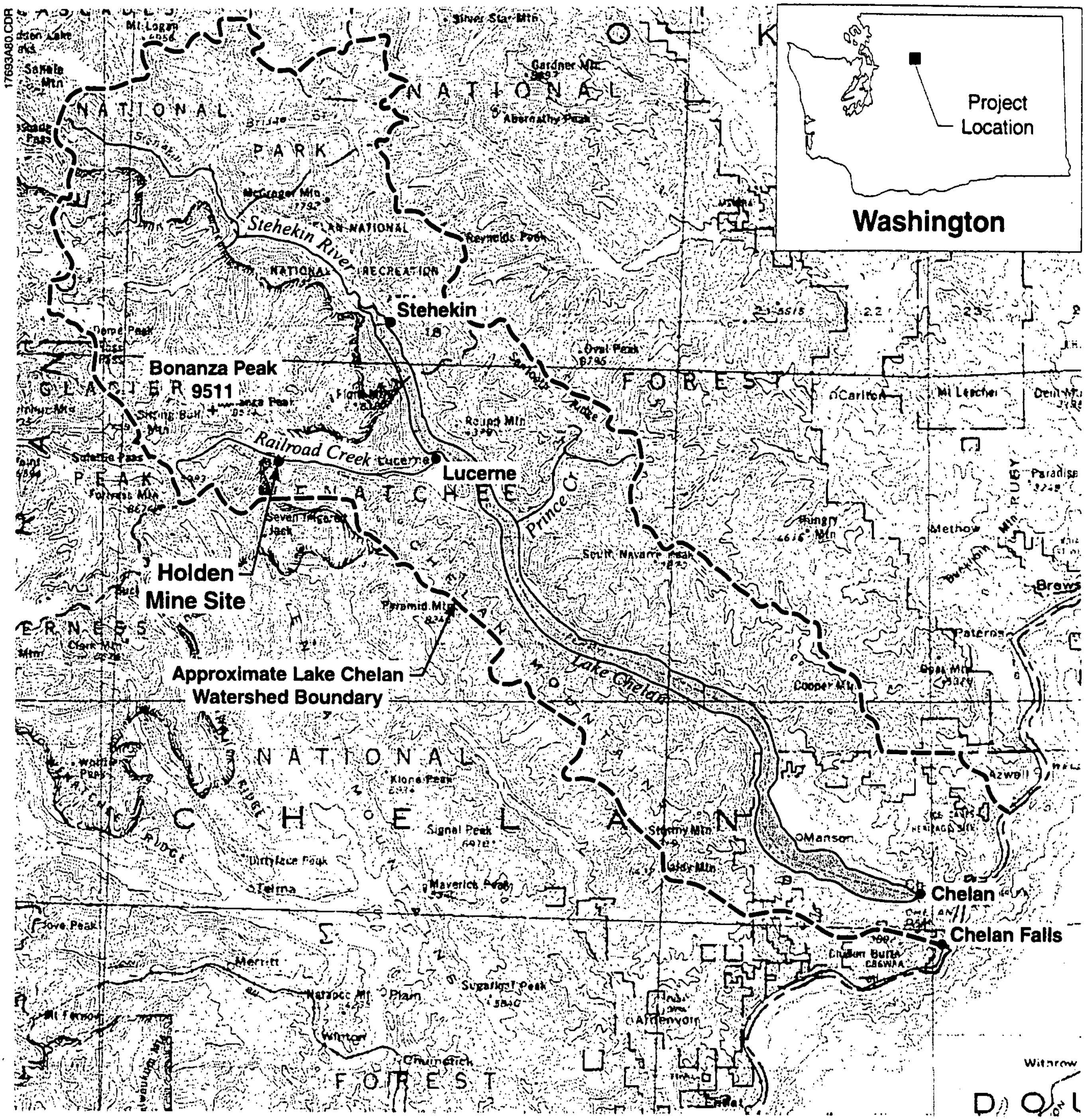
Section 10.0 presents the overall schedule of the RI/FS.

Section 11.0 presents the references utilized in the preparation of the RI.

- Volumes II, III, and IV

  Volumes II, III, and IV include the technical data used in support of the RI. Volume III presents the analytical laboratory data reports for the data collected at the Site; only select versions of this document contain this volume.

This report has been written for a wide audience, both technical and non-technical. The non-technical reader is encouraged to read the Executive Summary, Sections 1 through 3, and 8 through 11 to gain a fundamental understanding of the Site. The more technical audience will be able to gain a more detailed understanding of the Site by also reading Sections 4 through 7. As a result of this organization, some redundancy exists between sections of the report.



SOURCE: USGS Topographic Map, State of Washington, Scale 1:500,000, Compiled 1961, Revised 1982

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Figure 1.1-1

LAKE CHELAN WATERSHED MAP

Holden Mine RI/FS
Draft Final RI Report

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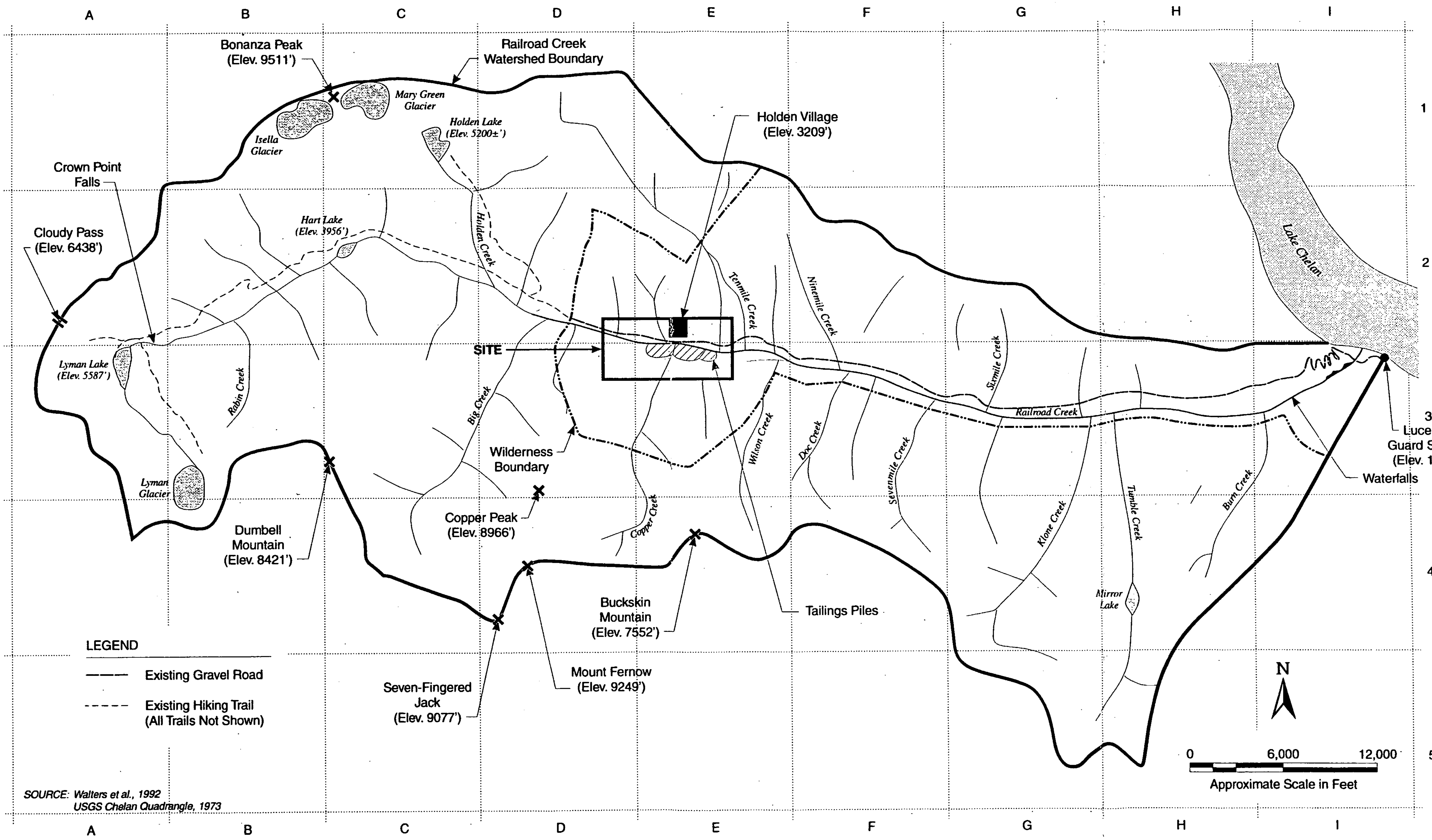

SOURCE: Walters et al., 1992
USGS Chelan Quadrangle, 1973

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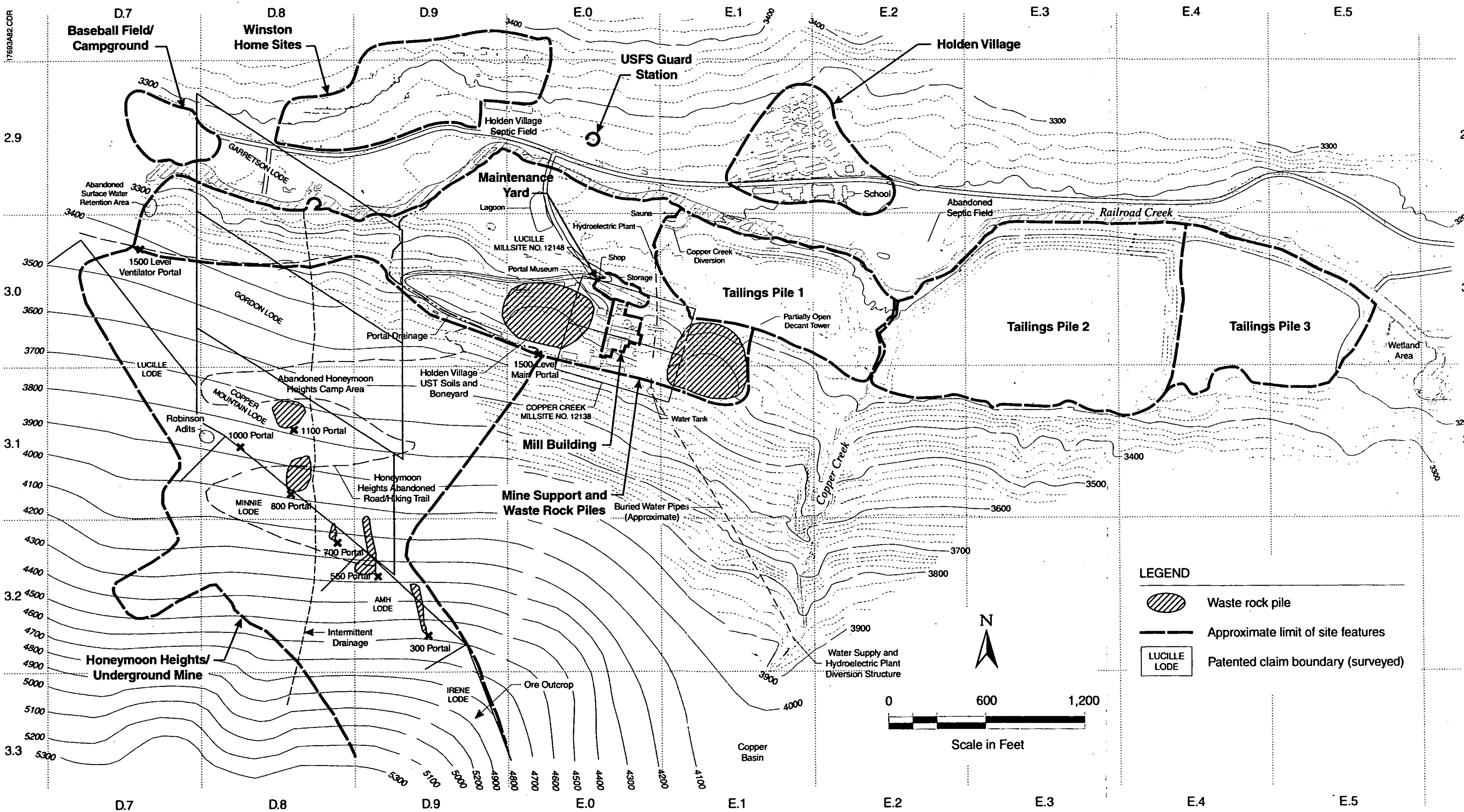
Figure 1.1-2
SITE VICINITY MAP

Holden Mine RI/FS
Draft Final RI Report



SOURCE: Base map information from USFS and Washington DNR, DEM CD ROM

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Figure 1.1-3

HOLDEN MINE SITE MAP

Holden Mine RI/FS
Draft Final RI Report

Job No. 17693-005-019

2.0 SITE DESCRIPTION AND BACKGROUND

2.1 SITE DESCRIPTION

The Holden Mine is an inactive copper, zinc, and silver mine located within the Wenatchee National Forest in north-central Washington State (Figures 2.1-1 and 2.1-2). The Site is situated within the Cascade Mountain Range approximately seven miles east of the Cascade crest. The mine was developed along Railroad Creek approximately 11 miles upstream from the creek's outlet at Lake Chelan. Physical access to the Site is provided by a gravel road from Lucerne, on Lake Chelan. Access to Lucerne is provided by commercial boats from the community of Chelan and Field's Point Landing, and float planes.

The underground mine was developed south of Railroad Creek; access was provided by a number of tunnels completed in the valley walls above the creek. A large portion of the mine-related facilities and associated tailings are situated near the floor of the steep-sided glacial valley, between the underground mine and Railroad Creek, at elevations ranging between 3,200 and 3,400 feet above mean sea level (MSL). The geology of the Site can be summarized as a glacial valley carved into bedrock in which the valley bottom and lower sidewalls have been covered with soil of glacial origin and deposits reworked by Railroad Creek. The tailings and waste rock piles were placed atop the glacial soil and alluvium. Groundwater is found perched within the glacial reworked deposits and tailings materials.

The tailings include three piles (tailings piles 1, 2, and 3) which together encompass approximately 90 acres (Figure 2.1-3) (ORB, 1975). The patented mining claims include two mill-site claims in the immediate area of the now abandoned mill facility, and 13 claims to the south, southwest, and west of the mill facility in which the ore body is located (not all of the claims are shown on Figure 2.1-3).

The Glacier Peak Wilderness generally bounds the Site to the west and south (Figure 2.1-2). Holden Village is situated immediately to the north of Railroad Creek, which generally bounds the mine property to the north. The downstream portion of the Railroad Creek watershed and Lake Chelan are east of the Site. Miscellaneous maintenance facilities associated with the village operations, as well as a mine-related museum, are located between the mill facility and Railroad Creek.

2.2 HISTORY OF SITE AND SURROUNDING AREA

2.2.1 Lake Chelan Basin

The Lake Chelan Basin has been documented to have been explored by non-native Americans in the early 1800s (Figure 2.1-1). The community of Chelan was established near the southernmost end of Lake Chelan in the mid-1800s. Commercial steamboat access up and down the lake from Chelan was started in 1889. During the 1900s, the northern portion of the basin was utilized mostly by inhabitants of Stehekin, as well as tourists, for hunting and fishing. Small farms and orchards were also established in the lower reach of the Stehekin River valley (Darvill, 1996).

Mining exploration of the area has been documented to have been initiated as early as 1875. Mineral claims were staked throughout the Stehekin River Valley and along the shores of Lake Chelan. Mine explorations, mostly shallow adits and other similar workings, were developed throughout the Stehekin River watershed. However, the difficulties of conveying the ore from mine to railroad, in conjunction with the relatively low grade of the ore and the short working season, made the mines not feasible economically, and none of the mines are in operation today (Darvill, 1996).

2.2.2 Railroad Creek Watershed

It is assumed that the Railroad Creek drainage was utilized historically for hunting and fishing by Native Americans, as well as for access to the western slopes of the Cascade Mountains (Lenz & Freiberg, 1989). There are no apparent records of the drainage being utilized by non-native Americans until discovery by J.H. Holden in 1887. The chronology of the Site from 1887 to present is summarized in the following section.

2.3 SITE DEVELOPMENT CHRONOLOGY

The following chronology is a summary of key events pertaining to the Site:

Date	Event
1887	The ore body was first discovered by J. H. Holden, who was a member of a railroad survey crew (Adams, 1981).
1892	Mr. Holden staked the first group of claims (Adams, 1981).
1897	20 mining claims were staked on the Site (Hodges, 1897). Mining claims were also staked northwest of Hart Lake (west of the Site), on Tenmile Creek, on Wilson Creek, and between Wilson Creek and Lucerne.
Early 1900s	Several unsuccessful attempts by companies formed by Holden were made in the early 1900s to develop a mine at the Site. During this time, five well-developed tunnels were completed, ore piles were developed, a mining camp was established above the valley floor (Honeymoon Heights) which included several buildings, and twelve miles of semi-completed railroad grade were completed near Lucerne (Adams, 1981).
1910s	Molybdenum was discovered and mined at Crown Point Falls, approximately 10 miles upstream of the Site near Railroad Creek; the mining discontinued with the end of World War I (1918). The development of this mine near Railroad Creek may have affected background concentrations of select metals detected in surface water today. Chelan Copper Mining Company was established as a subsidiary of Howe Sound Company and explored the ore body.
1931	As a result of concerns voiced by several conservation groups, a bench scale test was completed by Howe Sound Company to simulate the discharge of tailings-related water into Railroad Creek and to design a system that would minimize adverse impacts to trout. A study was also completed by "two well known Pacific

	Northwest mining engineer professors" to design the tailings ponds to minimize adverse impacts to Railroad Creek and the fishery (Adams, 1981).
1934	Howe Sound Company was provided a permit to utilize a portion of Railroad Creek and Copper Creek water for use in the mill and village. Plans were developed to build a transmission line from an electrical generation plant in Chelan (Adams, 1981).
1937	The concentrating plant, docks at Lucerne, shop buildings, living accommodations, 12 miles of road, and 54 miles of power line were constructed. Railroad Creek was relocated for the construction of tailings pile 1 (McWilliams, 1958).
1938	The Howe Sound Company completed construction of the mill and started production of ore concentrate. The 1500-level main portal and ventilator tunnel were established (McWilliams, 1958). The Honeymoon Heights and workings were abandoned in lieu of utilizing the 1500 main tunnel for accessing and removing portions of the ore body (Adams, 1981). The mine and mill structures were established on patented mining claims. The village, support buildings, and mine tailings piles were constructed on National Forest System (NFS) lands with the approval of the USFS.
1938-1957	During this period, the mine and mill were operated by Howe Sound. Nearly 10 million tons of tailings were generated resulting from the mining and milling of ore; approximately 8 million tons were placed in three tailings piles covering approximately 90 acres, and nearly 1.8 million tons of tailings material were used as backfill in the mine during the period of operation (McWilliams, 1958).
1960	The abandoned mine structures and 15 patented mining claims were deeded by Howe Sound Company to the Lutheran Bible Institute of Seattle, Washington (Adams, 1981).
1961	Holden Village, Incorporated was formed to manage the village as an interdenominational church retreat, which continues today (Quit Claim Deed, 1961).
1968	A Watershed Rehabilitation Plan for Railroad Creek and Copper Creek was prepared by USFS.
1970	The USFS burned down the Winston townsites for safety considerations (personal communications with Keith Anderson, formerly of the USFS, 1997); the underground storage tanks associated with the houses were not removed.
1971	Feasibility and pre-design reports were completed by USFS.
1973	Revegetation test plots were completed on tailings pile 1.

1977	An Environmental Analysis report, including three alternatives for tailings pile rehabilitation, was completed by USFS.
1982	A Decision Notice and Finding of No Significant Impact was signed by USFS to address the planned reclamation plans. A Preliminary Assessment (PA) was prepared by USEPA to assess potential environmental issues at the Site.
1986	A Preliminary Assessment (PA) was completed by Ecology to assess potential environmental issues at the Site.
1989	Pacific Northwest Laboratory (PNL) with CH2M Hill, under contract to USFS, characterized site conditions and developed a remedial design. A contractor (Del Hur) was selected for site work; the contractor started field work.
1990-91	Field work was conducted by Del Hur under the oversight of USFS. The principal work efforts completed included the covering of the tailings piles with gravel, filling in a depression near the center and removing tailings material from the edges of tailings pile 1, regrading tailings piles 2 and 3, establishing surface water run-on diversion and runoff ditches on the tailings piles, establishing revegetation plots on the surfaces of the piles, plugging of decant towers in the tailings piles, ripping of portions of the Railroad Creek substrate, and placement of rip-rap streambank protection along Railroad Creek. PNL also installed groundwater monitoring wells after construction was completed.
1995	The U.S. Bureau of Mines (USBM) installed additional groundwater monitoring wells across the Site for the USFS.
1996	Dames & Moore conducted an initial site visit on the behalf of Alumet, Inc., and completed *Existing Data Evaluation and Data Needs Assessment.*

2.4 PREVIOUS INVESTIGATIONS AND STUDIES

Table 2.4-1 is a summary of documented investigations and studies completed at the Site from the time of mine closure to present. The table focuses on those studies which were disclosed to contain data potentially of use for Site characterization. The quality of the data in terms of potential use for characterization of the Site is also presented. As noted in Table 2.4-1, a number of the studies were conducted prior to the Site restoration efforts completed by the USFS between 1989 and 1991; these studies are, therefore, not considered suitable for RI characterization because they are not representative of current Site conditions. A more detailed discussion of most of the information summarized hereafter is presented in the report prepared by Dames & Moore in September 1996, titled *Existing Data Evaluation & Data Needs Assessment, Holden Mine Site, Chelan County, Washington.* Section 11.0 References includes the complete list of documents noted in Table 2.4-1 by author and year.

2.5 SUMMARY OF ISSUES OF POTENTIAL CONCERN

Several issues of potential environmental concern have been identified at the Site by the agencies, as presented in the AOC, including the following:

- The presence of compounds of potential concern in surface and groundwater and stream sediments within the Railroad Creek watershed
- The potential release of tailings materials into Railroad Creek through erosion or possibly earthquake events
- Depletion of habitat, aquatic biota, and fisheries populations
- Wind-blown transport of, or direct exposure to compounds of potential concern in tailings or other site materials

The following sections of this report present the methods utilized to characterize the Site conditions and the results of analyses.

TABLE 2.4-1
PREVIOUS INVESTIGATIONS AND STUDIES

Year	Principal Author(s)	Summary of Investigation/Study	Use of Data
1963	Stroh	A report prepared for the USDA-Forest Service summarizing the results of sampling of the Holden Mine tailings and laboratory testing in terms of plant growth potential. The addition of lime, nitrogen, phosphorous, and potassium was noted to help plant establishment.	Data not applicable for RI Site characterization due to date of study and absence of quality assurance/quality control documentation
1966	Helmer, Hughes and Associates	Prepared a feasibility report for the USDA-Forest Service on channel improvement and erosion control for Railroad and Copper Creeks. The report included three alternatives for channel improvement and erosion control on which they based their recommendations.	Does not include data applicable for RI Site characterization
1966	Crates	A watershed rehabilitation plan was developed by the Chelan Ranger District of the Wenatchee National Forest. The plan called for rehabilitating Railroad Creek by reconstructing to contain a 50-year flood and stabilizing the tailings piles.	Does not include data applicable for RI Site characterization
1967	Krawczyk	Federal Water Pollution Control Agency issued laboratory analytical results to the U.S. Forest Service for water samples collected from Railroad Creek, the mine portal drainage, and tailing pile seepage in June and September. The analyses indicated that iron, copper, zinc and manganese levels in Railroad Creek downstream of the tailings piles at Lucerne were elevated compared to the levels detected in the upstream samples collected at the Glacier Peak Wilderness Boundary, approximately one mile upstream of the Site.	Data not applicable for RI Site characterization due to date of study, and absence of quality assurance/quality control documentation, and relatively high detection limits
1967	Krema	A report summarizing the relative abundance of fish was completed by the U.S. Department of Interior Fish and Wildlife. The report noted an absence of fish in the sample areas in Railroad Creek immediately downstream of the tailings and reduced numbers observed for an additional 2 to 3 miles downstream.	Data not applicable for RI Site characterization due to date of study and absence of quality assurance/quality control documentation
1967	Pine	The report summarized the effects of the Holden Mine tailings upon the aquatic insect fauna of Railroad Creek. The results concluded that wind erosional deposits and surface water runoff from the tailings had deposited tailings into the creek which filled the interstitial spaces between the rocks and rubble of the stream bottom, which precluded the survival of insects such as mayflies, stoneflies and caddisflies. Fish were noted to be absent in the segment of Railroad Creek near the tailings piles. The report also noted a reddish brown stain occurring on rocks below the waterline as far downstream as mile 6.3 (approximately 5 miles downstream from the Site)	Data not applicable for RI Site characterization due to date of study, absence of quality assurance/quality control documentation, and general descriptions of sample locations
1967-1980	STORET database	The database includes surface water data collected at the Site at several locations from 1967 to 1980. The parameters for which the samples were analyzed included select metals and/or bacteria.	Data not applicable for RI Site characterization due to date of sampling, absence of quality assurance/quality control, general absence of flow measurements, relatively high detection limits, and general descriptions of sample locations.
1970	Dean	An assessment of possible biological effects of the tailings was completed by the Forest Service. Analytical results of samples collected from ponded water on tailings pile 2, loose sand on top of the pile, and the outer crust and interior surface of one of the tailings piles indicated percent levels of iron, sulfur and silica were contained in the solid samples while low pH and milligram quantities of iron, sulfate, zinc, calcium and magnesium were detected in the pond water samples.	Data not applicable for RI Site characterization due to date of study and absence of quality assurance/quality control documentation

TABLE 2.4-1 (CONTINUED)
PREVIOUS INVESTIGATIONS AND STUDIES

Year	Principal Author(s)	Summary of Investigation/Study	Use of Data
1970	Thorsen	Report completed by the Washington Department of Natural Resources. Cementation through oxidation of iron sulfides and settlement appeared to have made the tailings piles at least as stable or possibly more stable than when originally emplaced. Proposed diverting Railroad Creek to remove dangers of undermining the tailings by stream erosion. Dust resulting from wind erosion of the piles did not seem to affect woody vegetation but did appear to be a barrier to reproduction by seedlings. Leachates from the tailings suspected to be present in Railroad Creek at concentrations sufficient to adversely affect aquatic life. Stream siltation by tailings appeared to be responsible for decreased insect population downstream of the tailings.	Does not include data applicable for RI Site characterization
1972	Dean	A letter prepared the U.S. Bureau of Mines regarding re-vegetation experiments on tailings pile 1. The letter concluded limited success due to the acidity of the soil; however, some native grasses were able to survive and grow on the tailings supplemented with 5 to 15 tons/acre of limestone mixed into the top two inches of tailings.	Does not include data applicable for RI Site characterization
1973	U.S. Bureau of Mines	Initiated a two-year program to seed perennial grasses and alfalfa on tailings pile No. 1. Eight continuous plots were prepared and treated with lime and milorganite (sewage sludge). The area was seeded with various grasses and fertilized with ammonium nitrate. Subsequent evaluation of the test plots indicated some grasses would do well on the treated tailings. In addition, pH measurements from each plot were higher compared to untreated plots.	Data not applicable for RI Site characterization due to date of study and absence of quality assurance/quality control.
1973	Dean and Havens	The Bureau of Mines initiated a three-year long dust bucket (particulate collectors) study in which nineteen monitoring stations were established around the Holden Mine in order to monitor air quality in regards to mine tailings erosion. The results concluded that tailings material was being eroded by wind and distributed throughout the watershed as fine dust.	Data not applicable for RI site characterization due to date of study, absence of quality assurance/quality control, general descriptions of sample locations, and sample method different than generally accepted guidance and more recent study (Air Resource Specialists, 1994)
1975	ORB	An environmental assessment of the tailings piles was conducted and recommendations presented to reclaim them. Identified areas of potential concern. Recommended establishing a rock and vegetative cover on the tailings piles after regrading to reduce erosion, diversion of runoff from the piles to limit the generation of leachate, moving Railroad and Copper Creeks away from the piles to prevent undercutting, and the development of an environmental monitoring plan.	*Geotechnical engineering data applicable for use in site characterization*
1976	Meschter	The U.S. Forest Service conducted an assessment of the value of the Holden Mine tailings piles by completing assays of boring samples collected from each of the three tailings piles. The results appeared to indicate that the tailings piles had "no known actual present or prospective economic value as a source of metals, silica flux, sulfur, or commercial silica."	Data not applicable for RI Site characterization due to date of study and absence of quality assurance/quality control documentation
1976	Wenatchee National Forest	An Environmental Assessment was completed regarding restoration and stabilization of the Holden Mine tailings. The report proposed three alternatives originally developed by ORB in 1975. Potential impacts to the environment from restoration measures were described. No significant adverse effects were anticipated.	No data applicable for RI Site characterization

TABLE 2.4-1 (CONTINUED)
PREVIOUS INVESTIGATIONS AND STUDIES

Year	Principal Author(s)	Summary of Investigation/Study	Use of Data
1977	Wenatchee National Forest	An environmental analysis of the site was completed by a team of federal, state, and local agencies. The report identified potential environmental impacts associated with the mine portal water, leachate flow, surface water erosion, and erosion from stream and wind erosion. The report also presented three treatment alternatives for further evaluation.	No data applicable for RI Site characterization
1977	Haner, Ross & Sporsen	A proposal was prepared by a consultant for Holden Village for rehabilitation of the tailings piles in general conformance with the conceptual plan developed by ORB in 1975. A scope of work was also provided for construction of a diversion dam and hydroelectric facility on Railroad Creek.	No data applicable for RI Site characterization
1980	U.S. EPA, Region X	A Potential Hazardous Waste Site Identification and Preliminary Assessment form was completed for the site. The form noted that fish in Railroad Creek had been affected by decreased invertebrates and plants in the creek bed. Sedimentation of Railroad Creek by erosion of the tailings piles was also noted.	No data applicable for RI Site characterization
1981	Wenatchee National Forest - Chelan Ranger District	A monitoring plan for the Holden Mine tailings piles was completed. The document detailed water quality monitoring as it related to Railroad Creek and the mine portal, and identified sample locations and sample frequency.	No data applicable for RI Site characterization
1982	Snyder	The existing data collected at the mine site was further assessed. Concluded that water quality data from historical studies conducted in Railroad Creek did not include sufficient test parameters, sample locations, or sample frequency to assess the magnitude of input from the tailings piles or the portal drainage. The review resulted in the development and implementation of a two-year monitoring plan.	*Data applicable for screening level RI Site characterization only due to date of study, absence of quality assurance/quality control documentation and relatively high detection limits*
1982	Washington State Dept. of Ecology, Central Region	A Potential Hazardous Waste Site Identification and Preliminary Assessment form was completed for the Site. The form noted that fish in Railroad Creek had been affected by decreased invertebrates and plants in the creek bed. Sedimentation of Railroad Creek by erosion of the tailings piles was also noted. The surface water was noted to contain sulfate, cyanide and low levels of heavy metals.	No data applicable for RI Site characterization
1982	Wenatchee National Forest	A Hazard Ranking form was completed by the U.S. Forest Service and reviewed by Ecology for the subject site. A score of 4.54% was provided after review of the site conditions.	No data applicable for RI Site characterization
1982	Wenatchee National Forest	A Decision Notice and Finding of No Significant Impact was filed by the U.S. Forest Service. The document discussed alternatives to rehabilitation of Holden Mine and stated that an environmental impact statement was not required in order to implement the rehabilitation plan.	No data applicable for RI Site characterization
1982	Wenatchee National Forest-Chelan Ranger District	Prepared an Environmental Assessment which discussed the 1977 Environmental Assessment and alternatives for rehabilitation of the mine tailings provided by ORB. The 1981 U.S. Forest Service water quality monitoring plan, based on Snyder's recommendations, was attached.	No data applicable for RI Site characterization
1982	Anderson and Benjamin	A report was prepared for the U.S. Forest Service Wenatchee National Forest-Chelan Ranger District which presented the results of Railroad Creek water quality sampling and analyses, benthic macroinvertebrate samples, and periphyton sampling and analysis. The report concluded that the benthic macroinvertebrate populations were reduced to approximately seven miles downstream of the Site. Surface water contained elevated concentrations of copper and zinc. Algae growth was observed, possibly due to the formation of complexes which reduced the metals concentrations.	*Data suitable for screening level RI Site characterization due to date of study and absence of quality assurance/quality control.*
1982	Bowhay, Washington State Department of Ecology	Completed an inspection of the site and a respective report. The report characterized the tailings piles as containing sulfate, cyanide and low levels of heavy metals and estimated quantities of eight million tons of tailings. The substances of greatest concern listed for the site were arsenic, iron, copper, cyanide and sulfate. Flora and fauna of Railroad and Copper Creek were listed as having been affected.	No data applicable for RI Site characterization

TABLE 2.4-1 (CONTINUED)
PREVIOUS INVESTIGATIONS AND STUDIES

Year	Principal Author(s)	Summary of Investigation/Study	Use of Data
1983	Wenatchee National Forest-Chelan Ranger District	Analytical results for surface water samples collected in 1982 and 1983 from Railroad Creek at various locations, Copper Creek, the mine portal, and Lake Chelan. Sampling was conducted in accordance with the monitoring plan based on Snyder's assessment in 1981. The results indicated relatively low concentrations of iron, lead, copper, and zinc in Railroad Creek, Copper Creek, and Lake Chelan. Results for samples collected from the mine portal indicated that it was a source of metal input to Railroad Creek.	*Data suitable for screening level RI Site characterization only due to date of study, absence of quality assurance/quality control documentation, and relatively high detection limits*
1984	Brown	The study reported baseline fishery information from which to prepare a fishery enhancement plan. Tributary streams were surveyed in September, 1982. Railroad Creek was included in the study and methods of fish sampling and population estimation were similar to those employed during the fall 1997 investigation.	*Data suitable for screening level RI Site characterization only due to the sampling locations selected being different than RI.*
1984	Haner, Ross & Sporseen, Inc.	An application and supporting documentation for construction of a hydro-electric power generating facility on Railroad Creek was prepared by a consultant. The application included hydrologic and geologic data as well as an environmental report which covered wildlife, environmental impacts resulting from Holden tailings, and a fish survey of Railroad Creek conducted by the Washington Department of Game in 1982.	No data applicable for RI Site characterization
1986	Science Applications International Corporation	A consultant to the Washington State Department of Ecology completed a Potential Hazardous Waste Site Preliminary Assessment of the mine site. The report presented recommendations for additional soil sampling in tailings areas and sampling of leachate and runoff from tailings piles and mine portal. Recommendations for construction of berms to prevent erosion into Railroad Creek were also presented.	No data applicable for RI Site characterization
1988	Energy and Environmental Systems Division, Argonne National Laboratory	Submitted a Draft Holden Mine Reclamation Plan Preliminary Scope of Work to the U.S. Forest Service, Wenatchee National Forest. Described the background and scope of work of the reclamation plan which provided for designing portal water treatment system, designing shape, treatment and revegetation of tailings piles, stream relocation and stabilization program, tailings stabilization assessment, environmental monitoring, and construction monitoring.	No data applicable for RI Site characterization
1988	Pacific Northwest Laboratories (PNL)	Developed a reclamation plan for the Wenatchee National Forest. PNL subcontracted to CH2M Hill of Bellevue, Washington to prepare the reclamation plans. PNL developed an environmental monitoring plan to evaluate the impacts of the mine-related elements on wind and water quality. PNL then implemented the monitoring plan.	No data applicable for RI Site characterization
1989	Peven	The purpose of this survey was to document the annual trends of kokanee and chinook production that occurs within the Lake Chelan drainage. Several drainages to Lake Chelan were surveyed. Railroad Creek is presented on the map which identifies it as a "spawner stream", however, no data are presented indicating that Railroad Creek was included in the spawning surveys.	No data applicable for RI Site characterization

TABLE 2.4-1 (CONTINUED)
PREVIOUS INVESTIGATIONS AND STUDIES

Year	Principal Author(s)	Summary of Investigation/Study	Use of Data
1989	Washington State Dept. of Ecology (Patmont et al./Harper Owes Consultants)	Prepared a Preliminary Water Quality Assessment of Lake Chelan. Describes water and sediment quality, impacts of continued growth in the region, and effects of Railroad Creek on Lake Chelan. The report concluded that Railroad Creek contributed over 80% of the zinc measured in Lake Chelan. However, water quality standards for zinc were not exceeded in samples of the lake water. The report also concluded that Railroad Creek was responsible for concentrating arsenic in deltaic sediments near the mouth of Railroad Creek due to iron binding with dissolved arsenic in lake water associated with use in orchards for pesticides and then orchard runoff into lake.	*Data suitable for screening level RI Site characterization only due to statistically low numbers of samples collected*
1989-91	PNL	Developed reclamation plans and constructed reclamation elements. Quarried limestone was placed at the mine portal and along a distance of 250 feet downstream. An intercept and runoff drainage system was constructed to reroute rainfall and snowmelt water from the adjacent hillslopes away from the tailings piles, and conveyed runoff to Railroad and Copper Creeks. The decant towers for all three piles were reportedly grouted with cement to prevent further inflow of water into the interior of the piles. Construction of an intercept channel at the base of the runoff slope, surface drainage channels on the pile surfaces, and runoff channels to collect the runoff from the other channels was completed. Quarried rock riprap was placed along the Railroad Creek bank-line at the base of the tailings piles. Placement of riprap was coordinated with fisheries habitat improvement efforts planned for the stream channel adjacent to the tailings piles. The surfaces of the tailing piles were covered with a gravel layer. Dunes at the toe of the tailings pile slopes were partially removed during reclamation. Soil amended islands were planted with trees, shrubs and herbaceous plants for vegetative monitoring following reclamation activities. PNL also characterized the fisheries habitat in Railroad Creek near the tailings pile. PNL's assessment of the habitat in Railroad Creek concluded that channel width, pool frequency and average pool size increased with distance from the Wilderness Boundary and the embeddiveness score increased from 1.5 upstream of the tailings to 2.8 downstream of the tailings. A quantitative measure of the degree of cementation of the stream bottom was not developed. However, visual surveys indicated that partial cementation of the stream bottom was observed near the tailings.	No data applicable for RI Site characterization
1989	PNL	PNL prepared a letter report to the U.S. Forest Service summarizing the construction activities on Railroad Creek. The assessment was part of the overall reclamation plan for the Holden Mine Site. The objective of the assessment was to evaluate the potential impact of construction equipment to Railroad Creek during reclamation associated construction activities. PNL reviewed available Railroad Creek hydrological and water quality data to assess the potential impact of construction activities within the creek near the tailings piles and downstream to its outlet at Lake Chelan. PNL concluded that construction activities associated with rehabilitation of the site would result in transient effects on the water quality of Railroad Creek during part of the year.	No data applicable for RI Site characterization
1989	PNL	Assessed the pH of mill tailings at the Holden Mine. Samples were collected by hand-coring the tailings surface to a depth of 1 dm. Samples were then immersed in a 1:1 solution of deionized water and the pH was measured. Eighteen samples were collected from the planted plots with pH readings in the range between 3.35 to 7.14. Six samples taken from within the raw tailings, ranged from 2.68 to 3.56.	*Data suitable for screening level RI Site characterization only due to absence of quality assurance/quality control documentation*
1989	PNL	Prepared a Draft Holden Mine Reclamation Project Water Quality Monitoring Plan for the U.S. Forest Service. The plan proposed a water quality monitoring program to document changes in the water quality of Railroad Creek during and after the construction activities associated with reclamation of the Holden Mine tailings. The report presented background water quality data, sources of contaminants to Railroad Creek, and proposed several measures to treat the mine portal effluent.	No data applicable for RI Site characterization

TABLE 2.4-1 (CONTINUED)
PREVIOUS INVESTIGATIONS AND STUDIES

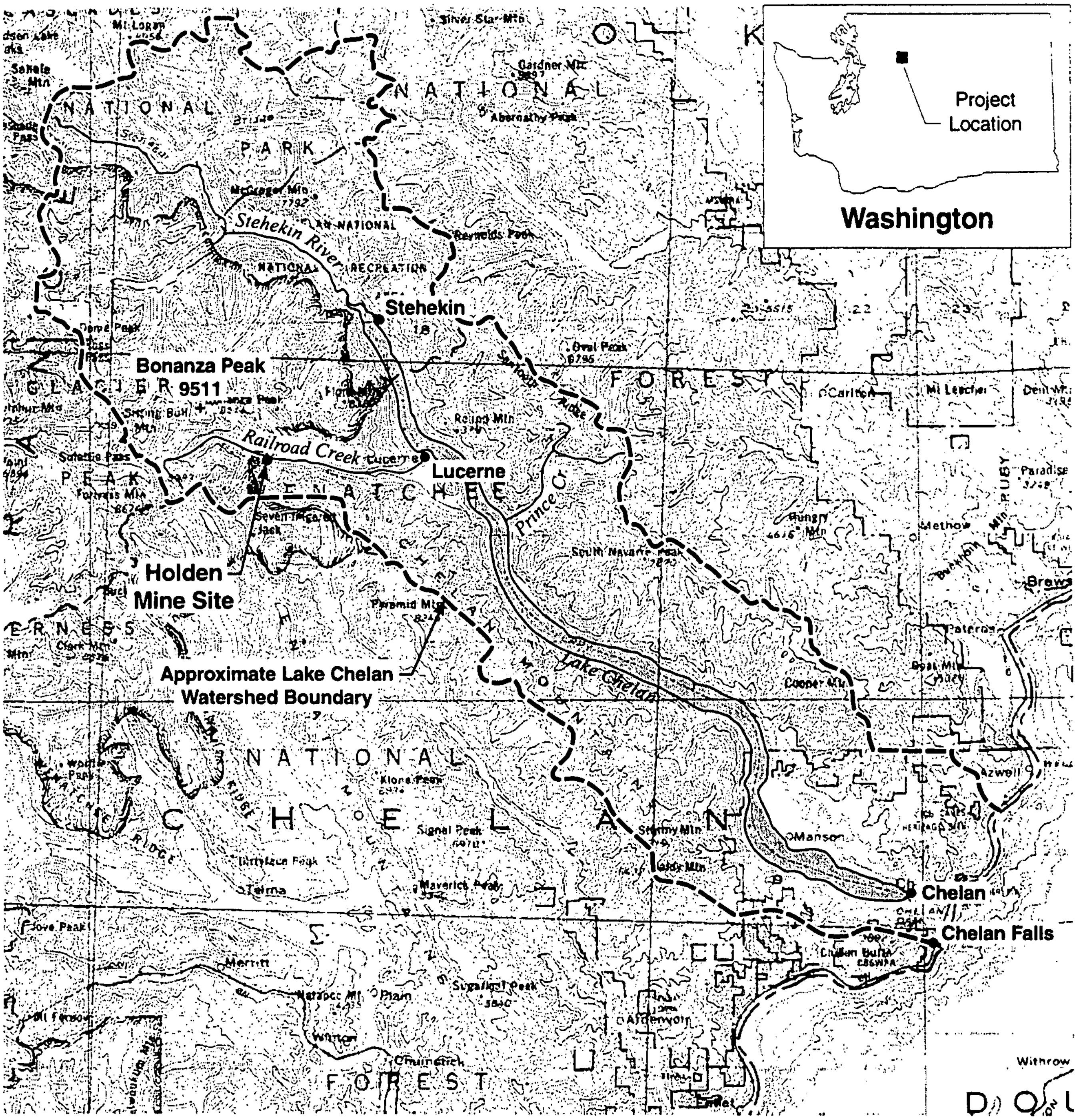
Year	Principal Author(s)	Summary of Investigation/Study	Use of Data
1989	PNL	Prepared a report which presented the results of aquatic biota data collected during October 1989 sampling in Railroad Creek as part of a Holden Mine Pre-Reclamation Baseline Study. Raw data and graphs describing fish and macro invertebrate survey in Railroad Creek prior to construction activities were presented. The data indicated a decrease in aquatic biota near the mine site.	*Data suitable for screening level RI Site characterization only due to absence of quality assurance/quality control documentation*
1989	Wenatchee National Forest	Completed a Determination of Significance and Effect form for the proposed Holden tailings pile Rehabilitation. The form provided description of project and potential environmental impacts from reclamation activities. No significant impacts were determined.	No data applicable for RI Site characterization
1990	PNL	Completed a Revised Draft Holden Mine Reclamation Project Proposed Plan for Aquatic Biota Monitoring. The plan proposed parameters for evaluation including fish abundance, macro invertebrate abundance, and algae biomass. Proposed sample locations, frequency and procedures were also provided.	No data applicable for RI Site characterization
1990	PNL	Provided a status report for the Holden Mine Reclamation Project. The report provided an overview of activities conducted by PNL and their subcontractor, CH2M Hill. Descriptions of the analysis of portal water, development of a water quality monitoring plan, and various treatment options for the mine portal drainage were provided. A liming option was considered by PNL to be an ineffective treatment option because of dilution, diminishing amounts of limestone reactant over time, and reactivity decreases due to alumina precipitation onto the limestone surface. They recommended using a "wetlands" approach to treating the effluent.	No data applicable for RI Site characterization
1990	PNL	Presented an Environmental Monitoring Plan for the Holden Mine Reclamation Project to the U.S. Forest Service in order to establish an on-site monitoring program for the Holden Mine Reclamation Project. The monitoring plan focused on identifying long-term trends following the completion of the reclamation work scheduled for 1993. It included the following monitoring plans: 1) water quality; 2) tailings interior water; 3) aquatic biota; 4) air quality; and 5) re-vegetation success of the tailings piles.	No data applicable for RI Site characterization
1991	PNL	Prepared a laboratory record book of fisheries and related water quality data for the Holden Mine Reclamation Project. The record book contained information concerning observations recorded by field personnel during sampling and other site visits during 1989 through 1991.	No data applicable for RI Site characterization
1992	PNL	Presented Environmental Water Quality Data for Railroad Creek, the mine portal drainage, and selected piezometer water samples as part of the Environmental Monitoring Plan conducted for the U.S. Forest Service. Results from selected monitoring locations above the tailings piles at the wilderness boundary, downstream of railroad creek and at Lucerne, as well as the mine portal and selected piezometer wells were presented. Results of the analysis of the water samples from Railroad Creek and the mine portal indicated continued input of metals and sulfate to Railroad Creek from the mine portal and increased concentrations of copper, lead, zinc and sulfate downstream of the tailings as compared to the upstream concentrations. The downstream concentrations were not compared to state or federal water quality standards. Piezometer chemistry data indicated that water within tailings pile 3 may originate directly from Railroad Creek since metals and sulfate levels were much lower in the deep wells.	*Data suitable for screening level RI Site characterization only due to absence of quality assurance/quality control documentation and relatively high detection limits*
1992	PNL	Presented fish tissue analysis raw data for Railroad Creek. The raw data included metal analysis of trout muscle tissue collected in 1992; the samples were analyzed in 1993 and reported by the USFS in 1998 in an unpublished document (Archibald, P.). The data indicated similar concentrations of metals in tissue from fish collected from the segment of Railroad Creek and other portions of the creek.	*Those data for which quality assurance/quality control documentation have been provided were determined to be applicable for use in Site characterization. The remaining data were determined to be suitable for screening level RI Site characterization only.*

TABLE 2.4-1 (CONTINUED)
PREVIOUS INVESTIGATIONS AND STUDIES

Year	Principal Author(s)	Summary of Investigation/Study	Use of Data
1992	PNL	Prepared a Statement of Work for the Holden Mine Reclamation Project. The scope of work included the training of USFS personnel to conduct water and air sampling at the Holden Mine site. Attached was the analytical data from 1992 water quality samples collected from Railroad Creek and the Mine Portal.	No data applicable for RI Site characterization
1992	PNL	Prepared a Draft Holden Mine Reclamation Project Final Report, which was issued to the U.S. Forest Service. The report includes results of the pre- and post-construction monitoring conducted in 1989 and 1991 and historical water quality data related to the Holden Mine. Also included were air quality data, fish and aquatic biota surveys and macro invertebrate survey results.	No data applicable for RI Site characterization
1993	Fielder	The purpose of this survey was to document the annual trends of kokanee and chinook production that occurs within the Lake Chelan drainage. Several drainages to Lake Chelan were surveyed. No data are presented indicating that Railroad Creek was included in the spawning surveys.	No data applicable for RI Site characterization
1993	Wenatchee National Forest	Presented water quality data collected from Railroad Creek in 1993. Included was water quality data for cations and anions from sampling stations RC-1, RC-2 and RC-3, and stream flow data. Samples collected from north bank only.	*Data suitable for screening level RI Site characterization only due to sampling methods employed*
1993	Scherer, Wenatchee National Forest, Forestry Sciences Lab	Presented a report of revegetation project status and results of revegetation for trials on the Holden tailings piles. The report discussed results and status of revegetation work conducted on the tailings piles. Significant variability was noted with the physical-chemical makeup of the tailing material combined with the gravel which resulted in some patches of vegetation doing well while vegetation in other areas never started growing.	No data applicable for RI Site characterization
1994	Ader, EPA Region X	A letter from EPA was presented to the U.S. Forest Service regarding additional sampling required as part of the EPA's preliminary assessment. The letter called for soil samples, tailing samples, sediment samples, and air monitoring.	No data applicable for RI Site characterization
1994	Air Resource Specialists, Inc.	A consultant to the Wenatchee National Forest completed a Monitoring and Quality Assurance Plan for the Holden Mine Tailings Air Quality Site Inspection Program, including 1) a Quality assurance and monitoring plan for collection of air quality data as part of the EPA Region 10 Preliminary Assessment conducted in 1994; and 2) a Preliminary Data Transmittal Report for the same Air Quality Site Inspection Program. The report summarized air quality data including particulate and TAL inorganic analysis.	*Data suitable for screening level RI Site characterization due to absence of quality assurance/quality control*
1994	Treclean Laboratories (USFS)	Compiled water quality data collected in Railroad Creek. A spreadsheet included sample results for RC-1, RC-2, and RC-3 along with laboratory analytical results. No QA/QC was included with data set. No information concerning stream flow was included. Analyzed for total metals only.	*Data suitable for screening level RI Site characterization only due to sampling methods employed*
1994	Parametrix	Data contained in this document is not pertinent to Railroad Creek or Lake Chelan in the vicinity of Railroad Creek. The report presents results of a creel survey focused on the lower portion of Lake Chelan (near Chelan and Manson, Washington) during the spring and summer of 1993.	No data applicable for RI Site characterization
1994	U.S. Department of the Interior Bureau of Mines	Collected interstitial fluid data from the Railroad Creek substrate between RC-4 and RC-2, and mapped iron oxide precipitates. No formal report provided; data only with no QA/QC.	*Data suitable for screening level RI Site characterization due to absence of quality assurance/quality control*
1994	USGS	The U.S. Geological Survey collected data from surface water, sediment, and concentrate samples collected in the mine area. The results indicated concentrations of selected metals above apparent background. Surface water samples were collected from south bank only.	*Surface water data suitable for screening level RI Site characterization only due to sampling methods completed. Seep data suitable for RI site characterization*
1995	Quest Environmental	Holden Village reportedly removed 12 leaking USTs discovered in the Holden Village. Approximately 2,400 cubic yards of petroleum hydrocarbon-contaminated soil removed from the UST excavation was placed on top of the waste rock pile to the west of the abandoned mill facility.	No data applicable for RI Site characterization

TABLE 2.4-1 (CONTINUED)
PREVIOUS INVESTIGATIONS AND STUDIES

Year	Principal Author(s)	Summary of Investigation/Study	Use of Data
1995	U.S. Department of the Interior Bureau of Mines	Prepared a letter to Keith Anderson with U.S. Forest Service, Wenatchee National Forest-Chelan Ranger District, describing sample locations and collection procedures for soil samples, stream substrate samples, and tailings samples collected by the Bureau of Mines in 1994 for the Forest Service in support of EPA Region X data requests as part of their Preliminary Assessment. Attached to the letter were a complete CLP data package from Laucks Testing Labs.	*Data suitable for use in Site characterization*
1995	Treclean Laboratories (USFS)	Prepared a spreadsheet and analytical report for samples collected from RC-1, RC-2, and RC-3 in Railroad Creek. Some data for P-1 and P-5 were collected, however, no stream flow data were presented. Analyzed for total metals only.	*Data suitable for screening level RI Site characterization only due to sampling methods employed*
1995	Kilburn, et al.; USGS	Collected water quality samples for analytical testing from Railroad Creek, mine tailing seeps, pond water, portal effluent, and water dripping from sulfate deposits in the mill building. Included was a map with sample locations and analytical data, but no QA/QC or other field data. Surface water samples collected from south bank only.	*Surface water data suitable for screening level RI Site characterization only due to sampling methods employed. Seep data suitable for RI site characterization*
1996	Fielder	The purpose of this survey was to document the annual trends of kokanee and chinook production that occurs within the Lake Chelan drainage. Several drainages to Lake Chelan were surveyed. No data are presented indicating that Railroad Creek was included in the spawning surveys.	No data applicable for RI Site characterization
1996	Huntamer	Collected sediment samples in Railroad Creek and analyzed by microscopical methods to conclude that tailings materials were present.	*Data suitable for screening level RI Site characterization only due to analytical methods employed*
1996	Johnson; Washington State Dept. of Ecology,	Collected water samples in Railroad Creek on June 12, 1996. Water quality data from: Railroad Creek Stations RC-1, RC-2, and RC-3; portal drainage station P-5; Copper Creek station CoC-1; and tailings seepage were presented. The data included metals and general chemistry. Also included sediment, macroinvertebrate counts, and macroinvertebrate bioassay data. No stream flow data provided.	*Data suitable for RI Site characterization*
1996	Zambowski	A graduate student at the University of Washington completed a plant uptake study on one or more of the Holden Mine tailings piles. The results indicated relatively low uptake of select metals for plants on the tailings piles	*Data suitable for screening level RI Site characterization only due to sample methods employed*
1996	U.S. EPA	Collected one soil sample in the Holden Village School Yard at the request of Holden Village residents. The sample was analyzed by Manchester Environmental Laboratory. The results indicated concentrations of metals below current action levels.	*Data suitable for screening level RI Site characterization only due to absence of quality assurance/quality control documentation*
1996	Kilburn et al.; USGS	Completed additional sampling and analytical testing of surface water, seeps, and other smaller drainages not previously sampled. The assessment provided additional information regarding water quality at the site than previously known. Surface water samples collected from south bank only.	*Surface water data suitable for screening level RI Site characterization only due to sampling methods employed. Seep data suitable for RI site characterization*
1997	Quest Environmental	The consultant to Holden Village Inc. developed a work plan to complete bio-remediation of petroleum contaminated soils by transported and treating them on the top of the waste rock pile to the east of the abandoned mill site.	No data applicable for RI Site characterization



SOURCE: *USGS Topographic Map, State of Washington, Scale 1:500,000, Compiled 1961, Revised 1982*

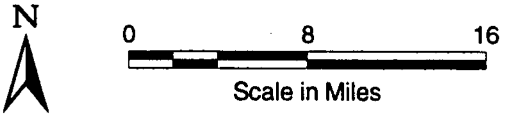


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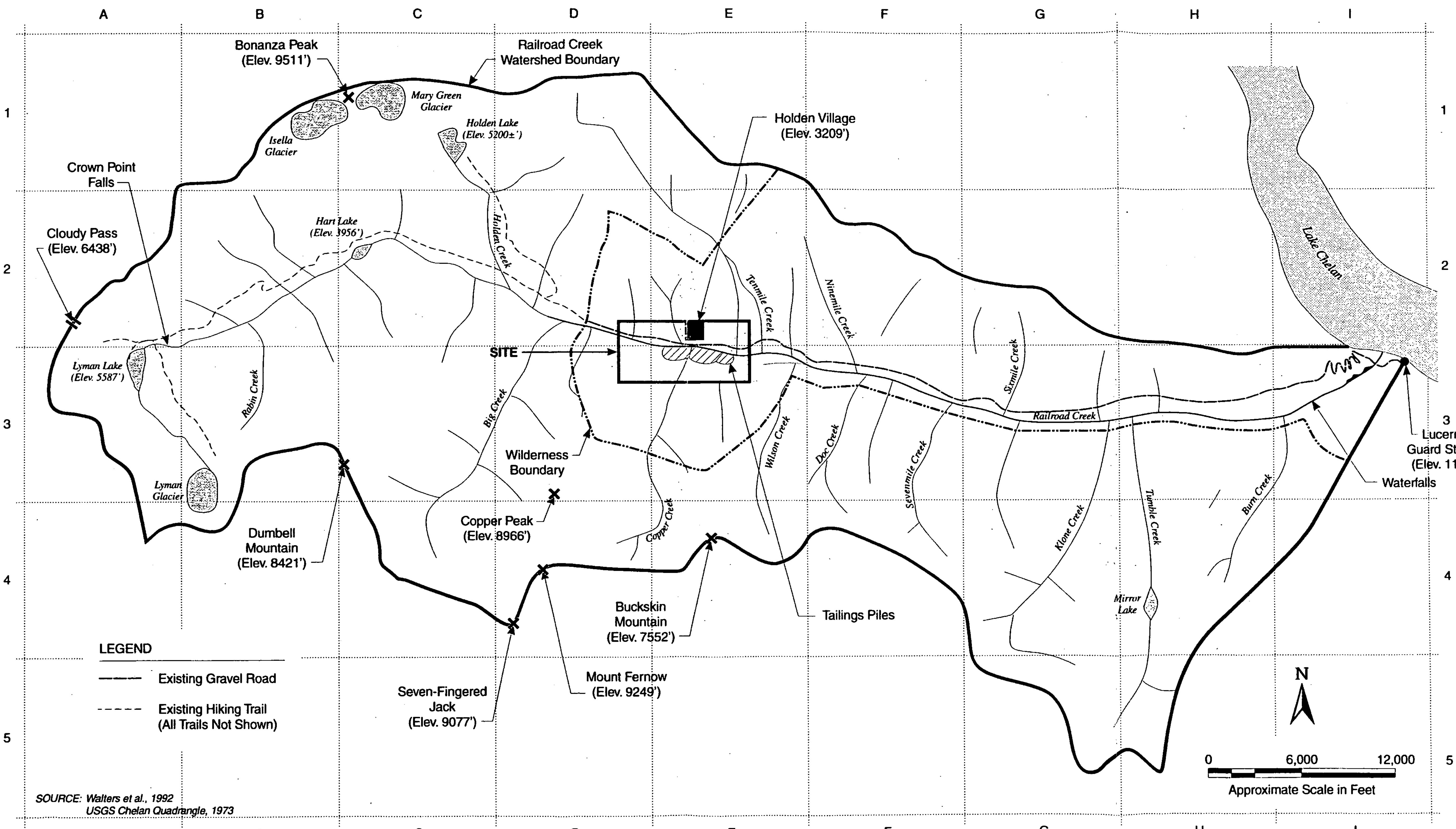
Figure 2.1-1
LAKE CHELAN WATERSHED MAP

Holden Mine RI/FS
Draft Final RI Report



SOURCE: Walters et al., 1992
USGS Chelan Quadrangle, 1973

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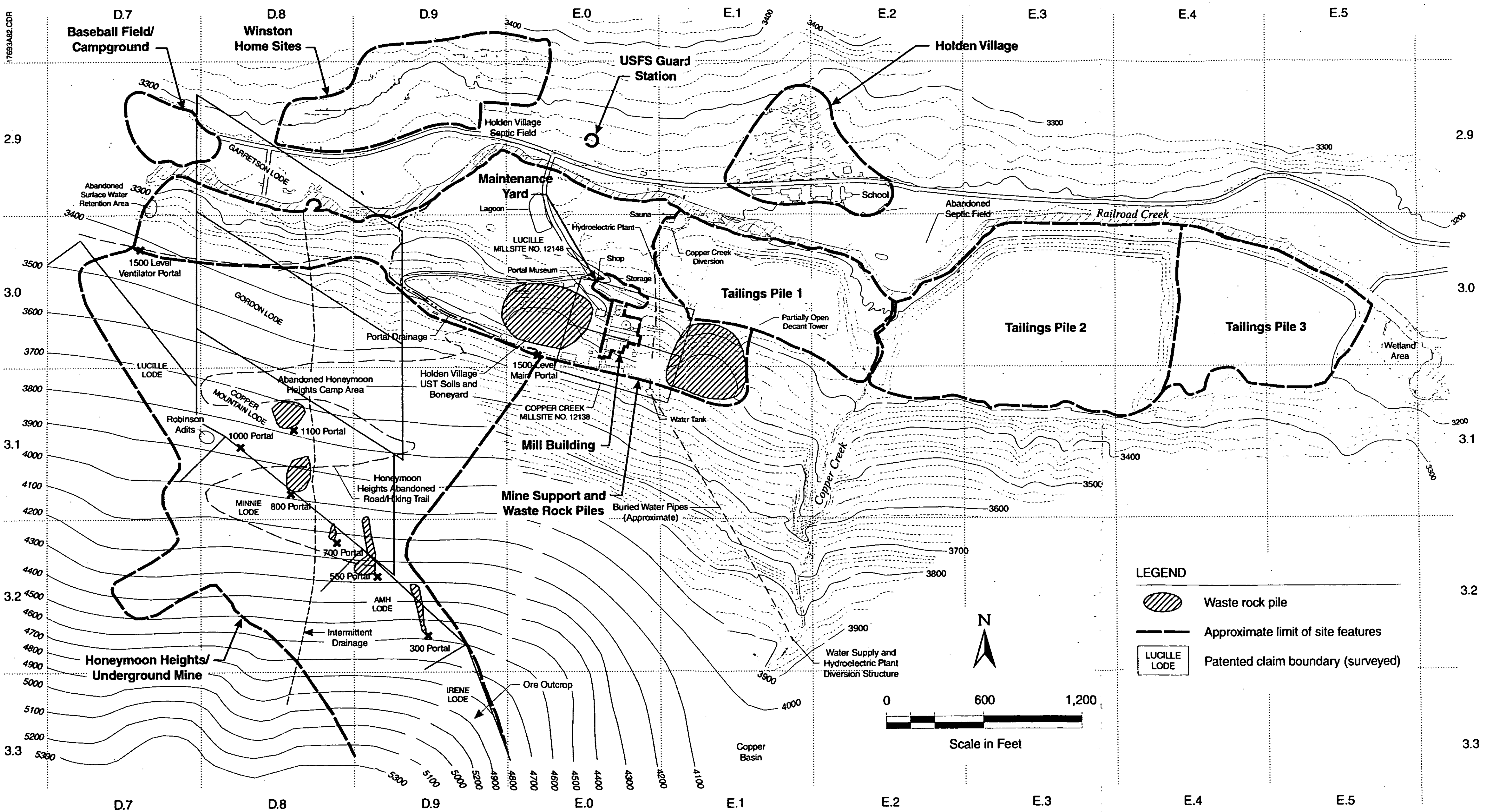
Figure 2.1-2
SITE VICINITY MAP

Holden Mine RI/FS
Draft Final RI Report

Job No. 17693-005-019



SOURCE: *Base map information from USFS and Washington DNR, DEM CD ROM*

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Figure 2.1-3
HOLDEN MINE SITE MAP

Holden Mine RI/FS
Draft Final RI Report

3.0 REMEDIAL INVESTIGATION METHODOLOGIES

This section summarizes the scope of work presented in the Draft Work Plan and Sampling and Analysis Plans completed for the Phase I, II, and III RI. The RI field investigation techniques were designed to achieve the following data quality objectives:

- Characterize the physical and chemical characteristics of groundwater and surface water directly related to the Site.
- Characterize the interrelationship of groundwater, surface water, and metals loading to Railroad Creek and refine the Conceptual Site Model.
- Characterize the impact of metals loading on surface water quality in Railroad Creek.
- Characterize the geotechnical characteristics and stability of the tailings piles in regard to natural occurrences such as floods and earthquakes.
- Better define tailings pile drainage fate and transport in Railroad Creek applicable to evaluating environmental and human health and ecological risks.
- Evaluate existing data quality based on confirmatory sampling of various media.

Field methodologies were in accordance with the Draft RI/FS Work Plan; the April 1997 and Phase I through Phase III SAPs; the QAPPs; and the H&S Plans listed in Section 1.0 of this report. The field program was performed using a phased approach. Successive phases were refined based on field and laboratory results from previous field efforts. Changes and refinements to the field program phases were discussed in technical sessions (which included representatives of Alumet and the Agencies) between field efforts. Consensus was reached between Alumet and the Agencies prior to implementing changes to the field program. The RI field program included the following:

- Surface water sampling and flow measurements
- Groundwater/seep sampling and water level and flow measurements
- Geophysical surveys
- Surface and subsurface soil sampling
- Geologic hazards assessments
- Sediment sampling
- Ecological sampling and surveys
- Dye tracer survey
- Field screening analysis
- Quality assurance/quality control

A brief description of the RI tasks and methodologies used in the RI field program are presented in this section and includes any deviations that occurred in the field as compared to the Work Plans (any deviations that occurred were verbally approved by the Agencies). A more detailed discussion is provided in the above-mentioned RI Work Plan, SAPs, and QAPPs. The locations of the areas evaluated on the Site are presented on Figures 3.0-1, 3.0-2, and 3.0-3. Table 3.0-1 presents a key of site features and media sampling/data collection locations utilizing the coordinates presented on the relevant figures.

A background of the Site history and past land uses for the different portions of the Site is presented in Section 2 of this report and in the report prepared by Dames & Moore in September 1996, titled *Existing Data Evaluation and Data Needs Assessment, Holden Mine Site, Chelan County, Washington.* Sections 4 through 8 of this report provide added detail associated with the areas evaluated and the results of laboratory and office analyses.

3.1 TASK 1 - GEOLOGY AND SOILS INVESTIGATION

3.1.1 Surface and Subsurface Soil Sampling

Referring to Figures 3.1-1 through 3.1-5 and Table 3.1-1, surface soil samples were collected throughout the area from background locations, Holden Village, the baseball field, the maintenance yard, the lagoon, tailings piles, and downwind windblown tailings material during the RI; the upwind and downwind portions of the Site were determined based on the results of studies and data from others (Air Resource Specialists, 1994, and USFS onsite weather station data). The purpose of the sampling was to characterize area background soils, and Site soils and tailings that may contain potential compounds of concern associated with the historic mining operations.

Surface soil samples are defined as 0 to 6 inches below ground surface (bgs); surface soil samples were collected from all of the above-mentioned areas. Subsurface samples were defined as being collected greater than 6 inches bgs. The subsurface soil samples were collected from the maintenance yard, lagoon, and tailings piles.

Brief descriptions of the physical locations sampled are presented hereafter. A discussion of the geology and soils related to these areas is presented in Section 4.2.3. The results of the laboratory analyses are presented in Section 5.2.

3.1.1.1 Area Background

Nineteen area surface background soil samples (DMBG-1 through DMBG-19) were collected from the Railroad Creek drainage at locations hydraulically upgradient and/or sidegradient of mine influences. The sample locations are shown on Figure 3.1-1. The samples were collected for metals analyses as presented in Table 3.1-1. The results of the analyses are presented in Section 5.2.1.

3.1.1.2 Holden Village

Seven surface soil samples (DMSS-1 through 7) were collected throughout Holden Village, including one sample from within the Holden Village vegetable garden (Figure 3.1-2). The samples were collected for metals analyses as presented in Table 3.1-1. The results of the analyses are presented in Section 5.2.2.

3.1.1.3 Baseball Field and Wilderness Boundary

One surface soil sample was collected in the area of the baseball field to the west of Holden Village and east of the wilderness boundary (DMSS-25). Two samples were also collected to the west of the wilderness boundary with the intent of establishing background metals concentrations (DMSS-26 and 27) (Figure 3.1-2); these sample locations are approximately one mile from the nearest tailings pile, and are upwind based on the prevailing wind direction reported in Air Resource Specialists, 1994, and onsite USFS weather station data. All three samples were collected for metals analyses as presented on Table 3.1-1. The results of the analyses are presented in Sections 5.2.1 and 5.2.3.

3.1.1.4 Maintenance Yard

Four surface (DMSS-8 through 10, and one sample noted as Storage 6") and three subsurface soil samples (DMSS-8 through 10) were collected in the maintenance yard area, to the northwest of the former mill facility (Figures 3.1-2 and 3.1-3). The three subsurface samples were collected at a depth of 2 feet bgs. The samples were collected for metals, total petroleum hydrocarbon (TPH), and PCB analyses as presented on Table 3.1-1. The results of the analyses are presented in Section 5.2.4.

Lagoon

One surface (Lagoon 6") and one subsurface soil sample (Lagoon 2') were collected in 1997 from the bottom of the lagoon feature located northwest of the former mill facility (Figure 3.1-2 and 3.1-3). The subsurface sample was collected at a depth of 2 feet bgs. The samples were collected for metals, TPH, and PCB analyses as presented on Table 3.1-1.

In 1998, additional subsurface samples were collected to further assess the extent of chemical constituents in the lagoon area. The samples (DMLG-1-2', DMLG-1-4', DMLG-2-4', DMLG-2-7½', DMLG-3-2', DMLG-3-4', DMLG-4-2', DMLG-4-4', DMLG-5-2', and DMLG-5-4') were collected at approximately 2-foot intervals from test pits excavated on the perimeter and center of the lagoon. Test pits were terminated when groundwater was encountered. The test pit locations are shown on Figure 3.1-3. The additional samples collected were analyzed for cadmium, copper, lead, and total petroleum hydrocarbons (TPH diesel and heavier). The results of the analyses are presented in Section 5.2.5.

Tailings Piles

Referring to Figure 3.1-2, three surface soil samples were collected from each of the tailings piles for a total of nine samples (DMSS-11 through 19). The samples were collected for metals analyses as presented on Table 3.1-1.

Subsurface soil samples were also collected from the tailings piles during the excavation of trackhoe excavated test pits and trenches completed both on top and near the base of tailings piles slopes. The following samples were collected during the excavation of the test pits and trenches: four samples from tailings piles 1 (DMTP1-2, DMTP1-3A, DMTP1-38, and DMTP1-4); three samples from tailings pile 2 (DMTP2-1A, DMTP2-1B, and DMTP2-2), and seven samples from tailings pile 3 (DMTP3-1, DMTP3-2, DMTP3-3A, DMTP3-3B, DMTP3-4A, DMTP3-4B, and a duplicate sample, DMTP3-4AX). The samples were all collected for metals analyses as presented on Table 3.1-1. The results of the analyses are presented in Section 5.2.6.2.

Wind-Blown Tailings

The approximate extent of wind-blown tailings material downwind and adjacent to the tailings piles was mapped by utilizing relatively low altitude aerial photographs (USFS, 1997) and ground truthing. Five surface soil samples (DMSS-20 through -24) were collected in areas outside of Holden Village but within the borders of wind-blown tailings material (Figure 3.1-4). Four of the samples were collected exclusively of the apparent tailings materials based on visual evidence of color and texture. One sample was collected immediately below the layer of apparent tailings material to a depth of 5 inches below the ground surface. The samples were all collected for metals analyses as presented on Table 3.1-1. The results of the mapping of the wind-blown tailings are presented in Section 4.2.6. The results of laboratory analyses are presented in Section 5.2.7.

3.1.2 Seismic Refraction Survey

Referring to Figure 3.1-2 and Table 3.0-1 (under "Geophysical Survey Lines"), seismic refraction surveys were performed by Northwest Geophysical Associates, Inc., subcontracted by Dames & Moore, to determine the thickness of tailings materials, as well as the depth to bedrock. The location and orientation of several of the seismic lines were changed to accommodate field conditions as compared to lines specified in the SAP. A total of seven seismic lines were completed.

The seismic refraction lines were conducted in a generally north-south orientation across all three tailings piles, as well as to the west of tailings pile 1, and east of tailings pile 3. One seismic line was performed across the waste rock pile to the east of the abandoned mill facility. One seismic line was also completed in a generally north-south orientation between tailings piles 1 and 2, adjacent to Copper Creek.

One seismic line was completed parallel to Railroad Creek adjacent to tailings piles 2 and 3. Three of the lines (the westernmost, center, and easternmost lines) extended across Railroad Creek to the north. The lines were extended upslope and downslope of the tailings piles when possible. Each of the lines was surveyed in the field by a subcontractor (Erlandsen & Associates) to Dames & Moore. The results of the seismic refraction survey are presented in Section 4.2.3.1 and Appendix A.

3.1.3 Exploratory Test Pits and Sampling

3.1.3.1 Tailings Piles

The primary purpose of the exploratory test pits was to visually characterize the conditions of the tailings piles near the base and tops of slopes to support seismic and slope stability analyses. The SAP outlined a program of three test pits on the tops of each tailings pile, a test pit at the toe of the northwest corner of tailings pile 1, and a test pit at the toe of the northeast corner of tailings pile 3. Test pit locations are shown on Figure 3.1-2. Due to access restrictions, the test pit intended for completion on the northwest corner of tailings pile 1 (DMTP1-1) was not completed. Three test pits were completed on tailings pile 1 (DMTP1-2, DMTP1-3, and DMTP1-4) for geotechnical evaluation. Test pits on tailings pile 2 (DMTP2-1 and 2) and tailings pile 3 (DMTP3-1 through DMTP3-4) were completed for geotechnical evaluation as well. The results of the geotechnical laboratory analyses are discussed throughout Sections 4.2.3 and 4.2.4.

The test pits were excavated utilizing a track-mounted backhoe. The excavations were completed to a maximum depth of 19 feet bgs. The test pits allowed for the sampling of the subsurface materials for laboratory testing to assess engineering characteristics. The samples were also collected for analytical laboratory testing to characterize the metals concentrations. The results of the analytical testing are presented in Section 5.2.6.2.

Additional test pits (DMTP3E-4 through 6) were completed to the east of tailings pile 3 to assess the area as a potential source of granular soil for remedial activities. Test pits (DMTP1S-1, DMTP2S-1 and DMTP3S-1) were completed to the south of each tailings pile to assess the presence or absence of glacial till soils. The results of the borrow source evaluation are presented in Section 4.2.8.

One test pit (DMTP1E-1) was completed near the toe of the northeast corner of tailings pile 1, west of the confluence of Railroad Creek and Copper Creek, to assess ferricrete formation in Railroad Creek. Three additional test pits (DMP3E-1 through -3) were completed near the toe of the northeast corner of tailings pile 3 also to assess ferricrete formation. The results of the ferricrete assessment are presented in Section 4.3.9.

Winston Home Sites

Seven test pit excavations (DMTPW-1 through -7) were completed by a track-mounted backhoe in the Winston home sites area. The purpose of the test pits was to assess the presence or absence of petroleum hydrocarbons associated with the underground storage tanks (USTs) inventoried as part of the RI, and discussed in Section 4.1.2.6. One test pit was located immediately downgradient of each of the seven tanks identified at the downslope extent of the Winston home sites area (Figures 3.1-2 and 3.1-5). Due to the Winston home sites area being part of the Holden Mine Historic District (USFS, 1991), the test pits were excavated immediately outside the mapped boundary.

Test pits were not completed cross gradient to the area as the east and west boundaries of the Winston home sites Historic Area are not clearly defined. The characteristics of the subsurface soils were documented, as well as the presence or absence of petroleum hydrocarbons based on visual and olfactory indications. The program included the sampling of soil in the event that indications of petroleum hydrocarbons were observed; however, no indications of petroleum hydrocarbons were noted and, therefore, no laboratory analyses were conducted. A discussion of the geologic conditions is presented in Section 4.2.3.

3.1.4 Borrow Source Evaluation

A borrow source evaluation was conducted with the objective of identifying possible and likely sources of rock "riprap" (rock used for streambank erosion protection) and granular soil within the Site vicinity. Referring to Figure 3.1-6, the study area was limited to those portions of the Railroad Creek watershed outside the Glacier Peak Wilderness and Holden Village areas which were considered to be a reasonable distance from the existing roads, and not constrained by physiographic features such as Railroad Creek and steep slopes. Site visits to the areas identified during a literature and aerial photograph review were completed to map and sample the outcrops of rock and/or deposits. Materials currently on the Site were evaluated for potential use as a borrow source in addition to materials in other areas of the Railroad Creek drainage. The mapping focused on the rock type, competency, fracturing and weathering characteristics, and potential quantities of overburden and material. The relative character of the rock was determined utilizing a "Schmidt" hammer, or a hammer which applies energy to the rock and measures relative resistance. The results of the evaluation are presented in Section 4.2.8.

3.1.5 Geologic Hazards Assessment

Referring to Figure 3.1-7, this task included the collection of field data for the evaluation of seismic, slope stability and erosion potential, and a riprap investigation.

3.1.5.1 Seismic Potential Assessment

As noted above, a total of nine trackhoe excavations were completed to assess the engineering characteristics of the Site soils and tailings materials. The results were utilized to analyze the potential for liquefaction and slope instability of the tailings materials during a seismic event (earthquake). The data collected from the excavations included the relative density of the material and grain size, as well as the presence or absence of saturated conditions within the tailings materials completed both on top and near the toes of the tailings piles.

Data from geotechnical engineering-related laboratory testing (grain size and moisture content per ASTM Method D2216-92 and D422-63) of soil samples collected in the field, downhole geophysical surveys conducted by a subcontractor to Dames & Moore (Northwest Geophysical Associates, Inc.) in selected wells (TP1-4A, PZ-2A, and PZ-5A), as well as data generated by others (Hart Crowser, 1975) were analyzed for use in computer analysis of liquefaction potential, as described in Section 3.11.1.1. The results of the assessment are presented in Section 4.2.4.1.

3.1.5.2 Tailings Pile Slope Stability

Referring to Figure 3.1-7, the slopes of the tailings piles facing Railroad Creek were evaluated in the field in terms of their potential for mass movement. The methods utilized were generally consistent with the guidelines established in the Mass Wasting Module of the Washington State Department of Natural Resources (WDNR) Watershed Analysis Manual (version 3.1) for Level 2 analysis. The field program focused on evaluating the slopes adjacent to Railroad Creek. The field program included the documentation and mapping of slope angles, soil types, consistency of soil surface, and indications of slope instabilities. In addition, a cursory evaluation of the avalanche chute south of tailings pile 3 was conducted using the same methodologies. The field findings were analyzed in conjunction with computer slope stability analyses which also incorporated field and laboratory data collected by others, as described in Section 3.11.1.2 (Hart Crowser, 1975). A summary of field findings and slope stability analyses are presented in Section 4.2.4.2.

3.1.5.3 Erosion Potential Assessment

The slopes of the tailings piles facing Railroad Creek were also evaluated in the field in terms of their erosion potential. The methods utilized were generally consistent with the guidelines established in the Surface Erosion Module of the Washington State Department of Natural Resources (WDNR) Watershed Analysis Manual (version 3.1) for Level 2 hillslope erosion analysis. The field program focused on the evaluation of slopes adjacent to Railroad Creek. The field program included completing backhoe test trench excavations (noted above under Section 3.1.3) and the documentation and mapping of slope angles, soil types, consistency of soil surface, and indications of hillslope erosion. The field findings were transferred to AutoCAD maps of the Site. Polygons of erosion potential were mapped in the field based on the observations. The field findings and results of office analyses are presented in Section 4.2.4.3.

3.1.5.4 Mine Subsidence Potential Assessment

Based on a review of underground mine maps for the Holden Mine, the ore body was noted to have been present within metamorphic bedrock, was nearly vertical in orientation, had a strike in a northwest-southeast direction, and a width of approximately 80 feet. The ore body was mined by developing a number of underground openings, or stopes, which are noted on mine maps. The upper limit of the underground openings are indicated on the mine maps to approach within approximately 50 feet of the ground surface. The potential for subsidence exists in these areas. The zone of mapped shallow mine workings is noted to exist in the area noted as Honeymoon Heights (Figure 3.1-7).

The mine subsidence potential assessment evaluation included mapping of the field conditions along the mapped strike of the exposed ore body, including the documentation of the following:

- Frequency and orientation of bedding, fractures, and joints
- Rock type and consistency
- Slope angles
- Vegetative cover
- Presence or absence of surface water drainages
- Indications of potential subsidence features

The data were analyzed as described in Section 3.11.2. The field findings and results of office analyses are presented in Section 4.2.5.

3.1.5.5 Existing Riprap Investigation

A visual assessment of the existing riprap was conducted for the sections of Railroad Creek and Copper Creeks adjacent to the three tailings piles (Figure 3.1-7). During the reconnaissance, the riprap condition was characterized for each section (as defined in the Erosion Potential subsection above). The characterization included a reach by reach assessment of the predominant and maximum boulder size, boulder lithologic color and composition, and weathering characteristics. Boulder types were classified into six different types on the basis of lithologic composition and weathering condition. In addition, Schmidt-hammer tests were performed on representative boulder types to assess the relative hardness and competency of each riprap type. This information was used by Dames & Moore in estimating the quality of the riprap for each slope reach. The data collected in the field were utilized to complete an office analysis of whether the riprap is sufficient to protect the toes of the tailings pile slopes from erosion by Railroad Creek and Copper Creek. The field findings and results of the office analyses are presented in Section 4.2.7.

3.2 TASK 2 - HYDROLOGIC INVESTIGATION

Referring to Figures 3.2-1 and 3.2-2, the RI hydrologic investigation was designed to provide a comprehensive database in support of the feasibility study and ecological risk assessment, as well as augment the existing hydrologic information for the Site. The hydrologic database also provided a means to evaluate conditions in Railroad Creek in the vicinity of the Site as they relate to the regional hydrologic setting. The overall objective of the hydrologic investigation was to collect sufficient surface water quality and streamflow data, watershed and geomorphologic information to characterize and identify:

- Background water quality conditions upstream of the Site
- Potential compounds of concern in Railroad Creek
- Seasonal variability of flow and water quality in Railroad Creek along and downstream of the Site
- Flow and water quality relationships in Railroad Creek along and downstream of the Site
- Interaction between groundwater and surface water on the Site
- Sediment conditions and potential for channel erosion in Railroad Creek on the Site
- Possible water quality and streamflow trends in Railroad Creek that are related to the mine

The hydrologic investigation included the following elements:

- Streamflow surveys
- Water Quality Sampling
- Geomorphologic Surveys
- Water Balance, Watershed Evaluation and Hydrogeologic Synthesis
- Hydrologic Analysis and Synthesis

Referring to Figures 3.2-1 and 3.2-2, the nomenclature for the surface water sampling locations in Railroad Creek utilized a system initially developed by the USFS. The sampling station upstream of the Site was initially established by the USFS as RC-1 (Railroad Creek station 1). The sampling station immediately downstream of the Site was designated RC-2, and the station near the mouth of Railroad Creek at Lucerne was noted as RC-3. However, subsequent stations were added during the RI as the need arose for additional data, resulting in a total of 11 Railroad Creek stations (RC-1 through RC-11). Consequently, the nomenclature of the stations is not in numerical order from upstream to downstream. The need to compare the RI data with historical data precluded the ability to renumber the stations. It should be noted that water quality samples were not collected at station RC-9; this station was used for the aquatic habitat survey only.

In addition to the Railroad Creek sampling stations, surface water quality stations were also established on the 1500-level main portal drainage, the Copper Creek diversion, Copper Creek, Tenmile Creek, Big Creek and Holden Creek in order to assess potential loading sources, upstream water quality, and tributary water quality. Water quality and streamflow data were also collected from three reference streams located outside of the Railroad Creek watershed (Bridge Creek, South Fork Agnes Creek, and Company Creek).

3.2.1 Streamflow Surveys

Streamflow surveys were conducted during the April, May/June, July, and September/October 1997 and May 1998 sampling events. However, the April 1997 sampling event included the survey of Railroad Creek only due to the presence of snow cover, which precluded access to the other water bodies noted above.

The streamflow survey consists of flow measurements in Railroad Creek, Copper Creek and selected tributaries and out of basin streams. A flow measurement was attempted each time a surface water quality sample was collected, and during periods of high and low flow to characterize flow variability. Referring to Figures 3.2-1 and 3.2-2, and Table 3.0-1 under "Surface Water," streamflow measurements were made at RC-1, RC-2, RC-3, RC-4, RC-5 (and RC-5A), RC-6, RC-7, RC-10, and RC-11 in Railroad Creek, CC-1 and CC-2 (combined) in Copper Creek, CC-D1 (Copper Creek diversion) and in the portal drainage at P-1 and P-5.

Flow measurements were made in several tributaries (Holden Creek, Big Creek, and Ten Mile Creek) that were sampled and at all aquatic habitat sampling locations in Railroad Creek (see Section 3.9) and three locations (Bridge Creek, South Fork Agnes Creek, and Company Creek) outside the Railroad Creek watershed north of the Site. At stations RC-4 and RC-2, water levels were consistently monitored to develop stage-discharge rating curves (graphs which allow one to determine flow rate from a water height measurement) for these two stations. Flow data from the USFS (1996) was incorporated into the ratings for both of these stations. The rating curves developed for Railroad Creek stations RC-2 and RC-4 are discussed in Section 4.3.3.2.

A low flow or baseflow survey was completed during the September 1997 field program. The objective of the baseflow survey was to measure the groundwater inflow component to Railroad Creek adjacent to the Site. The baseflow survey was completed during a time of historical, steady low flow conditions (September 22, 1997) and consisted of measuring flow at all of the Railroad Creek stations (RC-4, RC-7, RC-2 and RC-5) adjacent to the Site. Tributary flow was also measured from Copper Creek (CC-1), the Copper Creek diversion (CC-D1), and SP-21 (located to the east of tailings pile 3, noted on Figure 3.3-2 and Table 3.0-1 under "seeps"). In October 1998, additional baseflow measurements were collected in Railroad Creek between stations RC-1 and RC-4 to further characterize an apparent flow loss that was observed in 1997. The additional survey was designed to characterize the flow loss and to evaluate the specific locations of the loss.

The streamflow measurements were made using standard USGS methods and equipment at each station (Rantz et al., 1984). The stream depth and velocity were measured by wading into the stream when depth and velocity were low enough to allow the hydrologist to enter the stream safely. Width was measured from a tagline (tape measure) strung across the channel section. During periods of higher flow when a wading measurement could not be accomplished, flow measurements were made from those stations that could be measured from a bridge; these stations included the footbridge (station RC-4), Svens bridge (station RC-2) and at Lucerne (station RC-3).

Rating curves were developed for the RC-4 and RC-2 gauging stations using the discharge and staff gage measurements at these locations. The rating curve provides a means to estimate streamflow from gage heights, and also averages errors associated with the discharge and staff gage measurements. The rating curve developed for RC-4 was used to estimate flows from the continuous water level recorder (known as a "Troll") to create a continuous hydrograph for this station. The rating curve data was also used to estimate concurrent flows at all stations enabling direct flow comparisons and relationships between stations to be developed.

All of the discharge measurements that were made at RC-2 and RC-4 were used to develop the ratings, unless a concurrent stage measurement was not available. Additionally, flow measurements that deviated by more than 20 percent from the average rating curve were excluded from the rating because these measurements were assumed to represent either unacceptable measurement error or a changed condition which did not persist in the remainder of the data base.

Three flow measurements were excluded based on this criteria, including the June 16, 1997, measurement at RC-4, and the July 10, 1997, measurement at RC-2 collected by Dames & Moore and the July 25, 1996, measurement at RC-2 collected by the USFS; additional discussion regarding the excluded flow measurements and their significance is presented in Section 4.3. The other findings of the streamflow surveys are also presented in Section 4.3.

3.2.2 Water Quality Sampling

Referring to Figure 3.2-1 and 3.2-2, Table 3.0-1 under "Surface Water," and Tables 3.2-1 through 3.2-5, surface water samples were collected from Railroad Creek during the four sampling events in 1997 and one event in May 1998, from Copper Creek at stations CC-1 (south and upstream of the tailings piles), CC-2 (near the confluence with Railroad Creek) during four sampling events, and from CC-D1 (the Copper Creek diversion) during the five sampling events. Samples were also collected during four sampling rounds from two stations in the 1500-level main mine portal drainage, P-1 and P-5. Miscellaneous surface water samples were collected in select Railroad Creek tributaries and at all aquatic habitat sampling locations (except RC-9).

Surface water quality samples were collected using a Teflon depth integrated sampler, which collects samples of the complete water column. The sampler was slowly lowered to the bottom of the stream allowing a constant inflow rate through the water column. The samples were also composited across the width of the stream by sampling at evenly spaced locations across the channel, and combining these discrete samples into one composite for the station. The depth integrated sampler could only be used when the water depth was greater than approximately one foot, and consequently could not be used to sample the portal drainage. For comparative purposes, discrete depth integrated samples were also collected (in addition to the width composite sample) at south bank locations at stations RC-1, RC-4 and RC-2.

The surface water samples were tested in the field for pH, specific conductance, temperature, dissolved oxygen, and redox potential. Laboratory analyses included total and dissolved metals (aluminum, arsenic, barium, beryllium, cadmium, calcium, chromium, copper, iron, lead, magnesium, manganese, mercury, molybdenum, nickel, potassium, selenium, silver, sodium, thallium, uranium, and zinc), ortho/total phosphorous, cyanide, total dissolved solids, total suspended solids, chloride, nitrite-nitrate, sulfate, silicates, alkalinity, color, and hardness as specified in the SAP and QAPP. Tailings pile 1 was reportedly used historically as a dump area for Howe Sound Company and Holden Village; thus, TPH and PCBs were analyzed at selected locations upstream (RC-6), adjacent to (RC-2) and downstream (RC-3) of the

Site. Samples collected for dissolved metals analysis were filtered in the field to remove sediment before sample preservation. The results of laboratory analyses are presented in Section 5.3.

3.2.3 Storm Event Sampling

The May/June 1997 work plan called for sampling a post melt season storm event to observe the effects of rainfall infiltration on water quality of seepage flow and baseflow into Railroad Creek from the mine workings. The sampling guidelines stipulated that storm event sampling at selected seep, portal and creek locations would be triggered after 0.5 inches of rainfall fell within 24 hours, and after a period of dry weather had occurred that was sufficient to result in observed build-up of metal salts on the surface of the tailings piles. In lieu of the occurrence of these climatic conditions, weekly sampling of selected seep, portal and creek stations would be completed during the May/June 1997 sampling round.

During the May/June 1997 sampling period, the climatic conditions which would have triggered a storm event sampling round were not observed. Consequently, the weekly sampling was undertaken. Referring to Figures 3.2-1 and 3.2-2, and Table 3.2-2, weekly sampling stations included the portal drainage at P-5, Railroad Creek stations RC-6 and RC-2 (upstream and downstream of the mine), and seeps SP-23 (upstream of the tailings), SP-15E (related to the mill site and maintenance yard), and SP-2 (downstream of the tailings). The weekly sampling rounds provided a more comprehensive time series comparison between water quality and flow conditions in the portal, selected seeps and Railroad Creek than would have been available if only one round of sampling were conducted during the May/June sampling event.

The samples were analyzed for the primary analyte list of metals (aluminum, barium, beryllium, cadmium, calcium, chromium, copper, iron, lead, magnesium, manganese, nickel, potassium, silver, sodium, and zinc), alkalinity, sulfate, total dissolved solids, total suspended solids, and hardness. The results of the laboratory analyses are presented in Section 5.3.

3.2.4 Geomorphologic Survey

As part of the streamflow survey and habitat evaluation, geomorphologic observations and channel geometry surveys were completed at each of the streamflow stations in Railroad Creek. Additional channel data were also collected at the aquatic habitat sampling stations (see Section 3.9). Aerial photographs and historic data on Railroad Creek were also reviewed to supplement the evaluation of the channel data.

The purpose of the survey was to provide sufficient data to characterize the erosion and sediment transport potential of Railroad Creek, provide baseline channel habitat data, and to characterize the nature of the streambed adjacent to the tailings piles where the build-up of an iron cemented layer, or ferricrete, has been documented.

Referring to Figures 3.2-1 and 3.2-2, an initial channel geomorphology survey was completed by observing the Railroad Creek bed beginning upstream of RC-6 to the mouth (at Lucerne). The survey included a characterization of bed material, channel slope, water quality (pH, specific conductance and temperature), bank conditions, riparian conditions, and mapping of areas of erosion and deposition. The data collection during this survey was designed to characterize overall channel conditions within surveyed reaches and was qualitative in nature. The results of the survey are presented in Section 4.3.3.3.

The erodibility of the bed and bank material and extent of ferricrete development was assessed in Railroad Creek adjacent to the tailings piles. A backhoe was used to break through the ferricrete material on the south bank and in the streambed at three locations adjacent to the tailings piles. The test pits were logged to document the nature of the bank materials and visually assess ferricrete and groundwater conditions on the streambank. The extent of the ferricrete was mapped based on field observations in the upstream and downstream direction as well as across the channel. The results of the ferricrete assessment are presented in Section 4.3.9.

3.3 TASK 3 - HYDROGEOLOGIC INVESTIGATION

3.3.1 Groundwater Quality and Water Level Data Collection and Analytical

The following sections summarize methods and equipment used in collecting groundwater-level and groundwater-quality data during the RI activities.

3.3.1.1 Tailings Pile

Referring to Figures 3.3-1 and 3.3-2 and Tables 3.0-1 (under "Groundwater Monitoring Wells") and 3.2-2 through 3.2-5, an initial assessment of groundwater monitoring wells at the Site was conducted in mid-May 1997 to evaluate the suitability of the wells for use for water-level and water-quality sampling. The assessment was completed by checking surface completions for well integrity and measuring total depths in wells for concurrence with depths noted during well construction. Well PZ-2A was concluded to be damaged below the surface and well TP2-5A was substituted for water quality sampling.

Water levels were collected from 48 wells at the Site during four sampling rounds in mid-May, mid-June, mid-July, and mid-September of 1997. Water levels were collected from wells located apparently upgradient and downgradient of tailings piles 1, 2, and 3, downgradient of the mill building complex, and on the north side of Railroad Creek; the inferred groundwater flow direction is generally to the north to northeast. Water levels were collected from piezometer clusters installed previously within the tailings piles in order to assess groundwater flow directions within the piles. The results of water level measurements are discussed in Section 4.4.3.

Water quality samples were collected from 24 wells at the Site during the May sampling round and 21 wells in September. Two wells scheduled for sampling in May-June (PZ-3C and CC-BKG) were not sampled as they were dry. Three additional wells (PZ-1A, TP2-5A, and TP3-4) were not sampled in September as they were also dry. Samples were collected following the removal of a minimum of three casing volumes and when water parameters were stabilized. Prior to the first sampling round, wells that had not previously been developed were developed (the removal of water from a well in order to remove sediment produced during well construction and to encourage flow) using either decontaminated downhole pumps, dedicated disposable bailers, or decontaminated PVC bailers.

Purging of groundwater wells was accomplished using either decontaminated downhole pumps or decontaminated PVC bailers. Samples were collected using decontaminated PVC bailers during the May sampling event, and decontaminated dedicated PVC bailers during the September sampling round. Groundwater samples were tested in the field for pH, specific conductance, temperature, ferrous iron, and oxidation/reduction potential as outlined in the associated SAPs. Samples were submitted to the laboratory for dissolved metal analyses (aluminum, arsenic, barium, beryllium, cadmium, calcium, chromium, copper, iron, lead, magnesium, manganese, mercury, molybdenum, nickel, potassium, selenium, silver, sodium, thallium, uranium, and zinc), alkalinity, sulfate, total dissolved solids, total suspended solids, hardness, chloride, nitrate/nitrite, color, cyanide, and ortho/total phosphorous as outlined in the associated SAPs. In addition, samples collected from HBKG-1 (located west of tailings pile 1) and DS-2 (located downgradient of tailings pile 3) were analyzed for TPH and PCBs. The results of laboratory analyses are presented in Section 5.4.2.

3.3.1.2 Seeps

Groundwater which flows from the slopes and/or ground surface are considered seeps. The presence of seeps is indicative of a shallow groundwater occurrence. Referring to Figures 3.2-1 and 3.3-2 and Tables 3.0-1 (under "Seeps") and 3.2-2 through 3.2-5, the RI included the sampling of seeps and immediate areas where the seep water collected in order to better characterize the shallow groundwater underlying the Site.

Discharge measurements and water quality samples were collected from all site seeps with measurable flow that were not derived completely by snowmelt. The discharge measurements were recorded through the use of portable flumes, collecting flow into containers of known volume, or visual estimation. A discussion of the seeps in terms of the groundwater conditions is presented in Section 4.3.3.7. In areas where multiple small-discharge seeps were found, composite, volume-weighted samples were collected. Samples were analyzed for the same parameter suite as groundwater samples. The results of laboratory analyses are presented in Section 5.4.2.

3.3.1.3 Dye Tracer Survey

A dye tracer test program was conducted in two areas of the Site. Testing was conducted by introducing dye in the Honeymoon Heights drainage to assess potential relationships of intermittent drainage from Honeymoon Heights to seeps SP-12, SP-23 and the portal drainage (Figure 3.3-2). An additional test was conducted by introducing dye into a partially open decant tower located on the top of tailings pile 1 to assess if water that flows into the decant tower contributes to the generation of seepage from the tailings pile.

Dye was input at three points: (1) Honeymoon Heights drainage down gradient of the mapped shallow mine workings but up gradient of seeps SP-12 and SP-23, (2) Honeymoon Heights drainage up gradient of the mapped shallow mine workings and up gradient of seeps SP-12 and SP-23, and (3) In partially open decant tower located in tailings pile 1.

Water samples were collected at SP-12, SP-23 and portal drainage (P-1) to assess water source relationships with the Honeymoon Heights drainage and from SP-1, SP-2 and the south bank of Railroad Creek up gradient of the Copper Creek confluence to assess water source relationships between the tailings piles and seeps at Railroad Creek. The samples were analyzed for the expected dye tracer compound. The results of the dye tracer study are provided in Section 4.4.3.3.

3.3.1.4 Background

Referring to Figure 3.3-2 and Tables 3.0-1 (under "Groundwater") and 3.2-2 through 3.2-5, two groundwater monitoring wells were installed by others in 1995 (USBM) in apparent upgradient locations (HBKG-1 and HBKG-2). However, subsequent sampling and analysis of the water collected in the wells indicated that the groundwater at these locations is apparently impacted by past mining-related activities. (HBKG-1 is situated within an area immediately west of tailings pile 1 with impacted groundwater, and HBKG-2 was installed immediately west of an abandoned access road constructed of rock that may have contained limited mineralization.) The ability to install additional upgradient wells was limited due to the presence of the Glacier Peak Wilderness boundary and difficult access conditions for conventional drilling equipment. Consequently, background groundwater quality sampling was accomplished on the north side of Railroad Creek at well HV-3 (also shown as H-3), which is located topographically above most of Holden Village and appears to be representative of background conditions.

The USBM also installed a groundwater monitoring well (CCBKG) near Copper Creek at the southwest corner of tailings pile 2. This well was dry during the RI groundwater monitoring efforts and was not sampled.

Since seeps are considered relatively representative of shallow groundwater, an attempt was made to locate and sample seeps apparently upgradient of the Site. SP-26 was located, near the western limit of apparent historical mining-related activity on the Site, and sampled. In May 1998, a sample was collected at seep SP-27 (Figure 3.2-1) located farther up-valley. This seep is suspected to be meteoric in nature and not reflective of groundwater. No other seeps were observed upgradient of the Site.

Lab analyte lists for these locations are similar to the Site analyte lists for groundwater and seeps, respectively. The results of the laboratory analyses are presented in Section 5.4.2.2.

3.3.1.5 Lucerne Water-Supply Well

Referring to Figure 3.3-1 and Tables 3.0-1, 3.2-2 and 3.2-4, water quality samples were collected from the well associated with the potable water supply for the USFS guard station facility in Lucerne during both the May and September 1997 sampling rounds. In both instances sufficient water was pumped to purge the supply system and allow water quality parameters to stabilize. Samples were analyzed for the same primary analyte list as site groundwater samples (aluminum, barium, beryllium, cadmium, calcium, chromium, copper, iron, lead, magnesium, manganese, nickel, potassium, silver, sodium, zinc, total dissolved solids, total suspended solids, sulfate, alkalinity, hardness, and field parameters). The results of the laboratory analyses are presented in Section 5.4.2.8.

3.3.1.6 Electromagnetic and Self Potential Geophysical Surveys

A subcontractor (Northwest Geophysical Associates, Inc.) to Dames & Moore completed an electromagnetic (EM) survey of select areas across the Site in order to better characterize potential pathways of near-surface, metals-containing water through the near surface soil. The SAP outlined a program to utilize either EM or self-potential geophysical methods. EM survey methods were used based on field conditions encountered and the relative success utilizing this method.

Referring to Figure 3.1-2 and Table 3.0-1 (under "Geophysical Survey Lines"), the EM survey was completed in two primary areas: the western portion of the Site, or mine support area, and the area immediately east of tailings pile 3, in an area where seeps were observed. The survey of the western portion of the Site consisted of two ~~seismic~~ lines (EM-1 and EM-2). The lines were located across an affected area based on field pH and conductivity readings collected from seeps. The first line (EM-1) was completed adjacent to Railroad Creek between the upstream most seep which appeared to contain elevated metals based on field screening methods, and the vehicle bridge north of the former mill facility. The second EM line (EM-2) was completed in the western portion of the Site upslope from the valley bottom and proceeded west to merge with the lower line.

The second area evaluated utilizing the EM survey methods was immediately east of tailings pile 3. The EM line (EM-3) was nearly north-south in orientation, paralleling the seismic line E-E'. The results of the EM survey are presented in Section 4.4.3.3 (under "Groundwater Flow in Native Materials" and "Groundwater Flow in Western Portion of Site") and Appendix A.

3.3.1.7 Tailings Pile Surface Percolation Testing

Percolation tests were performed at three locations on tailings pile 2 to evaluate the infiltration rates of water at the surface of the tailings piles. The three tests were located near or on seismic line C-C', situated in a north-south direction west of the center of the tailings pile (Figure 3.3-2). One of the tests was performed in the bottom of the surface water interceptor trench (installed by the USFS as part of the tailings pile rehabilitation project) located in the southern portion of the tailings pile (DMTP-3). The remaining two tests were conducted within the surface of the tailings piles (DMTP-1 and DMTP-2). Six-inch-diameter steel pipes were placed vertically within the surface materials and falling head methods were utilized. Constant head methods were not used due to difficulties in accessing a water supply sufficient to provide a constant head. The results of the percolation tests completed by Dames & Moore are presented in Section 4.4.3.1 under "Tailings Materials" and Appendix G. The results of percolation tests completed by Hart Crowser in 1975 are presented in Appendix E.

3.4 TASK 4 – FLOCCULENT AND SEDIMENT

3.4.1 Railroad Creek and Lake Chelan Sediment

3.4.1.1 Railroad Creek

Referring to Figures 3.4-1 and 3.4-2, the sediments within Railroad Creek have been evaluated by others within the recent past (Johnson, et al, 1997; Huntamer, 1997; USGS, 1994). The data collected from these studies were agreed upon by the Holden Mine RI/FS Technical Advisory Group to be sufficient and of adequate data quality for use in RI characterization of Railroad Creek, and to preclude additional sampling during the RI field programs.

3.4.1.2 Lake Chelan

Sediment near the mouth of Railroad Creek, within Lake Chelan was evaluated by others in 1989 (Patmont, et al.).

Referring to Figures 3.0-1, 3.4-3 and 3.4-4, and Tables 3.0-1 (under "Sediment") and 3.2-5, sediment samples were also collected by Parametrix, Inc., under subcontract to Dames & Moore in 1998 within the Lucerne Bar portion of Lake Chelan, near the mouth of Railroad Creek, and at a reference location at Stehekin (at the north end of Lake Chelan) to further evaluate sediment quality associated with sediment transport from Railroad Creek. Twelve discrete samples (1-1 through 5-1) were collected at Lucerne Bar (Figure 3.4-3). Seven of the samples were collected approximately 50 feet below the surface of the lake. The remaining five samples were collected approximately 150 feet below the surface of the lake. The samples were collected utilizing either Van Veen or Eckman samplers deployed from a boat. A second survey was conducted and a video of the surface of the bar was taken before sampling was completed in order to determine the sampling locations. The locations of the sonar and video survey, as well as the sampling locations, were civil surveyed using existing onshore features as references.

An additional six discrete sediment samples (1 through 4 and two duplicates) were collected near the mouth of the Stehekin River near the community of Stehekin at the northern end of Lake Chelan (Figure 3.4-4). All of the samples were collected at a depth of approximately 50 feet below the surface of the lake. A sonar survey was conducted prior to sampling in order to select the sampling locations. The locations of the sampling stations were civil surveyed in the field.

All Lake Chelan sediment samples collected were analyzed for metals (aluminum, arsenic, cadmium, copper, iron, lead, manganese, and zinc) and acid volatile sulfides (AVS), grain size, total organic carbon (TOC), total solids, pH, and total volatile solids. The results of the laboratory analyses are presented in Section 5.5.

3.4.2 Portal Drainage and Railroad Creek Flocculent

Several samples of flocculent, which are not considered sediment, but assist in characterizing the Site chemical processes, were collected by Dames & Moore and others at select stations in Railroad Creek. In addition, the USGS (1994) collected samples of sediment concentrate; the sampling method included the collection of the sediment sample and screening of the larger materials. The concentrate samples were analyzed for geochemical purposes but did not follow standard sediment sampling protocol. The results of the laboratory analyses are presented in Section 5.6.

The collection of portal film samples from the portal drainage near the 1500-level main portal was added to the field program at the request of the agencies during the RI (Figure 3.4-2). Samples were collected in July and October 1997. In addition, flocculent was collected from the substrate within Railroad Creek at three different locations between the area immediately upstream of the confluence with Copper Creek (RC-9), at the northeastern corner of tailings pile 3 (RC-2), and approximately 1/4 mile downstream of tailings pile 3 (RC-5) (Figures 3.2-1 and 3.4-2). The samples were collected to evaluate the chemistry of the flocculent material and in order to assess the geochemical processes associated with the formation of the material.

The samples were obtained from precipitate and flocculent that had coated streambed cobbles, and were sampled by mechanically dislodging the flocculent/precipitate coating from the cobble into a sample jar. After collection, the sample was allowed to settle and the water decanted from the sample jar. The precipitate/flocculent was analyzed for total metals (aluminum, arsenic, barium, beryllium, cadmium, calcium, chromium, copper, iron, lead, magnesium, manganese, molybdenum, nickel, potassium, silver, sodium, thallium, uranium, and zinc). The results of the laboratory analyses are presented in Section 5.6.

3.4.3 Railroad Creek Streambed

Referring to Figures 3.4-1 and 3.9-1, the characterization of sediment in Railroad Creek was qualitatively assessed at each aquatic habitat sampling station (see Section 3.9), and during the initial geomorphologic survey of the creek. Observations included mapping dominant bed material (based on observation and

Wolman pebble counts), occurrence and extent of iron flocculent and precipitate, sediment transport, and sediment sources. The field findings are summarized in Sections 4.3.3.3 and 4.6.1.2.

Sampling and analysis of streambed sediment at the Site was not feasible because the dominant streambed material was cobble and small boulder throughout the affected reach of Railroad Creek.

3.4.3.1 Railroad Creek Ferricrete Assessment

The main objective of the ferricrete assessment was to describe the extent, thickness and character of the ferricrete along Railroad Creek, and develop a conceptual model of ferricrete formation and its effect on the hydrologic/hydrogeologic regime. To achieve these objectives, field reconnaissance along the south and north banks of Railroad Creek (in the vicinity of the tailings) was conducted during late September and early October 1997. The channel and banks were inspected for conditions characteristic of ferricrete. In addition, test pits were excavated into areas of observed ferricrete formation to assess the vertical and lateral character of the deposits. Due to limited accessibility of the channel with mechanized excavation equipment, two areas were chosen to excavate test pits: immediately east of tailings pile 1 and immediately east of tailings pile 3.

During September 1997, four test pits were excavated by Cragg's Excavating under subcontract to Dames & Moore (Figure 3.1-2 and Table 3.0-1 under "Subsurface/Surface Soil"). Three of the test pits (DMTP3E-1, 2 and 3) were located in the high water channel or wetland floodplain of Railroad Creek, just east of tailings pile 3. One test pit (DMTP1E-1) was located in the high water channel of Railroad Creek about midway between the confluence of Copper Creek and the east end of tailings pile 1. Each test pit was photo-documented and described according to Unified Soil Classification System (USCS) methods and with additional comments related to the observed hydrogeologic conditions. In addition, partially cemented to cemented material was also encountered in trench DMTP3-4, which was excavated into the side and base of tailings pile 3, in the same general area of the three other test pits. The field findings are presented in Section 4.3.9.

3.5 TASK 5 - MILL BUILDING ASSESSMENT

Referring to Figures 3.1-2 and 3.1-3, and Table 3.0-1 (under "Feature/Area"), the mill site was assessed as part of the RI.

3.5.1 USGS Assessment of Mill Building-Related Salts and Unprocessed Ore

Samples of the mill-related salts and unprocessed ore have been sampled by others in the recent past (USGS, 1996 and 1997); seven samples were collected in 1995 and two samples were collected in 1996. The results of the studies were agreed upon by the Holden Mine RI/FS Technical Group to be sufficient and of adequate data quality for use in RI characterization. Additional sampling of the salts and unprocessed ore was not conducted during the RI. The data were evaluated in order to characterize the environmental conditions in the mill building. The laboratory test results are presented in Section 5.4.3.2 under "Mill Building Drip Water."

3.5.2 Asbestos Assessment

The partially salvaged mill building contains materials which are exposed and suspected to consist of asbestos-containing materials. Three samples of the materials (AM1 through AM3) were collected from the mill structure. The samples were representative of both wall insulation materials and a coating on the insulation. The sampling was conducted in general accordance with AHERA standards. The number of samples was agreed upon by the Holden Mine RI/FS Technical Advisory Group to be sufficient for RI characterization. The results of the laboratory analyses are presented in Section 5.8.

3.6 TASK 6 - MINE ASSESSMENT

Referring to Figure 3.0-3, the underground mine is situated south to southwest of the former mill building in the area noted as Honeymoon Heights. Access to the underground mine was provided by eight portals. Mine waste rock piles were generated during mine development; each of the piles is situated near the mine portals. The aboveground and belowground elements of the mine were evaluated as part of the RI.

3.6.1 Review of Aboveground and Underground Mine Maps

Relatively detailed mine maps were developed during the operation of the mine and after the mine was closed. The maps were reviewed to evaluate the presence and extent of internal workings of the mine and the potential pathways for groundwater migration, and to assess the options and safety considerations for possible mine portal entry during the RI field program. The maps were also reviewed by both a mining engineer and a miner who were subcontracted by Dames & Moore. The results of the assessment are discussed in Section 4.1.3.1.

3.6.2 Field Assessment of Aboveground Features

3.6.2.1 Evaluation of Mine Openings and Related Features

Inventory of Aboveground Features

The primary aboveground features associated with the historic mining at the 1500-level of the mine and in the Honeymoon Heights were inventoried in the field. The inventory focused on the portal openings and mine rock piles associated with the openings. The locations of the 1500-level openings were located by civil survey. The portals in the Honeymoon Heights area were located utilizing Global Positioning System (GPS) methods and aerial photographs of the Site. The results of the inventory are presented in Section 4.1.2.8.

The ore body mined by Howe Sound and others is nearly vertical in orientation and is exposed at the ground surface in the Honeymoon Heights area. Portions of the ore body were removed during the earlier years (1938 to 1945) of underground mining. The surface expression of the ore body is evident in the field. A reconnaissance of the area where the ore body is exposed at the ground surface was completed in order to document areas where subsidence may have occurred and the potential for future subsidence. A discussion of the methods employed to evaluate the mine subsidence potential was presented in Section 3.1.5. A discussion of the field findings is presented in Section 4.2.5.

Assessment by Mining Consultant

The Draft RI/FS Work Plan included entry of the mine for sampling of the mine water and precipitates, and to evaluate the structural integrity of the 1500-level tunnels. The possible mine entries were determined to be the 1500- and 1100-level portals. However, due to worker safety issues related to entering the mine, the underground mine maps were evaluated by a mining engineer, J.S. Knowlson & Associates of Seattle, Washington, subcontracted by Dames & Moore. The evaluation also included additional map review and visits to the relevant portals by a Dames & Moore geologist and a mining subcontractor (Atlas Fausett of Kellogg, Idaho). The results of the assessment have been incorporated into Section 4.1.3.1.

3.7 TASK 7 - WINSTON HOME SITES ASSESSMENT

The Winston home sites area located west of Holden Village (Figures 3.0-3 and 3.1-5) included 103 houses which were demolished by the USFS. Fuel oil stored in both aboveground tanks (ASTs) and underground storage tanks (USTs) were used to heat the houses. Some of the USTs remain as indicated by the presence of apparent fill and vent pipes across the area. It is our understanding that the USFS had not completed an inventory of USTs. Therefore, the scope of work included performing an inventory of the tanks and a series of trackhoe-excavated test pits as discussed in Section 3.1-3.

The inventory of the USTs was based on the presence of fill and vent pipes. The locations and types of fill pipes, as well as the condition of the tanks (if observed) were documented, when possible, on a map of the Site which included the surveyed locations of some of the remaining walls and other surface features as references. The results of the inventory are presented in Section 4.1.2.6.

3.8 TASK 8 - FIELD SCREENING

Field screening was used extensively across the Site during each of the sampling events. Screening was performed using a combination of field meters and qualitative/quantitative field chemistry tests. Temperature, pH, specific conductance, and turbidity were measured and recorded in surface water, groundwater, and seeps collected during the Phase I RI.

In addition, oxidation/reduction potential and dissolved oxygen were added in May through July 1997 as part of the Phase I RI. During the Phase I RI, a qualitative chemical test for ferrous iron was performed on groundwater and seep samples to aid in establishing significant changes in site chemistry based on determination of a reducing or oxidizing environment. The colormetric test included adding a reagent to a sample of seep and/or groundwater.

In addition to field measurements, field screening for pH and specific conductance was performed at additional locations based on field observations. These locations were not specified in the SAP, but included areas where water entered or potentially entered Railroad Creek that may result in a loading source. Additional samples were collected if the field results indicated that the resulting water was affected by mine related activities (low pH and/or high specific conductivity) and/or the flow rate was substantial. This resulted in several additional seep locations being identified on the Site for sampling which were not presented in the SAP.

The field screening data combined with the laboratory analytical data from the Phase I sampling round was used to characterize areas of common chemistry on the Site. The field screening program for the Phase II RI was reduced to pH, specific conductance, and temperature for all surface water, groundwater, and seep samples due to the results of the Phase I RI. The value of continuing oxidation/reduction potential, dissolved oxygen, and ferrous iron during Phase II sampling efforts was considered limited as general chemical characteristics of the site were not expected to change and were documented during the Phase I activities.

Turbidity and dissolved oxygen were measured during Phase II at stations RC-6, RC-2, and RC-3. Dissolved oxygen was measured by a quantitative chemical field test that allowed immediate titration of the sample and recording of the dissolved oxygen result. The results were compared to dissolved oxygen results measured by a field meter used in previous sampling rounds. The results obtained from the quantitative chemical field test were consistent with those obtained from the field meter.

The field screening results for each sample were evaluated with the associated laboratory analytical data to more completely evaluate site chemistry and to assist in the development of remedial action objectives (RAOs).

3.9 TASK 9 - ECOLOGICAL SURVEYS

Referring to Figures 3.9-1 and 3.9-2, the ecological surveys conducted during the RI were primarily focused on aquatic communities; however, terrestrial communities were investigated to provide general characterizations of these communities and assess the potential for various terrestrial species that inhabit the Site. The surveys were designed to collect site-specific information for the ecological risk assessment and identification of potential injuries to natural resources. The results of the ecological surveys are presented in Section 4.6.

3.9.1 Aquatic Biota

3.9.1.1 Background

Aquatic communities in the vicinity of the Site have been generally described in response to indications of impacts from mine activities. In particular, Pacific Northwest Laboratory (Battelle) investigated habitat, benthic macroinvertebrate communities, and fish populations in Railroad Creek from October 1989 to April 1990. The investigations were conducted to describe "baseline" conditions prior to the Railroad Creek habitat enhancement activities. The reclamation activities were intended to increase the productivity of Railroad Creek and to reduce the potential for an occurrence of a catastrophic erosion event.

The post reclamation aquatic biota monitoring plan recommended the sampling of aquatic biota during 1990, 1991, 1992, and 1996 (PNL, 1992). Post-reclamation aquatic monitoring was conducted in 1991 by Pacific Northwest Laboratory (Battelle) and in 1992 the USFS. A formal report was prepared for the 1991 data collection; however, the 1992 efforts, which included benthic macroinvertebrate and fish sampling (tissue and population data) were apparently not compiled in a formal or draft report. The 1992 data were received in various forms directly and indirectly from the USFS. A review of these data indicated that descriptions of sampling methods, sample locations, areas sampled, etc., were insufficient for adequately describing the 1992 results or comparing the results to the 1991 and 1997 results. As such, discussions of the 1992 data have not been included in this investigation. The following sections describe specific sampling objectives and procedures designed to discern the causes of conditions in Railroad Creek as they existed during the fall of 1997.

The general objectives of this program are to determine why fish and benthic macroinvertebrate populations in Railroad Creek downstream of the Site appear to be degraded relative to populations evaluated upstream and to identify injuries to natural resources. The objectives of the ecological surveys were to:

- Distinguish between potential chemical and physical influences on the creek
- Preliminarily identify potential exposure pathways
- Identify where chemical exposures and adverse effects may have occurred
- Quantify the magnitude of the effects of those exposures
- Identify potentially affected resources

The specific hypotheses tested were:

- There is no difference between populations of fish and benthos between potentially affected and reference areas.
- Differences observed between populations of fish and benthos in potentially affected and reference areas are due to physical impacts.
- Differences observed between populations of fish and benthos in potentially affected and reference areas are due to chemical impacts.

Sampling activities described herein were designed to test these hypotheses. The aquatic ecological assessment program consists of two phases. Phase I included the identification of aquatic biota sampling locations (reference and potentially affected) and investigation of the potential for rare, threatened, or endangered species to inhabit the Holden Mine area or the Railroad Creek drainage. Phase II included the collection of data necessary to address the objectives listed above. Additionally, a qualitative survey of terrestrial species was conducted during Phase II. The Phase II field program included: (1) assessing aquatic habitat conditions of Railroad Creek and reference areas, (2) assessing the benthic macroinvertebrate communities within Railroad Creek and reference areas, and (3) assessing fish communities within Railroad Creek and reference areas.

3.9.1.2 Phase I

Phase I ecological tasks included the identification of aquatic sample locations and the preliminary investigation of the potential for threatened and endangered species to occur in the vicinity of the Site. These tasks provided the basis for pursuing the Phase II field investigations.

Site Sample Locations Selection

In order to allow a comparison of historical and recent data, the 1997 aquatic biota sampling and habitat analysis locations were selected as near as practically possible to the locations sampled by Pacific Northwest Laboratory (PNL) during 1989 and 1991. The final selection of sampling locations was based on available and similar aquatic habitat. The selection of reference locations having habitats similar to the potentially affected locations was also performed and is a critical component of the analysis.

Five aquatic sampling locations considered to be potentially affected by mine activities and two reference locations were selected within Railroad Creek. These sampling locations are described in Section 4.6.

Reference Reach Selection

Three additional reference locations were identified within streams located outside the Railroad Creek drainage area for comparison to habitat conditions in Railroad Creek downstream of the Site. The selection process included review of existing literature, interviews with knowledgeable parties, the development of key habitat variables, the analysis of candidate reaches, and final selection after a field reconnaissance was completed. The results of the process are described in Section 4.6.

3.9.1.3 Phase II

Phase II aquatic biota field investigations were conducted during September and early-October 1997 and consisted of habitat analysis, benthic macroinvertebrate sampling, and fish sampling.

Aquatic Habitat

Habitat quality influences benthic macroinvertebrate and fish communities within Railroad Creek regardless of physical or chemical perturbations associated with the Holden Mine. Although it is desirable to select sampling locations with similar or comparable habitat quality, not all habitat components will be identical between sampling locations. Therefore, habitat analyses were conducted at each sampling site to provide data as to the relative capability of reference and affected locations to support benthic macroinvertebrate and fish communities in the absence of chemical perturbations. Therefore, the intent of the habitat analyses was to investigate non-mine related factors potentially limiting the establishment of benthic macroinvertebrate and fish communities.

Habitat analysis methodologies were employed to provide data for both qualitative and quantitative assessment of benthic macroinvertebrate and fish habitat conditions at each of the sampling locations. Macroinvertebrates are affected by a variety of habitat conditions including: substrate composition, substrate embeddedness and cementing, and current velocity (Bjornn et al., 1977; Minshall, 1985; Platts et al., 1983; Kiffney and Clements, 1996). Fish are also affected by these habitat conditions, in addition to pool/riffle and run/bend ratios, and bank stability conditions (Plafkin et al., 1989, and Rosgen, 1994).

To determine the physical habitat conditions at the aquatic biota sampling locations, procedures described in the rapid bioassessment procedure guidance document, "In-stream Biological Monitoring Handbook - For Wadable Streams in the Pacific Northwest" (EPA, 1993) were generally followed. Accordingly, the following parameters for riffle/run prevalent streams in the Pacific Northwest were assessed:

- Bottom Substrate - percentage of bottom substrate that is fines
- Instream Cover - percentage of the stream that provides stable fish habitat
- Embeddedness - the degree to which boulders, rubble, or gravel are surrounded by fine sediment indicating suitability of the stream substrate as habitat for benthic macroinvertebrates and for fish spawning and egg incubation

- Velocity/Depth - influences benthic macroinvertebrate and fish assemblages
- Channel Shape - identifies dominance of undercut banks and/or overhanging vegetation
- Width to Depth Ratio - ratio of the wetted channel width divided by the wetted channel depth
- Bank Vegetation Protection - indicates bank stability and potential sedimentation
- Lower Bank Stability - identifies potential for detachment of soils from the lower streambank and its potential movement into the stream
- Disruptive Pressure - estimates the amount of plant biomass that remains in the vegetated area immediately adjacent to the stream
- Zone of Influence - estimates the extent of human influence within the area adjacent to the stream

These parameters were qualitatively assessed at five transects established to represent equal subreaches within each sampling location. The scores for each transect were then averaged for the parameter score for a particular sampling location.

In addition to the rapid bioassessment procedures, coarse substrate composition was determined by applying the pebble count method developed by Wolman (1954) at ten points along each transect within each sampling location. At each point, a "pebble" was identified randomly. The intermediate axis of each pebble was measured or estimated and recorded. Therefore, a total of 50 data on coarse substrate was acquired from each sampling location.

Benthic Macroinvertebrates

Benthic macroinvertebrates were sampled at all locations during September and early-October 1997. Benthic macroinvertebrates were collected using a modified Hess (500-µm mesh) stream bottom sampler. Eight replicate samples were collected from riffle areas at each location. All benthic macroinvertebrate samples were preserved in 70 percent ethyl alcohol (ethanol) solution and transported to the laboratory for processing, identification, and enumeration.

The following field information was also collected at each benthic macroinvertebrate sample location whenever a sample was collected:

- Semi-quantitative particle size characterization (percent sand, gravel, and cobble)
- Current velocity
- Water depth
- Replicate location (a sketch depicting where replicates were collected within a given sample location)

Benthic macroinvertebrates retained were identified to the lowest practical taxon using appropriate taxonomic references and enumerated. A project-specific reference collection (vouchered reference collection) was established in the event that identifications needed to be reconfirmed or in situations where the taxonomic nomenclature changes or, for example, if there is a future need to separate a genus into three rather than two species. The reference collection of specimens identified is stored in 70 percent ethanol and archived in the laboratory.

Fish

Both electrofishing and snorkeling were employed to estimate fish populations within Railroad Creek and those streams outside the Railroad Creek drainage where reference reaches were identified. Two of the "non-Railroad Creek" reference locations were located in the Glacier Peak Wilderness and North Cascades National Park, both of which are "restricted use" areas prohibiting the use of motorized vehicles or equipment. Temporary permits were obtained to allow electrofishing at these locations during the RI. In addition to providing information on fish populations within these streams, each method was conducted to compare the two methods (see Appendix J) and provide indications as to the most efficient and cost effective way to monitor fish populations inhabiting these streams.

Approximately 100 meters of stream at each sampling location was identified and isolated with block nets for both electrofishing and snorkeling. Each stream segment sampled was as similar in habitat (e.g., pool: riffle ratio, substrate, gradient, etc.) as practical. The length and average width (n=10) of each site was measured and recorded and the boundaries marked. Each sampling location was photographed to document stream conditions. Snorkeling was conducted first followed immediately by electrofishing.

Snorkeling was conducted by a two-person team that swam upstream through the sampling location. Each snorkeler counted fish within approximately one half of the stream width. The snorkelers communicated the number, species, and size of fish observed to a recorder standing near stream. A more detailed description of the snorkeling survey can be found in Appendix J.

After the snorkeling survey was complete, a bank electrofishing unit consisting of a variable voltage pulsator (VVP) supplied by a 110-volt generator was used to capture fish within the isolated sampling location. The VVP for the bank electrofishing unit was equipped to produce and monitor variable output (i.e., watts, amps, and voltage) to accommodate variable conditions within the river (i.e., temperature, conductivity, hardness, and total dissolved solids). The VVP output was monitored and controlled to minimize adverse effects on fish. Voltage, watts, and amperage used to capture fish were recorded at each location. Temperature and conductivity at each location was measured and recorded prior to sampling.

At least two electrofishing passes were conducted at each location. The time required (effort) to complete each pass was recorded. A third pass was conducted to provide a more accurate estimate of the trout population if the number of trout (rainbow or cutthroat) collected during the first pass was less than 60 percent of the total trout collected during both the first and second pass. The "60 percent" was selected as a criterion by which a sufficient number of fish were considered removed from the population during the first pass to provide a noticeable reduction in the original population. This sufficient reduction, in turn, was considered to provide a reasonable indication of the original population size. However, if the number of trout collected during the first pass was greater than 60 percent of the total trout collected during both the first and second pass, the results of the first and second pass were used to estimate population size. Using data from three passes when sampling efficiency is less than 60 percent, provided additional confidence in the population estimate.

To the extent practical, electroshocking was conducted to cover all parts of the sampling area with the objective of capturing the maximum possible number of fish from that sampling area. The length of time spent (effort) electroshocking any sampling area depended on numerous water conditions at the location including, but not limited to, depth, temperature, conductivity, clarity, and velocity.

All captured fish were initially placed in a holding net during electroshocking passes. The net was maintained outside the field of electrical influence. At the completion of each pass the fish collected were transferred to large (5-30 gallon) containers for processing. The intent of this procedure was to process the fish as quickly and efficiently as feasible to minimize stress to the captured fish.

All fish captured were identified to the lowest practical taxon, measured to the nearest millimeter (total length), and weighed to the nearest gram. All data were recorded on field notebooks. After all data for each fish were recorded, the fish were returned to the stream.

3.9.1.4 Data Evaluation Procedures

The following sections provide descriptions of the procedures employed during the evaluation of benthic macroinvertebrate and fish data collected during the field sampling phase.

Benthic Macroinvertebrates

Metrics appropriate for evaluating metals-impacted streams were used during the evaluation of the benthic macroinvertebrate sampling results. These metrics are included in the Region 10 In-Stream Biological Monitoring Handbook (EPA, 1993) and are as follows:

- Taxa (species) richness
- Ratio of scrapers to filtering collectors
- Ratio of Ephemeroptera, Plecoptera, and Tricoptera (EPT) abundance to chironomid abundance
- Percent of contribution dominant taxon
- EPT index
- Community loss (similarity) index
- Ratio of shredders to total number of individuals collected (applicability as determined based on the presence of organic matter depositional locations noted in the field)

Although the Hilsonhoff Biotic Index is recommended by EPA (1993), this matrix is not appropriate for metals-affected communities.

Fish

In general, fish sampling by electrofishing was conducted to document fish species occurrence and relative abundance. Relative abundance was determined by calculating population estimates of trout (salmonids) present, where possible. Population estimates for trout for all reference locations were calculated and compared with the corresponding trout population estimates at each individual sampling location. Because of the low numbers of fish at each sampling location, length frequency histograms were not developed to ascertain the presence of specific age classes to judge presence/absence of recruitment, but were developed to compare with the size distribution from previous Railroad Creek investigations.

Population estimates were calculated using the Seber LeCren two-pass removal method (Everhart et al., 1975). This method assumes constant sampling effort for both passes, the population sampled is closed (i.e., no fish enter or exit the sample location during sampling), and that the chance of capture is equal for all individual fish and remains constant from sample to sample. The Seber LeCren two pass removal method equation incorporates the number of fish collected during each pass as follows:

$$N = \frac{C_1^2}{C_1 - C_2}$$

Where:

N = population size

C_1 = the number of fish captured in the first pass

C_2 = the number of fish captured in the second pass

Certain situations arose requiring more that two passes to provide a more accurate estimate of the trout population. Estimating populations with data from multiple (three or more) passes requires application of linear regression analyses. When multiple passes are required, the Leslie Method (Everhart, 1975) was used to estimate trout populations. This method is based on the understanding that the population at the start of any pass (excluding the first pass) is equal to some original population less what has been caught up to the beginning of that pass. This linear relationship implies that if catch-per-unit effort is plotted against cumulative catch, up to that pass, the result will be a straight line with slope equal to catchability and intercept equal to the original population times catchability (Everhart et al., 1975).

A third pass was conducted at 4 of the 8 locations electrofished. Only one location lent itself to the Leslie method. The relationship between catch per unit effort and cumulative catch at this location was not realistic (i.e., the slope of the regression was 0.0002), therefore, the total catch (of the 3 passes) was considered a reasonable estimate of the population. At two of the four locations, the third pass produced no fish and, as such, the total catch (of the first two passes) was considered a reasonable estimate of the population. At the remaining location, a third pass was conducted only because the first pass produced fewer fish than the second pass. The third pass at this location also produced no fish and, as such, the total catch (of the first two passes) was considered a reasonable estimate of the population.

In addition to calculating trout population numbers, several other parameters were quantified during this investigation. These parameters include, as appropriate:

- Total number of species present
- Total numbers of individuals in sample
- Number of non-trout species present
- Proportion of individuals as omnivores

- Proportion of individuals as top carnivores
- Proportion of individuals as hybrids
- Proportion of individuals with disease, tumors, fin damage, and skeletal anomalies

The data are presented in Section 4.6 in Table 4.6-3a.

Application of Obtained Information

As stated above, the hypotheses to be tested by this study are:

- There is no difference between populations of fish and benthos between potentially affected and reference areas.
- Differences observed between populations of fish and benthos in potentially affected and reference areas are due to physical impacts.
- Differences observed between populations of fish and benthos in potentially affected and reference areas are due to chemical impacts.

The first hypothesis will be tested directly by the rapid bioassessment protocol (RBP) data collected by comparing the overall summary statistics generated by the RBPs for potentially impacted and reference locations.

If the first hypothesis was rejected, the second hypothesis was tested by comparison of populations from potentially impacted and reference areas that are of similar habitat quality. When populations were not similar between physically similar reference and potentially impacted areas, chemical conditions were assumed to be the cause of the observed population decline on site. However, if, for example, when it was found that there were differences in population characteristics like dominance of "shredders" in reference areas and dominance of "scrapers" on site, this suggested that physical conditions are responsible for observed differences.

The third hypothesis was assumed to have been confirmed if both of the first two hypotheses were rejected.

3.9.2 Terrestrial Biota

During the initial stages of the threatened and endangered species investigation, letters were sent to several public agencies requesting information on special status plants and animals, and designated or proposed critical habitat in the vicinity of the Site area. Information was received from the U.S. Fish & Wildlife Service (USFWS), USFS, Washington Department of Fish and Wildlife (WDFW), and Washington Natural Heritage Program (WNHP). The latest inventories and database information from the USFS, WDFW, and WDNH were reviewed before the field survey effort began in September. Mallory Lenz, wildlife and plant biologist with the USFS (Chelan Ranger District), was the primary contact for the most up to date information regarding status species in the Railroad Creek drainage and surrounding areas.

Surveys were conducted from September 9 to 17, 1997, to assess habitat and observe wildlife at and surrounding the Site. The general surveys were conducted daily, regardless of the weather conditions.

Habitat parameters recorded included plant community type, tree density and height, the presence of snags, vertical diversity, and any wildlife signs.

Surveys for bats were also conducted where roosting habitat was available at the 1500-level main portal, the 1500-level ventilator portal, and the 1100-level main portal. The 300-level portal was also open; however, due to health and safety concerns related to access, the portal was not entered. The surveys were designed to be qualitative, as outlined in the SAP and approved by the agencies. The bat surveys were conducted from 7 p.m. to 8:30 p.m. on warm, dry nights. Two observers sat at a single portal and watched for bat activity. Only one portal was surveyed per night. The results of the survey efforts at this location are discussed in Section 4.6.

3.10 TASK 10 - LABORATORY ANALYSIS AND QUALITY ASSURANCE/QUALITY CONTROL

3.10.1 Laboratory Analysis Procedures and Quality Assurance/Quality Control

3.10.1.1 Geotechnical Laboratory Analysis

The data analysis presented in the following sections relied on the data presented by Hart-Crowser in their 1975 report and geotechnical samples collected by Dames and Moore in 1997. The laboratory analyses completed by Dames & Moore geotechnical laboratory included grain size and moisture content. Atterburg limits were not determined due to the absence of cohesive soils in the samples collected. Direct shear testing was not conducted as noted in the SAP due to the inability to collect undisturbed samples in the field.

3.10.1.2 Soil and Water Quality Analysis

Laboratory data was collected to satisfy the Data Quality Objectives (DQOs) presented in Section 5.0 of the draft RI Work Plan (June 16, 1997). The rationale for the selection of the most appropriate laboratory analytical methodologies for use during the RI were based on the risk based screening levels (RBSLs) for the compounds of concern as shown in Table 5-2 of the draft RI Work Plan. The DQOs and RBSLs were refined during each phase of the RI. The refined DQOs and RBSLs were provided in the Phase I, II, and III QAPPs. The selection of analytical methodologies was based on achieving analytical method detection limits (MDLs) and practical quantitation limits (PQLs) that were at or below the RBSLs.

A combination of methodologies from EPA Test Methods for Evaluating Solid Waste, SW846, Methods for Chemical Analysis of Water and Wastes, EP-600/4-79-020, Standard Methods for the Examination of Water and Wastewater, 18th edition, and Ecology methods were used in the analytical program. Sample analyses were performed by Analytical Resources, Incorporated (ARI) located in Seattle, Washington. Low level mercury analysis was subcontracted by ARI to Brooks Rand Ltd. located in Seattle, Washington. Low-level lead analyses were performed by Frontier Geosciences in Seattle, Washington. Specific laboratory methodologies that were used in each phase of the RI are provided in the associated QAPPs. Modifications to methods were necessary to achieve MDLs and PQLs. During the course of the program, method revisions to the QAPP were made due to more significant matrix interferences than originally anticipated. Method modifications and QAPP revisions were documented in the QAPP and in memoranda with the agencies at the time of occurrence. Low-level detection limits were achieved to provide adequate data to carry forward into the decision processes for the RI/FS. A summary of the methodology changes is provided in the following paragraphs in individual discussions per media.

The soil analytical plan was adapted to include analyses of ferricrete, flocculent, and portal film samples. Samples were analyzed for metals by EPA SW846 methods. Sample preparation prior to analysis was adjusted to account for the matrix. The ferricrete samples were crushed prior to analysis. The matrix was treated as a solid sample and prepared accordingly. The flocculent samples were centrifuged to separate the solid material from the water. An aliquot of solid material was then taken for analyses. The liquid and solid fractions of the portal film samples were allowed to separate. The liquid portion was decanted and the remaining film component was used for analysis. These procedures were documented in the laboratory analytical data.

Surface water samples were analyzed for metals, conventional parameters, PCB's, and total petroleum hydrocarbons by the methods previously described. In order to provide analytical data to achieve MDLs and PQLs as low as or as near to the RBSLs as technologically possible, modifications to the standard EPA methodologies were required. The modification for surface water metals analyses consisted of a 5-fold concentration step to aid in achieving the detection limits below the surface water quality criteria. To achieve the low level detection limit required to meet the chronic criteria for mercury, a specialized low level draft method by EPA (1631) was employed during the Phase I RI. Mercury analyses was deleted from the Phase II program based on the Phase I results. Evaluation of lead data from surface water collected during the Phase I and Phase II RI indicated that a lower detection limit was necessary to determine if lead concentrations in surface water were above or below chronic water quality criteria. The method for lead in surface water was revised in the Phase III RI sample collection to low level EPA Method (1638). PCBs were analyzed during the Phase I by a modified EPA method to achieve the lowest detection limits possible. Based on the Phase I results, PCB analyses were also deleted from the Phase II RI.

Groundwater and seep samples were analyzed for metals, conventional parameters, PCBs and total petroleum hydrocarbons by the methods previously described. During the Phase I RI, it was determined that the detection limits for metals provided in the QAPP were not achievable by the methods requested due to total dissolved solids present in groundwater and seep samples. A revision to the metal analyses in the QAPP was made to allow the majority of metals to be analyzed by ICP (EPA Method 6010) instead of ICPMS (EPA Method 200.8). The change in methodology was specifically for barium, chromium, copper, manganese, nickel, and sodium. In the Phase II program, the 5-fold concentration step was also eliminated for groundwater samples. Additional revisions were made to the Phase I QAPP in July due to similar issues with the seep samples. Samples collected in July were analyzed for metals using ICP (EPA 6010A) and graphite furnace analysis (GFAA EPA 7000 series) instead of ICPMS, with the exception of uranium, in an effort to meet the PQLs requested in the QAPP. The methodology for groundwater samples collected during the Phase II RI was revised to reflect the analytical plan provided for seep samples in the Phase II QAPP.

Data validation reviews were performed by Dames & Moore chemists and reviewed by the QA/QC manager for all laboratory analyses for organic and inorganic analytical data packages received from ARI. The following guidelines were used for data validation reviews of results for metals, PCBs, total petroleum hydrocarbons, and conventional parameters for surface water, groundwater, soil, sediment, ferricrete, flocculent, and portal film samples.

- Test Methods for Evaluating Solid Waste, SW846, USEPA, January 1995
- "USEPA Contract Laboratory Program (CLP) National Functional Guidelines for Inorganic Data Review," EPA 540/R-94-013, February 1994, where appropriate
- "USEPA Contract Laboratory Program (CLP) National Functional Guidelines for Organic Data Review," EPA 540/R-94/012, February 1994, where appropriate
- Methods for Chemical Analysis of Water and Wastes, EPA-600/4-79-020, 1983
- Standard Methods for the Examination of Water and Wastewater, 18th Edition, 1992
- Ecology, Petroleum Hydrocarbon Methods, April 1992

Data validation was performed using QA/QC criteria specified for each method in addition to the evaluation of holding times, instrument calibrations, method blanks, field duplicates, and analyte quantitation and reported detection limits. Data qualifiers were assigned using standard CLP definitions and flags.

Two types of data validation reviews were performed for all data received from the laboratory. The types of reviews are referred to as "standard" and "summary" in the data validation reports. The "standard" review refers to conducting a data validation review which requires spot checking the laboratory's raw data package and calculations in accordance with the Functional Data Validation Guidelines. A "summary" data validation review refers to conducting reviews which involve evaluating only the data summary and QA/QC summary sheets provided with all data packages. The "summary" reviews do not involve spot checking raw data packages and calculations. "Standard" data validation reviews were performed on all of the Phase I data and on 10 percent of the total number of samples collected per media and per individual type of analyses on the Phase II data. A "summary" data validation review was performed on the remainder of the Phase II and III data.

Data validation memoranda for all laboratory results were prepared for each analytical data package and are provided in Appendix L.

In general, the laboratory data were acceptable except where flagged by individual data qualifiers that modify the usefulness of the individual values. Specific data qualifiers that affect data quality are discussed in the relevant soil, surface water, groundwater, and sediment discussions (Section 5.0).

3.10.1.3 Asbestos

Asbestos samples were collected of "exposed insulation" on the walls of the abandoned mill building as described in the draft RI Work Plan (Section 5.6). The samples were analyzed using polarized light microscopy to determine presence of or absence of asbestos by Electron Microscopy Services Laboratory Inc. (EMSL) in Seattle, Washington.

3.11 TASK 11 - DATA EVALUATION

3.11.1 Geological/Geotechnical Data

Following is a discussion of the geological/geotechnical engineering analysis of data collected in the field. The results of the analysis are described in Section 4.2.4 of this report.

3.11.1.1 Seismic Analysis

Potential seismic hazards at the Site are soil liquefaction and seismic induced slope instability. The seismic aspects of slope stability are addressed in the slope stability sections of the text. According to the Uniform Building Code (1997) the Site is in a Seismic Zone 2B. The UBC states that Seismic Zone 2B has a seismic zone factor, Z, (or peak ground acceleration) of 0.2 g for an earthquake with a return period of 475 years. An earthquake with this return period is commonly used as the design basis for structures and earth slopes. A separate site-specific evaluation was performed to revise the estimated peak ground acceleration for the Holden tailings pile locations to 0.18 g. An evaluation of the liquefaction potential of the tailings material was conducted by the empirical method described by Seed, Idriss and Arango (1983). The objective of this analysis was to determine the probability of site soils liquefying during a seismic event based on the UBC criteria.

Historical seismic data from the National Oceanic and Atmospheric Administration were reviewed to determine what seismic events had occurred in the area around the Site since its inception. This review was performed to evaluate the ground acceleration levels to which the tailings piles have been subjected since their completion. The largest seismic events were evaluated by the method described in Dames and Moore report to the State of California (Dames & Moore, 1995).

not in reference list

3.11.1.2 Slope Stability Analysis

The objective of the analysis was to evaluate the probability of the slopes failing under static conditions and during a seismic event. Slope stability analyses were conducted on the tailings pile slopes by the pseudo-static method using the software Slope/W Version 3 (commercially available) that is produced by Geo-Slope International, Ltd. Slope/W uses the limit equilibrium theory to solve for the factor of safety of earth and rock slopes. The Spencer Method of Analysis was chosen as most appropriate for analyses of the Site. Data from Dames and Moore's current investigation and other previous investigations at the Site (Hart Crowser, 1975) were reviewed to determine appropriate engineering characteristics for the Site soils, as well as groundwater levels and topography. The objective of the analysis was to determine the factor of safety against sliding for the tailings slope. Typically, two-thirds of the peak ground acceleration is used as the seismic coefficient in pseudo-static analysis.

3.11.2 Mine Subsidence Potential Analysis

The results of the geologic mapping efforts along the strike of the surface expression of the ore body in the Honeymoon Heights area were analyzed to better define the mine subsidence potential. The analysis utilized the underground mine maps in conjunction with the method of Golder (1990), as presented by Betourney (1996), which is a specialized adaptation of the underground opening stability analysis method developed by the Norwegian Geotechnical Institute (Barten et al., 1974).

3.11.3 Surface Water Data

3.11.3.1 Basin-wide Climatic Water Balance

A general basin-wide, climatic water balance or budget was developed for the entire Railroad Creek watershed for use in analyzing flow characteristics and predicting minimum riprap sizing to protect the lowermost portions of the tailings piles from erosion by Railroad Creek. The results of the basin-wide water budget are discussed in Section 4.3.5.

3.11.3.2 Hydrologic Modeling

The results of the basin-wide climatic water balance were utilized to evaluate flood conditions in Railroad Creek using HEC-1 and HEC-2 (incorporated into a package for Windows called HEC-RAS) hydrologic models. These models were developed by the Army Corps of Engineers Hydrologic Engineering Center (HEC) and have been in use for more than 20 years. Their use is accepted by government agencies including FEMA and the USGS. HEC-1 employs statistical meteorological and watershed characteristics to develop flood estimates, and can be calibrated using actual flow data from the watershed. The Railroad Creek HEC-1 model was calibrated using flow data from the USGS Lucerne gage collected between 1911 and 1946.

The HEC-2 model uses uniform flow assumptions (Mannings equation) to route water through prescribed channel geometry to estimate water levels and velocities during flood events. The model uses channel geometry data from field measured cross-sections, and then interpolates between sections. Cross-sections for Railroad Creek were measured in the field at 12 stations from RC-6 to RC-2 along the Site to characterize the channel geometry. Values of roughness coefficients used by the model were estimated from actual flow measurements in the field for each station. The results of the analyses are presented in Section 4.3.6.

3.11.4 Groundwater Data

Techniques for groundwater data analysis are presented below. The results of the analyses are presented in Section 4.4.

3.11.4.1 Groundwater Flow Net Analysis

Flow nets are graphical representations of groundwater flow systems. Flow nets are constructed by drawing lines of equal groundwater elevation (equipotential lines) and from those equipotential lines drawing lines of anticipated groundwater flow. In cases where the permeable material through which groundwater flows has the same hydraulic properties in all directions, flowlines are drawn perpendicular to equipotential lines.

Flow nets were constructed based on groundwater elevation maps for the Site from May and September 1997. Hydraulic conductivity values from slug tests at site wells are used to provide ranges of values for discharge calculations. The thickness of the zone providing water to Railroad Creek is estimated based on evaluation of site water level measurements, boring logs, and geophysical data.

3.11.4.2 Two-Dimensional Groundwater Modeling

Numerical groundwater modeling (i.e., computer modeling) was not included in the RI. Hydraulic and hydrologic conditions at the Site are highly variable, which results in inherent difficulties in obtaining representative results using complex groundwater models.

3.11.4.3 Site-Specific Water Balance

In comparison to the basin-wide climatic water balance discussed in Section 3.11.3.1, a site-specific water balance was completed to evaluate the magnitude and importance of water source inputs to Railroad Creek in the vicinity of the Site. The potential sources of water analyzed on the Site included precipitation runoff, tributary inflow, and groundwater inflow. Groundwater inflow included flow through the tailings piles, flow through the alluvial aquifer associated with Railroad Creek, and groundwater inflow from the bedrock and mine workings.

The component source inflows were quantified within the accuracy of the available data, and compared with baseflow gain in Railroad Creek for the May/June 1997 and September 1997 timeframes. Average flow conditions were used or estimated for the source inflows and baseflow gain in Railroad Creek, and storage effects were not directly quantified. Railroad Creek adjacent to the Site was subdivided into two reaches: Reach 1 from station RC-1 to RC-4, and Reach 2 from station RC-4 to RC-2. These reaches represent unique hydrologic environments, with Reach 1 transitioning from background conditions to the impacted portions of the Site, including the effects of the Portal Drainage and groundwater from the western portion of the site, and Reach 2 representing conditions potentially impacted by the tailings piles.

The site-specific water balance approach is to reference all of the water balance components to gain or loss of water in Railroad Creek. Flow measurements made in Railroad Creek provide the most complete and accurate measure of the flow of water from the Site. The water balance analysis was completed for the period of May 15/June 15, 1997, and September 1997 using flow data obtained during the respective sampling periods. These two sampling periods represent the range of seasonal conditions observed during 1997.

The results of the site-specific water balance are presented in Section 4.4.4.

3.12 TASK 12 - BASELINE RISK ASSESSMENT

The methods utilized for the Human Health and Ecological Risk Assessments are described in Section 7.0 of this report.

TABLE 3.0-1
KEY OF SITE FEATURES & MEDIA SAMPLING/DATA COLLECTION LOCATIONS
HOLDEN MINE RI/FS
DAMES & MOORE JOB NO. 17693-005-019

Feature/Area or Media	Station No.	Location by Area	Coordinate	Comments
Feature/Area				
1500-Level Main Portal	N/A	Mine Support & Waste Rock	E.0-3.0	Near southern boundary
1500-Level Ventilator Portal	N/A	Mine Support & Waste Rock	D.7-3.0	Near western boundary
1100-Level Portal	N/A	Honeymoon Heights	D.8-3.1	
1000-Level Portal	N/A	Honeymoon Heights	D.8-3.1	
800-Level Portal	N/A	Honeymoon Heights	D.8-3.1	
700-Level Portal	N/A	Honeymoon Heights	D.8-3.2	
550-Level Portal	N/A	Honeymoon Heights	D.9-3.2	
300-Level Portal	N/A	Honeymoon Heights	D.9-3.2	
Abandoned Septic Field	N/A	SE of Holden Village	E.2-3.0	
Abandoned Surface Water Ret.	N/A	Mine Support & Waste Rock	D.7-2.9	
Baseball Field/Campground	N/A	Baseball Field/Campground	D.7-2.9, D.8-2.9	
Copper Creek	N/A	S. of Tailings Piles 1 & 2,	E.1-3.1, E.1-3.2, E.2-3.0, E.3-3.1	
Copper Creek Diversion	N/A	W. of Tailings Pile 1	E.0-3.0, E.1-3.0	
East Waste Rock Pile	N/A	Mine Support & Waste Rock	E.1-3.0, E.1-3.1	
Holden Village	N/A	Holden Village	E.1-2.9, E.2-2.9	
Holden Village Septic Field	N/A	SE of Winston Home Sites	D.9-2.9, E.0-2.9	
Honeymoon Heights	N/A	Honeymoon Heights	D.7-3.0, 3.1, 3.2; D.8-3.0, 3.1, 3.2, 3.3; D.9-3.0, 3.1, 3.2, 3.3	
Hydroelectric Plant	N/A	W. of Tailings Pile 1	E.0-3.0	
Intermittent Drainage	N/A	Honeymoon Heights	D.8-3.0, D.8-3.1, D.8-3.2, D.8-3.3	
Lagoon	N/A	Mine Support & Waste Rock	E.0-2.9, E.0-3.0	
Lucerne Bar	N/A	Lucerne		
Lucerne Guard Station	N/A	Lucerne	I-3	
Maintenance Yard	N/A	Maintenance Yard	E.0-3.0	
Mill Building	N/A	Mill Building	E.0-3.0	
Mine Support and Waste Rock	N/A	Mine Support & Waste Rock	D.7-2.9, 3.0; D.8-2.9, 3.0; D.9-2.9, 3.0; E.0-2.9, 3.0, 3.1; E.1-3.0, 3.1, 2.9	
Portal Museum	N/A	Mine Support & Waste Rock	E.0-3.0	
Sauna	N/A	NW of Tailings Pile 1	E.1-3.0	
Shop	N/A	Maintenance Yard	E.0-3.0	
Storage	N/A	Maintenance Yard	E.0-3.0	
Tailings Pile 1	N/A	Tailings Pile 1	E.1-3.0, E.2-3.0, E.2-3.1	
Tailings Pile 2	N/A	Tailings Pile 2	E.2-3.0, E.2-3.1, E.3-3.0, E.3-3.1, E.4-3.0, E.4-3.1	
Tailings Pile 3	N/A	Tailings Pile 3	E.4-3.0, E.4-3.1, E.5-3.0, E.5-3.1	
USFS Guard Station	N/A	USFS Guard Station	E.0-2.9	
West Waste Rock Pile	N/A	Mine Support & Waste Rock	E.0-3.0	
Winston Home Sites	N/A	Winston Home Sites	D.8-2.9; D.9-2.8, 2.9; E.0-2.8, 2.9	
Geophysical Survey Lines				
A-A'	N/A	North of West Waste Rock Pile	E.0-2.9, E.0-3.0	
B1-B1'	N/A	Tailings Pile 1	E.1-3.0	
B2-B2'	N/A	East Waste Rock Pile	E.1-3.1	
C-C'	N/A	Tailings Pile 2	E.3-3.0, E.3-3.1	
D-D'	N/A	Tailings Pile 3	E.4-3.0, E.4-3.1	
E-E'	N/A	East of Tailings Pile 3	E.5-3.0, E.5-3.1	

TABLE 3.0-1
KEY OF SITE FEATURES & MEDIA SAMPLING/DATA COLLECTION LOCATIONS
HOLDEN MINE RI/FS
DAMES & MOORE JOB NO. 17693-005-019

Feature/Area or Media	Station No.	Location by Area	Coordinate	Comments
EM1-EM1'	N/A	Western Mine Support Area	D.8-2.9, D.8-3.0, D.9-2.9, D.9-3.0, E.0-2.9	
EM2-EM2'	N/A	Western Mine Support Area	D.8-3.0, D.9-3.0, E.0-3.0, E.1-3.0	
EM3-EM3'	N/A	East of Tailings Pile 3	E.5-3.0, E.5-3.1	
F-F'	N/A	North of Tailings Piles 2 & 3	E.4-3.0	
G-G'	N/A	Between Tailings Piles 1 & 2	E.2-3.0, E.2-3.1	
Sample Locations				
Groundwater Monitoring Wells				
	HBKG-1	W. of Tailings Pile 1	E.0-3.0	Potential background
	HBKG-2	E. of Baseball Field/Campgr.	D.8-2.9	Potential background
	CC-BKG	SW Tailings Pile 2	E.2-3.1	Background
	H-1	Holden Village	E.1-2.9	
	H-2	Holden Village	E.2-2.9	
	HV-3/H-3	Holden Village	E.1-2.9	Background
	DS-1	East of Tailings Pile 3	E.5-3.0	Downstream Wells:
	DS-2	East of Tailings Pile 3	E.5-3.0	Downstream Wells:
	TP1-1A	Tailings Pile 1	E.1-3.0	
	TP1-2A	Tailings Pile 1	E.1-3.0	
	TP1-2L	Tailings Pile 1	E.1-3.0	
	TP1-3A	Tailings Pile 1	E.1-3.0	
	TP1-3L	Tailings Pile 1	E.1-3.0	
	TP1-4A	Tailings Pile 1	E.1-3.0	
	TP1-4L	Tailings Pile 1	E.1-3.0	
	TP1-5A	Tailings Pile 1	E.2-3.0	
	TP1-6A	Tailings Pile 1	E.1-3.0	
	TP1-6L	Tailings Pile 1	E.1-3.0	
	PZ-1A	Tailings Pile 2	E.3-3.1	
	PZ-1B	Tailings Pile 2	E.3-3.1	
	PZ-1C	Tailings Pile 2	E.3-3.1	
	PZ-2A	Tailings Pile 2	E.3-3.0	
	PZ-2B	Tailings Pile 2	E.3-3.0	
	PZ-2C	Tailings Pile 2	E.3-3.0	
	PZ-3A	Tailings Pile 2	E.3-3.0	
	PZ-3B	Tailings Pile 2	E.3-3.0	
	PZ-3C	Tailings Pile 2	E.3-3.0	
	TP2-1L	Tailings Pile 2	E.3-3.1	
	TP2-2L	Tailings Pile 2	E.3-3.0	
	TP2-4A	Tailings Pile 2	E.3-3.0	
	TP2-4B	Tailings Pile 2	E.3-3.0	
	TP2-5A	Tailings Pile 2	E.3-3.0	
	TP2-5B	Tailings Pile 2	E.3-3.0	
	TP2-6L	Tailings Pile 2	E.3-3.1	
	TP2-7N&S	Tailings Pile 2	E.4-3.0	
	TP2-8A	Tailings Pile 2	E.4-3.0	
	TP2-8B	Tailings Pile 2	E.4-3.0	
	TP2-9L	Tailings Pile 2	E.4-3.1	
	TP2-10L	Tailings Pile 2	E.2-3.1	
	TP2-11	Tailings Pile 2	E.2-3.0	
	TP2-11L	Tailings Pile 2	E.2-3.0	
	TP3-4	Tailings Pile 3	E.4-3.0	

Feature/Area or Media	Station No.	Location by Area	Coordinate	Comments
	TP3-4L	Tailings Pile 3	E.4-3.0	
	TP3-5A	Tailings Pile 3	E.5-3.0	
	TP3-6A	Tailings Pile 3	E.5-3.0	
	TP3-6BL	Tailings Pile 3	E.5-3.0	
	TP3-7	Tailings Pile 3	E.4-3.0	
	TP3-8	Tailings Pile 3	E.4-3.0	
	TP3-9	Tailings Pile 3	E.5-3.0	
	TP3-10	Tailings Pile 3	E.5-3.0	
	TP3-10L	Tailings Pile 3	E.5-3.0	
	PZ-4A	Tailings Pile 3	E.4-3.0	
	PZ-4B	Tailings Pile 3	E.4-3.0	
	PZ-4C	Tailings Pile 3	E.4-3.0	
	PZ-5A	Tailings Pile 3	E.4-3.0	
	PZ-5B	Tailings Pile 3	E.4-3.0	
	PZ-5C	Tailings Pile 3	E.4-3.0	
	PZ-6A	Tailings Pile 3	E.4-3.0	
	PZ-6B	Tailings Pile 3	E.4-3.0	
	PZ-6C	Tailings Pile 3	E.4-3.0	
	Lucerne Well	Lucerne	I-3	Lucerne Guard Station
Subsurface/Surface Soil				
	DMSS-1	Holden Village	E.2-2.9	Surface soil
	DMSS-2	Holden Village	E.2-2.9	Surface soil
	DMSS-3	Holden Village	E.1-2.9	Surface soil
	DMSS-4	Holden Village	E.1-2.9	Surface soil
	DMSS-5	Holden Village	E.1-2.9	Surface soil
	DMSS-6	Holden Village	E.2-2.9	Surface soil
	DMSS-7	Holden Village	E.1-2.9	Surface soil
	DMSS-8	Maintenance Yard	E.0-3.0	Surface soil
	DMSS-9	Maintenance Yard	E.0-3.0	Surface soil
	DMSS-10	Maintenance Yard	E.0-3.0	Surface soil
	DMSS-11	Tailings Pile 1	E.1-3.0	Surface soil
	DMSS-12	Tailings Pile 1	E.1-3.0	Surface soil
	DMSS-13	Tailings Pile 1	E.2-3.0	Surface soil
	DMSS-14	Tailings Pile 2	E.2-3.0	Surface soil
	DMSS-15	Tailings Pile 2	E.3-3.0	Surface soil
	DMSS-16	Tailings Pile 2	E.4-3.0	Surface soil
	DMSS-17	Tailings Pile 3	E.4-3.0	Surface soil
	DMSS-18	Tailings Pile 3	E.4-3.0	Surface soil
	DMSS-19	Tailings Pile 3	E.5-3.0	Surface soil
	DMSS-20	East of Tailings Pile 3	E.5-3.0	Windblown tailings
	DMSS-21	East of Tailings Pile 3	E.6-3.0	Windblown tailings
	DMSS-22	East of Tailings Pile 3	E.6-3.0	Windblown tailings
	DMSS-23	East of Tailings Pile 3	E.7-3.0	Windblown tailings
	DMSS-24	East of Tailings Pile 3	E.5-3.0	Windblown tailings
	DMSS-25	Baseball Field	D.7-2.9	Surface soil
	DMSS-26	Wilderness Area	D.7-2.9	Surface soil
	DMSS-27	Wilderness Area	D.7-2.9	Surface soil
	Lagoon 6"	Lagoon	E.0-2.9	Surface soil
	Lagoon 2'	Lagoon	E.0-2.9	Subsurface soil sample
	DMLG1	Lagoon	E.0-3.0	Subsurface soil sample
	DMLG2	Lagoon	E.0-2.9	Subsurface soil sample
	DMLG3	Lagoon	E.0-2.9	Subsurface soil sample

TABLE 3.0-1
KEY OF SITE FEATURES & MEDIA SAMPLING/DATA COLLECTION LOCATIONS
HOLDEN MINE RI/FS
DAMES & MOORE JOB NO. 17693-005-019

Feature/Area or Media	Station No.	Location by Area	Coordinate	Comments
	DMLG4	Lagoon	E.0-3.0	Subsurface soil sample
	DMLG5	Lagoon	E.0-2.9	Subsurface soil sample
	DMBG1	Approximately 1-mile West of Site	D-2	Background surface soil
	DMBG2	Holden Creek Drainage	D-2	Background surface soil
	DMBG3	Between Holden Creek & Hart Lake	C-2	Background surface soil
	DMBG4	East of Hart Lake	C-2	Background surface soil
	DMBG5	Between Hart Lake & Crown Point	B-2	Background surface soil
	DMBG6	Lyman Lakes	A-3	Background surface soil
	DMBG7	West of Hart Lake	B-2	Background surface soil
	DMBG8	West of Holden Creek	C-2	Background surface soil
	DMBG9	West of Big Creek	D-2	Background surface soil
	DMBG10	Copper Basin	E-3	Background surface soil
	DMBG11	Southwest of Site	D-3	Background surface soil
	DMBG12	South of Site	D-3	Background surface soil
	DMBG13	Near South Site Boundary	E-3	Background surface soil
	DMBG14	Near Holden Creek	D-2	Background surface soil
	DMBG15	Near Holden Creek	D-2	Background surface soil
	DMBG16	West of Site Boundary	D-2	Background surface soil
	DMBG17	Near Winston Home Sites	D-2	Background surface soil
	DMBG18	Northeast of Site	E-2	Background surface soil
	DMBG19	North of Holden Village	E-2	Background surface soil
	DMTP1-2	Tailings Pile 1	E.1-3.0	Test pit excavation
	DMTP1-3	Tailings Pile 1	E.1-3.0	Test pit excavation
	DMTP1-4	Tailings Pile 1	E.1-3.0	Test pit excavation
	DMTP1S-1	Tailings Pile 1	E.1-3.0	Test pit excavation
	DMTP2-1	Tailings Pile 2	E.2-3.0	Test pit excavation
	DMTP2-2	Tailings Pile 2	E.3-3.0	Test pit excavation
	DMTP2S-1	Tailings Pile 2	E.3-3.1	Test pit excavation
	DMTP3-1	Tailings Pile 3	E.4-3.0	Test pit excavation
	DMTP3-2	Tailings Pile 3	E.5-3.0	Test pit excavation
	DMTP3-3	Tailings Pile 3	E.5-3.0	Test pit excavation
	DMTP3-4	Tailings Pile 3	E.5-3.0	Test pit excavation
	DMTP3S-1	Tailings Pile 3	E.4-3.1	Test pit excavation
	DMTP3E-1	Immed. east of Tailings Pile 3	E.5-3.0	Test pit excavation
	DMTP3E-2	Immed. east of Tailings Pile 3	E.5-3.0	Test pit excavation
	DMTP3E-3	Immed. east of Tailings Pile 3	E.5-3.0	Test pit excavation
	DMTP3E-4	Immed. east of Tailings Pile 3	E.5-3.0	Test pit excavation
	DMTP3E-5	Immed. east of Tailings Pile 3	E.5-3.1	Test pit excavation
	DMTP3E-6	Immed. east of Tailings Pile 3	E.5-3.1	Test pit excavation
	DMTPW-1	Winston home sites	D.8-2.9	Test pit excavation
	DMTPW-2	Winston home sites	D.8-2.9	Test pit excavation
	DMTPW-3	Winston home sites	D.8-2.9	Test pit excavation
	DMTPW-4	Winston home sites	D.8-2.9	Test pit excavation
	DMTPW-5	Winston home sites	D.9-2.9	Test pit excavation
	DMTPW-6	Winston home sites	D.9-2.9	Test pit excavation
	DMTPW-7	Winston home sites	D.9-2.9	Test pit excavation
Surface Water				
	RC-1	Railroad Creek	D.7-2.9	
	RC-1 North Bank	Railroad Creek	D.7-2.9	
	RC-1 South Bank	Railroad Creek	D.7-2.9	
	RC-2	Railroad Creek	E.5-3.0	
	RC-2 South Bank	Railroad Creek	E.5-3.0	

TABLE 3.0-1
KEY OF SITE FEATURES & MEDIA SAMPLING/DATA COLLECTION LOCATIONS
HOLDEN MINE RI/FS
DAMES & MOORE JOB NO. 17693-005-019

Feature/Area or Media	Station No.	Location by Area	Coordinate	Comments
	RC-3	Railroad Creek	I-3	
	RC-4	Railroad Creek	E.0-2.9	
	RC-4 South Bank	Railroad Creek	E.0-2.9	
	RC-5	Railroad Creek	E-3	
	RC-5A	Railroad Creek	E-3	
	RC-6	Railroad Creek	D.7-2.9	
	RC-6 North Bank	Railroad Creek	D.7-2.9	
	RC-7	Railroad Creek	E.4-3.0	
	RC-8	Railroad Creek	I-3	
	RC-8 North Bank	Railroad Creek	I-3	
	RC-10	Near Seven Mile Creek	F-3	
	RC-11	Upstream of Holden Creek	D-2	
	CC-1	Copper Creek	E.2-3.1	
	CC-2	Copper Creek	E.2-3.0	
	CC-D	Copper Creek Diversion	E.1-3.0	
	CC-D1	Copper Creek Diversion	E.1-3.0	
	P-1	Mine Support & Waste Rock	E.0-3.0	Portal Drainage/1500 Main
	P-5	Mine Support & Waste Rock	D.9-2.9	Portal Drainage/RR Creek
	HC-1	Holden Creek	D-2	
	HC-2	Holden Creek	C-2	
	HC-3	Holden Creek	C-2	
	HC-4	Holden Creek	C-1	
	Big-1	Big Creek	D-2	
	Tenmile Creek	Tenmile Creek	E-2	
Seeps				
	A1	Honeymoon Heights	D.B-3.1	1100 Level Portal
	SP1	Tailings Pile 1	E.1-3.0	
	SP2	Tailings Pile 1	E.2-3.0	
	SP3	Tailings Pile 2	E.3-3.0	
	SP4	Tailings Pile 3	E.4-3.0	
	SP5	East of Tailings Pile 3	E.5-3.0	
	SP6	West Waste Rock Pile	E.0-3.0	
	SP7	West Waste Rock Pile	E.0-3.0	
	SP8	East Waste Rock Pile	E.1-3.0	
	SP9	Between P-5 & RC-4	D.9-2.9	
	SP10W	River Sauna	E.1-2.9	
	SP10E	River Sauna	E.1-2.9	
	SP11	West of Vehicle Bridge	E.0-2.9	
	SP12	West of P-5	D.9-3.0	
	SP13	South of Holden Village	E.1-2.9, 3.0; E.2-2.9, 3.0	"Black Seep"
	SP14	Honeymoon Heights	D.8-3.1	
	SP15W	North of West Waste Rock Pile	E.0-3.0	
	SP15E	North of West Waste Rock Pile	E.0-3.0	
	SP16	Lagoon	E.0-2.9	
	SP17	East of Tailings Pile 3	E.5-3.1	
	SP18	East of Tailings Pile 3	E.5-3.0	Bank sample
	SP19	Tailings Pile 1	E.1-3.0	
	SP20	Tailings Pile 1 (Near Copper Creek)		
	SP21	East of Tailings Pile 3	2.6-3.1	
	SP22	North of Maintenance Yard	E.0-3.0	
	SP23	Between RC-1 and P-5	D.8-3.0	
	SP23B	Between RC-1 and P-5	D.8-3.0	

TABLE 3.0-1
KEY OF SITE FEATURES & MEDIA SAMPLING/DATA COLLECTION LOCATIONS
HOLDEN MINE RI/FS
DAMES & MOORE JOB NO. 17693-005-019

Feature/Area or Media	Station No.	Location by Area	Coordinate	Comments
	SP24	West of RC-4	E.0-2.9	
	SP25	Between Vehicle Bridge & RC-4	E.0-2.9	
	SP26	Between RC-1 and RC-6	D.7-2.9	
	SP-27	Near Big Creek	D-2	
	CC-D1	Copper Creek Diversion	E.1-2.9	
Sediment - Lake Chelan				
	1-1	Lucerne	N/A	
	1-2	Lucerne	N/A	
	2-1	Lucerne	N/A	
	2-2	Lucerne	N/A	
	3-1	Lucerne	N/A	
	3-1A	Lucerne	N/A	
	3-1B	Lucerne	N/A	
	3-1C	Lucerne	N/A	
	3-2	Lucerne	N/A	
	3.5-1	Lucerne	N/A	
	3.5-2	Lucerne	N/A	
	5-1	Lucerne	N/A	
	5-2	Lucerne	N/A	
	1	Stehekin	N/A	
	2	Stehekin	N/A	
	3A	Stehekin	N/A	
	3B	Stehekin	N/A	
	3C	Stehekin	N/A	
	4	Stehekin	N/A	
USGS Select Samples				
	344	Ten Mile Creek	E.6-2.9	
	345	Railroad Creek near RC-2	E.5-3.0	
	346	Copper Creek Diversion	E.1-3.0	
	347	Railroad Creek at Vehicle Bridge	E.0-2.9	
	350	East of Tailings Pile 3	E.5-3.0	
	351	Nine Mile Creek	F-3	
	352	Railroad Creek near Seven Mile Creek	F-3	
	353	Seven Mile Creek	F-3	
	354	Railroad Creek at Lucerene	N/A	
	355	Holden Creek	D-2	
	356	Railroad Creek West of Site	D-2	
	MP-7	Railroad Creek at Mile Post 7	G-3	
USBM Select Samples				
	BKG 1/2	Downstream of Vehicle Bridge	E.0-2.9	
	DG-1	Downstream of Tailings Pile 3	E.6-3.0	
	TP1-2	Adjacent to Tailings Pile1	E.1-3.0	
	TP2-1	Downstream of Copper Creek	E.2-3.0	
	TP2-2	Adjacent to Tailings Pile 2	E.3-3.0	
	TP3-1	Adjacent to Tailings Pile 3	E.4-3.0	
	RC-2	At Railroad Creek RC-2 Station	E.5-3.0	

TABLE 3.1-1
ANALYTICAL PROGRAM FOR SURFACE & SUBSURFACE SOIL
HOLDEN MINE RI/FS
DAMES & MOORE JOB NO. 17693-005-019

Parameters			Analytical Program				
Media/Sample No.	**Locations**	**Sampling Frequency**	**Geotechnical**	**Total Metals***	**TPH (Gasoline , Range)**	**TPH (Diesel Range)**	**PCBs**
Subsurface/Surface Soil: **Area Background**	DMBG-1 through DMBG-19	Oct 1998		X			
Holden Village (Surface)	DMSS-1 through DMSS-7	Sept 1997		X			
Baseball Field (Surface)	DMSS-25	Oct 1997		X			
Wilderness Boundary (Surface)	DMSS-26, DMSS-27	Oct 1997		X			
Maintenance Yard (Subsurface/Surface)	DMSS-8 through DMSS-10 (0-6" and 2 ft bgs), Storage (6")	Oct 1997		X	X	X	X
Lagoon (Subsurface/Surface)	Lagoon 6" and Lagoon 2'	Oct 1997		X	X	X	X
	Lagoon 6" and Lagoon 2' DMLG-1-2', DMLG-1-4' DMLG-2-4', DMLG-2-4', DMLG-2-7 1/2', DMLG-3-2', DMLG-3-4', DMLG-4-2', DMLG-4-4', DMLG-5-2', DMLG-5-4'	Oct 1998		X**		X	
Tailings Pile (Surface)	DMSS-11 through DMSS-19	Sept 1997		X			
Tailings Piles (Subsurface)	DMTP1-2 through -4, DMTP2-1 through -2, DMTP3-1 through -4	Sept 1997	X	X			
Windblown Tailings (Surface)	DMSS-20 through DMSS-24	Oct 1997		X			

Notes:

bgs = below ground surface

* Metals included aluminum, arsenic, barium, beryllium, cadmium, calcium, chromium, copper, iron, lead, magnesium, manganese, molybdenum, nickel, potassium, silver, sodium, thallium, uranium, zinc

** Metals included cadmium, copper, and lead only.

TABLE 3.2-1
ANALYTICAL PROGRAM FOR SURFACE WATER (APRIL 1997)
HOLDEN MINE RI/FS
DAMES & MOORE JOB NO. 17693-005-019

Parameters	Field Measurements				Inorganic Analytes									Organic Analytes		
Media/Sample No.	pH/EC/Temp/ Turbidity	Fe^{+2} (qualitative)	RedOx Potential	Flow Estimates	Total Recoverable Metals	Dissolved Metals	TDS/TSS	Sulfate	Alkalinity	Hardness	Chloride	NO_3/NO_2	Cyanide (total/amenable)	Low-level PCBs	TPH (Gasoline Range)	TPH (Diesel Range)
SURFACE WATER																
<u>Railroad Creek:</u>																
RC-1	X			X	X	X	X	X	X	X	X	X				
RC-2	X			X	X	X	X	X	X	X	X	X				
RC-3	X			X	X	X	X	X	X	X	X	X				
RC-4	X			X	X	X	X	X	X	X	X	X				
RC-5	X			X	X	X	X	X	X	X	X	X				
RC-6	X			X	X	X	X	X	X	X	X	X				
RC-7	X			X	X	X	X	X	X	X	X	X				
RC-8	X			X	X	X	X	X	X	X	X	X				
<u>Copper Creek Diversion:</u>																
CC-D	X			X	X	X	X	X	X	X	X	X				

<u>Notes:</u>

Total recoverable and dissolved metals consist of Aluminum, Arsenic, Barium, Beryllium, Cadmium, Calcium, Chromium, Copper, Iron, Lead, Magnesium, Manganese, Mercury, Nickel, Potassium, Selenium, Silver, Sodium, Thalium, and Zinc.

Samples were collected at each Railroad Creek station in triplicate and labeled RC-#A, RC-#B, RC-#C. Only the first replicate (A) was analyzed at each station with the exception of RC-6 and RC-1, where all three replicates were analyzed.

TABLE 3.2-2
ANALYTICAL PROGRAM FOR GROUNDWATER, SEEP AND SURFACE WATER (MAY - JUNE 1997)
HOLDEN MINE RI/FS
DAMES & MOORE JOB NO. 17693-005-019

Parameters	Sample Event	Field Tests					Primary Analyte List						Supplemental Analyte List							Organic Analyte List			Groundwater Measurements		
Media/ Sample No.	Storm Event Alternative[1]	pH/EC/Temp/ Turbidity	Dissolved Oxygen	Fe^{+2} (qualitative)	RedOx Potential	Flow Estimates	Total Recoverable Metals	Dissolved Metals	TDS/TSS	Sulfate	Alkalinity	Hardness	Total Recoverable Metals	Dissolved Metals	Chloride	NO_3/NO_2	Color	Cyanide (total & amenable)	Ortho/Total Phosphorous	Low-level PCBs	TPH (Gasoline Range)	TPH (Diesel Range)	Manual Water Level Measurements	Slug Tests	Transducers
GROUNDWATER																									
Potential Background:																									
HBKG-1		X		X	X			X	X	X	X	X								X	X	X	X	X	X
HBKG-2		X		X	X			X	X	X	X	X											X		
CC-BKG																									
HV-3		X		X	X			X	X	X	X	X											X		
Downstream Wells:																									
DS-1		X		X	X			X	X	X	X	X											X		
DS-2		X		X	X			X	X	X	X	X		X	X	X	X	X	X	X	X	X	X	X	X
Tailings Pile 1:																									
TP1-1A		X		X	X			X	X	X	X	X											X		
TP1-2A		X		X	X			X	X	X	X	X											X		
TP1-2L		X		X	X			X		X	X	X													
TP1-3A		X		X	X			X	X	X	X	X											X		
TP1-3L		X		X	X			X		X	X	X													
TP1-4A		X		X	X			X	X	X	X	X											X		
TP1-4L		X		X	X			X		X	X	X													
TP1-5A		X		X	X			X	X	X	X	X											X	X	X
TP1-6A		X		X	X			X	X	X	X	X											X		
TP1-6L		X		X	X			X		X	X	X													
Tailings Pile 2:																									
PZ-1A		X		X	X			X	X	X	X	X											X		
PZ-1B		X		X	X			X	X	X	X	X											X		
PZ-1C																							X		
PZ-2A																							X		
PZ-2B																							X		
PZ-2C																							X		
PZ-3A		X		X	X			X	X	X	X	X		X	X	X	X	X	X				X		
PZ-3B																							X		
PZ-3C																									
TP2-4A		X		X	X			X	X	X	X	X											X		
TP2-4B																							X		
TP2-5A		X		X	X			X	X	X	X	X											X		
TP2-5B																							X		
TP2-7N&S																							X	X	X
TP2-8A		X		X	X			X	X	X	X	X											X		
TP2-8B																							X		
TP2-11		X		X	X			X	X	X	X	X											X	X	X
TP2-11L																									
Tailings Pile 3:																									
TP3-4		X		X	X			X	X	X	X	X											X		
TP3-4L								X		X	X	X													
TP3-5A																							X		
TP3-6A		X		X	X			X	X	X	X	X											X		
TP3-6BL		X		X	X			X		X	X	X													
TP3-7																							X		
TP3-8		X		X	X			X	X	X	X	X											X		
TP3-9		X		X	X			X	X	X	X	X											X		
TP3-10		X		X	X			X	X	X	X	X											X		
TP3-10L		X		X	X			X		X	X	X													
PZ-4A																							X	X	X
PZ-4B																							X		X
PZ-4C																							X		
PZ-5A																							X		
PZ-5B																							X		
PZ-5C																							X		
PZ-6A		X		X	X			X	X	X	X	X											X		
PZ-6B																							X		
PZ-6C																							X		
Other:																									
Lucerne Well		X		X				X	X	X	X	X													

TABLE 3.2-2
ANALYTICAL PROGRAM FOR GROUNDWATER, SEEP AND SURFACE WATER (MAY - JUNE 1997)
HOLDEN MINE RI/FS
DAMES & MOORE JOB NO. 17693-005-019

Parameters	Sample Event	Field Tests					Primary Analyte List						Supplemental Analyte List							Organic Analyte List			Groundwater Measurements		
Media/ Sample No.	Storm Event Alternative[1]	pH/EC/Temp/ Turbidity	Dissolved Oxygen	Fe^{+2} (qualitative)	RedOx Potential	Flow Estimates	Total Recoverable Metals	Dissolved Metals	TDS/TSS	Sulfate	Alkalinity	Hardness	Total Recoverable Metals	Dissolved Metals	Chloride	NO_3/NO_2	Color	Cyanide (total & amenable)	Ortho/Total Phosphorous	Low-level PCBs	TPH (Gasoline Range)	TPH (Diesel Range)	Manual Water Level Measurements	Slug Tests	Transducers
Seepage:																									
SP1		X		X	X	X		X	X	X	X	X								X	X	X			
SP2	X	X				X		X	X	X	X	X		X	X	X	X	X	X	X	X	X			
SP3		X		X	X	X		X	X	X	X	X		X	X	X	X	X	X						
SP4		X		X	X	X		X	X	X	X	X													
SP5		X		X	X	X		X	X	X	X	X													
SP6		X		X	X	X		X	X	X	X	X													
SP7		X		X	X	X		X	X	X.	X	X		X	X	X	X	X	X						
SP8		X		X	X	X		X	X	X	X	X													
SP9		X				X		X	X	X	X	X													
SP10W		X		X	X	X		X	X	X	X	X													
SP10E		X		X	X	X		X	X	X	X	X													
SP11		X		X	X	X		X	X	X	X	X													
SP12		X		X		X		X	X	X	X	X													
SP13 (Black Seep)		X				X		X	X	X	X	X													
SP14		X		X	X	X	X	X	X	X	X	X													
SP15W		X		X	X	X		X	X	X	X	X													
SP15E	X	X			X	X		X	X	X	X	X													
SP16		X		X	X	X		X	X	X	X	X		X	X	X	X	X	X	X	X	X			
SP17		X		X	X	X		X	X	X	X	X													
SP18 (Bank)		X		X	X	X		X	X	X	X	X													
SP19		X		X	X	X		X	X	X	X	X													
SP20																									
SP21		X		X	X	X	X	X	X	X	X	X													
SP22		X		X	X	X		X	X	X	X	X								X		X			
SP23	X	X		X	X	X		X	X	X	X	X													
SP23B																									
SP24		X		X	X	X		X	X	X	X	X													
SP25		X		X	X	X		X	X	X	X	X													
CC-D1		X			X	X		X	X	X	X	X		X	X	X	X	X	X						
SURFACE WATER																									
Railroad Creek:																									
RC-1		X	X				X	X	X	X	X	X	X	X	X	X	X	X	X						
RC-1 North Bank		X	X				X	X	X	X	X	X													
RC-1 South Bank		X	X				X	X	X	X	X	X													
RC-2	X	X	X			X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X			
RC-2 South Bank		X	X				X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X			
RC-3		X			X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X			
RC-4		X	X		X	X	X	X	X	X	X	X													
RC-4 South Bank		X	X		X		X	X	X	X	X	X													
RC-5		X			X		X	X	X	X	X	X													
RC-5A		X			X		X	X	X	X	X	X													
RC-6																									
RC-6 North Bank	X	X	X		X		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X			
RC-7		X			X		X	X	X	X	X	X													
RC-8																									
Copper Creek:																									
CC-1		X				X	X	X	X	X	X	X													
CC-2		X				X	X	X	X	X	X	X													
Portal Drainage:																									
P-1		X			X	X	X	X	X	X	X	X	X	X	X	X	X	X	X						
P-5	X	X			X	X	X	X	X	X	X	X	X	X	X	X	X	X	X						

Notes:
Primary Metals consist of Aluminum, Barium, Beryllium, Cadmium, Calcium, Chromium, Copper, Iron, Lead, Magnesium, Manganese, Nickel, Potassium, Silver, Sodium, Zinc
Supplemental Metals consist of Arsenic, Mercury, Molybdenum, Selenium, Thallium, Uranium
Groundwater wells with an "L" suffix are lysimeters.
[1] Water quality sampling for Primary Analyte List analysis only, field parameters, and flow collected weekly from May 19, 1997 to June 16, 1997

TABLE 3.2-3
ANALYTICAL PROGRAM FOR GROUNDWATER, SEEP AND SURFACE WATER (JULY 1997)
HOLDEN MINE RI/FS
DAMES & MOORE JOB NO. 17693-005-019

Parameters	Field Tests					Primary Analyte List						Supplemental Analyte List							Organic Analyte List			Groundwater Measurements		
Media/ Sample No.	pH/EC/Temp/ Turbidity	Dissolved Oxygen	Fe^{+2} (qualitative)	RedOx Potential	Flow Estimates	Total Recoverable Metals	Dissolved Metals	TDS/TSS	Sulfate	Alkalinity	Hardness	Total Recoverable Metals	Dissolved Metals	Chloride	NO_3/NO_2	Color	Cyanide (total and amenable)	Ortho/Total Phosphorous	Low-level PCBs	TPH (Gasoline Range)	TPH (Diesel Range)	Manual Water Level Measurements	Slug Tests	Transducers
GROUNDWATER																								
Potential Background:																								
HBKG-1																						X		X
HBKG-2																						X		
CC-BKG (dry)																								
HV-3																						X		
Downstream Wells:																								
DS-1																						X		
DS-2																						X		X
Tailings Pile 1:																								
TP1-1A																						X		
TP1-2A																						X		
TP1-2L																								
TP1-3A																						X		
TP1-3L																								
TP1-4A																						X		
TP1-4L																								
TP1-5A																						X		X
TP1-6A																						X		
TP1-6L																								
Tailings Pile 2:																								
PZ-1A																						X		
PZ-1B																						X		
PZ-1C																						X		
PZ-2A																						X		
PZ-2B																						X		
PZ-2C																						X		
PZ-3A																						X		
PZ-3B																						X		
PZ-3C (dry)																								
TP2-4A																						X		
TP2-4B																						X		
TP2-5A																						X		
TP2-5B																						X		
TP2-7N&S																						X		X
TP2-8A																						X		
TP2-8B																						X		
TP2-11																						X		X
TP2-11L																								
Tailings Pile 3:																								
TP3-4																						X		
TP3-4L																								
TP3-5A																						X		
TP3-6A																						X		
TP3-6BL																								
TP3-7																						X		
TP3-8																						X		
TP3-9																						X		
TP3-10																						X		
TP3-10L																								
PZ-4A																						X		X
PZ-4B																						X		X
PZ-4C																						X		
PZ-5A																						X		
PZ-5B																						X		
PZ-5C																						X		
PZ-6A																						X		
PZ-6B																						X		
PZ-6C																						X		
Other:																								
A-1 (1100 Portal)	X		X	X			X	X	X	X	X													
Lucerne Well																								

TABLE 3.2-3
ANALYTICAL PROGRAM FOR GROUNDWATER, SEEP AND SURFACE WATER (JULY 1997)
HOLDEN MINE RI/FS
DAMES & MOORE JOB NO. 17693-005-019

Parameters	Field Tests					Primary Analyte List						Supplemental Analyte List							Organic Analyte List			Groundwater Measurements		
Media/ Sample No.	pH/EC/Temp/ Turbidity	Dissolved Oxygen	Fe^{+2} (qualitative)	RedOx Potential	Flow Estimates	Total Recoverable Metals	Dissolved Metals	TDS/TSS	Sulfate	Alkalinity	Hardness	Total Recoverable Metals	Dissolved Metals	Chloride	NO_3/NO_2	Color	Cyanide (total and amenable)	Ortho/Total Phosphorous	Low-level PCBs	TPH (Gasoline Range)	TPH (Diesel Range)	Manual Water Level Measurements	Slug Tests	Transducers
Seepage:																								
SP1	X		X	X	X		X	X	X	X	X								X	X	X			
SP2	X		X	X	X		X	X	X	X	X		X	X	X	X	X	X	X	X	X			
SP3	X		X	X	X		X	X	X	X	X		X	X	X	X	X	X						
SP4	X		X	X	X		X	X	X	X	X													
SP5	X		X	X	X		X	X	X	X	X													
SP6- Dry																								
SP7	X		X	X	X		X	X	X	X	X		X	X	X	X	X	X						
SP8- Dry																								
SP9 - Submerged																								
SP10W - Submerged																								
SP10E - Submerged																								
SP11 - Submerged																								
SP12	X		X		X		X	X	X	X	X													
SP13 (Black Seep)																								
SP14																								
SP15W - Dry																								
SP15E	X		X	X	X		X	X	X	X	X													
SP16	X		X	X	X		X	X	X	X	X		X	X	X	X	X	X	X	X	X			
SP17	X		X	X	X		X	X	X	X	X													
SP18 (Bank)	X		X	X	X		X	X	X	X	X													
SP19 - Dry																								
SP20 - Dry																								
SP21	X		X	X	X		X	X	X	X	X													
SP22 (Rain only, low flow)																								
SP23 - No flow																								
SP23B - No flow																								
SP23 UP							X	X	X	X	X													
SP24 - Submerged																								
SP25 - Submerged																								
SP-26	X				X		X	X	X	X	X													
CC-D1	X				X		X	X	X	X	X		X	X	X	X	X	X						
SURFACE WATER																								
Railroad Creek:																								
RC-1	X					X	X	X	X	X	X	X	X	X	X	X	X	X						
RC-1 North Bank																								
RC-1 South Bank																								
RC-2	X				X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X			
RC-2 South Bank	X	X		X		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X			
RC-3	X				X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X			
RC-4	X	X			X	X	X	X	X	X	X													
RC-4 South Bank	X					X	X	X	X	X	X													
RC-5	X					X	X	X	X	X	X													
RC-6	X					X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X			
RC-7	X					X	X	X	X	X	X													
RC-8																								
Copper Creek																								
CC-1	X	X		X	X	X	X	X	X	X	X													
CC-2	X	X		X	X	X	X	X	X	X	X													
Portal Drainage:																								
P-1	X			X	X	X	X	X	X	X	X	X	X	X	X	X	X	X						
P-5	X			X	X	X	X	X	X	X	X	X	X	X	X	X	X	X						

Notes:
Primary Metals consist of Aluminum, Barium, Beryllium, Cadmium, Calcium, Chromium, Copper, Iron, Lead, Magnesium, Manganese, Nickel, Potassium, Silver, Sodium, Zinc
Supplemental Metals consist of Arsenic, Mercury, Molybdenum, Selenium, Thallium, Uranium
Groundwater wells with an "L" suffix are lysimeters.

TABLE 3.2-4
ANALYTICAL PROGRAM FOR GROUNDWATER, SEEP AND SURFACE WATER (SEPTEMBER - OCTOBER 1997)
HOLDEN MINE RI/FS
DAMES & MOORE JOB NO. 17693-005-019

Parameters	Field Tests				Primary Analyte List						Supplemental Analyte List							Organic Analyte List		Groundwater Measurements	
Media/ Sample No.	pH/Specific Conductance/Temp	Dissolved Oxygen	Turbidity	Flow Estimates	Total Recoverable Metals	Dissolved Metals	TDS/TSS	Sulfate	Alkalinity	Hardness	Total Recoverable Metals	Dissolved Metals	Chloride	NO_3/NO_2	Color	Cyanide (total & amenable)	Ortho/Total Phosphorus	TPH (Gasoline Range)	TPH (Diesel Range)	Manual Water Level Measurements	Transducers
GROUNDWATER																					
Potential Background:																					
HBKG-1	X					X	X	X	X	X								X	X	X	X
HBKG-2	X					X	X	X	X	X										X	
CC-BKG (dry)																					
HV-3	X					X	X	X	X	X										X	
Downstream Wells:																					
DS-1	X					X	X	X	X	X										X	
DS-2	X					X	X	X	X	X		X	X	X		X		X	X	X	X
Tailings Pile 1:																					
TP1-1A	X					X	X	X	X	X										X	
TP1-2A	X					X	X	X	X	X										X	
TP1-2L	X					X				X											
TP1-3A	X					X	X	X	X	X										X	
TP1-3L	X					X		X	X	X											
TP1-4A	X					X	X	X	X	X										X	
TP1-4L	X					X		X	X	X											
TP1-5A	X					X	X	X	X	X										X	X
TP1-6A	X					X	X	X	X	X										X	
TP1-6L	X					X				X											
Tailings Pile 2:																					
PZ-1A (dry)																					
PZ-1B	X					X	X	X	X	X										X	
PZ-1C																				X	
PZ-2B																				X	
PZ-2C																				X	
PZ-3A	X					X	X	X	X	X		X	X	X		X				X	
PZ-3B																				X	
PZ-3C (dry)																					
TP2-4A	X					X	X	X	X	X										X	
TP2-4B																				X	
TP2-5A (dry)																					
TP2-5B																				X	
TP2-7N&S																				X	X
TP2-8A	X					X	X	X	X	X										X	
TP2-8B																				X	
TP2-11	X					X	X	X	X	X										X	X
Tailings Pile 3:																					
TP3-4 (dry)																				X	
TP3-4L	X					X				X											
TP3-5A																				X	
TP3-6A	X					X	X	X	X	X										X	
TP3-6BL	X					X		X	X	X											
TP3-7																				X	
TP3-8	X					X	X	X	X	X										X	
TP3-9	X					X	X	X	X	X										X	
TP3-10	X					X	X	X	X	X										X	
TP3-10L	X					X				X											
PZ-4A																				X	X
PZ-4B																				X	X
PZ-4C																				X	
PZ-5A																				X	
PZ-5B																				X	
PZ-5C																				X	
PZ-6A	X					X	X	X	X	X										X	
PZ-6B																				X	
PZ-6C																				X	
Other:																					
Lucerne Well	X					X	X	X	X	X											

TABLE 3.2-4
ANALYTICAL PROGRAM FOR GROUNDWATER, SEEP AND SURFACE WATER (SEPTEMBER - OCTOBER 1997)
HOLDEN MINE RI/FS
DAMES & MOORE JOB NO. 17693-005-019

Parameters	Field Tests				Primary Analyte List						Supplemental Analyte List							Organic Analyte List		Groundwater Measurements	
Media/ Sample No.	pH/Specific Conductance/Temp	Dissolved Oxygen	Turbidity	Flow Estimates	Total Recoverable Metals	Dissolved Metals	TDS/TSS	Sulfate	Alkalinity	Hardness	Total Recoverable Metals	Dissolved Metals	Chloride	NO_3/NO_2	Color	Cyanide (total & amenable)	Ortho/Total Phosphorus	TPH (Gasoline Range)	TPH (Diesel Range)	Manual Water Level Measurements	Transducers
Seepage:																					
SP-1																					
SP-2	X			X		X	X	X	X	X		X	X	X		X		X	X		
SP-3	X			X		X	X	X	X	X		X	X	X		X					
SP-4																					
SP-5																					
SP-6																					
SP-7	X			X		X	X	X	X	X		X	X	X		X					
SP-8																					
SP-9																					
SP-10W																					
SP-10E																					
SP-11																					
SP-12																					
SP-13																					
SP-14	X			X		X	X	X	X	X											
SP-14 Upper	X			X		X	X	X	X	X											
SP-14 Lower	X			X		X	X	X	X	X											
SP-15W																					
SP-15E	X			X		X	X	X	X	X											
SP-16	X			X		X	X	X	X	X		X	X	X		X		X	X		
SP-17																					
SP-18																					
SP-19																					
SP-20																					
SP-21	X			X		X	X	X	X	X											
SP-22																					
SP-23	X			X		X	X	X	X	X											
SP-23 (Vent Rd)	X			X		X	X	X	X	X											
SP-24																					
SP-25																					
SP-26	X			X		X	X	X	X	X											
CC-D1	X			X		X	X	X	X	X		X	X	X		X					
SURFACE WATER																					
Railroad Creek:																					
RC-1	X			X	X	X	X	X	X	X	X	X	X	X		X					
RC-1 (North Bank)	X				X	X	X	X	X	X											
RC-1 (South Bank)	X				X	X	X	X	X	X											
RC-2	X	X		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X		
RC-2 (South Bank)	X	X			X	X	X	X	X	X	X	X	X	X	X	X	X	X	X		
RC-3	X	X		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X		
RC-4	X			X	X	X	X	X	X	X											
RC-4 (South Bank)	X				X	X	X	X	X	X											
RC-5	X			X	X	X	X	X	X	X											
RC-6	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X		
RC-7	X			X	X	X	X	X	X	X											
RC-8	X				X	X	X	X	X	X											
RC-10	X			X	X	X	X	X	X	X											
RC-11	X			X	X	X	X	X	X	X											
Tributaries:																					
Tenmile Creek	X			X	X	X	X	X	X	X	X	X									
Holden Creek	X			X	X	X	X	X	X	X											
Copper Creek:																					
CC-1	X			X	X	X	X	X	X	X											
CC-2	X			X	X	X	X	X	X	X											
Portal Drainage:																					
P-1	X			X	X	X	X	X	X	X	X	X	X	X		X					
P-5	X			X	X	X	X	X	X	X	X	X	X	X		X					
Reference Streams:																					
Company Creek	X	X		X	X	X	X	X	X	X											
Bridge Creek	X	X		X	X	X	X	X	X	X											
SF Agnes Creek	X	X		X	X	X	X	X	X	X											

Notes:
Primary Metals consist of Aluminum, Barium, Beryllium, Cadmium, Calcium, Chromium, Copper, Iron, Lead, Magnesium,
Manganese, Nickel, Potassium, Silver, Sodium, Zinc
Supplemental Metals consist of Arsenic, Molybdenum, Thallium, Uranium Note: Arsenic and molybdenum data were acquired for RC-11, CC-1, CC-2, and the Reference Streams.
Groundwater wells with an "L" suffix are lysimeters.

TABLE 3.2-5
ANALYTICAL PROGRAM FOR GROUNDWATER, SEEP, SURFACE WATER AND SEDIMENT (MAY 1998)
HOLDEN MINE RI/FS
DAMES & MOORE JOB NO. 17693-005-019

Parameters	Field Tests				Inorganic Analytes										Organic Analytes		Groundwater Measurements		Other
Media/ Sample No.	pH/Specific Conductance/ Temperature	Dissolved Oxygen	Turbidity	Flow Measurements *	Total/Total Recoverable Metals	Dissolved Metals	TDS/TSS	Sulfate	Alkalinity	Hardness	Total Organic Carbon (TOC)	Total Volatile Solids	Total Solids	Acid Volatile Sulfides (AVS)	TPH (As Gasoline)	TPH (Diesel Extended)	Manual Water Level Measurements	Transducers	Grain Size
GROUNDWATER																			
HBKG-1																	x	x	
Downstream Wells																			
DS-2																	x	x	
Tailings Pile 1																			
TP1-5A																	x	x	
Tailings Pile 2																			
TP2-7N&S																	x	x	
TP2-11																	x	x	
Tailings Pile 3																			
PZ-4A																	x	x	
PZ-4B																	x	x	
SEEPS																			
SP-1	X	X	X	X		X	X	X	X	X									
SP-2	X	X	X	X		X	X	X	X	X									
SP-4	X	X	X	X		X	X	X	X	X									
SP-23	X	X	X	X		X	X	X	X	X									
SP-27	X	X	X	X		X	X	X	X	X									
CC-D1	X	X	X	X		X	X	X	X	X									
SURFACE WATER																			
Railroad Creek																			
RC-1	X	X	X		X	X	X	X	X	X									
RC-2	X	X	X	X	X	X	X	X	X	X					X	X			
RC-3	X	X	X	X	X	X	X	X	X	X									
RC-4	X	X	X	X	X	X	X	X	X	X									
RC-5	X	X	X		X	X	X	X	X	X									
RC-6	X	X	X		X	X	X	X	X	X									
RC-7	X	X	X		X	X	X	X	X	X									
RC-10	X	X	X		X	X	X	X	X	X									
RC-11	X	X	X		X	X	X	X	X	X									
Copper Creek																			
CC-1	X			X	X	X	X	X	X	X									
CC-2	X			X	X	X	X	X	X	X									
Holden Creek																			
HC-1	X	X	X	X	X	X	X	X	X	X									
HC-2	X	X	X	X	X	X	X	X	X	X									
HC-3	X	X	X	X	X	X	X	X	X	X									
HC-4	X	X	X	X	X	X	X	X	X	X									
Portal Drainage																			
P-1	X			X	X	X	X	X	X	X									
P-5	X			X	X	X	X	X	X	X									
Big Creek																			
BIG-1	X			X	X	X	X	X	X	X									
Ventilator Portal																			
VP-1	X	X	X	X	X	X	X	X	X	X									
SEDIMENT																			
Lucerne					X						X	X	X	X					X
Stehekin					X						X	X	X	X					X

Notes:
Metals List - Aluminum, Arsenic, Barium, Beryllium, Cadmium, Calcium, Chromium, Copper, Iron, Lead, Magnesium, Manganese, Molybdenum, Nickel, Potassium, Silver, Sodium, Zinc for water matrix.
For sediment samples, the metals list included aluminum, arsenic, cadmium, copper, iron, lead, manganese, and zinc.
TDS = Total Dissolved Solids
TSS = Total Suspended Solids
TPH = Total Petroleum Hydrocarbons

* Flow measurement collected as possible. When high flow prevented wading measurements on Railroad Creek, flow measurements were collected only at RC-4, RC-2, and RC-3.

SOURCE: USGS Topographic Map, State of Washington, Scale 1:500,000, Compiled 1961, Revised 1982

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Figure 3.0-1
LAKE CHELAN WATERSHED MAP

Holden Mine RI/FS
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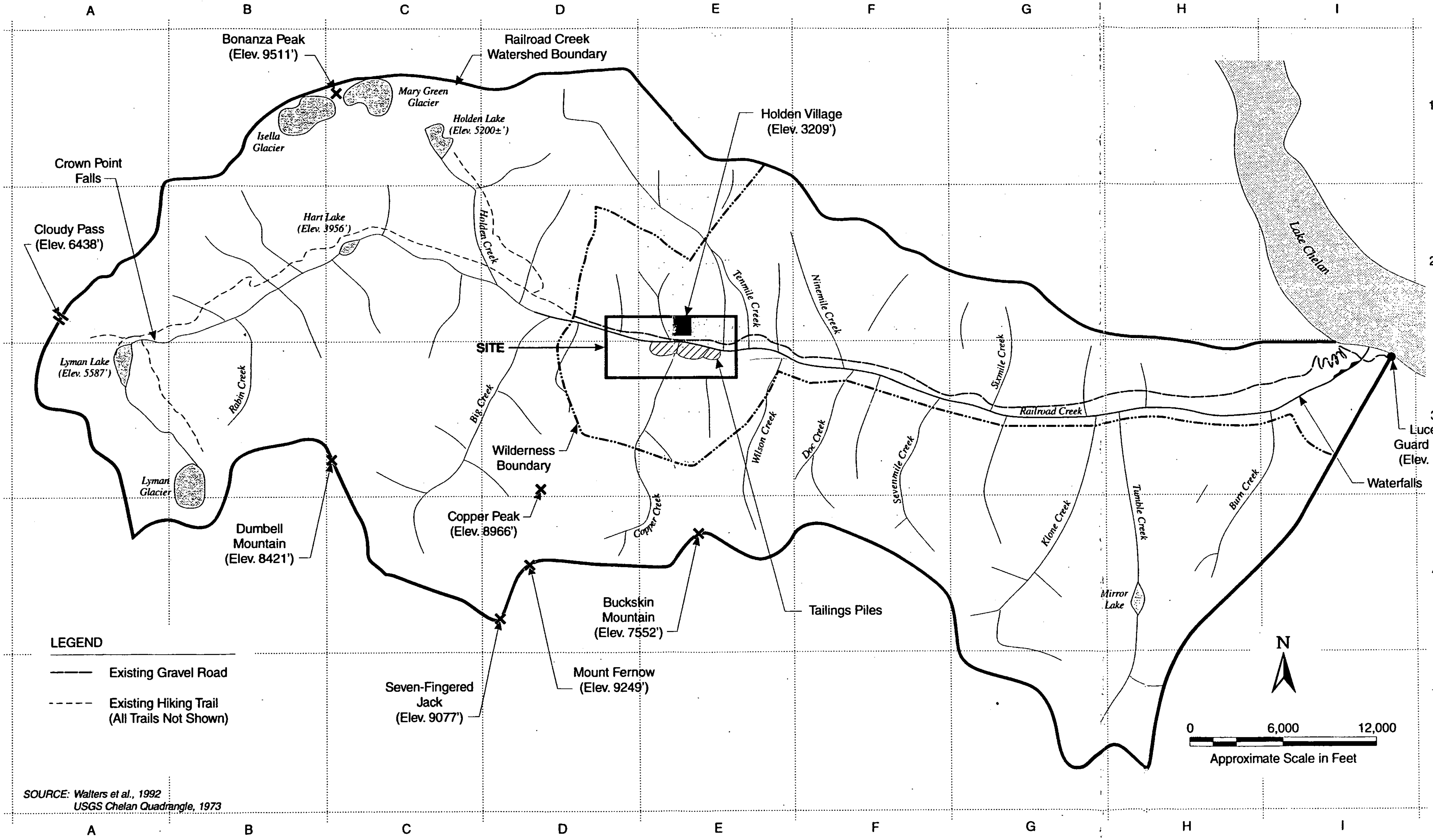
Job No. 17693-005-019

17693A83.CDR



SOURCE: Walters et al., 1992
USGS Chelan Quadrangle, 1973

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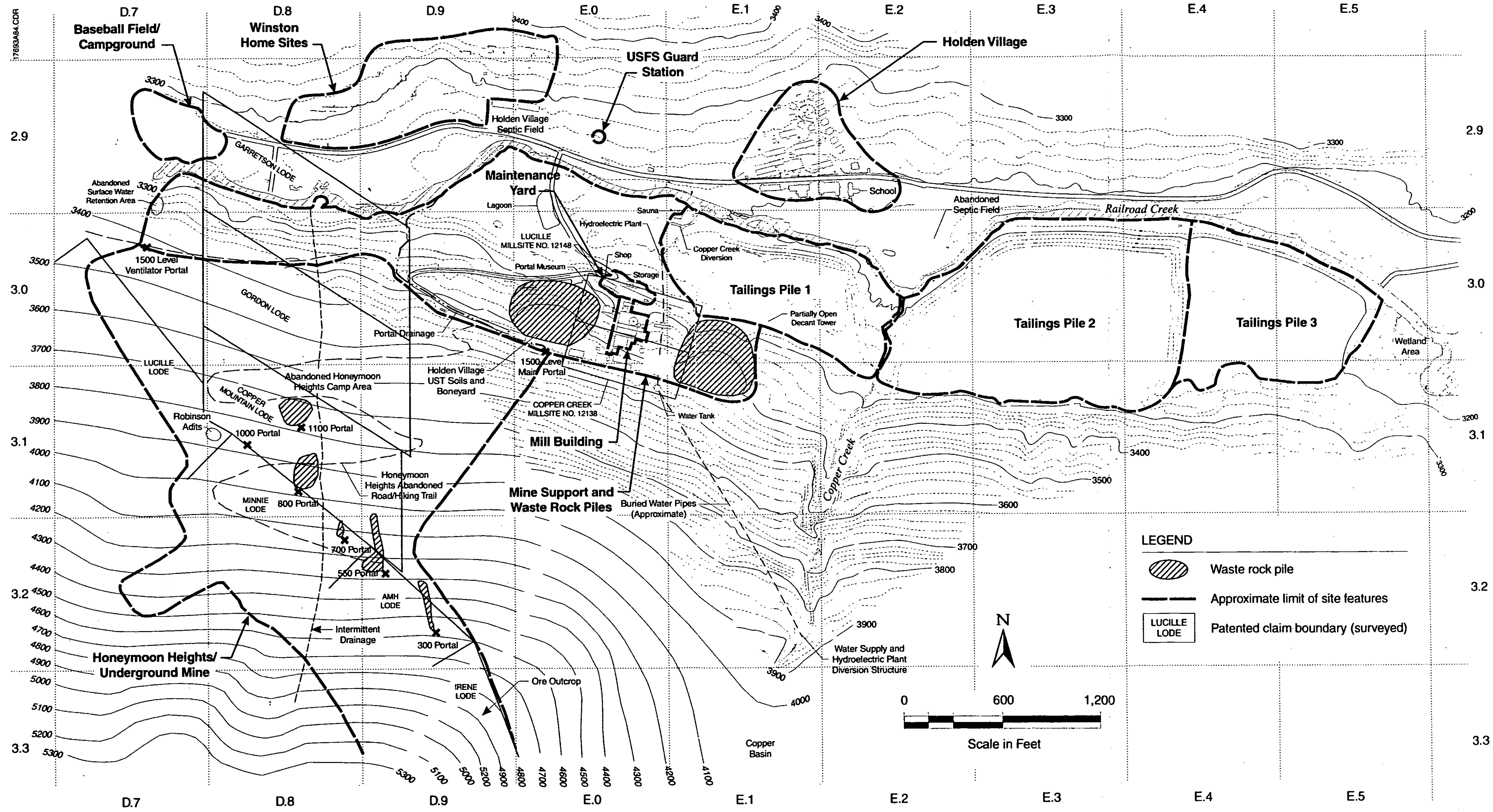
Figure 3.0-2
SITE VICINITY MAP

Holden Mine RI/FS
Draft Final RI Report

Job No. 17693-005-019



SOURCE: Base map information from USFS and Washington DNR, DEM CD ROM

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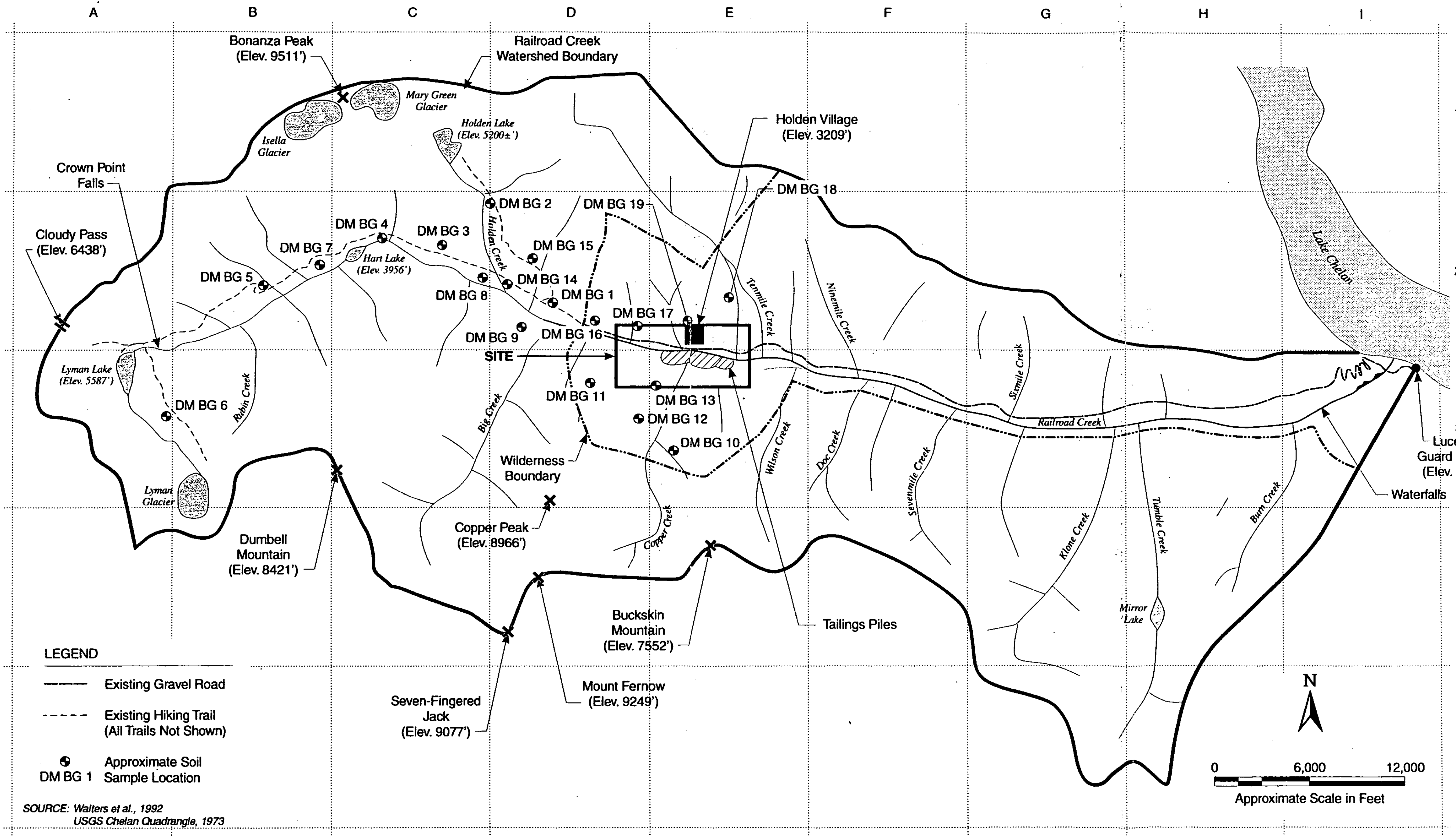
Job No. 17693-005-019

Figure 3.0-3

HOLDEN MINE SITE MAP

Holden Mine RI/FS
Draft Final RI Report

17695a65.cdr



SOURCE: Walters et al., 1992
USGS Chelan Quadrangle, 1973

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Figure 3.1-1

AREA BACKGROUND SURFACE SOIL SAMPLE LOCATIONS

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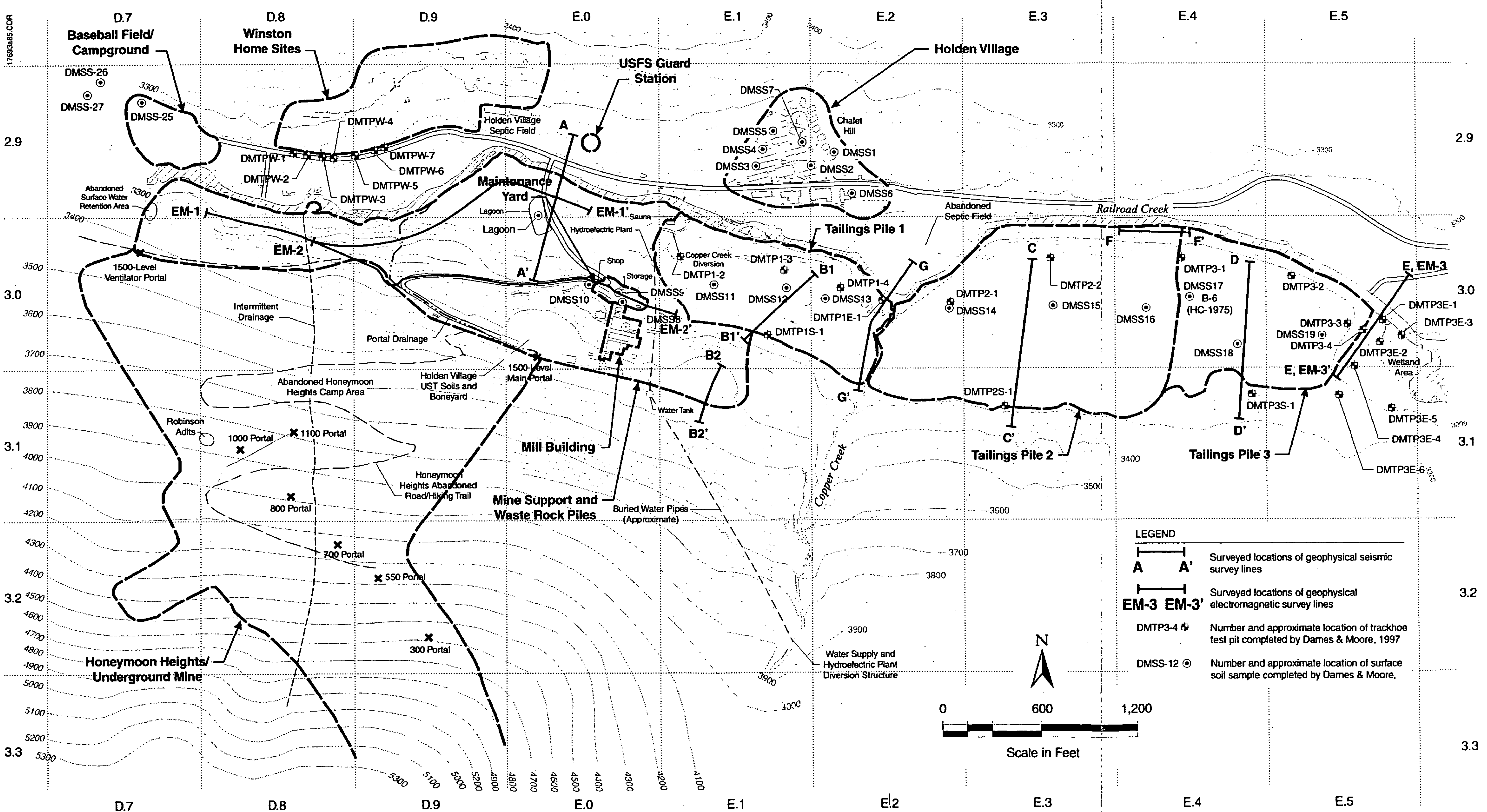

SOURCE: Base map information from USFS and Washington DNR, DEM CD ROM

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Figure 3.1-2
RI SOIL INVESTIGATION LOCATIONS

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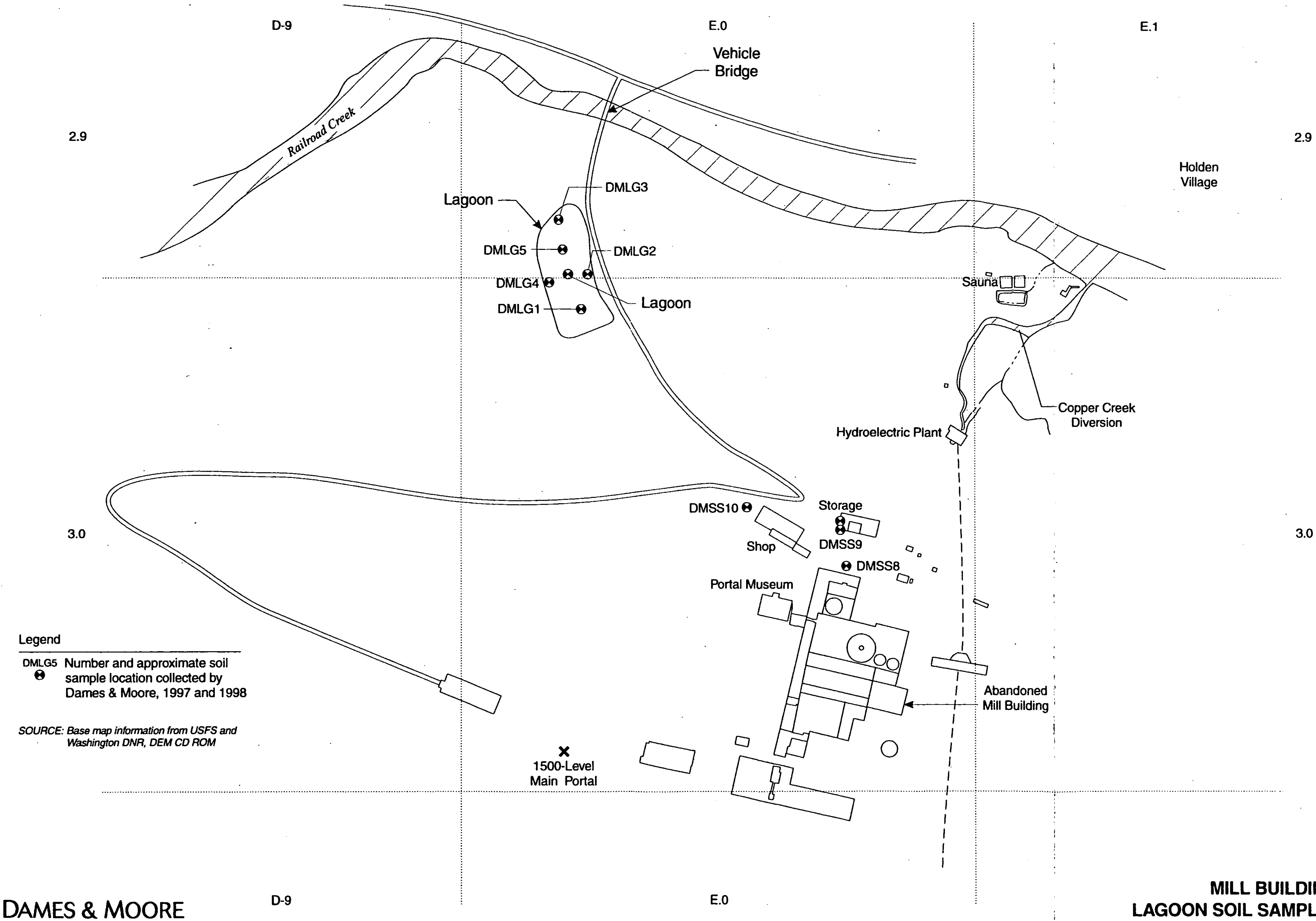
17693a66.CDR



Legend

DMLG5 ⊗ Number and approximate soil sample location collected by Dames & Moore, 1997 and 1998

SOURCE: Base map information from USFS and Washington DNR, DEM CD ROM

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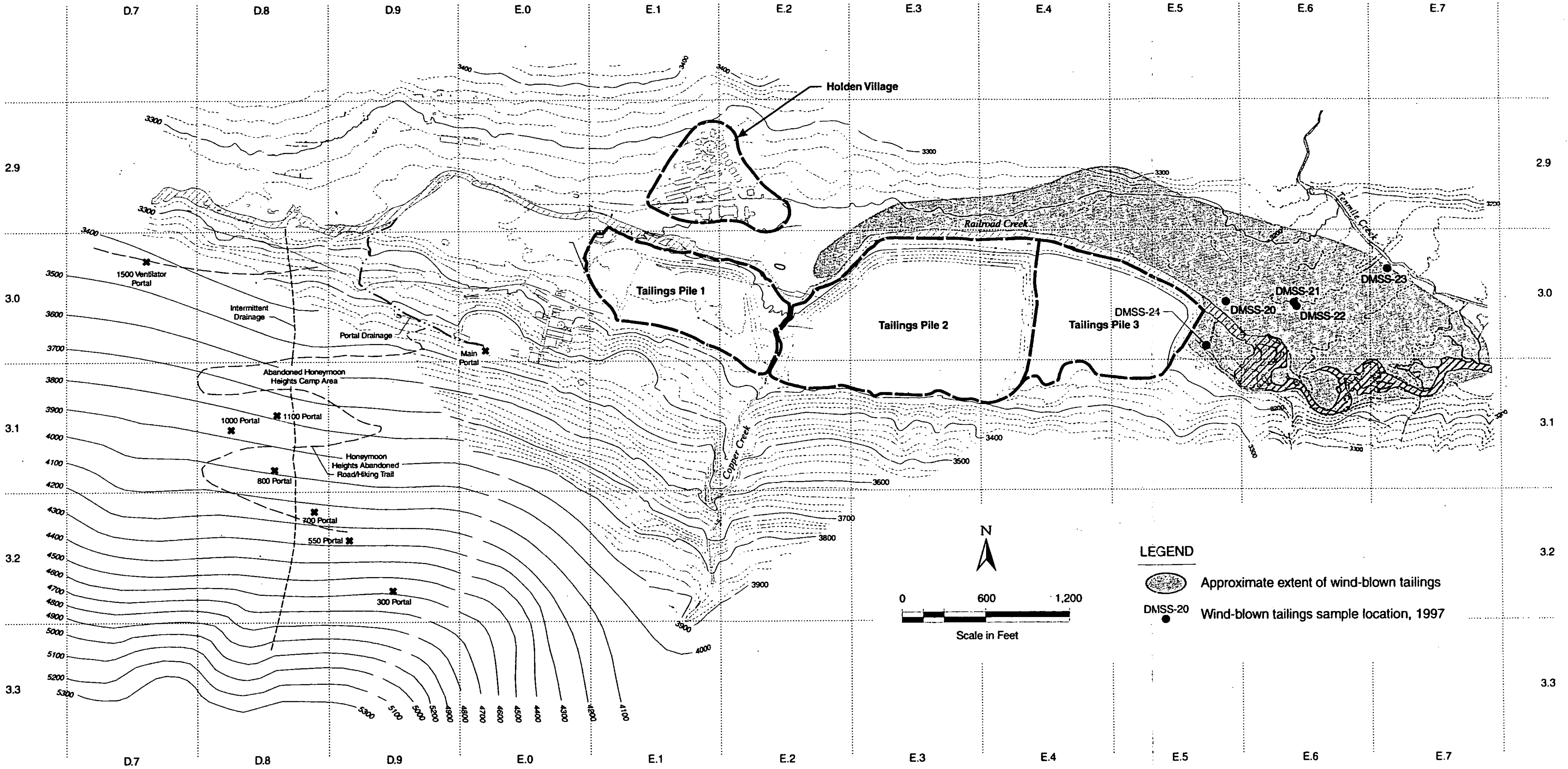
Figure 3.1-3

MILL BUILDING AREA AND LAGOON SOIL SAMPLE LOCATIONS

Holden Mine RI/FS
Draft Final RI Report

17693e67.CDR



SOURCES: Base map information from USFS and Washington DNR, DEM CD ROM

Figure 3.1-4

RI WIND-BLOWN TAILINGS SAMPLE LOCATIONS

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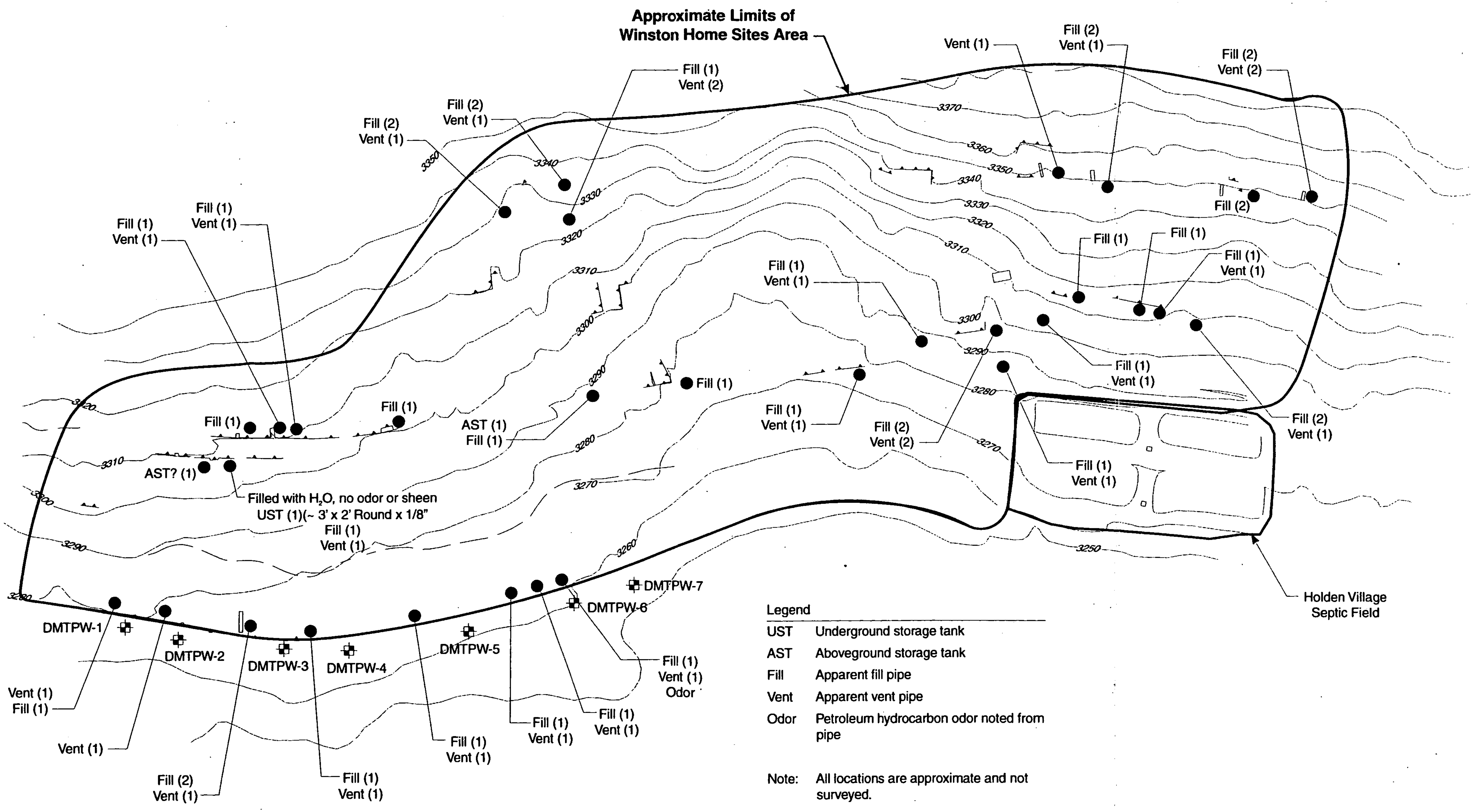
Holden Mine RI/FS
Draft Final RI Report

17693A88.CDR



Legend

UST	Underground storage tank
AST	Aboveground storage tank
Fill	Apparent fill pipe
Vent	Apparent vent pipe
Odor	Petroleum hydrocarbon odor noted from pipe

Note: All locations are approximate and not surveyed.

SOURCE: Base map information from USFS and Washington DNR, DEM CD ROM

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Figure 3.1-5

WINSTON HOME SITES TANK INVENTORY

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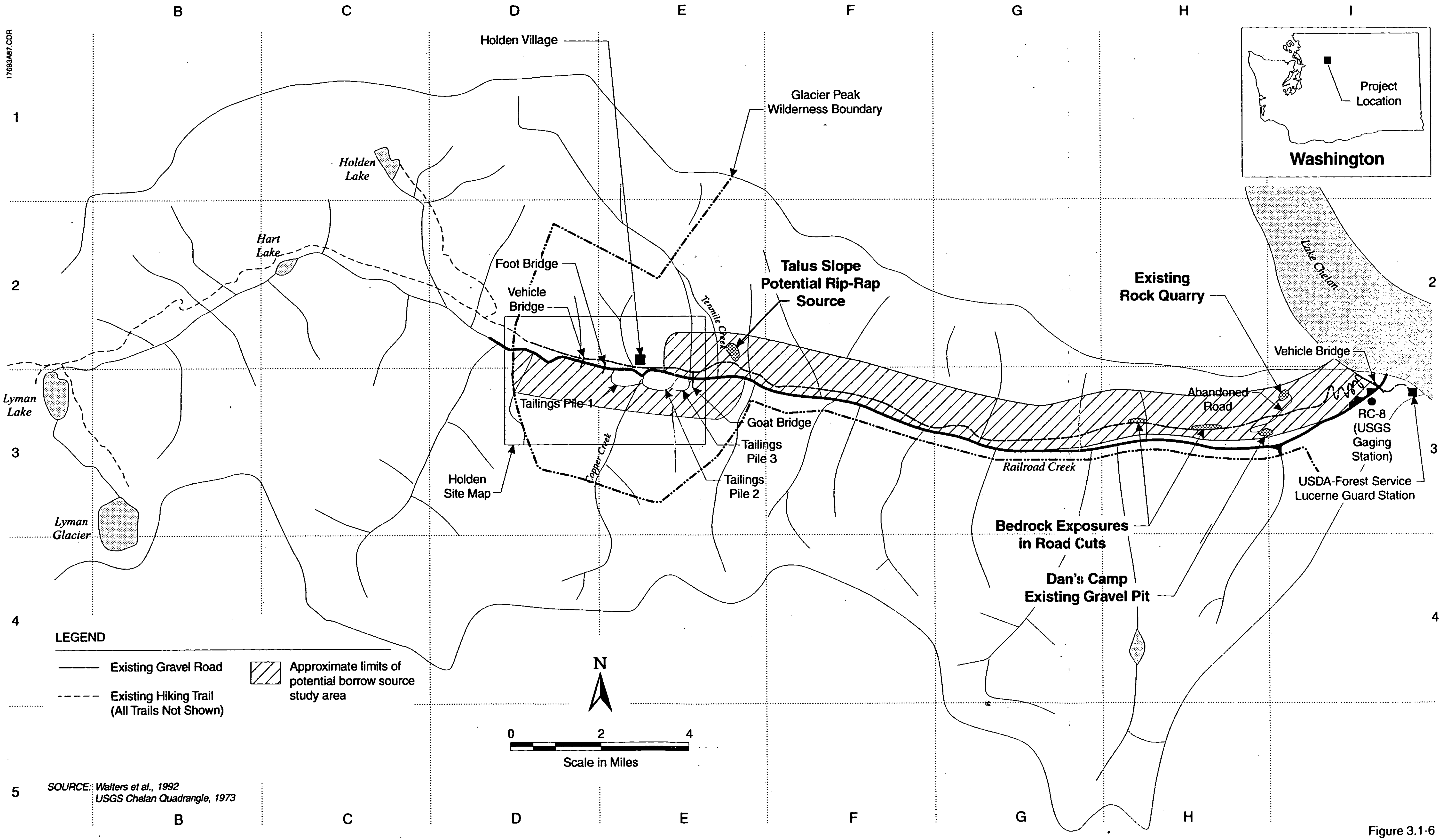

Figure 3.1-6

RAILROAD CREEK
POTENTIAL BORROW SOURCE STUDY AREAS MAP

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Draft Final RI Report

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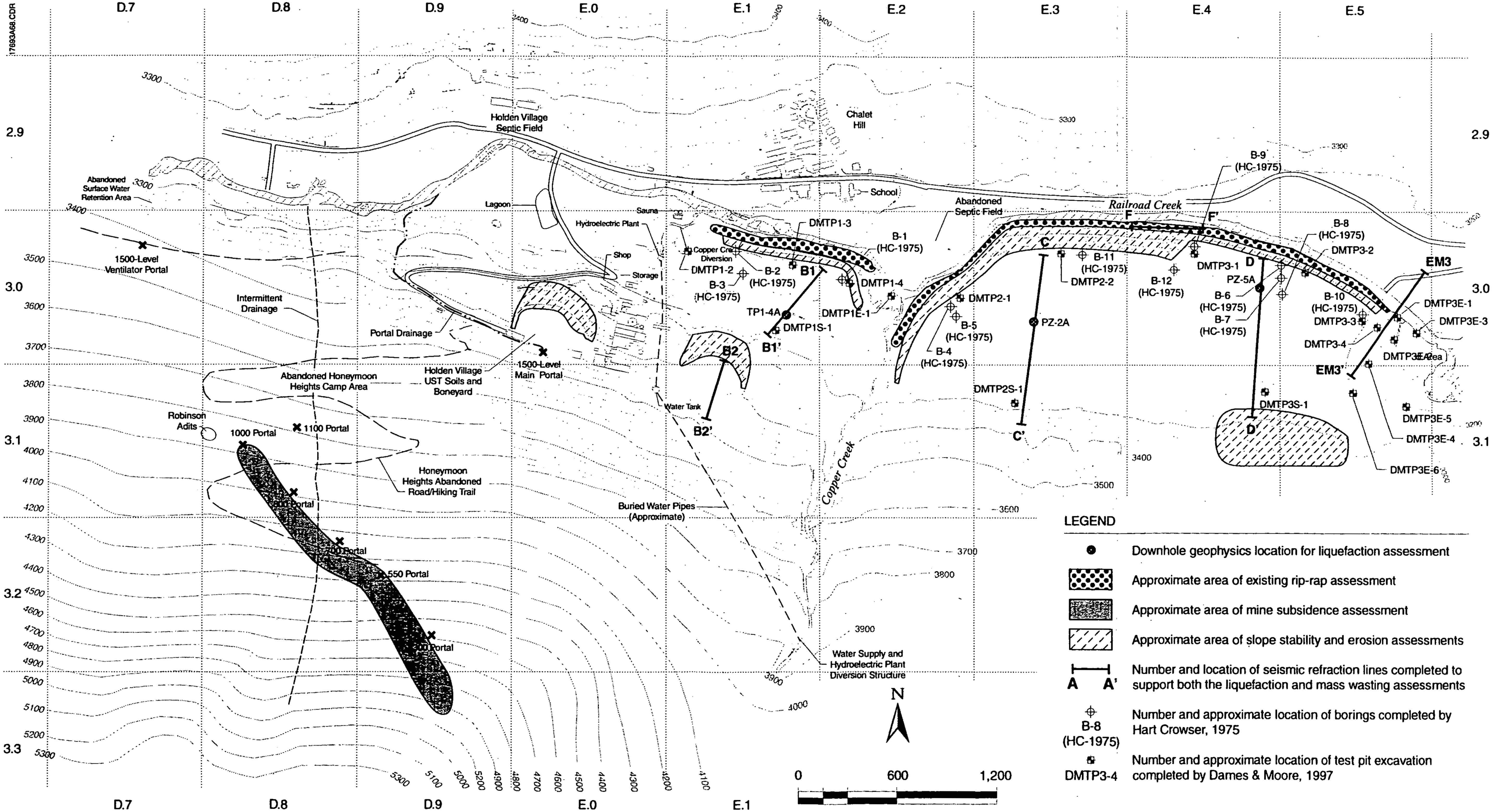

SOURCE: *Base map information from USFS and Washington DNR, DEM CD ROM*

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Figure 3.1-7

RI GEOLOGIC HAZARDS ASSESSMENT LOCATIONS

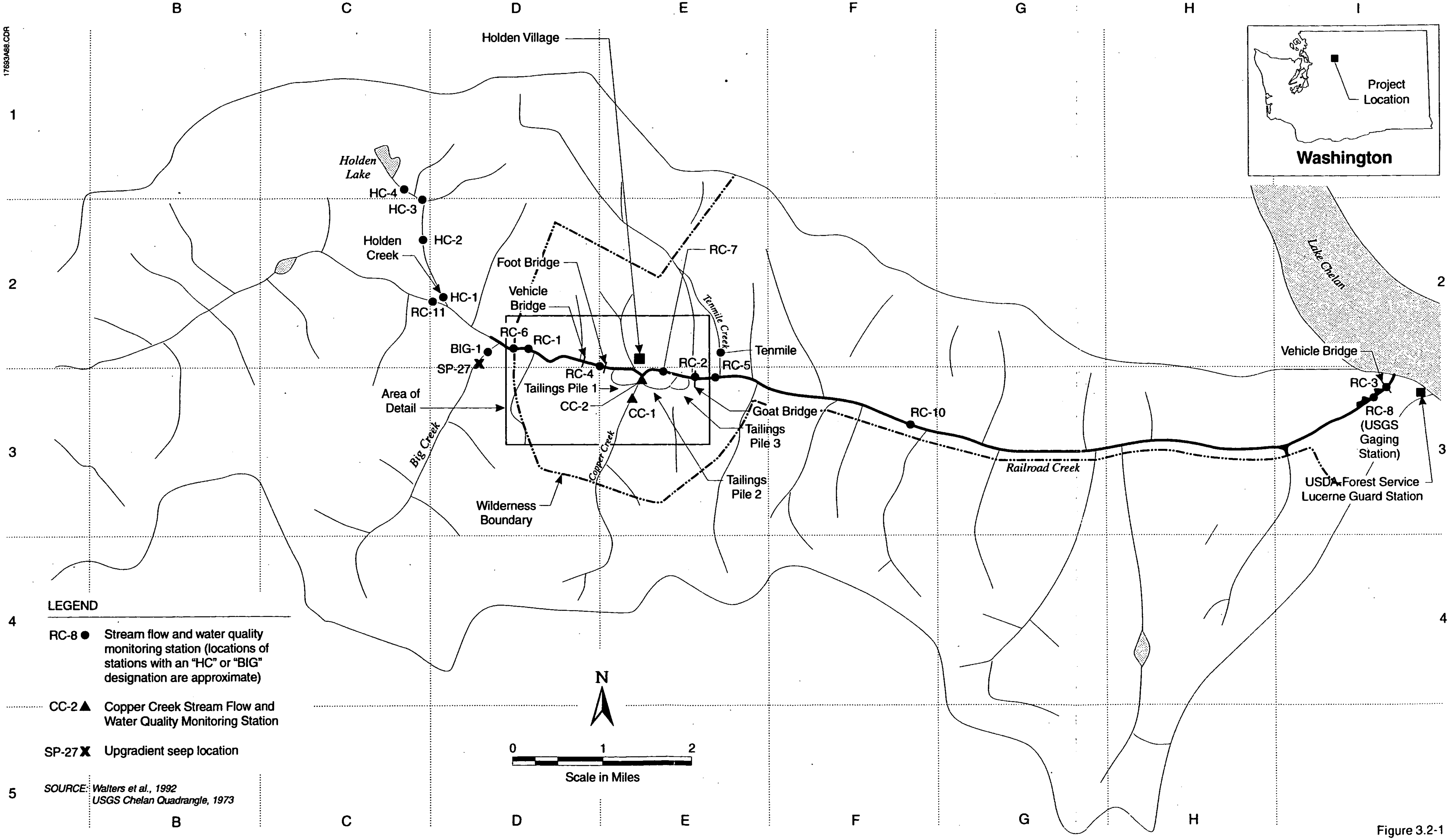

Figure 3.2-1

RI HYDROLOGIC INVESTIGATION LOCATIONS
RAILROAD CREEK WATERSHED

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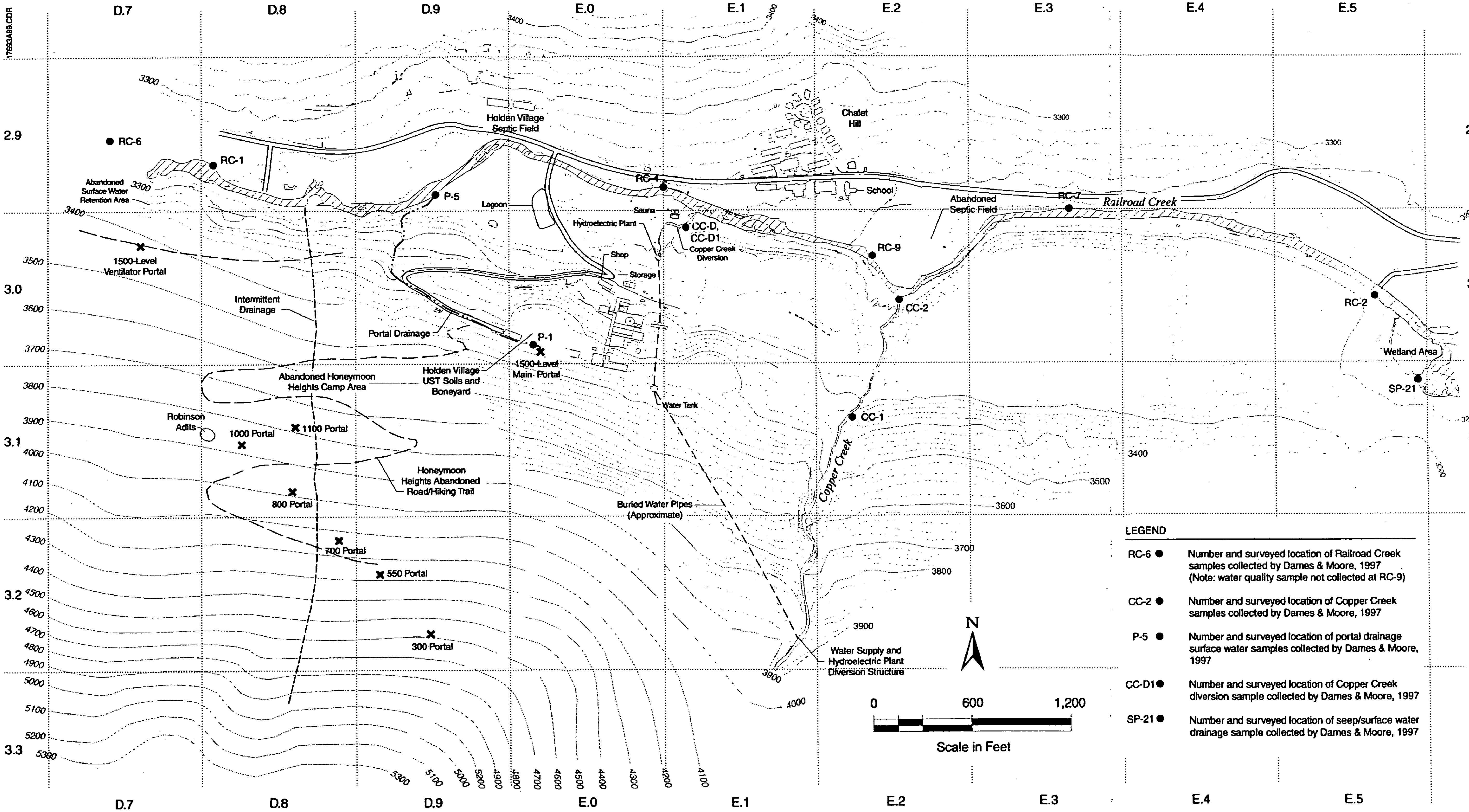

SOURCE: Base map information from USFS and Washington DNR, DEM CD ROM

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Figure 3.2-2

RI HYDROLOGIC INVESTIGATIONS—SITE

Holden Mine RI/FS
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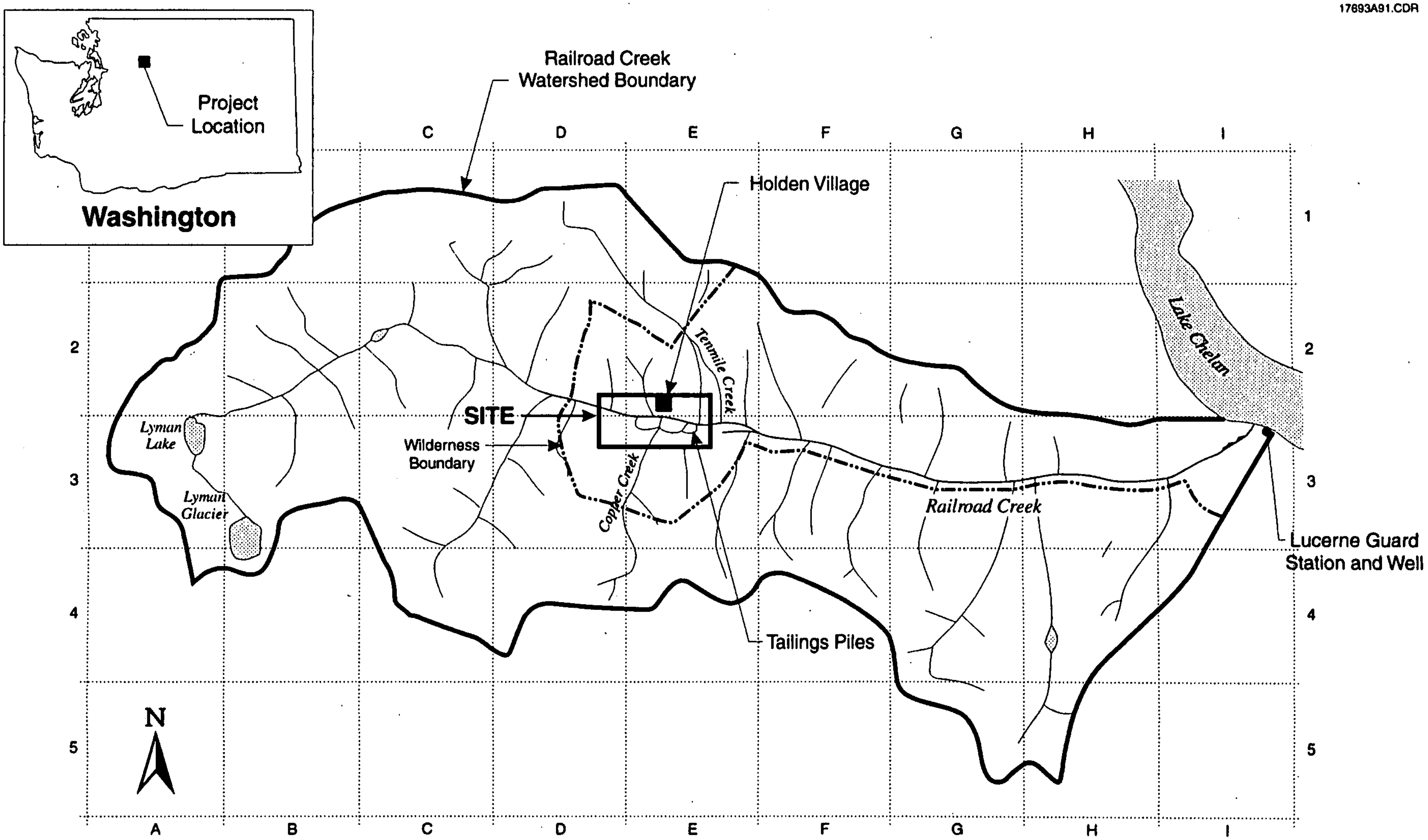
17693A91.CDR



SOURCE: Walters et al., 1992
USGS Chelan Quadrangle, 1973

0 2.5 5
Approximate Scale in Miles

Figure 3.3-1

RI HYDROGEOLOGIC INVESTIGATION LOCATIONS
RAILROAD CREEK

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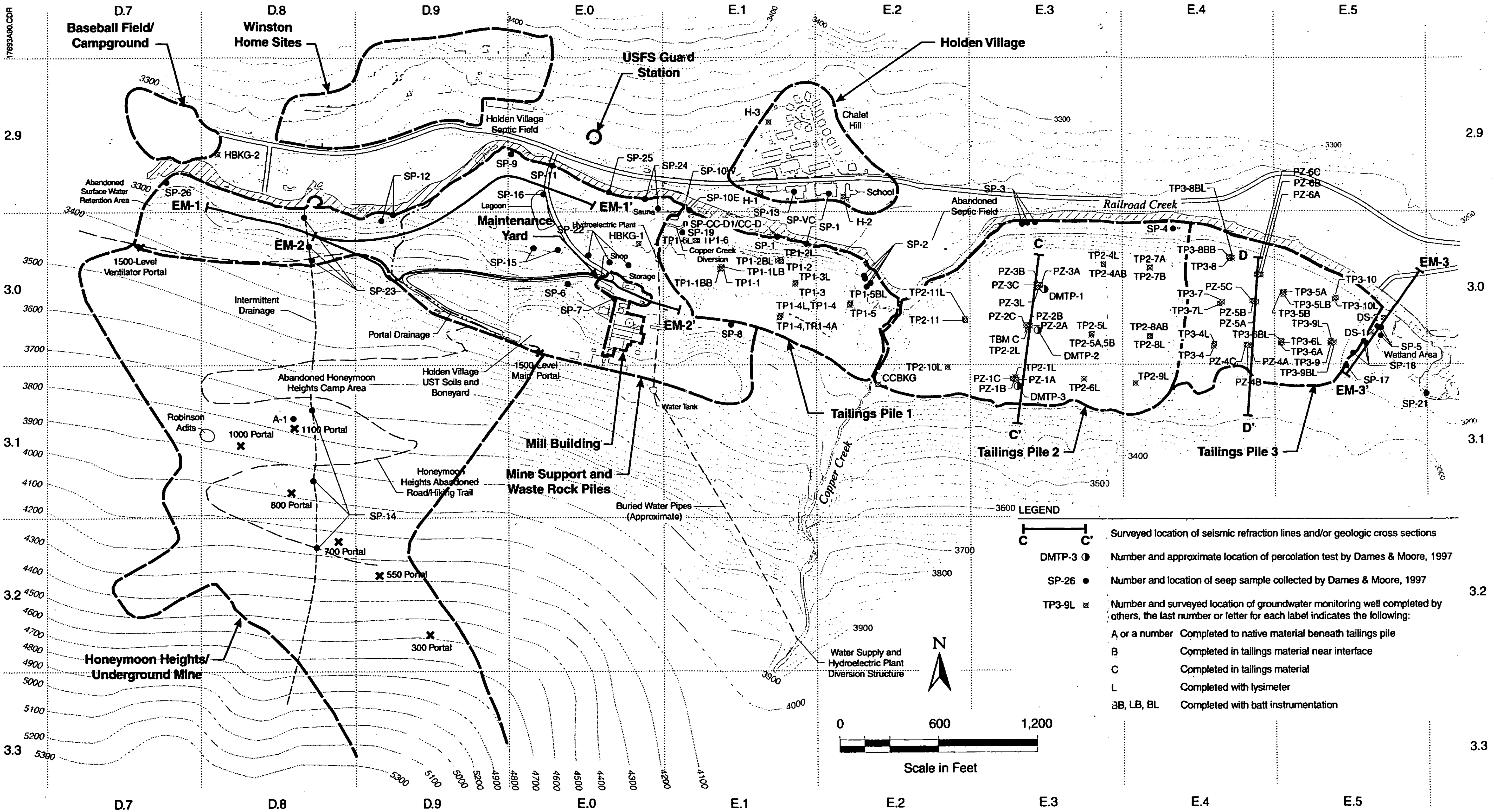

LEGEND

C ⊢—⊣ C'	Surveyed location of seismic refraction lines and/or geologic cross sections
DMTP-3 ◑	Number and approximate location of percolation test by Dames & Moore, 1997
SP-26 ●	Number and location of seep sample collected by Dames & Moore, 1997
TP3-9L ⊠	Number and surveyed location of groundwater monitoring well completed by others, the last number or letter for each label indicates the following:

A or a number	Completed to native material beneath tailings pile
B	Completed in tailings material near interface
C	Completed in tailings material
L	Completed with lysimeter
BB, LB, BL	Completed with batt instrumentation

SOURCE: Base map information from USFS and Washington DNR, DEM CD ROM

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Figure 3.3-2

RI HYDROGEOLOGIC INVESTIGATION LOCATIONS—SITE

Holden Mine RI/FS
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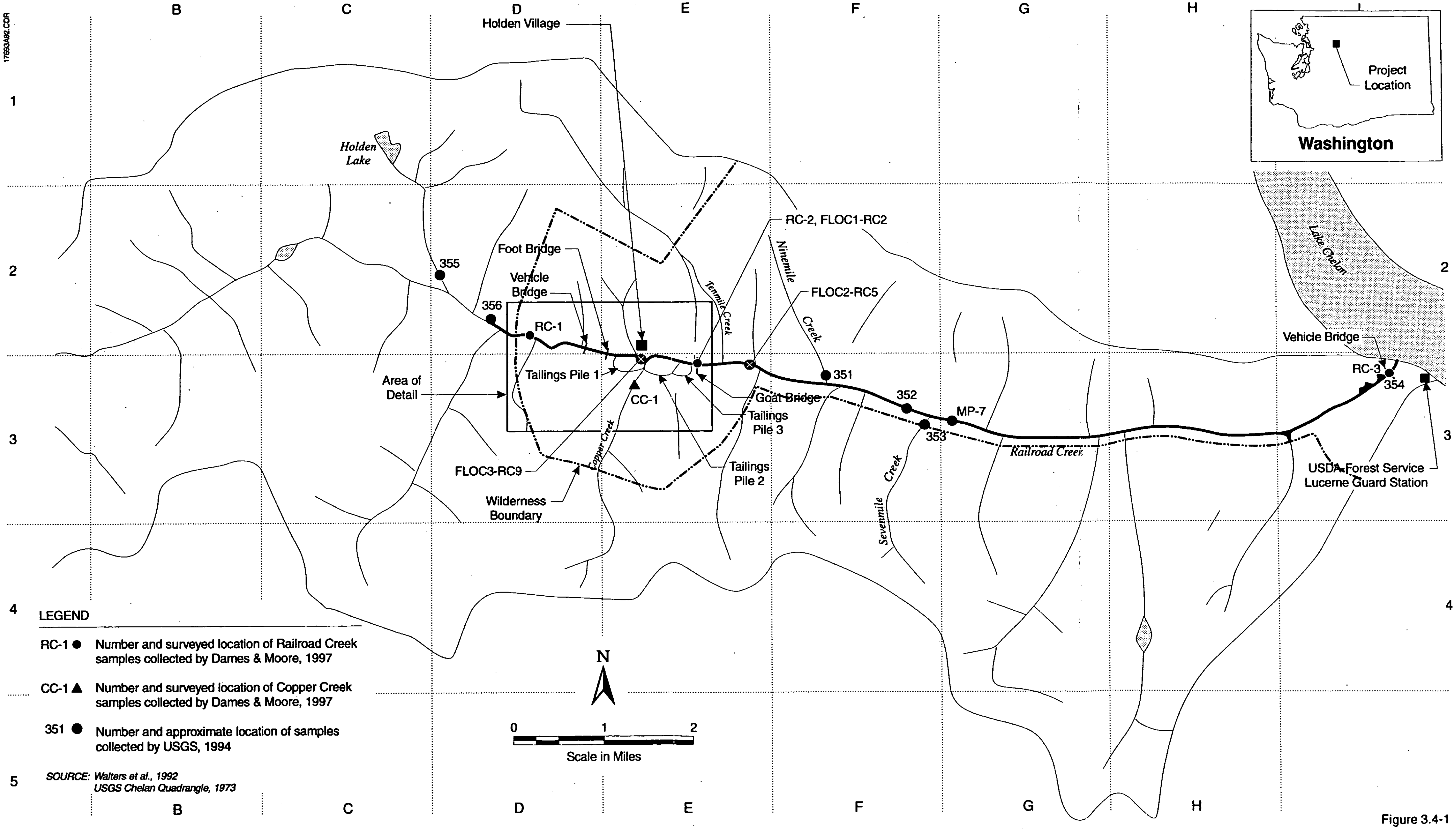

Figure 3.4-1

FLOCCULENT AND SEDIMENT SAMPLING LOCATIONS RAILROAD CREEK

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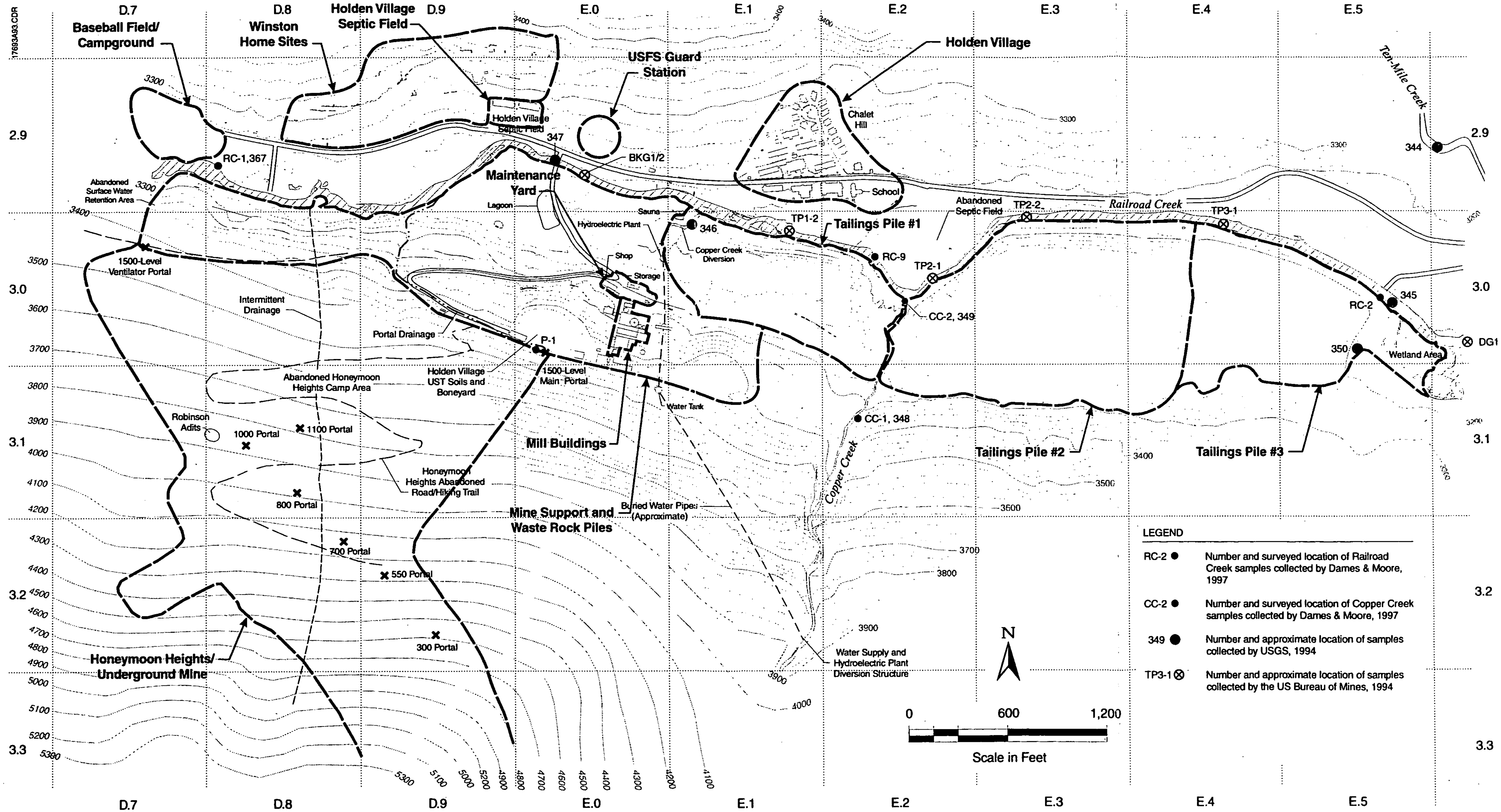
Holden Mine RI/FS
Draft Final RI Report



SOURCE: Base map information from USFS and Washington DNR, DEM CD ROM

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Figure 3.4-2
FLOCCULENT AND SEDIMENT SAMPLING LOCATIONS—SITE

Holden Mine RI/FS
Draft Final RI Report

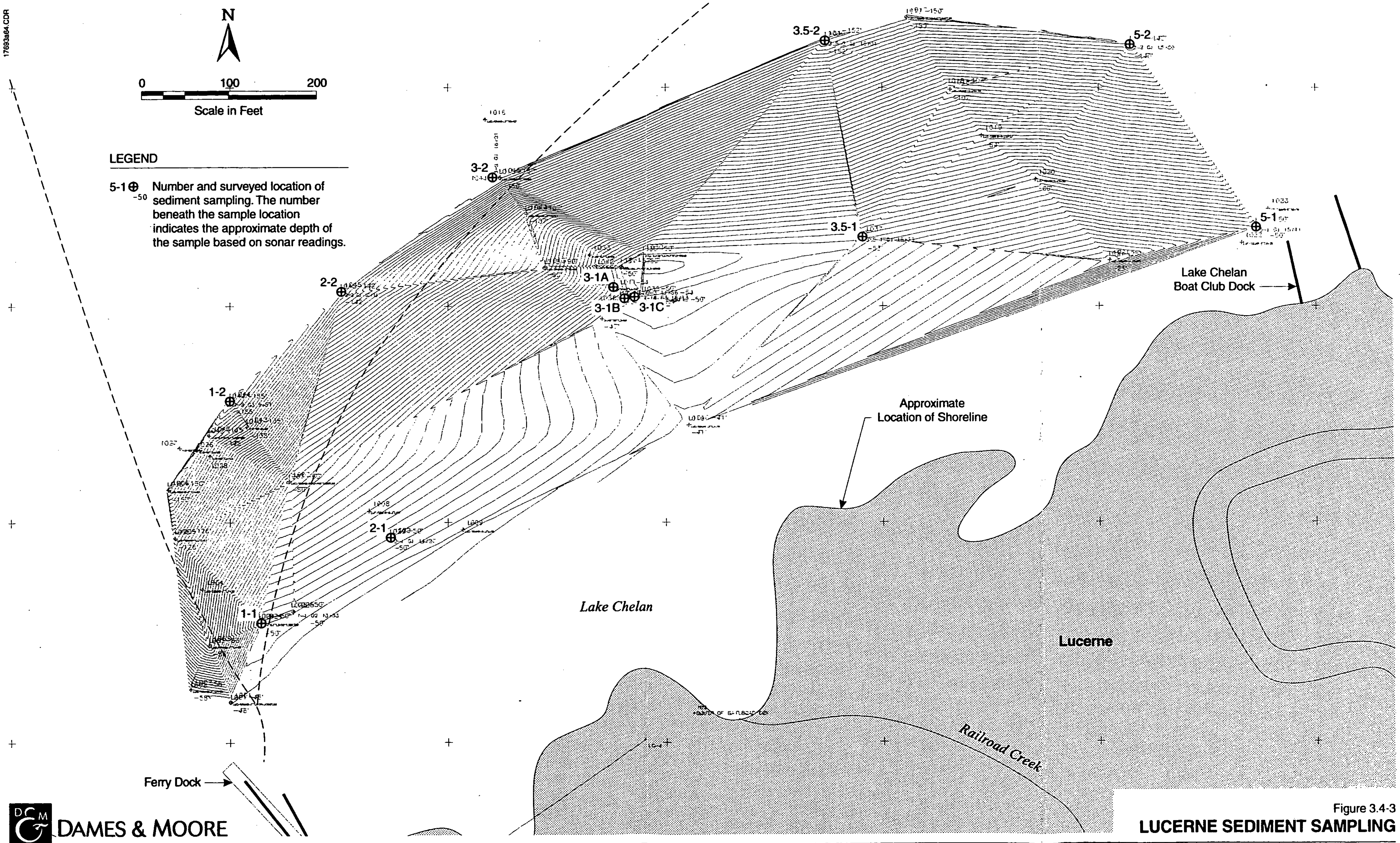

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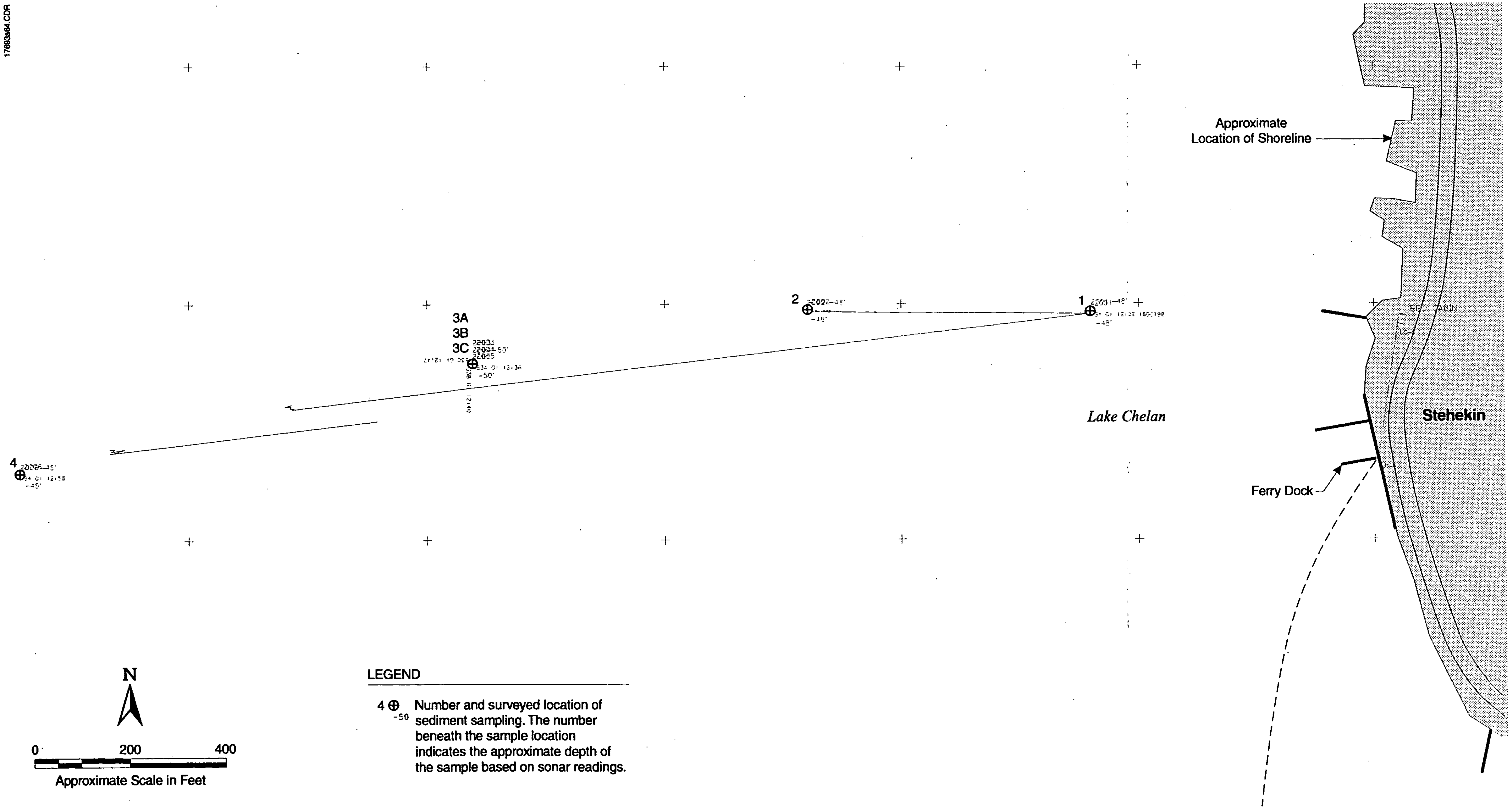
Figure 3.4-3
LUCERNE SEDIMENT SAMPLING

Holden Mine RI/FS
Draft Final RI Report

17693a64.CDR



LEGEND

4 ⊕ -50 Number and surveyed location of sediment sampling. The number beneath the sample location indicates the approximate depth of the sample based on sonar readings.

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Figure 3.4-4
STEHEKIN SEDIMENT SAMPLING

Holden Mine RI/FS
Draft Final RI Report

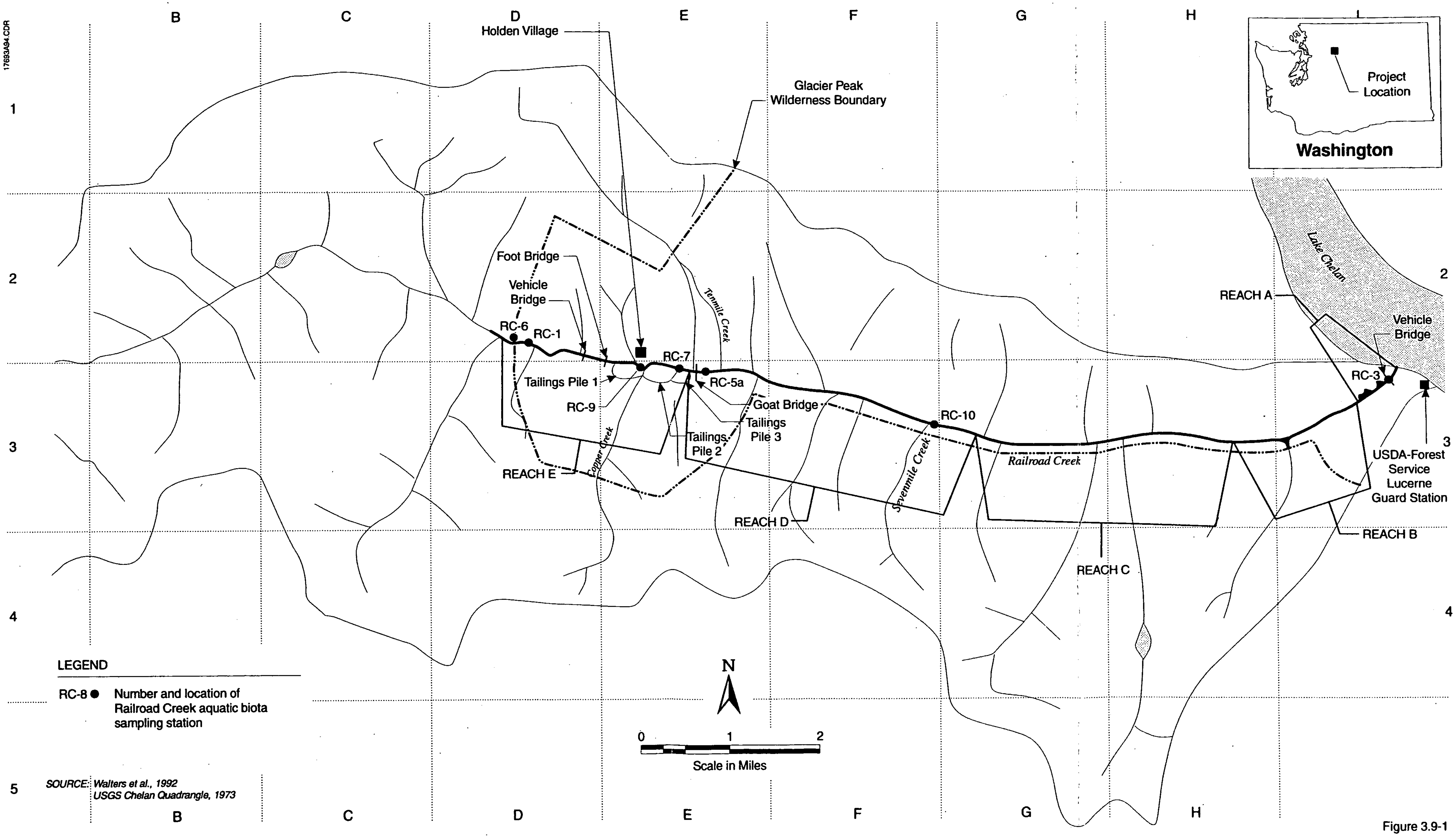

Figure 3.9-1

ECOLOGICAL SURVEY LOCATIONS – AQUATIC RAILROAD CREEK

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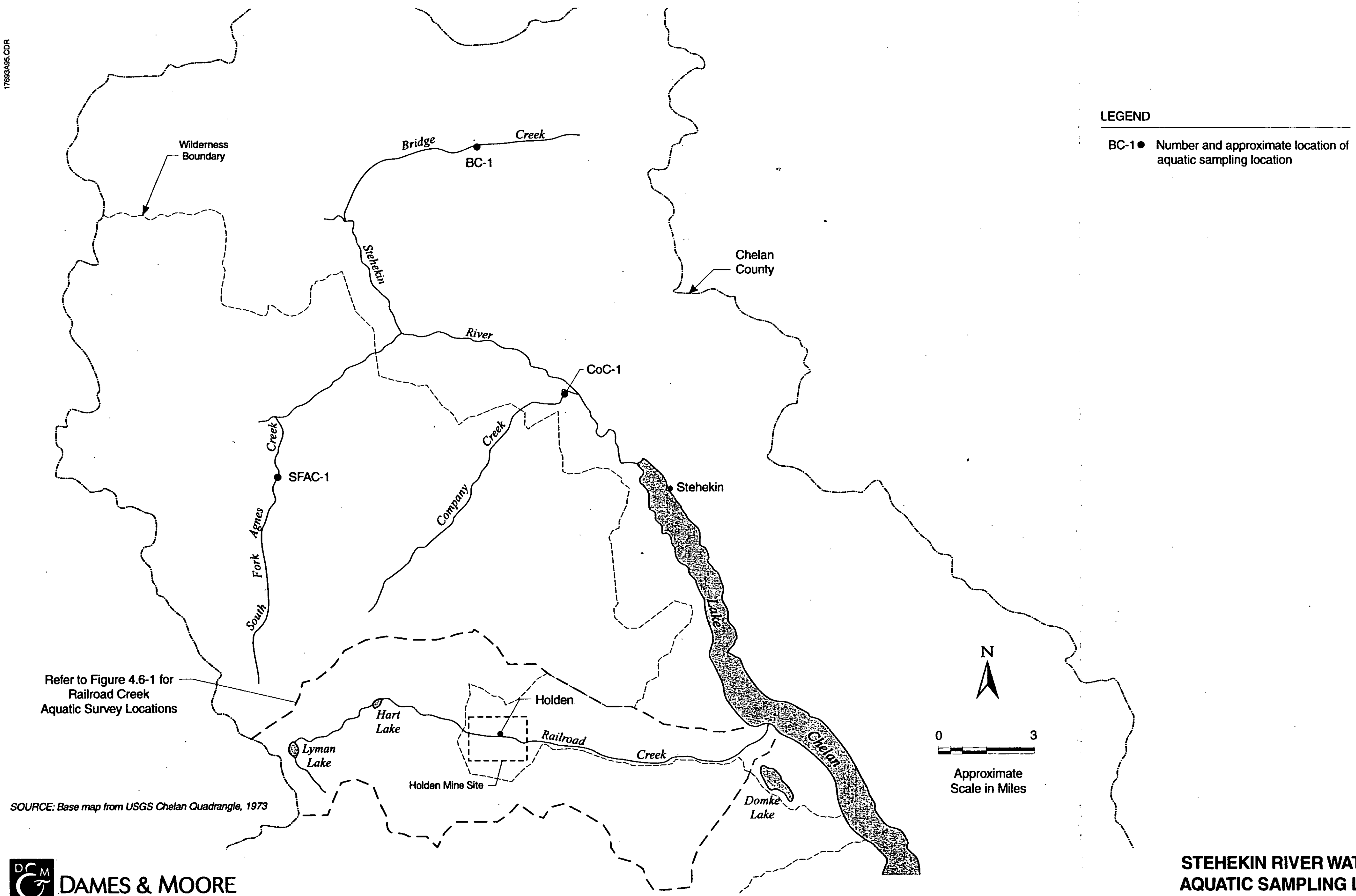
17693A95.CDR



SOURCE: Base map from USGS Chelan Quadrangle, 1973

Figure 3.9-2

STEHEKIN RIVER WATERSHED—AQUATIC SAMPLING LOCATIONS

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Job No. 17693-005-019

4.0 PHYSICAL CHARACTERISTICS OF THE SITE

4.1 PHYSICAL SETTING

4.1.1 Geographic Setting and Topography

4.1.1.1 Lake Chelan Basin

Referring to Figure 4.1-1, the Lake Chelan basin is a glaciated valley situated in north-central Washington State, on the east slope of the Cascade Mountains. The lake is the second deepest lake in the United States, and the largest and deepest lake in Washington. The deepest portion of the lake is near its center; the depth of the lake at this point based on sonar is 1,486 feet, or 453 meters. The length of the lake along its principal axis is approximately 50 miles. During the summer months, the water level in the lake is approximately 1,100 feet above sea level. The original elevation of the lake was reportedly raised 21 feet in 1928 by a dam, which is still in place, at the southernmost end of the lake at the town of Chelan. There are a number of tributaries entering the lake; the major drainages are Railroad Creek on the west, Prince Creek on the east, and the Stehekin River on the north at the head of the lake. The elevations within the u-shaped valley of the lake ranges from lake level to more than 8,000 feet above sea level (Darvill, 1996).

4.1.1.2 Railroad Creek Watershed

Referring to Figures 4.1-1 and 4.1-2, the Railroad Creek watershed is situated approximately three quarters of the way up the west side of Lake Chelan. The watershed is generally oriented in an east-west direction, and is approximately 20 miles in length. The Railroad Creek drainage was also glacially carved and is generally u-shaped, with steep side slopes. The portion of the drainage near Lake Chelan is gently sloping at the mouth for approximately one-half mile, becoming relatively steep, with several waterfalls for the first few miles. The drainage then transitions to a more moderate gradient past the Site. The western portion of the drainage again steepens before reaching Lyman Lake and Lyman Glacier.

Topographic coverage of the Site and vicinity is indicated in the United States Geological Survey, 7.5 minute Quadrangle for Holden, Washington, dated 1944 and corrected in 1968. The elevations within the watershed range from the level of Lake Chelan to more than 9,500 feet above sea level (Bonanza Peak) several miles west and north of Holden Village. Elevations of Railroad Creek range from 1,100 feet above sea level at Lucerne, which is located on Lake Chelan, to 6,500 feet above sea level at the headwaters near Lyman Glacier. The Site is situated approximately mid-way up the Railroad Creek drainage.

4.1.1.3 Holden Mine Site

The Site is located in Section 7, Township 31 North, Range 17 East in Chelan County. Referring to Figure 4.1-3, most of the abandoned mine facilities and tailings are between the 3,200 and 3,400 feet above sea level which is up to approximately 200 feet above Railroad Creek and Holden Village. The original mine workings are situated above the main Site vicinity in the area noted as Honeymoon Heights, which ranges in elevation up to approximately 4,600 feet above sea level.

4.1.2 Site Surface Features

Referring to Figures 4.1-3 and 4.1-3a and Table 4.1-1, the Site has been divided into defined areas, based on past and present uses, for discussion purposes.

4.1.2.1 Mill Building, Mine Support Area, and Waste Rock Piles

The mill building is located near the center of the Site on two patented mining claims (Lucille Millsite and Copper Creek Millsite) deeded to Holden Village, Inc. Referring to Figure 4.1-4, the mill building was constructed in a stair-step fashion down the slope from the 1500-level mine portal level (near the "Main office, warehouse, machine shop, compressor room" noted on the figure) to the valley bottom, approximately 200 feet below the portal elevation. The stair-step design allowed gravity to move the ore through the processing from the "ore storage bin," through the milling process, and to the "loading bay" as concentrate.

The method of metal extraction was a froth flotation treatment of the ore (McWilliams, 1958). The ore rock was mixed with water and further crushed to pass through a 200-mesh screen. The resulting mud was treated with pine oil reagents to coat the metallic minerals with a water repellent film. The slurry was then agitated in tanks while air bubbles were added to pull the water-repellent complexes with them. This process was repeated to separate the minerals. Recovery of copper and gold was reported in 1939 to be 94 and 81 to 83 percent, respectively (Pearse and Zanadvoroff). The extracted minerals were then transferred to trucks for transport to Lucerne, where the concentrate was transferred to a barge for transport to the Town of Chelan and then by rail to the City of Tacoma, Washington, approximately 175 miles west, for smelting (Huttl, 1937).

Some of the components associated with the historic crushing and grinding of the ore, as well as portions of concentration tanks, are still present. The mill building currently consists of concrete foundation walls and the remnants of the original metal structure and walls. A portion of the structure and the majority of equipment was apparently removed during the salvage operations (communications with Keith Anderson, formerly of the USFS, 1996). Water seepage was observed during the spring months throughout portions of the facility during the RI; the water appeared to originate from the southern foundation walls and flowed generally north to the northwest corner of the building before exiting to a storm drain and eventually into the lagoon feature northwest of the facility.

Due to safety considerations, the mill building was not entered during the RI. However, the perimeter of the building was assessed. An estimated 10 cubic yards of unprocessed ore was observed in the uppermost portion of the mill, in the area noted on Figure 4.1-4 as the "ore storage bin." Remnants of apparent insulation were observed in the exposed walls of the building; the material appears to be a wood product. The roof of the mill building was removed during the salvage operations and the area is, therefore, uncovered. Indications of mineral salts were observed on the surfaces of the ore material and remnant concentrate tanks, and mill foundation. A set of inclined tracks was observed along the western portion of the building, likely associated with an inclined tramway. Water was noted flowing from the uppermost portion of the building and down the tracks during the spring months. The source of the water appeared to be the cut slope to the south of the building.

Waste Rock Piles

Referring to Figures 4.1-3 and 4.1-3a, two waste rock piles are present in the immediate proximity of the abandoned mill building. One pile is located to the west and one to the east of the mill facility. The piles are estimated to range between approximately 120 to 150 feet in height. The uppermost surfaces of the piles are relatively level and near the same elevation as the mine portal. The slopes of the piles are relatively steep, in some cases approaching 45 degrees. The majority of the two piles are located outside the boundary of the patented mill site claims and are, therefore, on National Forest System (NFS) lands.

The surface of the western waste rock pile contains approximately 2,400 cubic yards of petroleum hydrocarbon-affected soils reportedly associated with the removal of 12 USTs from Holden Village in 1994 (QUEST, 1996). The top of the western waste rock pile is being utilized by Holden Village as a "bone yard," or for the storage of miscellaneous materials.

A relatively minor amount of water seepage was observed near the base of both the west and east waste rock piles during the spring months. The water from the western pile flows overland for a short distance before percolating into the ground surface. The seepage from the eastern rock pile flows into a surface water diversion onto the surface of tailings pile 1, which drains eventually into the Copper Creek diversion (see below under Hydroelectric Plant).

Portal Museum

Referring to Figures 4.1-3 and 4.1-3a, the portal museum is present to the west of the abandoned mill building, in a building that was constructed by Holden Village after the closure of the mine facility. The museum contains a collection of artifacts and information related to the past mine operations; the actual mine records were transferred to the University of Washington library archives (Adams, 1981).

Maintenance Yard and Buildings

Referring to Figures 4.1-3 and 4.1-3a, several Holden Village equipment maintenance buildings are located to the north of the mill building within the patented millsite area. The wood buildings are used to store equipment, parts, tools, and miscellaneous chemicals and lubricants associated with the equipment. The principal "shop" building is an "A-frame" structure which was reportedly constructed by Holden Village after the original building burned down in the early 1970s (personal communication with Warner Jansen, former Holden Village Operations Manager, 1998). The principal equipment maintained on the Site includes road grading, excavation, and transport vehicles. Electrical transformers, labeled as not containing polychlorinated biphenyls (PCBs), were observed outside the storage building. Fuels are stored in aboveground storage tanks (ASTs). There is a general absence of vegetation in the maintenance yard area, likely due to vehicle traffic, grading, and the compact nature of yard surface.

Holden Village completed a new building immediately to the east of the older shop building in 1998, which is used for additional vehicle maintenance and water treatment for the village.

Hydroelectric Plant

Electrical power for the primary operation of the mine was provided by a transmission line from a power plant in Chelan (Adams, 1981). A hydroelectric power generation facility was developed by Holden Village after the mine closed. Referring to Figures 4.1-3 and 4.1-3a, the hydroelectric plant is located to the west of tailings pile 1 and north of the boundary of the patented mill site claims. The water which drives the generators is from a diversion of Copper Creek approximately one-half mile to the southeast of the hydroelectric plant. The water coming out of the hydroelectric plant flows to the north through what is noted herein as the Copper Creek Diversion to Railroad Creek, coming into partial contact with the western margin of tailings pile 1. The Copper Creek Diversion splits before entering Railroad Creek, with a small portion of the drainage flowing into a concrete lined "dipping pool" located at one of the two sauna facilities utilized by Holden Village; the second sauna is located in the village.

Lagoon

Referring to Figures 4.1-3 and 4.1-3a, a feature noted in historic documents as a "lagoon" is present to the northwest of the abandoned mill facility, to the west of the road from the vehicle bridge. The lateral extent of the area is estimated to be less than one-third of an acre. The lagoon feature collects water draining from the west waste rock pile, mill, and maintenance yard areas. There is not a distinct outflow for the lagoon feature; it appears that the lagoon generally drains through the subsurface, with an occasional overflow through a small drainage to the northwest. The lagoon was observed during the RI to dry up in the later summer months. There is a general absence of vegetation in the immediate area of the lagoon. However, it is possible for wildlife to access the area.

Other Features in Mine Support Area

A series of walking trails and roads is present in the area of the mill building which allows physical access to the mill area and the portal. However, a seasonal fence to limit human access to the abandoned mill building was constructed along the southern boundary of the building in 1998 by Holden Village.

Organic municipal waste is composted in an area to the east of the maintenance yard, near the base of the eastern waste rock pile. Municipal waste associated with the mining operations may have been incinerated. Some non-burnable wastes from the mining operations, as well as municipal wastes associated with the operation of Holden Village, were reportedly deposited in a pit excavated in the surface of tailings pile 1. However, this practice was reportedly discontinued in 1989.

A water tank is present to the southeast of the mill facility. The water is transported via pipeline from the diversion of Copper Creek located approximately one-half mile from the mill site. The water is utilized by Holden Village residents. The water quality is monitored through regular sampling and analysis. The water will be treated in the future by the new facility recently constructed in the maintenance yard area.

4.1.2.2 Tailings Piles

Referring to Figure 4.1-3, three tailings piles cover a total area of approximately 90 acres to the north and east of the mill building. The piles were constructed from a mill tailings slurry which was transported to the tailings piles via wooden pipes after Railroad Creek was relocated (Figure 4.1-4a); the relocation of Railroad

Creek was documented on a Howe Sound map dated 1937; however, the previous location of the streambed in the area of tailings piles 2 and 3 is unknown. Each tailings pile was built by sequentially constructing a perimeter dike, then discharging tailings slurry inside the perimeter dike (Figures 4.1-4 and 4.1-5). The dike was constructed with "thickened" tailings, or waste rock material, recovered after mill processing, from which the majority of the extremely fine-grained fraction had been removed. This material was relatively angular and allowed for the construction of slopes in excess of 50 degrees (ORB, 1975).

The slurry that was not thickened was placed behind the perimeter dikes. Solids settled from the slurry, and water was discharged from concrete decant towers in the southern portion of the impoundment. The drains from the bottoms of the decant towers flowed through the tailings piles to Railroad Creek. When an impoundment filled with sediment, the process was repeated so that the piles were raised sequentially.

Deposition of tailings for tailings piles 1 and 2 below the 3,200-foot contour was accomplished by gravity flow from the mill facility. However, beginning in 1942, tailings required pumping from an installation near the southwest corner of tailings pile 2. The pumping method for deposition was reportedly utilized for the portions of tailings piles 2 and 3 above the 3,200-foot contour.

A discussion of each of the tailings piles is presented hereafter. A discussion of the chemistry is presented in Sections 5 and 6.

Tailings Pile 1

Tailings pile 1 is located to the northeast of the mill facility and is estimated to cover an area of 25 acres. The pile is bounded to the north by Railroad Creek, to the east by Copper Creek, and to the south by the east waste rock pile and a natural, conifer tree-covered slope which climbs to the south. The surface of tailings pile 1 is generally covered with rounded gravel. However, the southeastern and northwestern portions of the pile are uncovered. The areas are apparently not covered with gravel due to the relatively steep slope angles and the inability of the gravel to remain in place.

The tailings pile area is partially covered with plots of coniferous trees, some of which were reportedly established in the 1960s and are estimated to be more than 10 feet tall. Some of the plots have been irrigated and fertilized by USFS Forest Sciences Laboratory personnel (communications with George Shearer, USFS, 1997). Portions of the surface are also covered with miscellaneous woody debris in an attempt to increase the success of revegetation (PNL, 1992).

Several swales or ditches are present across the pile. The swales were installed in the surfaces of all three piles to limit surface water infiltration as part of the reclamation efforts completed by the USFS in 1989 through 1991. The swales are lined with a permeable geofabric and relatively small "rip rap" (rock used to protect areas from surface erosion). Some of the rip rap has decomposed to a coarse sand.

The northern and eastern margins of the pile have relatively steep slopes leading down to Railroad Creek. Site maps provided by the USFS indicate the maximum height to be approximately 40 to 50 feet. The angle near the top of slope was approximately 45 degrees, with isolated slope segments approaching vertical. The remainder of the slope is estimated to be less than 40 degrees. The slopes not covered with gravel are estimated to be in excess of 45 degrees. An organic matting with grass seed has been placed over portions of the slope for erosion protection. Grasses are growing out of some of the mats.

Water seepage emanates, in the spring, from the base of the northern and northwestern portions of the tailings pile, near Railroad Creek. Cemented sand and gravel exists in the immediate area near the level of Railroad Creek at the northwest corner of the pile.

A series of steel pipe monuments designed to protect the groundwater monitoring wells was noted across the surface of the pile. The groundwater monitoring wells were reportedly installed by contractors to the USFS during two separate events in 1991 (PNL) and 1995 (USBM).

The remnant of a decant tower was observed in the southern portion of the pile, immediately east of the east waste rock pile (Figure 4.1-5b. Grout was not observed and surface water was flowing into the feature during spring snowmelt. Based on a review of construction drawings completed for the Forest Service tailings rehabilitation project between 1989 and 1991, it appears that each tailings pile had decant towers which were identified for filling with grout; however none of the drawing shows the apparent remnant of a decant tower noted herein on tailings pile 1.

Tailings Pile 2

Tailings pile 2 is located to the east of tailings pile 1, and is estimated to be 45 acres in size. The pile is bounded to the west by Copper Creek, to the north by Railroad Creek, and the east by a slope which leads to tailings pile 3, and the south by a natural, conifer tree-covered slope which climbs to the south. The surface of the pile is generally covered with rounded gravel. Relatively young coniferous vegetation are present on the surface. Some grasses were reportedly drilled into the surface of the pile and growth appears to be relatively successful; however, it is understood that fertilizers and lime are necessary to promote growth (personal communication with Keith Anderson, formerly of the USFS, 1996). Some mature coniferous trees are present near the edges of the tailings pile, near the top of the slopes leading to Copper Creek and Railroad Creek; the trees apparently reseeded naturally. Portions of the surface are also covered with miscellaneous woody debris in an attempt to increase the success of revegetation (PNL, 1991). Other experimental test plots are also present.

Two interceptor ditches trend across the southern portion of the pile which drain mostly to the southeast corner of the pile, eventually flowing into Railroad Creek after crossing the southern margin of tailings pile 3. Like the ditches on tailings pile 1, they are lined with a permeable geofabric and small rip rap; some of the rip rap has decomposed to coarse sand. A series of steel pipe monuments associated with the groundwater monitoring wells also exist across the surface of the pile.

The northwestern, northern and eastern margins of the pile have relatively steep slopes leading down to Copper Creek and Railroad Creek. The maximum height is noted on Site maps to be approximately 120 feet. The maximum angle near the base of the slope is estimated to be in excess of 55 degrees near the confluence of Railroad Creek and Copper Creek. The remainder of the slope is estimated to be on the order of 40 to 45 degrees. The slopes steeper than 45 degree are generally not covered with gravel. An organic matting with grass seed had been placed over portions of the slope. Grasses were observed growing out of some of the mats.

Tailings Pile 3

Tailings pile 3 is located to the east of tailings pile 2, and is estimated to be 22 acres in size. The pile is bounded to the north by Railroad Creek, the east by a wetland area and trees, and to the south by a conifer tree-covered slope which climbs to the south. The surface of the pile is generally covered with rounded gravel. Areas of relatively young coniferous vegetation are present on the surface. Grasses were reportedly drilled into the surface of the pile and are apparently relatively successful when augmented with fertilizers. Mature coniferous trees are present near the northern edges of the tailings pile, near the top of the slope leading to Railroad Creek; the trees apparently were reseeded naturally (personal communication with Keith Anderson, 1996). Portions of the surface are covered with miscellaneous woody debris in an attempt to increase the success of revegetation (PNL, 1991). Other experimental test plots are present which are being studied by the USFS (personal communication with George Shearer, USFS, 1997).

A series of steel pipe monuments associated with the groundwater monitoring wells exist across the surface of the pile. An interceptor trench trends across the southern portion of the pile, which drains to the southeast corner and then into Railroad Creek, after crossing through a small wetlands area. The trench is lined with a permeable geofabric and small rip rap; some of the rip rap has decomposed to coarse sand.

An avalanche reportedly occurred during the winter of 1995/1996, which reached the southern margin of the tailings pile (personal communication with Keith Anderson, formerly of the USFS, 1996). The source of the avalanche was the relatively steep slope and drainage feature to the south of the tailings pile.

Springs are observed in the area to the east of the tailings pile, in the area of wetlands. Iron oxide staining is evident in much of the wetland area. The water which drains from the wetlands flows along the southern margin of the area and eventually into Railroad Creek.

4.1.2.3 Railroad Creek

Railroad Creek was assessed during the RI nearly continuously from an area several miles to the west of the Glacier Peak Wilderness boundary, to the mouth of Railroad Creek at Lucerne; due to health and safety concerns, the only portions of the creek bed not evaluated were a series of waterfalls near the mouth. Referring to Figure 4.1-2 and based on the review of topographic maps, the stream gradient is moderate from the base of Lyman Glacier to Lyman Lake before descending Crown Point Falls. The gradient of the streambed is moderate as it enters Hart Lake, approximately four miles west of the Site. Near the Site, the stream gradient lessens, continuing downstream of the Site. Several miles west of the mouth of the creek, the stream gradient steepens, descending several waterfalls before flattening near the mouth.

Upstream of the Site, the creek is in a relatively pristine state; however, limited precipitation of apparent iron oxides, which appeared to be naturally occurring, was observed on rocks within the stream bed. Natural iron stain on stream pebbles is a common feature regardless of whether mining has occurred in a drainage basin. The undersides of stable cobbles are usually not stained. It may be caused by slow weathering of iron minerals in the rocks, by adsorption of dissolved iron from the water column or by entrapment of natural iron flocculent by organic matter. The Site is situated in a watershed with naturally occurring iron mineralization. A visit to Lyman Lake, located approximately 10 miles upstream of the Site, disclosed the presence of naturally occurring iron cementation of the substrates of several small drainages located on a glacial moraine deposit; the streams flow eventually into Railroad Creek.

At the Site, approximately mid-way past tailings pile 1, distinct iron precipitation is present along the southern bank of the creek. Near the northeast corner of tailings pile 1, upstream of the confluence of Railroad Creek with Copper Creek, the southern banks of the creek were observed to be cemented with apparent iron oxide (ferricrete) and the iron precipitate appears to cover the majority of the substrate. The presence of apparent uncemented and surficial iron precipitates was observed to continue past tailings pile 3, but decreases to the east of the tailings pile. Approximately three miles downstream the iron precipitate on the substrate of Railroad Creek diminished and no indications of cementation were noted. No indication of significant oxidation and/or cementation was noted to the north of Railroad Creek. A more detailed discussion of the Railroad Creek conditions is presented in Section 4.3.

Portions of the south bank of Railroad Creek upstream of the tailings piles and downstream of the portal drainage confluence is covered with wood logs as erosion protection, the logs were apparently placed by Howe Sound Company. In the immediate area of the tailings piles, the south bank is covered with riprap placed during the rehabilitation completed by the USFS between 1989 and 1991. Wood cribbing had reportedly been originally placed along the creek by Howe Sound Company as scour protection, but the wood had apparently decomposed over time. The condition of the riprap is discussed in more detail in Section 4.2.7 of this report.

4.1.2.4 Copper Creek

Referring to Figures 4.1-2, 4.1-3, and 4.1-3a, Copper Creek drains from Copper Basin to the south of the Site. The Copper Creek streambed eventually crosses under the road which connects tailings pile 1 and tailings pile 2 through several metal culverts. The creek does not appear to come into contact with mine related materials until it flows through the culvert and then between tailings piles 1 and 2. The creek was lined with a permeable geotextile material and rip rap as part of the reclamation efforts completed by PNL and CH2M Hill between 1989 and 1991. A more detailed discussion of Copper Creek conditions is presented in Section 4.3.3.4.

4.1.2.5 Holden Village

Referring to Figures 4.1-3 and 4.1-3a, Holden Village is currently operated under a Special Use Permit from the USFS. The facility is utilized as an interdenominational church retreat. All of the buildings in the village are located on NFS property. The village includes approximately 25 buildings which were built in the late 1930s. The building uses presently include, but are not limited to, a school and associated play area, cafeteria, housing for the full-time residents, dorm housing for the visitors and seasonal volunteer staff, a meeting room, library, art studio, and store.

Holden Village has approximately 50 to 60 year-round residents. In addition, the facility accommodates as many as 400 visitors and volunteer staff daily between mid-June through the end of September.

An abandoned septic field is present to the southeast of the village school parking lot; the remnants of the septic field, primarily mounds and pipes, were observed in a meadow amongst the forested area between the confluence of Railroad Creek and Copper Creek, and the road to Lucerne. The septic field was moved during the period of the mine tailings rehabilitation (1989 to 1991) to an area immediately southeast of the abandoned Winston home sites.

The road from the village to Lucerne was constructed in the late 1930s and is maintained by the USFS. The road is utilized several times daily by buses operated by the village during the summer months. During the winter months, snow removal is performed by Holden Village until impractical; snow cats are then utilized until snow melt occurs.

4.1.2.6 Winston Home Sites

Summary of Historical Information

Referring to Figures 4.1-3 and 4.1-3a, the Winston home sites area reportedly included 103 single-family residences which were constructed to house families of the mining employees (Adams, 1981). The houses were wood-frame construction with concrete and/or stone foundations. The houses are assumed to have been heated with fuel oil. The fuel was evidently stored in a combination of aboveground storage tanks (ASTs) and underground storage tanks (USTs). The houses were demolished by the USFS but the tanks were not removed.

Records regarding the status of the tanks at the time that the mine closed were not found in the files reviewed. A qualitative assessment of the amount of fuel remaining in the tanks at the time of mine closure was, therefore, completed. Based on the review of historical records, the mine closed in July 1957. The tanks were most likely not filled in spring 1957 leading up to the mine closure, and were more likely partially empty if not nearly so at the time that the homes were vacated.

An interview with a volunteer at Holden Village, who had been volunteering at the village since the 1960s, disclosed that he had been personally involved in the pumping of at least some of the tanks in Winston in the 1960s to provide fuel oil for the village (personal communication with Mark Bjorkie, 1997). The interviewee noted that it made logical sense that the tanks would have been pumped considering the logistical challenges of transporting fuel to the village by barge and truck. He also reported that all of the tanks had been located adjacent to the streets on which the houses were situated, and were relatively easily accessible to the fuel trucks for both filling and pumping.

Inventory of Tanks

An inventory of the tanks in the Winston area was completed as part of the RI. The inventory was completed on October 4, 1997, and consisted of a visual reconnaissance of the area during which the locations of apparent tanks, vent pipes, and fill pipes were documented on an AutoCAD map of the Site, which included the Winston area. The map included the surveyed locations of walls and some of the foundation elements which were visible at the time of the civil survey completed by the USFS in 1989.

The results of the reconnaissance disclosed that the Winston area is currently covered with grasses and a combination of deciduous and coniferous trees. The remnants of some of the foundation elements can still be observed. Referring to Figure 4.1-5a, a number of metal pipes were observed protruding from the ground surface. Upon closer examination, the pipes were found to be associated with USTs.

The pipes were of two primary types: one which had a u-shaped, open end, which was interpreted to be a vent pipe; and a second type which normally was a larger-diameter and had a screw cap, which was interpreted to be a fill pipe. The pipes were all located near the remnants of the Winston pre-existing street system delineated by ditches and retaining walls for yards and foundations. In some cases, metal tanks were observed partially exposed, in which case the vent and fill pipe connections were visible. The exposed USTs exposed were generally found to be cylinders measuring on the order of 2 feet in diameter and 3 feet long. The partially exposed USTs were found with the axis of the cylinders parallel to the ground surface. The partially exposed tanks were observed with the vent and fill pipes at opposite ends of the tanks. The thickness of the tank walls was noted to be approximately 1/8 inch.

Figure 4.1-5a displays the results of the tank inventory, including the approximate locations of the tanks; in most cases the locations of the tanks were based on the presence of vent and/or fill pipes. Other observations noted during the inventory are also documented on the figure. However, due to the presence of vegetative ground cover, the inventory should not be considered all inclusive. In addition, it was found that some of the vent and/or fill pipes associated with the tanks had apparently been damaged and/or removed during the demolition of the houses.

An odor of apparent petroleum hydrocarbons was noted at several of the vent and/or fill pipes. However, no indications of stressed vegetation and/or spilled fuel product was noted on the ground surface surrounding the tanks. One of the tanks was observed with a hole created as a result of rust. The tank had filled with water; however, no indications of a sheen and/or petroleum hydrocarbons odor were noted.

Two apparent ASTs were also noted in the Winston area. The ASTs were noted to be cylindrical metal tanks with the fill pipes at one end and a vent near the center of the tank. The drain line was noted at the bottom of the tanks.

Assuming one pair of vent and fill pipes per tank, a total of 38 USTs and 2 ASTs were documented. It is likely that each house had more than one tank for fuel storage. It is also possible that additional USTs are present which were not inventoried due to vent and/or fill pipes which had been broken off. However, it is also possible that a majority of tanks have been inventoried, and that the remainder of the tanks were instead ASTs.

Based on the interview with the Holden Village volunteer (personal communication with Mark Bjorkie, Holden Village volunteer, 1997), it appears that the fuel used in the houses was diesel range petroleum hydrocarbons. The characteristics of the diesel product are such that it is normally possible to utilize the fuel in cold weather without insulation or auxiliary heating to decrease viscosity. Consequently, it is possible that the remainder of the homes utilized ASTs versus USTs.

4.1.2.7 Baseball Field and Campground

Referring to Figure 4.1-3, a baseball field exists approximately one-half mile to the west of the village, and is utilized intermittently throughout the summer months by Holden Village. The field appears to have been constructed by Howe Sound utilizing soil removed from a cut slope immediately north of the field. The entire area is mostly covered with grass vegetation. The Glacier Peak Wilderness boundary is located several hundred yards west of the baseball field. Hiking trails leading to the wilderness area originate to the north of the field. It is suspected that the trail was constructed atop portions of an abandoned roadbed utilized to gain access to mine workings and/or mineral claims upstream of the Site. The baseball field is bounded to the south by Railroad Creek, and the east by a campground.

The campground is used by backpackers and visitors to the area. An abandoned road and bridge crossing, which likely provided access to the mill area and Honeymoon Heights, exists to the southeast of the campground. Based on field observations, it appears that waste rock may have been used as road ballast during the road construction. No distressed vegetation was observed in the area. A monitoring well (HBKG-2) was observed adjacent to the road.

4.1.2.8 Honeymoon Heights

Referring to Figure 4.1-3, the Honeymoon Heights area is situated to the south and west of the mill building and tailings piles. The area consists of six mine portals, starting from the lower levels and progressing upward, at the 1100, 1000, 800, 700, 550, and 300 levels. These mine portals were apparently not used after the main access and ventilator tunnels were established at the 1500 level in 1937 by Howe Sound Company. Mine rock piles are associated with all of the mine portals. The Honeymoon Heights mine workings were apparently not utilized for full-scale ore removal and transport, but, primarily for exploratory purposes. The total quantity of waste rock at the portals of these workings appears to be significantly less than for either the west or east waste rock piles near the abandoned mill facility.

An abandoned road generally connects the rock piles in the Honeymoon Heights area with the road that runs to the 1500-level main mine portal; the road is maintained as a hiking trail by Holden Village. A system of mostly abandoned trails, apparently utilized by the miners, exists throughout the area to access the different mine portals.

An abandoned mining camp is situated near the 1100-level portal; several decomposed wood buildings and stone foundations remain in the area. Isolated remnants of the mining operations dating back to the late 1800s and early 1900s in the areas of the mine openings, including metal tracks for ore cars, cables associated with a pre-existing tram system which connected the 1100 level to a location near the existing ballfield area, a water storage tank, and other miscellaneous items were observed. Several other shallow mine workings are present southwest of the abandoned Honeymoon Heights village and are documented to not be associated with Howe Sound Company; the workings were established by a former associate of J.H. Holden by the name of Patterson; the workings are not connected to the Holden Mine underground network (Adams, 1981). Several exploratory adits exist along the strike of the ore body exposed at the surface; all of these workings are shallow, exploratory in nature, and are not connected to the underground mine system.

4.1.3 Site Subsurface Features

4.1.3.1 Underground Mine Workings

Due to safety concerns, the underground mine was not physically accessed during the RI. However, an assessment of the mine maps generated during and after the mine operation was conducted. The dates of the mine maps ranged from as early as 1908 to 1957, at the time of closure.

The maps indicated a total of 14 primary mine levels, and approximately the same number of secondary levels. Referring to Figure 4.1-5b, two cross-sections have been developed through the underground mine; cross-section H-H' is parallel to the strike of the ore body, and cross-section I-I' is perpendicular to the strike of the ore body. Figure 4.1-5c displays Section H-H' and shows the extent and condition of the underground mined openings, or "stopes," as well as the geology described in Section 4.2.3.2. Figure 4.1-5d displays

Section I-I' and shows the six tunnels which accessed the ore body and stopes. The levels of the mine were numbered based on the approximate elevation below an exposure of the ore body outcrop shown on Figure 4.1-5b; in other words, the exposure of the ore body is the hypothetical "0" level, with the 300-level being 300 feet lower, the 550-level being 550 feet lower, and so on to the 2500-level. The northing and easting grid system noted on the maps were established utilizing the general strike of the ore body as the northing line.

The six levels of the mine with portals to the surface, as well as the most laterally extensive lower level (2325), depicted on Figures 4.1-5c and 4.1-5d, were digitized utilizing the underground mine maps provided. Figure 4.1-5b shows all seven levels with the associated stopes and mine workings superimposed. However, Figures 4.1-6 through 4.1-13 show the extent of each individual mine level (300, 550, 700, 800, 1000, 1100, 1500, and 2325, respectively.

The map utilized to generate Figure 4.1-5c displayed the dates of mining for each of the stopes. The upper workings (300-, 550-, and 700-levels) (Figures 4.1-6 through 4.1-8) were apparently developed during the early periods of the exploratory efforts. The lower workings (800-, 1000-, and 1100-levels) (Figures 4.1-9 through 4.1-11) were developed during the period from approximately 1920 until 1937, and included several miles of tunnels. This corresponds to the relatively larger sizes of mine rock piles associated with the lower workings. All of the portals, except for the 300 level, were timbered.

When Howe Sound purchased the mine, they increased access to the underground mine workings by installing a primary tunnel at the 1500 level. Referring to Figures 4.1-5b and 4.1-12, the opening to this tunnel was constructed near and to the west of the uppermost level of the mill building. The tunnel was initially installed by timber supporting the approximately 60 to 70 feet of glacial soil encountered at the portal. The remainder of the tunnel was drilled and blasted with limited rock bolt support to intersect the ore body approximately 2,500 feet to the southwest. A track was placed on the floor of the tunnel to allow the use of ore cars which transported the non-mineralized rock to the west and east waste rock piles. The tunnel was driven at an incline of approximately one-half percent to take advantage of gravity when the ore cars were filled in the mine (McWilliams, 1958).

Once the ore body was intersected, the tunnel turned and continued to the northwest approximately another 2,500 feet before daylighting out to the west at the 1500-level ventilator portal (Figure 4.1-12). The maps indicate that the last approximately 300 feet of the tunnel was timbered through glacial soil. This tunnel was utilized to provide ventilation throughout the mine. Air was piped in through the 1500-level main portal and then exhausted through the 1500-level ventilator portal; an 8-foot-diameter fan was originally installed in the opening (Edmond, 1972). Based on a civil survey completed as part of the RI, the ventilator portal was found to be approximately 20 feet higher than the 1500-level main portal. This indicates that the one-half percent grade continues for the entire length of the tunnel from the 1500-level main portal.

The majority of the mine tunnels at the different levels were generally constructed outside the ore body, within the surrounding rock which, based on the mine maps, had relatively low concentrations of economic minerals. The rock removed during the construction of the tunnels, after the 1500-level main tunnel was completed, was generally placed in two piles developed to the west and east of the mill. The tunnels within rock were constructed without timber support; however, rock bolts were utilized where necessary. The 1500-level was utilized to explore the lateral extent of the ore body; the maps reviewed indicate that the tunnel which starts at the ventilator portal extends approximately 13,200 feet to the southeast; the tunnel does not daylight and, based on a review of both underground mine and topographic maps, there is at least 800 feet of bedrock cover for the entire length of the tunnel. Figure 4.1-12 only displays the portion of the 1500-level tunnel which was noted on the maps to contain mineable concentrations of the economic metals.

The ore was removed by a process described as a "modified form of sublevel stoping" (McWilliams, 1958). The ore body was drilled from the tunnels, or drifts, installed parallel to the ore body. A series of ore chutes were constructed in the rock to connect the ore body with the primary tunnels below the chutes. The rock was then blasted and the broken rock removed utilizing ore cars which transported the ore to the mill through the 1500-level main tunnel. The openings developed in the ore rock are known as stopes. The width of the stopes was limited to the width of the ore body, which was approximately 80 feet. The height of the stopes varied throughout the mine. As the mining proceeded, the stopes were enlarged as much as practicably possible in order to take advantage of the fall to break the rock after it had been blasted. Referring to Figure 4.2-14, which is oriented parallel to the ore body, the largest of the stopes are located above the 1500-level, and is noted to be approximately 600 feet in height.

Figure 4.1-5c also shows that the different levels of the mine above the 1500-level were connected by a series of inclines, two shafts, and air passage ways. As the mining proceeded below the 1500-level, the ore had to be removed utilizing one of two shafts. Sumps were installed in each of the shafts to pump water during operation. The pumps are noted in mine specifications to be 600 gallons per minute capacity (McWilliams, 1958); no records of actual pumping rates were discovered. An interview with a mining engineer who was employed at the mine for the entire period of operation, indicated that the majority of the mine water originated from diffuse sources above the 1500-level. The water from above the 1500-level was intercepted, when possible, to the drainage trench in the floor of the 1500-level tunnel (personal communication with John Blye, 1997).

The mining extended below the 1500-level to the 2500-level, which is approximately 800 feet below the floor of the Railroad Creek valley at the Site. Referring to Figures 4.1-13 and 4.2-14, the northernmost of the mine workings is the 2,325 level which is noted to terminate slightly north of the 1500-level ventilator portal. Approximately two-thirds of the stopes below the 1500-level were backfilled with slurried tailings materials by constructing concrete bulkheads after sealing the fractures and joints in the rock with cement, pumping in the slurry behind the walls, and decanting the water after the slurry was placed (McWilliams, 1958).

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The initial scope of the RI included sampling and analysis of the water within the mine. The proposed sampling program assumed that the one of the two portals at the 1500 level were open and safe for human access. However, it was discovered during the RI that both of the 1500-level portals were collapsed, and four of the remaining six mine portals above the 1500 level were also collapsed. A review of the mine workings and mine maps by both a mining engineer and a mining subcontractor to Dames & Moore indicated that the mine was not safe for entry without first making repairs to and reopening the 1500-level portal (personal communications with James Knowlson, JSK & Assoc., 1997, and Okie Ross, Atlas Fausett Contracting, 1997). However, it appears that the mine maps and mine portal drainage chemistry provide adequate data for RI characterization (refer to Section 6.5.1 for additional discussion of the underground mine and portal drainage chemistry).

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The uppermost stopes within the mine above the 1500-level are mapped to be within approximately 50 feet of the ground surface. No historical information was identified which addressed the potential for subsidence at the Site. Consequently, as part of the RI, a review of available underground mine maps, and a field reconnaissance of the areas identified as having potential for mine subsidence was conducted. The methods utilized to assess the potential for mine subsidence, and the results of the assessment, are discussed in Section 4.2.5.

The mine was closed in 1957 and eventually became flooded to the 1500-level. Water began discharging from the 1500-level main portal during the mid- to late 1960s (personal communication with Wes Prieb, Holden Village, 1997, and Warner Jansen, former Holden Village Operations Manager, 1998).

4.1.3.2 Mine Discharge

Referring to Figures 4.1-5c and 4.1-5d (which show two cross-sections of the underground mine), the portal drainage is the lowest mine opening for exit of groundwater from the mine and likely reflects the pool level of the mine groundwater. This is supported by portal drainage flow data collected by an automated data logger installed at the 1500-level portal. The data indicate a significant increase in flow (more than 10-fold) in response to precipitation within approximately 18 to 24 hours of a spring snowmelt event. Such a rapid and significant response would not be possible if flow through the failed portion of the tunnel was restricted (these data are discussed in Section 4.3.3.6).

Water was also observed flowing from the 1100-level portal during the May - June site visit at relatively low flow (estimated to be less than 5 gallons per minute). However, a review of underground mine maps strongly suggested that the water is not reflective of the actual water level in the mine; the water discharge instead appears to represent meteoric water which infiltrates into the mine above this level and ponds behind the rock and soil "dike-like" feature present at the portal opening due to collapse. The water stopped flowing from the 1100-level portal after the end of June. The chemistry of the water sampled and analyzed from the 1100-level portal was also determined to be meteoric in nature (see Sections 5 and 6 of this report).

A discharge of water was also noted emanating from the 1500-level ventilator portal. The flow was estimated to be less than 5 gallons per minute. A civil survey of the 1500-level portal indicated that the opening is approximately 25 feet higher in elevation than the 1500-level main portal. Consequently, the water in the 1500-level main portal would need to be backed up more than approximately 25 feet before water would start flowing from the 1500-level ventilator portal. The backup of this much water behind the obstructed 1500-level main portal appears unlikely but possible. It is also possible that the water observed flowing from the 1500-level ventilator portal is a combination of mine water and meteoric water seeping out of the glacial soil through which the portal was noted to have been timbered for the first 300 feet. This is supported by the chemistry which is discussed in more depth in Sections 5 and 6.5.1. It is possible that water may be exiting the mine through fracture flow in the bedrock. However, based on the results of the site-specific water balance (discussed in Section 4.4), as well as the results of the loading analysis presented in Section 6.6.1, it does not appear likely that fracture flow is occurring.

The chemistry of the portal drainage assists us in understanding the chemical processes in the mine. The portal drainage has been sampled and analyzed by others historically and Dames & Moore during the RI. Data collected intermittently between 1982 and 1998, within the May to September period, are available to analyze the chemistry. The analytical results are presented in Section 5.3. A discussion of the portal drainage chemistry in terms of mineralization is presented in Section 6.

4.2 GEOLOGY AND SOILS

4.2.1 Regional Geology

4.2.1.1 Tectonic Setting

A discussion of the tectonic setting is presented herein to support the analysis of seismic potential at the Site. The tectonic setting of the Pacific Northwest for the last 60 million years has been dominated by collisions between the largest tectonic elements of the earth, known as plates. Rafted along on the oceanic plates were island arcs and microcontinents which, during plate collisions, accreted to the North American Plate. With changing geometry and speed of the plate collisions, the patterns of faulting and volcanism on the continental plate changed in response. This convergent boundary characterizes and controls much of the geology and seismicity of the Pacific Northwest to this day.

The Pacific Northwest and adjacent continental margin have been divided into four major tectonic terrains reflecting the regional tectonic setting of converging plates. These are the continental margin, the fore-arc terrain, the volcanic arc, and the back-arc terrain. The dynamic interaction between the two major converging plates (Juan de Fuca and North American) define the characteristic structure and location of these four terrains with respect to plate geometry and configuration (Atwater, 1970) (Figures 4.2-1a and 4.2-1b)

The continental margin is the westernmost of the four major tectonic terrains of the North American Plates and includes the Cascadia Subduction Zone (CSZ), which occurs approximately 60 to 100 miles (100 to 175 kilometers) west of the Washington coastline.

The fore-arc terrain is the next terrain inland, and is characterized by deformed and metamorphosed sedimentary and igneous rocks accreted to the continental plate during the convergence episode.

The volcanic arc terrain lies directly east of the fore-arc terrain, and was caused by the melting of continental margin rocks during the subduction of the Juan de Fuca Plate beneath the North American Plate, which has been occurring for the past 38 million years (Vance, 1982).

The back-arc terrain of Washington is located east of the Cascade Mountains, and is underlain primarily by granitic and metamorphic rocks. Because the back-arc is composed of the accreted terrains of past collisions, the region east of the Cascade Mountains has complex bedrock geology.

The Site is located in the transition area between the volcanic arc terrain and back-arc terrain, and is situated approximately 20 miles east to northeast of Glacier Peak, a volcanic cone.

4.2.1.2 Seismicity

A discussion of the regional seismicity is presented herein to support the analysis of seismic potential at the Site. Earthquakes are the result of sudden releases of built-up stress within the tectonic plates that make up the earth's surface. The stresses accumulate because of friction between the plates as they attempt to move past one another. The movement can be between plates (such as when one plate moves over another, as in subduction zones) or within the plates themselves.

The recorded earthquakes (magnitude 4.0 or greater) in Washington State are presented on Figure 4.2-2. With this information, predictions have been made about the severity of future earthquakes. Intraplate seismic events appear to be more widespread geographically, and result from various structural sources in the shallow crust. These events often occur along mapped or postulated faults in the earth's surface. The largest instrumented earthquake in greater site vicinity was a magnitude 6.0 (Richter scale) event in 1990 approximately 44 miles from the Site (NOAA, 1998). The event resulted in an estimated horizontal acceleration of 0.03 g at the Site. A more in-depth discussion of the seismic potential is presented in Section 4.2.4 of this report.

The seismicity of the area is noted to be moderate. The Uniform Building Code (UBC, 1994) maps the seismicity as a Zone 2B on a scale of 0 to 4, with 0 having no seismic activity, and 4 having high seismicity. Three translational faults were mapped in the Site underground mine: steep, eastward-dipping normal faults, and westward-dipping thrust faults. No surface expressions of recent or historic faults are noted in the area. This observation would lead one to suspect that the faults are not active.

Based on the geology of the area, the potential hazards associated with seismicity are likely limited to ground shaking and liquefaction. Ground shaking is rapid movement of the surface which can result in damage to structures. Liquefaction is a condition in which saturated, loose sand soil behaves as a fluid during seismic events, therefore, resulting in a reduction in soil strength at the time of the event, much like quicksand.

4.2.1.3 Volcanic Activity

Referring to Figure 4.2-1a, Washington has several major composite volcanoes and one area of extensive basaltic shield volcanoes which have been active within the last 2 million years and, in some cases, active within the last 20 years. The nearest volcano is Glacier Peak, approximately 20 miles west of the Site, which experienced documented activity approximately 12,000 years ago (Tabor and Crowder, 1969).

4.2.1.4 Geology and Mineral Resources

A discussion of the North Lake Chelan geology is presented herein to support the selection of the aquatic reference reaches. Referring to Figure 4.2-3, the geology of the upper Lake Chelan area consists of bedrock overlain by unconsolidated to semi-consolidated glacial, fluvial, lacustrine and colluvial deposits of silt, sand and gravel (Cater and Crowder, 1967). The geologic basement rocks (bedrock) found within the North Lake Chelan watershed consist primarily of massive granitics and metamorphosed sedimentary rocks including hornblende, gneiss, and schist. The bedrock outcrops at the surface in the high mountain ranges and is encountered at depths ranging from 20 to greater than 100 feet deep in the valleys. The bedrock is, in places, fractured, folded and faulted.

As noted on Figure 4.2-3, the North Lake Chelan basin has been mapped as containing a number of economic mineral deposits with associated historic mineral claims and/or mine workings. In terms of the drainages sampled during the aquatic reference reach sampling program (Section 4.6), the mineralization appears to be relatively localized. No mineral claims and/or mapped deposits were noted in the immediate area and/or hydrologically upgradient of the Bridge Creek sampling location (BC-1) (Church et al., 1984).

Two relatively small mines were located apparently upgradient of the South Fork of Agnes Creek sampling location (SFAC-1). However, a more thorough assessment discovered that the two workings were actually located near the headwaters of Swamp Creek which joins the North Fork of Agnes Creek downstream of the aquatic sampling location.

The Company Creek aquatic sampling location (CoC-1) is situated approximately eight miles downstream of a relatively small mineral prospect. The mineral deposit is noted to be situated on the "Holden trend," and was documented to contain copper and silver. The concentration of mineralization was noted to be higher than found at the Holden Mine, but the physical location near a ridge top limited the potential for development (Church et al., 1984).

4.2.2 Railroad Creek Geology and Mineral Resources

Referring to Figure 4.2-4, the geology of the Railroad Creek watershed generally consists of bedrock overlain by unconsolidated to semi-consolidated glacial, fluvial, lacustrine, and colluvial deposits of silt, sand, and gravel (Cater and Crowder, 1967). The geologic basement rocks (bedrock) consist primarily of massive granitics and metamorphosed sedimentary rocks including hornblende, gneiss, and schist. The granitic rocks are predominant in the eastern portion of Railroad Creek. Bedrock outcrops at the surface along the valley walls and ridge lines, and is encountered at depths ranging from the ground surface to greater than 100 feet deep in the valleys. The granites are primarily biotite-hornblende quartz diorites, and the metamorphic rocks generally consist of hornblende, schist, and gneiss (Church et al., 1984).

In terms of the structural geology, the bedrock is, in places, highly fractured, folded, and faulted. However, referring to Figure 4.2-5, the faults have been mapped by others as being generally limited in lateral extent (Cater & Wright, 1957 and 1967). F3

The Railroad Creek watershed contains a relatively large number of economic mineral deposits, in addition to the Holden Mine, which have been developed as either prospects and/or mines. Referring to Figure 4.2-4 and Table 4.2-1, 21 prospects and/or mines were identified in the watershed; records were found for 18 of the workings (USGS, 1998). Four prospects were noted on the maps near the mouth of Railroad Creek for which no records were located; one of the prospects was observed in the field to be near surface water sampling station RC-8.

Based on the records reviewed, one of the prospects located northeast of Holden Lake, noted as the Mary Green (a.k.a. Martin Peak) was operated by Howe Sound Company in the late 1950s. The prospect included several adits approximately 370 feet in length with several prospect pits (Church et al., 1984). Ebbutt, 1938, documented the presence of a 280-foot-long drift, but with "no mineralization in evidence that would approach being commercial." The principal mineralization was reported as copper and silver. Observations during the RI disclosed a single mine opening, a limited waste rock pile, and no indications of seepage and/or drainage from either the mine opening or waste rock pile.

Three other prospects and/or mines were reported between Holden Lake and Railroad Creek. The owners and/or operators were not found. One of the deposits, known as the Ideal, reportedly was developed for silver, and included 34,000 tons of removed rock. However, no indications of the mine workings were discovered on aerial photographs or in the field during the RI.

Several other prospects and/or mines were developed at Crown Point Falls, approximately 10 miles west of the Site, as well as above Lyman Lake. The mineral deposits included antimony, arsenic, cadmium, copper, gold, lead, molybdenum, silver, and zinc. Based on observations during the RI, the Crown Point prospect included several workings in the cliff face to the south of Crown Point Falls, as well as a single drift to the north of the falls, with no apparent seepage flowing from the openings of the workings.

4.2.3 Site Geology

4.2.3.1 Near-Surface Geology

Summary of Historical Data

Referring to Figure 4.2.6a, the surficial geology in the Site area consists primarily of alluvial, colluvial, and glacial deposits overlying bedrock. The alluvial soil is deposited by water-related action and, therefore, found near the bottom of the Railroad Creek valley. The alluvium is normally composed of rounded sandy gravel- to cobble-size material. These alluvial deposits are considered to be normally very well drained, with localized areas of poor drainage.

The colluvium includes those materials which are deposited by gravity and are, therefore, generally found near the base of relatively steep slopes. The colluvium is generally characterized by a mixture of silt- to boulder-size, angular soil and rock fragments. These soils can range from poor to well drained.

The glacial soil in the area generally consists of glacial till, a dense mixture of rounded silt- to cobble-size materials. These materials are anticipated to underlie the alluvium and colluvium, and have been observed extending up the valley sidewalls. The glacial soil is normally more than 10 feet thick (ORB, 1975). During the construction of the main mine portal, the glacial materials were found to be approximately 65 feet thick (Adams, 1981), and were observed to thin with increased elevation above the valley floor, as would be expected from such a deposit. The mapping indicates that the glacial till terminates above the 1100 level in the Honeymoon Heights area; the glacial till appears absent, with bedrock exposed at the surface at the 300- through 1000-level portals (Figure 4.2.6a).

RI Findings

The geology of the Site was further characterized during the RI utilizing the results of: (1) a seismic refraction survey and downhole geophysical evaluation completed across selected portions of the Site for the RI (Appendix A); (2) borings drilled by others during the installation of the groundwater monitoring wells (Appendix B); (3) test pits completed for the RI (Appendix C); and (4) borings and test pits completed by others as part of a previous geotechnical engineering evaluation (Appendix E). The locations of the explorations are presented on Figures 4.2-6b and in Appendix K.

The Site geology was disclosed to consist of the following principal units: (1) native soil and fill soil, (2) colluvium, (3) alluvium, (4) tailings material, (5) waste rock, (6) alluvium/reworked glacial till, (7) glacial till, and (8) bedrock. A brief description of each unit follows.

Soil

Surficial materials at the Site south of Railroad Creek, except for the tailings and waste rock piles, are primarily either soil or a mixture of soil and man-made fill material. Soil is composed of relatively loose/soft fine-grained material originating from weathered local bedrock and organic material. Fill is composed of local soil plus rock, branches, stumps, and manmade artifacts which have been placed in conjunction with historic earthworks. Based on the results of borings (Appendix B) and test pit excavations (Appendices C and E), the thickness of the soil unit varies from less than one foot to approximately 10 feet.

Colluvium

Colluvium is material deposited by gravity. Grain-sizes present in colluvium range from silt and sand through cobbles and boulders. Colluvial deposits comprise the majority of surficial material in Holden Village and much of the north bank of Railroad Creek opposite the tailings piles. Based on the borings (Appendix B) and test pit excavations (Appendices C and E), colluvial deposits appear to underlie the southern portion of tailings pile 3, as well as beneath Holden Village and the Winston home sites area. The soil is noted as a mixture of low to moderate density, fine-grained soil with angular rock. The thickness of the colluvium may be in excess of 20 to 30 feet in isolated locations.

Alluvium

Alluvium is material moved and deposited by the action of moving water. Material size ranges from silt- to cobble- and boulder-size, and grains are usually rounded to subrounded. The density of the material normally ranges from loose to moderately dense. Alluvium (as differentiated from alluvium/reworked till described later) is limited in extent to areas beneath and adjacent to the current and recent channels of Railroad Creek.

Tailings Materials

Tailings are fine-grained materials and are the by-product of the milling/processing operation. The tailings are distributed along the south side of Railroad Creek in tailings piles 1, 2, and 3. The thickness of tailings pile 1 appears to range from less than 10 feet near the southern edge of the pile to about 60 feet at the TP1-2 location. Tailings materials within the three piles are relatively loose to moderately dense mixtures of silt to fine sand. The thickness of tailings pile 2 appears to range from 15 feet near the southern edge of the pile to about 120 feet at the northern edge. The thickness of tailings pile 3 appears to range from 10 feet or less near the southern boundary of the pile to approximately 70 feet along the northern edge. Tailings thicknesses are based on boring logs (Appendices C and E) and interpretation of geophysical survey data (Appendix A).

The engineering properties of the materials were investigated by Hart Crowser in 1975, and by Dames & Moore for the RI. The grain size of the material ranged from a silt (90 percent passing the No. 200 sieve; 0.075 mm) to a silty fine sand (approximately 40 percent passing the No. 200 sieve). The dry unit density is approximately 110 to 115 pounds per cubic foot. The relative density based on the Standard Penetration Test (SPT) conducted during the drilling and sampling completed by Hart Crowser was "medium dense." The densities noted in test pits completed by Dames & Moore were qualitatively determined to range between "loose" to "moderately compact." The moisture contents ranged from 15 to 30 percent. The shear strength was determined by Hart Crowser to range from 34 degrees for the medium dense sand, to as much as 38 degrees for the silt.

Approximately 85 percent of the tailings was reported to consist of insoluble silicate minerals. The relatively soluble fraction appears to consist largely of sulfide minerals, with only minor amounts of marble (calcium carbonate) (Thorsen, 1970). The sulfides were also reported to consist of pyrite (FeS), sphalerite (ZnS), and chalcopyrite ($CuFeS_2$) (PNL, 1992). As discussed in Section 6, the mineralogy of the tailings piles was confirmed by evaluating the chemistry of the seeps and groundwater sampled and analyzed as part of the RI.

Waste Rock

Waste rock is present in two large piles at the Site, one pile is located to the east of the mill building, the other directly west of the building. The piles cover a few acres and based on the results of the seismic refraction survey (Appendix A) range in thickness of up to about 70 feet. Smaller piles are associated with the 1100, 800-, 700-, 550-, and 300- level portals in the Honeymoon Heights area. The volumes of two waste rock piles near the mill building are estimated to be 250,000 cubic yards. The combined volume of the Honeymoon Heights waste rock piles are estimated to be less than either of the west or east waste rock piles. The waste rock consists of angular rock, ranging in grain size from mostly cobbles to some silt and gravel. The rock is oxidized with some minor economic mineralization observed.

The detailed composition of the waste rock material is unknown, although visual inspection during the RI indicates that they consist of some mineralized ore-type material containing pyrite, sphalerite and chaleopyrite mixed with host alumino-silicate rods and some marble. A detailed discussion of the mineralogy of the host rocks and ore deposits is provided in Section 6.1.

Alluvium/Reworked Till

A laterally extensive gravel unit, herein named the alluvium/reworked till unit, is indicated by boring logs throughout the Site south of Railroad Creek. The unit is logged in borings which penetrate the base of the tailings piles, except for borings TP3-4 and PZ-4A (Appendices B and E) at the southwest corner of tailings pile 3; at this location, the unit presumably underlies the colluvium logged at the base of those borings.

The alluvium/reworked till unit is described in various boring logs as a relatively loose to moderately dense silty gravel, a gravelly silty sand, and a gravel. The unit grades into or interfingers with the alluvium of Railroad Creek. The precise location of the contact is not known. Thickness of the alluvial reworked till ranges from approximately 5 to 15 feet based on boring logs.

Glacial Till

Dense glacial till underlies the Site on both sides of Railroad Creek. Based on evaluation of geophysical data (Appendix A) the till appears to range in thickness from about 5 feet (adjacent to Railroad Creek, along seismic line F-F') to about 95 feet (south of tailings piles 1 and 2 in Copper Creek drainage, at the southern end of seismic line G-G'). The only Site boring that penetrates the dense till at the Site is boring TP1-4A. While the boring log is incomplete, it does indicate that the dense till becomes dry with depth. Till at the

Site has been observed by Dames & Moore personnel to be composed of dense to very dense material ranging from clay- to boulder-size, with all intervening size fractions present.

Bedrock

Bedrock at the Site is composed primarily of quartz diorite, granodiorite, schist, and gneiss, and completely underlies the Site both north and south of Railroad Creek (Cater and Crowder, 1967). Based on interpretation of geophysical data (Appendix A) the shallowest identified depth to bedrock is approximately 12 feet, both adjacent to Railroad Creek along seismic line F-F', and south of the maintenance yard along seismic line A-A'. Greatest depth to bedrock is about 140 feet, beneath the central and northern portions of tailings pile 3, again based on interpretation of geophysical data.

Descriptions of the geology for each Site area, as shown on Figures 4.1-3 and 4.1-3a, are presented hereafter.

Mine Support and Waste Rock Piles Area

Referring to geologic cross-section and seismic-refraction line A-A' on Figure 4.2-7, the geology for the portion of the Site from the western waste rock pile to north of Railroad Creek in the area of the lagoon feature consists of alluvium/reworked till over bedrock. The thickness of the near-surface soil appears to be on the order of 10 to 15 feet thick. The alluvium/reworked till unit is underlain by approximately 15 to more than 70 feet of moderately dense to dense material, which is most likely glacial till. The till material is underlain by apparent bedrock materials which appear to dip to the north.

The southern segment of the geologic cross-section and seismic refraction line B-B' (Figure 4.2-8) crosses the eastern waste rock pile. Based on review of historical information, the waste rock is comprised of bedrock, removed during the completion of the 1500-level mine and ventilator portals, that was determined not to contain economic minerals in high enough concentration to warrant processing in the mill. Combined, these two tunnels comprise over a mile of underground mine workings through non-mineralized bedrock. The waste rock pile was placed on dense glacial till. The maximum height of the waste rock pile is on the order of 140 feet, based on topographic maps. However, the actual thickness of the waste rock when measured perpendicular to the slope appears to be less than 50 feet. The bedrock underlying the waste rock pile also generally follows the topography.

A reconnaissance of the Railroad Creek streambed between RC-1 and RC-6 disclosed the presence of an exposure of glacial till in the south bank of the creek. The soil was observed to consist of interbedded sequences of blue-gray clayey silt (glacial lake deposits), silty sand, and silty sandy gravel. The minimum thickness of the unit is on the order of 10 feet. Water was noted emanating from above the contact with the clayey silt layer (discussed in subsequent sections of this report as seep SP-26).

Tailings Pile 1

Referring to Figures 4.2-6b and 4.2-8, the majority of the tailings pile, other than steep slopes facing Railroad Creek and an isolated area near the southwest margin, is covered with approximately 4 to 6 inches of rounded gravel placed by the USFS during site rehabilitation efforts between 1989 and 1991. The northern portion of the B-B' cross-section across tailings pile 1 indicates that the tailings beneath the surface gravels are variable in thickness and density. The seismic refraction lines disclosed the center of the pile to consist of lower density materials than the underlying and surrounding tailings. This likely reflects the location of the pre-existing municipal dump area which was reportedly covered with tailings and/or soil fill during the 1989 to 1991 mine tailings rehabilitation project (PNL, 1992). Based on the results of the seismic refraction survey, it appears that the soils placed as backfill were not compacted to a density standard (i.e., 90 to 95 percent of the laboratory maximum density).

The thickness of the tailings ranged up to approximately 70 feet. The tailings materials encountered in both borings and test pits were found to be relatively consistent in grain size; ranging from a silty fine sand to fine-sandy silt; the more sandy soil was suspected to be present nearer the edges of the piles. Some soils with clay-size particles were encountered nearer the center of the pile and likely reflect the fine-grained "slimes" generated during the mill processing of the ore and settling within the ponds atop the piles during placement; these materials are likely cohesive in nature (Hart Crowser, 1975).

A relatively thin layer of organic-rich soil, less than 2 feet thick, was encountered at the contact with the native soil. The borings did not disclose the presence of a cemented layer at the contact between the tailings and native materials. However, a test pit completed immediately northeast of tailings pile 1 (DMTP1E-1) (Appendix C) disclosed the presence of a partially to cemented soil layer (ferricrete), likely associated with the seepage of mineral-rich water from the tailings pile.

The boring logs for boring B-1 and groundwater wells TP1-3 and TP1-4, completed by others, and both the seismic refraction lines and downhole geophysical surveys, disclosed the underlying native soil to be moderately dense sand and gravel (alluvium/reworked till). The density of the soil increased with depth, grading into a glacial till. The underlying bedrock was found to be 30 to 60 feet below the tailings/native soil contact. The bedrock was more shallow near the center of the pile, and slightly deeper to the north and south.

A seismic refraction line was also completed along the eastern margin of tailings pile 1, adjacent to Copper Creek, as well as across Railroad Creek; the results are presented in the following subsection titled "Copper Creek and Railroad Creek Confluence."

None of the subsurface explorations completed within the tailings by Dames & Moore and others, and the seismic refraction lines appeared to detect the presence of "hard pans" (layers of hard/dense, cemented materials) within the tailings pile, other than near the surface of the piles where a partially cemented layer was occasionally encountered.

Tailings Pile 2

Geologic cross-section and seismic refraction line C-C' (Figure 4.2-6b and 4.2-9) crosses near the center of tailings pile 2. The results of the borings by others and both the seismic refraction line and downhole geophysics completed for the RI, indicated that the tailings piles range in thickness from approximately 50 feet in the area of the PZ-1 series wells to approximately 120 feet near the north limit of the pile. The tailings encountered in the borings were found to be relatively consistent with the materials observed in tailings pile 1.

The underlying native soil was noted to be generally relatively dense gravel and sand (alluvium/reworked till and glacial till). The underlying bedrock was detected at depths ranging from approximately 15 to 30 feet below the tailings and native soil contact.

Tailings Pile 3

Geologic cross-section and seismic refraction line D-D' (Figures 4.2-6b and 4.2-10) crosses tailings pile 3. The entire surface of the tailings pile, other than the steepest slopes facing Railroad Creek, is covered with approximately 4 to 8 inches of rounded gravel placed by the Forest Service between 1989 and 1991. The seismic refraction line confirmed the thickness of the tailings materials beneath the gravel surface, and the apparent depth to bedrock.

The available subsurface information from the borings completed on the tailings pile suggest the presence of a soil layer overlying possible colluvium near the southern limit of the tailings pile. A test pit completed near the southern end of the seismic line (DMTP3S-1) encountered what appeared to be weathered glacial soil consisting of sandy silt with some sand, cobbles, and boulders to a depth of approximately 19 feet. This portion of the cross-section is coincident with the lowermost extent of an avalanche chute. Colluvium may have originated upslope of the area due to erosion of bedrock and/or glacial soils. The colluvium was interpreted to be on the order of 10 to 25 feet thick.

The cross-section indicates the presence of up to 70 feet of tailings. The density and consistency of the tailings materials were relatively consistent with tailings piles 1 and 2. The tailings piles were underlain by a thin layer of organic soils (less than 2 feet thick). The organics were then observed to be underlain by a layer of reworked glacial materials or alluvium consisting mostly of sand and gravel. Several of the borings interpreted that the silt content and density increased with depth. Therefore, the reworked glacial till appear to be limited to less than 10 feet in thickness.

The glacial till was noted in the seismic section to be underlain by bedrock. The bedrock varied in depth from approximately 25 feet to 75 feet below the contact between the tailings and native soil.

In contrast to tailings piles 1 and 2, several of the subsurface explorations and seismic refraction lines detected the presence of possible "hard pans" within the tailings pile; some partially cemented material was encountered at a depth which is underlain by less dense/hard material. The layer was encountered approximately 5 to 6 feet bgs in test pits DMTP3-2 and DMTP3-3 (Figure 4.2-6b). The test pits were completed at the eastern toe of tailings pile 3. The more dense layer appears to coincide with the zone where seepage from the pile would contact underlying groundwater. The layer was observed to be partially cemented, hard, and less than approximately 4 feet in thickness. The seismic refraction lines did not appear to detect the layer, likely due to the resolution of the seismic survey being too large to detect a non-continuous, relatively thin zone or layer of varying hardness and cementation.

Immediately East of Tailings Pile 3

Seismic refraction line E-E' (Figures 4.2-6b and 4.2-11) was placed immediately east of tailings pile 3, and extended from approximately 200 feet north of Railroad Creek to approximately 200 feet upslope of the existing wetland area. In addition, four test pits (DMTP3E-1 through 4) were excavated in the area of the wetlands and adjacent to Railroad Creek. Three test pits (DMTP3E-4 through 6) were also completed in the area southeast of tailings pile 3 as part of the borrow source evaluation.

The test pits completed south of the wetlands encountered medium dense to very dense, sand and gravel with subangular cobbles and boulders, indicating that the materials may be relatively close to the source bedrock, and are possibly reworked glacial till. However, two of the three test pits were terminated due to practical refusal conditions at 6 feet and 13 feet bgs due to increasing boulders with depth. Consequently, the soils encountered are likely weathered glacial till. The third test pit was completed to a depth of approximately 17 feet bgs. The seismic refraction indicated that the relatively dense glacial till materials underlying the looser materials ranged in thickness from approximately 40 to 50 feet. Bedrock was apparently encountered below the glacial materials.

Referring to Figure 4.2-11, the seismic refraction, boring, and test pit data collected in the area of the wetlands south of Railroad Creek and east of the tailings pile 3 suggest the presence of a trough-like feature, in the area of monitoring well DS-1, filled with relatively loose soil; the feature is assumed to represent an abandoned stream channel of Railroad Creek. The maximum depth of the feature appears to be on the order of 25 feet. The test pits encountered alluvium consisting of interlying silt, sand, and gravel in the wetland area. The relatively loose/soft alluvium was noted to be underlain by approximately 70 feet of relatively dense glacial till and bedrock. The bedrock surface also appears to form a trough-like feature as a result of glaciation.

The seismic refraction line suggests that Railroad Creek and the area to the north of the creek area are underlain by alluvial soil ranging from approximately 15 to 25 feet thick. The alluvial deposits are then underlain by the relatively dense glacial till materials and bedrock at depth.

As noted for tailings piles 1 and 2, none of the subsurface explorations and seismic refraction lines appeared to detect the presence of hardpans within the tailings pile, other than near the surface of the pile.

Tailings Piles 2 and 3 Adjacent to Railroad Creek

Section F-F' (Figures 4.2-6b and 4.2-12) is based solely on a seismic refraction line completed in an east-west direction immediately north of tailings piles 2 and 3 and adjacent to Railroad Creek; the line extended approximately 500 feet. The seismic section disclosed the presence of a relatively thin layer (less than 10 feet) of relatively loose to medium dense alluvium overlying approximately 5 to 25 feet of relatively dense glacial till soil. The glacial till soil was noted to be underlain by bedrock. The bedrock in this area was noted to be as shallow as approximately 15 to 20 feet bgs.

Copper Creek and Railroad Creek Confluence

Section G-G' (Figures 4.2-6b and 4.2-13) is based on a seismic refraction line trending generally north-south between tailings piles 1 and 2, and across Railroad Creek to the north by approximately 250 feet. Referring to Figure 4.2-6b and Appendix C, test pit DMTP1E-1 was completed on the south bank of the creek as part of the ferricrete assessment; due to encountering water, the test pit was terminated at a depth of approximately 3-1/2 feet. The combined test pit and seismic refraction data indicate the presence of a native soil layer (alluvium and reworked fill), approximately 10 to 20 feet thick overlying the entire section. The seismic refraction data indicate the soil to be underlain by relatively dense glacial till ranging in thickness from approximately 25 to 80 feet. The bedrock surface was noted to be variable in depth, with a trough-like feature noted to the north of Railroad Creek.

Holden Village

Based on data collected during the installation of groundwater monitoring wells in Holden Village by others (USBM, 1995), the village area appears to be underlain by a combination of colluvium and glacial till soils. The soils are moderately dense and consist of a mixture of silt, sand, and gravel.

Winston Home Sites

Seven test pits (DMTPW-1 through DMTPW-7) were completed immediately downslope of the western portion of the Winston home sites area as part of the underground storage tank assessment (Figures 4.1-5a and 4.2-6b, and Appendix C). The test pits were completed to depths ranging from 3-1/2 to 8 feet bgs. The excavations disclosed the soil underlying the area to consist of a mixture of relatively loose to medium dense silt, sand, gravel, and cobbles. The subangular nature of the soil indicated the origin to be colluvium originating upslope and to the north of the area.

Honeymoon Heights

In the area of the Honeymoon Heights, to the southwest of the mill area, the glacial till soil appears to terminate slightly south and upslope of the 1100-level portal. Bedrock is generally exposed near or at the ground surface above this level; a reconnaissance of the area during the RI disclosed a relatively thin layer of soil, consisting of weathered bedrock, covering portions of the area immediately above the 1100-level.

4.2.3.2 Geology Exposed in Mine

Referring to Figures 4.2-14 and 4.2-15, which are based on the review of available underground mine maps, the bedrock exposed in the underground mine is composed primarily of interlying sequences of metamorphic rocks with igneous intrusives. The igneous rocks are primarily biotite-hornblende quartz diorites and the metamorphic rocks generally consist of hornblende, schist, gneiss, amphibolite, marble, and quartzite.

The ore body was observed to occur within an extensive pyritized shear zone in the metamorphosed sedimentary rocks. The shear zone is one of several in the area and was found to be approximately 2,500 feet long with the width of economic mineralization up to 80 feet. The shear zone and ore body are oriented in a nearly east-west direction, and were found to be nearly vertical. The strike of the economic mineralization is exposed at the ground surface which allowed J.H. Holden to find it in 1887. The ore body is situated within a rock formation named the Buckskin schists, which consists of a thick series of quartz-amphibole schist containing two horizons of intermittent marble beds and calcareous schists (Youngberg and Wilson, 1952). Minerals observed in the ore zone are shown on Table 4.2-1a (Youngberg and Wilson, 1952). As discussed in Section 6, the mineralogy of the underground mine was confirmed by evaluating the chemistry of the mine discharge (1500-level main portal drainage) which was sampled and analyzed as part of the RI.

Several faults have been mapped in the mine. The prominent faults strike nearly east-west and appear to have been intersected by both the 1500-level tunnels. Referring to Figures 4.2-5, 4.2-6a, 4.2-14, and 4.2-15, two of the faults have been mapped with lateral and/or vertical displacement. However, as noted above, the faults in the Railroad Creek drainage, which generally parallel the direction of the faults intersected in the mine, appear to be limited in lateral extent and continuity. No indications of recent fault movement were noted.

4.2.4 Geologic Hazards

4.2.4.1 Seismic Liquefaction Potential

Summary of Historical Findings

Groundshaking occurs in conjunction with earthquakes. Foundation materials which are relatively dense transfer energy associated with an earthquake more efficiently than less dense materials. Less dense soils may be susceptible to seismically-induced settlement. Liquefaction is a phenomenon in which loose to medium dense, saturated, granular soils lose their shear strength during dynamic loading (usually during an earthquake) and behave as a fluid. Liquefaction causes soil settlements and sometimes lateral spreading or slope failure of a soil mass. Loose granular, saturated soils which are commonly susceptible to liquefaction are normally found in valley bottoms throughout the region.

The mine tailings piles were investigated in terms of geotechnical engineering characteristics as part of the ORB 1975 study. In summary, the results of the field and laboratory program indicated that the mine tailings consist of interlying sequences of clay-, silt- and fine sand-size material. The soil was noted to be non-plastic with an average *in situ* wet and dry density of 116 pounds per cubic foot (pcf) and 92 pcf, respectively. The optimum moisture content was noted to be 13 percent based on ASTM D-1557-70. The relative density of the material based on the Standard Penetration Test (a field test where the sampler is driven into the soil with a 140-pound hammer with a 30-inch stroke) was medium dense.

The 1975 Hart Crowser report indicated that the phreatic surface (groundwater level) was observed to be consistently about two feet above the interface of the northern extent of the tailings pile with the original ground surface, which indicated "nominal seepage pressure within the piles." The susceptibility of the tailings piles to liquefaction, or "quicking" of the material during a seismic event, was determined to be low, based on the assumption that the phreatic groundwater surface was 2 feet above the contact between the tailings and the underlying native alluvial soil.

RI Findings

Historical seismicity data were reviewed for the Site. Based on data collected by the National Oceanic and Atmospheric Administration (NOAA), the Site has been subject to two earthquakes of magnitude greater than 4 with epicenters close enough to cause potentially significant peak ground accelerations (Figure 4.2-2). The first earthquake occurred in 1942 at a distance of approximately 10 miles with a magnitude of 4.3 on the Richter scale which resulted in an estimated peak ground acceleration at the Holden site of 0.04 gravity (g). The second earthquake occurred in 1990 at a distance of approximately 44 miles with a magnitude of 6.0 on the Richter scale which resulted in an estimated peak ground acceleration at the Holden site of 0.03 g (NOAA, 1998). The former earthquake occurred during the operating life of the mine but before the tailings piles had reached any significant height. There were no documented reports and/or accounts that the latter earthquake caused any landslides at the Site.

An analysis of potential liquefaction at the Site was conducted using empirical methods (described in Seed et al. 1983) as part of the RI. The analysis included comparing the Standard Penetration Test (SPT) values (soil density derived from a standardized field test) collected during the drilling of the borings on the tailings piles in 1975, with cyclic stress ratios (ratio of estimated earthquake-induced shear stress divided by the effective overburden stress at a given point) based on a magnitude 6.75 seismic event with a horizontal acceleration of 0.18 g, and a return period of 475 years. The soils analyzed were a clean sand, a sand with less than 15 percent passing the No. 200 sieve, and a silty sand with more than 35 percent passing the No. 200 sieve.

In addition to SPT values from the Hart Crowser borings, the SPT values of soils encountered in one test pit excavated at the toe of the slope were estimated. The estimate was based on judgment using the resistance offered by the soil during excavation. The distribution of SPT values was not considered explicitly, but the lowest recorded values were used in the analysis. As required by the empirical method, the recorded SPT values are converted to "normalized" values, which are shown on Figure 4.2-16 in the Dames & Moore report.

Referring to Figure 4.2-16, the results appeared to support the findings by Hart Crowser in 1975 that the typical potential for liquefaction of the tailings material and/or native underlying soil is relatively low. A moderate potential for liquefaction may exist in zones of clean, loose sand near the toe of the slopes.

There is some level of uncertainty associated with the findings of the liquefaction assessment due to uncertainties related to the earthquake magnitude, the grain size of the soil underlying the tailings piles, the tailings SPT (density) data, and the liquefaction boundary curves. However, the analyses utilized the lower of the density values. Consequently, the findings are relatively conservative and consistent with the methods employed by the geotechnical engineering profession.

Due to the variability of both tailings density and moisture content values, the potential for conducting the liquefaction analyses utilizing a probabilistic approval was evaluated as part of the RI. However, existing literature provides insufficient evidence of sustained liquefaction above the free water level, which was utilized for the liquefaction potential analyses conducted for the RI.

A discussion of potential seismically-induced landslides are presented in the subsequent Section 4.2.4.2 of this report.

4.2.4.2 Tailings Pile Slope Stability

Summary of Historical Findings

Mass movement is generally considered the downslope movement of a mass of soil, rock, and/or snow/ice. The stability of soil is directly related to the physical characteristics of the soils and underlying bedrock. The mechanics and rates of slope movement are controlled by a variety of factors, including: slope gradient, water content and soil pore water pressure, and engineering properties of the materials, such as cohesion and the coefficient of friction. Geomorphic, hydrologic, and vegetative factors determine the occurrence, frequency, and significance of the processes in an area.

In terms of the Site, the tailings pile slopes facing Railroad Creek and Copper Creek are relatively steep. A perimeter dike failure was documented to have occurred at the east end of tailings pile 3 in 1946 resulting from the plugging of a decant tower with ice and overtopping of the containment dike which resulted in erosion of the tailings (miscellaneous written communications, 1946). It should be noted that the decant towers were reportedly backfilled and sealed during work efforts performed by the Forest Service between 1989 and 1991; however, the risk of overtopping of tailings ponds has been mitigated with the construction of surface water swales, and the closure of the mill which provided the water to the tailings ponds during the 1946 event.

Several other failures occurred later within the relatively steep slope of tailings pile 2 east and near the confluence of Railroad Creek and Copper Creek, during storm events (Crane, 1966). No other significant mass movement events were documented on the slopes of the tailings piles facing Railroad Creek and Copper Creek.

A report was completed in 1970 by the Washington Department of Natural Resources which discussed the mine tailings at Holden Mine (Thorsen). Conclusions were presented that cementation through oxidation of iron sulfides and settlement appeared to have made the tailings piles at least as stable or possibly more stable than when originally implaced. However, no actual slope stability analyses were apparently conducted.

A qualitative assessment of the stability of the relatively steep slopes of the tailings piles adjacent to Railroad Creek and Copper Creek was conducted as part of the ORB study. Geotechnical engineering-related laboratory analyses were conducted on soil samples collected from borings drilled mostly into the perimeter of the tailings piles. The internal angle of friction of the material ranged from 34 degrees for the coarser material to 38 degrees for the finer material. This angle is less than the steepest slope faces of the tailings piles. However, only limited samples were collected for direct shear testing. The slopes appeared to be stable in the present configuration. The report concluded that the tailings piles were relatively stable in their present configuration, but that flattening the slopes of the piles would likely improve the long-term stability of the piles.

RI Findings

Based on data collected by Dames and Moore and others, the groundwater elevations in the northern portions of tailings piles are relatively close to the bottom of the piles, as discussed in Section 4.4. This is confirmed by the observation that seeps occur only near the toe of the slopes of the three tailings piles. Based on exploration logs of Dames and Moore and others, the tailings consist of silty sands and sandy silts. Up to 2 to 3 feet of tailings at the surface are lightly cemented. Geotechnical laboratory tests performed by Hart-Crowser for the 1975 ORB report indicate silt contents of the tailings ranging from 28 to 100 percent. Grain size analysis by Dames & Moore indicated silt contents ranging from less than 20 to more than 50 percent (Appendix D). Based on the borings drilled by Hart-Crowser in 1975, the soils underlying the tailings are dense sands and gravels. A test pit excavated at the toe of tailings pile 3 as part of the RI (DMTP3-4) (Figure 4.2-6b) revealed loose sand under the tailings; the aerial extent of this loose sand is not known. The sand appears to be more dense than the tailings pile material. Based on seismic refraction data gathered by Northwest Geophysical for this report, the sand is underlain by dense glacial till.

The following engineering characteristics presented in the 1975 Hart-Crowser report were used for evaluation of slope stability:

Soil	Angle of Internal Friction (phi)	Total Unit Weight (pcf)	Cohesion (psf)
Tailings	37	116	50
Cemented Tailings	37	116	250
Sand	33	125	0
Glacial Till	40	140	200

The values for the tailings materials utilized in the slope stability analyses were based on laboratory testing performed by Hart-Crowser for their 1975 report and typical published values. The values for the sand were increased slightly directly beneath the tailings pile due to overburden pressures (as opposed to at the toe of the slope where the materials were less thick). For the purposes of the slope stability analyses, it is assumed that the wood cribbing that was used to suspend the tailings discharge line around the pond perimeter had rotted away.

In addition, the review of borings completed by others, as well as field observations during the RI, discussed the presence of soil units in addition to those utilized by Hart Crowser in the slope stability analyses completed in 1975. The parameters for these soil units were determined based on experience gained on other sites. The following engineering characteristics were used in the slope stability analyses completed by Dames & Moore for the units observed at the Site, but not utilized in the 1975 Hart Crowser study:

Soil	Angle of Internal Friction (phi)	Total Unit Weight (pcf)	Cohesion (psf)
Topsoil	32	110	0
Densified Topsoil	34	115	0
Talus	37	116	0
Densified Sand	36	130	0

An organic layer was mentioned in several logs of borings completed by PNL in 1990. Only one of the logs of borings completed by Hart Crowser in 1975 (B-6; see Figure 4.2-6b) indicated the presence of an organic layer at the base of the tailings. The layer was noted to be roughly at the level of the toe of the slopes for tailings piles 2 and 3 for those borings completed closest to the slopes facing Railroad Creek. The PNL logs appeared to indicate a relatively continuous layer of organic material near the tailings/native soil contact.

A soil friction angle of 34 degrees was used in the slope stability analyses for this layer, identified as "densified topsoil" in the above table and on Figures 4.2-17 through 4.2-20. The 34-degree soil friction angle is consistent with fibrous peat and silt or sandy silt with wood fragments, as described in the PNL logs.

The groundwater levels used for the stability analyses were conservatively chosen as 20 feet above the highest values measured by Dames & Moore during the spring and summer of 1997 at groundwater monitoring wells located closest to the slopes. This increase in water level over measured values was adopted to account for possible highly unfavorable rainfall and snowmelt conditions that might cause future water levels to exceed those observed. The water was assumed to emerge at the toe of the slope, since no reports of water emerging higher on the slope could be found. The water surface was depicted as a straight line between the nearest piezometer and the toe of the slope. Since the closest piezometers were approximately 300 feet from the slope face, the 20-foot "highly unfavorable" increase for purposes of analysis resulted in less than a 5-foot increase in water levels below the slope itself.

Slope stability analyses for static conditions (i.e., not under seismic conditions) were performed on cross-sections developed through tailings piles 2 and 3. For the assumed cross-section of tailings pile 2, the minimum static factor of safety for sliding was found to be 1.034. For the assumed cross-section of tailings pile 3, the minimum static factor of safety was found to be 1.10. The lowest factors of safety are for relatively shallow failures extending 10 to 15 feet below the face of the slope at the deepest point. Deeper failures were found to have higher factors of safety. Failure of the slope is defined as any down slope movement of the failed soil mass. The horizontal length of a particular failure zone along the face of the slope is expected to range from less than 100 feet to more than several hundred feet. Graphical representations of the analyses for static conditions are presented on Figures 4.2-17 and 4.2-18.

The graphical representatives of the analyses include cross sections of tailings piles with the hypothetical slope failures resulting from the stratigraphy, soil parameters, and groundwater conditions. The factor of safety is presented as contours in the upper left-hand corner of the figure. The contours represent slip circle centers having equal factors of safety. Each contour line is the collection of the centers of rotation for slip circles (i.e., circles representing the plane of sliding of potential slope failure masses within the slope) which have the same factor of safety. The contours typically converge at a central minimum value, as displayed on the figure. The contours can be used to assess how much of the slope may be near the minimum factor of safety.

An analysis of the potential for seismic induced landslides was performed using ground acceleration values recommended by the U.S. Geologic Survey in Frankel et al., 1996. The peak ground acceleration for a 475-year return period earthquake was accordingly estimated at 0.18 g for specific soil conditions at the tailings location. The pseudo-static method was used for the landslide analysis. The seismic coefficient typically used for pseudo-static analyses is two-thirds of the peak ground acceleration. Slope stability analyses performed on the tailing pile slopes above Railroad Creek indicate that the tailings pile 2 slopes would fail during a seismic event of this magnitude (safety factor of less than 0.98). The results of the analyses indicated a safety factor of 1.04 for tailings pile 3 slopes.

Knowing that slopes for two of the three tailings piles will clearly fail during the relatively large 475-year seismic event triggered a search for the smallest seismic event that could bring the slopes to the point of failure. The analyses indicated that a seismic event generating a peak ground acceleration of 0.05 g is large enough to cause slope failure, i.e., to reduce the "factor of safety" to a value of 1.0 or less. The "factor of safety" is the ratio of the magnitude of forces tending to resist slope failure (e.g., shear strength of the soil) to the magnitude of the forces tending to cause failure (e.g., weight of soil mass on the upper slope). In the opinion of the geotechnical engineering community, factors of safety higher than 1.2 indicate a suitably stable slope while factors of safety at or below 1.0 indicate impending failure of the slope. Slopes with factors of safety between 1.0 and 1.2 are considered marginally stable. This seismic event has an estimated return period of approximately 40 years at the Site location. Graphical representations of the analyses for seismic conditions, including site stratigraphy, groundwater elevation and topography, are presented on Figures 4.2-19 and 4.2-20. Only results for the smaller 40-year return period seismic event are shown on the figures.

As noted on Figures 4.2-17 through 4.2-20, the slope stability analysis included modeling a "cemented layer" on the surface of the slopes. It was not possible to complete subsurface explorations on the slopes of the tailings piles to characterize the thickness of the cemented layer due to the steepness of the slopes. However, based on boring and test pit data collected from the tailings piles, including test pits excavated by Dames & Moore in 1997 near the top and base of tailings piles 1 through 3 (DMTP1-2 through DMTP3-4, shown on Figure 4.2-6b), it appears that the thickness of the "cemented layer" ranges from several inches to approximately 10 feet. The slope stability analysis utilized the lower end of the range (approximately 3 feet). Since the slope stability failure circles noted on Figures 4.2-17 through 4.2-20 extend below the maximum observed thickness of the cemented layer, the effect of cementation is thought to be minimal.

The analyses did not include scenarios of either no cemented zone or a 10-foot-thick cemented zone. In addition, groundwater levels were assumed to be near the base of the tailings piles and not perched higher within the tailings. Given the various observations from the RI reconnaissance, boring logs, groundwater monitoring well data, test pits and slope performance over the years, the scenario utilized in the analyses appears to be reasonable.

As noted for the liquefaction analyses, there is some level of uncertainty associated with the findings of the slope stability analyses due to uncertainties related to the engineering properties of the tailings and native materials, groundwater levels, the presence/absence and degree of cementation, and the modeling utilized. The observed long-term performance of the slopes suggests they are actually more stable than indicated by the results of the static and seismic analyses. The tailings pile slopes are relatively steep, but have not experienced a reported failure since a flood which occurred in 1948 and appeared to have been a 50-year event (Crates, 1966); the 1948 storm event resulted in the eroding of the toe of the northwest portion of tailings pile 2 and the delivery of tailings to railroad Creek. The slopes have held the relatively steep angles since the 1948 event, but are steeper than the angle of repose as determined by the angle of internal friction (37 degrees) resulting from laboratory testing completed by Hart Crowser. In addition, the Site apparently experienced a relatively significant seismic event in 1990, which did not result in slope failure. Therefore, it is our opinion that the soils have been appropriately and possibly conservatively modeled during the slope stability analyses. Possible measures to mitigate the mass movement potential will be addressed in the FS document.

Any erosion at the toe of the slope (such as Railroad Creek cutting into the slope) will reduce the factors of safety described above. Erosion is discussed further in Section 4.2.4.3 below.

Based on the observed angular nature of the waste rock piles, it is estimated that potential for slope failure is relatively low. However, isolated, shallow failures have the potential to occur on the steepest slopes.

Tailings pile 3 is situated near the base of an avalanche chute. An avalanche reportedly terminated near the southern edge of the pile in 1996 (personal communication with Keith Anderson, USFS, 1997). The potential exists for an avalanche to deliver avalanche debris to the southern margin of the tailings pile.

4.2.4.3 Erosion Potential

Summary of Historical Findings

Erosion is the breakdown of soils and bedrock by natural processes including water, wind, and glaciation. Of these processes, water-related erosion during storm events has the most potential for adverse impact. Fine-grained soil is also susceptible to wind erosion. The susceptibility of any material to erosion is dependent upon: (1) chemical and physical characteristics, (2) topography, (3) the amount and intensity of precipitation and surface water, and 4) the type and density of vegetative ground cover, if present.

The tailings material was found in the ORB 1975 report to be "highly susceptible to erosion by wind and water" prior to the placement of the gravel surfacing and grass mats. The report noted that windblown deposits were measured 500 feet downwind of the piles in amounts over 3,000 pounds per acre. Based on the reported average dry unit density of 92 pcf, this would equal approximately 0.009 inches of tailings material at that location. The report also concluded that a wind velocity of 30 cm/sec was needed to start eroding the tailings material; the assumptions associated with this estimate were not provided.

RI Findings

Railroad Creek flows eastward for approximately 3,900 feet directly adjacent to the three tailings piles. The tailings piles lie from 30 to 120 feet above the main channel on the south side of the creek. A field reconnaissance along the creek and slopes of the tailings was conducted. During the reconnaissance, the 3,900 feet of creek reach along the tailings slopes was classified into 18 different slope reaches with apparent similar erosion processes and erosion potential (e.g., slope angle, setback from creek, amount of vegetation, relationship to high water, etc.). Schematic cross-sections for each slope reach are presented in Appendix F. The criteria for grading and ranking the slopes in terms of erosion potential are presented in Tables 4.2-2 and 4.2-2a, respectively. Physical characteristics for each slope reach are summarized in Table 4.2-3.

The logs of the test trench excavations are presented in Appendix C. In general, the trench excavations indicate that the undisturbed tailings soils are predominantly laminated fine-grained sands that grade to silts and have pockets or lenses of clay; however, due to an uneven decrease in oxidation from the slope inward and from the top down, the soils appear laterally and vertically heterogeneous in color and the degree of cementation. For example, there are abrupt and irregular contacts of well oxidized hard, dry, cemented, medium-orange fine-grained sands in contact with loose, moist to dry, non-cemented, medium- to dark-gray fine-grained sands. In some cases, the upper 2 to 4 ft of tailings soils are softer, looser and more uniform in color and have no internal structure (i.e., the sands and silts are well mixed), and appear to have been remolded. The remolding most likely took place when the slopes were reconfigured during the USFS reclamation activities. Soft, loose remolded soil also occurs on the slopes and at the base forming a thick talus in places. Wood pieces were also observed in most trenches, and in a few places, cut timber logs were found buried in a vertical position.

The results of an analysis of topographic map data (e.g., average slope, reach length, reach height) for each slope reach are summarized in Table 4.2-3. This data, in particular average slope, was used in combination with the field characterization and trench log data to determine the criteria for assessing erosion potential. Average slope was defined as the slope from the top of the tailings (at the tailings edge) to the base of the riprap (as best as could be determined from the map contours and field knowledge of the riprap location).

The criteria for determining erosion potential of each slope reach was based on the field mapping, observations of erosion processes occurring on the slopes, topographic map data, and the estimated high water lines. Specific criteria were developed that included:

- Average slope of reach from the top of the slope to the base of the riprap
- Range of slopes occurring across the reach
- Slope setback from creek channel (the average distance from the toe of the slope to the bank of the main channel)
- Slope setback from crest of riprap (the average distance from the toe of the slope to the crest of the riprap)
- Composition of slope materials (e.g., sand talus, gravel cap, cemented sands)
- Condition or existence of vegetation, and/or grass mats
- Extent and magnitude of current erosion processes

Table 4.2-2 summarizes the criteria for grading the slopes erosion potential.

Based on the developed criteria, an erosion potential for each slope reach was assigned (Table 4.2-3) (Figure 4.2-21). In general, slopes along tailings pile 1 have a moderate to moderately low erosion potential due to the low average slopes, the distance that the pile is setback from the creek, the amount of vegetation present, and the condition of the gravel cap. Slopes along tailings pile 2 have a high to moderately high erosion potential due to the steep slopes, high amount of exposed tailings, little or no setback to the creek, and the lack of a gravel cap or vegetation. Slopes along tailings pile 3 have a moderate to low erosion potential due to the lower height, relatively sufficient setback (i.e., sufficient space to build talus to the angle of repose), the amount of vegetation present, and the good condition of the gravel cap.

There is some level of uncertainty associated with the findings of the erosion potential evaluation due to the difficulty in quantifying all of the variables associated with surface erosion. However, the findings are consistent with our expectations based on past experience on other site with similar geologic and hydrologic conditions.

4.2.5 Mine Subsidence Potential

As mentioned in Section 4.1.3.1, the uppermost stopes within the mine above the 1500-level are mapped to be within approximately 50 feet of the ground surface. Figures 4.2-14 and 4.2-15 display the lateral and vertical extent of the underground mine workings, and approximate thickness of bedrock overlying the principal mine openings, or stopes. In addition, an article written at the time of mine operation (Huttl, 1938) confirmed a "surface pillar" of 50 feet. Referring to Figure 4.2-21a, the underground mine maps reviewed for this evaluation confirmed that the areas highlighted between the 1100 level and 300 level portals (Honeymoon Heights area), have bedrock approximately 50 feet thick overlying the stopes.

No historical information was identified which addressed the potential for subsidence at the Site. Consequently, as part of the RI, a review of available underground maps, and a field reconnaissance of the areas identified as having potential for mine subsidence was conducted. The reconnaissance of the ground conditions above the 1100-level to the 300-level of the mine was conducted in September 1997. No indication of openings to the subsurface and/or likely subsidence features were noted. In addition, no indications of surface water flow into the subsurface were observed in the area of the intermittent drainage during periods of flow. In addition, color aerial photographs (stereo coverage, 1:12,000 scale, shot near midday, June 6, 1997) were reviewed as well for possible indications of subsidence features; none were observed.

However, at the request of the agencies, the potential for subsidence at the Holden Mine Site was further evaluated using the method of Golder (1990), as presented by Betourney (1996). The method is a specialized adaptation of the underground opening stability analysis method developed by the Norwegian Geotechnical Institute (Barton et al., 1974). The method is applied by graphically comparing key geologic and geomechanical characteristics of the rock mass to a "normalized" mine opening dimension, then using case history data to identify the ranges of data that are known to be associated with subsidence. The geologic and geomechanical characteristics are combined into a Rock Mass Quality parameter Q, which is defined in the Barton et al. publication. The Q value is a function of six individual features of the rock mass and its environment:

1. RQD — Rock Quality Designation, which measures the continuity of core retrieved during drilling
2. Jn — Number of Joint Sets, which is estimated using outcrop or underground geologic mapping data
3. Jr — Joint Roughness Number, which is estimated from observations of the geometry of exposed joints
4. Ja — Joint Alteration Number, which is estimated from observations of the aperture and condition of joints and joint wall rock
5. Jw — Joint Water Reduction Factor, which is related to the water inflow rate or pore pressure conditions
6. SRF — Stress Reduction Factor, which is related to the nature of the in-situ stress regime

High Q values indicate a good quality rock mass which would have a longer stand-up time and would require less structural support to maintain stability.

Data used for estimating the Q value were obtained during an October 1998 field visit which included geologic mapping along the ore body where it outcrops above the mine at Honeymoon Heights (Figures 4.2-21a and 4.2-21b). The field data are presented in Appendix M. The joint strike and dip data noted on the tables were plotted on "stereonets" to assist in identifying the number of joint sets. Referring to Figures 4.2-21c through 4.2-21g, the stereonets provide a 3-dimensional interpretation of the joint features in order to evaluate whether the joint sets are coincident. The earlier data suggest that the occurrence of the fractures and/or joints are relatively random in nature.

The field mapping effort confirmed the absence of mine subsidence-related features along the strike of the ore body. Referring to Figure 4.2-21b, a depression was discovered southwest of the 700-level portal. However, the depression appears to have been excavated, and drill rod found adjacent to the feature suggests that the feature was associated with rock drilling to characterize the ore body.

Based on field data presented in Appendix M, Q values between 14 and 33 were obtained, indicating a rock mass of "Good" quality. The method requires that these values be plotted against a "Scaled Critical Crown Pillar Span" Cs, which is directly proportional to the span of the mine opening (Figure 4.2-21h). The data points representing the Q versus Cs relationship for the Holden site fall into a zone described as "Stable" based on similar data points obtained from a large number of mine opening case histories. However, the Holden data is near the border between the "Caving" and "Stable" zones on the plot. Accordingly, the stability of the mine "surface pillar" cannot be considered assured given the long time period over which the performance must be addressed and the potential for seismic events during that period.

The regional geologic structure, particularly faults in the vicinity of the mine, were also evaluated with respect to the subsidence potential. Although published descriptions of the geology of the Holden Mine area describe minor faults of varying size and orientation, only one fault appears to be significant enough to possibly affect the potential for subsidence. This fault directly transects the mine axis and is oriented in a roughly east-west direction (strike N90E, dip 70 to 80S), i.e., perpendicular to the direction of the measured maximum principal tectonic stresses for this region (Zoback, M.L. and Zoback, M., 1980, "State of Stress in the Conterminous United States," Journal of Geophysical Research, V.85, N. B11).

The fault transecting the mine was not included with the mapped joints and discontinuities in the stereonet used to identify joint sets because this fault serves as the boundary between the two portions of the stope for which the geologic data were collected (compare Figures 4.2-6a with 4.2-21a and 4.2-21b). The data for Scanline 1 were collected south of the fault, and data for Scanline 3 were collected north of the fault. Mine maps show the stope being discontinued at the fault location (compare Figures 4.1-5b through 4.1-13 with 4.2-6a). The Norwegian Geotechnical Institute (NGI) method of evaluation Rock Mass Quality (Q), which governs the subsidence potential assessment, does incorporate an option to consider "weakness zones intersecting" or simply influencing the excavation in the selection of the Stress Reduction Factor (SRF) component of Q. Our opinion is that since the fault does not directly intersect the stope itself, the SRF should be based on rock stress considerations rather than weakness zone considerations. However, even if an unfavorable SRF category is selected based on weakness zone considerations, the Q value increases by less than 1 percent. Overall, the value of SRF can exert only a very small influence on the Q value.

The method used by Dames & Moore in this analysis is an empirical one based on case history information and key features of the mine and geologic conditions. An alternative approach, one used more frequently for civil works projects, is to identify specific blocks kinematically capable of falling from the roof, then evaluating the forces causing and resisting the roof fall process. This approach was not used due to the obvious lack of roof fall activity observed during and after mining of the stope, and the relatively weak indications of joint sets shown in the stereonets.

The method of evaluating mine subsidence used for this project contains no direct means of incorporating the presence of a single fault, unless the characteristics of the fault (e.g., strike/dip for "number of joint sets," "joint" roughness and alteration) are averaged along with those of the other joints affecting the opening.

There is some level of uncertainty associated with the findings of the subsidence assessment due to uncertainties related to the engineering properties of the bedrock, the accuracy of the underground mine maps, and the methods utilized to analyze the subsidence potential. However, the finding that the "surface pillar" is marginally stable is consistent with the field observations and the case studies utilized as comparisons.

4.2.6 Windblown Tailings

An assessment of the lateral extent of windblown tailings was completed as part of the RI. The assessment include the review of aerial photographs with limited site reconnaissance and sampling. The results of the assessment are presented on Figure 4.2-22 and indicate that the amount of wind-blown deposits detectable utilizing the methods employed, are generally limited to the area to the northeast of three tailings piles. The depth of the deposits were noted to generally decrease with distance from the piles. The thickness of the deposits near the mapped limits were estimated to generally be less than one inch. Those deposits in the immediate vicinity of the Railroad Creek north and east of the tailings piles were noted in isolated areas to be on the order of several inches thick.

4.2.7 Existing Railroad Creek Riprap

4.2.7.1 Summary of Historical Findings

The existing riprap lining the south bank of Railroad Creek was placed during the Site reclamation efforts completed between 1989 and 1991. The rock reportedly originated from an existing rock quarry developed approximately nine miles to the east of the Site, north of the "Dan's Camp" existing gravel pit, as well as from road cuts in bedrock situated west of the existing rock quarry and Dan's Camp (Figure 4.2-23). A review of historical files dating back to the mine tailings rehabilitation project in 1989 to 1991 indicated that the riprap source was qualitatively assessed.

4.2.7.2 RI Findings

An assessment of the condition of the riprap was conducted as part of the RI. The riprap found at the base of the tailings was classified into six different types. Types A, B, and C were apparently derived from the granodiorite/monzonite quarry along the Holden Road, types D and E are volcanic in nature (source unknown) and type F (ferricrete blocks) was derived locally from the creek bottom (Figure 4.2-24). The criteria for ranking the riprap are presented in Table 4.2-4. Type A is comprised of large coherent blocks of competent granodiorite, but is found in significant portions only along reach 2-B (Table 4.2-5). Types B (quartz diorite to quartz monzonite) and C (diorite to monzonite) are the most prevalent riprap type, but by their more mafic-rich, generally smaller and more weathered nature are not good riprap types. In fact, the Type C boulders have weathered to the extent that, in many cases, all that remains of the original boulders are piles of gruss. The Schmidt-hammer tests generally corroborate the field observations, in that the Type A boulders had higher percentage recoveries (52 to 59 percent), than the Type B (24 to 42 percent) and C boulders (14 to 28 percent).

Types D (latite) and E (rhyodacite) appear to be better quality than Types B and C but at much smaller proportions along the tailings. Type F (ferricrete) appears to have been used sparingly along tailings pile 2, but is generally not a good riprap type because of the potential for the iron cement to break down.

In general, riprap deterioration appears to occur by three primary mechanisms:

- grain by grain collapse (grussification), which creates entrainable sediment which is removed during high flows
- boulders exfoliate into plates or flakes which reduce clast size
- boulders fragment into small blocks along pre-existing weathered fracture planes

In terms of the breakdown of ferricrete boulders, the scattered material was observed in the field to be crumbly and disaggregated, likely due to the breakdown of the cement (primarily iron) binding the conglomerate. This is consistent with observations of the intact ferricrete, which varied in hardness and cementation. The observed variation in cementation was apparently not only a result of the lack of cement, but also in some cases due to the degree to which the cement precipitate had fractured, softened or disaggregated in the channel environment.

In general, the breakdown of the riprap results in smaller boulder sizes with less resistance to motion under high stream power, and less protection to the tailings slopes.

Based on the above criteria, the riprap condition was graded for each creek slope reach and is summarized in Table 4.2-5. Overall, there are several areas with relatively competent boulders (i.e., reach 2-B); most of the reaches have boulders that are relatively weathered (i.e., grussified). Some of the rocks were observed to be grussified or broken down by weathering, in particular along tailings pile 1. In addition, there is field evidence that much of the gruss has been removed by high waters (i.e., high stream flows have eroded loose sediments from riprap, so that a high water line exists where there is no gruss below the high water line).

4.2.8 Potential Borrow Source Areas

Remedial strategies may require methods to improve protection from wind and stream erosion processes, and mass movement hazards. For example, riprap may need to be placed in specific areas due to river rerouting, places where it is now absent but required (e.g., slope reach 1-A), or supplemented in river reaches with present low quality riprap (see Section 4.2.7, Existing Railroad Creek Riprap). In addition, remedial work (e.g., revegetation, recontouring, etc.) of tailings may require a local soil cover source. A preliminary assessment of potential borrow source areas was conducted to achieve the following objectives:

- Identify potential accessible sources of riprap within the Railroad Creek drainage basin
- Identify potential accessible sources of soil cover within the Railroad Creek drainage basin

4.2.8.1 Sand and Gravel

Summary of Historical Findings

The gravel currently covering the tailings piles was placed during the 1991 site reclamation efforts. The gravel reportedly originated from a gravel pit developed at "Dan's Camp" (Figure 4.2-23). Other than the "Dan's Camp" pit utilized by the USFS previously, no onsite sources of granular borrow material were identified during the review of historical information.

RI Findings

A borrow source evaluation to identify potential sources of sand and gravel was conducted as part of the RI. The scope of work included the initial review of geologic maps and aerial photographs for the Railroad Creek watershed from the Glacier Peak Wilderness boundary down to Lucerne. The objective of the assessment was to identify a source or sources of granular borrow material as close to the Site as possible.

The gravel pit area at Dan's Camp was assessed visually and appears to be a good source of sand and gravel. The material exposed in the gravel pit was estimated to be a gravelly sand to sandy gravel, with relatively low percentages of silt. However, this source is approximately seven miles from the Site.

Referring to Figure 4.2-25, on September 30, 1997, six test pits were excavated in two potential source areas: (1) three pits east of tailings pile 3 (DMTP3E-4 through DMTP3E-6), and (2) three pits along the slopes south of the three tailings piles (DMTP1S-1, DMTP2S-1, AND DMTP3S-1). A second objective of the test pits completed south of the tailings piles was to characterize the near-surface groundwater conditions in the native soil. The test pit logs are presented in Appendix C. Soils in the test pits were described generally following USCS standards and were evaluated with respect to approximate grain size distribution (i.e., percent boulders, cobbles, sands, and fines), maximum boulder size, and range of boulder sizes.

The onsite potential borrow areas may be adequate sources for soil cover, particularly for elements of the Site which may require siltier soils. For general tailings pile slope cover, some sorting would be necessary to sift out the coarse fraction (which may be suitable as a riprap supplement) and the fine fraction (to prevent wind transport).

Information and data gathered about the potential source areas is summarized in Table 4.2-6. For each source area, the following criteria were evaluated: (1) the approximate haul distance to the center of the Site, (2) the composition and relative size of sources, and (3) the relative feasibility of developing the source.

4.2.8.2 Riprap

Summary of Historical Findings

The riprap currently covering portions of the southern streambed of Railroad Creek along the toes of the tailings piles was placed as part of the mine tailings rehabilitation project conducted by the USFS between 1989 and 1991. A review of the project files disclosed that several potential sources of riprap were identified by the USFS in the Railroad Creek watershed downstream of Glacier Peak Wilderness boundary (C. Blackburn, 1988). Referring to Figure 4.2-23, these areas included: (1) an outcrop of granitic bedrock north of the Dan's Camp existing gravel pit, (2) outcrops of granitic bedrock exposed in roadcuts between Dan's Camp and Holden Village, and (3) a talus slope approximately one mile east of Holden Village.

The talus materials were deposited on the slope as a result of fracturing and rockfall from upslope bedrock outcrops. The pile of rock on the slope was considered by the USFS to be a potential source of riprap. However, the risk for injury and/or road closure due to possible rockfall during development resulted in the source area being eliminated from further consideration (personal communication with Al Murphy, 1997). The bedrock outcrop north of Dan's Camp was, therefore, developed as a rock quarry, and portions of isolated exposures of the bedrock within roadcuts were removed to provide the riprap utilized for the project.

RI Findings

An assessment of potential riprap sources within appropriate portions of the Railroad Creek watershed were evaluated. The scope of work included the initial review of available geologic maps and aerial photographs for the Railroad Creek watershed from the Glacier Peak Wilderness boundary down to Lucerne. The objective of the assessment was to identify a source, or sources, of riprap as close to the Site as reasonably as possible.

In October 1997, a field reconnaissance was conducted of potential source areas adjacent to the Holden Road, from approximately milepost 1.6 to Holden Village. The source areas were evaluated with respect to compositional lithologies, rock genesis (i.e., till, plutonic stock, etc.), potential riprap or soil cover quality, potential haul distance, and accessibility. In addition, Schmidt-hammer tests were conducted at the potential riprap source areas on a reconnaissance level to get a relative gauge of potential hardness of the various sources that were encountered in the identified source areas.

The riprap source used by the USFS in 1989 is noted herein as the Existing Rock Quarry (Figure 4.2-23). Based on the assessment of current riprap quality along Railroad Creek, this source area would not appear to be a viable riprap source. This was confirmed upon visual inspection of the quarry site and by the Schmidt-hammer test survey. Although, some portions of the quarry appeared to have relatively competent granodiorite (Type A in Section 4.2.4; unweathered, low fracture density and relatively high Schmidt-hammer percentage recovery), most of the quarry was composed of Types B and C. Thus, use of this quarry for good quality riprap would necessitate a detailed assessment to determine the rock-type distribution followed by compositional hi-grading, which may not be practical and/or feasible. Two additional source areas, Holden Road at 3-mile and Holden Road at 4-mile, appear to contain rock-types with similar composition to the rock quarry, are not significantly closer than the rock quarry and, therefore, would not appear to be a good source. In addition, the sources would require further assessment to determine quantity, compositional quality and techniques for quarry development.

The talus pile at 9-mile has a high potential for a good riprap source. Preliminary findings suggest higher compositional grade of rock (e.g., relatively competent boulder hardness, sufficient quantity of large boulder sizes). In addition, the source is near the Site. However, there are a variety of rock types found throughout the talus pile, so some segregation may be required. In any case, the talus pile will need further assessment of accessibility, as there may be rock fall or slope stability hazards during excavation.

The waste rock piles southwest of tailings pile 1 were also considered as possible riprap sources, due to local accessibility. However, the range of sizes and quality is unknown (e.g., hardness tests were not conducted), and based on visual observations, the maximum boulder size appears to be limited. In addition, there may be a potential for mineralization which could adversely affect water quality.

The area east of tailings pile 3 and the slopes south of the three tailings piles were assessed for potential riprap sources. Neither area is apparently a good riprap source due to: (1) a predominance of fines that would necessitate hi-grading and large quarry sizes, and (2) the maximum boulder size is likely not large enough to prevent removal by stream action during high flow conditions.

It should be noted that a review of available geologic maps for the portion of Railroad Creek outside the Glacier Peak Wilderness indicates a number of dikes that include "alaskite" and "quartz diorite." Alaskite is an igneous rock with a greater proportion of alkali feldspar minerals and is, therefore, considered the most stable of the granitic rocks in the weathering environment. It is possible that some of the boulders present as riprap along the base of the tailings piles, as well as in the potential riprap sources identified above, may actually be alaskite. However, these rocks were combined with the other competent granites and granodiorites noted herein because they were not abundant as an individual riprap type. It is also possible that alaskite may be present in the form of dikes within the portions of the wilderness area near Lucerne, Martin Ridge, and/or Tenmile Creek; however, the deposits within the wilderness area were not evaluated in the field due to being considered inaccessible.

4.3 SURFACE WATER HYDROLOGY

4.3.1 Regional Climate and Hydrology

The climate in the Lake Chelan region is characterized by hot, dry summers and mild to severe winters. Average monthly temperature varies from highs in the 30s (in degrees C) in July and August to extreme low temperatures well below 0 in January. Average temperatures are generally below freezing between the months of November and March. Temperatures vary with elevation and in most circumstances decrease with elevation. Typically, temperatures decrease by about 2 degrees C for every one thousand feet of elevation gain (Wallace and Hobbs, 1977); however, this lapse rate can vary seasonally and with particular weather conditions.

Precipitation in the region can be highly variable due to strong orographic effects resulting from the mountainous terrain. Weather patterns generally follow a west to east movement, with precipitation falling heavily on the western side of the Cascades and diminishing as the weather system moves east across the mountains. In the Lake Chelan basin, precipitation is generally higher at greater elevation and decreases to the east and south (USGS, 1975). Average annual precipitation in the basin ranges from a high along the Pacific Crest of more than 100 inches, to less than 25 inches east of Chelan.

Streamflow patterns within the Lake Chelan basin are fairly consistent between individual watersheds, although total runoff can vary significantly due to basin aspect, elevation and extent of glacierization. Flow regimes are dominated by snowmelt with peak flows generally occurring in May and June. Low flows typically occur in late fall and persist until spring thaw. Comparison of average monthly flows for the Stehekin River, Railroad Creek and the Entiat River reflect elevational differences within each watershed and the presence of a relatively large percentage of glaciers in the Stehekin upper basin (Table 4.3-1 and Figure 4.3-1).

4.3.2 Overview of Railroad Creek Watershed Hydrology

The Railroad Creek watershed is elongated and steep, and oriented west to east. Figure 4.3-2 shows the Railroad Creek watershed and surrounding areas. The valley is characterized by steep-sided slopes carved by the most recent glaciation. The creeks on the side slopes have steep gradients. Elevations of Railroad Creek range from 6,500 feet msl at its headwaters in the Glacier Peak Wilderness area to approximately 1,100 feet msl at Lucerne, located on Lake Chelan. The average elevation of the basin upstream of Lucerne is 4,930 feet (USGS, 1984). Most of the Holden Mine facilities and the tops of the tailings piles are between 3,200 and 3,400 feet above msl, which is as much as 200 feet above Railroad Creek and Holden Village.

The Railroad Creek watershed is approximately 65 square miles in size upstream of Lucerne. Lakes comprise approximately 0.5 percent of the total watershed area (located at high elevations), and glaciers comprise approximately 1 percent (Figure 4.3-3). Approximately 68 percent of the basin is forested (USGS, 1984). The average slope of the main stream channel is 4.5 percent; however, the slope varies depending on location in the watershed. In the vicinity of Holden Mine Site, the channel slope varies from 1 to 2 percent and becomes steeper downstream. Approximately one half of the watershed is upstream of the Site (31 square miles).

The watershed experiences rapid response times from precipitation influx. During the September 1997 field program, streamflow was observed to rise quickly (less than one day) in response to rainfall, and recede as quickly when rainfall ceased. Because of these conditions, there is potential for flash flooding on Railroad Creek, particularly from a combination of high-density rainfall and rapid snowmelt. Historically, a flood of this type probably occurred on May 28, 1948, when soils were saturated from spring runoff, resulting in an estimated discharge of 3,900 cfs at Lucerne. During this same storm, a discharge of 3,000 cfs was estimated at Holden (PNL, 1992).

The Railroad Creek system is partially glacier fed, which contributes to the baseflow during the summer along with groundwater contribution. Referring to Figure 4.3-3, glaciers comprise approximately 2 percent of the watershed area of Railroad Creek upstream of the mine. Railroad Creek stream discharge in the Site area is characterized by generally low flows during winter and peak flows occurring during the months of

May and June, which coincide with the snowmelt period. Low flows also occur from late summer through fall; however, there is a possibility of large flow events occurring in the late summer and early fall due to rainstorms. The hydrologic pattern reflects a steady baseflow provided by glacial melt and groundwater in the summer and winter punctuated by seasonal storm events of short duration and snow melt of longer duration.

4.3.3 Site Climate and Hydrology

4.3.3.1 Site Climatic Conditions

Average precipitation at Holden Village from 1962 to 1997 is approximately 38 inches annually, with the highest monthly amounts occurring between November and January, and the lowest between May and August. Table 4.3-2 lists average monthly precipitation totals for the period of record at Holden Village along with estimated monthly totals for the Railroad Creek basin as a whole (above Lucerne). During the winter of 1996/1997 the second highest recorded snowfall occurred, with approximately 500 inches falling through the winter (NOAA weather records for Holden Village, Appendix H).

The snowpack accumulation during mid-April 1997 was approximately 72 inches at the weather station, and was 43 inches by May 1, indicating that approximately one-half of the accumulated snow had melted by the beginning of May. The snowpack had disappeared from the measuring location and most open areas by May 17 (NOAA weather records for Holden Village, Appendix H); however, field observations during the RI indicated that one to two feet of snow remained on the ground at this time in shaded areas. Due to the large snowpack, avalanches upslope of the Site were frequent during the winter of 1996/1997 (personal communications with Holden Village residents, 1997).

Monthly average daily temperatures for Holden Village are shown on Table 4.3-3, along with estimated average daily temperatures and potential evapotranspiration for the basin as whole. Potential evapotranspiration from Holden was estimated based on the average temperature values and estimated percent cloud cover. The cloud cover data was an average of percentages observed at Seattle and Yakima (data is unavailable for Holden). Based on these data, average annual potential evapotranspiration from the basin has been estimated to be on the order of 16 inches (see Section 4.3.5) and actual evapotranspiration approximately 10 inches.

4.3.3.2 Streamflow Monitoring

Streamflow Monitoring Stations

Streamflow monitoring stations used during the RI are shown on Figures 4.3-3 and 4.3-3a. Stations RC-1 (established to be upstream of the mine-affected area), RC-2 (immediately downstream of the tailings piles), and RC-3 (at Lucerne) were continued from previous work conducted by PNL and the USFS. New stations include RC-4 (immediately upstream of the tailings piles), RC-5 (approximately one-half mile downstream of tailings pile 3), RC-6 (established upstream of RC-1 to confirm the upstream limit of the mine-affected area), RC-7 (adjacent to tailings pile 2), RC-8 (established upstream of RC-3 in an attempt to collect data where Railroad Creek flows directly atop bedrock), RC-9 (an aquatics sampling station established upstream of the Copper Creek confluence adjacent to tailings pile 1), RC-10 (approximately three miles downstream of tailings pile 3), and RC-11 (established immediately upstream of the Holden Creek confluence after it was discovered that Howe Sound Company likely conducted limited mineral exploration in the Holden Creek watershed). Stream flow measurements and other relevant data collected during the RI are presented in Appendix H.

Streamflow monitoring stations on Copper Creek include CC-1 upstream of the tailings piles (established by PNL and the USFS), CC-2 near the confluence of Copper Creek and Railroad Creek (also established by PNL and the USFS), and CC-D/CC-D1, which is the Copper Creek diversion (established at the request of the Agencies). CC-D/CC-D1 flow is diverted from Copper Creek upstream of CC-1 and routed through the hydroelectric plant (Figure 4.3-3a). Flow from CC-D/CC-D1 is also diverted for water use at Holden Village. Flow was also monitored in the portal drainage at stations P-1 (where the drainage flows from the mine portal) and P-5 (upstream of the confluence with Railroad Creek).

Staff gages for measuring water levels are located at stations RC-2, RC-4 and RC-6 in Railroad Creek. Additionally, a continuously recording water level recorder (Troll) was installed in the stilling well at RC-4 on May 24, 1997. The Troll was removed during the winter due to the low water levels and freezing temperatures. A staff gage is also located behind the weir which controls flow out of the hydroelectric plant in the Copper Creek diversion.

Accuracy of Measurements

The accuracy of streamflow measurements in Railroad Creek is dependent on several factors, including the method of measurement, the irregularity of the cross-section, and the degree of turbulence in the water at the cross-section. Under ideal conditions, discharge measurements with the equipment used (Price AA or equivalent SWOFFER meter, wading rod and/or bridge board and sounding reel) is assumed to be accurate to within 2 percent of the actual flow (Rantz et al., 1982). However, all of the stations measured at the Site exhibit highly irregular cross-sections due to the cobble- to boulder-size substrate material. Based on professional judgment and experience, the irregular cross-section reduces accuracy to within 5 percent of the actual flow. In addition, using the bridge board and reel is less accurate than wading due to difficulties in measuring depth and maintaining stable position for the velocity meter; the bridge board is used at higher, much more turbulent velocities when wading is not possible. Thus, bridge board measurements are assumed to reduce accuracy by another 5 percent.

Based on the above, wading measurements which, based on experience, can be safely accomplished in Railroad Creek at the Site when RC-4 river stage levels are approximately 1.5 feet or lower, have an assumed accuracy within 5 to 7 percent of the actual flow. Bridge board measurements have an assumed accuracy within 10 to 12 percent of the actual flow.

Stage measurements observed on staff gages installed at RC-2, RC-4 and RC-6 also have a finite accuracy. During higher flows, staff gage readings have an assumed accuracy of 0.05 foot due to waves and turbulence disturbing the water level at the gage. This accuracy is based on site-specific experience reading the gages. At lower flows, less turbulence and waves allow for more accurate gage reading, and is assumed to be on the order of 0.02 foot. As noted above, a continuous water level recorder (Troll) was installed in a stilling well at RC-4. The accuracy of the pressure transducer in the data logger is reported by the manufacturer to be 0.01 foot.

Rating Calculations

Referring to Table 4.3-4, flow measurements were collected on the Site at RC-4 from April 16 to October 4, 1997. One flow measurement at RC-4 (June 16, 1997) and two flow measurements at RC-2 (July 10, 1997, collected by Dames & Moore, and July 25, 1996, collected by the USFS) were excluded; the excluded flow measurements appear to represent a physical shift in the stream channel conditions, probably due to scour and bed movement during the peak flow of June 16. Rating curves were developed for stations RC-4 and RC-2. A rating curve was not developed for RC-6 due to difficulties in collecting data at this station due to the irregular cross-section.

Typically, the Railroad Creek streambed is armored and immobile during most flows; however, during peak flows, the bed may become mobile (i.e., the stream power is capable of moving the cobble- to boulder-size material which armors the streambed), which affects the stage discharge relation. Subsequent flow measurements at these stations returned to the previous rating, indicating that the effect of the mobile bed was short lived due to restabilization of the streambed. The rating curve data and rating graphs are provided in Appendix H. The rating curves have been developed by fitting a single log-log curve to the stage-discharge data using linear regression techniques. For both rating curves (RC-2 and RC-4), the regression analysis showed very good predictability, with correlation coefficients of 0.994 or better. This indicates that a single flow control over the range of flows measured adequately represents the channel flow conditions.

The best fit rating equation for RC-4 is:

$$\text{Discharge} = 26.2(G-GZF)^{2.581} \tag{4-1}$$

where:

Discharge = flow estimate in cubic feet per second (cfs)

G = the observed staff gage height (feet)

GZF = the gage height of zero flow (feet) = -0.4

The best fit rating equation for RC-2 is:

$$\text{Discharge} = 0.05(G-GZF)^{5.515} \tag{4-2}$$

where:

GZF = -3.0

The GZF is the depth relative to the staff gage at which flow would be zero. The GZF for RC-4 agrees with channel cross-section data at the measurement section. However, the GZF for RC-2 appears to be too low to be physically realistic. This indicates that the rating for RC-2, although useful for the purposes of this project, may not be appropriate for long term use. Assuming a realistic value for GZF, determined from physical channel measurements, would yield a rating for RC-2 of:

$$\text{Discharge} = 20.1(G\text{-}GZF)\hat{}2.835 \qquad (4\text{-}3)$$

where:

$GZF = -0.8$

Equation 4-3 was not used for the RI, but should be used in the future if data extrapolation is required. This equation can be verified and updated if more flow data is collected at RC-2. For the purposes of this study, however, equation 4-2 was used to estimate flow at RC-2 in order to yield the highest accuracy for flow estimates in 1997.

4.3.3.3 Railroad Creek

Channel Geomorphology

Overview

Referring to Figure 4.3-2, Railroad Creek flows approximately 18 miles from its headwaters at Lyman Glacier near the Pacific Crest to Lake Chelan. Approximately 13 tributary streams with watersheds greater than 1 square mile enter Railroad Creek along its length. The largest tributaries include Big Creek, Copper Creek, Tenmile Creek, Klone Creek and Tumble Creek. Copper Creek enters Railroad Creek at the Site. The locations of the streams and the stream gradients were determined based on existing topographic maps of the watershed (USGS, 1967a and 1967b).

Upstream of Site to Tenmile Creek

Upstream of the Site, the stream gradient is steepest near the headwaters between Lyman Glacier and Crown Point Falls, just below Lyman Lake (Figure 4.3-3). Between Crown Point Falls and Hart Lake, the stream gradient averages 3 to 3.5 percent. The gradient steepens again for a short reach below Hart Lake, and then levels off again in the vicinity of the Site.

From approximately one mile upstream of the Site to one mile downstream of the Site, the stream gradient is nearly the flattest in the basin (other than immediately downstream of the Tenmile Creek confluence), averaging between 1 to 2 percent. In this reach, glacial sediments can be observed in occasional cutbanks with thicknesses in excess of 20 feet in some places.

The stream channel for this segment of stream exhibits bar development, occasional braiding, and a developed floodplain except in the reach adjacent to the tailings piles. Within the approximate one mile reach from the vehicle bridge west of Holden Village to the west end of tailings pile 1 (Figure 4.3-3a), the channel is confined by riprap and/or cribbing along its south bank, and in some areas confined by a steep embankment along the road on the north bank. Within this confined reach, the channel is relatively straight with little or no braiding. Upstream of the vehicle bridge, cutbanks supply sediment to the stream and are also associated with accumulations of large woody debris (logs and root wads), probably due to undercutting of trees on the banks as the cutbank erodes. Also at this location, sediment accumulation and channel braiding occurs because of proximity to the cutbank source.

Based on the review of a historic map of Railroad Creek, an old alluvial channel or braid of Railroad Creek appears to exist beneath the western portion of the Site and tailings pile 1 (Figure 4.3-3b); the map does not display information east of the northwest corner of tailings pile 2. Referring to Figures 4.2-6b and 4.2-11, geophysical investigation line E-E' (immediately east of tailings pile 3) appears to confirm the eastern extent of the historical alluvial channel. Reportedly, the main channel was relocated to its present location when the tailings piles were constructed. The tailings piles are also underlain by apparent alluvial/floodplain deposits, suggesting that, prior to mining, the channel reach adjacent to Holden Village occupied a relatively wide floodplain within which the channel could form braids and develop bars similar to the reaches upstream and downstream of the tailings.

Presently, a short segment of the creek bed at the east end of tailings pile 3 (immediately downstream of RC-2) is slightly higher in elevation than the adjacent ground surface. This condition would not be expected within a natural channel system, and probably exists because sediment which would normally accumulate within the floodplain has been transported within the straightened reach adjacent to the piles and accumulated just downstream of the tailings.

Adjacent to Holden Village, from RC-4 to RC-7 (downstream of the Copper Creek confluence), the north (left) bank exhibits floodplain and occasional woody debris. As stated earlier, the stream gradient within this reach varies from 1 to 2 percent and streambed materials consist of cobble with occasional small boulder and some gravel. Below the confluence with the Copper Creek diversion (CC-D/CC-D1) the streambed exhibits iron staining and accumulations of iron (orange) oxide flocculent/precipitate within the interstices of the cobbles (see Figure 4.3-3c).

Also in this reach, near the confluence of Railroad Creek and Copper Creek, isolated portions of the south bank of the creek (SP-1 area, RC-9 to Copper Creek confluence, and SP-3 area) are cemented with apparent iron oxyhydroxides (ferricrete) (refer to Figure 4.3-3d). The cementation was found in three portions of the streambank along tailings piles 1 and 2 and appeared to range in thickness from about 0 to 4 feet. Along this reach, the streambed itself does not appear to be entirely composed of ferricrete.

Below Copper Creek, ferricrete was generally not observed exposed in the streambed. However, approximately 50 meters of the south bank near the northwestern corner of tailings pile 2, which is coincident with seep SP-3 (Figure 4.3-3d), was observed to be cemented. It is possible that other isolated occurrences of ferricrete exist within this reach of the creek, but are masked by the presence of the riprap. The cobble substrate was generally loose, although a fine iron-oxide precipitate coating was present on the cobbles and boulders and within the interstices of the substrate. The depth of iron-oxide precipitate accumulation was not extensive, less than the embedded depth of the small boulders within the streambed (evidenced by the lack of orange staining on the underside of the larger bed particles).

From the eastern end of tailings pile 3 (RC-2) to RC-5, near the Tenmile Creek confluence, the ferricrete was not observed and the iron-oxide precipitate was noted as suspended material, but was not measurable on the stream substrate (Figure 4.3-3). However, iron staining was observed as coatings on the stream substrate throughout this stream segment. A more in-depth discussion of the iron-oxide precipitate and ferricrete is presented in Section 4.3.9.

Tenmile Creek to Lake Chelan

Less than approximately 500 feet downstream of the confluence of Tenmile Creek (approximately one-half mile downstream of the Site), a large log jam is present which causes a flattening of the stream gradient to less than one percent. This appears to be the flattest channel gradient in the portion of the basin downstream of the wilderness boundary, and minor accumulations of fine sediments were observed on the streambed in backwater areas. Also in this area, beaver activity is evident, wetlands occur, and the channel and floodplain broaden.

Downstream of the log jam below Tenmile Creek, the channel gradient gradually increases. Bar development and braiding in the channel decreases and bedrock outcrops at some locations. At approximately river mile 6.5 (as measured from the mouth and approximately 4 miles downstream of the Site), a large erosional feature occurs, which consists of a 50-foot-wide dry cobble and boulder channel that appears to have been recently carved by Railroad Creek. The channel, consisting of a vertical cutbank of 20 or more feet on the left (north) bank occurs where a recent avalanche entered the channel from the south (right) valley slope, depositing debris on the opposite bank. The eroded channel appears to have been caused by the avalanche debris blocking the channel.

Downstream of this erosional feature, the channel gradient increases to greater than 5 percent. The average substrate size, likewise, generally increases from predominantly cobble- to boulder-size particles in a downstream direction. The channel also becomes increasingly confined to a steep sided valley, with little floodplain development. Iron staining also diminishes in this reach. Iron staining on the streambed substrate becomes nearly indistinguishable from algae and other coatings on the rocks below approximate river mile 5.0 (approximately 5-1/2 miles downstream of the Site). Bedrock outcrops and channel control increase between river mile 5.0 to river mile 3.0, where the channel enters a steep walled bedrock canyon, with several large waterfalls. Below the canyon, the gradient gradually decreases until the creek enters Lake Chelan; however, bed substrate remains large, dominated by cobbles and small boulders.

Streamflow

Site

Streamflow in Railroad Creek exhibits a typical snowmelt dominated hydrograph, with sustained peak flows generally occurring in spring and low flows following through the fall and winter seasons. Large rain events can cause short lived peak events anytime during the summer and fall, and can contribute to peak flows in the spring. Baseflows are sustained by groundwater and upper basin meltwater, including glacial melt, in the summer. During the fall and winter months, groundwater sustains the baseflow, as melting of snow ceases when temperatures drop below freezing. During the September 1997 RI, flow in Railroad Creek adjacent to the Site was observed to decrease rapidly (commonly less than one day) when temperatures in the upper elevations appeared to fall below freezing based on observed snow accumulation, indicating the effect of freezing on the reduction of melt flow contribution to baseflow.

Discharge in Railroad Creek was monitored on a continuous basis at station RC-4 immediately upstream of the tailings piles at the Site. Additionally, water level and discharge was monitored closely at station RC-2 immediately downstream of the tailings piles. Other stations where discharge was frequently measured were station RC-1 upstream of the Site (considered to be a background station) and RC-3 at Lucerne. All of these stations could be measured from a bridge or log at relatively high flows. Stations RC-5, RC-5A, RC-6, and RC-7 were measured less frequently because of the difficulty in wading and measuring at higher flows.

The hydrograph of streamflow in Railroad Creek at RC-4 is shown on Figure 4.3-4 and includes flow from April 16 to October 4, 1997. Also on Figure 4.3-4, flow measurements from the other stations are plotted. RC-2 flows plotted on the hydrograph were estimated from the rating equation for that station (Appendix H). The hydrograph illustrates the seasonal variability of flows during spring, summer and fall of 1997. In general, the flow pattern is similar to the long term average for the period of record at Lucerne, with the highest flows occurring in May and June, followed by a gradual decline, and low flows in fall and early spring.

Comparison of Stations

The hydrograph also illustrates the comparability and relationship between flows at all stations. Comparing Figure 4.3-4 with the hydrograph for the Stehekin River for the same time period (Figure 4.3-5) indicates that the flow measurements at the two stations were very similar; however, the peak flow at each station occurred at a different time. The comparison of flows indicates similar general climatic conditions and basin response, and the difference in peak timing probably indicates micro-climatic and storage differences between the two basins, and differences in basin aspect which impact the snowmelt characteristics.

Flow relationships between stations was evaluated by comparing measured flows at stations RC-1, RC-2, RC-3, RC-4 and CC-1 (the primary tributary between RC-1 and RC-2) in relation to reference stations RC-2 and RC-4. RC-2 and RC-4 were chosen as the reference stations because they had the most usable and available data; rating curves were developed for both stations. The rating curves provide a smoothing or averaging of the measurement error inherent in the flow measurements and stage readings. The flow relationships were evaluated as ratios of station flow to reference flow computed from the ratings. Table 4.3-4 presents the results of this analysis. The flow ratios relative to RC-2 and RC-4 were statistically averaged to provide the most reliable values.

Table 4.3-4 indicates that the rating estimates at RC-4 averaged 2 percent lower than the measured values for that station, and the rating at RC-2 results in a 3 percent greater estimated flow value compared to the measured flows. Averaging this error by normalizing the flow ratios for the other compared stations by negative 2 percent for RC-4 and positive 3 percent for RC-2 (dividing each station ratio by the ratio of each reference), indicates that gain between stations RC-1 and RC-4 averages between negative one (indicating a loss of flow) and zero percent. In contrast, the gain measured between RC-4 and RC-2 averages 12 to 15 percent, of which 12 percent is accounted for by inflow from Copper Creek. The measured gain between RC-2 and RC-3 averages 79 to 101 percent.

Referring to Figure 4.3-3a, the flow ratios between RC-1, RC-4 and RC-2 appear to have seasonal variability; however, given the potential measurement error, the magnitude of the seasonal variability cannot truly be distinguished. However, assuming that the observed measurements reflect actual conditions, it appears that there is a loss of flow between RC-1 and RC-4 during periods of low flow in the early spring and in the fall. Referring to Figure 4.3-3b, the historical Railroad Creek channel intersects the present Railroad Creek channel at the approximate midpoint of this reach. Flow measurements collected on May 26, 1997, exhibited an apparent gain in flow between RC-1 and RC-2. This may reflect the overall recharge conditions resulting from snow melt. Similarly, flow between RC-4 and RC-2 appears to exhibit the least gain during fall and the greatest gain during spring. The flow ratios with Copper Creek do not appear to have seasonal variability, indicating that flow patterns at this station follow the seasonal flow patterns in Railroad Creek. This makes hydrologic sense because the basin of Copper Creek is similar, albeit smaller, than Railroad Creek and would be expected to behave similarly given the proximity of the two drainages.

The seasonal variability evident between stations at the Site and RC-3 at Lucerne are large, and therefore the difference in flow ratios was considered to be distinguishable from error. A relatively large seasonal variability in flow pattern is expected between the Site and Lucerne because of elevational differences. Snowmelt begins and ends earlier in the lower basin, and precipitation is lower; therefore, flows at Lucerne, which include a large percent of drainage from the lower basin, will reflect this contribution.

The flow relationships between RC-4 and RC-3 developed from Table 4.3-4 were used to estimate the relationship between monthly average flows measured during 1997 at RC-4 (continuous record for part of April, May, June, July, August and September) and the long-term record at Lucerne. A monthly average for April was estimated for 1997 by assuming the flows measured in mid-April were representative of flow early in the month, and daily staff readings maintained by Dave Harris of Holden Village from April 19 through May 19 were used to estimate flow at RC-4 from the rating equation. Table 4.3-5 shows the estimated historical record at RC-4 based on flow relationships between Lucerne (RC-3) and RC-4. Table 4.3-5 also shows the average of measured flows for 1997.

Comparison of 1997 Flow to Historical Data

The historic flow record for Railroad Creek is 46 years in length. The 1997 flows were larger than the estimated average monthly values for the Site. Based on a review of the historical record at Lucerne, the 1997 monthly average flows would be the highest on record for May, July and September (see Appendix H) and near the maximum for June and August. The estimated peak flow in 1997, to be approximately 1,100 cfs (which occurred June 16 at RC-4), would be approximately a 10-year flood event, based on comparison with the historical record at Lucerne. Thus, flow in 1997 was relatively high in total volume of flow, consistent with the large snowpack, but not extreme with respect to peak instantaneous floods due to relatively moderate melt rates.

Predicted Flood Event Flows

To evaluate flood potential at Holden, the historic flow record at Lucerne and historic precipitation data for the Cascades was used to calibrate a HEC-1 model of the Railroad Creek watershed (Appendix H). Previous flood estimates for Railroad Creek, developed from the historic flow data at Lucerne, indicate that the 100-year flood for Lucerne is approximately 3,500 cfs to 3,900 cfs (see Appendix H). The 50 to 100-year flood at Holden has been estimated to be greater than 3,000 cfs (ORB, 1975; PNL, 1992). The HEC-1 model predicted a 100-year flood at RC-4 to be approximately 3,100 cfs, and 3,500 cfs at RC-2, which are within the same range of previous estimates.

4.3.3.4 Copper Creek

Channel Morphology

Referring to Figure 4.3-3a, the channel of Copper Creek flows between tailings pile 1 and tailings pile 2, and is confined to a relatively steep, moderately incised channel. The portion of the creek bed between tailings piles 1 and 2 was observed lined with a permeable geotextile material as part of the reclamation efforts completed by PNL and CH2M Hill between 1989 and 1991. The channel is relatively steep, averaging 17 percent between stations CC-1 and CC-2. The channel bed is comprised of boulders, cobbles and gravel, and the flow reflects a series of falls and cascades. An old channel of Copper Creek exists to the west of the current main channel upstream of tailings pile 1. The old channel splits off near station CC-1, and does not presently carry any flow. However, it is conceivable that flow could re-occupy this channel in the future during a storm event. If this were to happen, Copper Creek has the potential to flow onto a portion of tailings pile 1.

Streamflow

Streamflow of Copper Creek was measured at CC-1, or between CC-1 and CC-2, 13 times between May and September during the RI. The flow distribution is plotted on Figure 4.3-6 and indicates that the Copper Creek flow characteristics are similar to Railroad Creek. Difficulties in collecting accurate flow measurements due to highly turbulent flow conditions in Copper Creek prevented any meaningful comparisons of flow within the channel reach between CC-1 and CC-2 (flow accuracy is estimated to be on the order of 15 percent). As previously stated, however, the statistical average of flow measurements indicate that Copper Creek (including the Copper Creek diversion) consistently comprises about 12 percent of the flow as measured at RC-4.

The watershed of Copper Creek was measured to be 3.5 square miles in area, which is approximately 12 to 13 percent of the watershed area of Railroad Creek above RC-4. This indicates that flow per unit area of watershed in Copper Creek is nearly the same as Railroad Creek above the Site. The HEC-1 model was used to estimate peak floods for Copper Creek, and predicted a 100-year flood event of approximately 350 cfs. This is about 11 percent of the 100-year flood flow predicted for RC-4 using the HEC-1 model.

4.3.3.5 Copper Creek Diversion

Channel Morphology

A portion of Copper Creek is routed through a diversion structure approximately one-half mile south of the Railroad Creek confluence for use in generating power and water supply at Holden Village (Figure 4.3-3a). The diversion structure, located approximately 650 vertical feet above the valley floor, includes an intake for a pipe which transports potable water to the water storage tank located to the south of the mill structure; the tank is connected to Holden Village by a system of pipes. The diversion structure also includes an intake for a pipe which acts as a penstock for the hydroelectric plant located to the north of the mill building.

After flowing through the hydroelectric power plant, water from the diversion flows to the west side of tailings pile 1 and into Railroad Creek upstream of tailings pile 1 (Figure 4.3-3a). This water is in partial contact with debris and some tailings material within the short reach downstream of the hydroelectric plant before it enters Railroad Creek. A small portion of this water also flows to the outdoor sauna pool.

Streamflow

Discharge in the Copper Creek diversion is routed over a weir downstream of the hydroelectric plant. The height of water behind the weir is measured by a staff gage, and can be converted to flow in cfs via a weir rating table that is kept in the hydroelectric plant. The discharge was also measured directly by Dames & Moore in the field. During the April 1997 field program, discharge in the diversion was estimated to be approximately 2.8 cfs based on the staff gage height in the pool behind the weir. According to the Holden Village operations manager, the majority of flow from Copper Creek was diverted during April to provide power and water to Holden Village (personal communication with Mark Schmidt, 1997).

In 1997 the staff gage behind the weir was read relatively frequently, and ranged uniformly throughout the spring, summer and fall observations. The weir table indicates the measurements correspond to flows of 6.8 to 7.1 cfs. Direct measurements at the weir indicated slightly lower flows, between 5.5 and 6 cfs. The relatively minor difference between the rated flow and the measured flow may be due to measurement error at the weir, or may also be partially due to loss of flow via infiltration within the diversion channel and stilling pool behind the weir.

4.3.3.6 Portal Drainage

Channel Morphology

Referring to Figure 4.3-3a, the portal drainage emerges from the 1500-level main mine portal and flows downslope in both a man-made ditch and a natural drainage to a point approximately mid-way between RC-1 and RC-4 where it enters Railroad Creek. The drainage channel is composed of cobble and gravel, with a millimeter or more of whitish precipitate (apparent aluminum hydroxide) coating the bed materials throughout its length. Flow measurements were made in the drainage at the upstream end where it emerges from the mine portal (Station P-1), and at its downstream end just before entering Railroad Creek (Station P-5) during each sampling round, and on a weekly basis throughout the May/June 1997 sampling round.

Streamflow

Flow measurements in the portal drainage at stations P-1 and P-5 during 1997 are shown on Figure 4.3-7. For two out of the three paired flow measurements, P-1 was greater than P-5, indicating a loss of flow as the drainage water flows downslope, probably resulting from infiltration into the channel bed. The exception was during May when snowmelt runoff between P-1 and P-5 resulted in a higher flow at P-5. Flows ranged from a high in May/June of approximately 3.5 cfs, to a low of less than 0.3 cfs in mid-September.

A weir and water level data logger (transducer or Troll) were installed at the 1500-level main portal opening in the portal drainage in early October 1997 to collect relatively continuous water level data. The weir consists of wood planking installed across the bottom of the portal opening, with plastic sheeting placed on the upstream side to prevent leakage, and a V-shaped notch in the planking through which the water flows.

The data logger, or transducer, was placed in the pool behind the weir and measures water level. A rating curve was developed to allow discharge flow rates to be determined based on the height of water measured behind the weir with the transducer.

Referring to Figure 4.3-7a, transducer output for the period from early October to late December 1997 was very erratic. The erratic nature of the data may have been the result of freezing temperatures, which would likely have caused ice build-up in the V-shaped notch in the weir. The ice buildup could have restricted water flow through the V-shaped notch, resulting in increased water levels behind the weir. As the water levels continued to increase, the water would eventually overtop the ice, resulting in melting and a decrease in the pool level. This phenomenon could have been cyclical, which would explain the plotted data on Figure 4.3-7a.

Based on the precipitation data presented in Table 4.3-2, the months of highest precipitation at Holden Village are October through March. Referring to Table 4.3-3, the average temperatures between November and February are below 0°C (32°F). Therefore, the precipitation would fall in the form of snow.

As snow continued to accumulate through the months of November and December, the portal opening would eventually be filled with snow. The snow would insulate the portal, thereby reducing the likelihood of freezing. Referring to Figure 4.3-7a, the transducer data output after December becomes less erratic. Another possible explanation for the erratic data during the period between October and December may be the impact of freezing temperatures on the operation of the transducer. Due to relatively low water levels during this period of time, the majority of the transducer would not be in the water, making it susceptible to freezing. Assuming that the portal opening becomes blocked with snow after December, as speculated above, the insulating conditions would reduce the likelihood of freezing conditions, and the transducer would function normally.

It is also possible that the erratic behavior depicted on Figure 4.3-7a from early October to late December is the result of a combination of the above-mentioned phenomena. As noted on Figure 4.3-7a, the discharge rate of the portal drainage was observed to be relatively constant from early January 1998 to late April 1998, and then climbed from approximately 0.05 cfs to approximately 1.80 cfs within approximately one to two days. Between late April to early June 1998, the discharge rates fluctuated between approximately 0.70 cfs to 1.70 cfs. However, the data record was interrupted for six days in May 1998 when the plastic lining placed on the upstream side of the weir failed, resulting in loss of water. The weir was repaired and the transducer reinstalled on May 7, 1998. Figure 4.3-7b is a graphical representation of portal drainage discharge and precipitation data collected at Holden Village in 1998. Precipitation data were not available for Holden Village for October 1997 through early May 1998 in order to allow a comparison of transducer data for that period of time. However, the comparison of precipitation and transducer data for the period between early May and mid-October 1998 indicate the following:

- For the period of time between early May and mid-June 1998, the portal drainage responded within approximately one day of precipitation events with discharge rate increases as high as 100 percent when compared to the pre-precipitation event conditions. The flow increases were short-lived and the discharge rate returned to pre-precipitation event conditions within approximately one day.

- As the summer season progressed, the response to precipitation events became less evident.

This relatively rapid response to precipitation events suggests that any of the following may be occurring: (1) the portal drainage reflects the pool level in the mine (it is not possible for the water levels in the mine to increase fast enough to account for the increased discharge rates observed); (2) the bedrock in the mine is relatively saturated during spring and early summer and, therefore, responds relatively quickly to precipitation events; and (3) as the summer months continue, the bedrock becomes less saturated and, therefore, responds less dramatically to precipitation events.

4.3.3.7 Seep, Surface Water Runon, Runoff, and Infiltration

This section addresses surface waters that contribute to flow in Railroad Creek from the Site that are intermittent and that do not flow in a defined tributary channel. These surface waters include select seeps which reflect surface water, runoff and runon. In addition, infiltration of runon and runoff into the tailings and soils at the Site is also addressed.

Water sample locations that have been designated as seeps include direct groundwater discharges observed at the ground surface, and drainage ditches which combine runoff generated on the Site and in some cases runon from upgradient sources. Groundwater discharge may also contribute to flow in ditches. At the request of the Agencies, ponded surface water that receives seepage and which was sampled during the field investigation have also been designated as seeps. Table 4.3-6 lists all of the designated seep sample locations, including seep water source, receiving water and measured/estimated flow rates for the four sampling rounds in 1997 and any additional sampling rounds that were collected at each seep location. All seep sample locations are shown on Figure 4.3-8.

Generally, seeps emerging from the banks of Railroad Creek and from the base of the tailings piles discharge groundwater directly, and do not include component runon/runoff flow. The groundwater seeps are expressions of general groundwater discharge from the valley sidewalls, and typically emerge along seepage fronts, which become concentrated in specific areas where they were observed and sampled. The flow in these seeps is greatest during spring immediately after snowmelt, and their highest flow coincides with the highest groundwater levels (see Section 4.4). Most of the groundwater seeps cease flowing during the late summer as groundwater levels drop; however, several were observed flowing, albeit at a low rate, throughout the 1997 field season.

Throughout September and early October 1997, a series of rainstorms resulted in a rise in groundwater levels with subsequent increase in seepage flow. However, seeps did not increase flow or begin to flow again until the beginning of October after several weeks of rainfall. Nearly 4.5 inches of rain fell in September and more than 3 inches at the beginning of October, including 6 storms exceeding 0.5 inch in 24 hours (Figure 4.3-9a), before seep flow was observed to increase. This relation suggests that there is a lag time between recharge and seep response, and that a relatively large amount of recharge is necessary to replenish groundwater levels before seepage flow is increased.

In general, flow from groundwater dominated seeps is low relative to flow in Railroad Creek. Groundwater seeps located along the streambanks of Railroad Creek are also impacted by the water levels in the creek. These seeps, including SP-1, SP-3, SP-4, SP-9, SP-10E, SP-10W, SP-11, SP-12, SP-24, and SP-25, become submerged at high water levels. Flow in SP-5 (near the northeast corner of tailings pile 3) varies in direct response to flow in Railroad Creek because the discharge point for this seep is below the water surface elevation in the adjacent Railroad Creek. Thus, head in the creek influences flow rates in SP-5.

Referring to Figure 4.3-8, surface water runon from offsite sources onto the tailings and mine workings, and subsequent direct surface runoff from the tailings and mine-related features was evaluated by observations made during the May/June, July and September 1997 field programs.

During May/June 1997, water was flowing in drainage ditches on the upslope side of tailings pile 1 (SP-20) which was routed directly into Copper Creek. The water in this ditch appeared to be meltwater from upslope wooded areas, and to a lesser degree meltwater generated on the access road to the tailings piles. Although the majority of this water was routed into Copper Creek, an unknown amount of surface water was observed infiltrating into an apparent open decant tower at the upstream end of tailings pile 1 (near the northeast corner of the base of the eastern waste rock pile), thus potentially contributing to groundwater stored within this pile.

During May/June, flow in the SP-18 drainage channel, which discharges to SP-21 and then into Railroad Creek downstream of tailings pile 3, also appeared to include snowmelt from areas upslope of tailings piles 2 and 3.

Seepage water was also observed in May emanating from the base of the eastern waste rock pile (SP-8). The water was observed flowing into a culvert and then across tailings pile 1 in a drainage ditch constructed by the USFS in 1991 (SP-19). The water eventually flowed into the Copper Creek diversion below the sauna pool. The potential exists that water infiltrates into tailings pile 1 for the brief period of seepage flow.

Direct meltwater runoff from the abandoned mill area and waste rock piles collected in seeps SP-6, SP-7 and SP-15 and was routed into the lagoon (SP-16), with limited discharge into Railroad Creek. Meltwater runoff also appeared to comprise a component of SP-12, SP-23, and the Honeymoon Heights intermittent drainage (SP-14). Flow from SP-12 and SP-23 discharges directly into Railroad Creek. Flow in SP-14 has no direct surface outlet into Railroad Creek; however, the drainage feature appears to be coincident with an apparent avalanche chute which terminates near both SP-12 and SP-23. A seep was observed flowing from the base of the 800-level waste rock pile and into the intermittent drainage (SP-14) during June 1998 (personal communication with Rick Roeder, Ecology, and Norm Day, Forest Service, 1998); however, the seep was not observed later during a visit in July 1998.

During sampling events in July and September 1997, surface water runoff was not observed on the tailings piles. During relatively high rainfall in mid-September, runoff was observed pooling in the drainage ditches at the southern end of tailings pile 1 and flowing in road ditches along the access road to the museum and portal area. Additionally, SP-14, SP-15E and SP-23, which were all dry before the precipitation events, began to flow again within several days, indicating a relatively rapid response to rainfall runoff. Surface water runoff also accumulated in meltwater ponds on tailings pile 1, in the wetland area east of tailings pile 3, and in the SP-2 area.

Based on these observations, it is concluded that drainages associated with SP-12, SP-14, SP-17, SP-18, SP-19, and SP-23, carry runoff from meltwater and heavy rainfall. SP-6, SP-7, and SP-15 also transport runoff into the lagoon (SP-16). Observations of the surface of the tailings piles and slopes within the Site area indicate that there is little evidence of rilling or any overland runoff from the tailings piles. This observation would include that infiltration to the tailings piles is more likely to occur as compared to runoff. The only area where rilling from overland runoff was observed was in windblown tailings piles and soils west of tailings pile 1, between the tailings piles, and the Copper Creek diversion in the area immediately down slope of the access road, and in the windblown tailings and soils within the Copper Creek channel and banks between tailings piles 1 and 2. Runoff from the west side of tailings pile 1 would flow into the SP-19 ditch or into the Copper Creek diversion channel, and runoff within the Copper Creek channel would flow directly into Copper Creek.

Runon from upgradient sources during melt and heavy rainfall would tend to be routed in existing drainages either to Copper Creek, the Copper Creek diversion, directly into Railroad Creek, or into the SP-16 lagoon; the water which collects in the lagoon appears to infiltrate into the subsurface soils. Some of the runon collected in the ditches and lower-lying areas on the surfaces of the tailings likely infiltrate into the subsurface. The amount of infiltration resulting from run-on into the tailings is not expected to be large because of the relatively small areas of infiltration and the relatively low permeabilities measured in surfaces of the tailings historically by others (Hart Crowser, 1975) and Dames & Moore during the RI.

Runoff from the tailings piles and surrounding areas would be generated when either snowmelt or rainfall exceeds the infiltration and holding capacity of the surface soils. The holding capacity is a function of the slope and storage capacity or condition of the surface. Surfaces that are highly irregular and include a porous material or dense leaf litter, tend to hold more water within interstices and in puddles. Smooth surfaces made up of uniform materials will generate more runoff. Surface slopes on the tailings piles are relatively flat and in some areas shallow ponds develop (as observed on the southern portion of tailings pile 2 during the May 1997 and 1998 sampling events). Additionally, loose gravel surfacing on the piles allows for water to be stored within the surface soils, encouraging infiltration and decreasing runoff potential. Surrounding soils on slopes are steeper; however, they include leaf litter and organic forest soils that would store water and inhibit the generation of runoff. Neither the surface conditions on the tailings piles or on surrounding areas are conducive to creating runoff and runon to adjacent areas.

Steep tailings pile slopes, areas that are not capped by the loose gravel, and compacted access road surfaces are more likely to generate runoff and runon during snowmelt and during large rainfall events. Limited rilling was observed during the RI in several of these areas. Runoff is also generated from areas that become saturated and are sloped. These saturated areas occur adjacent to drainages and where snow or rainfall accumulates. The saturated areas appeared to occur adjacent to drainage ditches on the upslope side of the tailings piles and in lowland areas on the banks of Railroad Creek.

The infiltration potential of the tailings material beneath the gravel cap has been estimated to be on the order of 4 to greater than 20 inches per day under saturated conditions (see Section 4.4). The saturated infiltration capacity, under most conditions, represents the lowest potential infiltration rate. Exceptions to this occur when extremely dry soil repels water due to surface tension of the dry dust. However, dryness under most conditions will accelerate infiltration because of negative pressure heads in the soil. Comparing the saturated infiltration capacity to expected snowmelt rates, assumed to have averaged 1.6 inches per day (50 inches of water equivalent snowpack for 1997 melted over the time period April 16 to May 19) indicates that melt rates are generally below potential infiltration capacities of the tailings pile material. Based on this, it is possible that the snow which accumulated on the tailings piles could have infiltrated in 1997, except in areas of steeper slopes and where the ground became saturated. However, during days of high snowmelt, runoff may be generated in areas where the infiltration capacity is lowest, as illustrated by the fact that the drainage ditches were observed flowing for periods of time in May and June. Few rainfall events are expected to exceed the infiltration capacity, except during the most extreme events, including hypothetical 50- and 100-year storms.

4.3.3.8 Other Tributaries to Railroad Creek

Several tributaries to Railroad Creek (Figure 4.3-2), other than Copper Creek (and the Copper Creek diversion), were sampled during 1997 and 1998 field programs and included Tenmile Creek, Holden Creek, RC-11, and Big Creek. The flow data collected for the tributaries was limited to one measurement. RC-11 is included as a tributary but is actually on Railroad Creek upstream of the Holden Creek confluence and is considered an upper basin tributary to the main channel of Railroad Creek.

Flow in Tenmile Creek in September 1997 was approximately 7 cfs, which was comparable to Copper Creek, excluding the Copper Creek diversion. The watershed area of Tenmile Creek is approximately 4 square miles (larger than the drainage of Copper Creek); however, the flow was significantly lower, by about one-half assuming the diversion was flowing at about 7 cfs. This indicates that flow contribution from the north side of the Railroad Creek basin may be less than the south side during spring due to the south-facing aspect of the slopes (solar gain during the winter months likely melts some of the snow before spring arrives).

Flow in the upper tributaries generally was not measured directly, but was visually estimated. During the October 1997 sampling event Holden Creek was estimated to be flowing at approximately 40 cfs, and Railroad Creek at RC-11 was estimated to be flowing at between 150 and 200 cfs. At the time of these estimates, flow at RC-4 was approximately 280 cfs. The watershed area of Railroad Creek above RC-11 is approximately 14 square miles, and the watershed area of Holden Creek is approximately 3 square miles. Based on watershed area ratios, the expected flow at RC-11 would be about 51 percent of the flow at RC-4 (watershed area 27 square miles) and Holden Creek would be about 11 percent of the flow at RC-4.

4.3.4 Railroad Creek Streambank Erosion

Channel observations in Railroad Creek indicate that sediment sources are limited within the basin, and that the channel carries a relatively low sediment load. For mountain streams in the Cascade Mountains, this condition is characteristic of channels exhibiting frequent cascading reaches alternating with relatively straight channel reaches with uniform bed material, and large clast riffle pool channels with bar development (Montgomery and Buffington, 1997); all of these conditions exist in Railroad Creek. This is also evidenced by relatively low amounts of sedimentation and limited delta development at the mouth of Railroad Creek. Because of the low sediment load and narrow valley for the majority of the basin, channel braiding is not a dominant feature of Railroad Creek. However, in the wider areas, braiding does occur, but likely does not shift frequently.

Channel erosion, therefore, is limited throughout most of the Railroad Creek channel reach, except for those cases where the presence of obstructions causes flow energy to be directed toward a bank. As noted above, this appears to have been the case at river mile 6.5, where an apparent avalanche during the winter of 1996/97 caused Railroad Creek to erode a side channel. This demonstrates that stream power within Railroad Creek can be large enough to move and transport large amounts of sediment, and erode its banks if flow becomes obstructed.

During most flow events, the channel bed material, which consists of cobble- to boulder-size material, is armored against bed movement and scour (i.e., the bedload is too large for typical flows to move). However, during peak flow events, channel scour can occur. This is evidenced by an apparent shift in the stage-discharge rating relationships at both RC-4 and RC-2 after the peak flow in June 1997. The stage-discharge rating seemed to recover (return to the pre-peak condition) within a relatively short time (several days to weeks); consequently, the channel scour effects do not appear to be long lasting and large.

Railroad Creek was observed to transport fine sediment during high flow events in the form of orange (iron-oxide) flocculent. During two high flow events (during May and September 1997), the water in Railroad Creek became relatively turbid and orange in color. This condition decreased significantly downstream, but was still visible at RC-3 (Lucerne) during the periods of storm events, but diminished soon thereafter.

For the channel reaches in Railroad Creek where Wolman pebble counts were completed to assess dominant channel bedsize (see Habitat study and Appendix H), an evaluation of the preferred channel form (straight or braided) is possible based on Henderson (1964). Henderson presents the following equation as a predictor of whether a channel will have a tendency to be straight or to braid based on channel slope and average bed grain size:

$$S = 0.64\,(d^{1.14})\,(Q^{-0.46}) \tag{4-4}$$

where:

S = channel slope

d = average grain size in feet

Q = dominant discharge in cfs

The dominant discharge is considered the discharge which would cause bed movement, usually taken to be the 2- to 5-year flood event. For Railroad Creek near the Site, the average bed size is typically 0.5 feet, and the dominant discharge can be taken to be about 900 to 1,000 cfs (the 2- to 5-year peak flow estimated from the Lucerne historical flow data, and the flood that apparently caused bed scouring at RC-4 and RC-2).

Based on the above values, a channel slope of less than about 1.2 percent would result in a straight channel, and a slope greater than 1.2 percent would be braided. At the Site, the channel slopes are around 1.5 percent on average, indicating that the channel is right on the edge of a geomorphologic threshold. This condition indicates that a channel disturbance could easily cause the channel to try and adopt a wider or braided channel to establish equilibrium. As the channel slope steepens downstream from the Site braiding does appear to develop (between RC-2 and RC-5A, and downstream of the log jam at Tenmile Creek) until the bed size increases in response to higher stream power (greater discharge and velocity), thus increasing the threshold slope value. This analysis does not consider the effect of the channel confinement by the valley sides and by riprap and/or cribbing along the tailings piles. However, it indicates the potential for the creek to erode its banks, especially if a channel blockage or disturbance were to occur.

4.3.5 Basin Average Climatic Water Budgets

Basin average monthly water balances or budgets were developed for the portion of the Railroad Creek watershed above Lucerne and the reach above RC-4 to evaluate the relationship between water inputs and outputs, including precipitation and glacial melt runoff (inputs), streamflow runoff and evapotranspiration (outputs). The water budgets assumed that, over the long term, change in storage within the basin, consisting of changes in groundwater storage and storage as permanent ice and snow (glaciers) were negligible. The long term precipitation and temperature data for Holden Village were used to develop the long term water budgets, adjusted to represent either the entire watershed above Lucerne, or the watershed above RC-4. Table 4.3-6a presents the water balance results.

The component parts of the water budgets are described by the equation:

$$Q = P + M - ET - I + GW + CS \tag{4-5}$$

where:

Q = streamflow runoff

P = precipitation

M = meltflow from glaciers and stored ice

ET = evapotranspiration

I - infiltration

GW = groundwater

CS = change in water storage in the watershed

The change in storage within the watershed reflects groundwater recharge and discharge, and accumulation and melt of precipitation stored as snow. Within typical watersheds, storage conditions tend to equalize over a period of years assuming climatic changes do not occur, or if so, the changes occur at a rate too slow to significantly impact watershed storage. Over the long term M, I, GW, and CS are assumed to equal zero.

In completing an annual basin average water budget for Lucerne, some of the variables presented in the above equation were found not to be applicable. The annual basin average water budget was calculated based on long term average annual precipitation (USGS, 1984), and discharge measured at Lucerne was completed as a check on the monthly estimates based on the following equation:

$$P = Q + AET \tag{4-6}$$

where:

P = average annual precipitation for the basin (52 inches)

Q = average annual streamflow runoff (42.5 inches)

AET = average annual evapotranspiration (10.5 inches)

Referring to Table 4.3-6a and 4.3-6b, the results of the annual water budget yields a comparable value for AET as was estimated from potential evapotranspiration (PET) and the monthly water budget data. The long term monthly water budgets are considered to be reasonably representative of actual conditions. Based on this, long-term and short-term (1997 spring and summer) water budgets were developed for the Site using the same estimating methods. The water budgets shown on Table 4.3-6b assume a Site area of 120 acres located between RC-4 and RC-2, including the tailings piles, the waste rock piles and the mill site. The water budget totals were estimated by subtracting the estimated evapotranspiration (in inches) and runoff (converted to inches by dividing the runoff totals for the month by the estimated 120 acres of contributing area) from the total precipitation. If the precipitation was less than the evapotranspiration, then evapotranspiration is limited to the available water, or the precipitation total.

The objective of the analysis is to evaluate whether climatic inputs (P) could account for the observed groundwater and seep runoff from the Site. As an average estimate of runoff, the Railroad Creek flow relationship ratios were used. As stated previously, runoff between RC-4 and RC-2 averages between 0 and 3 percent of the flow at RC-4, excluding input from Copper Creek (Table 4.3-4). Taking the average of this, runoff from the Site was assumed to be one half of the average (this assumes half of the estimated inflow arrives from the south side of the valley), or 0.75 percent of the monthly average flow at RC-4.

Based on these assumptions there is a significant deficit of water at the Site based on the negative net change in storage (Table 4.3-6b). The deficit in the Site water budgets indicate that a significant portion of inflow (groundwater and seepage) between RC-2 and RC-4 is generated from areas upgradient of the Site. On average, the upgradient source inflow could be as high as 40 percent (total deficit divided by total runoff). The upgradient inflow source areas probably include groundwater recharge higher up in the basin discharging through the bedrock and alluvial aquifers beneath the tailings and waste rock piles, down valley groundwater flow through the alluvial floodplain sediments which underlie the tailings piles, and to a lesser degree recharge upslope of the tailings and waste rock piles and the mill building from upgradient meltwater runoff.

A discussion of the site-specific water balance is presented in Section 4.4.4.

4.3.6 Hydraulic Analysis and Synthesis

4.3.6.1 Predicted Flood Levels at Site

The climatic data, watershed characteristics determined from topographic maps, and historic streamflow data were used to develop and calibrate a watershed model Hydrologic Engineering Center-1 (HEC-1) of the Railroad Creek basin. The model predicted the 100-year and lesser floods for comparison with previous flood estimates (ORB, 1975), and as input to the HEC-2 hydraulic model of the channel adjacent to the tailings piles.

The HEC-1 and HEC-2 models of Railroad Creek watershed and Railroad Creek channel adjacent to the Site provide estimates of water levels and flow velocities along the tailings piles. The results of the modeling indicate areas of potential erosion for use in the development of remedial design options to address the potential for erosion of the tailings piles. Geomorphologic observations and observations of surface erosional features provide information to assess the potential for transport of eroded tailings to and within Railroad Creek.

To further evaluate the potential for flood impacts and erosion within the reach adjacent to the Site during a hypothetical large flood event, a HEC-2 hydraulic model was developed for the reach with the estimated 100-year flood event routed through the reach from RC-1 to RC-2. The input data for the HEC-2 Site modeling was the HEC-1 basin modeling; the HEC-1 data and model results are provided in Appendix H. In summary, areas of potential erosion were identified when hypothetical Railroad Creek flow levels overtopped protected banks within the reach and flow could not expend energy within a floodplain on the opposite bank. This condition occurred upstream of the right abutment at the Railroad Creek foot bridge (at RC-4), at the Copper Creek confluence, and at the left abutment at the Goat Bridge ("Sven's Bridge") (at RC-2).

Based on the results of the modeling, the water levels within Railroad Creek at the Copper Creek confluence were elevated due to momentum exchange resulting from Copper Creek entering Railroad Creek at a 90 degree angle. In many places within the reach, the model indicated flow within Railroad Creek to be near or at "critical velocity." When flow is at or above critical velocity, flow is unstable and disturbances can cause a "hydraulic jump." Within this type of flow situation, water levels increase through the jump, and turbulence is extreme, as suggested by the model at the Copper Creek confluence. Because of this, the area at the junction of Copper Creek and Railroad Creek is susceptible to greater erosion potential than any other stream segment protected by riprap. During field observations, it was noted that cobbles and other alluvial sediments had been deposited near the top of the riprap protecting tailings pile 2 immediately downstream of the Copper Creek confluence. This was the only segment of Railroad Creek on the Site where this was observed and seems to verify the results of the HEC-2 model. At all other locations adjacent to the tailings, the predicted water levels appeared to be slightly below the top of the riprap.

A potential concern was identified during field observations of the portion of Copper Creek upstream of the tailings piles. An old channel of the creek was observed to the west of the existing channel. The abandoned channel is currently dry, and splits off from the main channel upstream of CC-1 (Figure 4.3-3a). However, in the event that this channel were to be reoccupied, flow could be directed onto the top of tailings pile 1.

4.3.6.2 Predicted Riprap Size to Prevent Erosion

The following summarizes the results of office analyses to estimate the size of the riprap for Railroad Creek adjacent to the tailings piles in order to prevent erosion during a hypothetical 100-year storm event. The methods used were based on an average velocity in the channel section for the 100-year event, based on Hydrologic Engineering Center-River Analysis System (HEC-RAS) model output and depth and slope method from the Soil Conservation Service (SCS, 1975). The baseline data included channel width, depth, side slope, average channel velocity and slope. These data were obtained in the field and from HEC-RAS hydraulic modeling results.

Average Stream Velocity Equations Method

The following equations were used to estimate the average riprap rock size (D50) in feet based on average channel velocity (Blodgett and McConaughy, 1986). The average channel velocity along tailings piles 2 and 3 was determined to be 10 to 11 feet per second, with a maximum estimated velocity between 13 and 15 feet per second during the hypothetical 100-year event.

$$D50 = 0.0273(Va)^{1.83} \qquad (4\text{-}7)$$

where:

Va = average channel velocity in feet per second

$D50$ = 2.2 feet

(Source: USDOT, 1970)

$$D50 = 0.0122(Va)^{2.06} \qquad (4\text{-}8)$$

where:

$D50$ = 1.7 feet

(Source: Blodgett and McConaughy, 1986)

$$D50 = 0.01(Va)^{2.44} \qquad (4\text{-}9)$$

where:

$D50$ = 3.5 feet

(Source: Blodgett and McConaughy, 1986)

Based on the above equations, the average D50 riprap size should be on the order of 2 to 3 feet in order to protect the lowermost tailings pile slopes from erosion by Railroad Creek.

SCS Method

Utilizing the SCS method, the following riprap rock size was calculated:

Input Data:

Channel side slope = 1.5 to 2.5 to 1, average 2 to 1
Channel slope = 1.5 percent
Average channel depth = 5 feet
Channel width = 50 feet
Channel discharge = 3,500 cfs

The D50 equation is obtained from the graphs in the SCS method and/or the following equation:

$$D50 = 12(118QS^{2.17}R/P)^{0.33} \tag{4-10}$$

where:

Q = discharge

S = channel slope

R/P = the hydraulic radius divided by the wetted perimeter which is a function of channel width, depth, and side slope

Utilizing the SCS method, the estimated D50 is, therefore, approximately 1.5 feet in order to protect the lowermost tailings pile slopes from erosion by Railroad Creek.

Summary of Riprap Size Analysis

Based on all of the above methods, the riprap D50 should be on the order of 1.5 to 2 feet in diameter in order to protect the lowermost tailings pile slopes from erosion by Railroad Creek. However, the D50 for the SCS method assumes straight channels; thus, these rock sizes should not be used at the confluence of Copper Creek, which is at a bend of Railroad Creek and has the potential to experience super elevation. The larger estimated rock sizes would, therefore, be determined to be necessary to prevent erosion immediately downstream of the Copper Creek confluence.

The results of the assessment of the condition of the existing riprap (Section 4.2.7) indicates a range of actual rock sizes (Table 4.2-5). A complete inventory of the riprap sizes was not completed. However, it appears that the existing riprap for portions of the Railroad Creek streambank is not of sufficient size to prevent erosion of the tailings piles during a 100-year event.

4.3.7 Baseflow and Surface Water/Groundwater Interaction

Groundwater and surface water interaction throughout the Lake Chelan Watershed and in the Site vicinity is assumed to be largely dependent on the highly variable geologic conditions. In general, the alluvial and glacial aquifers in hydraulic continuity with a river or stream typically experience a high degree of water exchange with the associated water source. These aquifers typically discharge to streams during low flow periods and receive recharge from the stream during high flow periods. Aquifers, like the bedrock aquifer, that are separated from surface water bodies by depth or distance are relatively "confined" and/or are composed of low permeability materials and require greater periods of time for water exchange to occur, resulting in attenuation or dampening of the seasonal variability associated with surface water trends.

Based on the hydrologic conditions in the Railroad Creek basin, the single most significant hydrologic event of the year is snowmelt, which comprises the primary groundwater recharge event and source of streamflow to Railroad Creek. Summer and fall rainfall events in excess of 0.5 inches occur relatively infrequently at the Site; however, they can result in rapid increases in streamflow and groundwater recharge. Rainfall events observed during the September 1997 sampling period indicated that flow in Railroad Creek and Copper Creek can rise relatively rapidly, once the watershed becomes saturated. However, seep flow appears to lag considerably behind the creeks in response to rainfall. Rain storms that began at the Site in mid-September 1997, and continued off and on through October resulted in significant increases in streamflow often within approximately 12 to 24 hours of the rainfall event. However, seepage flow increases were not observed during the summer rainfall events, but were noted during a larger rainfall event in October 1997, and then only in selected seeps along the tailings piles (SP-2 and SP-3) and selected seeps upstream of the tailings (SP-7, SP-14, SP-15, SP-23 and SP-23B). This indicates that a relatively large influx of rainfall infiltration is necessary to saturate the soils underlying the Site and cause seep flow increases after a prolonged dry period.

Baseflow in Railroad Creek is sustained by discharge from lakes and subsurface flow from glaciers, and from groundwater inflow along its length. Baseflow is defined as a steady low flow condition which reflects sustained inflow from groundwater and surface water stored in the basin, and is not a direct response to meteorological events such as rainfall and snow/ice melt. In the vicinity of the Holden Mine Site, groundwater inflow to Railroad Creek occurs from seeps and from groundwater discharge directly through the streambed.

Baseflow conditions were observed in Railroad Creek during the mid-April 1997 (Table 4.3-7) stream sampling event, and during the baseflow survey completed in mid-September 1997 (Table 4.3-8). An additional baseflow survey was performed in October 1998. At the time of these observations, the stage (water surface elevation) in Railroad Creek remained nearly constant, indicating a baseflow condition with runoff from rainfall and snow/ice melt not a significant contributor to flow.

4.3.7.1 April 1997 Survey

During the April baseflow observations, stage at RC-4 increased slightly after the first flow measurements were made (April 16, 1997), but then remained constant during the remainder of time that flow measurements were collected (April 17, 1997, to April 18, 1997). Table 4.3-7 shows the magnitude of flow measured at each station, displayed on the table from upstream to downstream (Figures 4.3-3 and 4.3-3a).

Flow measurements made on April 16, 1997, between RC-6, RC-1 and RC-4 indicate that there is a gain in flow between RC-6 and RC-1, and a loss of flow between RC-1 and RC-4. Considering the assumed accuracy of the wading measurements used to measure flow (+/-5 to 7 percent), the gain in flow between RC-6 and RC-1 may range between 0 to 16 cfs. Similarly, the loss of flow between RC-1 and RC-4 may range between approximately -11 cfs and a gain of 6 cfs. A gain in flow between RC-6 and RC-1 would be the expected condition for Railroad Creek, as the creek generally gains flow in a downstream direction over its length. However, the apparent loss of flow between RC-1 and RC-4, although not expected, is corroborated by the flow relationships identified in Table 4.3-4. As discussed previously (Section 4.3.3.3), the loss of flow between RC-1 and RC-4 may reflect downvalley flow through an old Railroad Creek channel buried beneath the tailings piles.

It is difficult to assess the groundwater inflow between RC-4 and RC-7 during the April 1997 sampling because of the contribution from Copper Creek, which could not be measured due to snow cover, and a slight increase in stage between the April 16 and 17 measurements which may have increased flow between flow measurements at RC-4 (morning of April 16) and RC-7 (afternoon of April 16). However, assuming that Copper Creek accounted for 4 to 10 cfs of the gain between the stations, and the increased stage (observed between the time that flow was measured at RC-4 and RC-7) accounted for 6 cfs (based on the effect of a 0.05-foot stage increase at RC-4 as estimated from the RC-4 rating curve), a baseflow increase of 1 to 7 cfs could be attributed to groundwater inflow along the channel reach.

Flows measured at RC-7 and RC-2 indicate a gain in flow between these stations of approximately 3 cfs accounting for an increase of 6 cfs between April 16 and April 17 due to a rise in stage of 0.05 feet. This groundwater gain is approximately 3 percent of the flow measured at RC-2, which is comparable to the maximum percentage gain estimated in Section 4.3.3.3 using the average flow increase between RC-4 and RC-2 (subtracting Copper Creek) for all of the 1997 measurements. Flow was observed to decrease between RC-2 and RC-5 (located downstream of RC-2; see Figure 4.3-3) by approximately 8 cfs (9 percent relative to RC-2), which is consistent with field observations.

4.3.7.2 September 1997 Survey

A baseflow survey was also completed during the September 1997 sampling round to evaluate the baseflow conditions before the winter season. During this survey, flow was measured in one day at all streamflow monitoring stations at the Site (Figures 4.3-3 and 4.3-3a). Table 4.3-8 shows the flow measurements obtained during this survey. The results of this survey indicate a different groundwater contribution pattern compared to April 1997. Flow measurements between RC-1 and RC-4 indicate a gain of approximately 5 cfs, of which 0.3 cfs was determined to be from the portal drainage. The measured flow gain, however, is within the measurement error (± 5 to 7 percent); consequently, the findings are not conclusive.

Flow measurements between RC-4 and RC-7 indicate a gain of 13 cfs which can be accounted for entirely by Copper Creek flowing into Railroad Creek within this reach. This indicates that there is little groundwater gain along this reach. During this sampling event, most of the seeps along this reach were not flowing or were flowing at extremely low rates. Additionally, flow was apparently lost between RC-4 and RC-9; however, there does not appear to be an explanation for this and may be the result of measurement error. The flow loss as measured indicates that the reach is not gaining significantly from groundwater. There also does not appear to be groundwater gain between RC-7 and RC-2. Flow between RC-2 and RC-5 (downstream of RC-2) indicates a similar pattern as April, with an apparent loss of flow. However, referring to Table 4.3-8 and Figure 4.3-3a, this flow is apparently regained downstream of SP-21, which indicates that there is a groundwater contribution near the valley wall on the south side of the creek (downstream of tailings pile 3).

4.3.7.3 October 1998 Survey

Additional baseflow measurements were made during October 1998 in Railroad Creek between stations RC-6 (encompassing RC-1) and RC-4 in order to further characterize the nature of the flow loss that was observed between RC-1 and RC-4 during 1997. The 1998 baseflow survey was designed to characterize the flow loss noted between RC-1 and RC-4 in 1997, and to evaluate the specific locations of this loss. The streamflow measurement error is assumed to be on the order of 5 to 7 percent of the actual flow because of the irregular streambed, and therefore individual measurement error could easily be greater than the necessary detection of flow gains and losses. Therefore, the streamflow measurement strategy included four measurements at each selected station to provide an average value of the flow.

The October 1998 baseflow survey included five stations (BF-1 through BF-5) between RC-6 and RC-4 (Figure 4.3-10). Over the course of the measurements (approximately 5 hours) the stage in Railroad Creek was measured continuously with an electronic data logger situated at RC-4. The data indicated that the stage in Railroad Creek did not change, indicating that the flow measurements are directly comparable.

Referring to Figure 4.3-10 and Table 4.3-9, the results of the survey indicate an apparent increase in flow between the 1500-level main portal drainage (P-5) and Railroad Creek adjacent to the Holden Village septic field (approximately midway between P-5 and RC-4), with a subsequent loss of a similar quantity of flow between the septic field and the vehicle bridge (upstream of RC-4).

Statistical analyses were completed in order to evaluate the results of the October 1998 baseflow survey in terms of accuracy and precision; the results of analyses are presented in Appendix N and are summarized herein. Referring to Figure 4.3-10 and Table 4.3-9, the mean flow measured at stations BF-1 and BF-5 during the October 1998 flow survey appear to remain relatively constant. However, there is an apparent increase in flow noted between stations BF-2 and BF-3 (8.5 percent), and a similar decrease in flow between stations between BF-3 and BF-4. The standard deviation was calculated for each station; the values were found to range between 0.8 and 2.2 cfs. Taking the standard deviation into account, the data appear to suggest no significant change between the stations.

Consequently, additional statistical analyses were performed in an attempt to further evaluate the accuracy and precision of measurements. The statistical differences between the means (utilizing the one-tailed students t-test) appears to confirm that there is no significant difference between the means of BF-1 through BF-5 at the 95 percent confidence level. Thus, there remains a question as to the significance and magnitude of the observed flow loss and gain within this reach of Railroad Creek. Due to this question, the water balance analysis has assumed that the loss (indicated as Qa1 in the water balance equation), may range from 0 to 1.0 cfs. The gain is (Qag) estimated to be 1.5 cfs in the spring and 0.5 cfs in the fall for the entire reach (see Section 4.4.4.8).

4.3.7.4 Other Related Observations

Water surface elevations observed on May 20, 1997 indicated that the water surface in the segment of Railroad Creek adjacent to the wetland area immediately east of tailings pile 3 (see Figure 4.3-3a) was nearly 2 feet higher than the elevation of the wetland. This appears to verify the observed flow loss within the reach between RC-2 and RC-5. This apparent condition may be the result of stream confinement, which has restricted the floodplain and associated sediment storage areas, with the result that higher permeability alluvial materials have been transported and deposited downstream of the tailings piles where the channel is no longer confined by the riprap and tailings piles.

A zone of mixing of surface water and groundwater likely exists beneath Railroad Creek. This area of mixing is called the hyporheic zone which is defined as a zone of mixed surface water and groundwater that may occur in the interstices of the bed sediment in direct contact with the water (Benner et al., 1995). However, the presence of ferricrete, as described in Section 4.3.9, may limit direct mixing between groundwater originating from the tailings piles and Railroad Creek water by armoring the streambed. The implications of the hyporheic zone in terms of the fate and transport of constituents of potential concern are discussed in Section 6.8.2 of this report. It is possible that during baseflow periods the interaction between surface water and groundwater is limited for those portions of Railroad Creek adjacent to the tailings piles, with interaction increasing immediately downstream of tailings pile 3. This is indicated by the apparent flow loss between RC-2 and RC-5, followed by an apparent gain in Railroad Creek flow measured approximately 100 feet downstream of RC-5, as discussed above.

Other observations with respect to surface water and groundwater interaction include the relationship between precipitation and flow rates in Railroad Creek and the 1500-level main portal drainage. Referring to Figures 4.3-4a and 4.3-7b, both Railroad Creek and the portal drainage appear to respond relatively rapidly (i.e., within approximately one day) to precipitation events that occur during the spring snowmelt period. This appears to suggest that the soil and bedrock are saturated during this period of time. However, as the snowmelt diminishes through the summer months, the response to precipitation becomes less pronounced for both the portal drainage and Railroad Creek, likely due to the soil and bedrock becoming less saturated.

4.3.7.5 Summary of Baseflow Survey

Railroad Creek upstream of the Site appears to be a gaining stream between RC-6 and RC-1 (Figure 4.3-3a). However, adjacent to the Site, flow gains and losses are variable. It appears that, at least during parts of the year, flow is lost between upstream stations RC-1 and RC-4, and immediately downstream of RC-2. Flow appears to be gained due to groundwater inflow (subtracting inflow from Copper Creek and the Copper Creek diversion) between RC-4 and RC-2 during spring. Gains and losses potentially attributed to groundwater flow are within the accuracy of the measurements during the fall and are, therefore, inconclusive when considered independent of other site information.

4.3.8 Hydrologic Conditions During the 1998 RI and Comparison With 1997 Rate

During 1998, stream flow measurements were collected in Railroad Creek with a data logger installed at the RC-4 and portal drainage P-1 stations (Figure 4.3-3a). In general, the discharge of Railroad Creek during the May 1997 sampling appeared higher than the discharge during the May 1998 sampling (compare Figures 4.3-4 and 4.3-4a). The discharge in the portal drainage was also higher in 1997 than 1998 (compare Figures 4.3-7 and 4.3-7a).

Based on these data, both the 1997 and 1998 RI spring runoff water quality samples were apparently collected on the rising limb or near the peak of the initial hydrograph rise (Figures 4.3-4 and 4.3-4a).

4.3.9 Interstitial Iron-Oxide Precipitate and Ferricrete

4.3.9.1 Summary of Historical Findings

The U.S. Bureau of Mines (USBM) completed an assessment of the Railroad Creek substrate in April 1994. The assessment included the mapping of the presence or absence of interstitial iron-oxide precipitates and ferricrete. The methods employed the probing of the substrate as part of the sampling of interstitial fluid (see Section 5.4.3). The probing did not allow the differentiation between non-cemented and cemented interstitial iron-oxide precipitates. However, it appeared that the cemented iron-oxide precipitates (ferricrete) were generally limited to the banks of Railroad Creek near the northeast corner of tailings pile 1 and the northwest corner of tailings pile 2 (Lambeth, 1998). Figures 4.3-3c and 4.3-3d display the results of the mapping.

4.3.9.2 RI Findings

The physical and chemical characteristics of the interstitial iron-oxide precipitates found in a cemented to partially cemented condition (ferricrete) adjacent to Railroad Creek were evaluated as part of the RI.

Test Pit Excavations

Four backhoe excavated test pits were completed as part of the ferricrete assessment (Figure 4.2-6b). The test pits were excavated within the highwater channel or wetland floodplain of Railroad Creek. The test pits were generally 3 to 4 ft wide and from 3.5 to 7.0 ft deep. Test pit logs are found in Appendix C. Water was encountered in all of the test pits.

Based on the test pits and the visual inspection of ferricrete exposures along the south bank of Railroad Creek, ferricrete varied considerably in thickness, hardness, degree of cementation, texture, grain size distribution, sorting and color. In places (i.e., along the south bank of Railroad Creek adjacent to tailings pile 1) ferricrete was observed as a non-sorted conglomerate (i.e., grain supported) or diamictite (i.e., matrix supported) of angular and rounded cobbles and wood pieces (i.e., timber) in a matrix of well indurated rusty red-brown cement. In other places (in the wetland area just east of tailings pile 3), interstitial iron-oxide precipitate was observed and consisted of well-sorted, laminated to cross-bedded sands and pebbles (with very little fines) cemented weakly by a film of iron oxide.

Although predominantly cemented by ferric oxide as indicated by the red, brown and rust colors, other colors such as green, blue-green, yellow and white (especially in the vicinity of DMTP1E-1) indicated that ferric, copper and aluminum precipitates could also be present (refer to Section 5 for a discussion of the chemistry of the ferricrete). The ferricrete exposed in DMTP1E-1 was observed to contain lenses of uncemented light yellow to orange-brown sands and silts, and pockets of dark gray to blue gray clay.

During the field reconnaissances, the thickness and distribution of ferricrete was observed to be highly variable. It is reported that the USFS attempted to remove and/or break up the ferricrete during Site rehabilitation efforts between 1989 and 1991 (PNL, 1992). Referring to Figure 4.3-3d, field observations at RC-9 indicated that a cemented vertical ledge greater than 4 feet thick formed the south bank of the channel. This ledge was observed to be almost continuous (although the thickness varied) along the south bank adjacent to tailings pile 1 from RC-9 to just upstream of the confluence with Copper Creek (see stream reach 1-E on Figure 4.2-21 and Figure F-4 in Appendix F which displays a schematic cross-section for reach 1-E). The presence of relatively mature trees adjacent to the ledge suggests that the ferricrete has been present in the area of tailings pile 1 for a relatively long period of time.

The relatively hard, thick and indurated ferricrete was not observed downstream of the Copper Creek confluence. However, iron-staining was observed along the entire Railroad Creek channel from midway of tailings pile 1 to downstream of tailings pile 3. In addition, the channel deposits observed in the test pits east of tailings pile 3 had zones of staining and relatively weak to moderate cementation.

Observations During Aquatic Snorkel Survey

A snorkel survey was completed for portions of Railroad Creek as part of the Site aquatic biota characterization (see Section 4.6). The survey included sampling stations adjacent to tailings pile 1 (RC-9) and tailings pile 2 (RC-7) (see Figure 4.6-1). The segments of Railroad Creek evaluated were approximately 100 meters long for each sample station. Two snorkelers participated in the survey.

Both individuals visually assessed the qualitative conditions of the Railroad Creek substrate and submerged sections of the streambank. The snorkelers reported that the substrate of Railroad Creek was loose and not cemented at these locations. However, isolated portions of the south streambank near the northeast corner of tailings pile 1 (RC-9) appeared to be cemented (Figure 4.3-3d).

4.4 HYDROGEOLOGY

4.4.1 Regional Hydrogeology

The groundwater in the region is normally found in both the bedrock and overlying material. The bedrock groundwater is present within fractures, joints, and faults. The rate of movement of groundwater within the bedrock is variable but is normally relatively slow, commonly requiring days to years to migrate the same distance which required only minutes to days in soil. Groundwater is also commonly "perched" within overlying weathered rock, alluvium, colluvium, and glacial materials (Patmont, 1989).

4.4.2 Overview of Railroad Creek Watershed Hydrogeology

The existing Railroad Creek valley was formed by glacial action and hence has steep sides cut into bedrock and a fairly broad, flat bottom. The surface of the valley bottom slopes to the east toward Lake Chelan (Figure 4.3-3). The valley bottom is covered throughout its length with a shallow and variable depth of glacial, colluvial, and alluvial deposits. These deposits thin where bedrock comes closer to ground surface (USGS, 1967a and 1967b).

Groundwater is recharged by snowmelt in the spring and early summer. Due to the relatively large amount of snowfall in the region, groundwater recharge is large during this period. Once snowmelt is complete, groundwater recharge is from rainfall and potentially from surface water loss from Railroad Creek. As discussed in Section 4.3.3, highest average precipitation recorded at Holden Village is in November through January and the lowest is during May through August. Therefore, groundwater recharge varies in both amount (large in spring, small in summer) and source (snowmelt in spring, rainfall in summer).

As noted for the remainder of the Lake Chelan Basin (Patmont, 1989), source water for Railroad Creek is supplied from glacial melting, snowmelt, and rainfall. Water is transported to the creek as groundwater, seep flow, or tributary surface water input. With the beginning of snowmelt in the spring, water is supplied to Railroad Creek from the adjacent valley sides as both overland flow and groundwater flow. Once snowmelt is complete, Railroad Creek is supported by up-valley glacial melt, local groundwater flow, and rainfall runoff from summer storms. Flow directions are generally to the north and south off the valley sides, to Railroad Creek, which flows in an easterly direction.

Water flow within the Railroad Creek valley is believed to occur principally as surface water within Railroad Creek and groundwater flow in the permeable materials within the valley. Limited groundwater is anticipated to occur within the bedrock (Patmont, 1989). Areas of shallow bedrock force more flow above ground and to Railroad Creek. As the depth to bedrock increases and surficial, higher permeability material thickness increases, surface water returns to the subsurface.

Processes and conditions described below for the Site are presumably in operation throughout the Railroad Creek watershed. Where groundwater elevations are greater than surface elevations, springs or seeps will form. This occurs most commonly in spring, as snowmelt saturates near-surface materials. Seep flow may continue later into summer where zones of discontinuity in surficial materials provide preferential pathways for flow or where impermeable zones create perched water conditions.

Groundwater is not used at the Site as a potable source. Groundwater is used as a domestic water supply at the Lucerne Bar USFS station, approximately 11 miles downstream.

4.4.3 Site Hydrogeology

The following sections describe the Site hydrostratigraphy, water levels, and groundwater flow.

4.4.3.1 Hydrostratigraphy

The characteristics of the geologic units at the Site affecting groundwater flow are summarized in Table 4.4-1. Figures 4.4-2 through 4.4-5 are interpretive geologic and hydrogeologic cross-sections through tailings pile 2 and tailings pile 3 for May and September 1997, respectively; the locations of the cross-sections are shown on Figure 4.4-1. The geologic and hydro-geologic cross-sections are based on the interpretation of geophysical survey results (Appendix A), review of site boring logs (Appendix B), and groundwater monitoring well levels measured in May 1997 (Table 4.4-2). The characteristics of the geologic materials as hydrostratigraphic units are based on groundwater occurrence as measured in monitoring wells and by hydraulic conductivities. Groundwater levels were measured in wells during the 1997 field program. Hydraulic conductivities for the tailings piles were calculated from slug test data (Appendix I) collected from monitoring wells screened within and beneath the tailings and percolation tests conducted by Dames & Moore (Appendix G) and others (Hart Crowser, 1975; Appendix E). Hydraulic conductivities for other native materials at the Site are based on literature (Freeze and Cherry, 1979; Daly, 1982). Slug test results for wells tested as part of the RI are compiled in Table 4.4-3.

Following the format provided in Table 4.4-1, each of the hydrostratigraphic units present at the Site is discussed in more detail below. A hydrostratigraphic unit is composed of one or more types of geologic materials that have similar properties related to groundwater flow and storage. The hydraulic conductivity and occurrence of groundwater within the hydrostratigraphic units are described below in generally descending stratigraphic order from the ground surface. The areal distribution of the principal geologic units is presented on Figure 4.2-6a.

Soil and Fill

Native soil thinly covers (assumed to be often less than approximately one foot) all undisturbed portions of the Site where bedrock is not exposed at the ground. Man-made fill, in addition to tailings and waste rock, covers limited portions of the Site where ground disturbance occurred in conjunction with development, and includes portions of the mill site, Holden Village, Winston Homesites, and the roads. Hydraulic conductivity has not been measured in the soil/fill unit. Due to the heterogeneous nature of the material, the soil/fill material likely exhibits a wide range of hydraulic conductivity. Hydraulic conductivity is small in areas of finer-grained or more compacted material and could be quite large in less compacted fill or that containing large rock fragments. Differences in horizontal and vertical hydraulic conductivity may occur due to layering or compaction within the fill material. The soil and fill unit may be saturated to a thickness of up to 5 feet.

Colluvium

Colluvium consists of soil deposited in conjunction with past mass movement of soil or rock, and is commonly found on and/or near the base of slopes. The colluvium is suspected to have been encountered during the installation of several of the groundwater monitoring wells and is anticipated to be limited in extent. Hydraulic conductivity within the colluvium ranges from 4.6×10^{-3} cm/sec to 1.2×10^{-2} cm/sec, based on slug test results for well PZ-4A (Table 4.4-3). Groundwater appears to occur in the colluvium on both sides of Railroad Creek. At well H-3 (HV-3) in Holden Village north of Railroad Creek, the saturated thickness of the alluvium ranged from at least 45 feet in May to at least 10 feet in September. The colluvium on the south side of the creek appears to be completely saturated (approximately 25 feet thick) in May; by September, approximately 15 feet of the unit is saturated.

Alluvium

Alluvium consists of granular materials deposited by the various creeks in the Railroad Creek watershed, and is generally limited to those areas near the creeks. The alluvium on the Site appears to range in thickness from 5 to 25 feet, based on interpretation of geophysical data (Appendix A) and boring logs (Appendix B). Hydraulic conductivity in the alluvium varies from 7.2×10^{-3} to 1.8×10^{-1} cm/sec, based on slug tests at wells HBKG-1 and DS-2. The alluvium contains groundwater throughout the Site and the saturated thickness appears to range from 5 to 25 feet.

Tailings Materials

The tailings materials were generated during the processing of the ore rock, and the tailings cover approximately 90 acres of the Site and range up to approximately 150 feet in thickness. Logs of borings (Appendix B) completed within each of the three tailings piles give indications that alternating wet and dry layers occur within the tailings. While fine-grained layers are found throughout each of the tailings piles, and in some instances can be correlated over parts of two of the piles, no evidence is found to suggest laterally extensive water perching zones in any of the piles. Hydraulic conductivity of the tailings is calculated to range from 2.0×10^{-4} to 4.4×10^{-3} cm/sec based on infiltration tests conducted on tailings pile 2 during the RI (Appendix G) and from data collected by others (Hart Crowser, 1975, Appendix E). As the infiltration tests only influence small portions near the surface of the tailings piles, the hydraulic conductivity values calculated from the infiltration tests may not be representative of conductivity throughout the pile. Vertical hydraulic conductivity within the tailings piles may be lower than horizontal hydraulic conductivity due to the presence of layers of finer materials within the piles, and the potential for limited cementation.

Groundwater occurs at the base of the tailings piles. The thickness of saturated tailings ranges from approximately 3 to 21 feet in May and 3 to 17 feet in September 1997, based on the boring logs (Appendix B) and water levels collected during 1997.

Referring to Figure 4.2-6b, a test pit excavated at the northeast corner of tailings pile 3 (DMTP3-4; see Appendix C) encountered a partially cemented layer at the contact between the tailings and native ground with flowing water noted beneath the layer and dry tailings above. This suggests the potential for a lower permeability layer at the contact between tailings and native ground. This layer was not logged on boring logs (Appendix B) of wells completed beneath the tailings, as well as in exploratory borings completed by Hart Crowser in 1975 as part of a geotechnical engineering evaluation (Appendix E).

Waste Rock

Waste rock piles are found associated with the six underground mine portals in the Honeymoon Heights area and near the 1500-level main portal, on both the west and east sides of the abandoned mill building. The hydraulic conductivity of the waste rock piles has not been measured; however, hydraulic conductivity is estimated to be large (greater than 1×10^{-1} cm/sec) due to the relatively large size and poor sorting of fragments which make up the piles. Groundwater is believed to occur intermittently (during the spring snowmelt period only) within the waste rock piles, and based on the limited flow rates of seeps SP-6 and SP-8 near the base of the west and east waste rock piles, respectively, is anticipated to be relatively small in quantity.

Alluvium/Reworked Till

The alluvium/reworked till is considered herein to consist of the transition from the alluvium, noted above to be associated with creeks, to the glacial till (discussed below) which has been reworked by glacial and post-glacial processes. The hydraulic conductivity of the alluvium/reworked till ranges from 9×10^{-4} to 5.3×10^{-2} cm/sec, based on slug tests performed at wells TP1-5, TP2-11, and TP2-7 (Table 4.4.3). Water level measurements collected during slug tests and slug test calculations are provided in Appendix I. Vertical and horizontal hydraulic conductivity within the alluvium/reworked till unit are likely comparable to a glacial till that has been to some degree washed of fine material.

Groundwater appears to occur within the alluvial/reworked till unit throughout the Site. In May, the unit apparently is fully saturated, based on water levels collected during the RI, hence, the saturated thickness ranges from 5 to 15 feet. As shown on Figures 4.4-4 and 4.4-5, in September some portions of the alluvial/reworked till unit become unsaturated beneath tailings piles 2 and 3.

Glacial Till

The glacial till consists of fine silt- to boulder-size material deposited and compacted by pre-historic glaciers within the Railroad Creek drainage. No hydraulic conductivity data are available for the dense glacial till at the Site. Hydraulic conductivity values of 1×10^{-8} to 1×10^{-10} cm/sec have been reported in the geologic literature (Freeze and Cherry, 1979). The values above are for intergranular hydraulic conductivity. Weathered and fractured till may have larger hydraulic conductivity values.

Bedrock

Bedrock underlies the entire watershed and is exposed at the ground surface along the valley sidewalls where glacial materials and/or weathered bedrock is not present, and in isolated circumstances within and near Railroad Creek. Hydraulic conductivity has not been measured for bedrock at the Site. Published values range from 4.7 x 10^{-2} to 9.3 x 10^{-8} cm/sec for fractured metamorphic and igneous rocks and 1.3 x 10^{-8} to 2.3 x 10^{-12} cm/sec for unfractured metamorphic and igneous rocks (Daly, 1982). Water transmitted by bedrock at the Site is presumably moved through fractures.

4.4.3.2 Groundwater Monitoring Well Levels

Most groundwater monitoring wells at the Site include a series designation as either "A," "B," or "C" series wells. "A" series wells monitor groundwater within the colluvium, alluvium, or alluvium/reworked till units (i.e., native materials). "B" and "C" series wells monitor groundwater within the tailings. "B" series wells are completed near the base of the tailings and "C" series wells are screened just above potential perching layers. Groundwater monitoring wells without a designation monitor the same units as "A" series wells. Well screen intervals and water level data are summarized in Table 4.4-2. The locations of the monitoring wells are noted on Figure 4.4-1. Table 4.0-1 presents the coordinates for all of the wells. During 1997 RI field activities, water-level measurements of site wells were conducted on four occasions. Dates of the measurements were May 17, June 17-20, July 13, and September 17-19. All groundwater level data collected manually are presented in Table 4.4-2. Water-level elevation maps for each round based on measurements in wells screened in native materials are provided as Figures 4.4-6 through 4.4-9. Surface water elevations have been plotted in some instances to provide additional control. Groundwater elevations in May and September 1997, for wells screened in tailings on tailings piles 2 and 3, are shown in Figures 4.4-10 and 4.4-11, respectively.

Geologic units do not overlie the tailings and water within the tailings pile is in indirect contact with the atmosphere through the pores between the grains of tailings. Water within the tailings is termed unconfined and "B" series wells monitor a free water surface. Although not shown on Figures 4.4-2 and 4.4-3, "C" series wells were also found to monitor a free water surface. Water within the alluvial/reworked till unit becomes confined between the dense till below and the tailings above, near the southern margin of the tailings piles. The tailings act as a confining unit either because of their lower overall hydraulic conductivity and/or because of the apparent presence of a lower permeability unit at the base of the tailings. "A" series wells monitor either a potentiometric surface within the alluvial/reworked till unit where this unit is confined, or monitor a free water surface where unconfined conditions occur. In areas where groundwater occurs under confined conditions, water levels measured in wells rise higher than the top of the contact between the tailings and the underlying hydrostratigraphic unit since the water is under pressure transferred from waters originating at a higher elevation. The potentiometric surface shown on Figures 4.4-2 and 4.4-3 does not imply that the tailings are saturated to the pressure head level shown for the "A" series wells, but only that water within the "A" series wells rises to the levels shown.

Water levels/pressure heads measured during May 1997 in monitoring wells completed in both the tailings and the alluvium/reworked till unit are shown on Figure 4.4-2 (tailings pile 2), and Figure 4.4-3 (tailings pile 3). Water levels/pressure heads in wells completed in both units are shown for September 1997 on Figure 4.4-4 (tailings pile 2) and Figure 4.4-5 (tailings pile 3). Note that although monitoring well PZ-6A is an "A" series well, it appears to be screened within tailings pile materials rather than the alluvial/reworked till based on review of the boring log for this well (Appendix B).

When two or more monitoring wells are completed at adjacent locations in different hydrostratigraphic units, those monitoring wells can be used to compare water levels in the units and assess the direction of potential groundwater flow between the units. Referring to Figure 4.4-1, clusters of adjacent wells occur at locations PZ-1, PZ-2, and PZ-3 on tailings pile 2, and PZ-4, PZ-5, and PZ-6 on tailings pile 3.

Figures 4.4-12, 4.4-13, and 4.4-14 show groundwater levels measured in groundwater monitoring wells at locations PZ-1 (south side tailings pile 2), PZ-3 (north side tailings pile 2), and PZ-4 (south side tailings pile 3), respectively (Figure 4.4-1). Pressure heads/water levels in the "A" series wells exhibit a decrease in water level from May through September 1997. Water levels in the "B" and "C" series wells react in a similar manner to each other, remaining relatively constant, with slight rises seen in June or July. Pressure heads/water levels in the "A" series monitoring wells do not exhibit the same trend as water levels in the "B" and "C" series monitoring wells, as would be expected if all three series of monitoring wells were completed in a fully hydraulically connected unit.

Throughout the Site, monitoring wells completed in native material indicate the same water level trend as described for the "A" series wells above. Groundwater level declines were large enough in two "A" series wells (PZ-1A and PZ-4A) to result in their being dry in September 1997.

"B" series monitoring wells, completed near the base of the tailings, showed the trend described above. One exception was monitoring well TP3-7B, which indicated decreasing water levels throughout the monitoring period. This monitoring well was identified during the initial well assessment as having a loose surface seal. It is possible that the downhole seal at this well has failed, and that surface water is allowed to drain into the well.

Water level data for the RI were collected over a period of approximately five months (mid-May to late-September). This interval is believed to include the period of highest groundwater levels (mid-May to mid-June) and of relatively low groundwater levels (September).

4.4.3.3 Groundwater Flow

Groundwater flow directions can be established from water-level elevation maps by drawing flow lines that run perpendicular to the groundwater elevation contour lines. Figures 4.4-6 through 4.4-9 are water level elevation maps based on measurements from wells completed in the alluvium, colluvium, and the alluvium/reworked till unit, respectively. Figures 4.4-10 and 4.4-11 are water level elevation maps based on measurements from monitoring wells screened in the tailings.

Groundwater Flow in Native Materials

The May water-level elevation map (Figure 4.4-6) shows a strong component of groundwater flow from the Site north toward Railroad Creek. Groundwater to the south of Railroad Creek is recharged by snowmelt from the southern side walls of the valley and flows primarily north toward Railroad Creek. Much of the groundwater flow is discharged to Railroad Creek, as described below; however, some groundwater likely flows longitudinally down valley beneath the creek. Groundwater gradients are relatively high, ranging as high as 0.1 to 0.2 feet per foot (ft/ft) beneath tailings piles 2 and 3. Groundwater gradients generally decrease closer to Railroad Creek, to approximately 0.05 ft/ft. Beneath tailings pile 1, groundwater gradients range as high as 0.1 ft/ft and as low as 0.03 ft/ft. Copper Creek in the vicinity of the tailings piles is shown as a losing stream (i.e., the base of the stream is above the local groundwater elevation) based on a comparison of the elevation of Copper Creek at the southern edge of tailings piles 1 and 2 (mapped to be approximately 3,270 feet above MSL) to local groundwater elevation at well CC-BKG (based on a civil survey and water level measurements to be <3,265 feet above MSL).

The June 1997 groundwater elevation map (Figure 4.4-7) shows lower (approximately 2 to 5 feet) groundwater elevations than in May 1997. Large decreases in groundwater elevations (10 to 15 feet) are indicated for wells along the southern edge of tailings piles 2 and 3. Groundwater south of Railroad Creek appears to flow north to northeast. Groundwater flow from the vicinity of Holden Village on the north side of the creek appears to be primarily to the southeast. Gradients are generally lower than in May 1997.

The groundwater elevation map for July 1997 (Figure 4.4-8) shows a lower groundwater gradient. Groundwater gradients beneath the southern portion of tailings pile 2 range to as high as 0.1 ft/ft. Closer to Railroad Creek, the gradient decreases to approximately 0.04 ft/ft. Beneath tailings pile 1, the gradient is approximately 0.02 ft/ft. Groundwater on the south side of the creek appears to flow north to northeast. On the north side of the creek near Holden Village, flow appears to be generally to the southeast.

The September 1997 groundwater elevation map (Figure 4.4-9) denotes trends similar to the July data. Groundwater flow south of Railroad Creek appears to be to the north, northeast, and east. Groundwater flow from the north side of the creek appears to be to the southeast. Groundwater gradients beneath tailings pile 2 range from approximately 0.2 ft/ft at the southern end of the pile to 0.05 ft/ft close to Railroad Creek. Groundwater gradients beneath tailings pile 1 range from approximately 0.02 to 0.03 ft/ft. The groundwater high at the southern border of tailings pile 2 remains; however, the groundwater mound no longer extends to tailings pile 3, as noted in July. Also, groundwater elevation contours depict Railroad Creek as a losing stream beginning at some point opposite tailings pile 3, and a "trough" is evident on the contour map below the tailings piles. This trough may correspond to the alignment of a former channel for Railroad Creek; a discussion of contaminant transport related to the effect of the former channel is presented in Section 6.5.2.1. The presence of the "trough" is supported by the results of the electromagnetic survey line (EM3-EM3') and seismic refraction line E-E' (coincident with EM3-EM3') completed immediately east of tailings pile 3 (Appendix A and Figure 4.2-11).

Groundwater Flow in Tailings Piles

Groundwater elevations in May and September 1997, for wells screened in tailings for tailings piles 1 and 2 and 3, are shown in Figures 4.4-10 and 4.4-11, respectively. Only one well installed in tailings pile 1, TP1-4B, is screened within the tailings. As shown on the figures, groundwater elevations are highest at the southern boundary of the tailings piles and decrease to the north and northeast, indicating groundwater flow in those directions. Groundwater gradients range from approximately 0.1 to 0.02 ft/ft in both May and September, and generally decrease to the north and east.

Vertical groundwater flow in native materials and tailings piles water level data from the PZ-3 location, shown on Figure 4.4-13, indicate that for May through September 1997, water levels in the tailings were higher than water levels in the alluvial/reworked till unit. Therefore, groundwater flow between the units, if it occurred, was downward from the tailings and into the alluvial/reworked till unit. At the PZ-1 location (Figure 4.4-12) and the PZ-4 location (Figure 4.4-14), water levels in the alluvial/reworked till unit were higher than those in the tailings in May 1997. By June 1997, water levels in the alluvial/reworked till unit had dropped and were lower than water levels in the tailings. This condition was maintained throughout the rest of the monitoring period, ending in September 1997. Therefore, water may have flowed from the alluvial/reworked till unit upward into the tailings in the spring, and then reversed from the tailings back downward into the alluvial/reworked till from June through September. Water level data from well clusters throughout tailings piles 2 and 3 indicate the trends shown on Figures 4.4-12 through 4.4-14.

The relationship of water levels, and hence the direction of potential groundwater flow, for wells screened in the tailings and the alluvial/reworked till units is shown for cross-sections through tailings pile 2 on Figures 4.4-2 and 4.4-4 and for tailings pile 3 on Figures 4.4-3 and 4.4-5.

Groundwater Flow in Western Portion of Site

Groundwater flow in the western portion of the Site (west of tailings pile 1) appears to take place through the soil and fill material and potentially within the alluvium/reworked till and dense till layers that presumably underlie the soil/fill. Groundwater in the western portion of the Site appears to be recharged by snowmelt and rainfall on the slopes to the north and south of the Site, and on the western portion of the Site itself. This includes the mill building area and the waste rock piles. Seep flow from the waste rock piles is collected at the base of the piles and transported via ditches to the lagoon south of Railroad Creek. Infiltration into the western waste rock pile also likely contributes to seep SP-15W, located at the break in slope south of the lagoon area (see Figure 4.3-8). Surface water loss from the ditches or pond also appears to recharge groundwater in this portion of the Site. A loss of water from the portal drainage (P-1 to P-5) has been demonstrated. The water is assumed to infiltrate to the alluvial/reworked till and ultimately exit into Railroad Creek.

Results from the electromagnetic (EM) terrain conductivity survey (Appendix A), which investigated to a depth of approximately 18 to 20 feet, show relatively high resistivity from the vicinity of the mill building toward Railroad Creek, indicating the presence of shallow groundwater. The survey shows that the water flows in relatively narrow pathways based on the spikes on the EM survey which are narrow rather than broad peaks, which would indicate diffuse flow. Several of the EM "spikes" were coincident with the portal drainage and seep SP-23.

Groundwater Flow - Honeymoon Heights Area

Snowmelt and rainfall are assumed to enter fractures and faults in the bedrock in the Honeymoon Heights area and move downward into stopes associated with the underground mining (Figures 4.2-6a, 4.2-14, and 4.2-15). This water is assumed to travel downward to the 1500-foot level and becomes part of the mine pool before emerging at the 1500-level main portal. A dye test was conducted during the RI to assess the surface water/groundwater flow path of an intermittent drainage in the Honeymoon Heights area as it potentially relates to mine infiltration and seepage flow at seeps SP-12 and SP-23; however, the results were inconclusive.

Generalized Site-Wide Groundwater Recharge/Discharge

Groundwater at the Site is recharged by snowmelt in the spring from the valley slopes and from the Site itself. Due to the relatively large amount of snowfall that occurred in 1996/1997, groundwater recharge rates were likely high compared to other years. Once snowmelt is complete, groundwater recharge results from rainfall and from water loss from surface water tributaries (Copper Creek, Portal Drainage) via infiltration through the bed. This phenomenon occurs because the water surface elevation in the tributaries is above the water surface elevation of the groundwater.

Groundwater discharge occurs at the Site in response to variable recharge. Groundwater discharge via seeps was observed to peak in May and June 1997 and decrease after that (see Section 4.3.3.7). Diffuse groundwater discharge into Railroad Creek apparently follows the same trend, with the May 1997 groundwater discharge observed to be larger than September 1997 discharge as quantified by flow net analysis, described below. A more detailed description of baseflow conditions in Railroad Creek is provided in Section 4.3.7.

4.4.3.4 Groundwater Discharge to Railroad Creek

In order to provide quantitative estimates of groundwater discharge to Railroad Creek, flow net analyses were conducted using the May and September 1997 groundwater level data. A flow net is commonly used to quantify groundwater flow through use of basic laws of groundwater movement if an appropriate cross-section can be determined in the third dimension. Referring to Figures 4.4-15 through 4.4-18, each area bounded by two flowlines is termed a "flowtube." Since no water crosses the flowlines, discharge within the flowtube is considered constant. Discharge can be calculated by measuring the dimensions of the flowtube (length, width, and saturated thickness) the hydraulic gradient (i.e., the change in groundwater elevation) over the length of the flowtube, and the hydraulic conductivity of the material within the flowtube. Summing the discharge of adjacent flowtubes provides values of total groundwater flux over the area of the flow net. The flow net analyses for the Site followed this procedure.

The equation used to quantify groundwater flow is:

$$QT = K \bullet WT \bullet iT \bullet bT \tag{4-11}$$

where:

Q_T = groundwater discharge of flowtube

K = hydraulic conductivity

W_T = width of flowtube at Railroad Creek

i_T = groundwater gradient of flowtube near Railroad Creek

b_T = saturated thickness of aquifer near Railroad Creek.

Hydraulic conductivity was measured through slug tests for the alluvium, colluvium, and alluvium/reworked till unit and through infiltration tests for the tailings. Groundwater discharge is calculated based on minimum, mean, and maximum slug and infiltration test results.

Referring to Figures 4.4-15 through 4.4-18, flowtube width and groundwater gradient are measured off of the flow net. Saturated thickness of the aquifer is based on hydrostratigraphic unit thicknesses derived from boring logs and geophysical data, and on water levels collected in 1997. The saturated thickness of the alluvial/reworked till unit is estimated to be 10 feet throughout the Site, except in the vicinity of geophysical survey line F-F' (north of tailings Pile 2; Figures 4.2-6b and 4.2-12, and Appendix A) where bedrock was detected to be as shallow as approximately 10 feet below the surface. The saturated thickness of the alluvial/reworked till unit is assumed to be similar to September to May 1997. While the alluvial/reworked till unit becomes unsaturated beneath the southern portion of tailings piles 2 and 3 in September, the unit appears to remain fully saturated adjacent to Railroad Creek.

The saturated thickness of the tailings in both May and September 1997 was estimated to be 10 feet, based on groundwater elevations measured in May and September 1997 and elevations of the base of the tailings from boring logs completed by others (Appendix B). The quantity of water calculated using this approach should be considered a conservative estimate because it includes potential discharge from seeps located near Railroad Creek.

The parameters used for each flow tube and the calculated discharge for each tube are provided in Appendix I. Separate flow net analyses were completed for groundwater within the native material (e.g., alluvial/reworked till unit), and the tailings. The analyses evaluated two reaches along Railroad Creek: RC-4 to RC-7; and RC-7 to RC-2 (Figures 4.4-15 through 4.4-18). The flow net constructed for the alluvium/reworked till unit in May 1997 is shown on Figure 4.4-15, and the flow net for the tailings unit in May 1997 is shown on Figure 4.4-16. Flow net evaluation of groundwater recharge to Railroad Creek, based on May groundwater levels, is summarized in Table 4.4-4. The discharges developed by flow net evaluation range between 0.6 and 11.4 (mean 2.2) cfs for RC-4 to RC-7, and 0.3 and 5.2 (mean 1.0) cfs for RC-7 to RC-2; these values compare reasonably with spring baseflow estimates of 5 cfs and 1.7 cfs for the respective reaches from surface water measurements provided in Section 4.3.7.1. The mean discharge estimates represent approximately 50 percent of the estimated baseflow. The remainder of the baseflow is likely provided by groundwater discharge from areas not included in the flow net analysis (i.e., the area north of Railroad Creek).

The September 1997 flow nets for the alluvium/reworked till unit and the tailings are shown on Figures 4.4-17 and 4.4-18, respectively. The flow net evaluation of groundwater recharge to Railroad Creek based on September 1997 groundwater levels is summarized in Table 4.4-5. The discharges developed from the flow net evaluation of 0.3 to 6.1 (mean 1.2) cfs for RC-4 to RC-7 and 0.2 to 0.0 (mean 0.1) cfs for RC-7 to RC-2 are within the approximate range of those discharges measured during the September 1997 baseflow monitoring described in Section 4.3.7.2. The groundwater discharge appears to be less in September than in May 1997 due to decreases in hydraulic gradient, especially beneath tailings pile 1.

As indicated on Tables 4.4-4 and 4.4-5, the contribution of tailings drainage to Railroad Creek as a ratio to total groundwater contribution increases approximately 3 times from May to September 1997. In May, mean tailings contribution is estimated at 0.2 cfs of a mean total of 3.2 cfs of groundwater, or approximately 3 percent of the total groundwater contribution. In September, mean tailings discharge appears to be 0.1 cfs of a mean total of 1.3 cfs, or approximately 10 percent of total.

4.4.3.5 Groundwater Uses

Groundwater is not used as a potable source at Holden Village. The well at the Lucerne Bar USFS guard station provides that facility with domestic water; the well is installed in alluvium near the mouth of Railroad Creek, and is assumed to include a mixture of Railroad Creek and Lake Chelan water.

4.4.4 Site Specific Water Balance

4.4.4.1 Approach and Background

Objectives and Approach

A general basin-wide, climatic water balance or budget was developed for the entire Railroad Creek watershed for use in analyzing flow characteristics and predicting minimum riprap sizing to protect the lowermost portions of the tailings piles from erosion by Railroad Creek. The results of the basin-wide water budget were discussed previously in Section 4.3.5. The results of the analyses to predict minimum riprap sizing utilizing HEC-1 modeling are presented in Section 4.3.6.2.

This section describes the site-specific water balance that was developed to assess the seasonal flow characteristics of water source inputs to Railroad Creek in the vicinity of the Site only. The potential sources of water analyzed on the Site include precipitation runoff, tributary inflow, and groundwater inflow. Groundwater inflow may include flow through the alluvial aquifer associated with Railroad Creek, flow through the tailings piles, and groundwater inflow from the bedrock and mine workings.

The site-specific water balance approach is to reference all of the water balance components to gain or loss of water in Railroad Creek. Flow measurements recorded in Railroad Creek provide the most representative, complete, and accurate measure of the flow of water entering and leaving the Site. Railroad Creek, adjacent to the Site, was subdivided into two reaches: Reach 1 from station RC-1 to RC-4, and Reach 2 from station RC-4 to RC-2. These reaches represent unique hydrologic environments. Reach 1 transitions from background conditions to the affected portions of the Site, including the inputs from the Portal Drainage. Reach 2 represents conditions potentially affected by the tailings piles.

The water balance analysis was completed for the period of May 15/June 15, 1997, and September 1997 using flow data obtained during the respective sampling periods. Data collected in 1997 is reflective of a greater than normal snowpack for this area. The relatively high snowpack resulted in higher than normal spring and summer melt flows. These two sampling periods represent the range of seasonal conditions observed during 1997. The component source inflows were quantified within the accuracy of the available data, and compared with baseflow gain in Railroad Creek for the May/June 1997 and September 1997 timeframes. Average flow conditions were used or estimated for the source inflows and baseflow gain in Railroad Creek, and storage effects were not directly quantified.

Flow data was also collected in October 1998; however, only select stations were measured. The October 1998 flow data was used to refine the water balance analysis.

Background

The results of the climatic water budget (Section 4.3.5) indicate that the baseflow gain observed in Railroad Creek from the 1997 flow measurements at RC-4 and RC-2 is not solely attributable to direct precipitation and snowmelt in the Site area. The climatic water budget analysis estimated an approximate 23.8 inch (Table 4.3-6b) influx of water in excess of direct precipitation and snowmelt over a 120 acre mine area from April to September (183 days). This quantity, averaged over the analysis period, indicates a baseflow increase of 0.65 cfs over what would be expected solely from direct precipitation on the mine site.

4.4.4.2 Site Water Balance Model

The general hydrogeologic model for the Railroad Creek valley at the Site includes a thin reworked alluvial aquifer which underlies the creek in most places and forms much of the valley sediments. This unit is believed to be underlain by a transitional unit composed of alluvium and reworked glacial till, which in turn is underlain by compacted glacial till and then bedrock. The bedrock forms the upper valley sidewalls. The tailings piles have been placed directly over the alluvial aquifer.

Groundwater inflow to Railroad Creek occurs from the alluvial aquifer either as seep flow and/or upwelling through the bed and banks. Where the alluvial aquifer is not present, groundwater flows from the underlying glacial till or bedrock. Groundwater contained in the bedrock may also flow directly into the creek from seep water that flows from the valley sidewalls and the 1500-level main portal drainage. Other contributions to Railroad Creek flow include tributaries and surface water runoff.

The general water balance equation for Railroad Creek is expressed as follows:

$$Qr = Qru + Qa + Qb + Qsr + Qt \tag{4-12}$$

where:

Qr = flow at the Railroad Creek station of interest

Qru = flow at the Railroad Creek station upstream of the station of interest

Qa = the baseflow contribution to Railroad Creek between Qr and Qru from the alluvial aquifer beneath the creek

Qb = the baseflow contribution to Railroad Creek between Qr and Qru from the bedrock aquifer either as seep flow or as groundwater flow through the basal till

Qsr = surface runoff contributed to Railroad Creek between Qr and Qru

Qt = tributary inflow to Railroad Creek contributed between Qr and Qru

Reach 1

Since there are no observed tributaries to Railroad Creek within this reach, the water balance equation for Reach 1 is expressed as follows:

$$Qrc4 = Qrc1 + Qa + Qb + Qsr \tag{4-13}$$

where:

Qrc4 = average flow measured at RC-4 over the period of interest (cfs)

Qrc1 = average flow measured at RC-1 over the period of interest (cfs)

Qa = (Qag + Qal) the gain (Qag) and loss (Qal) of flow from the alluvial aquifer on both sides of the creek over the period of interest (cfs). This value includes seeps along the streambanks, up-welling into the streambed and losses of flow back into the alluvial materials.

Qb = the contribution of flow from the bedrock aquifer from both sides of the valley over the period of interest (cfs)

Qsr = direct surface runoff contributions to Railroad Creek from both sides of the valley over the period of interest (cfs)

Reach 2

Since there are no identified sources of inflow from the bedrock aquifer within this reach, the water balance equation for Reach 2 is expressed as follows:

$$Qrc2 = Qrc4 + Qa + Qsr + Qt \tag{4-14}$$

where:

Qrc2 = flow measured at RC-2 over the period of interest (cfs)

Qrc4 = flow measured at RC-4 over the period of interest (cfs)

Qa = (Qag + Qal) the contribution of flow (both gaining and losing) from the alluvial aquifer on both sides of the creek over the period of interest (cfs)

Qsr = direct surface runoff contributions to Railroad Creek from both sides of the valley over the period of interest (cfs)

Qt = tributary flow into Railroad Creek over the period of interest (cfs)

4.4.4.3 Average Railroad Creek Flow

Reach 1

The flow values in Railroad Creek used for the analysis were estimated from the continuous hydrograph at station RC-4, which was developed from the rating curve for this station (see Section 4.3.3.2). Flow at station RC-4 for the period May 15 to June 15, 1997, averaged approximately 460 cfs, and for September 1997 averaged approximately 125 cfs (Figure 4.3-4). The average flow was interpolated from the hydrograph which includes the transducer data. The average flow at RC-1 was estimated based on the average difference between the RC-1 and RC-4 measurements, observed from flow measurements during the 1997 field season. The RC-4 flows were estimated from the rating curve because direct flow measurements at RC-1 and RC-4 were not recorded simultaneously.

The flow at RC-1 averaged 1.01 (101 percent) to 1.0 times the flow at RC-4 as estimated from the RC-4 rating curve over the course of the 1997 field season. For the purpose of this analysis, estimated flow at RC-1 (variable "Qrc1" as noted above in equation (4-13) in this subsection) was estimated to range between 1.00 and 1.01 times the flow at RC-4 based on the field season average.

The average flow at Station RC-4 (Qrc 4) during the May/June 1997 event is estimated to be approximately 460 cfs (Figure 4.3-4); therefore, the average flow at RC-1 is estimated to range between 460 and 465 cfs based on the field season average flow relationships. The average flow at RC-4 during September 1997 is estimated to be approximately 125 cfs; thus, the estimated flow at RC-1 ranges from 125 and 126 cfs based on the field season average.

An apparent slight loss of flow between RC-1 and RC-4 was observed during the April 1997 baseflow survey, but was not observed in September 1997. However, over the course of the field season in 1997, an analysis of the average flow relationship between RC-1 and RC-4 indicated a loss of zero to 1 percent of the flow at RC-4. The loss of flow between these stations was observed even though the portal drainage flows into this reach, as does runoff observed in seeps. Additionally, it is expected that overland runoff and groundwater contribute to flow in the creek within this reach as well.

Additional baseflow measurements were collected in October 1998 between stations RC-6 and RC-4 to further characterize the nature of the apparent flow loss between RC-1 and RC-4 observed in 1997. The results of this survey were discussed previously in Section 4.3.7.3. The data was inconclusive and suggests that there is not a net significant change or loss in baseflow from RC-1 to RC-4.

Reach 2

The flow relationships between RC-4 (Qrc4) and RC-2 (Qrc2), based on the field season averaged values, indicates that flow at RC-2 is 112 percent to 115 percent of the flow at RC-4 during both spring and fall (Table 4.3-4). This percentage range is based on the values presented in Table 4.4-3 and is estimated based on the differences between RC-2 and RC-4, and between stations' measured values and rating curve values. A transducer was not placed at RC-2; therefore, a hydrograph presenting flow data for RC-2 is not provided. The observed gain in flow is expected because of groundwater and seep contribution, and tributary contribution from Copper Creek and the Copper Creek diversion. Based on the field season average flow relationship with RC-4, the flow at RC-2 for the May/June period is estimated to range between 515 and 529 cfs, and 140 to 144 cfs for the September period.

Accuracy

The accuracy of the flow measurements were found to range between an estimated 5 and 7 percent of the actual value and are a function of the measurement technique used. Error may also result from the development of the rating curve, although the averaging process inherent in development of the rating is expected to compensate for some of the measurement error. The accuracy of the flow estimates are evaluated on the basis of judgment and comparative evidence, assuming the field season averages are representative of the actual conditions.

4.4.4.4 Tributary Inflow

Inflow Measurements and Characteristics

Tributary inflow from Copper Creek (including flow at CC-1 and CC-D) averaged 13 percent of the flow at RC-4 over the course of the 1997 field season. Flow in Copper Creek (Qt) is estimated to be represented by a consistent flow, that is 13 percent of the flow at RC-4 (Table 4.3-4, Figure 4.3-6). Based on this average, the Copper Creek inflow (Reach 2) for the May/June and September periods was estimated to be 60 cfs and 16 cfs, respectively.

Water levels in both Copper Creek and the Copper Creek diversion were observed to be above groundwater levels in the tailings piles adjacent to these tributary channels. The channel bed in both tributaries consist of reworked tailings and alluvial materials. Thus, water is free to infiltrate through the beds of Copper Creek and the Copper Creek diversion into the surrounding soils. The rate of loss was not measured in the field (and is likely well below measurement accuracy); however, estimated losses have been developed from the observed head relationships and assumed hydraulic conductivities of the bed material (see Appendix N). The results of the estimates indicate that combined losses to groundwater from the tributaries may be on the order of several tenths of a cfs.

Accuracy

The accuracy of the Copper Creek tributary inflow estimates is a function of the flow measurement technique (estimated to range between 7 and 10 percent) and the field season averaging. The accuracy of the estimates of exfiltration into the tailings piles is based on the assumed values of hydraulic conductivity of the streambed, and the limitations of the analysis method used. The hydraulic conductivity values used represent an average of the range of values measured in the tailings, both during the RI (see Section 4.3.3.7) and by Hart Crowser in 1975 (see Appendix E).

4.4.4.5 Average Portal Flow and Seeps

Portal Flow

The hydrograph of flow in the portal drainage (Figure 4.3-7) indicates an average flow at P-5 of approximately 1.8 cfs for May/June 1997, and 0.15 cfs for September 1997. The hydrograph shows differences between flow directly downstream of the 1500-level main portal (P-1), and the confluence with Railroad Creek (P-5). The portal drainage at P-1 represents the only measurable flow from the bedrock aquifer. During May/June 1997, the portal drainage gains flow between P-1 and P-5. The gain in flow in May/June averages approximately 0.5 cfs (ranging from 1 cfs in mid-May to 0 cfs in mid-June). The gain in flow is due to snowmelt and surface runoff entering the portal drainage ditch between P-1 and P-5. For the water balance, P-1 flow measurements were used to represent flow from the bedrock aquifer (Qb).

A loss of flow was identified between P-1 and P-5 in July and September 1997 (Figure 4.3-7). It is assumed that a loss also occurred in May/June 1997, but was not measurable due to high flow conditions. The observed flow loss ranges from 0.11 cfs in July 1997 to 0.06 cfs in September 1997. Assuming that the loss in flow is related to the log-discharge in the drainage, an estimate of flow loss from the drainage between P-1 and P-5 was calculated to be in the range of 0.35 cfs for May/June, and 0.06 cfs for September. Loss from the portal contributes to the shallow alluvial aquifer (Qa) and is reflected in the estimate for this inflow component (see Section 4.4.4.8).

Seep Flow

Seeps seasonally emerge along the streambanks, at the base of the tailings and at the base of the waste rock piles. In determining the overall estimate of inflow from the alluvial aquifer (Qa), seep source flows were evaluated for use in the water balance as described below.

Reach 1 Seeps

Referring to Figures 4.4-20 and 4.4-21, seeps that were observed during spring to contribute to Reach 1 include SP-6, SP-7, SP-9, SP-11, SP-12, SP-15E, SP-15W, SP-16, SP-22, SP-23, SP-23B, SP-24, and SP-25. The likely flowpaths of water (overland and underground) at the Site to Railroad Creek are illustrated on Figures 4.4-20a through d and indicate inflow to Railroad Creek starting from upstream of the Holden Mine to downstream of tailings pile 3.

Seeps SP-6 and SP-7 flow from the west waste rock pile and mine workings located in the vicinity of the 1500-level main portal. Both of these seeps contribute flow to SP-15E and SP-15W and, as part of SP-15, flow eventually into the lagoon (SP-16). The lagoon has a limited surface outlet and, therefore, inflow generally infiltrates over the course of the year, contributing to recharge of the alluvial aquifer which underlies the lagoon. Thus, the flow from the lagoon appears to contribute to subsurface outflow from the alluvial aquifer to Railroad Creek.

Seeps SP-9, SP-11, SP-12, SP-24 and SP-25 emerge during spring along the south bank of Railroad Creek, and are considered expressions of surface outflow from the alluvial aquifer. Seep SP-22 does not flow directly into the creek, but instead appears to infiltrate into the alluvial aquifer, contributing to aquifer recharge and, therefore, subsurface flow into Railroad Creek.

Seep SP-23 appears to form an independent flow system that emerges adjacent to Railroad Creek, downslope of an avalanche chute which originates in the Honeymoon Heights area, and the intermittent drainage which flows adjacent to the 800- and 1100-level waste rock piles; however, the source of the seep SP-23 water has not been determined. Seep SP-23B appears to be an extension of SP-23 that flows subsurface along the streambank. Flow from seeps SP-23 and SP-23B was estimated to be 0.17 cfs for the May/June 1997 period, and 0.05 cfs for September 1997, reflecting a response to a somewhat different recharge condition as compared to the groundwater seeps. Table 4.4-7 summarizes general flow data for these seeps for the May/June and September 1997 periods, based on Table 4.4-8a.

As noted on Table 4.4-7, the majority of seeps observed within Reach 1 during the spring sampling event (May/June 1997) were not flowing during the fall sampling event (September 1997). It should also be noted that during the fall sampling event, seeps SP-7 and SP-23 had not been flowing since early summer, and only started flowing after several days of consistent precipitation. The general flow characteristics of the seeps (i.e., presence/absence, location, etc.) were observed during the 1998 RI field effort and found to be similar to those observations made during the 1997 RI field effect.

The total average flow for seeps (SP-9, SP-11, SP-12, SP-22, SP-24, SP-25, SP-6 and SP-7) that are associated with groundwater baseflow from the south side of Reach 1 for the May/June 1997 period was estimated to be approximately 0.19 cfs, and for the September period was estimated to be approximately 0 cfs.

Based on the seep flow evaluation, SP-15E and SP-15W flow measurements were included as components of Qa. Seeps SP-23 and SP-23B were incorporated as a component of surface runoff, Qsr. The total average seep flow for SP-9, SP-11, SP-12, SP-22, SP-24, SP-25, SP-6 and SP-7 was not included in the water balance because the flows represent groundwater and are already accounted for in the groundwater component.

Reach 2 Seeps

Referring to Figure 4.4-20, seeps that were observed during spring 1997 and 1998 to contribute to Reach 2 include SP-1, SP-2, SP-3, SP-4, SP-8, SP-10E, SP-10W and SP-19. Seeps SP-5, SP-17 and SP-18 flow to the east of RC-2 and, therefore, do not flow into Reach 2 of Railroad Creek. Instead these seeps contribute to flow observed at seep SP-21, which includes seep flow and runoff from the slopes south of tailings piles 2 and 3, as well as runoff from tailings piles 2 and 3 (Figures 4.4-20a through d).

Seeps SP-1, SP-2, SP-3, SP-4, SP-10E, and SP-10W are all considered surface expressions of flow from the alluvial aquifer which underlies the tailings piles. Seep SP-5 and SP-18 are also considered to be expressions of flow from the alluvial aquifer beneath the tailings piles; however, they flow easterly beyond RC-2 (as mentioned above). Seep SP-17 primarily reflects runoff routed into the cutoff ditches upgradient of the tailings, routing this flow to SP-21. SP-8 and SP-19 are associated with intermittent flow from the base of the east waste rock pile upslope from tailings pile 1 and include snowmelt runoff from surrounding areas and, to a limited degree, from the surface of tailings pile 1. Table 4.4-8 summarizes the range of flow observed in the above seeps, and an assumed average flow for the May/June and September 1997 periods.

As noted for the seeps observed in Reach 1 of Railroad Creek, the majority of seeps in Reach 2 were observed to flow only during the spring sampling event (May/June 1997). Referring to Figure 4.4-21, several exceptions were seeps SP-1 through SP-3, which were observed to flow during both the spring and fall sampling events. In addition, seep SP-21 was observed flowing during the fall sampling event after several consecutive days of precipitation. Seep SP-8 was observed flowing from the base of the east waste rock pile in late May 1997 only.

The average total seep flow associated with groundwater baseflow from the tailings piles was estimated to be approximately 0.18 cfs (excluding SP-5 and SP-21) for the May/June period, and 0 cfs for September. Flow in seep SP-21 includes both surface runoff from the upgradient slopes during May/June and groundwater baseflow originating downstream of Tailings Pile 3. During the September 1997 period, flow in seep SP-21 appears to reflect groundwater baseflow only.

As noted for Reach 1 of Railroad Creek, the general flow characteristics of the seeps (i.e., presence/absence, location, etc.) were observed during the 1998 RI and found to be similar to those observations made during the 1997 RI.

Based on the seep flow data, seep measurements would not fully account for Qa and were not included in the water balance.

Accuracy

Seep flow measurements at SP-6 through SP-9, SP-15 through SP-19, SP-21, SP-23 and SP-23B were determined utilizing streamflow measurement methods with an accuracy of ± 25 percent. Flow in drainages that were measured using velocity meters (portal drainage, SP-17 and SP-21) were assumed to have accuracies on the order of ± 20 percent.

The remainder of the seeps observed within this reach had relatively low flows (SP-1 through SP-5, SP-10E, SP-10W through SP-13, and SP-24 through SP-25) and, therefore, did not allow the use of either streamflow measurements and/or velocity meters. The flows were estimated and are assumed to be accurate within ± 50 percent of the actual values. However, as discussed in Section 6, the lower flow seeps contribute a relatively minor amount of metals loading to Railroad Creek. Therefore, the inaccuracy of the flow measurements for the low flow seeps is not considered significant for this analysis.

4.4.4.6 Infiltration and Outflow from the Tailings and Waste Rock Piles

Estimates of outflow from the waste rock piles were developed based on estimated values of snowmelt infiltration, and outflow over a two month period. Based on these estimates, outflow from the base of the waste rock piles are on the order of 0.1 to 0.15 cfs. These estimates compare well with the observed May/June seep flows in SP-6 and SP-7 (western waste rock pile), and SP-19 (eastern waste rock pile). Along with infiltration, the outflow from the waste rock piles has no surface flow into Railroad Creek. The outflow from these sources is considered to contribute to downslope seeps and ultimately to the alluvial aquifer.

The surfaces of the three tailings piles are relatively flat and slope gently toward the south. Surface water interceptor ditches were constructed near the southern margin of each of the tailings piles during Site rehabilitation efforts completed by the USFS between 1989 and 1991. The ditches are connected to diversion channels that direct runoff and snowmelt to either Copper Creek, the Copper Creek diversion, or to SP-21 east of tailings pile 3. Based on field observations in 1997, the drainage ditches intercept meltwater and runoff from areas upslope and runoff from along an access road which traverses the south side of tailings piles 1, 2 and 3.

A limited amount of runoff is also assumed to be intercepted from the tailings piles themselves; however, because the tailings are essentially flat, there is little slope to encourage meltwater and rainfall to runoff. The snowpack and the overlying gravel cover on the tailings hold water as a porous media, and since the vertical gradient is much larger than the horizontal gradient (which is nearly flat), runoff is encouraged to infiltrate much more readily than flow toward the drainage ditches. Infiltration rates measured within the surface of tailings pile 2 during the RI (see Section 4.3.3.7), and infiltration rates measured within the surface of tailings pile 3 by Hart Crowser in 1975 (Appendix E) indicate moderate permeability. The interceptor ditches likely carry primarily runoff that is generated up slope of the tailings piles, with the majority of runoff and snowmelt generated on the tailings piles infiltrating. The ditches probably decrease the amount of infiltration from runoff generated from up slope areas that would otherwise drain onto the surfaces of the tailings piles.

Consequently, infiltration of precipitation (rain and snowmelt) is assumed to approach nearly 100 percent on the surfaces of the tailings piles. Based on these assumptions, available precipitation (precipitation minus evaporation, see Table 4.3-6b) over the 1997 field season is approximately 52.6 inches, which translates to an average discharge of 1.1 cfs (this assumes the tailings piles cover 90 acres, and the infiltration/discharge occurs over the period April through September). It is assumed that this total discharge infiltrates vertically and recharges the underlying alluvial aquifer, and reemerges as flow into Railroad Creek, forming a part of the total Qa component in the water balance equation.

Within the Railroad Creek watershed, snowmelt on the south facing slopes (north side of the valley) and exposed areas (such as the tailings piles) occurs earlier than on the north facing side of the valley and in shaded/wooded areas. Because of this, the timing of snowmelt is associated with the slope aspect and location of a given area of study within the watershed. During the 1997 field season, it was observed that the snowmelt on the tailings piles occurred earlier than the surrounding forested areas, as well as on the exposed south facing slopes. This phenomenon is important when evaluating the seasonal water balance and relative contributions of water from different watershed locations.

Accuracy

The accuracy of the estimated outflow from the tailings and waste rock piles, based on infiltration, is controlled by the accuracy of precipitation and snow depth estimates which are extrapolated from the weather station in Holden Village, and the assumption that nearly 100 percent of the precipitation infiltrates and discharge over a six month period. Although these assumptions cannot be directly validated with the data available, measurements of seep flow from the base of the waste rock piles corroborate the order of magnitude of the estimates.

4.4.4.7 Estimates of Precipitation Runoff

Direct runoff of precipitation (Qru in the water balance equation) which does not recharge underlying aquifers or evapotranspire was estimated based on observed runoff gain in the portal drainage for a specific contributing watershed area. The portal drainage during snowmelt runoff was observed for May/June 1997 (31 days) to gain an average net flow of approximately 0.5 cfs from apparent snowmelt runoff as the portal drainage crosses the slope to the west and before entering Railroad Creek (Figure 4.4-20). This net gain in flow due to surface water runoff does not include estimated losses from exfiltration or loss of water through the bottom of the portal drainage. The loss of water through the bottom of the portal drainage is estimated to be 0.35 cfs in May/June 1997 and 0.06 cfs in September 1997 based on the comparison of flow measurements at P-1 (at the 1500-level main portal) and P-5 (at Railroad Creek) (Figure 4.3-7). Therefore, accounting for the loss of flow, the total gain is estimated to be 0.85 cfs. The gain in flow is contributed from an upslope watershed area estimated to be approximately 60 acres in size.

Based on these values, the runoff snowmelt component during April/May/June 1997 is estimated to be approximately 10 inches. However, only about one-half to two-thirds of the runoff occurred over the period of interest (May 15 to June 15, 1997), thus the runoff component for the water balance analysis during the May/June 1997 time period is estimated to be approximately 6 inches over each contributing watershed.

Using the 6-inch runoff estimate, runoff was then estimated for the contributing watersheds on both banks of Railroad Creek for Reach 1 and Reach 2. Runoff (Qsr) for Reach 1 during the May/June 1997 time period is estimated to be 0.8 cfs from the south bank, and 1.3 cfs from the north bank. Runoff for Reach 2 during May/June 1997 from the north bank is estimated to be 3.4 cfs. Runoff generated upslope of the tailings piles was assumed to be routed around the tailings by the interceptor drainage ditches and, therefore, is assumed not to contribute significant flow to the south bank in Reach 2 (i.e., it is already accounted for in Copper Creek flow). Runoff estimates for the September time period are assumed to be zero for both Reach 1 and 2 because there was no observed runoff from rainfall until the end of the month.

Accuracy

The accuracy of the runoff estimates is based on limited observations of runoff gain in the portal drainage. This calculation is based on the absence of a continuous record of flow data for the portal drainage in 1997 (Figure 4.3-7). If a continuous record of flow data had been available for the portal drainage in 1997, as was the case in Station P-1 in 1998 (see Figure 4.3-7a), it is likely that the record would have documented short-term events of higher flow. It should be noted that it was not possible to utilize the 1998 P-1 data due to the limited flow data collected at portal drainage station P-5 during the 1998 RI field effort.

4.4.4.8 Groundwater Contribution from the Alluvial Aquifer

Reach 1

Estimates of groundwater flow into Railroad Creek (Qa in the water balance equation) from the alluvial aquifer were developed based on estimated recharge rates from the portal drainage, inflow to the lagoon and direct precipitation (minus evapotranspiration = 52.6 inches) over a 20 acre portion of the valley floor which overlies the aquifer (in the vicinity of the lagoon). It was assumed that over the course of the summer, the change in alluvial aquifer storage was negligible, and that average recharge rates would equal the discharge.

The components of Qa for Reach 1 include: direct precipitation into the valley bottom area, recharge from the portal drainage, recharge from the lagoon (SP-15E and SP-15W), north bank contribution, and estimated loss from Railroad Creek to groundwater.

Recharge from the lagoon was assumed to equal the inflow rate of 0.19 cfs (seep SP-15). The estimated runoff from infiltration due to precipitation was 0.24 cfs (52.6 inches times 20 acres over 183 days). The recharge from the portal drainage was estimated to average 0.2 cfs (average of 0.35 plus 0.06). The total discharge rate was, therefore, estimated to be 0.6 cfs. Based on the assumption that this discharge follows seasonal trends, the peak outflow (Qag) in May/June was estimated to be 0.9 cfs, and the discharge (Qag) in September 1997 was estimated to be 0.3 cfs.

The inflow of groundwater in the form of seepage from the alluvial aquifer was observed in the south bank of Railroad Creek in the area of RC-4 (Figure 4.4-21). This seepage is suspected to reflect recharge from the lagoon, portal drainage, and direct precipitation.

There were no observations that allow the development of estimates of groundwater inflow from the north bank portion of the alluvial aquifer. However, the segment of Railroad Creek adjacent to the Site is generally situated on the north side of the valley floor. Therefore, the alluvial deposits underlying the north bank are suspected to be less extensive, resulting in the assumption that groundwater contribution from this bank is smaller than for the south bank. The septic drainfield for Holden Village is located on the north bank (Figure 4.4-19). It is estimated to contribute less than 0.05 cfs, assuming an average Holden Village water use of 50 gal/day per person, and a population of 300 persons. The resulting discharge from the alluvial aquifer on the north bank is, therefore, estimated to be on the order of two-thirds or less of the south bank; less than 0.6 cfs for May/June 1997 and 0.2 cfs for September 1997.

Qal, an assumed loss from Railroad Creek back into the aquifer, is estimated to range from 0 to 1 cfs. The relatively low, estimated alluvial aquifer discharge rates appear to be supported by the results of flow measurements collected within the reach of Railroad Creek between the portal drainage confluence (P-5) and the vehicle bridge during the 1997 and 1998 RI field efforts. An apparent small gain in baseflow within this reach was documented from the average flow measurements made during the 1997 RI field effort. However, the more detailed survey conducted in October 1998 suggested no significant changes in flow rates between RC-1 and RC-4 (see Section 4.3.7.3).

In summary, the Qa value for Reach 1 in May/June is 1.5 to 0.5 cfs and 0.5 to -0.5 cfs in September.

Reach 2

Estimates of discharge from the alluvial aquifer into Reach 2 of Railroad Creek were developed utilizing flow net analyses completed for groundwater monitoring wells screened beneath the tailings piles as presented in Section 4.4.3.4 (Figures 4.4-15 and 4.4-17). Based on these analyses, the flow estimates for May/June 1997 are 3.2 cfs and 1.3 cfs for September 1997 (Tables 4.4-4 and 4.4-5). The resulting alluvial aquifer discharge on the north bank is estimated to be approximately two-thirds or less of the south bank, 2.1 cfs in May/June, and 0.8 cfs (Qag) in September 1997.

The September 1997 flow net analysis (Figure 4.4-17) appears to indicate a loss of flow from Railroad Creek into the alluvial aquifer beneath the tailings just upstream of RC-2. This flow loss from Railroad Creek (and gain to the aquifer) is estimated to be approximately 0.5 cfs (Qal) based on observed head differences between water levels in Railroad Creek and adjacent groundwater, and would be considered a flow loss in the water balance. The flow loss occurs because water levels in Railroad Creek are above water levels in the alluvial aquifer in this portion of the stream reach. The apparent flow loss provides recharge to the wetland area immediately east of tailings pile 3, replenishes groundwater storage, and is assumed to discharge back into Railroad Creek along the reach in and near SP-21, immediately east of RC-2. This assumption is based on the observed exposure of bedrock on the south bank of Railroad Creek immediately downstream of seep SP-21. The presence of the bedrock, and absence of alluvial material, indicates that the groundwater likely becomes surface water (Railroad Creek) at this location.

Discharge from the alluvial aquifer on the north bank, similar to Reach 1, is assumed to be less than the south bank because of less extensive alluvial deposits on the north side of the valley. The discharge estimate is assumed to be less than one-half, and possibly in the range of one-third of discharge from the south bank.

As stated previously, a baseflow gain of approximately 0.65 cfs was not accounted for from precipitation falling on the portion of the Site between RC-1 and RC-2, on the south side of Railroad Creek, based on the climatic water budget (Section 4.3.5). The measured apparent loss of flow from Railroad Creek to the aquifer between the vehicle bridge and RC-4 (in the range of 0.5 cfs) is of the same magnitude as the 0.65 cfs needed to correct the climatic water balance. Additionally, if loss from Copper Creek (several tenths of a cfs) is included, the discharge from the alluvial aquifer beneath the tailings as estimated from the flow net analysis can be accounted for entirely by direct infiltration through the tailings and recharge via flow loss from Copper Creek and Railroad Creek. However, conclusions based on the 1998 low flow survey should be made with caution as the standard deviations are in the same general range as the measured flow rates. Consequently, one should be able to conclude that the apparent loss or gain within this reach of Railroad Creek is small relative to the flow in Railroad Creek.

In summary, the Qa value for Reach 2 in May/June 1997 is 5.3 cfs and 1.6 cfs in September 1997.

Accuracy

The accuracy of the Reach 1 south bank inflow estimates is principally controlled by the assumed recharge rates, and the assumption of no change in storage. Estimates of inflow from the north bank are based on comparative judgment. Although the percentage error in these values may exist, the assumption that the north bank inflows are less than the south bank inflows is reasonable, and the relative contribution of north bank inflow to the site water balance is small compared to other water sources. The estimated groundwater baseflow values within this reach of Railroad Creek are within the range observed during the October 1998 baseflow survey which provides justification of the estimated values used.

Errors associated with the Reach 2 estimates are based on the hydraulic conductivity (K) values used. These values were based on averages for the groundwater monitoring wells screened within the alluvial materials beneath the tailings piles. Although there is a large range of (K) values, the use of the average values are justified since the estimates fall within the range of baseflow values observed in Railroad Creek.

4.4.4.9 Groundwater Contribution from the Bedrock Aquifer and Mine Stopes

Reach 1 contains the portal drainage which is the only measurable outflow from the bedrock aquifer (see Section 4.4.4.5 above). The average flow in this drainage at Station P-1 (Qb) for May/June 1997 is estimated to be 1.8 cfs, of which 0.5 cfs is estimated to be from runoff (assuming a contributing watershed area of 60 acres). Thus, direct inflow from this source to Railroad Creek is approximately 1.3 cfs (Table 4.4-9). As previously mentioned, however, an estimated 0.35 cfs from this source during the May/June 1997 period apparently exfiltrates out of the drainage into the underlying sediments, recharging the alluvial aquifer. For the September 1997 period, flow from the portal drainage to Railroad Creek is estimated to be 0.15 cfs, of which 0.06 cfs recharges the underlying alluvial aquifer.

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Accuracy

The accuracy of the bedrock aquifer baseflow contribution is based on the accuracy of the portal drainage flow measurements and assumptions regarding the average portal drainage flow (see above), and on the assumption that there are no other unobserved significant sources of flow from the bedrock aquifer entering the creek. Although it is possible that a fracture system capable of transporting groundwater underlies the creek bed and contributes groundwater baseflow to the creek, several considerations justify the assumption that a significant bedrock source other than the portal drainage is not present. These considerations include the following:

- The presence of low permeability glacial till underlying the creek and overlying a large part of the bedrock near the valley floor would likely restrict groundwater flow from a bedrock fracture system.
- 13S A fracture system large enough to contribute significant amounts of groundwater (0.1 cfs) to the creek would likely be expressed on the valley sidewalls as well, with resultant emergent springs which have not been observed.
- The loading analysis (see Section 6.0) can account for the observed changes in water chemistry using the baseflow sources.

4.4.4.10 Results of Water Balance Analysis

The results of the water balance for each reach are tabulated and summarized in Tables 4.4-9 and 4.4-10 for the average May/June 1997 period (31 days), and the average September 1997 period (30 days), respectively. These periods coincide with the flow net analyses presented on Figures 4.4-15 and 4.4-17.

Figures 4.4-20a through 4.4-20d provide detailed schematics of site flow paths, which are based on groundwater and surface water observations. The water balance equations provide a simplified picture of these pathways as illustrated in Figures 4.4-21.

The theoretical outcome of the water balance analysis is that both sides of the equation are equal. Thus, the sum of the water balance components listed in Tables 4.4-9 and 4.4-10 should equal zero. A non-zero sum indicates error in the estimates of the water balance components and/or that not all flows are accounted for. If the summation is negative, too much water is accounted for; in other words, the error is positive in a downstream direction. If the sum is positive, too little water is accounted for; in other words, the error is negative in a downstream direction.

In general, the flow in Railroad Creek is much greater than potential flow gains or losses from the site. Summation of the error in the water balance tabulations for summer and fall in each reach are well below the measurement error of flow in Railroad Creek (i.e., less than 5 to 7 percent of the flow at RC-4). The water balance accuracy is not sufficient to rule out small water sources not specifically identified as a component of the inflow, or to evaluate the accuracy of the individual component inflow estimates.

Since error in the water balance is within the measurement error of Railroad Creek, and the magnitude of the inflow components is generally (with the exception of Copper Creek) well below the error in streamflow measurement, the absolute magnitude of the inflow components cannot be evaluated from the water balance results. The conclusions presented herein were developed based on field measurements with inherent variability. The variability in field measurements result in a potential error in water balance values, depending on the methods utilized to analyze the data. Potential error is assumed randomly distributed about the mean such that mean values can be compared directly. The accuracy of the water balance inputs, therefore, is subject to the assumptions made in the analysis and the observations made in the field. Given these constraints, the water balance analysis generally indicates that there are no significant missing inflow components. This conclusion is supported by the chemical loading analysis presented in Section 6 and, therefore, provides substantiation of the above conclusion as well as the general magnitude of the estimated inflows to Railroad Creek.

Reach 1 – RC-1 to RC-4 (Table 4.4-9, and Figures 4.4-20 and 4.4-21)

The water balance results for Reach 1 generally indicates that too much water has been accounted for, although the error relative to the flow at RC-4 is low, ranging less than -1 to -2 percent for the spring water balance and 0.3 percent to -1.7 percent for the fall (Table 4.4-9). The water balance equation for Reach 1 is expressed as:

$$Qrc4 = Qrc1 + Qa + Qb + Qsr \qquad \text{(Reference Equation 4-13)}$$

where:

Qrc4 =	460 cfs (spring)	125 cfs (fall)
Qrc1 =	460 to 465 cfs (spring)	125 to 126 cfs (fall
Qa =	1.5 to 0.5 cfs (spring)	0.5 to -0.5 cfs (fall)
Qb =	1.3 cfs (spring)	0.15 cfs (fall)
Qor =	2.3 cfs (spring)	0.02 cfs (fall)

$$Qr = Qrc4 - (Qrc1 + Qa + Qb + Qsr) \qquad (4\text{-}15)$$

where:

Qr =	-4.1 to -10.1 cfs (spring)	0.3 to -1.7 cfs (fall)

The inflow estimates for this reach are within the measurement error for streamflow and the estimates appear to be biased toward too much inflow. Thus, it is likely that inflow components large enough to impact the water balance have not been overlooked. Additionally, the water balance components as estimated can adequately account for chemical inputs observed within Railroad Creek (see Section 6.0).

The water balance results also show that direct seep flow, measured as surface flow, is only a small component of baseflow inputs from the alluvial aquifer. The contribution of water flow from the bedrock aquifer (Qb) as measured at the 1500-level main portal drainage station P-1 (Qp1) was estimated to be relatively low for the May/June time period (0.3%) and negligible for the September time period. Flow from the portal drainage, even considering losses from the drainage as it flows from P-1 to P-5, is sufficient to account for inflow from the bedrock aquifer during both periods. Recharge to the alluvial aquifer from the portal drainage, observed as seep flow into the lagoon, provides adequate recharge to provide sufficient discharge from the alluvial aquifer to account for flow in Railroad Creek.

Reach 2 – RC-4 to RC-2 (Table 4.4-10, and Figures 4.4-20 and 4.4-21)

Similar to Reach 1, the sum of the water balance estimates generally indicate an error bias toward negative values, although the estimate errors in this reach may also be slightly positive. The water balance equation for Reach 2 is expressed as:

$$Qrc2 = Qrc4 + Qa + Qsr + Qt \qquad \text{(Reference Equation 4-14)}$$

where:

Qrc2 = 515 to 529 cfs (spring) 140 to 144 cfs (fall)
Qrc4 = 460 cfs (spring) 125 cfs (fall)
Qa = 5.3 cfs (spring) 1.6 cfs (fall)
Qsr = 3.4 cfs (spring) 0 cfs (fall)
Qt = 59.8 cfs (spring) 16.3 cfs (fall)

$$Qr = Qrc2 - (Qrc4 + Qa + Qsr + Qt) \qquad (4\text{-}16)$$

where:

Qr = -13.5 to 0.5 cfs (spring) -2.9 to 1.1 cfs (fall)

Relative to RC-4, the estimate errors range from approximately 1 percent to -3 percent. This magnitude of error is well within the measurement error for flow in Railroad Creek. Thus, there does not appear to be any missing flow components that are large enough to impact the water balance.

There is a gain in flow in Railroad Creek between RC-4 (Qrc4) and RC-2 (Qrc2) for both the May/June and September 1997 time periods; the increased flow was measured to range between 12 and 15 percent.

During the May/June 1997 time period, there was an estimated gain of direct surface water runoff contribution to Railroad Creek from the north bank of Railroad Creek (Qsr north bank) of less than 0.7 percent. There was no gain of surface water from the south bank of Railroad Creek (Qsr south bank) due to the presence of surface water interceptor ditches to the south of the tailings piles. During the September time period, the runoff from the south and north banks was assumed to be approaching zero.

There was no measurable contribution of water flow from the bedrock aquifer for both the May/June and September time periods within this reach.

4.5 CULTURAL RESOURCES

The 1975 ORB report noted that the Site is eligible for nomination as a historic site. This was confirmed by a USFS, Pacific Northwest Region, Determination of Significance and Effect form which indicated that the Site was determined to be eligible as early as 1979. A "Draft Determination of Eligibility Report," dated 1991, was prepared by the USFS and nominated the Holden Mine Historic District to the National Register of Historic Places. In that report, the historic district includes the Railroad Creek drainage from Lucerne on Lake Chelan, the Holden Village townsite, the Holden Mine mill and mine complex with its associated buildings and features, and the outlying properties known as Honeymoon Heights and Winston home sites. Consequently, any proposed modifications to the structures and/or immediately surrounding areas are required to be reviewed by the USFS.

4.6 ECOLOGICAL CONDITIONS

4.6.1 Aquatic Biota

The aquatic biota field investigations (benthic macroinvertebrate sampling, fish sampling and habitat evaluations) were conducted between mid-September to mid-October 1997. Although aquatic biota, particularly fish, may relocate during other periods of the year (e.g., runoff), the fall sampling afforded the safest and most efficient sampling of aquatic biota within Railroad Creek and the upper Stehekin River drainage. Surface water quality samples were also collected at the aquatic biota sampling locations during this period.

4.6.1.1 Sampling Locations

Site

Five aquatic sampling locations considered potentially affected by mine activity and two reference locations were selected within Railroad Creek. Referring to Figure 4.6-1, these sampling locations are described as follows:

- **RC-6.** Railroad Creek immediately downstream from the Wilderness Boundary. This location was established as a reference location representing conditions upstream from mine activities. This location was selected to be compared with PNL's sampling Station - 1.
- **RC-1.** Railroad Creek approximately 300 yards downstream from the Wilderness Boundary. This location was also established as a reference location representing conditions upstream from mine activities. This location was selected to be compared with PNL's sampling Station - 2.
- **RC-9.** Railroad Creek immediately upstream from Copper Creek. This location was established to represent conditions downstream from tailings pile 1 and the portal drainage and was selected to be compared with PNL's sampling Station - 3.
- **RC-7.** Railroad Creek adjacent to tailings pile 3. This location was established to represent aquatic conditions from Copper Creek downstream from tailings pile 2 and was selected to be compared with PNL's sampling Station - 4.
- **RC-5a.** Railroad Creek immediately upstream from Tenmile Creek. This location was established to represent conditions from tailings pile 2 downstream to Ten Mile Creek and was selected to be compared with PNL's sampling Station - 5.

- **RC-10.** Railroad Creek immediately downstream from Seven Mile Creek. This location was established to represent conditions from Ten Mile Creek downstream to Seven Mile Creek and was selected to be compared with PNL's sampling Station - 6.
- **RC-3.** Railroad Creek approximately 100 yards upstream from Lake Chelan. This location was established to represent conditions of the lower segment of Railroad Creek prior to Lake Chelan and was selected to be compared with PNL's sampling Station - 8.

Reference Reaches

Referring to Figure 4.6-2, three additional reference locations were identified within streams located outside the Railroad Creek drainage for comparison to habitat conditions in Railroad Creek downstream of the Holden Mine. Available aerial photographs were also reviewed and representatives of the USFS and Washington Department of Game & Fish were contacted for assistance in identifying alternative reference sampling locations outside the Railroad Creek drainage. The "non-Railroad Creek" reference reach selection process initially included the identification of stream reaches that were within drainage basins greater than 30 square miles within the Lake Chelan watershed, appeared to include a 100 meter reach length suitable for comparison with reaches in Railroad Creek, and were located at elevations that approximated the range of elevation of Railroad Creek downstream from the mine. This selection process resulted in the identification of reaches that could possibly contain habitat similar to reaches in Railroad Creek and reaches that may generally be compared to Railroad Creek. The process was carried out with the understanding that the reference reaches selected would merely approximate conditions in Railroad Creek in the absence of mine-related activities and no reach outside the drainage would be an exact match to any particular reach in Railroad Creek.

Key habitat variables were identified to characterize stream reaches in the Lake Chelan watershed. These habitat variables were associated with topographic map indices which were used to compare the reference reaches with the map indices for the reaches in Railroad Creek downstream from the Holden Mine. Table 4.6-1 lists the key habitat variables and their associated map indices.

The reaches of Railroad Creek were delineated by slope and identified from downstream to upstream as Reach A (downstream), B, C, D and E (upstream) (see Figure 4.6-1). The reference reaches were selected to compare with these reaches based on a review of the watersheds in the Lake Chelan Basin, discussions with the USFS, and the results of a reconnaissance conducted in September 1997. The only watersheds of sufficient size that would potentially provide habitat comparable to Railroad Creek were in the upper Stehekin River (upstream from Lake Chelan) and 25-Mile Creek. Within the Stehekin River watershed, streams draining watersheds with large glacier areas were excluded because these would likely result in significant differences in water quality due to glacial flour and associated impacts to sight feeding, sun penetration and temperature of the water. In addition, watersheds that were not accessible by road or trail were not considered.

The references for the reach of Railroad Creek from adjacent to the mine at Holden downstream to approximately Seven Mile Creek (Reach D) have been previously established from the Glacier Peak Wilderness boundary downstream to the Holden Mine influence (several hundred yards upstream of the Vehicle Bridge). The two reference locations have been identified as RC-1 and RC-6 within this reach.

This reach is similar to Reach D adjacent to and immediately downstream from the mine because it is contiguous, drains to the same watershed, has a similar channel slope and is believed to have the same riparian and valley conditions as the reach near the Holden Mine.

The reaches of Railroad Creek downstream from approximately Seven Mile Creek to Lake Chelan (Reaches C, B, and A) exhibit different characteristics compared to the reference reach at RC-1 and RC-6. In general the channel slope is steeper, the contributing watershed area is larger and the valley width is narrower than at the Site. The reference reaches for Railroad Creek downstream from Seven Mile Creek (reaches C, B, and A) were selected for conditions that may be generally comparable to natural conditions of the lower reaches of Railroad Creek (i.e., in the absence of the Holden Mine).

The candidate reference reaches (including RC-6 and RC-1) were compared to each of the Railroad Creek reaches (A through E) to identify the most representative reference reach for each Railroad Creek reach based solely on information obtained from topographic and geologic maps. Ten hydro- and geomorphological parameters were considered pertinent to the identification of representative reference reaches. The ten parameters have varying influence on the quality of potential aquatic resources at each reference site. Furthermore, other factors such as fishing pressure, and presence or absence of quality trout habitat also have influence on the quality and quantity of aquatic resources. The parameters considered during the selection of reference reaches are as follows:

1. Channel slope
2. Valley width
3. Watershed area size
4. Presence of glaciers within the watershed
5. Lakes within the watershed
6. Dominant geology
7. Elevation
8. Drainage network (stream order)
9. Aspect
10. Presence of downstream fish barriers

Evaluation of these parameters resulted in the selection of those reference reaches that had seven or more parameters which matched within a particular Railroad Creek reach. Final selection of reference reaches was determined through field verification during early September 1997, and with USFS concurrence.

As a result of the above process, the following reference locations and their comparable Railroad Creek reaches were selected:

Reference Location	Comparable Railroad Creek Reach
Railroad Creek (RC-6)	D and E (RC-9 and RC-7)
Railroad Creek (RC-1)	D and E (RC-9 and RC-7)
Bridge Creek (near 6-mile camp)	D (RC-5a and RC-10)
South Fork Agnes Creek (downstream from Swamp Creek)	D (RC-5a and RC-10)

The evaluation of potential reference sites failed to identify segments suitable for comparing to Railroad Creek reaches "C" "B" and "A." Reaches "C" and "B" are relatively steep in gradient as the creek flows down through a deep canyon before entering reach "A." Various points within reaches "B" and "A" were accessed, including the RM-3 "Dan's Camp" station sampled by Pacific Northwest Laboratories (1992), during the initial reconnaissance of the creek. Because of the steep gradient and flows, both of which were considered a potentially unacceptable risk to the sampling team, no aquatic sampling locations were identified within these reaches. However, based on field observations, RC-10 could be considered representative of reach "C" and, thus, the reference locations at Bridge Creek and South Fork Agnes Creek could be considered suitable references for reach "C."

Reach "A" is at the mouth of Railroad Creek and is unique due to channel slope, valley width, the percentage of glaciers, and the proximity of the lake. A reach of Company Creek, a tributary to the Stehekin River, was identified as a potential reference reach based on the evaluation of the ten hydro- and geological parameters previously described. This particular reach was approximately 4 miles upstream from the confluence with the Stehekin River and was the only reach within Company Creek considered to qualify for reference based on the evaluation of the ten parameters. However, during field verification, the Company Creek reach was determined inaccessible and of substantially lower discharge than any of the Railroad Creek reaches. Therefore, the Company Creek reach was eliminated as a reference reach candidate.

Subsequent to the final selection of stream reaches determined to be qualified as reference reaches, the USFS identified the need to select a reference reach to represent Railroad Creek reach "A" with the primary criteria being the potential for migratory species to frequent the reach during the spawning season. The migratory species of particular concern in this case was the Kokanee salmon. Although the importance of the ten parameter criteria and its application for selecting reference reaches were recognized, the primary criteria for selecting a reference reach for lower Railroad Creek (which is accessible to Lake Chelan spawning kokanee salmon) was the documented occurrence of kokanee salmon in the reference reach. The lower segment of Company Creek has historically served as a quality spawning tributary to the Stehekin River for Lake Chelan kokanee salmon. Therefore, a reach of lower Company Creek was selected as a possible reference for lower Railroad Creek with the qualification that Company Creek was not similar to lower Railroad Creek with respect to the ten hydrologic and geologic parameters and the stream discharge but with respect to the potential for kokanee salmon to access the stream.

4.6.1.2 Habitat Evaluations

Aquatic sampling locations were selected in an attempt to minimize variations attributable to habitat. However, since not all habitat variables could be held constant, habitat was evaluated to estimate the potential for supporting viable aquatic resources based on physical habitat quality in comparison to reference locations. As previously described, habitat was qualitatively evaluated using the guidance provided in the U.S. EPA (1993), Region 10 In-stream Biological Monitoring Handbook for Wadable Streams in the Pacific Northwest. Furthermore, the evaluation of habitat was not intended to indicate trout carrying capacity but was employed merely to contribute to the weight of evidence used to assess the conditions of the aquatic communities within Railroad Creek and the various reference streams.

All ten locations (including the reference locations) were evaluated. The average (five transects per location) habitat parameter ratings by location are presented in Table 4.6-2. Again, it is emphasized that the habitat scores do not represent potential trout biomass or carrying capacity but are used only to compare stations with respect to overall habitat quality. Furthermore, although certain stations may appear to be similar based on the total habitat scores, the composition of the total score for the "similar" stations may be influenced by different habitat parameters.

In general and as described in PNL (1992), Railroad Creek stream gradient and discharge increase as the creek flows from the Glacier Peak Wilderness Area boundary downstream to Lucerne. Average substrate size generally increases from predominately cobble to mainly boulder-size particles downstream from Sevenmile Creek. The results of the habitat assessments indicate that, in general, habitats were similar averaging 104 with the notable exceptions of RC-9 (77) and BC-1 (120). Excluding RC-9 and BC-1, the habitat scores ranged from 93 at RC-3 to 113 at SFAC-1.

The Railroad Creek reference locations RC-6 and RC-1 (scores of 111 and 105, respectively) provided near average habitat for aquatic biota. Bottom substrate was void of fines and embeddedness was low primarily due to the relatively high stream gradient at both locations. RC-6 provided slightly more fish habitat related to the abundance and disbursement of cobble. The channels of both locations were overall relatively wide and shallow. Although RC-1 provided more pool habitat than RC-6, both had relatively shallow channels overall. Both locations exhibited instability along the banks. Although vegetation was present along the banks, particularly at RC-6, various stages of bank erosion were observed.

Location RC-9 exhibited the lowest habitat rating (77). The evaluation resulted in low scores in all parameters except disruptive pressure which scored high primarily because of the low occurrence of vegetation immediately adjacent to the bank. RC-9 provided less instream cover (cobble habitat) than all stations, excluding RC-7. This location is adjacent (south bank) to tailings pile 1 and the seep (SP-2) that originates from tailings pile 1. Ferricrete was found encroaching the creek along the bank adjacent to the tailings. However, the ferricrete appeared to break up at the creek's edge with staining and precipitate occurring in the lower portions of the location only. Large boulders presumably placed during historic reclamation efforts provided a majority of the fish habitat within this location. Approximately 75 percent of the stream substrate at this location experiences a precipitate or flocculent which appears to originate near the tailings pile 1 seep.

RC-7 located adjacent to tailings pile 3 has comparatively less instream cover (cobble habitat) than all stations, excluding RC-9. The overall habitat rating for RC-7 was 94. Both banks of this location support alders; however, some erosion was evident especially along the south bank near the tailings pile where the bank was unstable. The bottom substrate at RC-7 is generally covered with an orange-yellow precipitate (presumably iron) which could be easily disturbed and suspended within the water column.

RC-5a and RC-10 provide trout habitat primarily in the form of occasional deep runs and undercut banks along the south bank. Iron precipitate continues to occur throughout both of these locations. However, the precipitate's presence continually reduced as the stream flows downstream from RC-5a. Alders are prevalent adjacent to the bank affording bank stability at each location. The banks of these locations remain undisturbed and the established vegetation provides shading, overhangs for fish cover and a possible source of terrestrial insects.

Sampling location RC-3, located near the mouth of Railroad Creek is characterized as a high gradient stream with numerous large boulders in the deeper water upstream near the bridge. The lower portion of this location is shallow with a relatively wide channel. RC-3 has been somewhat disturbed by human activity.

The banks are relatively nonvegetated, possibly as the result of human encroachment from the road (bridge) that crosses the upstream end of the location and the general increase in human activities associated with the USFS campgrounds nearby and the Lucerne boat dock. A mine adit is present approximately one-quarter mile upstream of the sampling station.

Reference streams selected outside the Railroad Creek drainage were for the most part undisturbed, with the exception of Company Creek which is immediately downstream from the Chelan Public Utilities District hydropower outfall and included a road crossing (Bridge). Bridge Creek and South Fork Agnes Creek were located within wilderness areas and, as such, receive minimal human impact. Human access to both creeks is attainable only by the Pacific Crest Trail.

Based on the habitat analysis results, BC-1 had the best overall habitat. The only parameter noticeably suppressed at the Bridge Creek location was the "width to depth ratio." Unlike any of the other stations, approximately 25 percent of the Bridge Creek location consists of a single pool of five to six feet maximum depth which provide excellent trout cover and holding habitat for feeding. The remainder of the location is relatively wide, but consists of numerous large cobbles and boulders which provide relatively good instream cover for trout.

South Fork Agnes Creek (SFAC-1) provides instream trout cover in the form of scattered cobbles and boulders and undercut banks and overhanging vegetation. Although the stream is relatively wide at this location, several pockets backwater (downstream from the cobble and boulders) provide good holding habitat for trout.

Of all the reference locations (Railroad Creek and non-Railroad Creek), the Company Creek location (CoC-1) exhibits the most influence from human activity. As previously mentioned, CoC-1 is located downstream from the outfall of a hydropower plant. CoC-1 also contains a road crossing (bridge). The stream has high gradient with numerous large cobble and boulders which provide excellent trout habitat. Vegetation is nearly nonexistent immediately adjacent to the bank.

4.6.1.3 Benthic Macroinvertebrate Communities

The benthic macroinvertebrate communities within Railroad Creek and the reference streams exhibit a wide range of conditions. The benthic macroinvertebrate sampling and analysis procedure originally called for six to eight replicates to be analyzed at each location, pending the results of a power analysis on six randomly selected replicates from each site. However, in an attempt to account for the anticipated variation at each location all eight replicates were analyzed. The results of sampling eight replicates per location were applied to six indices, the results of which provide indications of community health or impairment. The indices evaluated are species richness (diversity), ratio of scrapers to filtering collectors, ephemeroptera, plecoptera and trichoptera (EPT) and chironomid abundance, percent dominant taxon, EPT index, and the ratio of shredders to total number of individuals collected. In addition to these indices, total number of organisms per square meter were determined as an indication of productivity at each sampling location. The results of these evaluations are presented in Tables 4.6-2a and b. The results are presented as means for all eight replicates at a given location. A listing of taxa and number of individuals for each replicate at each location is presented in Appendix O.

Species Richness

Species richness provides an indication of community health through a measurement of the variety of taxa (species) present. Species richness generally increases with increasing water quality, habitat diversity, and/or habitat suitability (EPA, 1989). As indicated from the 1997 benthic macroinvertebrate sampling results, species richness at the reference locations ranged from 37 at SFAC-1 to 52 at BC-1 while locations downstream from the Site ranged from 9 at RC-5a to 37 at RC-9.

Ratio of Scrapers to Filtering Collectors

The scraper and filtering collector functional feeding group ratio reflects the possible unbalanced community responding to an overabundance of a particular food source. Scrapers are usually herbivorous and typically feed on periphyton (attached algae) while filtering collectors will gather food that is suspended in the water column. The overabundance of scrapers indicates the presence of periphyton while the opposite imbalance reflects the possible lack of periphyton. The ratio of scrapers to filtering collectors at the reference locations ranged from 0.81 at CoC-1 to 0.92 at SFAC-1. Locations downstream from the Site ranged from 0 (locations RC-7, 5a, and 10) to 0.78 (RC-9).

Ratio of EPT Taxa and Chironomid Abundance

The EPT and Chironomidae abundance also provides an indication of relative benthic macroinvertebrate community health. Good biotic condition is reflected in communities having a fairly even distribution among all four major groups and with substantial representation in the sensitive groups Ephemeroptera, Plecoptera, and Trichoptera (EPA, 1989). Populations having more Chironomids relative to the EPT group may indicate environmental stress. EPT taxa and Chironomid ratios at the reference locations ranged from 0.93 at RC-6 to 0.97 at SFAC-1. Downstream from the Site this index ranged from 0.40 at RC-5a to 0.82 at RC-9.

Percent Contribution of Dominant Taxa

The percent of contribution of the numerically dominant taxon to the total number of organisms is an indication of benthic macroinvertebrate community balance at the lowest positive taxonomic level (EPA, 1989). A community dominated by relatively few taxa would be considered under stress. Dominant taxa contributions at the reference locations ranged from 30 percent at RC-6 and BC-1 to 44 percent at SFAC-1 while downstream from the Site this index ranged from 12 percent at RC-9 to 54 percent at RC-5a.

EPT Index

Similar to the EPT Taxa and Chironomid ratio, the EPT index reflects the total number of distinct taxa within the orders Ephemeroptera, Plecoptera, and Tricoptera. The index generally increases with increasing water quality. The EPT index at the reference locations was generally consistent ranging from 26 at SFAC-1 to 36 at BC-1 while the EPT index at the locations downstream from the Site ranged from 5 at RC-5a to 25 at RC-9.

Ratio of Shredder Functional Feeding Group and Total Number of Individuals Collected

Shedders typically feed on living vascular hydrophyte plant tissue and decomposing vascular plant tissue or coarse particulate organic material (CPOM). Shredders are typically sensitive to riparian zone impacts and are particularly good indicators of toxic effects when the toxicants involved are readily adsorbed to the CPOM and either affect the microbial communities colonizing the CPOM or the shredders directly (Plafkin et al., 1989). This index at the reference locations ranges from 0.05 (CoC-1) to 0.14 (SFAC-1) and from 0.15 (RC-10) to 0.54 (RC-5a) at the location downstream from the Site.

Total Number of Organisms

Total number of organisms reflects the general productivity of a community. In general, the abundance of organisms indicates the availability of food sources for fish. Productivity within the Railroad Creek locations was lowest at locations RC-7, -5a, and -10 with total number of organisms of 64, 52, and 75, respectively. The reference locations exhibited considerably higher total numbers of organisms ranging from 997 at BC-1 to 1266 at CoC-1.

The substrate sampled for benthic macroinvertebrates was generally homogenous within a given sampling station. Upstream from the Site (RC-6 and RC-1) and the remote reference stations (SFAC-1, BC-1 and CoC-1) were void of any visible precipitate or flocculent. Precipitate was most evident at stations located adjacent to and immediately downstream from the tailings piles (RC-7 and RC-5a). Although present, the precipitate was reduced downstream at RC-10 and RC-3.

RC-9, immediately upstream from Copper Creek, presented a unique opportunity for observing the affects of the precipitate with respect to benthic macroinvertebrates. RC-9 was located adjacent to a seep (SP-2) that originated at tailings pile 1. Approximately two thirds of RC-9 exhibited a transition to substrate covered with precipitate which appeared to be associated with one or more seeps originating from tailings pile 1 (Figure 4.6-3). Of the eight replicate samples collected at this station, one sample (replicate A) was collected upstream and along the opposite bank (north) from the precipitate, two samples (replicates B and D) were collected immediately upstream from the where the precipitate became obvious but possibly within the influence of the precipitate, two samples (replicates F and H) were collected along the bank opposite the seep but within the precipitate, and three samples (replicates C, E, and G) were collected adjacent to the seep and well within the influence of the precipitate.

The results of the individual replicates indicate probable influence from the precipitate assumed to originate from the tailings pile 1 seep or seeps. The sample collected upstream from and opposite the seep or seeps (and upstream from the precipitate) resulted in 1510 organisms per square meter which is much greater than either of the Railroad Creek reference stations (RC-1 and RC-6). Those samples collected immediately upstream resulted in reduced densities (240 and 300 organisms per square meter) compared to the replicate collected further upstream. The samples obtained along the bank opposite the seep or seeps (200 and 260 organisms per square meter) were similar to those collected immediately upstream from the precipitate. The greatest affect from the precipitate is exhibited by the low numbers of organisms within the replicates collected adjacent to the seep or seeps (10, 20, and 70 organisms per square meter). Species composition also changed from upstream to downstream of the precipitate. In general, the number of organisms which feed by collecting detrital materials in the stream substrate were reduced downstream from the precipitate.

Other Related Findings

Comparison of Railroad Creek Locations with Respective Reference Locations

Data collected for the benthic invertebrate community metrics were evaluated using the W test to determine if the data were lognormally or normally distributed. The results from these distribution fits were then utilized for statistical comparison in accordance with the pairings of Railroad Creek locations and their respective reference locations previously described. The results of the distribution fit for each pair of locations are presented in Table 4.6-2c while the statistical comparisons of the Railroad Creek location pairs with the respective reference pairs are presented in Table 4.6-2d. Because lognormal and normal fits and "no fit" conditions were encountered during the distribution fit evaluations, both parametric and nonparametric tests were used on the Railroad Creek and reference locations for the comparisons. The parametric test (independent t-test with 95 percent confidence) was performed if the reference and Railroad Creek metrics were found to be both either lognormally or normally distributed. A nonparametric test (Wilcoxin Rank Sum test with 95 percent confidence) was performed if the distribution fits from both data sets were not identical or the evaluation indicated no fit. Results of the statistical comparisons indicated that the percent dominant taxa were similar between both groups (RC1 and RC-6 reference compared with RC9 and RC-7 affected and SFAC-1 and BC-1 reference compared with RC-5a and RC-10). The only other comparison indicating similarity was the ratio of shredders in the comparison of RC1 and RC-6 reference with RC-9 and RC-7.

Comparison of Species and Sampling Stations

Benthic invertebrate communities in Railroad Creek at the upstream reference sites are similar to communities in other streams outside the drainage (Bridge Creek, South Fork Agnes Creek, and Company Creek). Other sampling locations at and downstream of the Site are variously affected. The number of taxa and organisms are reduced at all stations at or downstream of the former operations. A more careful analysis of trophic and habitat requirements for the organisms present at the various sites indicate that the primary effect immediately downstream of the tailings piles is a reduction in habitat capability for benthic invertebrates. This conclusion is based on several factors including the following:

- Benthic communities at the reference sites contain the full spectrum of trophic types (scrapers, shredders, collectors, filter feeders, and predators) as well as habitat usage (free ranging, burrowers, net spinning, upper stone surface).
- This full range and similar density is also found in upstream unaffected (by iron oxyhydroxide precipitate) portions of RC-9. This sampling station is downstream of the portal drainage where the portal water will be fully mixed with Railroad Creek water and yet the upstream portion of this sampling station shows no apparent toxicological effect from that discharge. The concentration of metals of concern does not change appreciably at sampling stations downstream of RC-9.
- The lower portion of RC-9 (affected by iron oxyhydroxide precipitate) and all other downstream sites except RC-3 demonstrate an affected benthic community. These sampling stations (except RC-3) have communities without large free ranging predators,

without scrapers and organisms requiring a clean upper stone surface and without organisms requiring large interstitial spaces for hiding. The organisms found within these affected communities are those that feed by collecting detrital materials, burrow in the substrate and require small interstitial space. The numbers of these organisms are generally reduced downstream from RC-9, in comparison with the Railroad Creek reference stations. The prevalence of the iron oxyhydroxide precipitate on and in the substrate has influenced the substrate downstream from RC-9 by infilling the interstitial spaces and coating the surface of the substrate which generally limits the establishment of periphyton. The benthic macroinvertebrates inhabiting the stations downstream from RC-9 will expend more energy in burrowing in the affected substrate because of its finer and more compact nature. In addition, these organisms will have to ingest a larger quantity of sediment, because the sediments contain a quantity of metal hydroxides that do not occur in native sediment, to obtain an adequate amount of fine organic matter. The fine organic detritus is the food source for these organisms and will be more dilute in the sediments than would otherwise occur because of the addition of the metal hydroxides. Therefore, the basic principles of bioenergetics would indicate that these organisms expend more energy to live in the substrate and to ingest and pass this added amount of material through their digestive tract than the same organisms in unaffected areas of the stream.

- It is noted that at sampling stations RC-7 and RC-9 a total of three new genera are found that do not occur at any other site sampled. These genera are the Plecopteran Leuctra sp. found at RC-7 and the Plecopteran Kathroperla sp. and the Dipteran Oreogeton sp. found at RC-9. The organisms are detrital feeding organisms that generally live in the substrate. The new Plecopteran genera, as members of the Ephemeroptera, Plecoptera, and Trichoptera group of pollution sensitive organisms, are generally considered pollution sensitive (EPA, 1989), and are so likely represented because of the alteration in habitat. It is also interesting to note that the filter feeders are variously present throughout Railroad Creek. Filter feeding insects are generally considered to be sensitive to compounds of concern in the water column because of their necessary greater exposure to water containing compounds of concern. That is, they must position themselves in the flow of the stream for their food capturing nets to work efficiently.

- Sampling station RC-3 demonstrates a level of recovery from habitat effects because the benthic community is largely restored in composition.

Comparison With Recent Data Collected by Others

The review of the July 1997 report by Washington State Department of Ecology (Ecology), *Effects of the Holden Mine on Water, Sediments and Benthic Invertebrates of Railroad Creek (Lake Chelan), Publication No. 97-330* disclosed the following:

- The report describes work conducted in June and September 1996. The June effort was a reconnaissance and water sampling event. The September sampling included the sampling of water, sediment and benthic invertebrates.

- The invertebrate sampling was performed using a kick net of 500 micron mesh. The work performed by Dames & Moore used an enclosed sampler with 250 micron mesh netting and is considered a preferred sampling procedure. The invertebrates collected by Ecology did not represent the full range of invertebrates collected by Dames & Moore and demonstrates a lack of disturbance of the substrate when collecting.
- The taxa list, metals tolerance list, and mean number of organisms provided in the Ecology report show a nearly complete lack of invertebrate organisms at and downstream of the Site. The Dames & Moore data demonstrate a very different picture with a change in community structure and reduction in numbers.
- The invertebrates found by Dames & Moore at and downstream of the Site are among the most metal intolerant organisms found on the list provided by Ecology. It is not likely that the community changed significantly between 1996 (Ecology sampling) and 1997 (Dames & Moore sampling) but the difference is more likely a result of the collection methods employed in the two studies.
- Ecology found the sediment not toxic and the toxicity of water was uncertain.

4.6.1.4 Fish Communities

Fish communities within Railroad Creek consist of primarily cutthroat (*Oncorhynchus clarki* spp.) and rainbow trout (*O. mykiss*). Mottled sculpin (*Cottus bairdi*) have also been observed within Railroad Creek (PNL, 1992). Numerous fish barriers located within the canyon relief of reach B preclude the upstream movement of fish originating in lower Railroad Creek or Lake Chelan. Occasionally, Kokanee (*O. nerka nerka*) will enter the creek from Lake Chelan in late September or early October in search of spawning areas. During the fall (1997) investigations, approximately 10 Kokanee salmon were observed in lower Railroad Creek. Although a comprehensive spawning survey was not included in the 1997 investigations, opportunistic observations were made of the stream substrate conditions during a reconnaissance of Railroad Creek in early September and during the subsequent benthic macroinvertebrate and fish sampling. Upon observing Kokanee in the lower segment of Railroad Creek (within approximately 300 yards of Lake Chelan), a more thorough reconnaissance of substrate conditions was conducted within that segment of Railroad Creek in an attempt to identify the existence of gravel suitable for spawning. Considering female salmon usually dig redds in a riffle area in small- to medium-size gravel (Wydoski and Whitney, 1979), the results of the reconnaissance indicated that very little, if any, substrate suitable for spawning existed within this segment of Railroad Creek.

Fish communities were sampled by snorkeling at all ten locations while electrofishing was utilized at all locations excluding South Fork Agnes Creek and Company Creek. The results of the snorkeling and electrofishing sampling are presented in Table 4.6-3. A summary of the general composition and condition of the fish at each location electrofished is presented in Table 4.6-3a.

As indicated during past fisheries studies of Railroad Creek (PNL, 1992), cutthroat trout were the most abundant trout collected throughout all locations while rainbows and rainbow/cutthroat hybrids were occasionally collected. Cutthroat trout were present at all ten sampling locations. Rainbow trout were present at RC-6, RC-1, RC-3, SFAC-1 and CoC-1. Rainbow/cutthroat hybrids were identified at RC-6 and RC-1 only. One brook trout (*Salvelinus fontinalis*) was observed by both snorkelers in Company Creek. Although none were collected, approximately 10 Kokanee were observed immediately upstream from RC-3. The mottled sculpin was the only non-trout fish species collected during the survey. Sculpins were collected at RC-3 only. No signs of gross abnormalities or disease were observed with any of the fish collected during electrofishing or observed during snorkeling.

The results of each sampling method were similar with the exception of the number of fish observed and estimated at RC-10, BC-1, SFAC-1 and CoC-1. At RC-10 and BC-1, several small trout (<40 mm) were collected by electrofishing. Four trout at RC-10 and three trout at BC-1 less than 40 millimeters were collected by electrofishing but not observed by the snorkelers. Because of their small size, these fish were not observed during the snorkeling survey, therefore contributing to the greater electrofishing population estimates. Since the electrofishing produced tangible evidence of the fish population (i.e., fish captured) at RC-10 and BC-1, these estimates are considered more representative of the true populations at these locations. Electrofishing was not conducted at SFAC-1 because of logistical constraints. Electrofishing was not conducted at CoC-1 because of the presence of spawning.

Length Frequency Histograms

Length frequency histograms were developed for cutthroat trout collected at all aquatic biota sampling locations where electrofishing was employed (Figure 4.6-4). The low numbers of cutthroat trout collected at each location, with the possible exception of BC-1, preclude the identification of obvious year classes. However, age 0+ cutthroat trout (hatched during the spring/summer of 1997) can be identified with reasonable certainty to include cutthroat trout of lengths ranging from approximately 10 to 60 millimeters. Locations where 0+ cutthroat trout were collected are BC-1 and RC-10. The maximum age of cutthroat trout collected during the survey is estimated to be 4+ years. However, age determination of these species in mountainous streams is difficult.

Summary

Trout populations (based on electrofishing results) appear to be reduced in the segments adjacent to and immediately downstream from tailings pile 3. Trout populations range from 64 to 93 fish per hectare at locations (RC-6, RC-1, RC-9) upstream from Copper Creek (upstream from tailings pile 2), while the two locations (RC-7 and RC-5a) established adjacent to and immediately downstream from tailings piles 2 and 3 exhibited populations of 10 and 20 fish per hectare, respectively. Trout populations return to numbers similar to the upstream locations near 7-Mile Creek (RC-10, 92 fish per hectare) and continue at that level near Lake Chelan (RC-3, 89 fish per acre).

4.6.2 Terrestrial Biota

4.6.2.1 Background

The Holden Mine Site is located on the north-facing side of a steep-sided glacial valley which runs east-west, and is drained by Railroad Creek. Elevations at the Site range from approximately 3,200 feet at the valley floor to about 6,500 feet along the ridge tops. The tailings piles are located on the valley bottom, and Railroad Creek flows adjacent to the north side of the tailings. The Site is on USFS land which borders the

Glacier Peak Wilderness Area. Due to the remote setting and the presence of both north- and south-facing slopes in the valley, the Site is surrounded by a rich diversity of plant community types and wildlife habitats.

For wildlife survey purposes, the Site and the surrounding area was regarded as five sub-areas which differed by cover type. These sub-areas consisted of the mine tailings, the north facing slopes and old mine works, the south facing slopes, the riparian area upstream of the tailings, the riparian area downstream of the tailings, and the tailings themselves. Vegetative differences of these areas are described hereafter. Although all habitats were surveyed, effort in each area was not equal, due both to different amounts of time spent in each habitat, and the variable weather conditions encountered. A summary of surveys conducted is presented in Table 4.6-4.

4.6.2.2 Vegetation

The vegetation in the Site area varied by aspect, elevation, and available moisture, and was broken into five sub-areas for purposes of the terrestrial surveys. These sub-areas consisted of the tailings piles, the north-aspect slopes and old mine works, the south-aspect slopes, the riparian area upstream of the tailings, and the riparian area downstream of the tailings (Figure 4.6-5). A table providing common species name with scientific name is presented as Table 4.6-5. Vegetative differences of these areas are detailed below.

North-Aspect Coniferous Forest and Mine Workings

The abandoned mine workings (portals and waste rock dumps) are located on the north-facing valley wall. The plant diversity is high and vegetation is relatively dense in the moist coniferous forest surrounding the mine workings. Trees on this slope include Douglas fir, ponderosa pine, western white pine, Englemann spruce, western red cedar, subalpine fir, Pacific silver fir, western hemlock, mountain hemlock, and lodgepole pine. The trees are all relatively young and closely spaced, probably as a result of a fire in the early 1900s. The herbaceous layer contains many species that are common in the wetter Western Cascades, including devil's club, various ferns, and goat's beard. Other understory species include Oregon boxwood, blueberry, and thimbleberry. Numerous avalanche chutes, vegetated with deciduous shrubs such as Sitka alder, mountain ash, Douglas maple, white-flowered rhododendron, and Scouler's willow, bisect the area. The steep waste rock areas are mostly barren, with scattered alder and conifer seedlings, grasses, sedges, and forbs.

South-Aspect Coniferous Forest and Open Areas

A much drier, more open forest dominated by ponderosa pine and Douglas fir is found on the south-facing slope. The forest understory is predominantly Oregon boxwood and grasses. Pinegrass is common in forest openings. Shrubs in forest openings and the subalpine areas include Douglas maple, ocean spray, snowbrush, bitter cherry, snowberry, serviceberry, elderberry, and willow. Quaking aspen stands are also present in the avalanche chutes at lower elevations. Rock ferns (e.g., *Cryptogramma crispa*) grow in the rocky outcrops, and lichen hangs from tall tree trunks and branches.

Upstream Riparian

Large areas of mixed (deciduous and coniferous) forest with a sparse understory are found in the upstream riparian zone. Large cottonwood trees up to five feet in diameter dominate in some areas, and large snags and stumps with bark piles surrounding them, which provide valuable wildlife habitat, are common. Mature coniferous trees include ponderosa pine, Englemann spruce, Douglas fir, subalpine fir, and western white pine. The forest floor is covered in places with false Solomon's seal and wild lily of the valley. Bracken fern, lady fern, and Devil's club grow in lower patches. Dense willow and alder thickets and small, gravel bottomed ponds are present along the borders of Railroad Creek. Several sedge species are associated with the rocky pools.

Downstream Riparian

The areas immediately downstream of the tailings include wetlands dominated by extensive willow and alder thickets near the creek and coniferous forest upland from the creek. Farther downgradient from the tailings, western red cedar dominates in a large wetland forest pocketed with numerous small ponds. Other trees present include black cottonwood and Englemann spruce. This wetland area has a lush understory of mosses, sedges, horsetail, ferns, and herbs, including bog orchids. Fallen timber and large snags surrounded by bark piles are also present.

Tailings Piles

The tailings piles are sparsely vegetated with a combination of planted and volunteer plant species. Volunteer tree species found growing along on steep sides of the tailings include Douglas fir, subalpine fir, and Englemann spruce. Willow and alder shrubs are also common along the tailings pile edges near Railroad Creek. Various grasses, forbs, and sedges cover approximately 5 to 10 percent of the tops of the tailings piles. Revegetation studies and plant inventories of the tailings piles are available from the USFS.

4.6.2.3 Wildlife

Herpetofauna

Herptiles observed during the September 1997 surveys were limited to long-toed salamander larva and a garter snake in a small pool, adjacent to Railroad Creek, one half mile upstream of the Site. Caddisfly and other insect larva were also found in this still pool surrounded by bulrushes and alders. Other opportunistic searches during the seven day survey did not reveal any additional herpetofauna in Railroad Creek, adjacent pools and wetlands, and upland forested and talus slopes. Amphibian, snake, and lizard species known to exist in this area are listed in Table 4.6-6.

The amphibian species listed in Table 4.6-6 are found near water throughout all or part of their life stages. These species all have aquatic larva within their reproduction life stages. The long-toed salamander has pond adapted larva while the Pacific giant has stream adapted larva. The tailed frog breeds and lives near fast moving, rocky mountain streams, while the other frog species breed in ponds, wetlands, or still, shallow water near streams. Adult western toads and Pacific treefrogs may range far from water in a variety of habitats (Leonard et al., 1993). The snakes listed in the table could be found in any of the habitats near the Site. Rubber boas and garter snakes are usually found near water, and they sometimes share rocky denning sites in winter (Brown et al., 1995).

Other herpetofauna potentially occurring within the area include the northwestern salamander, Van Dyke's salamander, Larch Mountain salamander, rough-skinned newt, western fence lizard, western skink, racer, sharptail snake, gopher snake, and western rattlesnake. The known ranges of these species do not currently extend to the Site area, but habitat for these species is available in the Railroad Creek drainage. For example, western rattlesnakes could potentially be found in rocky outcrops on the south-facing slopes, and isolated populations of Larch Mountain salamanders could be found in moist talus on north-facing slopes.

4.6.2.4 Avifauna

Because the terrestrial biota surveys were conducted in early September, most species observed were either year-round residents of the area, or migrants passing through. Most summer residents (breeders) had already departed for southern latitudes. Species which would be expected to use the area for breeding in summer, as well as probable residents which were not observed, are listed in Table 4.6-7.

Mixed feeding flocks of both resident and migrating bird species were common in all cover types surveyed. Red-breasted nuthatches, mountain chickadees, dark-eyed juncos, American robins, and golden-crowned kinglets were the most abundant bird species observed. Other commonly observed species included chestnut-backed chickadees, Townsend's warbler, white-crowned sparrows, hermit thrushes, cedar waxwings, finch species (Cassin's and/or purple) and crossbills. A complete list of species observed, by cover type, is given in Table 4.6-8. A short description of the avifauna found in each survey area is given below.

North-Aspect Coniferous Forest and Mine Workings

Bird density was generally high, with many mixed feeding flocks present. Bird species of interest observed around the mine workings include a Pileated woodpecker, sharp-shinned hawk, varied thrush, and Clark's nutcracker. Finch species were also common.

South-Aspect Conifer Stands and Open Areas

Birds were abundant on this slope, although not as abundant as on the north facing slope. Townsend's solitaire, finches and crossbills were common in this habitat, as were robins. A golden eagle, a rough-legged hawk and a pair of sharp-shinned hawks were also observed on Martin's Ridge.

Upstream Riparian

A red-tailed hawk was observed perched along the edge of Railroad Creek, and blue grouse were also observed in the shrubby cover along the Holden Lake trail. Large feeding flocks composed primarily of robins, cedar waxwings, and sparrows were also present. No wading birds or water fowl were observed in riparian areas during the survey. However, dabbling ducks may breed near pools adjacent to Railroad Creek.

Downstream Riparian

Bird density appeared relatively low in this area. However, the number of birds observed may have been influenced by rainy weather during the surveys of this area. Two juvenile American dippers were observed feeding on invertebrates in Railroad Creek, just below the foot of the tailings piles. No other dippers were observed in the study area.

Tailings Piles

A flock of violet-green swallows (>50 birds) and a few barn swallows foraged daily for insects over the tailings piles. Swallows were not observed in other habitats surrounding the Site, with the exception of the open areas around Holden Village. A large flock of American pipits (ca. 35 birds) was also observed foraging at the tailings piles; this species nests in open alpine areas and probably uses the tailings pile primarily during migration. Two immature red-tailed hawks were observed hunting along the tailings piles suggesting a nest in the area.

A variety of avian species are expected to use both the tailings piles and the affected areas of Railroad Creek, to varying degrees. All insectivorous species which use the riparian zone surrounding Railroad Creek probably consume flying insects which spend their larval stage in the creek. Vegetation gleaning species (warblers, vireos, chickadees) would consume fewer such insects than species which hawk for insects on a regular basis (flycatchers, cedar waxwings). Dippers consume almost exclusively aquatic insects.

Most bird species living in the vicinity of the Site are unlikely to use the tailings piles on a regular basis. Birds of the Cascades are adapted to structurally complex habitats and the tailings piles are predominately structurally simple. Some species, however, are likely to frequent the tailings piles, including raptors and owls in search of small mammals. Although small mammal densities on the tailings are probably not high, suitable habitat for a variety of species does exist and the lack of cover makes them available to avian predators.

Other avian species observed on the tailings or likely to be present include barn and violet-green swallows, American pipits, and common nighthawks. Swallows feed on airborne insects which may originate from the tailings pile and railroad creek. During aquatic insect hatches, a large proportion of swallow diets consist of insects from Railroad Creek. Pipits eat insects and seeds gleaned from the ground and are therefore likely consuming forage originating from the tailings pile. However, pipits are only visitors to the area during migration. Common nighthawks, which also feed on airborne insects, are ground nesters, and prefer open, gravelly nest sites.

4.6.2.5 Mammals

Bat species which are potentially present in the Site area are listed in Table 4.6-9. The western big-eared bat appears to roost exclusively in caves and mines, buildings, and bridges, while most of the other species will also roost under loose bark and in rock crevices. For most species, caves, mines, and buildings are used for maternity roosts and hibernacula (Christy and West, 1993).

Potential bat roosts exist at the 1500-level main portal, the 1500-level ventilator portal, and in the 1100-, 500-, and 300-level portals. Depending on the time of year, the mine portals may be used for night or day roosts, colonial roosts (males and non-breeding females), maternity colonies, or hibernacula. The 1500-level main portal which provides both roosting habitat and drinking water, appears to be the most suitable for bat roosting.

During the bat surveys, bats were observed at dusk near the surface of the 1500-level main mine portal drainage. However, there was insufficient daylight to determine whether they were exiting or entering the portal itself. Bats were not observed anywhere else at the Site or the surrounding area during the September 1997 surveys, but large numbers were observed at the ballfield in July (personal communication with Steve Arnett, Dames & Moore, 1997). Bats may have been less active in September than July because of the cooler temperatures and damper weather. Due to the timing of the survey, data were not collected on the use of the Site by breeding bats. Although warmer environmental conditions are generally required for maternity roosts, no conclusions can be made from the existing literature or bat expert knowledge as to the potential presence or absence of breeding bats at the Holden Mine Site.

During the general surveys, mammal species commonly observed included Douglas squirrel, mule deer, chipmunks (yellow pine and/or Townsend's), and golden-mantled ground squirrels. Except for black bears, no predators were observed. Given the ample prey base, predators are expected to use the area regularly. However, these species are secretive by nature and can easily avoid detection at the Site, as thick cover is available, and only a relatively small area is used by humans. A complete list of all mammals observed is provided in Table 4.6-10 by survey area. Observed animal species of special note are listed below by habitat.

North-Aspect Coniferous Forest and Mine Workings

Small mammals were common, including both Douglas squirrels and chipmunks. Pikas and their hay piles were observed on the west and east waste rock piles.

South-Aspect Conifer Stands and Open Areas

High on the ridge deer sign was common, and the remains of a fresh deer carcass suggested the presence of mountain lion and/or coyotes.

Upstream Riparian

Mule deer and a bear were observed in the shrubby cover along the Holden Lake trail, as well as numerous chipmunks, Douglas squirrels, and golden-mantled ground squirrels.

Downstream Riparian

Bear and deer sign were common.

Tailings Piles

Deer tracks and deer pellets were observed on the tailings, especially where the cover was somewhat better established. Golden-mantled ground squirrels and chipmunks were also observed in these areas.

A variety of mammals are expected to use the tailings pile and Railroad Creek. However, with the exception of small mammals, most of these species would not use these areas exclusively as they are highly mobile and have large home ranges. Species which might live exclusively on the tailings piles include golden-mantled ground squirrel, chipmunk spp., deer mouse, and bushytail woodrat. Species potentially inhabiting the riparian zone exclusively, include the aforementioned small mammals as well as vole spp., Pacific jumping mouse, and beaver. Additionally, all the species listed in Table 4.6-9 as potentially present in the Site area may use the tailings areas to some degree.

4.6.3 Threatened or Endangered Species

This section provides descriptions of federal- and state-listed and candidate species potentially occurring in the vicinity of the Site. Table 4.6-11 summarizes the information presented on these species.

4.6.3.1 Federal- and State-Listed Species

Gray Wolf (*Canis lupus*)

Status

The gray wolf is listed by the USFWS and the State of Washington as endangered. The gray wolf is a FS sensitive species.

Background Information

Wolves formerly occupied most of the North American continent. Their current distribution is from Alaska through Canada and into the northern United States from Washington to Michigan.

Populations in Vicinity of the Site

The Site is surrounded by suitable gray wolf habitat with a year round supply of mule deer prey. Three confirmed wolf den sites were discovered in the North Cascades in 1990 (USFWS, 1992). Several unconfirmed sightings in the vicinity of the Site are on record with the USFS. The closest sighting just east of Copper Creek (T31N R17E S18 NE1/4) and less than .5-mile from the Site occurred on July 26, 1995. Two other sightings in the Railroad Creek watershed include one near Hart Lake (T31N R16E S4) in July 1993, and one south of Mirror Lake near the head of Tumble Creek (T31N R18E S31) in September 1991. Wolf howling surveys have been conducted by USFS biologists following visitor reports of wolf sightings in the Railroad Creek drainage. These surveys have failed to confirm any of the sightings to date. The most reliable sighting so far has been one in Copper Basin (personal communication with Mallory Lenz, USFS, 1997).

Peregrine Falcon (Falco peregrinus)

Status

The peregrine falcon is federally listed by the USFWS as endangered. It is also listed by Washington State as endangered.

Background Information

The peregrine falcon has a worldwide distribution except for Antarctica. Peregrine falcons are usually observed in Washington as a migrant or winter visitor, although some are known to breed here. Two subspecies currently breed in Washington State: Peale's (*F.P. pealei*) and Continental Peregrine Falcon (*F.P. anatum*). Peale's subspecies is found along the ocean coasts while the continental subspecies is rare in eastern Washington. Most Washington breeding records of Peale's subspecies occur along coastal cliffs in the San Juan Islands, northern Washington, and the western Olympic Peninsula. The continental subspecies has been reintroduced at various locations east of the Cascade Mountains (Smith et al. 1997).

Populations in Vicinity of the Site

The steep, rugged mountainous terrain and open forests of this area provide habitat for peregrine falcons. Birds, the falcon's prey, are abundant, and potential nest sites like rock cliffs and large trees are plentiful in the Railroad Creek drainage basin. Peregrine falcons have been observed in the Railroad Creek watershed basin according to USFS database records. The records include sightings in the vicinity of Dumbell Mountain (T31N R16E S16), Hart Lake (T31N R16E S10, 3, and 4) (T32N R16E S34), and Copper Creek (T31N R17E S17). Two other records in the area are north of the basin on Lucerne Mountain (T31N R17E S1), and south near Lake Chelan (T31N R18E S14). All of these sightings were made in June 1989, with the exception of the Dumbell Mountain observation in August 1980.

Bald Eagle (Haliaeetus leucocephalus)

Status

The bald eagle is federally listed in Washington State by the USFWS as threatened.

Background Information

The bald eagle is found breeding from central Alaska south through Canada and in the United States from coast to coast south to the Florida Keys, Texas, Arizona, New Mexico and into Baja California (AOU, 1983). Bald eagles occur in Washington as residents near large waters west of the Cascade Mountains, with fewer breeding birds found in eastern Washington (Rodrick and Milner, 1991). Birds wintering in Washington are found on the Olympic Peninsula, San Juan Islands, the major tributaries of the Puget Sound, the Cowlitz and Columbia Rivers, and Hood Canal.

Populations in Vicinity of the Site

The lower part of Railroad Creek and the area around Domke Lake are designated as Bald Eagle Recovery Territory. The most suitable habitat for bald eagles in the vicinity of the Site is found along Lake Chelan as the lake provides a year-round prey base of fish and waterfowl. In addition, mature trees for nesting and roosting are located in places within one-half mile of the lake. Although the USFS has no records of bald eagles in the Railroad Creek drainage, bald eagles have been observed north of Railroad Creek on the west side of Lake Chelan (T32N R18E S19) and on the east side (T31N R18E S2).

Grizzly Bear (Ursus horribilis)

Status

The grizzly bear is listed by the USFWS as threatened and by the State of Washington as endangered. The FS considers the grizzly bear a sensitive species.

Background Information

Grizzly bears historically occupied most of western North America from Alaska, south through Canada, all the way down to central Mexico (Hall and Kelson, 1959). Currently, this species is restricted to some areas in Washington, Idaho, Montana, and Wyoming in the lower 48 states. In Washington, they are found in the north and central Cascade Mountains and in the north eastern part of the state.

Populations in Vicinity of the Site

The Site is within the North Cascades Grizzly Bear Recovery Zone which covers about 9,565 square miles in north-central Washington State. The USFS and wilderness areas surrounding the Site provide suitable habitat and a large enough area for grizzly bears. Grizzly bear observations evaluated by the Washington Department of Fish and Wildlife suggest that a small resident population occupies the North Cascades (USFWS, 1992). Although there are no recent sightings in the Railroad Creek Watershed, the USFS has recorded a sighting of a grizzly bear near the southwestern edge of Domke Lake (T31N 18E S22) on July 4, 1995. In addition, the Department of Fish and Wildlife's Heritage Database has on record two sightings of an adult grizzly bear (live animal, photo, tracks, and scat) south of Dole Lakes near the Entiat River (T31N R17E S28). Dole Lakes feed into Dole Creek, a tributary of Railroad Creek.

Northern Spotted Owl (Strix occidentalis)

Status

The northern spotted owl is federally listed as threatened with designated critical habitat. It is listed by the State of Washington as endangered. This species is also considered a FS sensitive species.

Background Information

Spotted owls occur in mountainous and humid coastal forests from southwestern British Columbia, south through western Washington and western Oregon, to southern California and possibly northern Baja California; and in the Rocky Mountains from southern Utah and southwestern Colorado, south to the mountains of Arizona, New Mexico, and western Texas, and south into northern and central Mexico (AOU, 1983). The northern spotted owl occurs in Washington from the Olympic Peninsula east through the Cascades from Canada south to the Columbia River (Jackson et al., 1995).

Populations in Vicinity of the Site

The riparian areas adjacent to Railroad Creek generally provide more suitable habitat for spotted owls than the nearby forested slopes. The riparian and wetland forests along the creek contain mature deciduous and coniferous trees, some up to 5 feet in diameter. Large, broken topped trees are relatively common. Tree species in the valley bottom forests include black cottonwood, Englemann spruce, Douglas Fir, western red cedar, western white pine, and ponderosa pine. According to spotted owl habitat definitions presented in the Washington Administrative Code (WAC 222-16-085), this forest would be classed as old forest habitat having the features typically required by spotted owls.

Other forest communities surrounding the Site are not currently as suitable for spotted owls as the valley bottom forest. The south aspect slope north of the Site is an open ponderosa pine/Douglas fir forest from about 3,200 to 4,200 feet. Spotted owls are not usually found in open forests at higher elevations (Smith et al., 1997). The north aspect slope surrounding the old mine workings is a more moist, dense forest, with a rich mix of conifer species. Tall snags are present which attract cavity dwellers like pileated woodpeckers. This forest is still maturing, only a few large trees remain at higher elevations (>4,800') due to a fire in the early 1900s. The north aspect forest should become better spotted owl habitat as it matures.

Spotted owl surveys in the Railroad Creek Watershed Basin have been limited due to the rugged terrain and the noise of Railroad Creek. However, a female spotted owl was followed to the upper Railroad Creek area during radiotelemetry monitoring work in 1993. This female owl was reportedly a subadult and was observed with a male. This subadult pair was not likely a breeding pair, and no nest was found in 1993, or in 1988 when another survey was conducted in an attempt to find spotted owls at this location. No spotted owls were observed during the 1988 survey. A male currently resides near Domke Lake (Personal communication with Mallory Lenz, Forest Service). This male owl has an established territory surrounding Domke Lake, within a 0.5 mile south of Railroad Creek. This territory is represented on the Washington State Priority Habitat and Species: Lucerne Quad as a spotted owl management circle (WNHP, 1997).

Ute Ladies-Tresses (*Spiranthes diluvialis*)

Status

Ute ladies-tresses is listed by the USFWS as threatened.

Background Information

Ute ladies-tresses is an orchid which before 1997 was known only from northern and eastern Utah, central Colorado, and along the Snake River in southern Idaho. In 1997, a small population was discovered in Okanogan County. It is generally found in open shrub or grassy wetland and riparian areas.

Populations in Vicinity of the Site

No populations are known in the area except for the population in Okanogan County. Habitat for this species is found in the riparian and wetland areas of Railroad Creek, especially near the Creek where there are some open grassy springs and ponds.

Bull Trout (Salvelinus confluentis)

Status

The bull trout populations in the Columbia Basin are listed by the USFWS as threatened.

Background Information

The bull trout is found in Western North America from Southern Oregon to Alaska and as far East as Montana and Alberta (Wydoski, 1979). Bull trout are closely related to dolly varden trout and belong to the Arctic Char complex of species. This species occurs throughout Washington with both resident and anadromous populations occurring in the Puget Sound Basin and only resident fish occurring in the Columbia River Basin (Brown, 1994). Populations west of the Cascade Mountains appear to be healthy and stable while most populations East of the Cascade Mountains in the Columbia Basin are depressed (Mongillo, 1993).

Bull trout are primarily piscivorous and prey heavily upon young salmonids and other fish. Lake dwelling populations exist in many Washington lakes. Mature bull trout ascend tributary streams to spawn in the fall months and display an ability to pass stream barriers that can block chinook and steelhead migration.

Populations in the Vicinity of the Site

Bull trout have not been found in the Railroad Creek drainage.

4.6.3.2 Candidate Species

Wenatchee Mountain's Checkermallow Sidalcea oregana var. calva

Status

The Wenatchee Mountain's checkermallow is a federal candidate and a state threatened species. It is also on the USFS list of sensitive plant species.

Background Information

The Wenatchee Mountain's checkermallow grows in wet meadows and near streams. It is a local endemic found only in a few places in the Wenatchee Mountains in Chelan and Kittitas counties (WNHP, 1981).

Populations in the Vicinity of the Site

There are no known populations in the Railroad Creek drainage or near Lake Chelan.

Canada Lynx (Lynx canadensis)

Status

The Canada lynx is a Federal Candidate species, and Washington State lists it as a threatened species. It is considered a sensitive species by the USFS.

Background Information

The Canada lynx is found in Canada and in the United States in Alaska, the Pacific Northwest states, the Rocky Mountains, the northern lake states, and northern New England (Rodrick and Milner, 1991). In Washington, this species occurs in the northern portion of the state from the northeastern Cascades to isolated areas in the Okanogan Highlands of northeastern Washington above 4,500 feet elevation in Chelan, Okanogan, Ferry, Stevens, and Pend Oreille counties.

The distribution of the lynx appears tied to that of the snowshoe hare. Both species are found in spruce, subalpine fir, and lodgepole pine forests. Lynx primarily prey on snowshoe hare but they also eat mice, squirrels, grouse, and ptarmigan. Breeding occurs in March or April with kittens being born in late May (Koehler, 1990 *in* Koehler and Aubry, 1994).

Populations in Vicinity of the Site

Lynx habitat is found at higher elevations in the Railroad Creek drainage. The USFS has a record of lynx near a ridge south of Dumbell Mountain (T31N R16E S27).

Federal Species of Concern

Table 4.6-12 lists the Federal Species of Concern whose ranges encompass the Site vicinity. A discussion follows, detailing which of these species may occur within the vicinity of the Site.

Many of the wildlife species of federal concern are at least partially dependent upon streams and riparian habitats. Railroad Creek and its associated wetlands and riparian habitats may provide habitat for these amphibians and mammals throughout the year, and for Harlequin ducks and little willow flycatchers in summer.

The existing literature and historic photographs do not document the habitat present in the Railroad Creek drainage prior to the construction of the tailings piles. However, based on the habitat observed immediately downstream of tailings pile 3, it appears possible that riparian habitat existed that may have included areas of scrub-shrub, emergent, and open-water wetlands, and mixed forest; this area could have provided habitat for one or more species of concern. New roosting habitat for bats may have been created by the underground mining activities.

The forested areas along Railroad Creek and on the mountain slopes provide potential breeding habitat for northern goshawks and olive-sided flycatchers. Northern goshawks have been sighted near Railroad Creek according to USFS database records. Northern goshawks inhabit forested areas with high canopy closure, sparse understory, and small forest openings. They prefer to nest in areas with permanent water within 0.5 mile of their nest. Goshawks build large stick nests in large mature trees. Three eggs are normally laid from April to early June, with eggs hatching around mid-May (Marshall, 1992). Hatchlings stay in the nest for about 45 days and continue to rely on adults for food until late summer.

Potential habitat exists for California wolverines and Pacific fishers. They have been observed near the highest reaches of the Railroad Creek drainage according to the USFS database.

Suitable habitat including mature trees and rock caves and crevices is available for the western big-eared bat and the myotis bats. Bats have been observed flying near the main mine portal and at the ballfield area near Holden Mine. Bats may use cave-like mine portals for day or night roosting, maternity colonies, or hibernacula.

Habitat for the ferruginous hawk, western burrowing owl, western sage grouse, whited milk-vetch, and Thompson's clover is not found near the Site. The current range of the Columbia sharp-tailed grouse does not extend into Chelan County (Smith et al., 1997). Black terns are not likely to be found in the Railroad

Creek drainage, they are more common east of this site in Washington. California bighorn sheep are not found near the Site. The closest bighorn sheep population is located about 20 miles south of the Site (personal communication with Mallory Lenz, USFS, 1997).

The Washington Natural Heritage Program identified no records of rare plants or high quality ecosystems near the Site. However, two rock ferns which are state sensitive, *Pellaea breweri* (Brewer's cliffbrake) and *Cryptogramma stelleri* (Steller's rockbrake), grow about three miles from the Site (letter dated August 13, 1997, from the Washington Natural Heritage Program, attached as Appendix P).

The following USFS sensitive plant species are found about 3/4 mile away from the Site:

Epipactis gigantea	Giant Helleborine
Githopsis specularioides	Common Bluecup
Pellaea brachyptera	Sierra Cliff-Brake (blackish wire stipes)
Spiranthes romanzoffiana var. porrifolia	Western Ladies-Tresses

USFS Protection Buffer Species which may be present include:

Great Grey Owl

Black-backed Woodpecker

White-headed Woodpecker

Pygmy Nuthatch

Flammulated Owl

4.6.3.3 Survey and Manage Component 2 and Protection Buffer Species

Survey and manage component 2 and protection buffer species which could potentially be found in the Railroad Creek watershed and the Holden Mine Site include salamanders, mollusks, fungus, non-vascular, and vascular plant species. The majority of these species are usually found in the moist forests of the western Cascades or Olympic Mountains. Although the Railroad Creek watershed is located on the east side of the Cascades, the east-west orientation of the drainage creates microclimate extremes on the steep sided north-facing and south-facing slopes on either side of the valley. In the moist riparian area of Railroad Creek and the north-facing slope where the Holden Mine is located, moist microhabitats contain plant species and microclimatic conditions similar to those found in wet western Washington forests. Therefore, potential habitat for many of these survey and manage species is present at the Holden Mine Site even though the site is beyond the suspected range for most of these species.

Salamanders

Both of the survey and manage salamanders, Van Dyke's (*Plethodon vandykei*) and Larch Mountain (*Plethodon larselli*) salamanders, are rare terrestrial salamanders with patchy distributions. The current range for Van Dyke's salamander includes the Olympic Mountains, the southern Cascades, and the Willapa Hills. This salamander is considered the most aquatic of the *Plethodon* genus. Suitable habitat includes the splash zones of creeks, streams, or falls, the undersides of rocks or logs, and seepages over talus slopes on moss-covered, north-facing slopes (Leonard et al. 1993). The Larch Mountain salamander has been found in the Columbia River Gorge area and the Central Cascades (Blaustein 1995). This species generally inhabits steep forested and non-forested talus slopes, and has also been found in non-talus areas underneath large woody debris. If either of these salamander species were found in the Railroad Creek watershed, the siting would represent an extension of their range.

Although the Holden Mine Site is beyond the current range of the survey and manage salamanders, potential habitat does exist here, especially along Railroad Creek for Van Dyke's salamander and on the steep north-facing slopes of the valley for the Larch Mountain salamander. The tailings piles which intersect the Creek and the tailings deposits on the north-facing slope do not contain suitable habitat for either species of survey and manage salamander. During the September 1997 opportunistic surveys for amphibians upstream and downstream of the tailings, a long-toed salamander larva was observed upstream, but no amphibians were found in downstream reaches of the Creek.

Mollusks

Table 4.6-13 presents the USFS survey and manage component 2 mollusk species with the potential to be found in the Railroad Creek watershed and the Holden Mine Site.

All of these survey and manage mollusk species, with the exception of the masked duskysnail, are identified as old growth associates, and all are riparian associates. In general, the land species require some deciduous leaf litter, although many are found in old coniferous forests. Three of these species, the Chelan mountain snail, papillose tail-dropper, and masked duskysnail are known to occur in the Wenatchee National Forest. Masked dusky snails are possibly found in the Railroad Creek watershed in small pools associated with the creek. Surveys in the Wenatchee National Forest, Chelan Ranger District are required for projects which may impact the habitat of these species.

Potential habitat for these survey and manage mollusk species is found primarily upstream and downstream of the mine in the moist microhabitats of the mixed deciduous and coniferous forest areas near and in the Railroad Creek riparian area. Survey and manage mollusks are unlikely to be found where the tailings piles are located. Specific surveys for survey and manage mollusks were not conducted during the September 1997 wildlife surveys in the Railroad Creek area. Survey protocols for these species were not published at the time of the wildlife surveys.

Plants

A number of the survey and manage plants are likely to exist upstream or downstream of the tailings piles in the Railroad Creek riparian area or in other forested or alpine habitats in the watershed. Three species of survey and manage component 1 and 3 fungi have been found in the Lyman Lake camp area (T31N

R16E S7). These species include an uncommon false truffle (*Macowanites lymanensis*), an uncommon gilled mushroom (*Collybia bakerensis*), and a rare cup fungi (*Helvella crassitunicata*). These species will also need to be considered, and surveys for these species may be needed before any ground disturbing activities because of their presence in the site vicinity.

Surveying for a number of survey and manage plant species considered protection buffer or survey and manage component 2 species is not required because they may only be present for a few weeks during a season, or because not enough is known about their biology to develop appropriate survey protocols. The species of this nature with potential to be found in the Wenatchee National Forest have been organized into Table 4.6-15 by Terry Lilibridge of the Wenatchee National Forest.

Future Survey Efforts for Survey and Manage Species

Protocol surveys for survey and manage species are required before ground-disturbing activities on Federal land where potential habitat for these species exists. Survey protocols for the non-vascular plants and mollusk species became available after the September 1997 survey of Holden Mine area. For this mine remediation project, surveys should only be required if ground-disturbing activities are proposed in areas of potential habitat for survey and manage species. Because so many of these species are found in similar forested habitats, a multi-species survey approach is recommended for potential impact areas. For example, mollusk and salamander surveys could be combined, and an intuitive controlled survey for lichens and bryophytes could be combined with a survey for vascular plants.

TABLE 4.1-1
KEY OF SITE FEATURES & MEDIA SAMPLING/DATA COLLECTION LOCATIONS
HOLDEN MINE RI/FS
DAMES & MOORE JOB NO. 17693-005-019

Feature/Area or Media	Station No.	Location by Area	Coordinate	Comments
Feature/Area				
1500-Level Main Portal	N/A	Mine Support & Waste Rock	E.0-3.0	Near southern boundary
1500-Level Ventilator Portal	N/A	Mine Support & Waste Rock	D.7-3.0	Near western boundary
1100-Level Portal	N/A	Honeymoon Heights	D.8-3.1	
1000-Level Portal	N/A	Honeymoon Heights	D.8-3.1	
800-Level Portal	N/A	Honeymoon Heights	D.8-3.1	
700-Level Portal	N/A	Honeymoon Heights	D.8-3.2	
550-Level Portal	N/A	Honeymoon Heights	D.9-3.2	
300-Level Portal	N/A	Honeymoon Heights	D.9-3.2	
Abandoned Septic Field	N/A	SE of Holden Village	E.2-3.0	
Abandoned Surface Water Ret.	N/A	Mine Support & Waste Rock	D.7-2.9	
Baseball Field/Campground	N/A	Baseball Field/Campground	D.7-2.9, D.8-2.9	
Copper Creek	N/A	S. of Tailings Piles 1 & 2	E.1-3.1, E.1-3.2, E.2-3.0, E.3-3.1	
Copper Creek Diversion	N/A	W. of Tailings Pile 1	E.0-3.0, E.1-3.0	
East Waste Rock Pile	N/A	Mine Support & Waste Rock	E.1-3.0, E.1-3.1	
Holden Village	N/A	Holden Village	E.1-2.9, E.2-2.9	
Holden Village Septic Field	N/A	SE of Winston Home Sites	D.9-2.9, E.0-2.9	
Honeymoon Heights	N/A	Honeymoon Heights	D.7-3.0, 3.1, 3.2; D.8-3.0, 3.1, 3.2, 3.3; D.9-3.0, 3.1, 3.2, 3.3	
Hydroelectric Plant	N/A	W. of Tailings Pile 1	E.0-3.0	
Intermittent Drainage	N/A	Honeymoon Heights	D.8-3.0, D.8-3.1, D.8-3.2, D.8-3.3	
Lagoon	N/A	Mine Support & Waste Rock	E.0-2.9, E.0-3.0	
Lucerne Bar	N/A	Lucerne		
Lucerne Guard Station	N/A	Lucerne	I-3	
Maintenance Yard	N/A	Maintenance Yard	E.0-3.0	
Mill Building	N/A	Mill Building	E.0-3.0	
Mine Support and Waste Rock	N/A	Mine Support & Waste Rock	D.7-2.9, 3.0; D.8-2.9, 3.0; D.9-2.9, 3.0; E.0-2.9, 3.0, 3.1; E.1-3.0, 3.1, 2.9	
Portal Museum	N/A	Mine Support & Waste Rock	E.0-3.0	
Sauna	N/A	NW of Tailings Pile 1	E.1-3.0	
Shop	N/A	Maintenance Yard	E.0-3.0	
Storage	N/A	Maintenance Yard	E.0-3.0	
Tailings Pile 1	N/A	Tailings Pile 1	E.1-3.0, E.2-3.0, E.2-3.1	
Tailings Pile 2	N/A	Tailings Pile 2	E.2-3.0, E.2-3.1, E.3-3.0, E.3-3.1, E.4-3.0, E.4-3.1	
Tailings Pile 3	N/A	Tailings Pile 3	E.4-3.0, E.4-3.1, E.5-3.0, E.5-3.1	
USFS Guard Station	N/A	USFS Guard Station	E.0-2.9	
West Waste Rock Pile	N/A	Mine Support & Waste Rock	E.0-3.0	
Winston Home Sites	N/A	Winston Home Sites	D.8-2.9; D.9-2.8, 2.9; E.0-2.8, 2.9	
Geophysical Survey Lines				
A-A'	N/A	North of West Waste Rock Pile	E.0-2.9, E.0-3.0	
B1-B1'	N/A	Tailings Pile 1	E.1-3.0	
B2-B2'	N/A	East Waste Rock Pile	E.1-3.1	
C-C'	N/A	Tailings Pile 2	E.3-3.0, E.3-3.1	
D-D'	N/A	Tailings Pile 3	E.4-3.0, E.4-3.1	
E-E'	N/A	East of Tailings Pile 3	E.5-3.0, E.5-3.1	

TABLE 4.1-1

KEY OF SITE FEATURES & MEDIA SAMPLING/DATA COLLECTION LOCATIONS

HOLDEN MINE RI/FS

DAMES & MOORE JOB NO. 17693-005-019

Feature/Area or Media	Station No.	Location by Area	Coordinate	Comments
EM1-EM1'	N/A	Western Mine Support Area	D.8-2.9, D.8-3.0, D.9-2.9, D.9-3.0, E.0-2.9	
EM2-EM2'	N/A	Western Mine Support Area	D.8-3.0, D.9-3.0, E.0-3.0, E.1-3.0	
EM3-EM3'	N/A	East of Tailings Pile 3	E.5-3.0, E.5-3.1	
F-F'	N/A	North of Tailings Piles 2 & 3	E.4-3.0	
G-G'	N/A	Between Tailings Piles 1 & 2	E.2-3.0, E.2-3.1	
Sample Locations				
Groundwater Monitoring Wells				
	HBKG-1	W. of Tailings Pile 1	E.0-3.0	Potential background
	HBKG-2	E. of Baseball Field/Campgr.	D.8-2.9	Potential background
	CC-BKG	SW Tailings Pile 2	E.2-3.1	Background
	H-1	Holden Village	E.1-2.9	
	H-2	Holden Village	E.2-2.9	
	HV-3/H-3	Holden Village	E.1-2.9	Background
	DS-1	East of Tailings Pile 3	E.5-3.0	Downstream Wells:
	DS-2	East of Tailings Pile 3	E.5-3.0	Downstream Wells:
	TP1-1A	Tailings Pile 1	E.1-3.0	
	TP1-2A	Tailings Pile 1	E.1-3.0	
	TP1-2L	Tailings Pile 1	E.1-3.0	
	TP1-3A	Tailings Pile 1	E.1-3.0	
	TP1-3L	Tailings Pile 1	E.1-3.0	
	TP1-4A	Tailings Pile 1	E.1-3.0	
	TP1-4L	Tailings Pile 1	E.1-3.0	
	TP1-5A	Tailings Pile 1	E.2-3.0	
	TP1-6A	Tailings Pile 1	E.1-3.0	
	TP1-6L	Tailings Pile 1	E.1-3.0	
	PZ-1A	Tailings Pile 2	E.3-3.1	
	PZ-1B	Tailings Pile 2	E.3-3.1	
	PZ-1C	Tailings Pile 2	E.3-3.1	
	PZ-2A	Tailings Pile 2	E.3-3.0	
	PZ-2B	Tailings Pile 2	E.3-3.0	
	PZ-2C	Tailings Pile 2	E.3-3.0	
	PZ-3A	Tailings Pile 2	E.3-3.0	
	PZ-3B	Tailings Pile 2	E.3-3.0	
	PZ-3C	Tailings Pile 2	E.3-3.0	
	TP2-1L	Tailings Pile 2	E.3-3.1	
	TP2-2L	Tailings Pile 2	E.3-3.0	
	TP2-4A	Tailings Pile 2	E.3-3.0	
	TP2-4B	Tailings Pile 2	E.3-3.0	
	TP2-5A	Tailings Pile 2	E.3-3.0	
	TP2-5B	Tailings Pile 2	E.3-3.0	
	TP2-6L	Tailings Pile 2	E.3-3.1	
	TP2-7N&S	Tailings Pile 2	E.4-3.0	
	TP2-8A	Tailings Pile 2	E.4-3.0	
	TP2-8B	Tailings Pile 2	E.4-3.0	
	TP2-9L	Tailings Pile 2	E.4-3.1	
	TP2-10L	Tailings Pile 2	E.2-3.1	
	TP2-11	Tailings Pile 2	E.2-3.0	
	TP2-11L	Tailings Pile 2	E.2-3.0	
	TP3-4	Tailings Pile 3	E.4-3.0	

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HOLDEN MINE RI/FS
DAMES & MOORE JOB NO. 17693-005-019

Feature/Area or Media	Station No.	Location by Area	Coordinate	Comments
	TP3-4L	Tailings Pile 3	E.4-3.0	
	TP3-5A	Tailings Pile 3	E.5-3.0	
	TP3-6A	Tailings Pile 3	E.5-3.0	
	TP3-6BL	Tailings Pile 3	E.5-3.0	
	TP3-7	Tailings Pile 3	E.4-3.0	
	TP3-8	Tailings Pile 3	E.4-3.0	
	TP3-9	Tailings Pile 3	E.5-3.0	
	TP3-10	Tailings Pile 3	E.5-3.0	
	TP3-10L	Tailings Pile 3	E.5-3.0	
	PZ-4A	Tailings Pile 3	E.4-3.0	
	PZ-4B	Tailings Pile 3	E.4-3.0	
	PZ-4C	Tailings Pile 3	E.4-3.0	
	PZ-5A	Tailings Pile 3	E.4-3.0	
	PZ-5B	Tailings Pile 3	E.4-3.0	
	PZ-5C	Tailings Pile 3	E.4-3.0	
	PZ-6A	Tailings Pile 3	E.4-3.0	
	PZ-6B	Tailings Pile 3	E.4-3.0	
	PZ-6C	Tailings Pile 3	E.4-3.0	
	Lucerne Well	Lucerne	I-3	Lucerne Guard Station
Subsurface/Surface Soil				
	DMSS-1	Holden Village	E.2-2.9	Surface soil
	DMSS-2	Holden Village	E.2-2.9	Surface soil
	DMSS-3	Holden Village	E.1-2.9	Surface soil
	DMSS-4	Holden Village	E.1-2.9	Surface soil
	DMSS-5	Holden Village	E.1-2.9	Surface soil
	DMSS-6	Holden Village	E.2-2.9	Surface soil
	DMSS-7	Holden Village	E.1-2.9	Surface soil
	DMSS-8	Maintenance Yard	E.0-3.0	Surface soil
	DMSS-9	Maintenance Yard	E.0-3.0	Surface soil
	DMSS-10	Maintenance Yard	E.0-3.0	Surface soil
	DMSS-11	Tailings Pile 1	E.1-3.0	Surface soil
	DMSS-12	Tailings Pile 1	E.1-3.0	Surface soil
	DMSS-13	Tailings Pile 1	E.2-3.0	Surface soil
	DMSS-14	Tailings Pile 2	E.2-3.0	Surface soil
	DMSS-15	Tailings Pile 2	E.3-3.0	Surface soil
	DMSS-16	Tailings Pile 2	E.4-3.0	Surface soil
	DMSS-17	Tailings Pile 3	E.4-3.0	Surface soil
	DMSS-18	Tailings Pile 3	E.4-3.0	Surface soil
	DMSS-19	Tailings Pile 3	E.5-3.0	Surface soil
	DMSS-20	East of Tailings Pile 3	E.5-3.0	Windblown tailings
	DMSS-21	East of Tailings Pile 3	E.6-3.0	Windblown tailings
	DMSS-22	East of Tailings Pile 3	E.6-3.0	Windblown tailings
	DMSS-23	East of Tailings Pile 3	E.7-3.0	Windblown tailings
	DMSS-24	East of Tailings Pile 3	E.5-3.0	Windblown tailings
	DMSS-25	Baseball Field	D.7-2.9	Surface soil
	DMSS-26	Wilderness Area	D.7-2.9	Surface soil
	DMSS-27	Wilderness Area	D.7-2.9	Surface soil
	Lagoon 6"	Lagoon	E.0-2.9	Surface soil
	Lagoon 2'	Lagoon	E.0-2.9	Subsurface soil sample
	DMLG1	Lagoon	E.0-3.0	Subsurface soil sample
	DMLG2	Lagoon	E.0-2.9	Subsurface soil sample
	DMLG3	Lagoon	E.0-2.9	Subsurface soil sample

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HOLDEN MINE RI/FS
DAMES & MOORE JOB NO. 17693-005-019

Feature/Area or Media	Station No.	Location by Area	Coordinate	Comments
	DMLG4	Lagoon	E.0-3.0	Subsurface soil sample
	DMLG5	Lagoon	E.0-2.9	Subsurface soil sample
	DMBG1	Approximately 1-mile West of Site	D-2	Background surface soil
	DMBG2	Holden Creek Drainage	D-2	Background surface soil
	DMBG3	Between Holden Creek & Hart Lake	C-2	Background surface soil
	DMBG4	East of Hart Lake	C-2	Background surface soil
	DMBG5	Between Hart Lake & Crown Point	B-2	Background surface soil
	DMBG6	Lyman Lakes	A-3	Background surface soil
	DMBG7	West of Hart Lake	B-2	Background surface soil
	DMBG8	West of Holden Creek	C-2	Background surface soil
	DMBG9	West of Big Creek	D-2	Background surface soil
	DMBG10	Copper Basin	E-3	Background surface soil
	DMBG11	Southwest of Site	D-3	Background surface soil
	DMBG12	South of Site	D-3	Background surface soil
	DMBG13	Near South Site Boundary	E-3	Background surface soil
	DMBG14	Near Holden Creek	D-2	Background surface soil
	DMBG15	Near Holden Creek	D-2	Background surface soil
	DMBG16	West of Site Boundary	D-2	Background surface soil
	DMBG17	Near Winston Home Sites	D-2	Background surface soil
	DMBG18	Northeast of Site	E-2	Background surface soil
	DMBG19	North of Holden Village	E-2	Background surface soil
	DMTP1-2	Tailings Pile 1	E.1-3.0	Test pit excavation
	DMTP1-3	Tailings Pile 1	E.1-3.0	Test pit excavation
	DMTP1-4	Tailings Pile 1	E.1-3.0	Test pit excavation
	DMTP1S-1	Tailings Pile 1	E.1-3.0	Test pit excavation
	DMTP2-1	Tailings Pile 2	E.2-3.0	Test pit excavation
	DMTP2-2	Tailings Pile 2	E.3-3.0	Test pit excavation
	DMTP2S-1	Tailings Pile 2	E.3-3.1	Test pit excavation
	DMTP3-1	Tailings Pile 3	E.4-3.0	Test pit excavation
	DMTP3-2	Tailings Pile 3	E.5-3.0	Test pit excavation
	DMTP3-3	Tailings Pile 3	E.5-3.0	Test pit excavation
	DMTP3-4	Tailings Pile 3	E.5-3.0	Test pit excavation
	DMTP3S-1	Tailings Pile 3	E.4-3.1	Test pit excavation
	DMTP3E-1	Immed. east of Tailings Pile 3	E.5-3.0	Test pit excavation
	DMTP3E-2	Immed. east of Tailings Pile 3	E.5-3.0	Test pit excavation
	DMTP3E-3	Immed. east of Tailings Pile 3	E.5-3.0	Test pit excavation
	DMTP3E-4	Immed. east of Tailings Pile 3	E.5-3.0	Test pit excavation
	DMTP3E-5	Immed. east of Tailings Pile 3	E.5-3.1	Test pit excavation
	DMTP3E-6	Immed. east of Tailings Pile 3	E.5-3.1	Test pit excavation
	DMTPW-1	Winston home sites	D.8-2.9	Test pit excavation
	DMTPW-2	Winston home sites	D.8-2.9	Test pit excavation
	DMTPW-3	Winston home sites	D.8-2.9	Test pit excavation
	DMTPW-4	Winston home sites	D.8-2.9	Test pit excavation
	DMTPW-5	Winston home sites	D.9-2.9	Test pit excavation
	DMTPW-6	Winston home sites	D.9-2.9	Test pit excavation
	DMTPW-7	Winston home sites	D.9-2.9	Test pit excavation
Surface Water				
	RC-1	Railroad Creek	D.7-2.9	
	RC-1 North Bank	Railroad Creek	D.7-2.9	
	RC-1 South Bank	Railroad Creek	D.7-2.9	
	RC-2	Railroad Creek	E.5-3.0	
	RC-2 South Bank	Railroad Creek	E.5-3.0	

TABLE 4.1-1
KEY OF SITE FEATURES & MEDIA SAMPLING/DATA COLLECTION LOCATIONS
HOLDEN MINE RI/FS
DAMES & MOORE JOB NO. 17693-005-019

Feature/Area or Media	Station No.	Location by Area	Coordinate	Comments
	RC-3	Railroad Creek	I-3	
	RC-4	Railroad Creek	E.0-2.9	
	RC-4 South Bank	Railroad Creek	E.0-2.9	
	RC-5	Railroad Creek	E-3	
	RC-5A	Railroad Creek	E-3	
	RC-6	Railroad Creek	D.7-2.9	
	RC-6 North Bank	Railroad Creek	D.7-2.9	
	RC-7	Railroad Creek	E.4-3.0	
	RC-8	Railroad Creek	I-3	
	RC-8 North Bank	Railroad Creek	I-3	
	RC-10	Near Seven Mile Creek	F-3	
	RC-11	Upstream of Holden Creek	D-2	
	CC-1	Copper Creek	E.2-3.1	
	CC-2	Copper Creek	E.2-3.0	
	CC-D	Copper Creek Diversion	E.1-3.0	
	CC-D1	Copper Creek Diversion	E.1-3.0	
	P-1	Mine Support & Waste Rock	E.0-3.0	Portal Drainage/1500 Main
	P-5	Mine Support & Waste Rock	D.9-2.9	Portal Drainage/RR Creek
	HC-1	Holden Creek	D-2	
	HC-2	Holden Creek	C-2	
	HC-3	Holden Creek	C-2	
	HC-4	Holden Creek	C-1	
	Big-1	Big Creek	D-2	
	Tenmile Creek	Tenmile Creek	E-2	
Seeps				
	A1	Honeymoon Heights	D.B-3.1	1100 Level Portal
	SP1	Tailings Pile 1	E.1-3.0	
	SP2	Tailings Pile 1	E.2-3.0	
	SP3	Tailings Pile 2	E.3-3.0	
	SP4	Tailings Pile 3	E.4-3.0	
	SP5	East of Tailings Pile 3	E.5-3.0	
	SP6	West Waste Rock Pile	E.0-3.0	
	SP7	West Waste Rock Pile	E.0-3.0	
	SP8	East Waste Rock Pile	E.1-3.0	
	SP9	Between P-5 & RC-4	D.9-2.9	
	SP10W	River Sauna	E.1-2.9	
	SP10E	River Sauna	E.1-2.9	
	SP11	West of Vehicle Bridge	E.0-2.9	
	SP12	West of P-5	D.9-3.0	
	SP13	South of Holden Village	E.1-2.9, 3.0; E.2-2.9, 3.0	"Black Seep"
	SP14	Honeymoon Heights	D.8-3.1	
	SP15W	North of West Waste Rock Pile	E.0-3.0	
	SP15E	North of West Waste Rock Pile	E.0-3.0	
	SP16	Lagoon	E.0-2.9	
	SP17	East of Tailings Pile 3	E.5-3.1	
	SP18	East of Tailings Pile 3	E.5-3.0	Bank sample
	SP19	Tailings Pile 1	E.1-3.0	
	SP20	Tailings Pile 1 (Near Copper Creek)		
	SP21	East of Tailings Pile 3	2.6-3.1	
	SP22	North of Maintenance Yard	E.0-3.0	
	SP23	Between RC-1 and P-5	D.8-3.0	
	SP23B	Between RC-1 and P-5	D.8-3.0	

TABLE 4.1-1
KEY OF SITE FEATURES & MEDIA SAMPLING/DATA COLLECTION LOCATIONS
HOLDEN MINE RI/FS
DAMES & MOORE JOB NO. 17693-005-019

Feature/Area or Media	Station No.	Location by Area	Coordinate	Comments
	SP24	West of RC-4	E.0-2.9	
	SP25	Between Vehicle Bridge & RC-4	E.0-2.9	
	SP26	Between RC-1 and RC-6	D.7-2.9	
	SP-27	Near Big Creek	D-2	
	CC-D1	Copper Creek Diversion	E.1-2.9	
Sediment - Lake Chelan				
	1-1	Lucerne	N/A	
	1-2	Lucerne	N/A	
	2-1	Lucerne	N/A	
	2-2	Lucerne	N/A	
	3-1	Lucerne	N/A	
	3-1A	Lucerne	N/A	
	3-1B	Lucerne	N/A	
	3-1C	Lucerne	N/A	
	3-2	Lucerne	N/A	
	3.5-1	Lucerne	N/A	
	3.5-2	Lucerne	N/A	
	5-1	Lucerne	N/A	
	5-2	Lucerne	N/A	
	1	Stehekin	N/A	
	2	Stehekin	N/A	
	3A	Stehekin	N/A	
	3B	Stehekin	N/A	
	3C	Stehekin	N/A	
	4	Stehekin	N/A	
USGS Select Samples				
	344	Ten Mile Creek	E.6-2.9	
	345	Railroad Creek near RC-2	E.5-3.0	
	346	Copper Creek Diversion	E.1-3.0	
	347	Railroad Creek at Vehicle Bridge	E.0-2.9	
	350	East of Tailings Pile 3	E.5-3.0	
	351	Nine Mile Creek	F-3	
	352	Railroad Creek near Seven Mile Creek	F-3	
	353	Seven Mile Creek	F-3	
	354	Railroad Creek at Lucerene	N/A	
	355	Holden Creek	D-2	
	356	Railroad Creek West of Site	D-2	
	MP-7	Railroad Creek at Mile Post 7	G-3	
USBM Select Samples				
	BKG 1/2	Downstream of Vehicle Bridge	E.0-2.9	
	DG-1	Downstream of Tailings Pile 3	E.6-3.0	
	TP1-2	Adjacent to Tailings Pile1	E.1-3.0	
	TP2-1	Downstream of Copper Creek	E.2-3.0	
	TP2-2	Adjacent to Tailings Pile 2	E.3-3.0	
	TP3-1	Adjacent to Tailings Pile 3	E.4-3.0	
	RC-2	At Railroad Creek RC-2 Station	E.5-3.0	

Table 4.2-1
Railroad Creek Watershed Mineral Resources

Site Name	Location (T, R, Sec.)	Quarter Section	Location Comments	Owner(s)	Operators(s)	Commodities	Primary Commodities	Workings	Map Number, Figure 4.2-4*	Misc.
Crown Point Mine[1,2,3,4]	T31N, R16E, Sec. 8	NE/4	At head of cirque basin southwest of Hart Lake at the head of Railroad Creek.	Chemical Products Assc. (1926)1; ACME Moly Assc 2	Bear Creek (1958), under ACME Moly Assc.[2]	Mo, Cu, Pb, Zn, Ag, Au, As[2]	Mo[2]	3 Adits, totalling 780 feet, and "open cuts" [2]	43	1,300 tons
Silver Trail Mine[1, 4]	T31N, R16E, Sec. 8	NA	On Railroad Creek	Chemical Products Assc (1926)	NA	Cu, Pb,	NA	NA	A	36 claims, part of Crown Point?
North Star Prospect[1,3]	T31N, R16E, Sec. 18	NA	On summit near Lyman Lake	Cascade Range Mining Co (1897)	NA	As, Pb	NA	NA	B	NA
Victor [2,4]	T31N, R16E, Sec. 8	NA	About 0.7 miles northeast of outlet of Lyman Lake, unsurveyed, near head of Railroad Creek	NA	NA	Ag, Pb, Zn, Cd, Cu[2]	Ag, Pb, Zn	92 foot adit	44	NA
NA[4]	T31N, R16E, Sec. 16	NA	NA	NA	NA	NA	NA	NA	52	Prospect
NA[4]	T32N, R16E, Sec. 32, 33	NA	NA	NA	NA	NA	NA	NA	37	Area of multiple claim locations or altered rock
NA[4]	T31N, R16E, Sec. 3, 10	NA	NA	NA	NA	NA	NA	NA	42	Area of multiple claim locations or altered rock
NA[4]	T31N, R16E, Sec. 3, 11	NA	NA	NA	NA	NA	NA	NA	41	Prospect
NA[4]	T31N, R16E, Sec. 3, 2	NA	NA	NA	NA	NA	NA	NA	40	Prospect
NA[4]	T31N, R16E, Sec. 3	NA	NA	NA	NA	NA	NA	NA	39	Area of multiple claim locations or altered rock
Ideal[2,4]	T32N, R16E, Sec. 34, 35	Sec. 34, SE/4; Sec. 35, SW/4	About 0.3 miles south of Holden Lake	NA	NA	Ag	Ag	NA	38	34,000 tons
NA[4]	T31N, R16E, Sec. 26	NA	NA	NA	NA	NA	NA	NA	54	Area of multiple claim locations or altered rock
Mary Green, a.k.a. Martin Peak[2,4]	T32N, R16E, Sec. 26, 35	NA	About 0.8 miles northeast of Holden Lake	NA	Howe Sound (circa 1950's)	Cu, Ag,	Cu, Ag,	370 foot adit, several propect pits	29	NA
Holden Mine	T31N, R16E; R17E, Sec. 18, 19; 12, 13	NA	About 0.3 miles southwest of Holden on Railroad Creek	Howe Sound Mining Co.	Howe Sound Mining Co.	Cu, Au, Zn, Ag,	Cu, Au, Zn, Ag,	Approximately 55 miles	23	
Marcus Stein[2,4]	T31N, R17E, Sec. 9, 17	Sec. 9, SW/4; Sec. 17, NE/4	About 1.5 miles northwest of Dole Lakes, at mouth of Wilson Creek	Marcus Stein (1897)	NA	Ag, Au, Sb, Hg	Ag, Au	NA	C	NA
Raymond Prospect[1]	T31N, R17E, Sec. 17	Sec. 17, NE/4	On Wilson Creek adjacent to Marcus Stein claims on south	Seattle Gold Mining and Development Co., (1897)	NA	NA	NA	NA	D	NA
Edit Mine[4]	T31N, R17E, Sec. 3, 4	NA	NA	NA	NA	NA	NA	NA	25	Prospect
Sevenmile Antimony, a.k.a. Sevenmile Creek[2,4]	T31N, R17E, Sec. 15	Sec. 15, SE/4	About 2.75 miles south-southeast of Riddle Peaks, near wilderness boundary	NA	Oscar Getty (1952)	Ag, Au, Sb, Ni	Ag, Au	100 foot adit[2]; 50 foot adit[4]	24	NA

Notes:
NA - Not available/unknown

References:

1) Huntting, M.T., 1943, Inventory of Mineral Properties in Chelan County, Washington, Washington Division of Mines and Geology, Report of Investigations, No. 9, 63p., 1pl.
2) Mineral Resource Database System, 1998, USGS, Regional Minerals Dept., Spokane, Washington
3) Huntting, M.T., 1956, Inventory of Washington Minerals Part-II, Metallic Minerals, Washington Division of Mines and Geology, Bulletin No. 37, v. 1, 428p., v. 2, 67p
4) Church, S.E., et al., 1984, Mineral Resource Potential of Glacier Peak Wilderness and Adjacent areas, Chelan, Skagit, and Snohomish Counties, Washington, USGS Miscellaneous Feild Studies Map and Pamphlet MF-1652-A

* - Based on nomenclature presented in Church, 1984, and modified by Dames & Moore

TABLE 4.2-1A
OCCURRENCE OF MINERALS IN HOLDEN MINE ORE BODY
HOLDEN MINE SITE REMEDIAL INVESTIGATION

Mineral	Chemical Composition	Occurrence
Magnetite	-Ferrous and ferric iron oxide	-Outcrops with hornblende diorite intrusive
Pyrite	-Iron sulfide	-Mineralized zone and argillites
Pyrrhotite	-Ferrous sulfide	-Mine ore zone
Sphalerite	-Zinc sulfide	-Disseminations and massive replacements
Chaleopyrite	-Copper and iron sulfide	-Central portion of mineralized zone
Galena	-Lead sulfide	-Sporadically along footwall of mine zone
Molybdenite	-Molybdenum disulfide	-Bladed crystals in pyrite, chaleopyrite and gangue
Quartz	-Silicon dioxide	-Mine zone
Gold	-Gold	-Associated with pyrite, pyrrhotite and chalcopyrite in mine zone
Silver	-Silver	-Footwall zinc zone
Bourronite	-Lead and copper sulphantimonide	-Crystals on quartz crystals in one open fissure
Pitchblende	-Uranium oxide	-Heavy biotite schist zones in lead-zinc areas of footwall
Sericite	-Hydrons potassium, aluminum silicate	-Hanging wall
Biotite	-Hydrous potassium, magnesium, iron, aluminum silicate	-Center of mine zone

Source: Youngberg & Wilson, 1952

TABLE 4.2-2
CRITERIA FOR GRADING THE SLOPES EROSION POTENTIAL

Erosion Potential	Criteria
Low	All slopes less than or equal to angle of repose or 33°, the base of the slope is setback more than 10 ft from the crest of the riprap; a talus or gavel cap covers all of the slope (no tailings are exposed); vegetation (e.g., conifers, brush) is present on the slope; a well-vegetated bar separates the main channel from the slope
Moderately Low	The average slope is less than 33°, but portions of the slope are greater than 33°; the base of the slope is setback sufficiently from the crest of the riprap to allow talus to build to the angle of repose and not inundate riprap; minor sloughing may be occurring
Moderate	The average slope is greater than 33°, but the base of the slope is set back significantly (greater than 50 ft) from the main channel; riprap is at the base of the slope and may occupy only the bank of an overflow channel; slopes are mostly stable and covered with gravel cap; portions of slope are steep and eroding
Moderately High	The average slope is greater than 33°, portions of the slope are steep (greater than 45°); near-vertical cliffs or overhanging ledges may be present; there is little or no setback between the base of the slope and the crest of the riprap; vegetation is not present or is sparse; if grass mats are present they may be in need of repair; significant portions of the slope are sloughing into the riprap
High	The average slope is greater than 33°, major portions of the slope are steep (greater than 45°) or very steep (greater than 60°); near-vertical cliffs or overhanging ledges may be present; there is no setback between the base of the slope and the crest of the riprap; vegetation is not present or is sparse; grass mats are not present or have been significantly damaged beyond repair; significant portions of the slope are sloughing directly into the creek

TABLE 4.2-2a
EROSION POTENTIAL RANKING CRITERIA FOR OBSERVED EROSION
HOLDEN MINE RI/FS
DAMES & MOORE JOB NO. 17693-005-019

Ranking	Gravel Cap Cover	Tailings Exposure	Cliffs Present	Block Sloughing	Vegatation
None	> 90%	No	No	Not Occuring	mature trees, abundant saplings, brush grass
Minor	> 70%	< 20 %	Uncertain	Small (< 10 cm), minor in a few spots	few trees and saplings, some bush or grass
Moderate	30-70%	20-60 %	Yes	Medium (10-30 cm), present across slope	Small amount of brush or grass
Extensive	< 30%	> 60%	Yes	Large (> 30 cm), extensive across slope not present	--

TABLE 4.2-3
SUMMARY OF CHARACTERISTICS AND EROSION POTENTIAL FOR TAILINGS PILES AND SLOPES
HOLDEN MINE RI/FS
DAMES & MOORE JOB NO. 17693-005-019

Tailings Location	Reach	Approximate Length (ft)	Height Range (ft)	Average Slope Angle	Range in Slope Angle	Slope Setback	Slope Material	Condition of Grass Mats	Observed Erosion	Erosion Potential
Tailings Pile 1	1-A	225	5-10	> 33	30-60	No	No	None	Moderate	High
	1-B$_{west}$	175	30-65	26.9	25-75	Yes	Yes	None	Minor	Moderately Low
	1-B$_{east}$	175	50-65	35.9	25-75	Yes	Yes	None	Minor	Moderate
	1-C	200	60-65	40.2	25-80	No	Yes	None	Minor	Moderate
	1-D	300	65-70	40.2	30-85	No	Yes	None	Minor	Moderate
	1-E	210	68-72	32.4	25-75	-	No	None	Minor	Moderately Low
	1-F	160	55-75	30.2	15-75	-	-	None	Minor	-
Tailings Pile 2	2-As	210	50-80	30.2	20-90	-	Yes	None	Minor	Moderately Low
	2-An	225	80-110	31.3	20-60	No	No	Good	Moderate	Moderately High
	2-B	350	100-110	37.5	30-60	No	No	Fair	Moderate	High
	2-C	160	105-115	38.7	30-60	No	No	Poor	Extensive	High
	2-D$_{west}$	350	110-120	37.2	10-50	Yes	No	Good	Moderate	Moderate
	2-E	475	120-125	39.0	30-55	No	No	None	Moderate	Moderately High
	2-F$_{west}$	760	125-130	35.0	30-60	-	Yes	Good	Moderate	Moderately High
Tailings Pile 3	2-F$_{east}$		50-55	40.2	30-50	-	Yes	None	Moderate	Moderately High
	3-A	550	50-60	31.1	30-50	Yes	-	None	Minor	Moderate
	3-B	435	55-65	35.2	20-45	-	No	None	None	Moderately Low
	3-C	215	60-65	29.4	15-32	Yes	No	None	None	Low

Notes:

Average Slope - estimated from the top of the slope to the mean elevation of the bottom of the rip rap.
Range in Slope - the approximate range in slopes found vertically and laterally across the entire slope reach.
Slope Setback: "Yes" - the slope is setback sufficiently from the top of the rip-rap to allow for accumulation of talus at the angle of repose.
Slope Setback: "No" - the slope is not setback sufficiently from the top of the rip-rap to allow for accumulation of talus at the angle of repose.
Creek Setback: "Yes" - the main channel of the creek is setback significantly from the base of the rip-rap.
Creek Setback: "No" - the main channel of the creek is at the base of the rip-rap.
Present Erosion - see Table 4.2-3 (*Erosion Potential Ranking Criteria*)

TABLE 4.2-4
RIP-RAP CONDITION RANKING CRITERIA
HOLDEN MINE RI/FS
DAMES & MOORE JOB NO. 17693-005-019

Rip-rap Type	Lithologic Composition	Color	Condition	Predominant Size (inches)	Maximum Size (inches)	Schmidt-Hammer Test			Relative Quality Grade
						n	Range	Median	
A	granodiorite	white with black	large coherent blocks, non-fractured, smooth surface, some edges rounded	48 to 60	72	10	52-59	56	good
B	quartz diorite to quartz monzonite	beige white to light brown	uneven semi-rough surface, edges flaking into plates, cracking along weathered fractures, some fragmented into small angular blocks, some gruss	24 to 36	< 48	20	24-42	37	fair
C	diorite to monzonite	tan brown weathering to yellow brown	highly fractured and weathered, rough, bumpy surface, flaking into thin sheets, parts entirely grussified	many less than 12, mainly < 18	< 36	10	24-28	22	poor
D	latite	light pink brown weathering to yellow brown	small coherent blocks, smooth surface, non-fractured	6 to 12	< 36	10	58-68	62	good
E	rhyodacite	light pale green	small coherent blocks, smooth to semi-rough surface, minor cracking along fractures	6 to 18	< 48	10	38-66	56	good to fair
F	ferricrete	red brown to dark brown	rough, bumpy surface, hard and indurate, to crumbly and disaggregated	many less than 6, mainly < 24	< 42	no tests performed	no tests performed	no tests performed	fair to poor

TABLE 4.2-5
SUMMARY OF RIP RAP ASSESSMENT RESULTS
HOLDEN MINE RI/FS
DAMES & MOORE JOB NO. 17693-005-019

Tailings	Reach	Length	Rip-rap Types	Reach Characteristics	Rip-rap Grade
West of Tailings	1-A	225	none	no rip-rap along the 5 to 10 ft high vertical to steep (> 45) river cut bank with exposed tailings	absent
Tailings Pile 1	1-B	350	mostly C with B	approximately 6 ft high grussified rip-rap at base of tailings, seedlings and saplings are abundant on grussy rip-rap surface	poor
	1-C	200	mostly C with B	approximately 6 ft high grussified rip-rap at base of tailings, seedlings and saplings are abundant on grussy rip-rap surface	poor
	1-D	300	mostly C with B	approximately 6 to 8 ft high grussified rip-rap at base of tailings	poor
	1-E	210	mostly C with B	approximately 8 to 9 ft high grussified rip-rap at base of tailings; 1 to 3 ft high brush is scattered throughout the top of rip-rap and slopeward	poor
	1-F	160	mostly C with B	approximately 5 to 8 ft high grussified rip-rap at base of tailings; height decreases around bend of tailings to southeast; rip-rap is sparsely covered with brush	poor
Tailings Pile 2	2-As	210	B and C	approximately 6 to 8 ft high grussified rip-rap at base of tailings	poor
	2-An	225	B and C	grussified rip-rap lies on steep bank; much of rip-rap is covered by slough material; with scattered small bushes	poor
	2-B	350	A and B at south end, with B with E at north end	large blocks of competent rip-rap; iron-stained at base	good
	2-C	160	mostly C with B and some E	talus and block sloughs have covered rip-rap, so that hillslope blocks slough directly into creek; rip-rap is generally competent but covered	fair
	2-D	350	B and C, with patches of E and scattered F	slopewash has invaded rip-rap	fair
	2-E	475	B and C	grussified rip-rap covered with small brush and conifer saplings; inundated by slopewash; two tall trees stand slone along mid-section of reach; otherwise rip-rap is against main channel	fair to poor
	2-F	760	B and C with D at west end	grussified rip-rap is inundated by tailings talus and covered by small bushes	fair to poor
Tailings Pile 3	3-A	550	B, C with patches of D	partially grussified rip-rap is spread over a wide area (approx 25 ft) and across a lowlope; west section is covered with patchy scrub bushes; east section is densely covered with scrub bushes	fair to poor
	3-B	435	B and C, with patches of A and D	partially grussified rip-rap is covered with brush and occupies fairly narrow belt at base of slope; talus is built up to crest of rip-rap	fair
	3-C	160	A, B and C	brushy, sparse	fair

TABLE 4.2-6
BORROW SOURCE EVALUATION
HOLDEN MINE RI/FS
DAMES & MOORE JOB NO. 17693-005-019

Source/Location	Potential Use	Approximate Distance	Description (composition, size, etc.)	Schmidt-Hammer Tests	Feasibility
Rock Quarry, approximately 1500 ft north of road at milepost 2.5	rip-rap	9 miles	granodiorite-diorite-monzonite assemblage: weathered in part; fractured - fracture density variable but relatively high with several conjugate sets	on fresh exposures: red-brown monzonite - < 30%; gray white diorite - 20-45 %; white granodiorite > 50 %; hard contact zones 55-65 %	medium to low quality; would need hygrading; relatively long haul distance; quantity appears sufficient
Holden Road at 3-Mile, on north side of road	rip-rap	8 miles	glacially eroded (smoothed, fluted) fractured bedrock composed primarily of quartz diorite to granodiorite	on weathered surfaces: quartz diorite 35-45%; granodiorite - 30-50% with a few > 50%	apparent medium to low quality; would need hygrading and further assessment; relatively long haul distance; quantity unknown; quarry development may be pose difficulties with Holden Road road use
Holden Road at 4-Mile, adjacent to and upslope of north side of road	rip-rap	7 miles	glacially eroded (smoothed, fluted) densely fractured bedrock composed primarily of quartz diorite to granodiorite, and monzonite	not performed	apparent low quality; would need hygrading and further assessment; relatively long haul distance but close to road; quantity unknown
Holden Road at 6.5-Mile, adjacent to and upslope of north side of road	rip-rap	4.5 miles	many 5 to 10 ft (and >) erratics mixed with smaller talus/colluvium and glacially eroded bedrock exposures; primarily granodiorite-diorite	on weathered surfaces: primarily granodioritic erratics on slope - consistently between 50-58%, with some <40%, and a few >60%	apparent medium quality; would need hygrading and further assessment; relatively moderate haul distance but close to road; quantity unknown
Talus Pile at 9-Mile, approximately 500 ft north of road	rip-rap	1.5 miles	many large variety of lithologies: fine-grained volcanics (latites, rhyodacites), mafic hypabyssal suites, coarse granodiorites;	hypabyssal and volcanics - 60-70%, coarse granodiorites - 45-55%	apparent high to medium quality; would need hygrading and further assessment; relatively short haul distance; quantity appears sufficient; quarry development may pose technical/safety challenges

TABLE 4.2-6
BORROW SOURCE EVALUATION
HOLDEN MINE RI/FS
DAMES & MOORE JOB NO. 17693-005-019

Source/Location	Potential Use	Approximate Distance	Description (composition, size, etc.)	Schmidt-Hammer Tests	Feasibility
Waste Rock Pile, upslope of Tailings Pile 1	rip-rap	local	primarily local host rock	not performed	quality not assessed; maximum boulder size may be limiting factor; may be undesireable source due to visual aesthetics and source
Gravel Quarry, approximately 750 ft south of road at milepost 2.5	soil cover	7 miles	stream gravels: poorly graded rounded to subrounded cobbles, pebbles, sands with silts	n/a	excellent source of stable (I.e., not wind transportable) gravel cap material; relatively long haul distance; quantity appears sufficient
Slope east of Tailings Pile 3 along old road bed	rip-rap soil cover	local	till, colluvium and old road bed material: zones and mixtures of angular coarse small boulders and cobbles with fine-grained sands and silts	n/a	good soil cover source, but fines can be wind-transported, so would need additional cover or protection; very short haul distances;quantity appears sufficient
Slopes South of Tailings	soil cover	local	till and colluvium: predominantly fine-grained (silt, fine sand - matrix supported), with zones of small (< 36-inch) boulders	n/a	good soil cover source, but fines can be wind-transported, so would need additional cover or protection; very short haul distances; quantity unknown and dependent on quarry location

TABLE 4.3-1
AVERAGE MONTHLY FLOW PER UNIT AREA OF WATERSHED (cfs/mile^2)
HOLDEN MINE RI/FS
DAMES & MOORE JOB NO. 17693-005-019

Month	Stehekin River	Entiat River	Railroad Creek
October	1.89	0.48	1.36
November	2.06	0.58	1.36
December	1.63	0.59	1.06
January	1.26	0.52	0.79
February	1.22	0.54	0.73
March	1.62	0.71	0.90
April	4.48	1.55	2.84
May	11.00	5.16	7.93
June	12.85	6.91	9.71
July	8.06	2.96	6.20
August	3.88	1.03	2.96
September	2.17	0.55	1.65

Notes:

Stehekin River Flow data from USGS (1994) 73 years of record;
Watershed Area = 321 mile^2

Entiat River Flow data from USGS (1994) 37 years of Record;
Watershed Area = 203 mile^2

Railroad Creek Flow data from USGS (1984) 46 years of record;
Watershed Area = 65 mile^2

TABLE 4.3-2
AVERAGE MONTHLY PRECIPITATION AT RAILROAD CREEK
HOLDEN MINE RI/FS
DAMES & MOORE JOB NO. 17693-005-019

Month	Holden Village Precipitation[a] (inches)	Estimated Basin Average Precipitation[b] (inches)
January	6.620	8.937
February	4.740	6.399
March	2.810	3.794
April	1.600	2.160
May	0.930	1.256
June	1.110	1.499
July	0.760	1.026
August	1.110	1.499
September	1.620	2.187
October	3.410	4.604
November	6.500	8.775
December	7.390	9.977
Total Annual Precipitation	**38.600**	**52.110**

Notes:

(a) - NOAA climatological data for Holden Village (Data collected from 1962-1997)

(b) - Estimated as a ratio of average annual basin precipitation (52 in.) and average annual Holden precipitation. (USGS, 1975)

TABLE 4.3-3
AVERAGE MONTHLY POTENTIAL EVAPOTRANSPIRATION (PET) AT HOLDEN MINE & RAILROAD CREEK BASIN
HOLDEN MINE RI/FS
DAMES & MOORE JOB NO. 17693-005-019

Month	Temperature (C°)		Absolute Humidity (Pt)[c]					Estimated Potential Evapotranspiration (PET)[f]	
	Holden Village[a]	Railroad Basin[b]	Holden Village	Railroad Basin	Maximum Hours of Sunlight[d]	Percent Cloud Cover[e]	Possible Hours of Sunlight[h]	Holden Village (inches)	Railroad Basin (inches)
January	-5.7	-7.7	3.07	2.68	8.8	0.31	2.73	0.22	0.19
February	-2.6	-4.6	3.77	3.30	10.2	0.41	4.18	0.38	0.33
March	0.7	-1.3	4.70	4.11	11.8	0.52	6.14	0.76	0.67
April	4.2	2.2	5.94	5.20	13.6	0.59	8.02	1.22	1.06
May	8.55	6.55	7.94	6.95	15.2	0.62	9.42	1.97	1.73
June	12.55	10.55	10.37	9.08	16	0.61	9.76	2.58	2.26
July	15.7	13.7	12.80	11.20	15.6	0.74	11.54	3.90	3.41
August	15.8	13.8	12.89	11.28	14.3	0.71	10.15	3.45	3.02
September	11.5	9.5	9.67	8.46	12.6	0.63	7.94	1.96	1.71
October	5.9	3.9	6.65	5.82	10.9	0.48	5.23	0.92	0.80
November	-0.9	-2.9	4.23	3.70	9.5	0.33	3.14	0.34	0.30
December	-5.4	-7.4	3.13	2.74	8.3	0.26	2.16	0.18	0.16
Total Annual PET								**17.86**	**15.63**

Notes:

(a) - NOAA climatological data for Holden Village (data collected from 1962-1997).

(b) - estimated from Holden Village temperatures with an assumed lapse rate of -2° C per 1000 foot increase in elevation.
(Holden Village elevation is 3200 ft, where as average basin elevation is 4300 ft.)

(c) - maximum water holding capacity of air at given temperature.

(d) - computed for latitude 48 degrees.

(e) - percent of cloud cover estimated from data average taken in Seattle and Yakima, Washington.

(f) - PET = 0.26 x (Pt) x (H) x (1/12) x (1/25.4) x (days/month)
from (Hamon (1963) as reported in Satterlund and Adams (1992)

TABLE 4.3-4
SUMMARY OF FLOW RELATIONSHIPS
HOLDEN MINE RI/FS
DAMES & MOORE JOB NO. 17693-005-019

Station	Date	Time	Measured Flow (cfs)	RC-4 Stage (feet)[a]	RC-2 Stage (feet)[a]	RC-4 Flow (cfs)[b]	RC-2 Flow (cfs)[c]	RC-4 Flow (Ratio)[d]	RC-2 Flow (Ratio)[d]
RC-1	4/16/97	9:45	63	1	0.8	62.4	78.8	1.01	0.80
	5/18/97	10:15	575	2.9	2.5	570.9	605.4	1.01	0.95
	5/26/97	10:45	313	2.34	2.08	353.3	390.7	0.89	0.80
	9/15/97	10:26	132	NA	1.12	123.0	123.1	1.07	1.07
							Average Flow	**0.99**	**0.91**
RC-2	4/17/97	9.00	86	1.05	0.86	68.4	85.9	1.26	1.00
	5/19/97	19:00	569	2.8	2.5	527.3	605.4	1.08	0.94
	5/26/97	11:10	376	2.34	2.07	353.3	386.4	1.06	0.97
	6/1/97	11:35	805	3.22	2.72	725.0	751.6	1.11	1.07
	6/2/97	11:35	605	2.94	2.51	589.0	611.5	1.03	0.99
	6/9/97	13:40	501	2.64	2.29	462.0	488.5	1.08	1.03
	9/15/97	15:30	136	1.3	1.1	103.1	119.8	1.32	1.14
	9/22/97	12.30	99	1.2	0.9	88.1	90.9	1.12	1.09
							Average Flow	**1.13**	**1.03**
RC-4	4/16/97	10:50	60	0.95	0.8	56.8	78.8	1.06	0.76
	5/21/97	9:00	370	2.45	2.2	391.1	444.4	0.95	0.83
	5/25/97	14:30	300	2.27	1.99	330.5	354.0	0.91	0.85
	5/31/97	9:30	780	3.38	2.8	810.6	811.5	0.96	0.96
	6/1/97	9:00	823	3.64	2.83	962.4	834.9	0.86	0.99
	6/2/97	10:15	567	2.85	2.52	548.9	617.7	1.03	0.92
	6/9/97	11:10	424	2.64	2.29	462.0	488.5	0.92	0.87
	7/10/97	9.15	496	2.75	2.4	506.3	547.2	0.98	0.91
	9/15/97	12:45	123	1.31	1.1	104.6	119.8	1.18	1.03
	9/22/97	11.00	87.5	1.21	0.9	89.6	90.9	0.98	0.96
							Average Flow	**0.98**	**0.91**
RC-3	4/18/97	12:00	196	1.05	0.86	68.4	85.9	2.87	2.28
	5/22/97	14:35	748	2.3	2.08	340.1	390.7	2.20	1.91
	7/11/97	12:00	665	2.3	2	340.1	357.9	1.97	1.87
	9/16/97	14:45	150	1.22	1	91.0	104.6	1.65	1.43
	9/20/97	13:25	172	1.24	1.01	93.9	106.0	1.94	1.72
							Average Flow	**2.12**	**1.84**
CC-1[e]	5/23/97	13:45	30	2.3	2.05	340.1	378.1	0.09	0.08
	5/31/97	13:10	100	3.35	2.8	794.1	811.5	0.13	0.12
	6/1/97	13:45	91	3.2	2.75	714.7	773.6	0.13	0.12
	6/2/97	16:30	84	2.95	2.52	593.5	617.7	0.14	0.14
	6/9/97	16:05	58	2.64	2.28	462.0	483.4	0.13	0.12
	7/10/97	17:40	59	2.58	2.25	438.8	468.4	0.13	0.13
	9/14/97	17:15	17.5	1.35	1.17	111.1	131.5	0.16	0.13
	9/15/97	14:30	14.6	1.31	1.1	104.6	119.8	0.14	0.12
	9/16/97	10:15	11.8	1.23	1.02	92.5	107.5	0.13	0.11
	9/22/97	10:20	13.6	1.2	0.9	88.1	90.9	0.15	0.15
							Average Flow	**0.13**	**0.12**

Notes:
NA - Not Available
(a) - Stage readings at time of flow measurements
(b) - Flow estimate from RC-4 rating for given stage reading; Flow = 26.2(stage+0.4)^2.581
(c) - Flow estimate from RC-2 rating for given stage reading; Flow = 0.05(stage+3.0)^5.515
(d) - Flow ratios computed by dividing Station flow by reference flow (either RC-4 or RC-2)
(e) - CC-1 flow includes flow from the Copper Creek diversion (Average flow of CC-D1 estimated at 7 cfs)

Note: October 4, 1997 data is not shown for RC-4 as there are no corresponding data points for the other Railroad Creek stations

TABLE 4.3-4a
SURFACE WATER FIELD PARAMETERS
HOLDEN MINE RI/FS
DAMES & MOORE JOB NO. 17693-005-019

Surface Water Sampling Station	Sample Date	Field Parameters							
		pH	Electrical conductivity (µS)	Temperature (C°)	Turbidity (NTU)	Dissolved Oxygen (mg/L)	Redox Potential (mV)	Fe^{+2} (Qualitative)	Stream Discharge (cfs)
<u>**Railroad Creek**</u>									
RC-1A	4/16/97	5.93	57	4.7	NT	NT	NT	NT	63.1
RC-1B	4/16/97	5.81	56	4.6	NT	NT	NT	NT	
RC-1C	4/16/97	5.82	55	4.7	NT	NT	NT	NT	
RC-1 South Bank	5/19/97	5.73	6.2	29	4	15.28	NT		
RC-1 South Bank	9/15/97	**See RC-1 Composite 9/15/97**							
RC-1 North Bank	5/19/97	6.1	29	5.6	5	15.85	NT		
RC-1 North Bank	9/15/97	**See RC-1 Composite 9/15/97**							
RC-1 Composite	5/19/97	5.45	50	5.9	111	15.44	NT		
RC-1 Composite	9/15/97	6.3	29	8.9	0	10.3	NT	NT	
RC-1	5/21/97	7.7	28	5	NT	NT	130	NT	
RC-1	7/10/97	8	22	6.6	NT	NT	NT	NT	
RC-1	9/15/97	5.8	68	9.7	NT	NT	NT	NT	132.27
RC-2	5/19/97	6.7	40	4.4	NT	NT	NT	NT	569
RC-2	5/21/97	7.1	44	6.2	NT	NT	146	NT	
RC-2	5/26/97	7.43	51	6.8	1	13.68	137	NT	376
RC-2	6/2/97	7	46	7.9	NT	NT	114	NT	605
RC-2	6/9/97	6	34	11.3	NT	NT	170	NT	501
RC-2	6/16/97	6	27	9	NT	NT	238	NT	822
RC-2	7/10/97	8	27	9.5	NT	NT	NT	NT	619
RC-2A	4/17/97	6.16	103	5.7	NT	NT	NT	NT	86.4
RC-2B	4/17/97	6.01	96	4.2	NT	NT	NT	NT	
RC-2C	4/17/97	6.07	95	4.3	NT	NT	NT	NT	
RC-2RB	5/19/97	6.75	42	4.6	66	14.1	NT	NT	
RC-2RB	6/2/97	6.8	118	8	80	15.5	190	NT	
RC-2RB	6/9/97	6.3	35	12.7	411	19.04	192	NT	
RC-2RB	6/16/97	6.13	27	10	109	14.54	227	NT	
RC-2RB	7/10/97	7.74	30	10.4	213	14.48	21.8	NT	
RC-2RB	9/15/97	**See RC-2 Composite 9/15/97**							
RC-2LB	5/19/97	6.74	38	4.2	4	13.1	NT	NT	
RC-2LB	6/2/97	6.86	48	7.8	11	15.3	137	NT	
RC-2LB	6/9/97	6.37	33	10.3	226	17.14	143	NT	
RC-2LB	6/16/97	6.25	26	8.8	232	15.28	238	NT	
RC-2 Composite	5/19/97	6.74	38	4.2	4	13.1	NT		
RC-2 Composite	6/2/97	6.92	46	7.9	6	14.7	114	NT	605
RC-2 Composite	9/15/97	5.7	76	10	NT	9.8 (Winkler)	NT	NT	135.8
RC-3A	4/18/97	6.19	90	5.7	11	NT	NT	NT	195.6
RC-3B	4/18/97	6.25	89	5.6	11	NT	NT	NT	
RC-3C	4/18/97	6.31	88	15	6.4	NT	NT	NT	
RC-3LB	5/22/97	8.18	56	9.6	65	NT	173	NT	
RC-3RB	5/22/97	8.04	57	10.2	NT	NT	178	NT	
RC-3 (c)	5/22/97	8.1	57	9.8	NT	NT	176		748
RC-3	7/11/97	7.8	37	10.5	NT	NT	NT	NT	665
RC-3	9/6/97	6.7	57	10.5	NT	NT	NT	NT	
RC-3	9/16/97	6.56	56	10.7	NT	10.6 (Winkler)	NT	NT	149.7

TABLE 4.3-4a
SURFACE WATER FIELD PARAMETERS
HOLDEN MINE RI/FS
DAMES & MOORE JOB NO. 17693-005-019

Surface Water Sampling Station	Sample Date	Field Parameters							
		pH	Electrical conductivity (µS)	Temperature (C°)	Turbidity (NTU)	Dissolved Oxygen (mg/L)	Redox Potential (mV)	Fe^{+2} (Qualitative)	Stream Discharge (cfs)
Railroad Creek									
RC-4 Grab	4/16/97	5.68	85	6	NT	NT	NT	NT	60.4
RC-4	9/15/97	6.71	32	10	NT	NT	NT	NT	
RC-4A	4/16/97	5.52	67	4.2	NT	NT	NT	NT	
RC-4B	4/16/97	5.55	66	3.7	NT	NT	NT	NT	
RC-4C	4/16/97	5.65	66	3.9	NT	NT	NT	NT	
RC-4(duplicate)	4/16/97	5.72	65	3.9	NT	NT	NT	NT	
RC-4LB	5/21/97	6.98	45	4.6	3	13.8	NT	NT	
RC-4RB	5/21/97	7.29	38	4.2	5	15.26	142	NT	
RC-4RB	7/10/97	7.55	24	7.7	NT	NT	NT	NT	
RC-4RB	9/15/97	6.78	33	9.6	NT	NT	NT	NT	
RC-4 (c)	5/21/97	7.1	42	4.4	NT	NT	142	NT	370
RC-4	7/10/97	7.66	26	9.8	3	13.48	NT	NT	496
RC-4	9/15/97	6.71	32	10	NT	NT	NT	NT	123
RC-5A	4/17/97	6.13	95	4.3	NT	NT	NT	NT	78.56
RC-5B	4/17/97	6.16	94	4.2	NT	NT	NT	NT	
RC-5C	4/17/97	6.21	96	4.3	NT	NT	NT	NT	
RC-5	5/20/97	7	50	3.8	NT	NT	NT	NT	
RC-5	5/21/97	NT	48	6.2	NT	NT	205	NT	
RC-5A	5/22/97	7.6	63	6.2	NT	NT	155	NT	
RC-5A	7/10/97	7.6	30	8.4	NT	NT	NT	NT	
RC-5A	9/5/97	7.9	51	11.2	NT	NT	NT	NT	
RC-5	9/16/97	7.13	53	8.5	NT	NT	NT	NT	129.2
RC-5A	9/24/97	6.3	54	11.3	NT	NT	NT	NT	
RC-6A	4/15/97	5.96	99	6.2	NT	NT	NT	NT	314
RC-6B	4/15/97	5.54	105	4.5	NT	NT	NT	NT	
RC-6C	4/15/97	.6	76	4.5	NT	NT	NT	NT	
RC-6	5/19/97	5.9	28	7.4	NT	NT	NT		
RC-6	5/21/97	7.11	24	4.2	NT	NT	122	NT	
RC-6	5/26/97	7.07	40	5.5	0	15.5	157	NT	314
RC-6	6/2/97	6	63	5.9	13	15.73	179	NT	
RC-6	6/9/97	6.26	35	6.9	31	16.06	190	NT	429
RC-6	6/16/97	5	61	6.9	210	14.76	208	NT	802
RC-6	7/10/97	7.8	51	7.3	NT	NT	NT	NT	
RC-6	9/15/97	6.1	29	8.9	0	9.6 (Winkler)	NT	NT	131.2
RC-7A	4/16/97	5.84	94	5	NT	NT	NT	NT	77.12
RC-7B	4/16/97	5.78	95	4.4	NT	NT	NT	NT	
RC-7C	4/16/97	5.84	94	4.9	NT	NT	NT	NT	
RC-7LB	5/20/97	6.9	31	4	NT	NT	NT	NT	
RC-7LB	5/21/97	7.1	42	6.4	NT	NT	151	NT	
RC-7RB	5/20/97	7.08	39	4.2	6	13.1	NT	NT	
RC-7RB	5/21/97	7.16	44	6.2	7	15.03	146		
RC-7	7/10/97	7.6	28	8.7	NT	NT	NT	NT	
RC-7	9/15/97	7	42	9.7	NT	NT	NT	NT	145.8

TABLE 4.3-4a
SURFACE WATER FIELD PARAMETERS
HOLDEN MINE RI/FS
DAMES & MOORE JOB NO. 17693-005-019

Surface Water Sampling Station	Sample Date	Field Parameters							
		pH	Electrical conductivity (µS)	Temperature (C°)	Turbidity (NTU)	Dissolved Oxygen (mg/L)	Redox Potential (mV)	Fe^{+2} (Qualitative)	Stream Discharge (cfs)
Railroad Creek									
RC-8A	4/18/97	6.08	148	6.3	NT	NT	NT	NT	▨
RC-8B	4/18/97	6.18	110	5.7	NT	NT	NT	NT	▨
RC-8C	4/18/97	6.17	92	6.5	NT	NT	NT	NT	▨
RC-8	9/16/97	6.54	60	10.7	NT	NT	NT	NT	▨
RC-9	9/14/97	7.9	76	11.5	NT	NT	NT	NT	128
RC-10	9/16/97	7	57	9.8	NT	NT	NT	NT	126.3
RC-11	10/4/97	6.22	15	7	NT	NT	NT	NT	60-70
Bridge Creek	9/28/97	6.35	31	8.9	NT	11.06	NT	NT	76.43
SF Agnes Creek	9/30/97	6.48	16	8.3	NT	11.62	NT	NT	131.35
Company Creek	10/2/97	6.07	60	7.3	0	11.75	NT	NT	▨
Holden Creek	10/4/97	6.27	25	6.8	NT	NT	NT	NT	▨
Copper Creek									
CC-D	5/21/97	7.15	39	4.1	1	15.85	131	NT	5.9
CC-D	5/26/97	7.2	39	4.4	NT	NT	NT	NT	5.9
CC-D	6/2/97	6.82	31	4.8	NT	NT	NT	NT	5.9
CC-D	6/9/97	6.63	30	5.4	NT	NT	NT	NT	5.9
CC-D	7/12/97	6.85	36	7.6	NT	NT	NT	NT	6
CC-D	9/16/97	5.5	25.5	14.4	NT	NT	NT	NT	
CC-1	5/23/97	6.2	40	4	NT	15	NT	NT	23
CC-1	5/26/97	7.6	30	4	NT	NT	NT	NT	16
CC-1	6/2/97	NT	NT	NT	NT	NT	NT	NT	77
CC-1	6/16/97	5.8	37	5.5	16	17.18	199	Negative	NT
CC-1	7/11/97	5.96	44	5.9	NT	NT	NT	NT	52
CC-1	9/16/97	6	96	7.9	NT	NT	NT	NT	4.8
CC-2	5/23/97	6.99	33	4.2	0	14.83	NT	NT	(CC-1)
CC-2	5/26/97	7	33	42	NT	NT	NT	NT	(CC-1)
CC-2	6/2/97	5.8	31	4.4	NT	NT	NT	NT	(CC-1)
CC-2	7/11/97	7.3	25	6	NT	NT	NT	NT	(CC-1)
CC-2	9/16/97	6	40	7.6	NT	NT	NT	NT	(CC-1)

TABLE 4.3-4a
SURFACE WATER FIELD PARAMETERS
HOLDEN MINE RI/FS
DAMES & MOORE JOB NO. 17693-005-019

Surface Water Sampling Station	Sample Date	Field Parameters							
		pH	Electrical conductivity (µS)	Temperature (C°)	Turbidity (NTU)	Dissolved Oxygen (mg/L)	Redox Potential (mV)	Fe^{+2} (Qualitative)	Stream Discharge (cfs)
Portal Drainage									
P-1	5/18/97	4.8	692	8.4	NT	NT	420	NT	2.63
P-1	7/12/97	5.75	575	10	NT	NT	188	Positive	0.42
P-1	9/15/97	7	780-1010	10.5	NT	9.8	NT	NT	0.21
P-5	5/18/97	4.91	441	6.3	NT	NT	346	NT	3.42
P-5	5/26/97	5.28	379	6.7	NT	NT	285	NT	1.55
P-5	6/2/97	4.38	522	7.4	NT	14.8	230	NT	0.99
P-5	6/9/97	5.25	586	9.7	1	12.72	182	Negative	1.07
P-5	6/16/97	4.28	610	11.9	39	4.71	210	NT	0.45
P-5	7/12/97	5.56	572	12.1	NT	NT	185	Positive	0.31
P-5	9/15/97	6.7	782-1010	11.1	NT	9.7	NT	NT	0.15
Honeymoon Hts. Adit									
A-1	7/11/97	8	141	6.6	NT	NT	154	Negative	(In adit)
Ten Mile Creek									
Upstream near confuence	5/22/97	8.03	61	5	NT	13.1	NT	NT	NT
Directly upstream of bridg	9/16/97	7.25	75	7.6	NT	NT	NT	NT	76.43

NOTES:

µS	Micro-Siemens
C°	Degrees Celsius
mg/L	Milligrams per liter
mV	Millivolts
gpm	Gallons per minute
cfs	Cubic feet per second
NT	Not tested for specified field parameter
▨ Grey Shading ▨	Indicates specified field parameter not applicable to sample location

NF	No flow
(c)	Indicates composite sample results

Seeps SP-4 and SP-5 flow related to streamflow in RR Creek

Turbidity results should be used with caution. Field meter readings were suspect.

TABLE 4.3-5
MONTHLY STREAMFLOW AVERAGES FOR RAILROAD CREEK
HOLDEN MINE RI/FS
DAMES & MOORE JOB NO. 17693-005-019

Month	Lucerne		Watershed Adjustment Factor[b]	Holden		1997 Data	
	RC-3[a] (cfs)	RC-3 (inches)		RC-4[c] (cfs)	RC-4 (inches)	RC-4 (cfs)	RC-4 (inches)
January	51	0.91	1.60	31.88	1.36		
February	47	0.76	1.60	29.38	1.25		
March	58	1.03	1.60	36.25	1.55		
April	184	3.17	2.00	92.00	3.93	83	3.43
May	514	9.14	2.90	177.24	7.57	407	16.82
June	629	10.83	2.10	299.52	12.79	477	19.71
July	402	7.15	1.90	211.58	9.03	421	17.40
August	192	3.42	1.90	101.05	4.31	174	7.19
September	107	1.84	1.60	66.88	2.86	116	4.79
October	88	1.57	1.60	55.00	2.35		
November	88	1.52	1.60	55.00	2.35		
December	69	1.23	1.60	43.13	1.84		
Monthly Average	**202.42**	**42.57**	**1.83**	**99.91**	**51.19**		

Notes:

(a) - Average monthly flow for period of record, 1911 - 1957 (USGS, 1984)

(b) - Adjustment factors developed from 1997 Channel Flow relationships

(c) - Estimated by dividing Measured Lucerne flow by adjustment factor

Grey Shading indicates measurements were not taken, therefore not reported nor analyzed.

TABLE 4.3-6
SEEP SOURCE AND DISCHARGE (1997)

Seep Station	Water Source	Receiving Water	Flow						
			May 18-23 (gpm)	June 2 (gpm)	June 9 (gpm)	June 16 (gpm)	July 9 - 12 (gpm)	Sept. 16 (gpm)	Oct. 3 - 5 (gpm)
SP-1	Groundwater Seepage -Tailings Pile 1	Railroad Creek	6	2-4	3-5	1-2	1-2	NF	NF
SP-2	Groundwater Seepage-Tailings Pile 1	Railroad Creek	5	1	5-6	2-5	1-2	1-2	2-3
SP-3	Groundwater Seepage-Tailings Pile 2	Railroad Creek	1-2	5	3-4	2	2-4	L	0.5
SP-4	Groundwater Seepage-Tailings Pile 2	Railroad Creek	8-15 (5/26/98)	18	28	3-5	4-6	NF	NF
SP-5	Groundwater Seepage-Tailings Pile 3	Wetland Area and SP-21	19	NA	22	NA	19	NF	NF
SP-6	Runon/Runoff and Groundwater Seepage-Waste Rock Pile	SP-16 (Lagoon)	30	NF	NF	NF	NF	NF	NF
SP-7	Runon/Runoff and Groundwater Seepage-Mill Site	SP-16 (Lagoon)	68	10-20	NA	NA	5	L	2-3
SP-8	Runon/Runoff and Groundwater Seepage-Waste Rock Pile	SP-19	9	5-8	NA	NF	NF	NF	NF
SP-9	Groundwater/Interflow-Downgradient of Lagoon (SP-16).	Railroad Creek	3-5	S	1-2	S	S	NF	NF
SP-10W	Groundwater Seepage-Downgradient of Copper Creek Diversion	Railroad Creek	L	S	1-2	S	1	NF	NF
SP-10E	Groundwater Seepage-Downgradient of Copper Creek Diversion	Railroad Creek	L	S	NA	S	S	NF	NF
SP-11	Groundwater Seepage-Downgradient of Lagoon (SP-16)	Railroad Creek	4	L	<1	S	S	NF	NF
SP-12	Groundwater Seepage-near Portal Drainage	Railroad Creek	30-40	40-60	26-31	11-23	<0.5	NF	NF
SP-13	Groundwater Seepage-Beneath Village	Wetland- Railroad Creek	NA	36	NA	NA	L	NF	NA
SP-14	Runon/Runoff and Groundwater Seepage-Honeymoon Heights	Infiltrates (possibly re-emerges in SP-23)	20-30	NA	NA	NA	L	L	15 (10/3) 11-17
SP-15W	Groundwater Seepage-Waste Rock Pile and Mill Site	SP-16 (Lagoon)	34	10-15	NA	NA	NF	NF	NF
SP-15E	Groundwater Seepage-Waste Rock Pile and Mill Site	SP-16 (lagoon)	68	86	70	11.5	2-3	NF	<1
SP-16	Groundwater Seepage and Runon/Runoff-from upgradient seeps and surrounding areas	Infiltrates into Ground (no surface outlet)	P	P	P	P	P	P	P
SP-17	Groundwater Seepage and Runon/Runoff-Tailings Pile 3 and upgradient areas	Wetland Area and SP-21	>30	NA	NA	NA	1.5	NF	NF
SP-18	Groundwater Seepage-Tailings Pile 3	Wetland Area and SP-21	>1	NA	NA	NA	1	NF	NF
SP-19	Groundwater Seepage and Runon/Runoff-Tailings Pile 1	Copper Creek Diversion (CoC-D)	40-45	60	NA	NF	NF	NF	NF
SP-20	Runon/Runoff-upgradient areas	Copper Creek	NA	10-20	NA	NF	NF	NF	NA
SP-21	Groundwater Seepage and Runon/Runoff-Tailings Pile 3 and surrounding wetland and upgradient areas	Railroad Creek (downstream of Tailings Pile 3)	884	1456	458	NA	242	1-2	NA
SP-22	Groundwater Seepage and Runon/Runoff-Mill Site	Infiltrates into Ground	15	6-10	NA	NA	L	NF	NF
SP-23	Groundwater Seepage and Runon/Runoff-below Honeymoon Heights	Railroad Creek	60-100	NA	63	100-150	NF	NA	20-30
SP-23B	Groundwater Seepage-Below SP-23	Railroad Creek	20	10-20	3-4	5	3-5	NF	1-2

TABLE 4.3-6 (CONTINUED)
SEEP SOURCE AND DISCHARGE (1997)

Seep Station	Water Source	Receiving Water	Flow						
			May 18-23 (gpm)	June 2 (gpm)	June 9 (gpm)	June 16 (gpm)	July 9 - 12 (gpm)	Sept. 16 (gpm)	Oct. 3 - 5 (gpm)
SP-24	Groundwater Seepage-Downgradient of SP-22	Railroad Creek	8	NF	NF	NF	NF	NF	NF
SP-25	Groundwater Seepage-Downgradient of SP-22	Railroad Creek	1-2	S	S	S	NF	NF	NF
SP-26	Groundwater Seepage-emerging from cutbank upgradient of mine	Railroad Creek	NA	NA	NA	NA	3-5	3	NA
A-1	Direct discharge from mine adit	Infiltrated into ground	NA	NA	NA	NA	NA	NA	NA

NA = not measured
NF = no flow
S = submerged
L = very low flow
P = ponded with no outflow

TABLE 4.3-6a
AVERAGE MONTHLY WATER BUDGET FOR RAILROAD CREEK WATERSHED ABOVE LUCERNE
HOLDEN MINE RI/FS
DAMES & MOORE JOB NO. 17693-005-019

Month	Average Precipitation[a] (inches)	Average Streamflow[b] (inches)	Potential Evapotranspiration[c] (inches)	Actual Evapotranspiration[d] (inches)	Glacial Melt Runoff[e] (inches)	Basin Change[f] (inches)
January	8.94	0.91	0.19	0.19	0	7.84
February	6.4	0.76	0.33	0.33	0	5.31
March	3.79	1.03	0.67	0.67	0	2.09
April	2.16	3.17	1.06	1.06	0	-2.07
May	1.25	9.14	1.73	1.25	0	-9.14
June	1.5	10.83	2.26	1.5	0	-10.83
July	1.03	7.15	3.41	1.03	0.37	-6.78
August	1.5	3.42	3.02	1.5	0.38	-3.04
September	2.19	1.84	1.71	1.71	0.37	-0.99
October	4.6	1.57	0.8	0.8	0	2.23
November	8.77	1.52	0.3	0.3	0	6.95
December	9.98	1.23	0.16	0.16	0	8.59
Total	**52.11**	**42.57**		**10.5**	**1.12**	**0.16**

Notes:

(a) - Monthly average Precipitation estimated from Holden Village data
(b) - Monthly average streamflow runoff from period of record, USGS station at Lucerne
(c) - Potential evapotranspiration estimated from temperature data for basin.
(d) - Actual evapotranspiration assumed equal to PET unless Precipitation is less than PET, then equal to precipitation.
(e) - Glacial melt runoff based on basin estimate from Pelto (1993)
(f) - computed from S = (P)-(Q)-AET+(G) vhere S is the basin change in storage including groundwater recharge/discharge and snow accumulation/melt.

TABLE 4.3-6b
AVERAGE MONTHLY WATER BUDGET FOR HOLDEN MINE SITE
HOLDEN MINE RI/FS
DAMES & MOORE JOB NO. 17693-005-019

Month	Monthly Averages					1997 Field Season Data				
	Average Precipitation[a] (inches)	Average Potential Evapotranspiration[b] (inches)	Groundwater Runoff[c] (cfs)	Mine Site Area Runoff[d] (inches)	Net Change in Storage[e] (inches)	Precipitation[f] (inches)	Estimation of Potential Evapotranspiration[g] (inches)	Groundwater Runoff[h] (cfs)	Groundwater Runoff[i] (inches)	Net Change in Storage[j] (inches)
January	6.62	0.22	0.24	1.48	4.92	▨	▨	▨	▨	▨
February	4.74	0.38	0.22	1.35	3.01	▨	▨	▨	▨	▨
March	2.81	0.76	0.27	1.66	0.39	▨	▨	▨	▨	▨
April	1.6	1.22	0.69	4.24	-3.86	26.37	1.22	0.62	3.7	21.45
May	0.93	0.93	1.33	8.18	-8.18	26.1	1.1	3.05	18.9	6.1
June	1.11	1.11	2.25	13.83	-13.83	1.02	1.02	3.57	21.2	-21.2
July	0.76	0.76	1.59	9.78	-9.78	1.13	1.13	3.16	19.4	-19.4
August	1.11	1.11	0.75	4.61	-4.61	1.12	1.12	1.3	8	-8
September	1.62	1.62	0.5	3.07	-3.07	4.45	1.96	0.87	5.2	-2.71
October	3.41	0.92	0.41	2.52	-0.03	▨	▨	▨	▨	▨
November	6.5	0.34	0.41	2.52	3.64	▨	▨	▨	▨	▨
December	7.39	0.18	0.32	1.97	5.24	▨	▨	▨	▨	▨
Total	**38.6**	**9.55**		**55.22**	**-26.17**	**60.19**	**7.55**		**76.4**	**-23.76**

Notes:
(a) - Holden Village average precipitation
(b) - Holden Village estimated average potential evapotranspiration
(c) - estimated runoff (groundwater) from mine site; equal to 0.75% of the average monthly flow
(d) - runoff in inches for mine site area, assumed equal to 120 acres.
(e) - net change in storage from mine site.
(f) - Holden Village precipitation for 1997 - April and May values include estimated snowmelt of 50 inches (water equivalent of 500 inch snowfall)
(g) - Estimated PET from monthly average temperature for 1997,
(h) - estimated runoff as 0.75% of 1997 monthly average values at RC-4
(i) - runoff in inches.
(j) - change in storage in mine site area
▨ Grey Shading indicates measurements were not taken, therefore not reported nor analyzed.

TABLE 4.3-7
APRIL BASEFLOW MEASUREMENTS

Station	Date of Measurement	Flow	Stage
RC-6	4/16/97	54.9 cfs	0.95 ft (RC-4)
RC-1	4/16/97	63.1 cfs	0.95 ft (RC-4)
RC-4	4/16/97	60.4 cfs	0.95 ft (RC-4)
Copper Creek*	4/17/97	3.6 cfs	NA
RC-7	4/16/97	77.0 cfs	1.00** ft (RC-4)
RC-2	4/17/97	86.4 cfs	1.05 ft (RC-4) and 0.86 ft (RC-2)
RC-5 (above SP-21) 500 ft downstream of RC-2	4/17/97	78.5 cfs	1.05 ft (RC-4) and 0.86 ft (RC-2)
RC-3	4/18/97	195.6 cfs	1.05 ft (RC-4)

* Copper Creek was measured only at the diversion. Flow in the main channel was below ice and snow and was assumed to be less than based on low flow conditions observed in September.

** Stage interpolated.

TABLE 4.3-8
SEPTEMBER BASEFLOW MEASUREMENTS

Station	Date of Measurement	Flow	Stage
RC-1	9/22/97	82.4 cfs	1.21 ft (RC-4)
RC-4	9/22/97	87.5 cfs	1.21 ft (RC-4)
RC-9	9/22/97	82.4 cfs	1.21 ft (RC-4)
Copper Creek*	9/22/97	14.2 cfs	NA
RC-7	9/22/97	100.9 cfs	1.21 ft (RC-4)
RC-2	9/22/97	99.3 cfs	1.21 ft (RC-4) and 0.90 ft (RC-2)
RC-5 (above SP-21) 500 feet downstream of RC-2	9/22/97 9/22/97 9/22/97 9/22/97	94.2 cfs 110.8 cfs** 91.6 cfs 98.1 cfs	0.90 ft (RC-2) 0.90 ft (RC-2) 0.90 ft (RC-2) 0.90 ft (RC-2)
RC-5 100 feet downstream of SP-21 (flow in SP-21 is 0.2 cfs)	9/22/97	99.6 cfs	0.90 ft (RC-2)

* Copper Creek includes the diversion (7.6 cfs) and the main channel (6.6 cfs).

** RC-9 is located just above the confluence with the main channel of Copper Creek and below the Copper Creek diversion.

** This measurement is greater than 5 percent different than the others, and is considered an outlier.

RC-6 was not measured in September.
RC-9 is located between RC-4 and Copper Creek.

TABLE 4.3-9
RESULTS OF OCTOBER 1998 BASEFLOW SURVEY – RC-6 TO RC-4 (REACH 1)

Station	Measured Mean Flow	Standard Deviation
BF-1 Located RC-6	28.1 cfs	0.8 cfs (27.3 – 28.9)
BF-2 Located 50 feet downstream of P-5	28.0 cfs	1.3 cfs (26.7 – 29.3)
BF-3 Located adjacent to the septic field	30.4 cfs	2.2 cfs (28.2 – 32.6)
BF-4 Located 50 feet downstream of the vehicle bridge	27.9 cfs	1.9 cfs (26.0 – 29.8)
BF-5 Located at RC-4 (40 feet upstream of the footbridge)	28.2 cfs	0.9 cfs (27.3 – 29.1)

TABLE 4.4-1
HYDROSTRATIGRAPHIC UNITS

Hydrostratigraphic Unit	Distribution	Thickness (ft)	Lithology/ Grain Size	Hydraulic Conductivity (cm/sec)*	Permeability Type
Soil/Fill	West portion site, SP-5 area	0-10	Clay-boulder, with branches/stumps	Small where fine-grained or compact, large where large-grained or poorly sorted	Intergranular/discontinuity
Colluvium	North of Railroad Creek, beneath TP3	25-40+	Silt-boulder	1.2×10^{-2} to 4.6×10^{-3}	Intergranular
Tailings	TP1, TP2, TP3	10-120	Clayey silt-sand	4.4×10^{-3} to 2.0×10^{-4}	Intergranular
Waste Rock	East/west of mill building	10-70	Sand-cobble	Estimated at $>1 \times 10^{-1}$ Large due to large grain size and poor sorting	Intergranular
Alluvium	Underneath/adjacent to Railroad Creek	5-25	Silt-cobble	1.8×10^{-3} to 7.2×10^{-3}	Intergranular
Alluvium/reworked till	South of Railroad Creek	5-10?	Silt-gravel	5.3×10^{-2} to 9.0×10^{-4}	Intergranular
Dense Till	Entire site	5-95	Clay-boulder	1×10^{-8} to 1×10^{-10} (unfractured)	Fracture
Bedrock	Entire site	12-140 (depth to bedrock)	Quartz diorite, granodiorite, schist, gneiss	4.7×10^{-2} to 9.3×10^{-8} (fractured) 1.3×10^{-8} to 2.3×10^{-12} (unfractured)	Fracture

* Refer to text for sources of hydraulic conductivity values

TABLE 4.4-2
GROUNDWATER FIELD PARAMETERS
HOLDEN MINE RI/FS
DAMES & MOORE JOB NO. 17693-005-019

Groundwater Sampling Stations	Sample Date	Field Parameters							Well Construction Details and Water Level Measurements					
		pH	Electrical conductivity (µS)	Temperature (C^o)	Turbidity (NTU)	Dissolved Oxygen (mg/L)	Redox Potential (mV)	Fe^{+2} (Qualitative)	Screen Interval (feet below ground surface)	Lithology in which well is screened*	Groundwater Level (feet below Top of Casing)	Monitoring Well Elevation (Top of Casing)	Groundwater Elevation (feet)	Slug Test Hydraulic Conductivity (cm/sec)
Upstream Wells														
HBKG-1	5/16/97	NT	NT	NT	NT	NT	NT	NT	?-15	Native	3.03	3218.3	3215.27	0.015-0.184
	5/26/97	5.6	492	5.1	2	NT	NT	NT			3.31	3218.3	3214.99	
	6/3/97	5.13	383	5	3	NT	229	Positive			3.34	3218.3	3214.96	
	6/7/97	5.1	369	5.9	2	NT	NT	NT			3.46	3218.3	3214.84	
	6/18/97	NT	NT	NT	NT	NT	NT	NT			3.68	3218.3	3214.62	
	6/20/97	NT	NT	NT	NT	NT	NT	NT			4	3218.3	3214.3	
	7/13/97	NT	NT	NT	NT	NT	NT	NT			5.29	3218.3	3213.01	
	9/17/97										7.08	3218.3	3211.22	
	9/20/97	5.11	430	9.6	NT	NT	NT	NT			6.96	3218.3	3211.34	
	10/5/97										5.6	3218.3	3212.7	
HBKG-2	5/16/97	NT	NT	NT	NT	NT	NT	NT	?-20	Native	3.37	3270.5	3267.13	
	5/26/97	6.3	84	5	160	NT	NT	NT			4.43	3270.5	3266.07	
	6/3/97	6.01	73	5.5	610	NT	195	Negative			4.11	3270.5	3266.39	
	6/20/97	NT	NT	NT	NT	NT	NT	NT			4.53	3270.5	3265.97	
	7/13/97	NT	NT	NT	NT	NT	NT	NT			9.44	3270.5	3261.06	
	9/17/97										11.11	3270.5	3259.39	
	9/20/97	6.3	92	8	NT	NT	NT	NT			11.37	3270.5	3259.13	
CC-BKG	5/16/97	NT	NT	NT	NT	NT	NT	NT	?-10	Native	10.2	3275.27	3265.07	
	7/13/97	NT	NT	NT	NT	NT	NT	NT			10.15	3275.27	3265.12	
	9/17/97										10.18	3275.27	3265.09	
HV-3	5/16/97	NT	NT	NT	NT	NT	NT	NT	62-75	Native	30.4	3272.11	3241.71	
	6/9/97	6.64	172	7.8	48	NT	181	Negative			45.46	3272.11	3226.65	
	6/20/97	NT	NT	NT	NT	NT	NT	NT			49.17	3272.11	3222.94	
	7/13/97	NT	NT	NT	NT	NT	NT	NT			59.18	3272.11	3212.93	
	9/17/97										67.65	3272.11	3204.46	
	9/20/97	6.54	770	9.8	NT	NT	NT	NT			67.56	3272.11	3204.55	
Downstream Wells														
DS-1	5/14/97	NT	NT	NT	NT	NT	NT	NT	15-20	Alluvial	1.48	3149.55	3148.07	
	5/26/97	5.4	975	5.8	1	NT	NT	NT			2.02	3149.55	3147.53	
	6/3/97	5.44	655	8.8	9	NT	169	Negative			1.66	3149.55	3147.89	
	6/20/97	NT	NT	NT	NT	NT	NT	NT			2.1	3149.55	3147.45	
	7/13/97	NT	NT	NT	NT	NT	NT	NT			2.85	3149.55	3146.7	
	9/17/97										5.06	3149.55	3144.49	
	9/20/97	5.24	529	6.1	NT	NT	NT	NT			5.39	3149.55	3144.16	
DS-2	5/14/97	NT	NT	NT	NT	NT	NT	NT	15-20	Alluvial	5.75	3153.26	3147.51	0.0072-0.0244
	5/20/97	4.2	862	6.2	NT	NT	NT	NT			8.11	3153.26	3145.15	
	5/26/97	4.2	744	6.4	13	NT	NT	NT			6.51	3153.26	3146.75	
	6/5/97	4.01	516	6.3	NT	NT	165	Positive			5.98	3153.26	3147.28	
	6/11/97	NT	NT	NT	NT	NT	NT	NT			6.14	3153.26	3147.12	
	6/18/97	NT	NT	NT	NT	NT	NT	NT			5.8	3153.26	3147.46	
	6/20/97	NT	NT	NT	NT	NT	NT	NT			6.3	3153.26	3146.96	
	7/13/97	NT	NT	NT	NT	NT	NT	NT			6.75	3153.26	3146.51	
	9/17/97										8.45	3153.26	3144.81	
	9/20/97	4.07	1050	6.8	NT	NT	NT	NT			9.11	3153.26	3144.15	
Tailings Pile 1														
TP1-1A	5/16/97	NT	NT	NT	NT	NT	NT	NT	?-59.5	Native	46.49	3251.99	3205.5	
	6/3/97	5.54	1120	6.1	137	NT	187	Positive			46.96	3251.99	3205.03	
	6/20/97	NT	NT	NT	NT	NT	NT	NT			48.9	3251.99	3203.09	
	7/13/97	NT	NT	NT	NT	NT	NT	NT			50.74	3251.99	3201.25	
	9/17/97										52.51	3251.99	3199.48	
	9/18/97	5.51	1690	6.4	NT	NT	NT	NT			52.49	3251.99	3199.5	

TABLE 4.4-2
GROUNDWATER FIELD PARAMETERS
HOLDEN MINE RI/FS
DAMES & MOORE JOB NO. 17693-005-019

Groundwater Sampling Stations	Sample Date	Field Parameters							Well Construction Details and Water Level Measurements					
		pH	Electrical conductivity (µS)	Temperature (C^0)	Turbidity (NTU)	Dissolved Oxygen (mg/L)	Redox Potential (mV)	Fe^{+2} (Qualitative)	Screen Interval (feet below ground surface)	Lithology in which well is screened*	Groundwater Level (feet below Top of Casing)	Monitoring Well Elevation (Top of Casing)	Groundwater Elevation (feet)	Slug Test Hydraulic Conductivity (cm/sec)
TP1-2A	5/16/97	NT	NT	NT	NT	NT	NT	NT	?-59.5	Native	46.63	3248.27	3201 64	
	6/3/97	5.16	1560	6.4	26	NT	214	NA			47.18	3248.27	3201.09	
	6/20/97	NT	NT	NT	NT	NT	NT	NT			48.57	3248.27	3199.7	
	7/13/97	NT	NT	NT	NT	NT	NT	NT			49.98	3248.27	3198.29	
	9/17/97										52.11	3248.27	3196.16	
	9/18/97	4.91	4710	6.9	NT	NT	NT	NT			52.06	3248.27	3196.21	
TP1-2L	6/6/97	6.28	5630	10.7	8	NT	80	Positive						
	9/20/97	5.75	4840	10.2	NT	NT	NT	NT						
TP1-3A	5/16/97	NT	NT	NT	NT	NT	NT	NT	54?-64	Alluvial/Reworked Till	45.45	3246.6	3201.15	
	6/3/97	5.3	2400	6.1	200	NT	202	Positive			45.99	3246.6	3200.61	
	6/20/97	NT	NT	NT	NT	NT	NT	NT			47.42	3246.6	3199.18	
	7/13/97	NT	NT	NT	NT	NT	NT	NT			48.85	3246.6	3197.75	
	9/17/97										50.88	3246.6	3195.72	
	9/18/97	5.25	4470	6.8	NT	NT	NT	NT			50.88	3246.6	3195.72	
TP1-3L	6/3/97	5.43	4760	7.3	81	NT	195	Positive						
	6/4/97	5.65	4980	NT	139	NT	187	Positive						
	9/19/97	6.04	4520	9.8	NT	NT	NT	NT						
TP1-4A	5/16/97	NT	NT	NT	NT	NT	NT	NT	95.5-100.5	Moderately Dense to Dense Glacial Material	66	3275.07	3209.07	
	6/10/97	6.74	537	8.9	126	NT	122	NA			72.71	3275.07	3202.38	
	6/20/97	NT	NT	NT	NT	NT	NT	NT			73.67	3275.07	3201.4	
	7/13/97	NT	NT	NT	NT	NT	NT	NT			75.4	3275.07	3199.67	
	9/17/97										77.05	3275.07	3198.02	
	9/18/97	6.9	804	7.4	NT	NT	NT	NT			77.05	3275.07	3198.02	
TP1-4B	5/16/97	NT	NT	NT	NT	NT	NT	NT	NA	NA	65.48	3275.2	3209.72	
	6/20/97	NT	NT	NT	NT	NT	NT	NT			73.62	3275.2	3201.58	
TP1-4L	6/6/97	4.2	2790	10.7	1	NT	128	Positive						
	9/19/97	4.81	3570	9.1	NT	NT	NT	NT						
TP1-5A	5/16/97	NT	NT	NT	NT	NT	NT	NT	?-65	Native	50.76	3249.14	3198.38	0.0118-0.0534
	6/3/97	4.31	250	5.1	395	NT	257	Positive			51.77	3249.14	3197.37	
	6/12/97	NT	NT	NT	NT	NT	NT	NT			53.41	3249.14	3195.73	
	6/20/97	NT	NT	NT	NT	NT	NT	NT			52.88	3249.14	3196.26	
	7/13/97	NT	NT	NT	NT	NT	NT	NT			54.61	3249.14	3194.53	
	9/17/97										56.47	3249.14	3192.67	
	10/5/97	4.14	1820	6.2	NT	NT	NT	NT			56.28	3249.14	3192.86	
TP1-6A	5/16/97	NT	NT	NT	NT	NT	NT	NT	?-44	Native	30.8	3239.59	3208.79	
	5/27/97	4.5	1670	5.9	9	NT	NT	NT			23.04	3239.59	3216.55	
	6/3/97	4.26	1750	6.1	9	NT	196	Positive			32.02	3239.59	3207.57	
	6/20/97	NT	NT	NT	NT	NT	NT	NT			33.24	3239.59	3206.35	
	7/13/97	NT	NT	NT	NT	NT	NT	NT			34.55	3239.59	3205.04	
	9/17/97										35.95	3239 59	3203.64	
	9/20/97	4.51	659	7.1	NT	NT	NT	NT			35.98	3239.59	3203.61	
TP1-6L	6/6/97	5.06	1850	10	0	NT	116	Positive						
TP1-6L	9/19/97	4.3	3180	8.7	NT	NT	NT	NT						
Tailings Pile 2														
PZ-1A	5/15/97	NT	NT	NT	NT	NT	NT	NT	59-61.2	Alluvial/ Reworked till	24.37	3283 62	3259.25	
	6/11/97	6.43	743	8.6	122	NT	NT	NA			39.21	3283.62	3244.41	
	6/20/97	NT	NT	NT	NT	NT	NT	NT			40.33	3283.62	3243.29	
	7/13/97	NT	NT	NT	NT	NT	NT	NT			DRY			
	9/17/97	Dry	Dry	Dry	Dry	Dry	Dry	Dry			DRY			
PZ-1B	5/15/97	NT	NT	NT	NT	NT	NT	NT	49.25-51.4	Tailings	46.7	3282.96	3236.26	
	6/5/97	6.85	1680	7.5	72	NT	140	NA			38.32	3282.96	3244.64	
	6/20/97	NT	NT	NT	NT	NT	NT	NT			39.59	3282.96	3243 37	
	7/13/97	NT	NT	NT	NT	NT	NT	NT			42.41	3282.96	3240.55	
	9/17/97	6.48	1420	6.9	NT	NT	NT	NT			44.17	3282.96	3238.79	

TABLE 4.4-2
GROUNDWATER FIELD PARAMETERS
HOLDEN MINE RI/FS
DAMES & MOORE JOB NO. 17693-005-019

Groundwater Sampling Stations	Sample Date	Field Parameters							Well Construction Details and Water Level Measurements					
		pH	Electrical conductivity (µS)	Temperature (C^{O})	Turbidity (NTU)	Dissolved Oxygen (mg/L)	Redox Potential (mV)	Fe^{+2} (Qualitative)	Screen Interval (feet below ground surface)	Lithology in which well is screened*	Groundwater Level (feet below Top of Casing)	Monitoring Well Elevation (Top of Casing)	Groundwater Elevation (feet)	Slug Test Hydraulic Conductivity (cm/sec)
PZ-1C	5/15/97	NT	NT	NT	NT	NT	NT	NT	25.22-27.37	Tailings	DRY			
	6/20/97	NT	NT	NT	NT	NT	NT	NT			DRY			
	7/13/97	NT	NT	NT	NT	NT	NT	NT			DRY			
	9/17/97										DRY			
PZ-2A	5/15/97	NT	NT	NT	NT	NT	NT	NT	83.75-85.9	Alluvial/ Reworked till	55.69	3282.42	3226.73	
	6/20/97	NT	NT	NT	NT	NT	NT	NT			60.64	3282.42	3201.78	
	7/13/97	NT	NT	NT	NT	NT	NT	NT			72.37	3282.42	3210.05	
	9/17/97										DRY			
PZ-2B	5/15/97	NT	NT	NT	NT	NT	NT	NT	70.32-72 47	Tailings	DRY	3281.96		
	6/20/97	NT	NT	NT	NT	NT	NT	NT			72.98	3281 96	3208.98	
	7/13/97	NT	NT	NT	NT	NT	NT	NT			70.69	3281.96	3211.27	
	9/17/97										DRY			
PZ-2C	5/15/97	NT	NT	NT	NT	NT	NT	NT	27.7-29.85	Tailings	29.94			
	6/20/97	NT	NT	NT	NT	NT	NT	NT			29.98	3282 12	3252.14	
	7/13/97	NT	NT	NT	NT	NT	NT	NT			29.9	3282.12	3252.22	
	9/17/97										29.94	3282.12	3252.18	
PZ-3A	5/15/97	NT	NT	NT	NT	NT	NT	NT	113.9-116.05	Alluvial/ Reworked till	103.8	3285.24	3181.44	
	6/6/97	6.57	1160	9.2	148	NT	115	Positive			103.81	3285.24	3181.43	
	6/20/97	NT	NT	NT	NT	NT	NT	NT			104.58	3285 24	3180.66	
	7/13/97	NT	NT	NT	NT	NT	NT	NT			106.14	3285.24	3179.1	
	9/17/97	6.61	1150	9.2	NT	NT	NT	NT			108.88	3285.24	3176.51	
PZ-3B	5/15/97	NT	NT	NT	NT	NT	NT	NT	93.52-95.67	Tailings	94.96	3284.91	3190.15	
	6/20/97	NT	NT	NT	NT	NT	NT	NT			94.98	3284.91	3189.93	
	7/13/97	NT	NT	NT	NT	NT	NT	NT			94.8	3284.91	3190.11	
	9/17/97										95.95	3284.91	3188.96	
PZ-3C	5/15/97	NT	NT	NT	NT	NT	NT	NT	30.92-33.07	Tailings	DRY	3284.45		
	6/20/97	NT	NT	NT	NT	NT	NT	NT			DRY			
	7/13/97	NT	NT	NT	NT	NT	NT	NT			DRY			
	9/17/97	Dry	Dry	Dry	Dry	Dry	Dry	Dry			DRY			
TP2-4A	5/15/97	NT	NT	NT	NT	NT	NT	NT	125.5-128.5	Native	110 74	3283.89	3173.15	
	6/6/97	7.21	1320	8	78	NT	114	Positive			111.14	3283.89	3172.75	
	6/20/97	NT	NT	NT	NT	NT	NT	NT			111.8	3283.89	3174.22	
	7/13/97	NT	NT	NT	NT	NT	NT	NT			112.98	3283.89	3170 91	
	9/18/97	6.94	1120	7.5	NT	NT	NT	NT			115.33	3283.89	3168.69	
TP2-4B	5/15/97	NT	NT	NT	NT	NT	NT	NT	111-114	Tailings	111.27	3283.88	3172.61	
	6/20/97	NT	NT	NT	NT	NT	NT	NT			109.87	3283.88	3172.08	
	7/13/97	NT	NT	NT	NT	NT	NT	NT			109.87	3283 88	3174.01	
	9/17/97										111.33	3283.88	3172.55	
Tailings Pile 2														
TP2-5A	5/15/97	NT	NT	NT	NT	NT	NT	NT	64-66.5	Native	53.64	3281.73	3228.09	
	6/7/97	6.02	740	7.7	210	NT	133	Negative			55.99	3281 73	3225.74	
	6/20/97	NT	NT	NT	NT	NT	NT	NT			60.25	3281 73	3221.48	
	7/13/97	NT	NT	NT	NT	NT	NT	NT			67.92	3281.73	3193.81	
	9/17/97	NT	NT	NT	NT	NT	NT	NT			67.99	3281.73	3213.74	
TP2-5B	5/15/97	NT	NT	NT	NT	NT	NT	NT	NA	Tailings	60.48	3281.75	3221.27	
	6/20/97	NT	NT	NT	NT	NT	NT	NT			59.65	3281.75	3222.1	
	7/13/97	NT	NT	NT	NT	NT	NT	NT			60.4	3281.75	3221 35	
	9/17/97										60.47	3281.75	3221.28	
TP2-7A	5/15/97	NT	NT	NT	NT	NT	NT	NT	130-132	Native	119 59	3286.92	3167.33	0.0236-0.0527
	6/11/97	NT	NT	NT	NT	NT	NT	NT			121 3	3286 92	3165 62	
	6/17/97	NT	NT	NT	NT	NT	NT	NT			121.37	3286 92	3165.55	
	7/13/97	NT	NT	NT	NT	NT	NT	NT			123.95	3286.92	3162.97	
	9/17/97										127 85	3286.92	3159.07	
	10/5/97										127.79	3286.92	3159.13	

TABLE 4.4-2
GROUNDWATER FIELD PARAMETERS
HOLDEN MINE RI/FS
DAMES & MOORE JOB NO. 17693-005-019

Groundwater Sampling Stations	Sample Date	Field Parameters							Well Construction Details and Water Level Measurements						
		pH	Electrical conductivity (µS)	Temperature (C^0)	Turbidity (NTU)	Dissolved Oxygen (mg/L)	Redox Potential (mV)	Fe^{+2} (Qualitative)	Screen Interval (feet below ground surface)	Lithology in which well is screened*	Groundwater Level (feet below Top of Casing)	Monitoring Well Elevation (Top of Casing)	Groundwater Elevation (feet)	Slug Test Hydraulic Conductivity (cm/sec)
TP2-7B	5/15/97	NT	NT	NT	NT	NT	NT	NT	113-117	Tailings	118.11	3287.04	3168.93	
	7/13/97	NT	NT	NT	NT	NT	NT	NT			117.17	3287.04	3169.87	
	9/17/97										118.7	3287.04	3168.34	
TP2-8A	5/15/97	NT	NT	NT	NT	NT	NT	NT	114-119	Native	80.46	3284.9	3204.44	
	6/6/97	5.12	1410	7.1	173	NT	162	Negative			83.09	3284.9	3201.81	
	6/20/97	NT	NT	NT	NT	NT	NT	NT			88.25	3284.9	3196.65	
	7/13/97	NT	NT	NT	NT	NT	NT	NT			99.27	3284.9	3185.63	
	9/19/97	5.32	1440	9.8	NT	NT	NT	NT			112.66	3284.9	3172.45	
TP2-8B	5/15/97	NT	NT	NT	NT	NT	NT	NT	95-100	Tailings	90.04	3284.68	3194.64	
	6/20/97	NT	NT	NT	NT	NT	NT	NT			87.63	3284.68	3197.05	
	7/13/97	NT	NT	NT	NT	NT	NT	NT			94.41	3284.68	3190.27	
	9/17/97										DRY			
TP2-11A	5/15/97	NT	NT	NT	NT	NT	NT	NT	99-104.5	Native	84.7	3283.02	3198.32	0.0009-0.0119
	6/5/97	5.06	432	8.3	999	NT	145	Negative			82.15	3283.02	3200.87	
	6/13/97	NT	NT	NT	NT	NT	NT	NT			82.74	3283.02	3200.28	
	6/20/97	NT	NT	NT	NT	NT	NT	NT			121.93	3283 02	3161.09	
	6/20/97	NT	NT	NT	NT	NT	NT	NT			83.08	3283.02	3199.94	
	7/13/97	NT	NT	NT	NT	NT	NT	NT			86.61	3283.02	3196.41	
	9/19/97	5.36	914	6.4	NT	NT	NT	NT			93.77	3283.02	3189.25	
TP2-11B	5/15/97	NT	NT	NT	NT	NT	NT	NT	84.7-90	Tailings	88 24	3283.06	3194.82	
	6/20/97	NT	NT	NT	NT	NT	NT	NT			81.35	3283.06	3201.71	
TP2-11L														
Tailings Pile 3														
TP3-4	5/15/97	NT	NT	NT	NT	NT	NT	NT	?-45	Native	4.62	3206.3	3201.68	
	6/4/97	3.97	340	4.8	52	282	NT	Positive			14.17	3206.3	3192.13	
	6/20/97	NT	NT	NT	NT	NT	NT	NT			28.54	3206.3	3177.76	
	7/13/97	NT	NT	NT	NT	NT	NT	NT			41.67	3206.3	3164.63	
	9/17/97	NS	NS	NS	NS	NS	NS	NS			DRY	3206.3		
TP3-4L	5/30/97	6.37	1180	8	9	13.3	NT	NT						
	6/4/97	6.16	1027	9.7	145	8.35	215	Positive						
	9/19/97	5.72	1350	12	NT	NT	NT	NT						
TP3-5A	5/14/97	NT	NT	NT	NT	NT	NT	NT	?-77	Alluvial/ Reworked till	51.07	3213.9	3162.83	
	6/20/97	NT	NT	NT	NT	NT	NT	NT			54.91	3213.9	3158.99	
	7/13/97	NT	NT	NT	NT	NT	NT	NT			57.89	3213.9	3156.01	
	9/17/97										63.47	3213.9	3150.43	
TP3-6A	5/15/97	NT	NT	NT	NT	NT	NT	NT	60-65	Colluvium	21.57	3211.24	3189.67	
	6/4/97	5.2	154	4.7	NT	NT	225	NA			27.2	3211 24	3184.04	
	6/20/97	NT	NT	NT	NT	NT	NT	NT			38.37	3211.24	3172.87	
	7/13/97	NT	NT	NT	NT	NT	NT	NT			47.63	3211.24	3163.61	
	9/19/97	6.14	103	6.4	NT	NT	NT	NT			60.18	3211.24	3150.74	
TP3-6BL	6/4/97	6.23	2790	9.1	0	NT	183	Positive						
	9/19/97	6.77	2940	9.8	NT	NT	NT	NT						
TP3-7A	5/15/97	NT	NT	NT	NT	NT	NT	NT	66.5-71.5	Native	43 11	3210.11	3167	
	6/20/97	NT	NT	NT	NT	NT	NT	NT			44.69	3210.11	3165.42	
	7/13/97	NT	NT	NT	NT	NT	NT	NT			51.51	3210 11	3158.6	
	9/17/97										61.2	3210.11	3148.91	
TP3-7B	5/15/97	NT	NT	NT	NT	NT	NT	NT	?-59.3	Tailings	35.6	3210 02	3174.42	
	6/20/97	NT	NT	NT	NT	NT	NT	NT			42.87	3210.02	3167.15	
	7/13/97	NT	NT	NT	NT	NT	NT	NT			47 28	3210 02	3162.74	
	9/17/97										54.67	3210.02	3155.35	
TP3-8	5/15/97	NT	NT	NT	NT	NT	NT	NT	73-78	Dense till	54.55	3211 52	3156.97	
	6/4/97	5.65	844	7	12	NT	212	Positive			55.55	3211 52	3155.97	
	6/20/97	NT	NT	NT	NT	NT	NT	NT			57 07	3211 52	3154.45	
	7/13/97	NT	NT	NT	NT	NT	NT	NT			57.74	3211 52	3153.78	
	9/19/97	5.53	2120	8.1	NT	NT	NT	NT			62.9	3211.52	3148.96	

TABLE 4.4-2
GROUNDWATER FIELD PARAMETERS
HOLDEN MINE RI/FS
DAMES & MOORE JOB NO. 17693-005-019

Groundwater Sampling Stations	Sample Date	Field Parameters							Well Construction Details and Water Level Measurements						
		pH	Electrical conductivity (µS)	Temperature (C°)	Turbidity (NTU)	Dissolved Oxygen (mg/L)	Redox Potential (mV)	Fe^{+2} (Qualitative)	Screen Interval (feet below ground surface)	Lithology in which well is screened*	Groundwater Level (feet below Top of Casing)	Monitoring Well Elevation (Top of Casing)	Groundwater Elevation (feet)	Slug Test Hydraulic Conductivity (cm/sec)
TP3-9	5/14/97	NT	NT	NT	NT	NT	NT	NT	70.6-75.6	Native	36 21	3214.57	3178.36	
	6/4/97	3.81	709	5.9	6	NT	258	Positive			42.92	3214.57	3171.65	
	6/20/97	NT	NT	NT	NT	NT	NT	NT			47.87	3214.57	3166.7	
	7/13/97	NT	NT	NT	NT	NT	NT	NT			55.43	3214.57	3159.14	
	9/19/97	4.37	1820	6.2	NT	NT	NT	NT			67.42	3214.57	3146.93	
TP3-10	5/14/97	NT	NT	NT	NT	NT	NT	NT	75-80	Native	59.09	3215.79	3156.7	
	6/4/97	4.99	2870	5.7	88	NT	184	Negative			60.19	3215.79	3155.6	
	6/20/97	NT	NT	NT	NT	NT	NT	NT			61.67	3215.79	3154.32	
	7/13/97	NT	NT	NT	NT	NT	NT	NT			63.52	3215.79	3152.27	
	9/19/97	5.44	1210	6.8	NT	NT	NT	NT			68.82	3215.79	3148.16	
TP3-10L	6/6/97	6.69	2640	10.7	21	13.88	117	Positive						
	6/4/97							Positive						
	9/19/97	6.36	2710	8.8	NT	NT	NT	NT						
Tailings Pile 3														
PZ-4A	5/14/97	NT	NT	NT	NT	NT	NT	NT	44.14-46.29	Colluvium	11.25	3206.97	3195.72	0.0051-0.0116
	6/11/97	NT	NT	NT	NT	NT	NT	NT			28.16	3206.97	3178.81	
	6/17/97	NT	NT	NT	NT	NT	NT	NT			31.5	3206.97	3175.47	
	7/13/97	NT	NT	NT	NT	NT	NT	NT			44.95	3206.97	3162.02	
	9/17/97										DRY			
PZ-4B	5/14/97	NT	NT	NT	NT	NT	NT	NT	23.03-25.18	Tailings	DRY	3207.01		
	6/11/97	NT	NT	NT	NT	NT	NT	NT			23.22	3207.01	3183.79	
	6/17/97	NT	NT	NT	NT	NT	NT	NT			22.98	3207.01	3184.03	
	6/20/97	NT	NT	NT	NT	NT	NT	NT			22.06	3207.01	3184.95	
	7/13/97	NT	NT	NT	NT	NT	NT	NT			21.96	3207.01	3185.05	
	9/17/97										23.02	3207.01	3183.99	
	10/5/97										23.43	3207.01	3183.58	
PZ-4C	5/14/97	NT	NT	NT	NT	NT	NT	NT	16.27-18.42	Tailings	15.86	3206.23	3190.37	
	7/13/97	NT	NT	NT	NT	NT	NT	NT			17.03	3206.23	3189.2	
	9/17/97										18.94	3206.23	3187.29	
PZ-5A	5/14/97	NT	NT	NT	NT	NT	NT	NT	60.62-62.77		45.9	3209.19	3163.29	
	6/20/97	NT	NT	NT	NT	NT	NT	NT		Alluvial/ Reworked till	49.97	3209.19	3159.22	
	7/13/97	NT	NT	NT	NT	NT	NT	NT			54.01	3209.19	3155.18	
	9/17/97										59.42	3209.19	3149.77	
PZ-5B	5/14/97	NT	NT	NT	NT	NT	NT	NT	22.65-24.8	Tailings	DRY	3209.2		
	6/20/97	NT	NT	NT	NT	NT	NT	NT			DRY	3209.2		
	7/13/97	NT	NT	NT	NT	NT	NT	NT			DRY	3209.2		
	9/17/97										DRY	3209.2		
PZ-5C	5/14/97	NT	NT	NT	NT	NT	NT	NT	15.79-20.09	Tailings	DRY	3208.83		
	6/20/97	NT	NT	NT	NT	NT	NT	NT			18.96	3208.83	3189.87	
	7/13/97	NT	NT	NT	NT	NT	NT	NT			18.95	3208.83	3189.88	
	9/17/97										DRY	3208.83		
PZ-6A	5/14/97	NT	NT	NT	NT	NT	NT	NT	64.48-66.63	Tailings	57.96	3211.7	3153.74	
	6/2/97	7	2270	8.3	999	NT	NT	NT				3211.7		
	6/10/97	5.95	2430	11.6	213	NT	98	Positive			57.29	3211 7	3154.41	
	6/20/97	NT	NT	NT	NT	NT	NT	NT			57.32	3211.7	3154.38	
	7/13/97	NT	NT	NT	NT	NT	NT	NT			58.17	3211.7	3153.53	
	9/17/97	6.45	2900	8	NT	NT	NT	NT			60.31	3211.7	3151.39	
PZ-6B	5/14/97	NT	NT	NT	NT	NT	NT	NT	24.62-26.77	Tailings	26.93	3211.26	3184.33	
	6/20/97	NT	NT	NT	NT	NT	NT	NT			DRY	3211.26		
	7/13/97	NT	NT	NT	NT	NT	NT	NT			DRY	3211.26		
	9/17/97										DRY	3211.26		
PZ-6C	5/14/97	NT	NT	NT	NT	NT	NT	NT	15.46-17.61	Tailings	16.46	3211.85	3195.39	
	6/20/97	NT	NT	NT	NT	NT	NT	NT			DRY	3211.85		
	7/13/97	NT	NT	NT	NT	NT	NT	NT			DRY	3211.85		
	9/17/97										DRY	3211 85		

TABLE 4.4-2
GROUNDWATER FIELD PARAMETERS
HOLDEN MINE RI/FS
DAMES & MOORE JOB NO. 17693-005-019

Groundwater Sampling Stations	Sample Date	Field Parameters							Well Construction Details and Water Level Measurements					
		pH	Electrical conductivity (µS)	Temperature (C^o)	Turbidity (NTU)	Dissolved Oxygen (mg/L)	Redox Potential (mV)	Fe^{+2} (Qualitative)	Screen Interval (feet below ground surface)	Lithology in which well is screened*	Groundwater Level (feet below Top of Casing)	Monitoring Well Elevation (Top of Casing)	Groundwater Elevation (feet)	Slug Test Hydraulic Conductivity (cm/sec)
Lucerne Well														
Forest Service Station	6/15/97	5.49	140	9	5	NT	NT	Positive	▨	▨	NT	NT	▨	▨
	10/3/97	5.25	105	9.1	NT	NT	NT	NT	▨	▨	▨	▨	▨	▨

Notes:

* - Lithology based on interpretation of boring logs completed by others.

(µS)	MicroSiemens per centimeter
C°	Degrees Celsius
mg/L	Milligrams per liter
mV	Millivolts
cm/sec	centimeters per second

NT	Not tested for specified field parameter
Grey Shading	Indicates specified field parameter not applicable to sample location
NF	No flow
(c)	Indicates composite sample results

Turbidity results should be used with caution Field meter readings were suspect.

TABLE 4.4-3
HYDRAULIC CONDUCTIVITY VALUES

Sample Location	Values in cm/sec				Hydrostratigraphic Unit Monitored
	In 1	In 2	Out 1	Out 2	
TP1-5	0.0534	0.0482	0.0118	--	Alluvium/reworked till
TP2-11	0.0119	0.0087	0.0018	0.0009	Alluvium/reworked till
TP2-7	0.0527	0.0457	0.0236	--	Alluvium/reworked till
DS-2	0.0072	0.0244	0.0074	--	Alluvium
HBKG-1	0.0196	0.0150	0.1840	0.1559	Alluvium
PZ-4A	0.0053	0.0116	0.0046	0.0051	Colluvium

Summary of Hydraulic Conductivities

	(cm/sec)	(ft/sec)
Low	0.0009	0.0003
Mean	0.0333	0.011
High	0.184	0.006

TABLE 4.4-4
RECHARGE TO RAILROAD CREEK, MAY 1997 (VALUES IN CFS)
(Based on Mean Values of Flow Net Analysis)

Stream Reach	Alluvial/reworked till contribution	Tailings contribution	Total groundwater contribution	Ratio of tailings contribution to total
RC-4 to RC-7	2.1	0.1	2.2	0.04
RC-7 to RC-2	0.9	0.1	1.0	N/A
Total RC-4 to RC-2	3.0	0.2	3.2	0.03

TABLE 4.4-5
RECHARGE TO RAILROAD CREEK, SEPTEMBER 1997 (VALUES IN CFS)
(Based on Mean Values of Flow Net Analysis)

Stream Reach	Alluvial/Reworked Till Contribution	Tailings Contribution	Total Groundwater Contribution	Ratio of tailings contribution to total
RC-4 to RC-7	1.1	0.1	1.2	0.08
RC-7 to RC-2	0.1	0.0	0.1	N/A
Total RC-4 to RC-2	1.2	0.1	1.3	0.09

TABLE 4.4-6
RESULTS OF OCTOBER 1998 BASEFLOW SURVEY – RC-6 TO RC-4 (REACH 1)

Station	Measured Mean Flow	Standard Deviation
BF-1 Located RC-6	28.1 cfs	0.8 cfs (27.3 – 28.9)
BF-2 Located 50 feet downstream of P-5	28.0 cfs	1.3 cfs (26.7 – 29.3)
BF-3 Located adjacent to the septic field	30.4 cfs	2.2 cfs (28.2 – 32.6)
BF-4 Located 50 feet downstream of the vehicle bridge	27.9 cfs	1.9 cfs (26.0 – 29.8)
BF-5 Located at RC-4 (40 feet upstream of the footbridge)	28.2 cfs	0.9 cfs (27.3 – 29.1)

TABLE 4.4-7
REACH 1 SEEP FLOW

Seep	May/June Approximate Range (cfs)	May/June Assumed Average (cfs)	September Approximate Range (cfs)	September Assumed Average (cfs)
SP-23	0.2 - 0.3	0.15	0 - 0.1	0.05
SP-23B	0.01 - 0.04	0.02	0 - 0.003	0
SP-9	0.01	0	0	0
SP-11	0.002 - 0.004	0	0	0
SP-12	0.01 - 0.1	0.05	0	0
SP-24	0.02	0.01	0	0
SP-25	0.003	0	0	0
SP-22	0.01 - 0.03	0.02	0	0
SP-15E	0.03 - 0.19	0.14	0	0
SP-15W	0.03 - 0.07	0.05	0	0
SP-6	0.01 - 0.06	0.03	0	0
SP-7	0.02 - 0.15	0.08	0.005	0

TABLE 4.4-8
REACH 2 SEEP FLOW

Seep	May/June Approximate Range (cfs)	May/June Assumed Average (cfs)	September Approximate Range (cfs)	May/June Assumed Average (cfs)
SP-1	0.002 - 0.01	0	0	0
SP-2	0.01 - 0.02	0.015	0.003	0
SP-3	0.01	0	0.001	0
SP-4	0.01 - 0.1	0.05	0	0
SP-5	0.01- 0.04	0.02	0	0
SP-8	NA	NA	NA	NA
SP-10 E&W	0.003	0	0	0
SP-19	0.09 - 0.13	0.11	0	0
SP-17	0.2	0.1	0	0
SP-18	0.005	0	0	0
SP-21	1.0 -3.2	2.1	0.004	0

* Seep SP-8 was observed flowing in late April only.

TABLE 4.4-8a
SEEPAGE FIELD PARAMETERS
HOLDEN MINE RI/FS
DAMES & MOORE JOB NO. 17693-005-019

Seeps Sampling Stations	Sample Date	Field Parameters								
		pH	Electrical conductivity (µS)	Temperature (C°)	Turbidity (NTU)	Dissolved Oxygen (mg/L)	Redox Potential (mV)	Fe^{+2} (Qualitative)	Seep Discharge Estimate (gpm)	Seep Discharge (cfs)
SP1A	5/23/97	3.3	2570	7.6	NT	13.94	332	Positive	0.1	2.0 x 10-5 CFS
SP-1A	5/26/97	3.74	2960	6.1	NT	NT	NT	NT	NT	
SP-1B	5/23/97	3.2	2240	7	NT	4.86	NT	NT	6	0.01332
SP-1	6/2/97	3.43	2750	7.1	NT	NT	NT	NT	2 to 4	0.0044-0.00888
SP-1	6/9/97	3.3	2540	10.5	NT	NT	NT	NT	3 to 5	0.00666-0.0111
SP-1	6/16/97	3.3	2690	7.8	<4	15.97	239	Positive	1 to 2	0.00222-0.0044
SP-1	7/12/97	3.56	4310	9.5	NT	NT	318	Positive	1 to 2	0.00222-0.0044
SP-1	9/5/97	NF	NF	NF	NF	NF	NF	NF	NF	
SP2-1	5/18/97	2.9	2370	8.8	29	15.13	NT	NT	NT	
SP2-1	6/2/97	3	Low flow	NT	NT	NT	NT	NT	NT	
SP2-1	6/7/97	3.09	4040	12.6	NT	NT	NT	NT	1 to 2	0.0022-0.0044
SP2-1	6/9/97	2.8	3740	20.7	202	10.49	401	NT	1 to 2	0.0022-0.0044
SP2-1	6/16/97	3.1	3700	9	28	15.6	389	Positive	<0.5	<0.0011
SP2-2	5/18/97	3.1	3910	6.8	22	15.7	NT	NT	3.1	0.006882
SP2-2	5/26/97	3.54	3920	6.1	NT	NT	NT	NT	2 to 5	0.0044-0.0111
SP2-2	6/7/97	3.22	3740	7.5	NT	NT	NT	NT	3 to 4	0.0067-0.0088
SP2-2	6/9/97	3.16	3420	9.6	67	NT	196	NT	4	0.0088
SP2-2	6/16/97	3.2	3760	8	31	16.7	388	Positive	2	0.0044
SP2-3	5/18/97	3.1	3450	6.3	31	16.6	NT	NT	2.2	0.0049
SP2-3	5/26/97	3.4	3800	8.1	NT	NT	NT	NT	2 to 3	0.0044-0.0067
SP2-3	6/2/97	3.25	4210	10.7	NT	NT	427	NT	0.5	0.0011
SP2-3	6/7/97	3.03	3580	14.7	NT	NT	NT	NT	<1	<0.0022
SP2-4	6/7/97	3.2	3430	11	NT	NT	NT	NT	3 to 5	0.0067-0.0111
SP2-5	6/7/97	NT	NT	NT	NT	NT	NT	NT	NT	
SP2-6	6/7/97	3.15	2950	9.9	NT	NT	NT	NT	1	0.0022
SP-2	6/2/97	3.32	3710	6.5	36	2.59	377	NT	1	0.0022
SP-2	6/7/97	3	3890	10.1	NT	NT	NT	NT	5 to 6	0.0111-0.01332
SP-2	6/9/97	3	3580	15.1	NT	NT	300	NT	5 to 6	0.0111-0.01332
SP-2 (c)	6/16/97	3.2	3790	8.4	127	15.14	386	Positive	2.5	0.0056
SP-2 (c)	7/12/97	2.9	4495	16	NT	NT	360	Positive	1-2 gpm	0.0022-0.0044
SP-2	9/16/97	3 12	3050	10	NT	NT	NT	NT	1-2 gpm	0.0022-0.0044
SP-2	10/5/97	3.37	2810	9.3	NT	NT	NT	NT	2-3 gpm	0.0044-0.0067
SP-3-1	5/20/97	3.5	1650	5.3	NT	NT	NT	NT	NT	
SP-3-4	5/20/97	3.8	2590	5	NT	NT	NT	NT	NT	
SP-3-5	5/20/97	3.8	1830	4.7	NT	NT	NT	NT	NT	
SP-3-7	5/20/97	3.5	1810	4.4	NT	NT	NT	NT	NT	
SP-3	5/20/97	3.61	1790	5.2	NT	NT	386	Positive	1 to 2	0 0022-0.0044
SP-3	6/2/97	3.77	1540	11.8	NT	NT	NT	NT	5	0.0111
SP-3	6/7/97	3.5	1960	7.1	NT	NT	NT	NT	1 to 2	0.0022-0.004
SP-3	6/9/97	3.36	1760	9.2	NT	NT	NT	NT	3 to 4	0 0067-0 0088
SP-3 (c)	6/16/97	3.6	1880	7.5	NT	15.3	240	Positive	2	0.0044
SP-3	7/12/97	3.5	2030	13.2	NT	NT	331	Positive	2 to 4	0.0044-0.0088
SP-3	9/16/97	3.5	2040	14	NT	NT	NT	NT	Pond	
SP-3	10/5/97	3.48	2090	8.9	NT	NT	NT	NT	<0.5GPM	<0.0011

TABLE 4.4-8a
SEEPAGE FIELD PARAMETERS
HOLDEN MINE RI/FS
DAMES & MOORE JOB NO. 17693-005-019

Seeps Sampling Stations	Sample Date	Field Parameters								
		pH	Electrical conductivity (µS)	Temperature (C^0)	Turbidity (NTU)	Dissolved Oxygen (mg/L)	Redox Potential (mV)	Fe^{+2} (Qualitative)	Seep Discharge Estimate (gpm)	Seep Discharge (cfs)
SP-4	5/20/97	3.64	1290	6	NT	NT	400	Positive	NT	
SP-4	5/26/97	3.8	1650	10.1	NT	NT	NA	NA	8 to 15	0.0178-0.0333
SP-4	6/2/97	3.61	1360	12.1	NT	NT	NT	NT	18	0.03996
SP-4	6/7/97	3.35	1480	12.5	NT	NT	NT	NT	45	0.0999
SP-4	6/9/97	3.35	1470	17.4	NT	NT	NT	NT	28	0.06216
SP-4	6/16/97	3.4	1830	7.9	0	15.95	219	Positive	3 to 5	0.0067-0.0111
SP-4	7/12/97	3.5	1260	4.4	NT	NT	331	Positive	4 to 6	0.00888-0.01332
SP-4	10/5/97	NF	NF	NF	NF	NF	NF	NF	NF	
SP-5-1	5/19/97	3.46	1110	5.8	NT	NT	NT	NT	NT	
SP-5-2	5/19/97	3.3	1600	6.4	NT	NT	NT	NT	NT	
SP-5-3	5/19/97	3.95	899	10.3	NT	NT	NT	NT	NT	
SP-5-4	5/19/97	3.54	1210	6.9	NT	NT	NT	NT	NT	
SP-5-5	5/19/97	4.56	563	4.9	NT	NT	NT	NT	NT	
SP-5	5/20/97	3.37	1160	5	NT	NT	372	Positive	19	0.0422
SP 5 (1)	5/26/97	3.9	1170	5.7	NT	NT	NA	NA	8.8	0.01954
SP-5 (1)	6/2/97	3.54	968	6.7	NT	NT	NT	NT	NT	
SP-5 (1)	6/7/97	3.59	832-1090	7.9	NT	NT	NT	NT	3 to 5	0.0063-0.0111
SP-5	6/9/97	3.52	763-1110	7.8	NT	NT	NT	NT	22	0.04884
SP-5	7/12/97	3.78	608	8.6	NT	NT	265	NT	19	0.0422
SP-5	9/5/97	NF	NF	NF	NF	NF	NF	NF	NF	
SP-6	5/18/97	4.3	940	5.3	NT	NT	NT	NT	30	0.0666
SP-6	5/21/97	4.2	1040	4.8	31	15.26	336	Negative	7	0.0155
SP-6	6/2/97	NF	NT	NT	NT	NT	NT	NT	NT	
SP-6	6/16/97	NF	NT	NT	NT	NT	NT	NT	NT	
SP-6	7/9/97	NF	NT	NT	NT	NT	NT	NT	NT	
SP-7	5/21/97	5.63	240	6.9	38	14.34	267	Negative	67.9	0.1507
SP-7	6/2/97	NT	NT	NT	NT	NT	NT	NT	10 to 20	0.0222-0.0444
SP-7	7/12/97	6.91	264	19.1	NT	NT	170	Positive	5	0.0111
SP-7	9/19/97	4.69	505	14	NT	NT	NT	NT	NT	
SP-7	10/5/97	4.64	840	8.8	NT	NT	NT	NT	2 to 3	0.0044-0.00666
SP-8	5/21/97	4.61	623	5.1	NT	NT	409	Negative	9	
SP-8	6/2/97	NT	NT	NT	NT	NT	NT	NT	5 to 8	
SP-8	6/16/97	NF	NT	NT	NT	NT	NT	NT	dry	
SP-8	7/9/97	NF	NT	NT	NT	NT	NT	NT	dry	
SP-8	10/5/97	NF	NF	NF	NF	NF	NF	NF	NF	
SP-9	5/22/97	4.4	186	4.2	NT	NT	NA	NA	NA	
SP-9	5/22/97	5.7	150	4.1	NT	NT	NA	NA	NA	
SP-9	5/23/97	6.4	198	5.2	NT	NT	NA	NA	3 to 5	0.0067-0.0111
SP-9	6/2/97	Submerged	NT	NT	NT	NT	NT	NT	NT	
SP-9	6/9/97	NT	85	4.9	NT	NT	NT	NT	1 to 2	0.0022-0.0044
SP-9	6/16/97	Submerged	NT	NT	NT	NT	NT	NT	NT	
SP-9	7/9/97	Submerged	NT	NT	NT	NT	NT	NT	NT	

TABLE 4.4-8a
SEEPAGE FIELD PARAMETERS
HOLDEN MINE RI/FS
DAMES & MOORE JOB NO. 17693-005-019

Seeps Sampling Stations	Sample Date	Field Parameters								
		pH	Electrical conductivity (µS)	Temperature (C°)	Turbidity (NTU)	Dissolved Oxygen (mg/L)	Redox Potential (mV)	Fe+2 (Qualitative)	Seep Discharge Estimate (gpm)	Seep Discharge (cfs)
SP-10W	5/21/97	4.15	370	4.2	5	NT	382	Negative	v low	
SP-10W	6/2/97	Submerged	NT	NT	NT	NT	NT	NT	NT	
SP-10W	6/9/97	4.49	392	6.9	NT	NT	NT	NT	1 to 2	0.0022-0.0044
SP-10W	6/16/97	Submerged	NT	NT	NT	NT	NT	NT	NT	
SP-10W	7/9/97	Submerged	NT	NT	NT	NT	NT	NT	NT	
SP-10W	7/12/97	4.69	301	11.1	NT	NT	165	Negative	1	0.0022
SP-10W	10/5/97	NF	NF	NF	NF	NF	NF	NF	NF	
SP-10E	5/21/97	3.3	594	7	11	14.19	497	Positive	Very Low	
SP-10E	6/2/97	Submerged	NT	NT	NT	NT	NT	NT	NT	
SP-10E	6/16/97	Submerged	NT	NT	NT	NT	NT	NT	NT	
SP-10E	7/9/97	Submerged	NT	NT	NT	NT	NT	NT	NT	
SP-10E	10/5/97	NF	NF	NF	NF	NF	NF	NF	NF	
SP-11	5/18/97	5.19	347	5.6	NT	NT	NT	NT	3	0.00666
SP-11 (c)	5/22/97	5.8	258	4	NT	NT	NA	Negative	4	0.0089
SP-11-1	5/22/97	5.74	262	3.8	NT	NT	NT	NT	Very Low	
SP-11-2	5/22/97	5.98	255	5	NT	NT	NT	NT	2	0.0044
SP-11-3	5/22/97	5.85	258	3.4	NT	NT	NT	NT	Very Low	
SP-11-4	5/22/97	5.86	258	3.2	NT	NT	NT	Negative	2	0.0044
SP-11	6/2/97	4.96	314	5.5	NT	NT	NT	NT	Very Low	
SP-11	6/9/97	6.2	233	5.3	NT	NT	NT	NT	<1	<0.0022
SP-11	6/16/97	Submerged	NT	NT	NT	NT	NT	NT	NT	
SP-11	7/9/97	Submerged	NT	NT	NT	NT	NT	NT	NT	
SP-12B-1	5/23/97	4.9	114	3.5	NT	NT	309	Negative	15 to 20	0.0333-0.0444
SP-12B-2	5/23/97	5.1	117	3.6	NT	NT	NT	NT	15 to 20	0.0333-0.0444
SP-12B-3	5/23/97	5.1	263	5.9	NT	NT	NT	NT	< 5	<0.0111
SP-12A	6/2/97	4.57	249	5.4	NT	NT	NT	NT	5	0.0111
SP-12B	6/2/97	4.52	221	4.4	NT	NT	NT	NT	1 to 2	0.0022-0.0044
SP-12C	6/2/97	NT	NT	NT	NT	NT	NT	NT	1 to 2	0.0022-0.0044
SP-12D	6/2/97	4.55	103	4	NT	NT	NT	NT	20 to 30	0.0444-0.0666
SP-12E	6/2/97	4.4	100	3.8	NT	NT	NT	NT	20 to 30	0.0444-0.0666
SP-12East	6/9/97	5.46	225	4.4	NT	NT	NT	NT	11	0.0244
SP-12East	6/16/97	4.56	220	6.5	34	8.02	204	Negative	1 to 3	0.0022-0.0067
SP-12West	6/9/97	5.8	105	43	NT	NT	NT	NT	15 to 20	0.0333-0.0444
SP-12West	6/16/97	4.58	100	5.1	17	8.31	202	Negative	10 to 20	0.0222-0.0444
SP-12	7/9/97	Low flow	NT	NT	NT	NT	NT	NT	NT	
SP-12	7/12/97	5.48	197	5.1	NT	NT	206	Negetive	<0.5	<0.0011
SP-12	10/5/97	NF	NF	NF	NF	NF	NF	NF	NF	
SP-13-1	6/2/97	6.15	89	9.3	22	NT	NT	NT	3	0.0067
SP-13-2	6/2/97	6.28	90	7.9	157	NT	NT	NT	3	0.0067
SP-13-3	6/2/97	6.33	88	7.7	129	NT	NT	NT	10	0.0222
SP-13-4	6/2/97	6.3	91	8.7	15	NT	NT	NT	10	0.0222
SP-13-5	6/2/97	6.29	98	7.4	94	NT	NT	NT	10	0.0222
SP-13 (Composit	6/2/97	NT	NT	NT	NT	NT	196	Positive	NT	
SP-13	7/9/97	Low flow	NT	NT	NT	NT	NT	NT	NT	
SP-14	5/23/97	5.1	36	2.3	1	NT	199	Negative	20 to 30	0.0444-0.0666
SP-14	7/11/97	7	27	8.8	NT	NT	NT	NT	NT	
SP-14	9/18/97	6.05	17.5	14.8	NT	NT	NT	NT	NT	
SP-14 (Upper)	10/3/97	5.78	2	5.5	NT	NT	NT	NT	10-15 gpm	0.0222-0.0333
SP-14 (Lower)	10/3/97	4.45	71	7.7	NT	NT	NT	NT	1-2 gpm	0.0022-0.0044

TABLE 4.4-8a
SEEPAGE FIELD PARAMETERS
HOLDEN MINE RI/FS
DAMES & MOORE JOB NO. 17693-005-019

Seeps Sampling Stations	Sample Date	Field Parameters								
		pH	Electrical conductivity (µS)	Temperature (C^o)	Turbidity (NTU)	Dissolved Oxygen (mg/L)	Redox Potential (mV)	Fe^{+2} (Qualitative)	Seep Discharge Estimate (gpm)	Seep Discharge (cfs)
SP-15W	5/22/97	6.5	226	5.6	16	14.14	269	Negative	33.6	0.0746
SP-15W	6/2/97	NT	NT	NT	NT	NT	NT	NT	10 to15	0.0222-0.0333
SP-15W	7/9/97	NF	NT	NT	NT	NT	NT	NT	NT	
SP-15W	10/5/97	NF	NF	NF	NF	NF	NF	NF	NF	
SP-15E	5/22/97	5.5	460	8.2	36	13.15	318	NT	67.9	0.1507
SP 15E	5/26/97	5.55	371	6.6	11	12.9	NA	NT	88	0.1954
SP-15E	6/2/97	5.62	423	13.5	295	7.13	258	NT	86	0.1909
SP-15E	6/9/97	5.11	544	16.6	91	1.49	180	Negative	70	0.1554
SP-15E	6/16/97	4.69	569	13.2	10	11.55	208	Negative	11.5	0.02553
SP-15E	7/12/97	7.03	252	17.6	NT	NT	163	Negative	2 to 3	0.0044-0.0067
SP-15E	10/5/97	4.94	471	8.2	NT	NT	NT	NT	<1 GPM	<0.0022
SP-16	5/22/97	5.4	467	8.1	NT	NT	326	Negative	Lagoon	
SP-16	7/12/97	4.76	403	23.9	2	NT	186	Positive	Lagoon	
SP-16	9/16/97	4.43/4.38	423/290	12	NT	NT	NT	NT	Pond	
SP-17	5/20/97	6.38	43	4.6	NT	NT	127	Positive	> 30	>0.0666
SP-17	6/7/97	5.8	39	6.3	NT	NT	NT	NT	80 to 120	0.1776-0.2664
SP-17	7/12/97	7.4	47	8.9	NT	NT	90	Positive	1.5	0.00333
SP-17	9/5/97	NF	NF	NF	NF	NF	NF	NF	NF	
SP-18	5/19/97	3.34	1080	10.8	43	12.86	460	Positive	>1	>0.0022
SP-18 (Above Tr	6/7/97	3.49	1540	5.5	NT	NT	NT	NT	2	0.0044
SP-18 (Below Tr	6/7/97	3.35	1530	7.5	NT	NT	NT	NT	4	0.0088
SP-18	7/9/97	NT	NT	NT	NT	NT	NT	NT	2 to 3	0.0044-0.00666
SP-18	7/12/97	3.58	1040	6.9	NT	NT	303	NT	1	0.0022
SP-18	9/5/97	NF	NF	NF	NF	NF	NF	NF	NF	
SP-19	5/21/97	4.61	418	6.9	1	13.06	363	Negative	40 to 45	0.0888-0.0999
SP-19	6/2/97	6.74	75	16.3	NT	NT	NT	NT	60	0.1332
SP-19	6/9/97	6.41	106	21.9	NT	NT	NT	NT	NT	
SP-19	6/16/97	NF	NT	NT	NT	NT	NT	NT	NT	
SP-19	7/9/97	NF	NT	NT	NT	NT	NT	NT	NT	
SP-19	10/4/97	NF	NF	NF	NF	NF	NF	NF	NF	
SP20-1	5/23/97	6.2	30	4	NT	NT	NT	NT	NT	
SP20-2	5/23/97	6.3	30	3	NT	NT	NT	NT	NT	
SP20-3	5/23/97	5.9	90	5	NT	14.1	NT	NT	NT	
SP-20	6/2/97	Snow melt	NT	NT	NT	NT	NT	NT	10 to 20	0.0222-0.0444
SP-20	7/10/97	NF	NT	NT	NT	NT	NT	NT	NT	
SP-21	5/22/97	5.42	285	7.2	1	14.95	228	Positive	884	1.96
SP 21	5/26/97	5.57	195	5.9	NT	11	NT	NT	1207	2.68
SP-21	6/2/97	4.95	202	6.7	NT	NT	NT	NT	1456	3.23
SP-21	6/9/97	5.42	252	8.8	5	NT	NT	NT	458	1.017
SP-21	6/16/97	Inundated	NT	NT	NT	NT	NT	NT	NT	
SP-21	7/12/97	4.98	220	8.5	NT	NT	114	Positive	242	0.5372
SP-21	9/15/97	4.6	448	8.5	NT	NT	NT	NT	1.5-2 gpm	0.00333-0.0044
SP-21	10/5/97	4.92	374	7.2	NT	NT	NT	NT	NT	
SP-22	5/23/97	NT	433	9.5	NT	NT	282	Negative	15	0.0333
SP-22	6/2/97	NT	NT	NT	NT	NT	NT	NT	6 to 10	0.01332-0.0222
SP-22	7/9/97	ery Low Flo	NT	NT	NT	NT	NT	NT	NT	
SP-22	10/5/97	NF	NF	NF	NF	NF	NF	NF	NF	

TABLE 4.4-8a
SEEPAGE FIELD PARAMETERS
HOLDEN MINE RI/FS
DAMES & MOORE JOB NO. 17693-005-019

Seeps Sampling Stations	Sample Date	Field Parameters								
		pH	Electrical conductivity (µS)	Temperature (C^o)	Turbidity (NTU)	Dissolved Oxygen (mg/L)	Redox Potential (mV)	Fe^{+2} (Qualitative)	Seep Discharge Estimate (gpm)	Seep Discharge (cfs)
SP-23	5/23/97	4.2	360	2.5	1	14.77	327	Negative	60 to 100	0.1332-0.2228
SP 23	5/26/97	4.9	276	4.2	4	15.14	290	Negative	143	0.3175
SP 23	6/2/97	4.23	277	3.4	10	NT	344	NT	NT	▨
SP-23	10/5/97	4.57	196	6.6	NT	NT	NT	NT	40-50 gpm	0.0888-0.111
SP-23 (Vent Roa	10/5/97	4.54	182	6.3	NT	NT	NT	NT	20 to 30	0.0444-0.0666
SP-23A	6/9/97	4.8	260	4.2	0	16.4	187	NT	63	0.1399
SP-23A	6/16/97	3.86	203	7	3	10.22	207	NT	100 to 150	0.222-0.333
SP-23A	7/9/97	NF	NT	NT	NT	NT	NT	NT	NT	▨
SP-23B	5/23/97	4.3	285	2.6	0	15	325	Negative	20	0.0444
SP-23B	6/2/97	4.19	267	3.4	NT	NT	NT	NT	10 to 20	0.0222-0.0444
SP-23B	6/9/97	4.88	255	3.9	NT	NT	NT	NT	3 to 4	0.00666-0.00888
SP-23B	6/16/97	4 05	210	5.6	16	9.88	208	Negative	5	0.0111
SP-23B	7/9/97	NF	NT	NT	NT	NT	NT	NT	NT	▨
SP-23B (Above	7/11/97	5	186	7.7	NT	NT	151	Negative	3 to 5	0.0067-0.0111
SP-23B	10/5/97	4.5	192	6.9	NT	NT	NT	NT	1-2 gpm	0.0022-0.0044
SP-24	5/23/97	4.9	382	7.8	13	12.48	282	Negative	8	0.01776
SP-24	6/2/97	NF	NT	NT	NT	NT	NT	NT	NT	▨
SP-24	6/9/97	NF	NT	NT	NT	NT	NT	NT	NT	▨
SP-24	6/16/97	NF	NT	NT	NT	NT	NT	NT	NT	▨
SP-24	7/9/97	NF	NT	NT	NT	NT	NT	NT	NT	▨
SP-25	5/23/97	5.5	323	4.4	6	16.2	301	Negative	1 to 2	0.00222-0.0044
SP-25	6/2/97	Submerged	NT	NT	NT	NT	NT	NT	NT	▨
SP-25	6/9/97	Submerged	NT	NT	NT	NT	NT	NT	NT	▨
SP-25	6/16/97	Submerged	NT	NT	NT	NT	NT	NT	NT	▨
SP-25	7/9/97	NF	NT	NT	NT	NT	NT	NT	NT	▨
SP-25	10/5/97	NF	NF	NF	NF	NF	NF	NF	NF	▨
SP-26	7/11/97	8.26	25	7.2	NT	NT	NT	NT	3 to 5	0.0067-0.0111
SP-26	9/16/97	6	31.8	7.2	NT	NT	NT	NT	3 gpm	0.0067
A-1	7/11/97	7.59	141	6.6	NT	NT	NT	NT	No outflow	▨

Notes:

ohs/cm	Microohms per centimeter
C°	Degrees Celsius
mg/L	Milligrams per liter
mV	Millivolts
gpm	Gallons per minute
cfs	Cubic feet per second
NT	Not tested for specified field parameter
Grey Shading	Indicates specified field parameter not applicable to sample location

NF	No flow
(c)	Indicates composite sample results
SP-5(1)	From main bubbling seep only

Seeps SP-4 and SP-5 flow related to streamflow in RR Creek

Turbidity results should be used with caution. Field meter readings were suspect.

TABLE 4.4-9
REACH 1 SITE-SPECIFIC WATER BALANCE RESULTS

Water Balance Component	Flow May/June Based on Field Season Average	Flow September Based on Field Season Average
Qrc1	460 - 465 cfs	125 - 126 cfs
Qrc4	460 cfs	125 cfs
Qsr	Qsr south bank = 0.8 cfs Qsr north bank = 1.3 cfs Qsp-23 = 0.2 cfs	Qsp-23 = 0.02 cfs
Qb	Qb = Qp1 = 1.3 cfs	Qb = Qp1 = 0.15 cfs
Qa	Qa = Qag - Qal Qal = 0 to 1 cfs Qag = 1.5 Qa = 1.5 to 0.5 cfs	Qa = Qag - Qal Qal = 0 to 1 cfs Qag = 0.5 Qa = 0.5 to -0.5 cfs
Qr	-1 to -2% of the flow at RC-4 (-4.1 to -10.1 cfs)	0 to -1% of the flow at RC-4 (0.3 to -1.7 cfs)

Qrc1 - Flow at Railroad Creek Station RC-1
Qrc4 - Flow at Railroad Creek Station RC-4
Qsr - Direct surface runoff contributions to Railroad Creek
Qb - Contribution of flow from the bedrock aquifer as measured at the portal drainage station P-1 (Qp1)
Qa - Net flow from the alluvial aquifer and is the sum of the gain (Qag) and loss (Qal)
Qsp-23 - Flow contribution to Railroad Creek from seep SP-23

Water Balance Equation:

$$Qrc4 = Qrc1 + Qa + Qb + Qsr \qquad \text{(Equation 4-13)}$$

where:

$$Qr = Qrc4 - (Qrc1 + Qa + Qb + Qsr)$$

TABLE 4.4-10
REACH 2 SITE SPECIFIC WATER BALANCE RESULTS

Water Balance Component	Flow May/June Based on Field Season Average	Flow September Based on Field Season Average
Qrc2	515 - 529 cfs	140 - 144 cfs
Qrc4	460 cfs	125 cfs
Qsr	Qsr south bank = 0 cfs Qsr north bank = 3.4 cfs	Qsr south bank = 0 cfs Qsr north bank = 0 cfs
Qt	Qt = Qcc = 59.8 cfs	Qt = Qcc = 16.3 cfs
Qa	Qa south bank = 3.2 cfs Qa north bank = 2.1 cfs	Qa = Qag + Qal Qag south bank = 1.3 cfs Qag north bank = 0.8 cfs Qal south bank = -0.5 cfs Qal north bank = 0 cfs
Qr	Water Balance error less than 1 to -3% of the flow at RC-4 (0.5 to -13.5 cfs).	Water Balance error 1% to -2% of the flow at RC-4 (-2.9 to +1.1 cfs).

Qrc2 - Flow at Railroad Creek Station RC-2
Qrc4 - Flow at Railroad Creek Station RC-4
Qsr - Direct surface runoff contributions to Railroad Creek
Qt - Tributary inflow to Railroad Creek contributed between RC-4 and RC-2
Qa - Net flow from the alluvial aquifer and is the sum of the gain (Qag) and loss (Qal)

Water Balance Equation:

$$Qrc2 = Qrc4 + Qa + Qsr + Qt \qquad \text{(Equation 4-14)}$$

where:

$$Qr = Qrc2 - (Qrc4 + Qa + Qar + Qt)$$

TABLE 4.6-1
HABITAT VARIABLES AND MAP INDICES USED DURING REFERENCE REACH EVALUATION

Habitat Variable	Map Indices
Stream Velocity and Discharge	Channel Slope and Contributing Watershed Area
Water Quality	Percent Glacier Area in the Contributing Watershed, Percent Lake Area in th Contributing Watershed, and Underlying Geology with related Historic Mining
Stream Substrate and Channel Shape	Channel Slope, Valley Width and Underlying Geology
Riparian Vegetation	Channel Elevation, Watershed Aspect, Valley Width and Mapped Green Areas o Topographic Map
Habitat Complexity and Stream Network	Valley Width, Stream Order, Percent Lake Area in the Contributing Watershed presence of Fish Barriers downstream of Reach - Fish Barriers were assumed to occu in channel sections with slopes greater than 7%.

TABLE 4-6-2
AQUATIC HABITAT PARAMETER RATINGS
HOLDEN MINE SITE REMEDIAL INVESTIGATION

Habitat Parameter (maximum possible)	Aquatic Sampling Location Average Rating									
	RC-6	RC-1	RC-9	RC-7	RC-5a	RC-10	RC-3	BC-1	SFAC-1	CoC-1
Bottom Substrate (20)	20	20	14	15	17	17	20	20	20	20
Instream Cover (20)	20	15	11	11	14	14	14	16	16	15
Embeddedness (20)	20	19	9	16	16	16	19	19	19	20
Velocity/Depth (20)	14	17	12	13	16	14	10	15	13	11
Channel Shape (15)	6	8	4	6	8	9	5	8	9	9
Width to Depth Ratio (15)	3	3	4	4	4	1	0	4	0	6
Bank Vegetation Protection (10)	4	6	4	6	8	9	4	9	9	2
Lower Bank Stability (10)	7	5	5	8	8	9	9	9	9	8
Disruptive Pressure (10)	8	6	9	9	9	9	9	10	8	10
Zone of Influence (10)	9	6	5	6	10	10	8	10	10	7
Total Rating (150)	111	105	77	94	110	108	93	120	113	108

TABLE 4.6-2A
BENTHIC MACROINVERTEBRATE EVALUATION RESULTS, HOLDEN MINE SITE REMEDIAL INVESTIGATION

Sampling Location	Species Richness	Scraper/ Filtering Collectors	EPT/ Chironomidae	Dominant Taxa (%)	EPT Index	Shredders/ Total Individuals	Total Number of Organisms
RC-6; Railroad Creek immediately downstream from Wilderness Boundary	48	0.78	0.93	30	34	0.07	1006
RC-1; Railroad Creek approx. 400 yards downstream from Wilderness Boundary	43	0.79	0.93	36	31	0.12	1065
RC-9; Railroad Creek immediately upstream from Copper Creek	37	0.78	0.82	12	25	0.29	330
RC-7; Railroad Creek adjacent to Tailings Pile No. 3	21	0	0.44	33	10	0.16	64
RC-5a; Railroad Creek immediately upstream from 10-Mile Creek	9	0	0.40	54	5	0.54	52
RC-10; Railroad Creek near 7-Mile Creek	13	0	0.66	27	10	0.15	75
RC-3; Railroad Creek appr. 300 ft upstream from Lake Chelan	36	0.59	0.74	22	24	0.40	381
BC-1; Bridge Creek near 6-Mile Camp	52	0.83	0.93	30	36	0.09	997
SFAC-1; South Fork Agnes Creek approx. 0.25 mile downstream from Swamp Creek	37	0.92	0.97	44	26	0.14	1058
CoC-1; Company Creek approx. 150 ft downstream from Chelan PUD hydroplant	39	0.81	0.95	31	28	0.05	1266

Macroinvertebrate community analysis results are presented as means for all replicates at a given location.

TABLE 4.6-2B
BENTHIC MACROINVERTEBRATE EVALUATION RESULTS, COMMUNITY LOSS INDEX
HOLDEN MINE SITE REMEDIAL INVESTIGATION

	RC-9	RC-7	RC-5a	RC-10
RC-6	0.49	1.48	--	--
RC-1	0.38	1.38	--	--
BC-1	--	--	5.11	3.08
SFAC-1	--	--	3.44	1.92

TABLE 4.6-2C
DISTRIBUTION FIT FOR METRIC DATA
HOLDEN MINE SITE REMEDIAL INVESTIGATION

Group	Type of Metric						
	Total (#/m^2)	Species Richness	Abundance of Scrapers	Abundance of EPT Taxa	Percent of Dominant Taxon	EPT Index	Ratio of Shredders
RC-1 & RC-6	Lognormal	Lognormal	No fit	No fit	Lognormal	No fit	Normal
RC-9 & RC-7	Lognormal	Lognormal	No fit	No fit	Lognormal	No fit	No fit
SFAC-1 & BC-1	Lognormal	Lognormal	Normal	No fit	Normal	Lognormal	No fit
RC-5a & RC-10	Lognormal	Lognormal	No data	Normal	Lognormal	Normal	Normal

TABLE 4.6-2D
SUMMARY OF STATISTICAL COMPARISON OF METRIC DATA HOLDEN MINE SITE REMEDIAL INVESTIGATION

Group	Type of Metric						
	Total (#/m^2)	**Species Richness**	**Abundance of Scrapers**	**Abundance of EPT Taxa**	**Percent of Dominant Taxon**	**EPT Index**	**Ratio of Shredders**
Reference (RC-1 & RC-6) Affected (RC-9 & RC-7)	Not similar*	Not similar*	Not similar**	Not similar**	Similar*	Not similar**	Similar
Reference (SFAC-1 & BC-1) Affected (RC-5a & RC-10)	Not similar*	Not similar*	No data	Not similar**	Similar**	Not similar**	Not similar**

* Independent T-test comparison performed

** Wilcoxin Rank Sum was used for nonparametric distributions

TABLE 4.6-3
TROUT POPULATION ESTIMATE RESULTS, HOLDEN MINE SITE REMEDIAL INVESTIGATION

Sampling Location (location length; area)	**Snorkeling* (observed)**		**Electrofishing (pop. est.)**	
	#/hectare	**#/100 meters**	**#/hectare**	**#/100 meter**
RC-6; Railroad Creek immediately downstream from Wilderness Boundary (86 meters; 0.09 hectare)	64	7	64	7
RC-1; Railroad Creek approximately 400 yards downstream from Wilderness Boundary (79 meters; 0.10 hectare)	128	16	93	11
RC-9; Railroad Creek immediately upstream from Copper Creek (87 meters; 0.10 hectare)	114	14	72	8
RC-7; Railroad Creek adjacent to Tailings Pile No. 3 (91 meters; 0.11 hectare)	10	1	10	1
RC-5a; Railroad Creek immediately upstream from 10-Mile Creek (87 meters; 0.10 hectare)	20	2	20	2
RC-10; Railroad Creek near 7-Mile Creek (91 meters; 0.13 hectare)	8	1	92	13
RC-3; Railroad Creek approximately 300 feet upstream from Lake Chelan (61 meters; 0.09 hectare)	153	21	89	13
BC-1; Bridge Creek near 6-Mile Camp (62 meters; 0.07 hectare)	302	35	384	45
SFAC-1; South Fork Agnes Creek approximately 0.25 mile downstream from Swamp Creek (76 meters; 0.15 hectare)	59	12	ND	ND
CoC-1; Company Creek approximately 150 feet downstream from Chelan PUD hydroplant (69 meters; 0.06 hectare)	571	54	ND	ND

ND = No Data

* Based on average counts (PIE, 1998)

TABLE 4.6-3A
GENERAL COMPOSITION AND CONDITION OF FISH AT RAILROAD CREEK

Sampling Location	Total Number of Species	Total Number of Individuals in Sample	Number of Non-Trout Species	Proportion of Individuals as Omnivorous	Proportion of Individuals as Top Carnivores	Proportion of Individuals as Hybrids	Total Number of Individuals with Physical Anomalies
RC-6	2	6	0	100%	0	17%	0
RC-1	2	5	0	100%	0	60%	0
RC-9	1	7	0	100%	0	0	0
RC-7	1	1	0	100%	0	0	0
RC-5a	1	2	0	100%	0	0	0
RC-10	1	9	0	100%	0	0	0
RC-3	3	11	1	100%	0	0	0
RC-1	1	28	0	100%	0	0	0

TABLE 4.6-4
SUMMARY OF WILDLIFE SURVEYS CONDUCTED AT HOLDEN MINE
SEPTEMBER 9 to 17, 1997

Date	Type	Location	Weather
September 9	General (am) General (pm) Bat	North-facing slope Upstream riparian	Fair
September 10	General (am) General (pm) Bat	North-facing slope Tailings pile	Fair
September 11	General (am) General (pm) Bat	South-facing slope Upstream riparian	Fair
September 12	General (pm) Bat	Upstream riparian	
September 13	Opportunistic (am) General (pm)	Tailings North-facing slope	
September 14	Opportunistic	Downstream riparian	rain
September 15	General (am, pm)	Downstream riparian	
September 16	General (am, pm)	South-facing slope	Fair, rain, snow
September 17	General (am)	Tailings pile	

TABLE 4.6-5
COMMON PLANT SPECIES

Scientific Name	Common Name
Trees	
Abies amabilis	Pacific silver fir
Abies lasiocarpa	Subalpine fir
Picea engelmannii	Engelmann spruce
Pinus contorta	Lodgepole pine
Pinus monticola	Western white pine
Pinus ponderosa	Ponderosa pine
Populus balsamifera	Black cottonwood
Populus tremuloides	Quaking aspen
Prunus emarginata	Bitter cherry
Pseudotsuga menziesii	Douglas fir
Thuja plicata	Western red cedar
Tsuga heterophylla	Western hemlock
Tsuga mertensiana	Mountain hemlock
Shrubs and Vines	
Acer glabrum	Douglas or mountain maple
Alnus sinuata	Sitka alder
Amelanchier alnifolia	Serviceberry
Ceanothus velutinus	Snowbrush
Cornus stolonifera	Red-osier dogwood
Holodiscus discolor	Oceanspray
Mahonia nervosa	Oregon grape
Oplopanax horridum	Devil's club
Pachistima myrsinites	Oregon boxwood
Rhododendron albiflorum	White-flowered rhododendron
Rosa gymnocarpa	Baldhip rose
Rubus lasiococcus	Dwarf bramble
Rubus parviflorus	Thimbleberry
Salix scouleriana	Scouler's willow
Salix spp.	Willows
Sambucus racemosa	Elderberry
Sorbus scopulina	Mountain ash
Symphoricarpos alba	Snowberry
Vaccinium spp.	Blueberries/Huckleberries
Herbs	
Aruncus dioicus	Goat's beard
Athyrium filix-femina	Lady fern
Calamagrostis rubescens	Pinegrass
Carex spp.	Sedges
Cryptogramma crispa	Parsley fern
Elymus glaucus	Blue wildrye
Epilobium angustifolium	Fireweed
Epilobium paniculatum	Willow-weed
Juncus mertensianus	Rush
Pteridium aquilinum	Bracken fern
Smilacina spp.	False Solomon's seal, wild lily of the valley
Verbascum thapsus	Common mullein

TABLE 4.6-6
HERPETOFAUNA LIKELY TO OCCUR WITHIN THE RAILROAD CREEK DRAINAGE

Amphibians	Lizards and Snakes
Long-toed salamander Pacific giant salamander Tailed frog Western Toad Pacific treefrog Cascades frog Columbian spotted frog	Northern alligator lizard Rubber boa Western terrestrial garter snake Common garter snake

TABLE 4.6-7
MASTER LIST OF AVIAN SPECIES OBSERVED AND POTENTIALLY OCCURRING AT AND IN THE VICINITY OF HOLDEN MINE

Species Observed	Probable Summer Breeders	Probable Year Round Residents not observed (due to secretive nature, etc.)
Golden Eagle	Spotted sandpiper	Cooper's hawk
Sharp-shinned hawk	Common nighthawk	Northern goshawk
Red-tailed hawk	Calliope hummingbird	Ruffed grouse
Rough-legged hawk	Olive-sided flycatcher	Spruce grouse
Blue grouse	Dusky flycatcher	Great horned owl
Northern flicker	Willow flycatcher	Barred owl
Yellow-bellied sapsucker	Western flycatcher	Northern pygmy owl
Hairy woodpecker	House wren	Northern saw-whet owl
Pileated woodpecker	Winter wren	Three-toed woodpecker
Hammond's flycatcher	Swainson's thrush	Black-backed woodpecker
Violet-green swallow	Solitary vireo	Gray jay
Barn swallow	Warbling vireo	Brown creeper
Stealer's jay	Yellow warbler	Pine siskin
Clark's nutcracker	Wilson's warbler	Pine grosbeak
Common raven	Fox sparrow	Evening grosbeak
Mountain chickadee	Lincoln's sparrow	
Chestnut-backed chickadee	Western tanager	
Red-breasted nuthatch		
Golden-crowned kinglet		
Ruby-crowned kinglet		
Townsend's solitaire		
Hermit thrush		
Varied thrush		
American robin		
American pipit		
American dipper		
Ceder waxwing		
Yellow-rumped warbler		
Townsend's warbler		
MacGillvary's warbler		
Song sparrow		
Dark-eyed junco		
White-crowned sparrow		
Golden crowned sparrow		
Red crossbill		
White-winged crossbill		
Rosy finch		
Finch spp.		

TABLE 4.6-8
BIRD SPECIES OBSERVED BY SURVEY AREA

North-aspect Slope	South-aspect Slope	Upstream Riparian	Downstream Riparian	Mine Tailings
Sharp-shinned hawk Pileated woodpecker	Golden eagle	Red-tailed hawk	Stellar's jay	Red-tailed hawk
Stellar's jay	Sharp-shinned hawk	Blue grouse	Mountain chickadee	Hairy woodpecker
Clarks nut cracker	Red-tailed hawk	Northern flicker	Chestnut-back chickadee Red-breasted nuthatch	Barn swallow
Raven	Rough-legged hawk	Hammond's flycatcher	Golden-crowned kinglet	Violet-green swallow
Mountain chickadee	Northern flicker	Violet-green swallow	American dipper	Stealer's jay
Chestnut-backed chickadee	Yellow-bellied sapsucker Clark's nutcracker	Mountain chickadee	Dark-eyed junco	American pipit
Red-breasted nuthatch	Mountain chickadee	Red-breasted nuthatch		Song sparrow
Golden-crowned kinglet	Red-breasted nuthatch	Golden-crowned kinglet		Dark-eyed junco
Ruby-crowned kinglet Hermit thrush	Golden-crowned kinglet	Townsend's solitaire		
Varied thrush	Townsend's solitaire	American robin		
American robin	American robin	Hermit thrush		
Yellow-rumped warbler	Dark-eyed junco	Cedar waxwing		
Townsend's warbler	Red crossbill	Townsend's warbler		
Dark-eyed junco	Rosey finch	McGillvary's warbler		
White-winged crossbill	Finch spp.	Dark-eyed junco		
Finch spp.		White-crowned sparrow		
		Golden-crowned sparrow		
		Red crossbill		
		Finch spp.		

TABLE 4.6-9
MASTER LIST OF ALL SPECIES OBSERVED, PROBABLY PRESENT AND POSSIBLE PRESENT AT HOLDEN MINE

All Species Observed	Bat Species Potentially Present	Species Probably Present, but Not Observed	Species Possible Present, but Not Observed
Bat spp. Pika Douglas squirrel Golden-mantled ground squirrel Mule deer Deer mouse Chipmunk sp. Black bear	California myotis Western small-footed myotis Long-eared myotis Keen's myotis Little brown myotis Fringed myotis Long-legged myotis Yuma myotis Hoary bat Silver-haired bat Big brown bat Western (Townsend's) big-eared bat	Masked shrew Dusky shrew Northern water shrew Snowshoe hare Bushytail woodrat Pacific jumping mouse Southern redbacked vole Heather vole Longtail vole Hoary Marmot Porcupine Coyote Marten Long-tailed weasel Short-tailed weasel Mink Mountain lion Bobcat	Fisher Wolverine Lynx Elk

TABLE 4.6-10
MAMMAL SPECIES OBSERVED, BY SURVEY AREA, AT HOLDEN MINE

Observations may have been of actual animals or their sign

North-facing slope	South-facing Slope	Upstream riparian	Downstream riparian	Mine tailings
Bat spp.	Douglas squirrel	Douglas squirrel	Douglas squirrel	Golden-mantled ground squirrel
Pika	Golden-mantled ground squirrel	Golden-mantled ground squirrel	Golden-mantled ground squirrel	Chipmunk sp.
Douglas squirrel	Chipmunk sp.	Chipmunk sp.	Chipmunk sp.	Black bear
Golden-mantled ground squirrel	Deer mouse	Black bear	Deer mouse	Mule deer
Chipmunk sp.	Mule deer	Mule deer	Beaver	
Deer mouse			Black bear	
Mule deer			Mule deer	

TABLE 4.6-11
SPECIES OF FEDERAL CONCERN WHICH MAY OCCUR IN THE VICINITY OF HOLDEN MINE, AS INDICATED BY U.S. FOREST SERVICE, AUGUST 13, 1997

Common Name	Habitat requirements	Potential to Occur in Project Area
Cascades frog *Rana cascadae*	Small pools and marshy areas adjacent to streams	Possible. Suitable habitat for this species exists in the project area.
Columbia spotted Frog *Rana luteiventris*	Marshy edges of lakes, springs, ponds, or streams	Possible. Suitable habitat exists for this species in the project area.
Tailed frog *Ascaphus truei*	Cold, rocky mountain streams	Possible. Suitable habitat exists for this species in the project area.
Black tern *Ascaphus truei*	Fresh water marshes and lakes	No. There is no suitable habitat for this species in the project area.
Columbian sharp-tailed grouse *Tympanuchus phasianellus columbianus*	Prairie, thickets, forest edges and openings	No. There is no suitable habitat for this species in the project area.
Ferruginous hawk *Buteo regalis*	Plains, prairies	No. There is no suitable habitat for this specie sin the project area.
Harlequin duck *Histrionicus histrionicus*	Mountain streams in summer, rocky coastal waters in winter	Possible. Suitable habitat exists for this species in the project area.
Little willow flycatcher *Empidonax traillii brewsteri*	Stream side, willow thickets	Probable. Suitable habitat exists for this species in the project area.
Loggerhead shrike *Lanius ludovicianus*	Open country with scattered trees and small shrubs, shrub-steppe	Possible. Suitable habitat exists on southern aspects.
Northern goshawk *Accipiter gentilis*	Coniferous and deciduous forests, winters in lowlands	Probable. Suitable habitat exists for this species in the project area.
Olive-sided flycatcher *Contopus borealis*	Conifer forests, burns, slashings (summer)	Probable. Suitable habitat exists for this species in the project area.
Western burrowing owl *Athene cunicularia hypugea*	Shrub-steppe, nonforested plains, and grasslands.	No. There is no suitable habitat for this specie sin the project area.
Western sage grouse *Centrocercus urophasianus phaios*	Sagebrush plains and foothills	No. There is no suitable habitat for this specie sin the project area.
California bighorn sheep *Ovis canadensis californiana*	Alpine meadows and grassy slopes near mountain cliffs	Unlikely. The closest bighorn sheep population is 20 miles to the south.
California wolverine *Gulo Gulo luteus*	Wide ranging, especially in coniferous forest and montane areas	Possible. Wolverine have been observed at the higher elevations of Railroad Creek drainage
Long-eared myotis *Myotis evotis*	Forests	Possible. Suitable habitat exists.
Long-legged myotis *Myotis volans*	Forests, some hibernate in caves in winter	Possible. Suitable habitat exists.
Pacific fisher *Martes pennanti pacifica*	Dense, mature spruce-fir and lowland forests	Possible. Fisher have been observed at the higher elevations of Railroad Creek drainage
Western big-eared bat *Plecotus townsendii pallescens*	Forests, roost in caves, mines, and under bark on trees	Possible. Suitable habitat exists.
Small-footed myotis *Myotis ciliolabrum*	Open, arid areas, roosts in rocky crevices, caves, mines, and old buildings	No. There is no suitable habitat for this species in the project area.
Yuma myotis *Myotis yumanensis*	Open areas in forests	Possible. Suitable habitat exists.
Westslope cutthroat trout *Oncorhynchus (=Salmo) clarki lewisi*	Streams, tributaries, and lakes	Most abundant trout species in Railroad Creek. See Section 4.8.1.4.
White milk-vetch *Astragalus sinuatus*	Rocky hillsides, associated with big sagebrush	No. There is no suitable habitat for this species in the project area.
Grape-fern *Botrychium paradoxum*	Old, disturbed, gravelly areas, often associated with spruce seedlings.	Possible. Suitable habitat exists.

TABLE 4.6-11 (CONTINUED)
SPECIES OF FEDERAL CONCERN WHICH MAY OCCUR IN THE VICINITY OF HOLDEN MINE, AS INDICATED BY U.S. FOREST SERVICE, AUGUST 13, 1997

Common Name	Habitat requirements	Potential to Occur in Project Area
Clustered lady's slipper *Cypripedium fasciculatum*	Moist to dry and rocky open coniferous forest (Douglas fir and ponderosa pine	Possible. Suitable habitat exists.
Wenatchee larkspur *Delphinium viridescens*	Moist meadows from 2500-5000'	Possible. Suitable habitat exists.
Showy stickseed *Hackelia venusta*	Rocky slopes with ponderosa pine	Possible. Suitable habitat exists.
Chelan rockmat *Petrophyton cinerascens*	Basalt cliffs and bluffs	Possible. Suitable habitat exists.
Seely's silene *Silene seelyi*	Steep talus slopes and rock crevices	Possible. Suitable habitat exists.
Thompson's clover *Trifolium thompsonii*	Open areas on sandy loam and gravelly soils with sagebrush	No. There is no suitable habitat for this species in the project area.

TABLE 4.6-12
SPECIAL STATUS SPECIES IN THE PROJECT AREA.

Species	Status	Habitat Requirements	Potential to Occur in Project Area
Peregrine falcon *Falco peregrinus*	FE, SE	• Mainly open country, nests on ledges high on cliffs • Often hunts in riparian zones	Possible. The area contains good hunting habitat and there are recorded sightings in the Railroad Creek drainage.
Bald eagle *Haliaeetus leucocephalus*	FT, ST	• Lakes and rivers, nests in tall trees and on cliffs • Diet consists primarily of fish	Possible. Bald eagles have been observed on Lake Chelan and the lower part of Railroad Creek and Domke Lake are designated as bald eagle recovery territory.
Northern spotted owl *Strix occidentalis*	FT, SE, FSS	• Old growth forest with a multi-layer canopy • Usually nests in old cavities • Preys on small mammals, especially woodrats	Possible. A female spotted owl was radio tracked to the upper Railroad Creek drainage in 1993 and a male currently resides near Domke Lake.
Gray wolf *Canis lupus*	FE, SE, FSS	• All habitats with a sufficient prey base and protection from human harassment • Three wolf dens have recently been confirmed in the Northern Cascades	Possible. A number of unconfirmed wolf sightings have recently been reported in the Railroad Creek drainage.
Grizzly bear *Ursus arctos*	FT, SE, FSS	• All habitat types with a suitable food base and isolated from human activity. • A small population may exist in the Northern Cascades	Possible. A grizzly bear siting at Domke Lake in 1995. was reported to and recorded by the USFA
Lynx *Lynx canadensis*	FC, ST, FSS	• Spruce, subalpine fir and lodgepole pine forests • Distribution is tied to that of snowshoe hare, which makes up to 80% of its diet.	Possible. Suitable lynx habitat is found at higher elevations around Holden Mine, and there is a lynx record from Dumbell Mountain.
Bull trout *Salvelinus confluenis*	FP	• Cold water mountain lakes and streams	Possible. Railroad Creek provides suitable habitat.
Wenatchee mountain's checkermallow *Sidalcea oregana var. calva*	FC, ST	• Wet meadows, near streams • Endemic to Chelan and Kittitas counties	No. There are no known populations in the Railroad Creek drainage.

FE = Federally Endangered
FT = Federally Threatened
FC = Federally Candidate for threatened or endangered status
FP = Proposed for federal status
SE = State endangered
ST = State threatened
FSS = Forest Service sensitive species

TABLE 4.6-13
U.S. FOREST SERVICE SURVEY AND MANAGE COMPONENT 2 MOLLUSK SPECIES WITH POTENTIAL TO OCCUR IN THE PROJECT AREA

Scientific Name	Common Name	Occurrences on Federal Lands (Frest 1993) (Burke 1999)
Land Snails		
Cryptomastix devia	Puget Oregonian	Fort Lewis Military Reservation, Columbia Gorge National Scenic Area
**Cryptomastix hendersoni*	Columbia oregonian	Naches Ranger District only
**Megomphix hemphilli*	Oregon Megomphix	Mt. Baker and Olympic National Forests
Oreohelix n. sp. 1	Chelan mountain snail	Wenatchee National Forest, in Chelan and Entiat Ranger Districts
Slugs		
**Deroceras hesperium*	Evening Field Slug	Olympic National Park
**Hemphillia burringtoni*	Burrington Jumping Slug	Olympic National Park
Hemphillia glandulosa	Warty Jumping Slug	Olympic National Park and Olympic National Forest, Gifford Pinchot National Forest
**Hemphillia malonei*	Malone Jumping Slug	Mt. Hood National Forest, Columbia River Gorge National Scenic Area
**Hemphillia pantherina*	Panther Jumping Slug	Gifford Pinchot National Forest
Prophysaon coeruleum	Blue-grey Tail-dropper	Gifford Pinchot National Forest
Prophysaon dubium	Papillose Tail-dropper	Trinity National Forest, probably Mt. Hood National Forest, Wenatchee National Forest
Freshwater Snails		
Lyogyrus n. sp. 2	Masked Duskysnail	Wenatchee National Forest

*May occur, but surveys are not required in the Wenatchee National Forest

TABLE 4.6-14

U.S. FOREST SERVICE SURVEY AND MANAGE COMPONENT 2 AND PROTECTION BUFFER PLANTS WITH POTENTIAL TO OCCUR IN THE PROJECT AREA

Scientific Name	Common Description	Habitat Associations
Fungi		
Oxyporus nobilissimus	noble polypore	the base or major root branches of large diameter old-growth noble fir and Pacific silver fir trees, snags and stumps (Hibler and O' Dell 1998)
Lichens		
Hypogymnia duplicata	foliose lichen w/hollow narrow lobes, arboreal	an epiphyte on mountain and western hemlock, Pacific silver fir, subalpine fir, and Douglas fir
Lobaria linita	foliose lichen, N-fixing	on lower boles of Pacific silver fir, in sub-alpine areas, and on rock outcrops and boulders in moist conifer forests
Pseudocyphellaria rainierensis	foliose lichen, N-fixing	an epiphyte on conifer trees in old-growth forests with cool, humid microclimates
Bryophytes		
Diplophyllum plicatum	leafy liverwort	on decayed wood, down logs, trunks of Douglas fir Pacific Yew, Sitka spruce, mineral soil, and rock in cool habitats with high humidity (USFS 1997)
Kurzia makinoana	leafy liverwort	in forested and bog sites on decaying wood or humus, rocky cliffs, ledges, soil banks, in shaded moist sites (USFS 1997)
Marsupella emarginata aquatica	aquatic liverwort	in colonies attached to submerged rocks in cold perennial streams, only one site is known at Waldo Lake in the Oregon Cascades (USFS 1997)
Schistostega pennata	Luminous moss (Protection Buffer species)	On damp rock, soil and decaying wood in dark places such as cave or mine shaft mouths, rock crevices or overhangs. Low light is required.[1]
Tritomaria exectiformis	leafy liverwort	on dry to moist, partially shaded soil, litter and soil in rock crevices, decaying logs, peaty soil over cliffs, and wet soil banks (USFS 1997)
Ulota meglospora	Giant-spored tree moss (Protection Buffer species)	Epiphytic on conifers, hardwoods, particularly maples, alder and tanoak and numerous other shrubs. Prefers branch tips away from competition of other bryophytes. Can be in dry sites.[1]
Vascular Plants		
Allotropa virgata	candystick	in deep humus of coniferous forests at lower elevations, including east Cascade slopes (Hitchcock and Cronquist 1973)
Botrychium minganense	grape fern	moist sites, in old-growth western red cedar, on mossy slopes, ridges, and benches (Smith-Kuebel and Lillybridge 1993) — Correct spelling
Botrychium montanum	grape fern	same as *B. minganense*
Coptis aspleniifolia	spleenwort-leaved goldthread	moist woods and bogs (Hitchcock and Cronquist 1973)
Galium kamtschaticum	boreal bedstraw	wet areas with seeps or sanding water in the Pacific silver fir zone and the mountain hemlock zone (Potash 1991)
Habenaria orbiculata	round-leaved rein-orchid	moist, mossy forests (Hitchcock and Cronquist 1973)

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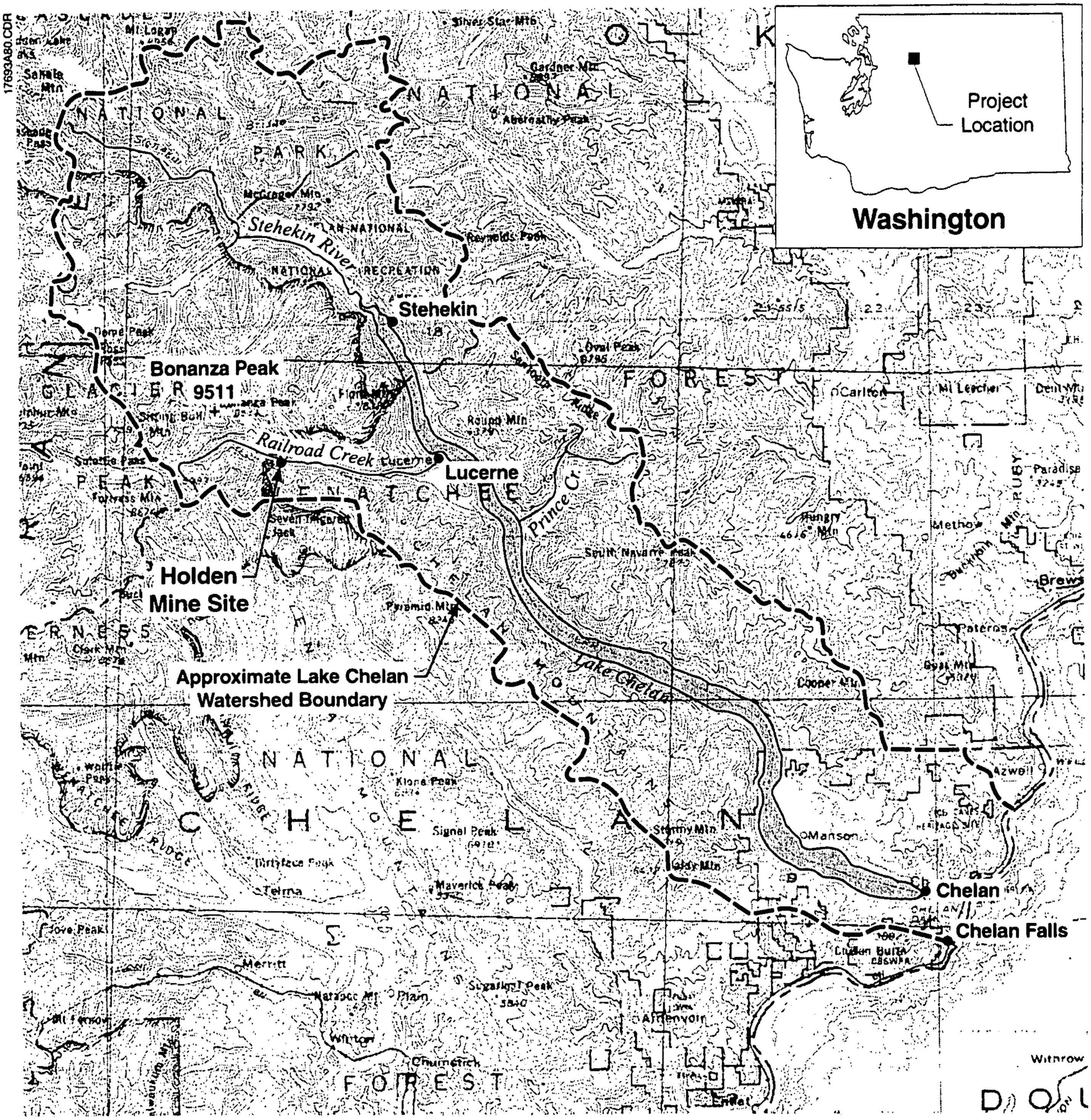
[1] From a table created by Terry Lillibridge, Botanist, Wenatchee National Forest

TABLE 4.6-15
SURVEY AND MANAGE SPECIES FOR WHICH NO SURVEY PROTOCOLS ARE AVAILABLE DUE TO THE UNIQUE OR UNKNOWN LIFE HISTORY OF THESE SPECIES

Source: Terry Lilibridge, Botanist, Wenatchee National Forest

Scientific Name	Common Name	Group	Wen. NF	Status	Habitat
Brotherella roellii	R ll's golden log moss	Moss	S	PB	On rotten logs/stumps; Alder/Maple tree bases in cool to moist coniferous/deciduous forest at low elev. TSHE/ABAM/TSME
Buxbaumia viridis	Green bug moss, Green shield moss	Moss	S	PB	Well decayed, rotten logs (Class 4/5), peaty soil and humus in dense, shady and humid coniferous forest-low elev. to subalpine. No perennial gametophyte generation.
Rhizomnium nudum	Naked round moss, Naked mnium	Moss	S	PB	On moist (not wet) organic soil typically in concave areas; sometimes among rocks or rotten logs from middle elevations to alpine (with persistent snow banks); closed canopy TSHE, ABAM, TSME, often with OPHO.
Tetraphis geniculata	Bent-kneed four-tooth moss, Ant spearmoss	Moss	S	PB	On well rotted stumps and logs (rarely rocks), in shaded , humid locations at low to middle elevations. Difficult to ID w/o sporophyte. 100% OG; easily confused with T. pellucida
Bondarzewia mesenterica (montana)		polypore	D	2	Moist ABGR, TSHE, ABAM zones saprophytic on Abies spp. or PSME
Sowerbyella (Aleuria) rhenana	Stalked orangepeel fungus	cup fungus	S	PB	Saprophytic on twigs/duff of mixed conifers in ABAM/TSME zones.
Otidea leporina	Donkey ears	cup fungus	S	PB	Moist ABGR/TSHE, ABAM, or TSME zones under PSME or TSHE.
Otidea onotica	Donkey ears	cup fungus	D	PB	On exposed soil, duff or moss in moist, ABAM, or TSME zones under PSME or TSHE. Also possible in moist ABGR/TSHE.
Otidea smithii	brown clustered ear cup	cup fungus	S	PB	On exposed soil, duff or moss in moist, ABAM, or TSME zones under PSME or TSHE. Also possible in moist ABGR/TSHE and riparian w/cottonwoods.
Polyozellus multiplex	Blue chanterelle	chanterelle	D	PB	ABAM/TSME zones, mycorrhizal on Abies
Sarcosoma mexicana	Starving-man's licorice	cup fungus	D	PB	On conifer duff in moist ABGR/TSHE, ABAM, and TSME zones; also riparian in drier ABGR.



SOURCE: *USGS Topographic Map, State of Washington, Scale 1:500,000, Compiled 1961, Revised 1982*

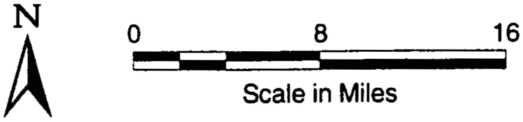


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Figure 4.1-1
LAKE CHELAN WATERSHED MAP

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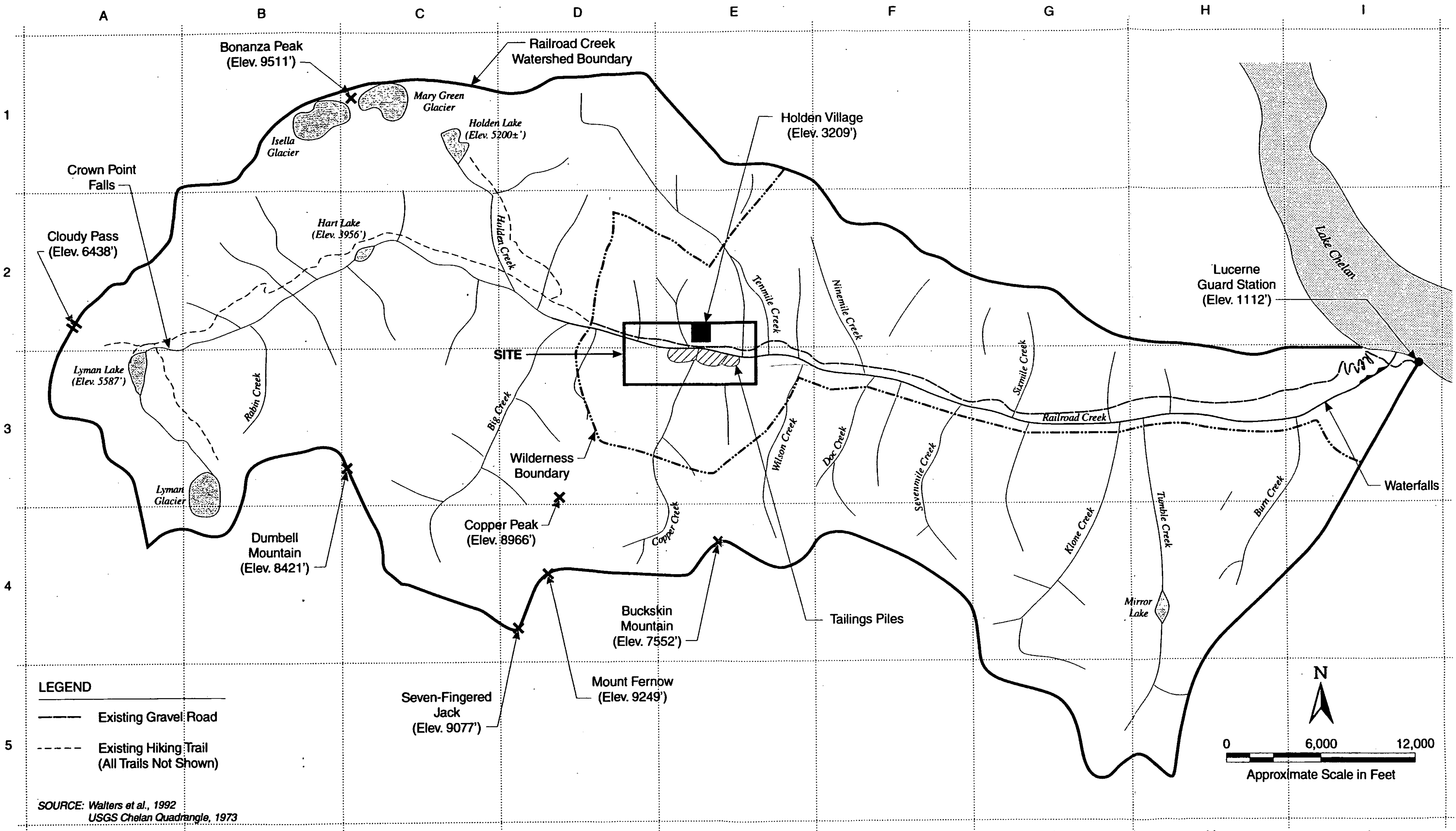

SOURCE: Walters et al., 1992
USGS Chelan Quadrangle, 1973

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Figure 4.1-2
RAILROAD CREEK WATERSHED MAP

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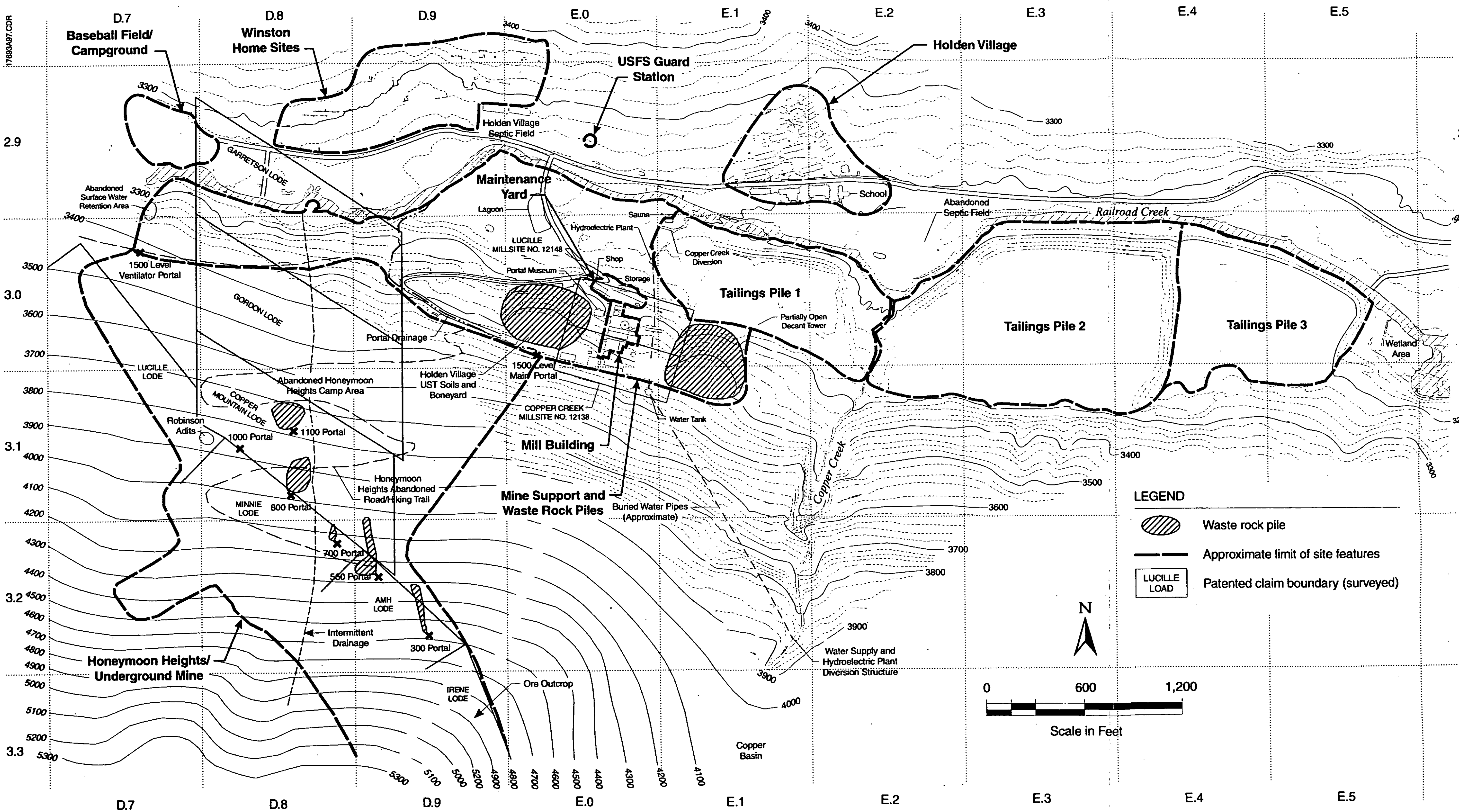

SOURCE: Base map information from USFS and Washington DNR, DEM CD ROM

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Figure 4.1-3

HOLDEN MINE SITE MAP

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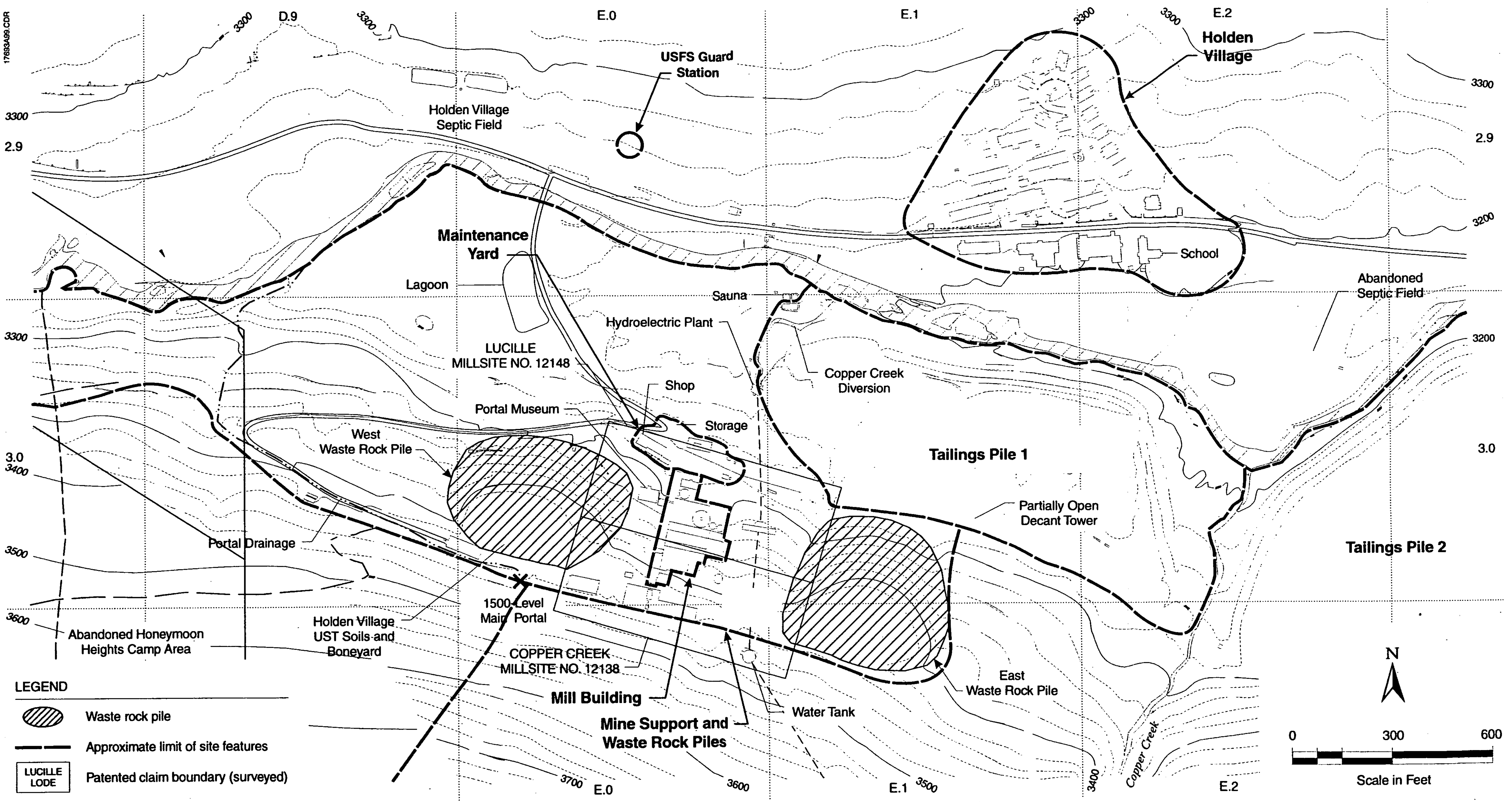

SOURCE: Base map information from USFS and Washington DNR, DEM CD ROM

Figure 4.1-3a

DETAIL OF MINE SUPPORT WASTE ROCK PILES AREA, TAILINGS PILE 1 AND HOLDEN VILLAGE

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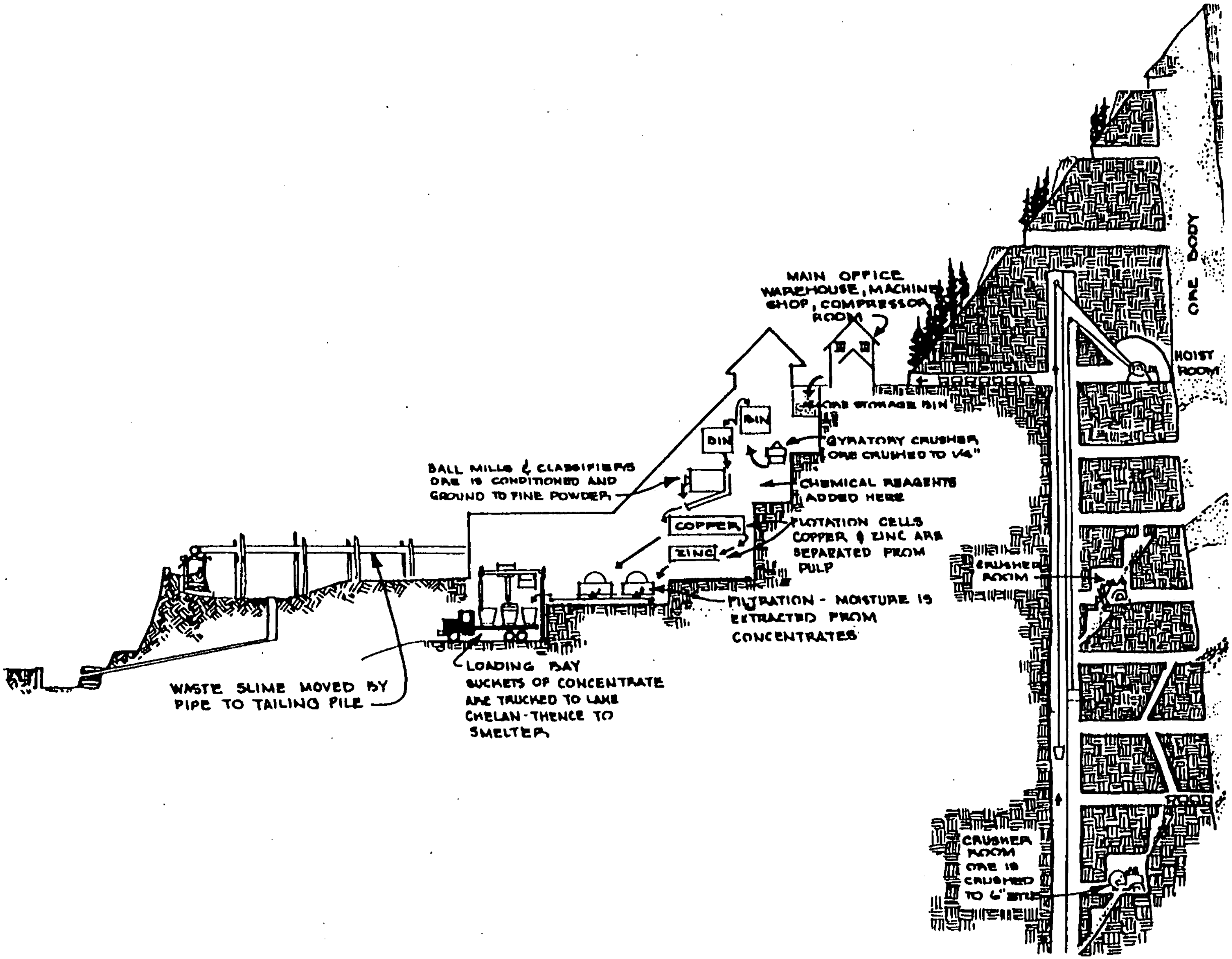

Figure 4.1-4

DIAGRAMMATIC CROSS SECTION OF HOLDEN MINE AND MILL

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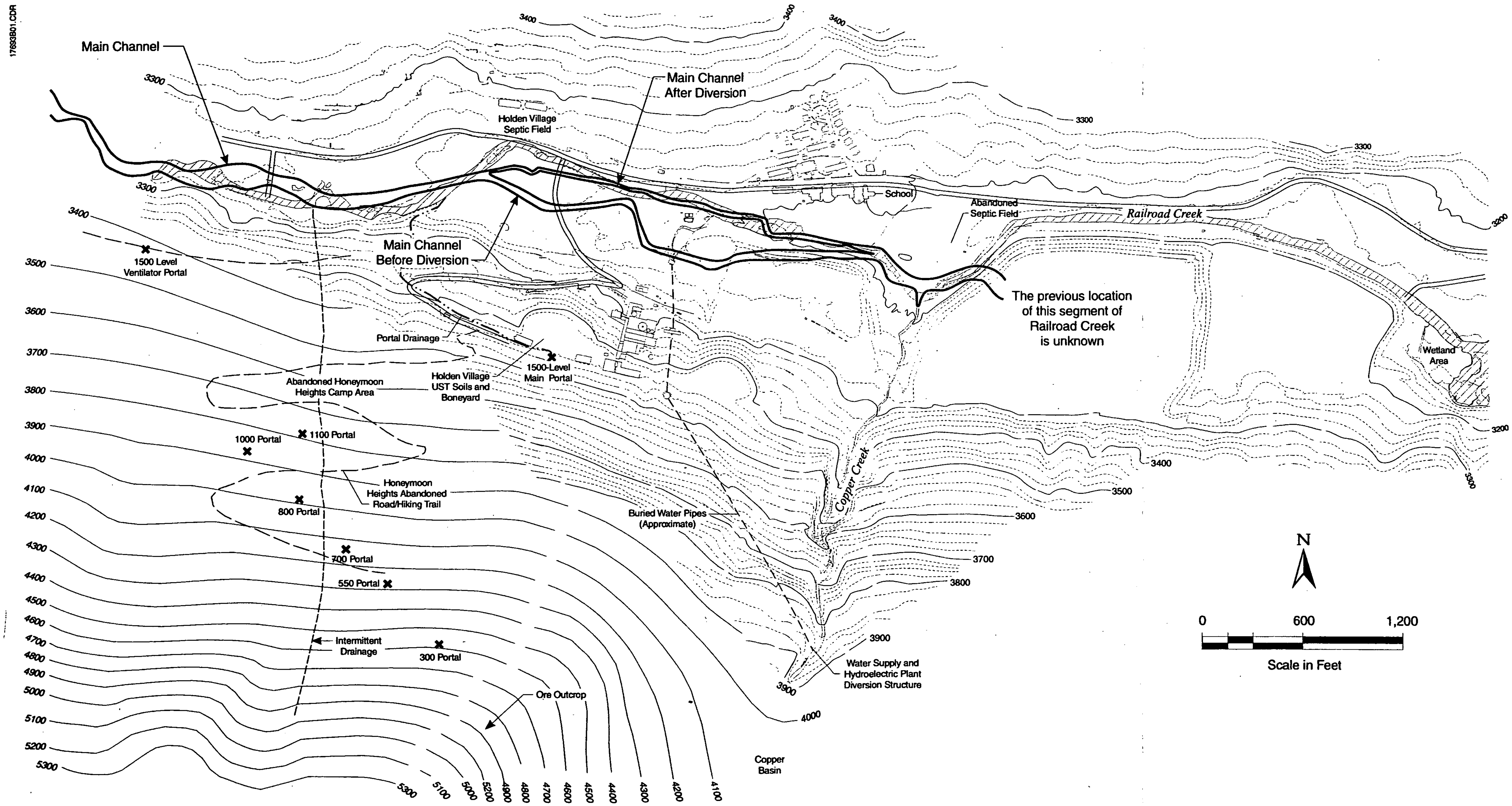

SOURCES: Base map information from USFS and Washington DNR, DEM CD ROM. Relocation of Railroad Creek based on Howe Sound Co. map dated 1937.

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Figure 4.1-4a

HOLDEN MINE SITE MAP
RAILROAD CREEK CHANNEL - 1937

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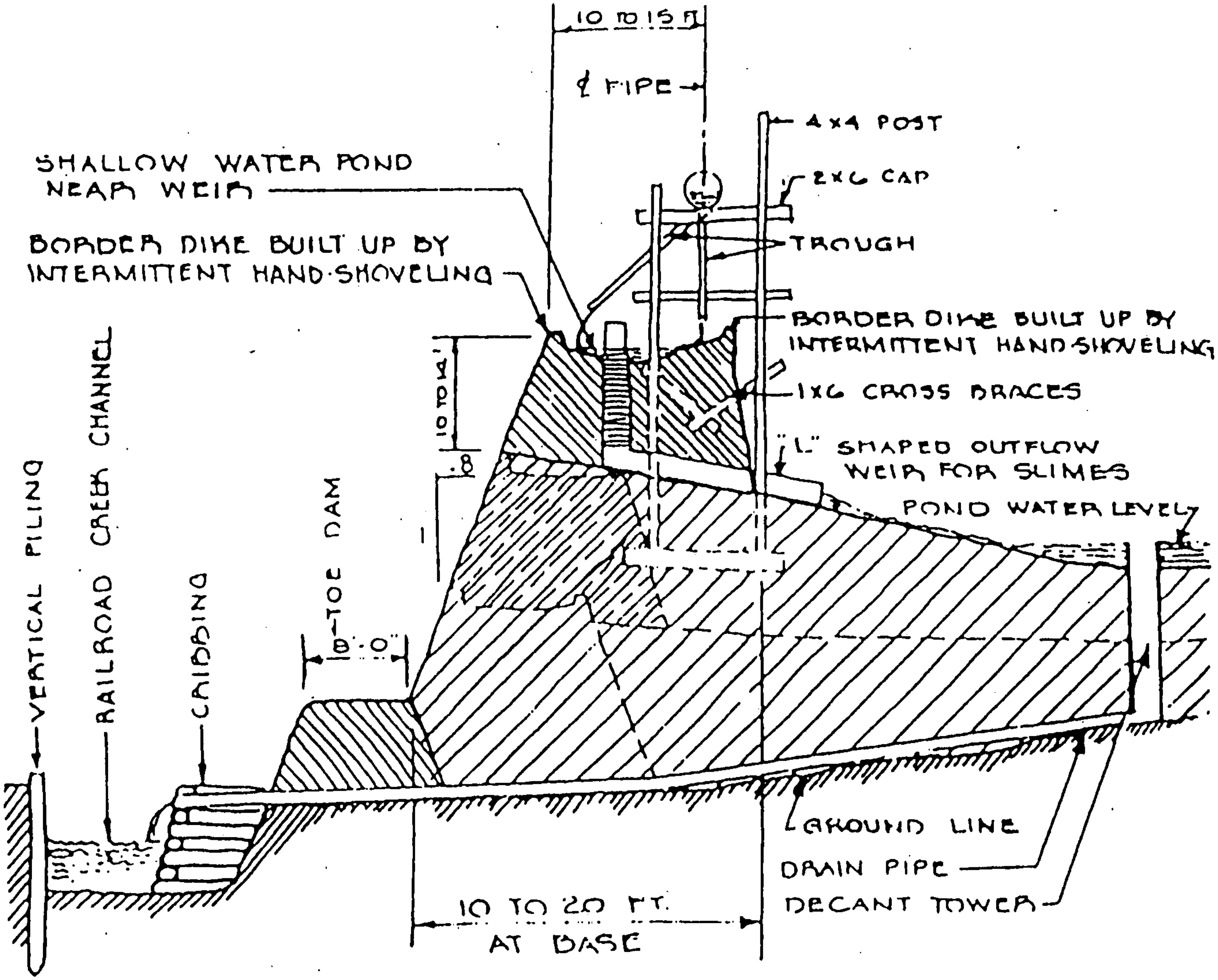

Figure 4.1-5

CONSTRUCTION OF TAILINGS PILES

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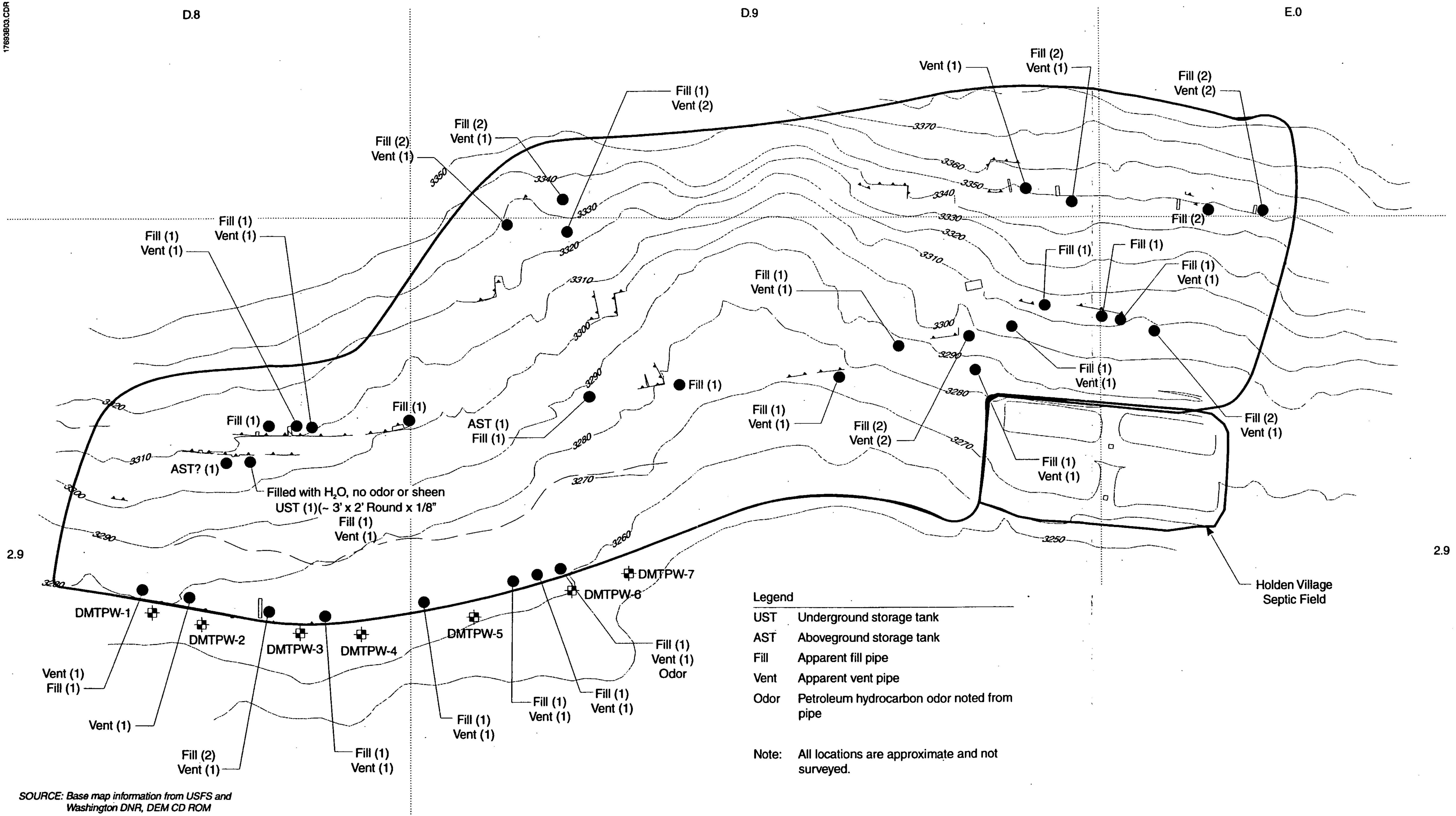

Legend

UST	Underground storage tank
AST	Aboveground storage tank
Fill	Apparent fill pipe
Vent	Apparent vent pipe
Odor	Petroleum hydrocarbon odor noted from pipe

Note: All locations are approximate and not surveyed.

SOURCE: Base map information from USFS and Washington DNR, DEM CD ROM

Figure 4.1-5a

WINSTON HOME SITES TANK INVENTORY

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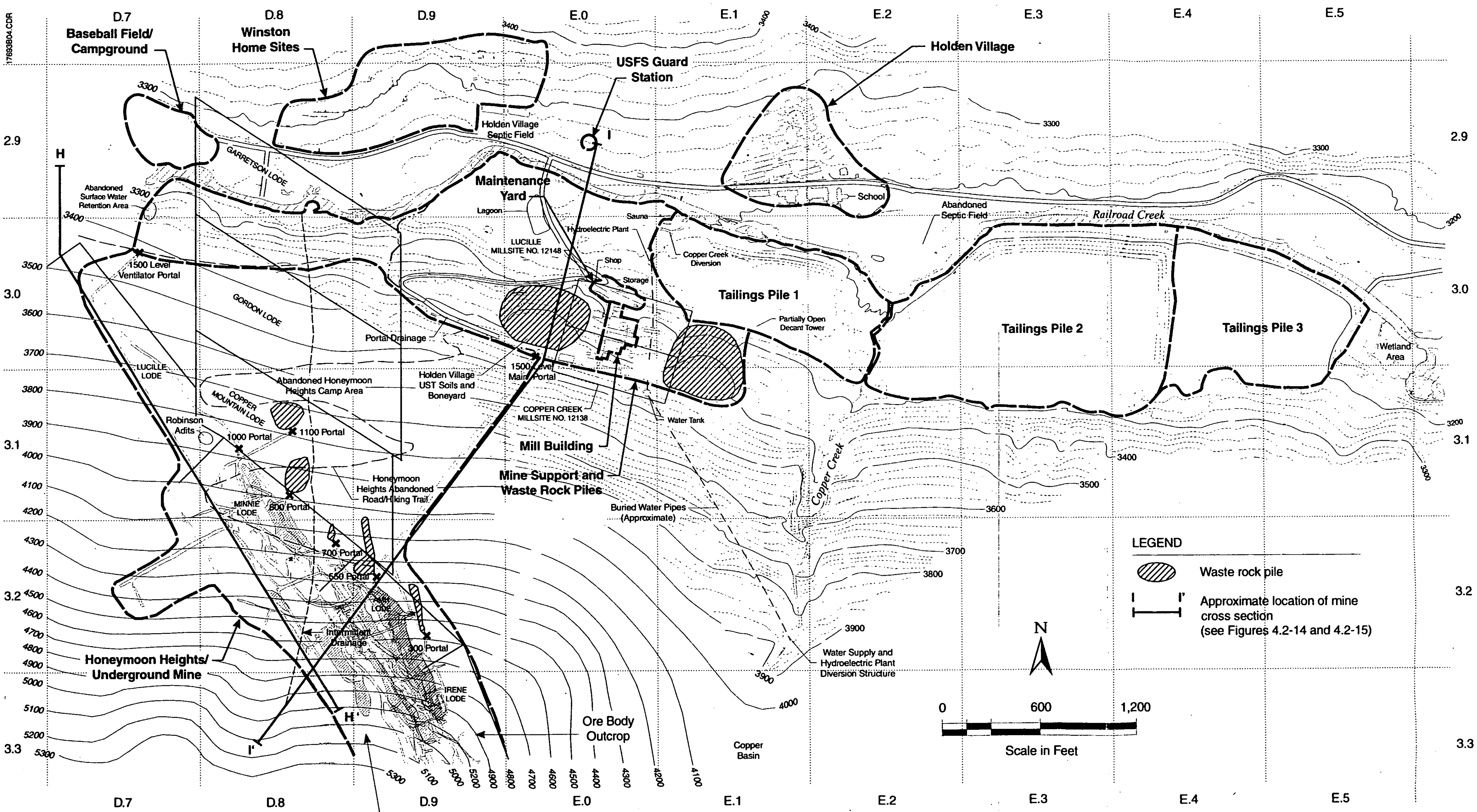

SOURCE: Base map information from USFS and Washington DNR, DEM CD ROM

See Figures 4.1-6 through 4.1-13 for Individual Mine Level Workings

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Figure 4.1-5b

HOLDEN MINE SITE MAP WITH PRINCIPAL UNDERGROUND MINE WORKINGS

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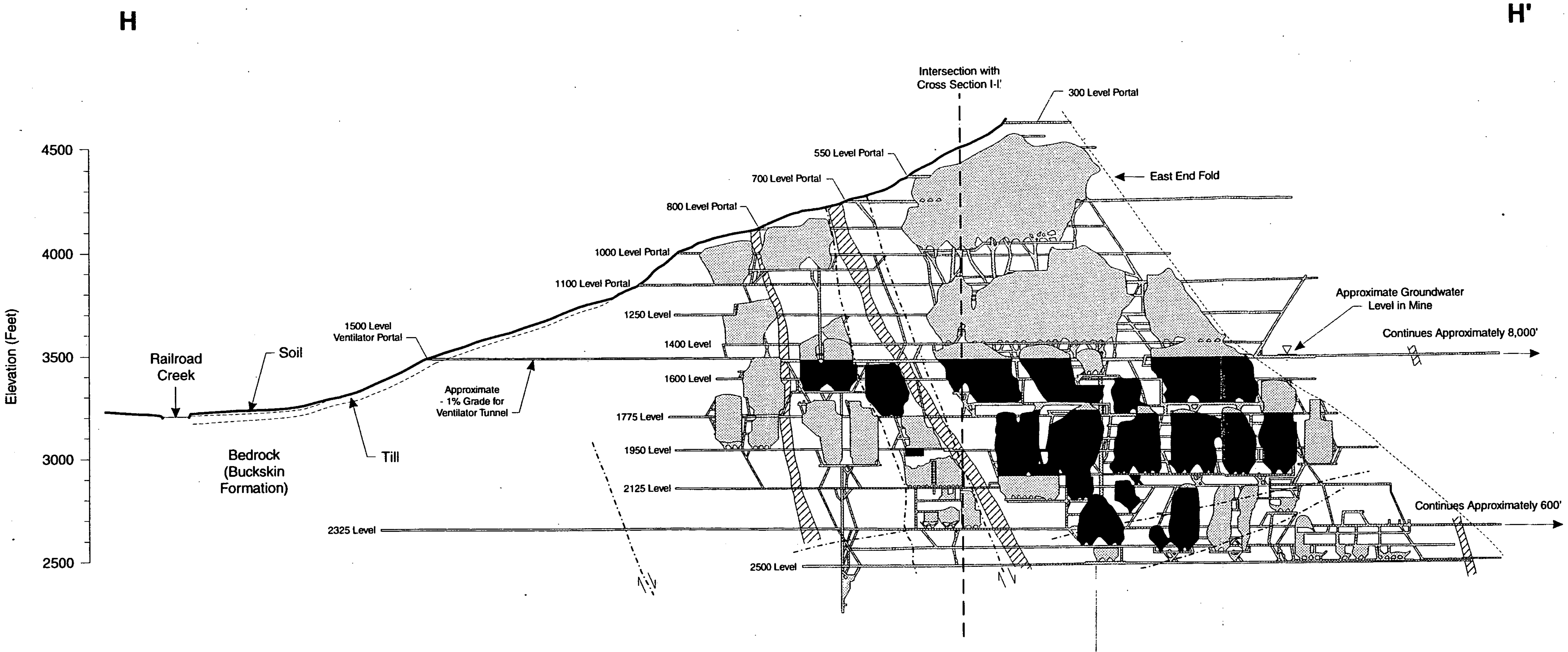

NOTE: This cross section is generally parallel to ore body and 1500 level ventilator tunnel

SOURCES: *Northwest Geophysical Associates, 1997, Seismic Line A-A', B-B', Holden Mine Geophysical Investigation.*

Youngberg, E. A., Wilson, T. L., 1952, The Geology of the Holden Mine, Economic Geology, V. 47, No. 1, 1952, pp. 1-12.

W.A.B., 1942, Detailed Surface Geology Map, Howe Sound Co., Chelan Division

F.E., H.B.S., 1938, Geology of 1500 Level, Howe Sound Company Chelan Division

Howe Sound Co, 1957, Holden Mine, East West Section

LEGEND

▨ Open stope
■ Backfilled stope
▨ Dike
-·-·-· Transform fault

0 500 1,000

Approximate Horizontal and Vertical Scale in Feet

Figure 4.1-5c

HOLDEN MINE SITE
CROSS SECTION H-H'

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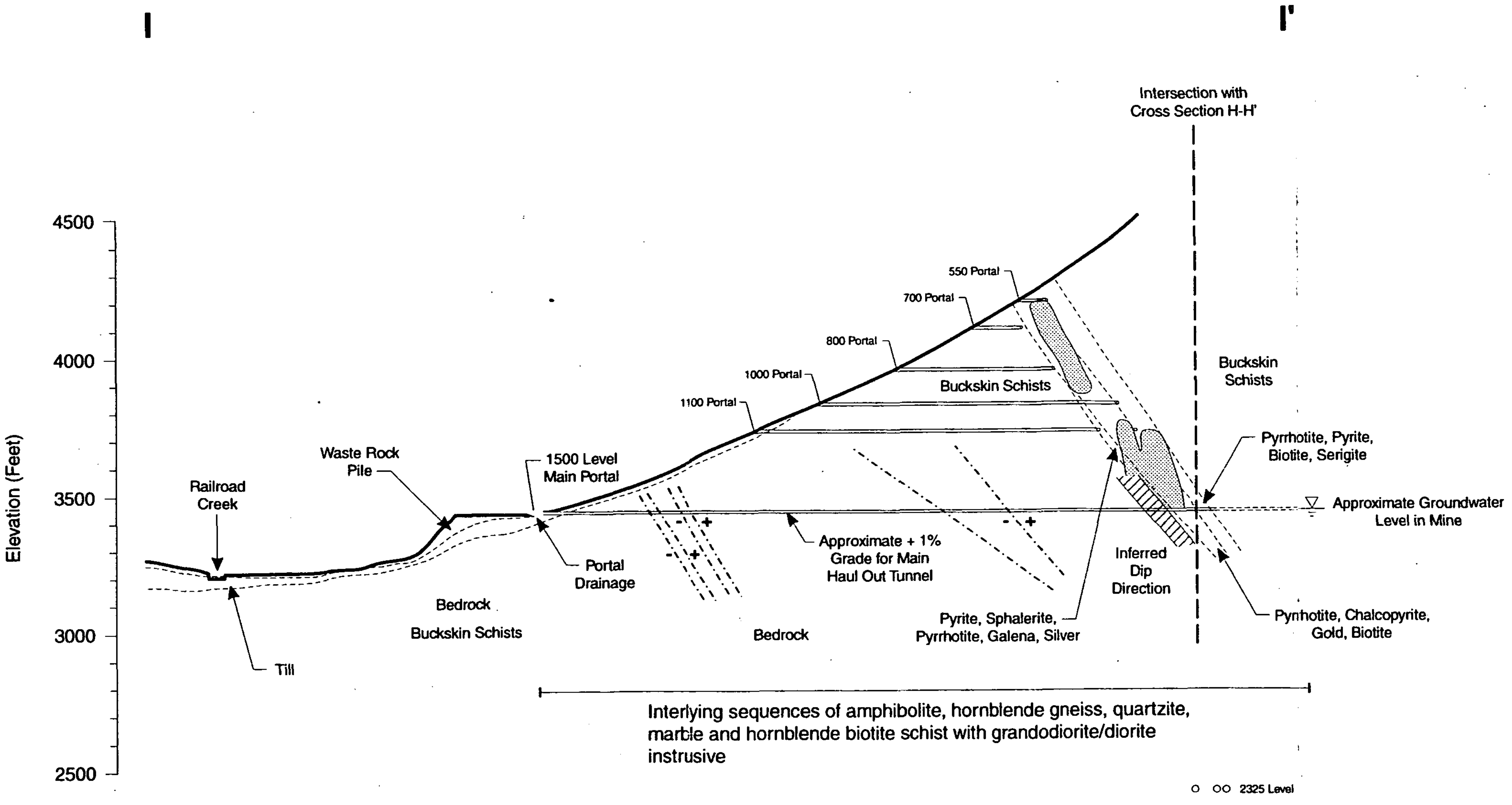

SOURCES: *Northwest Geophysical Associates, 1997, Seismic Line A-A', B-B', Holden Mine Geophysical Investigation.*

Youngberg, E. A., Wilson, T. L., 1952, The Geology of the Holden Mine, Economic Geology, V. 47, No. 1, 1952, pp. 1-12.

W.A.B., 1942, Detailed Surface Geology Map, Howe Sound Co., Chelan Division

F.E., H.B.S., 1938, Geology of 1500 Level, Howe Sound Company Chelan Division

LEGEND

▒	Open stope
▨	Intermediate to acid intrusives diorite, quartz diorite
-·-·-·-	Transform fault
+	Transform fault, away
-	Transform fault, toward

0 500 1,000

Approximate
Horizontal and Vertical
Scale in Feet

Figure 4.1-5d

HOLDEN MINE SITE
GEOLOGIC CROSS SECTION I-I'

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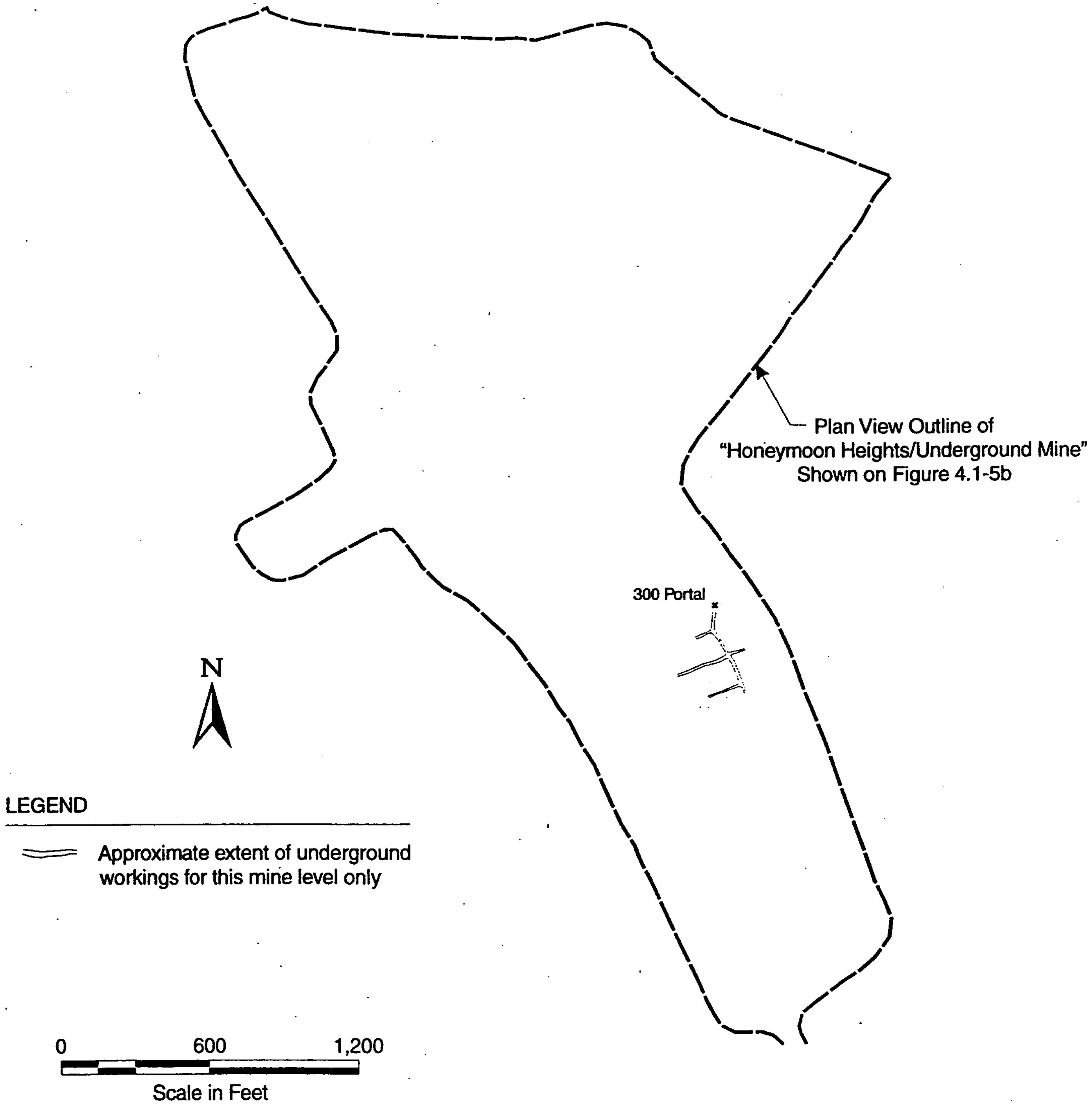

Figure 4.1-6

HOLDEN MINE SITE UNDERGROUND MAP
300 LEVEL

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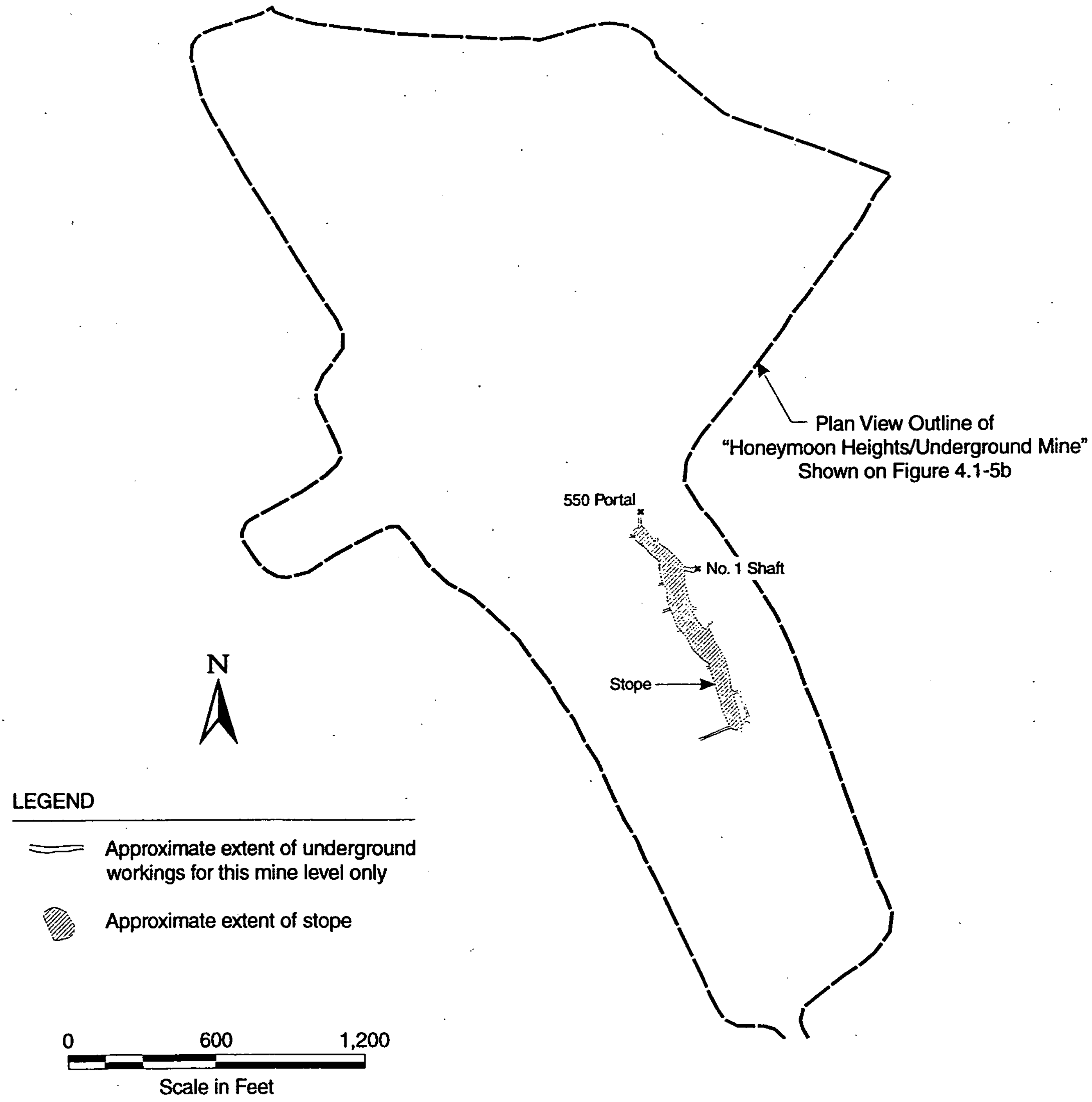

Figure 4.1-7

HOLDEN MINE SITE UNDERGROUND MAP
550 LEVEL

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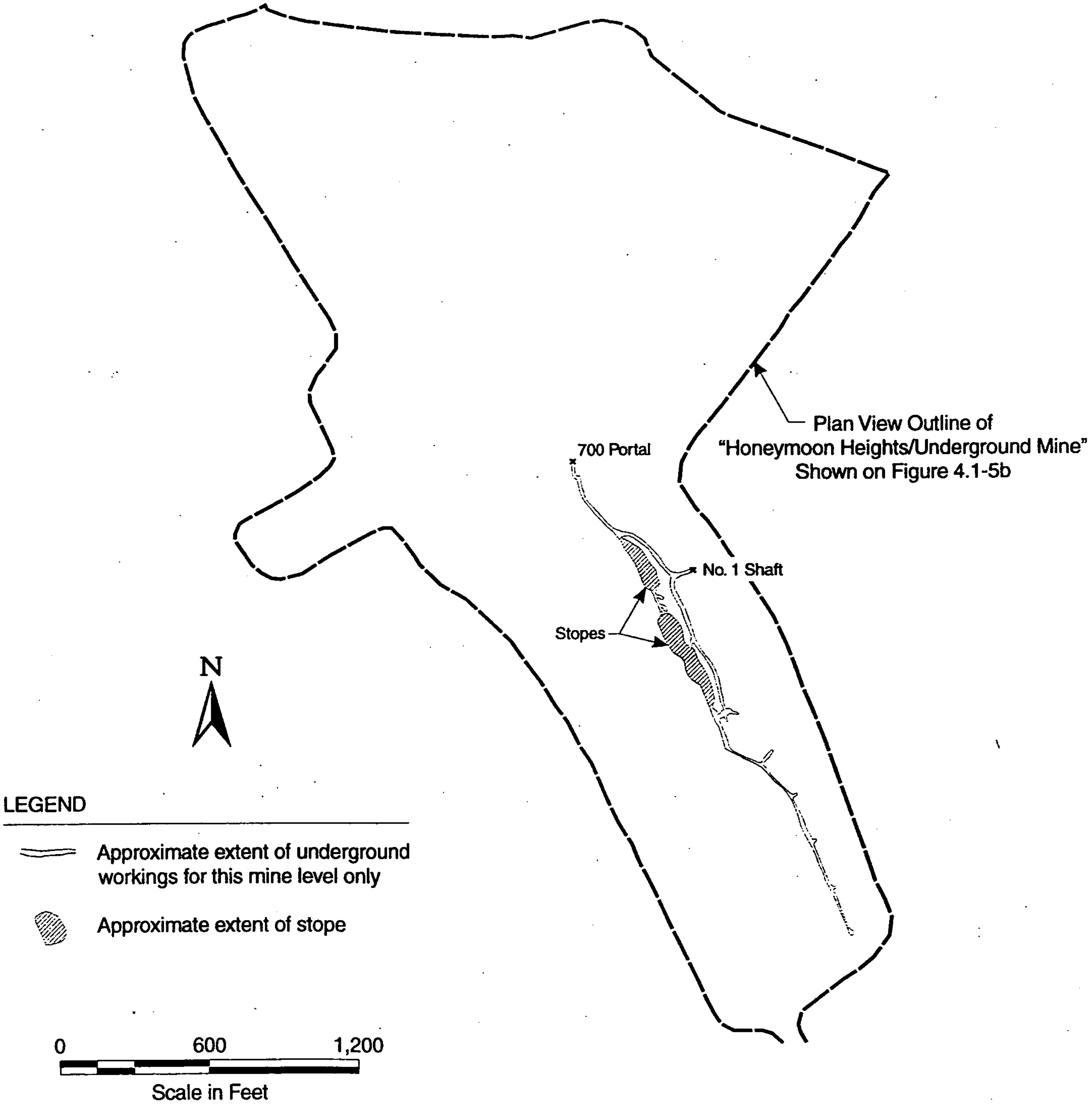

Figure 4.1-8

HOLDEN MINE SITE UNDERGROUND MAP
700 LEVEL

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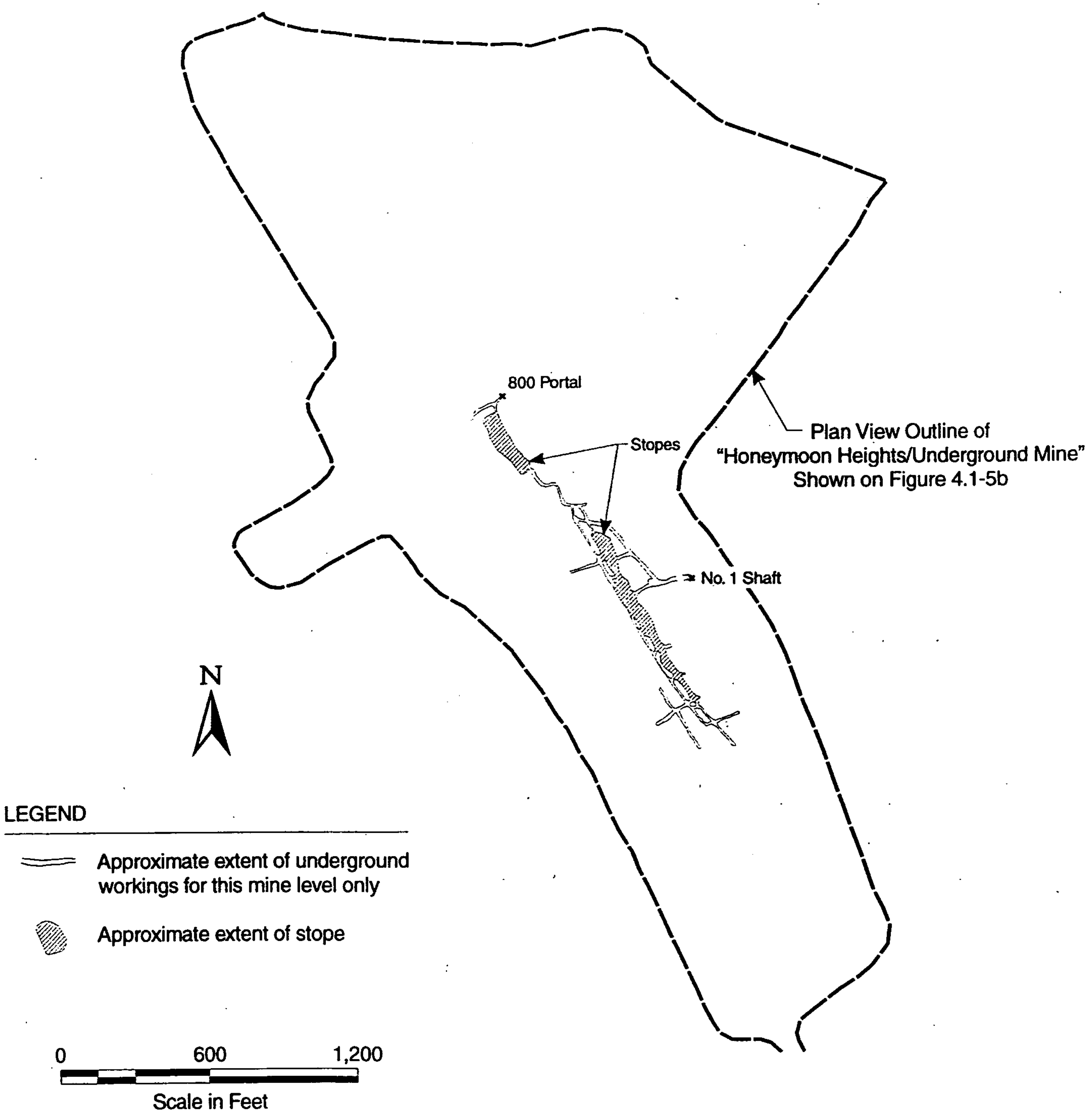

Figure 4.1-9

HOLDEN MINE SITE UNDERGROUND MAP
800 LEVEL

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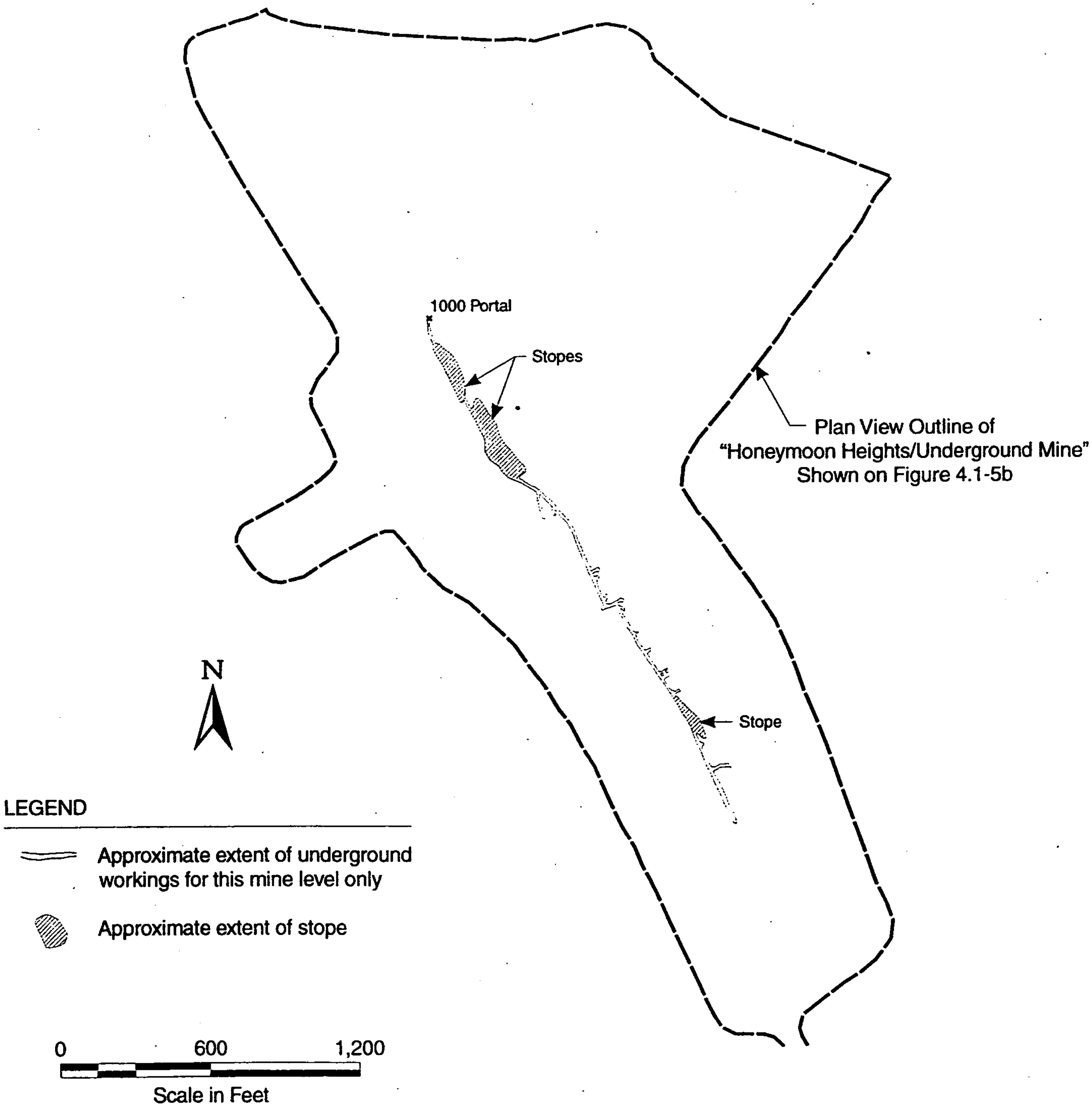

Figure 4.1-10

HOLDEN MINE SITE UNDERGROUND MAP
1000 LEVEL

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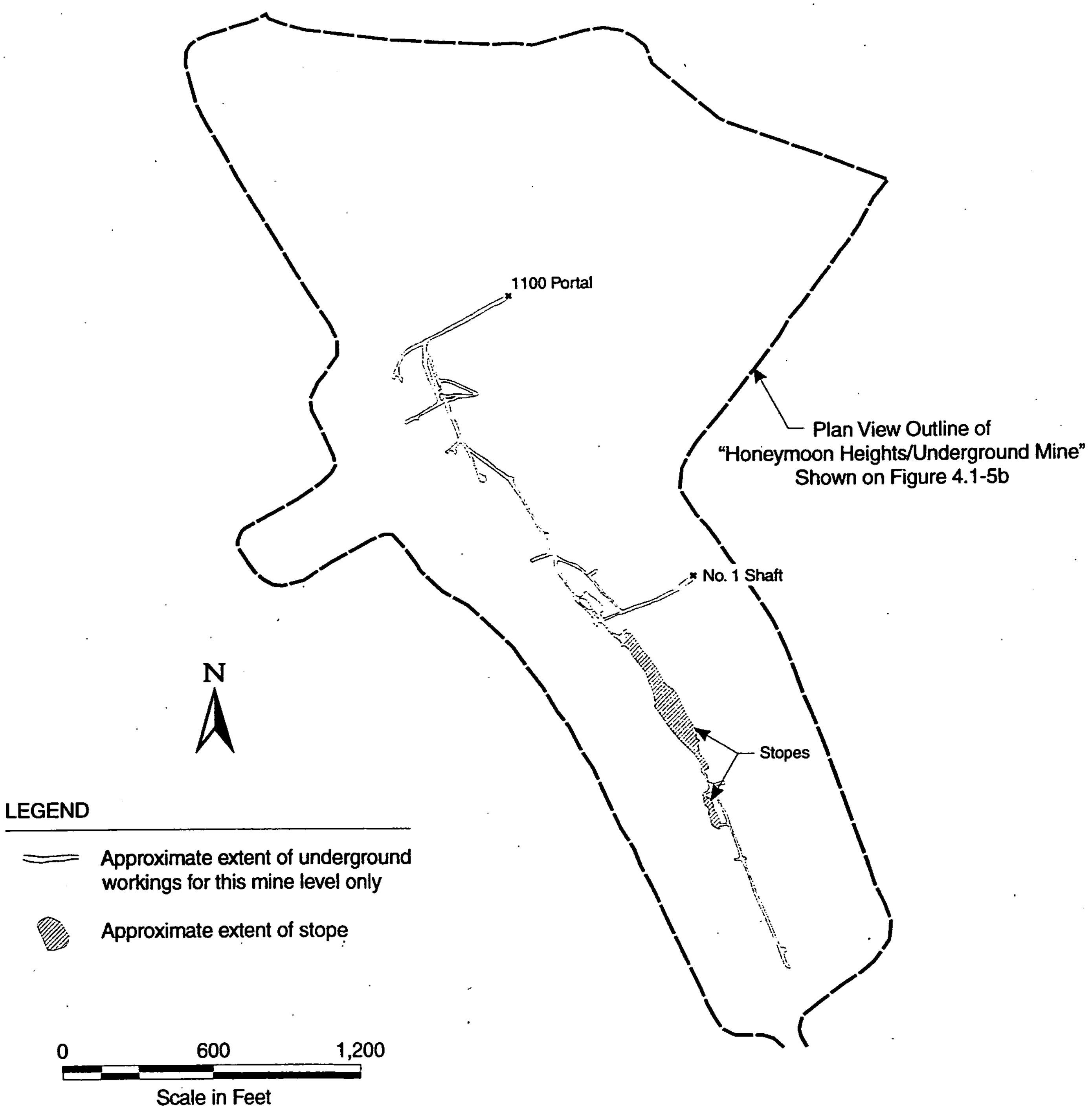

Figure 4.1-11

HOLDEN MINE SITE UNDERGROUND MAP
1100 LEVEL

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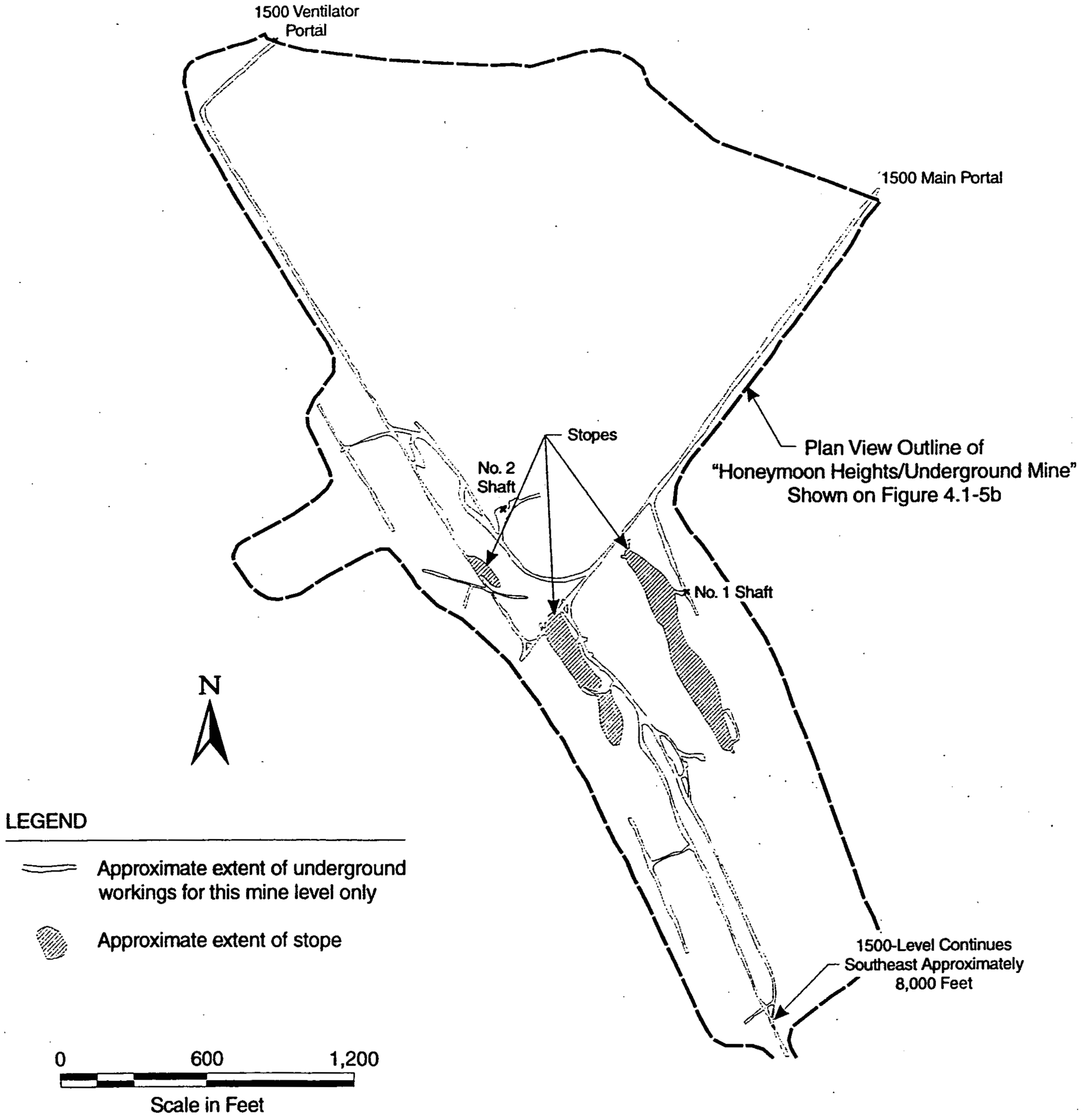

Figure 4.1-12

HOLDEN MINE SITE UNDERGROUND MAP
1500 LEVEL

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17693B08.CDR

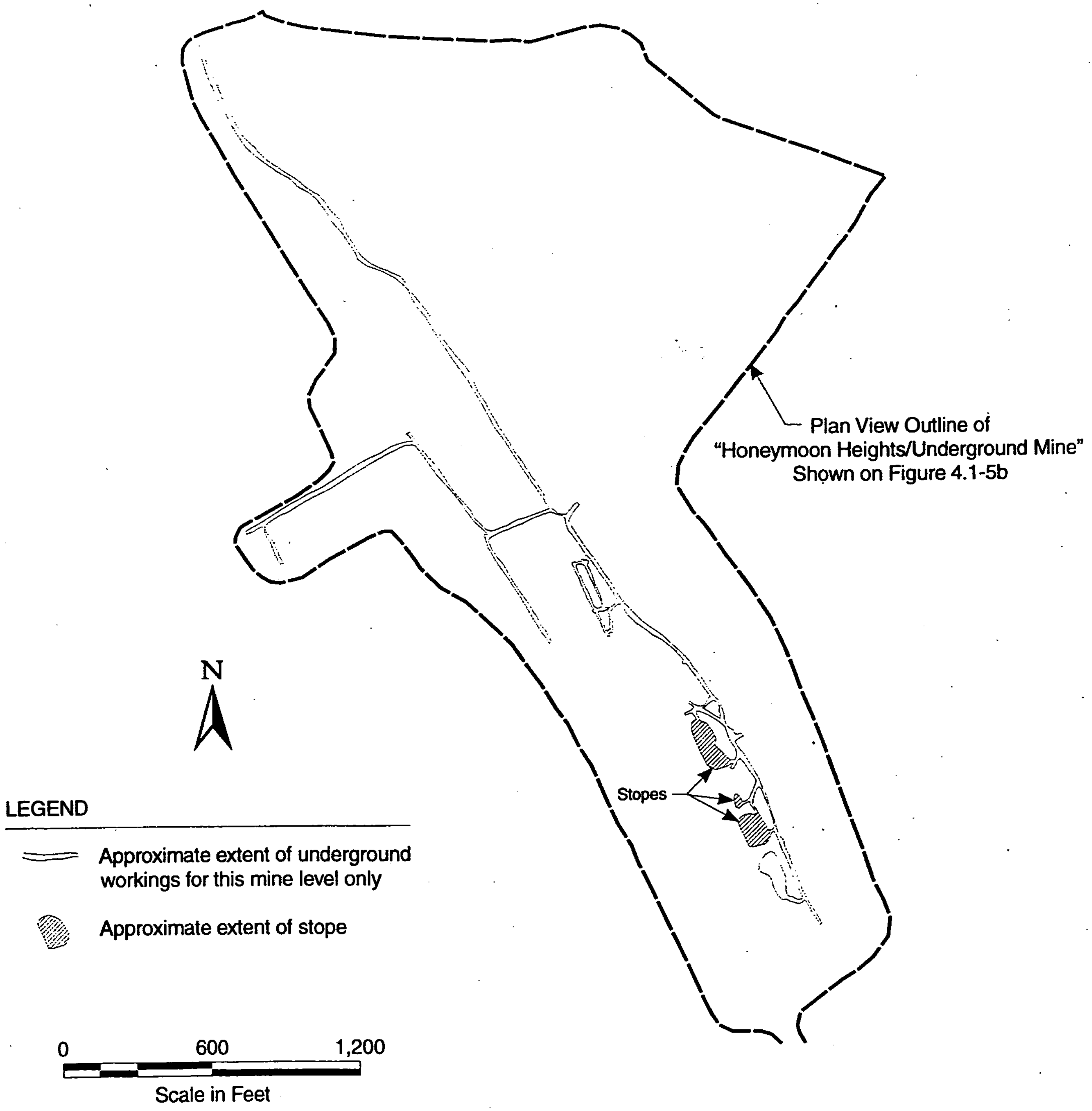

Figure 4.1-13

HOLDEN MINE SITE UNDERGROUND MAP
2325 LEVEL

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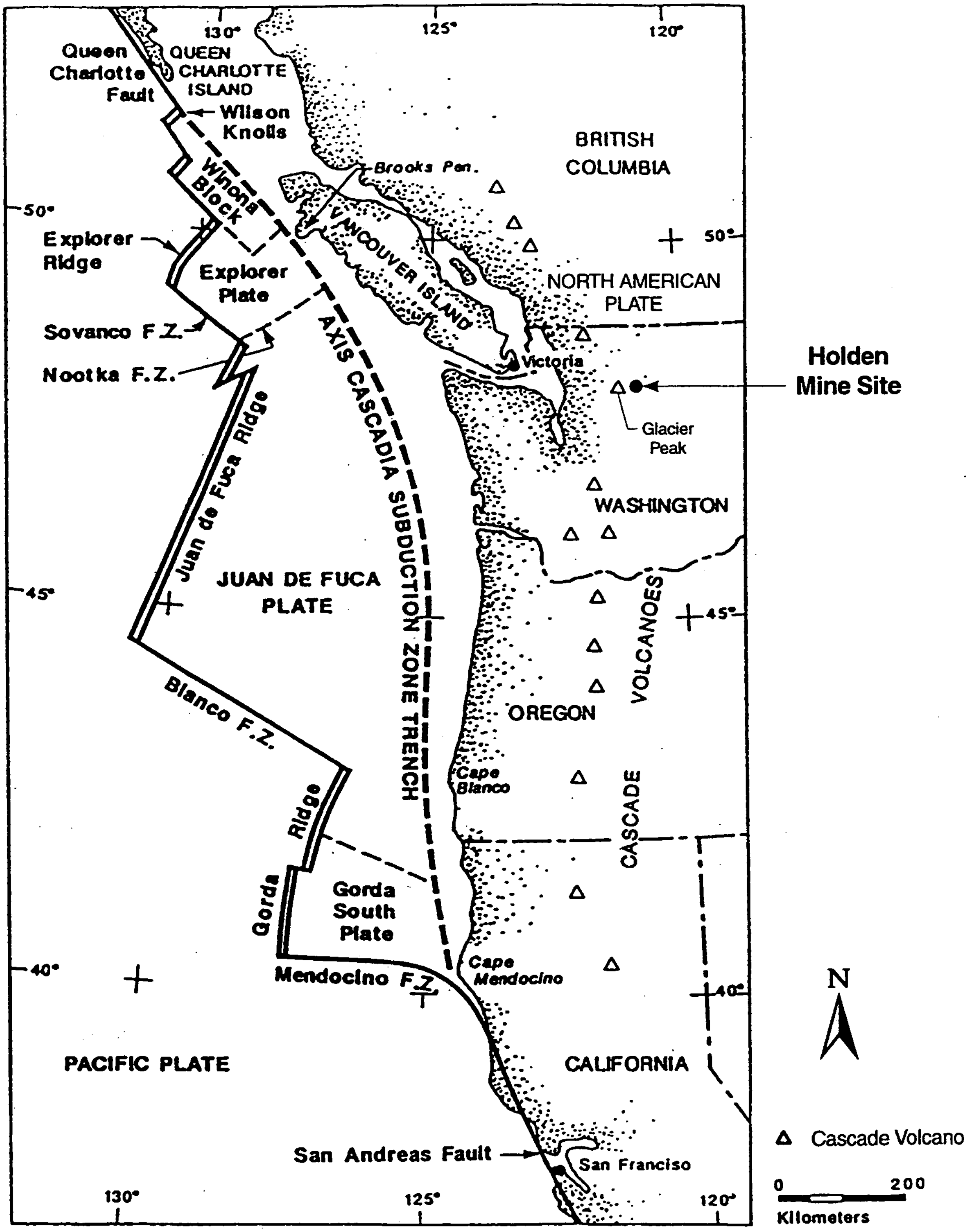
17693B07.CDR



Modified from Washington Public Power Supply System (1988)
(after Riddihough, 1984).

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Figure 4.2-1a

REGIONAL TECTONIC SETTING

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17693B09.CDR

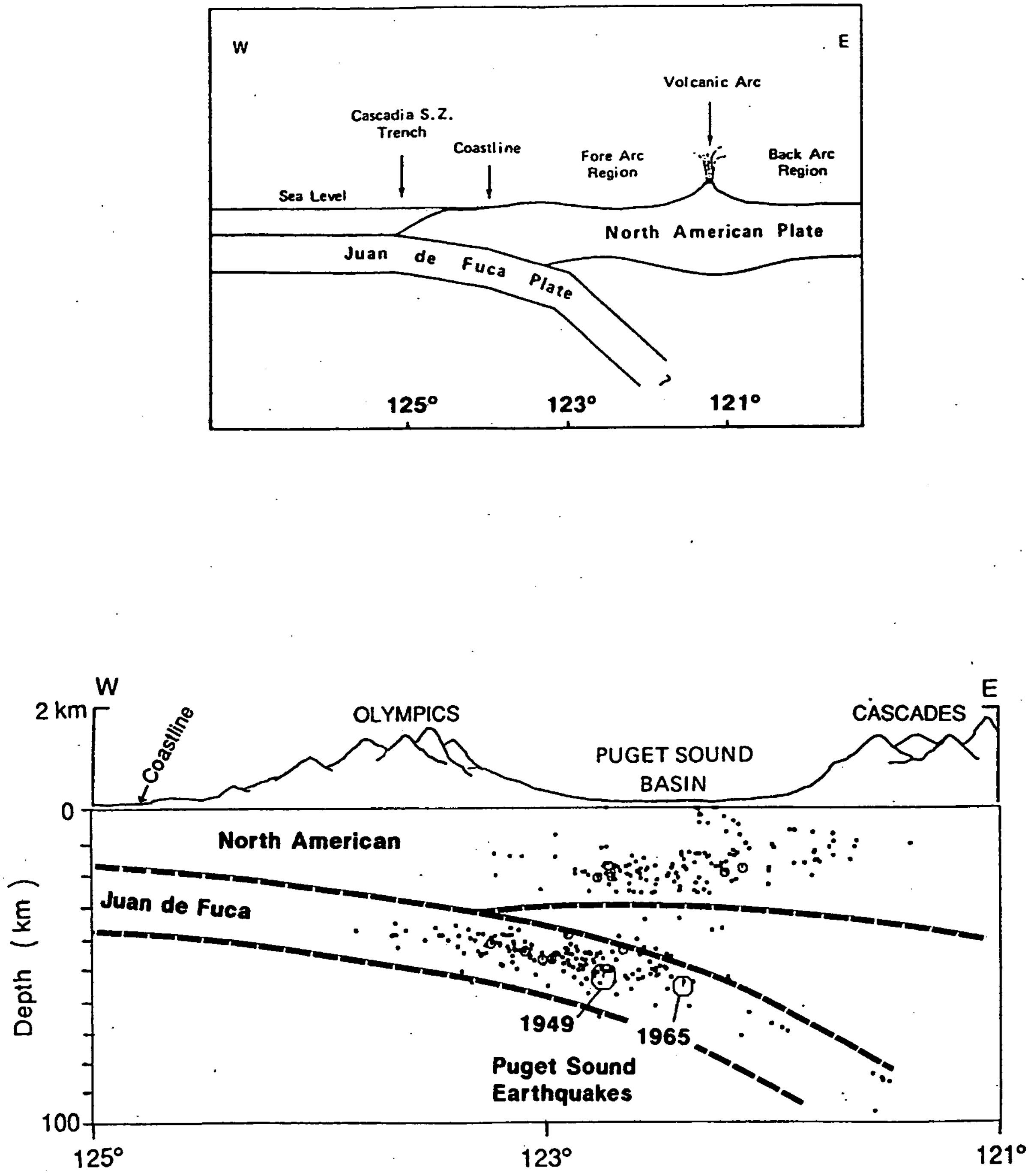

Figure 4.2-1b

SCHEMATIC TECTONIC CROSS SECTION AND INSTRUMENTALLY RECORDED SEISMICITY

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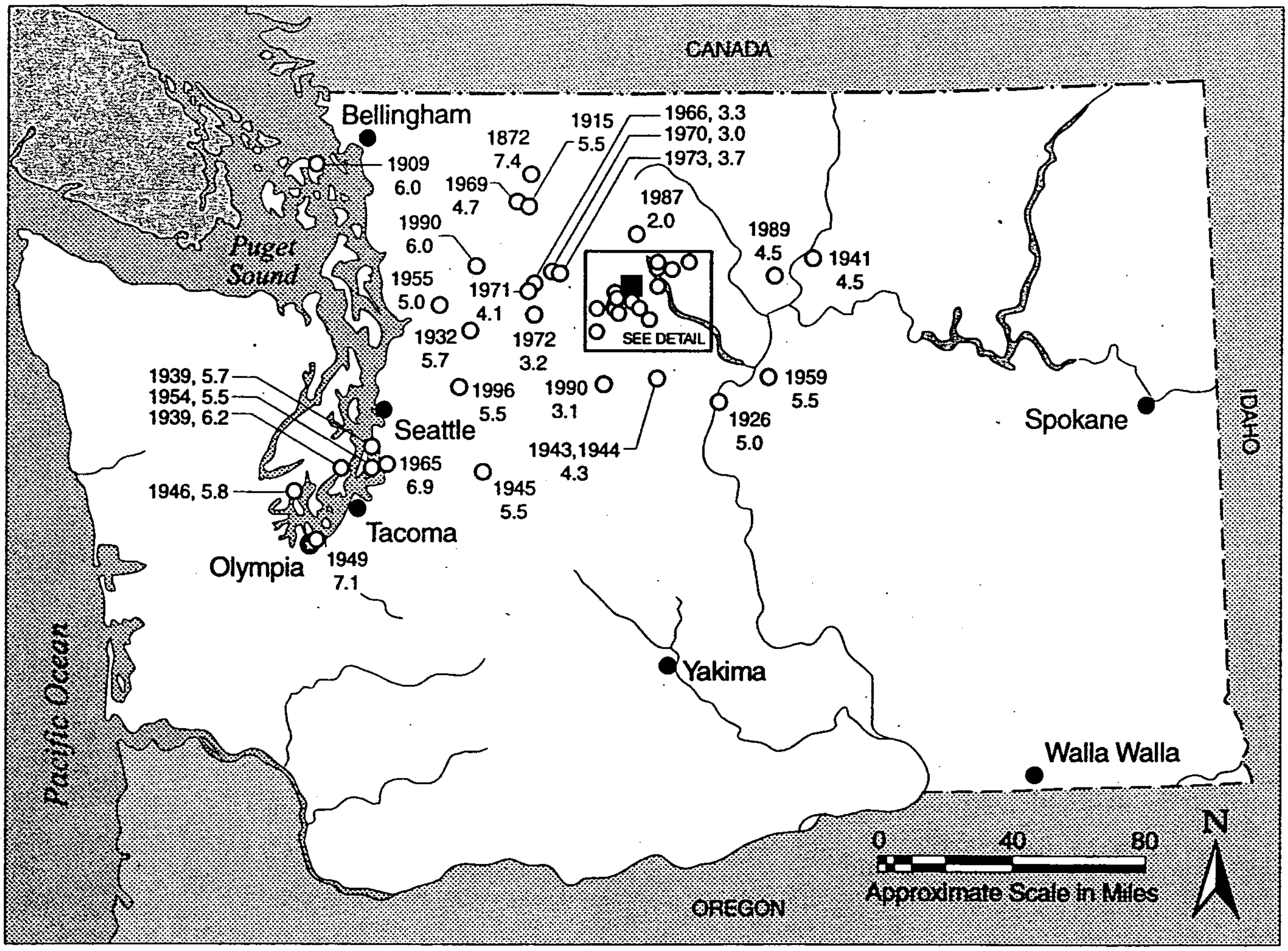
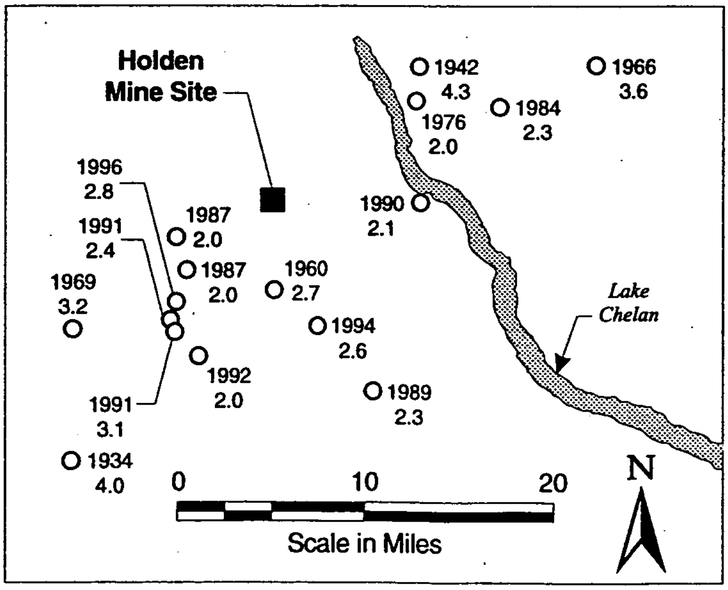
17693B10.CDR





DETAIL

LEGEND

○ 1990 2.1	Earthquake epicenter with year and magnitude, earthquake magnitudes based on Richter scale

Source: NOAA, 1998.

Figure 4.2-2

REGIONAL RECORDED SEISMIC EVENTS

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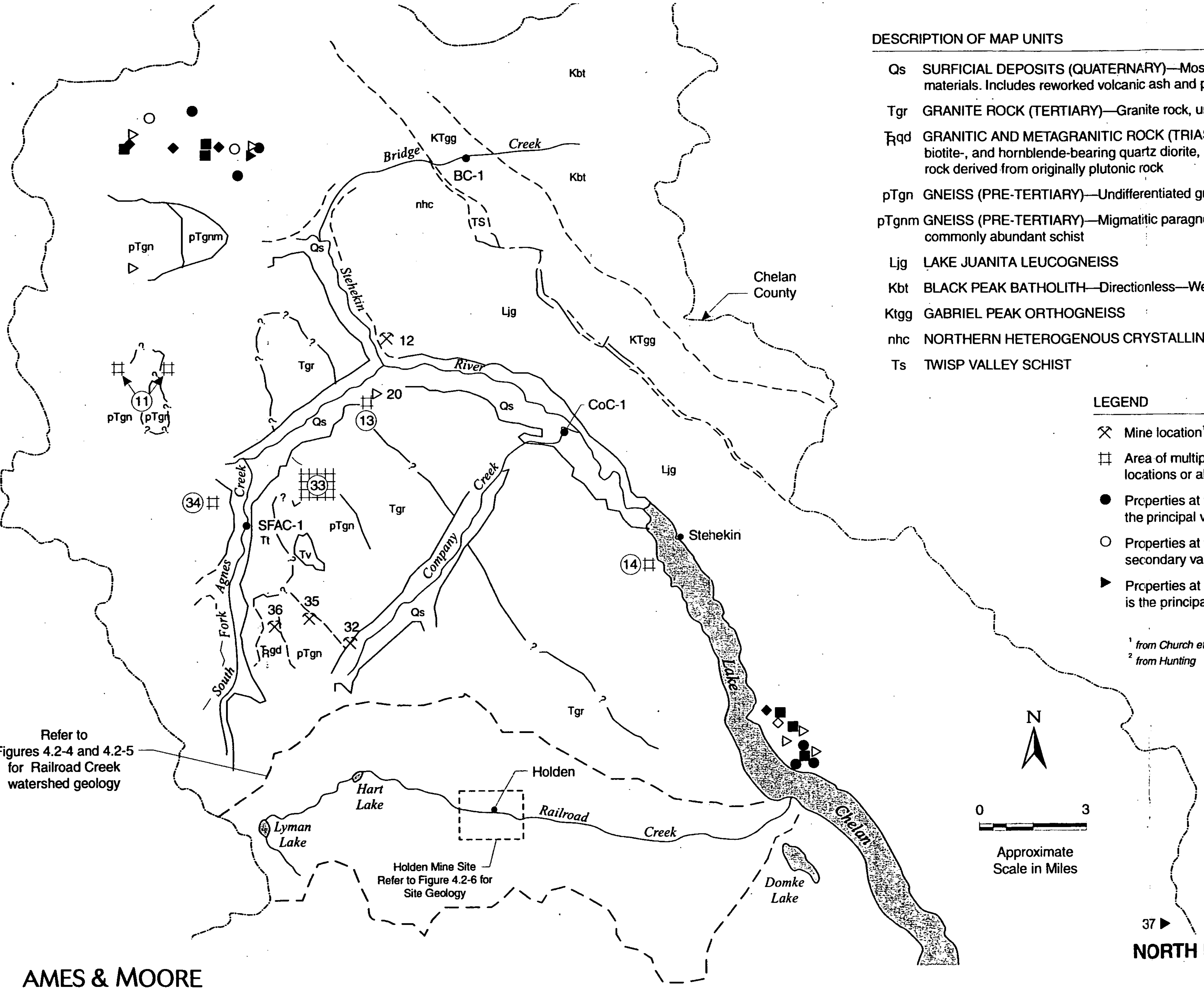


DESCRIPTION OF MAP UNITS

Qs	SURFICIAL DEPOSITS (QUATERNARY)—Mostly unconsolidated alluvium, colluvium, and glacial materials. Includes reworked volcanic ash and pumice of postglacial eruptions of Glacier Peak volcano
Tgr	GRANITE ROCK (TERTIARY)—Granite rock, undifferentiated
TRqd	GRANITIC AND METAGRANITIC ROCK (TRIASSIC)—Commonly foliated and heterogeneous chlorite-, biotite-, and hornblende-bearing quartz diorite, metaquartz diorite, and gneiss or other metamorphic rock derived from originally plutonic rock
pTgn	GNEISS (PRE-TERTIARY)—Undifferentiated gneiss
pTgnm	GNEISS (PRE-TERTIARY)—Migmatitic paragneiss and orthogneiss heterogeneously mixed with commonly abundant schist
Ljg	LAKE JUANITA LEUCOGNEISS
Kbt	BLACK PEAK BATHOLITH—Directionless—Weakly foliated phase
Ktgg	GABRIEL PEAK ORTHOGNEISS
nhc	NORTHERN HETEROGENOUS CRYSTALLINE COMPLEX
Ts	TWISP VALLEY SCHIST

LEGEND

⚒	Mine location[1]
⌗	Area of multiple claim locations or altered rock[1]
●	Properties at which ***lead*** is the principal value[2]
○	Properties at which ***lead*** is of secondary value[2]
▶	Properties at which ***copper*** is the principal value[2]
▷	Properties at which ***copper*** is of secondary value[2]
■	Properties at which ***arsenic*** is the principal value[2]
□	Properties at which ***arsenic*** is of secondary value[2]
◆	Properties at which ***zinc*** is the principal value[2]
◇	Properties at which ***zinc*** is of secondary value[2]
•	BC-1 (aquatic reference reach sampling station)

[1] *from Church et al.*
[2] *from Hunting*

Sources: *Hunting, M.T., 1956, Inventory of Washington Minerals, Division of Mines and Ecology, Bull. No. 37, V.2.*

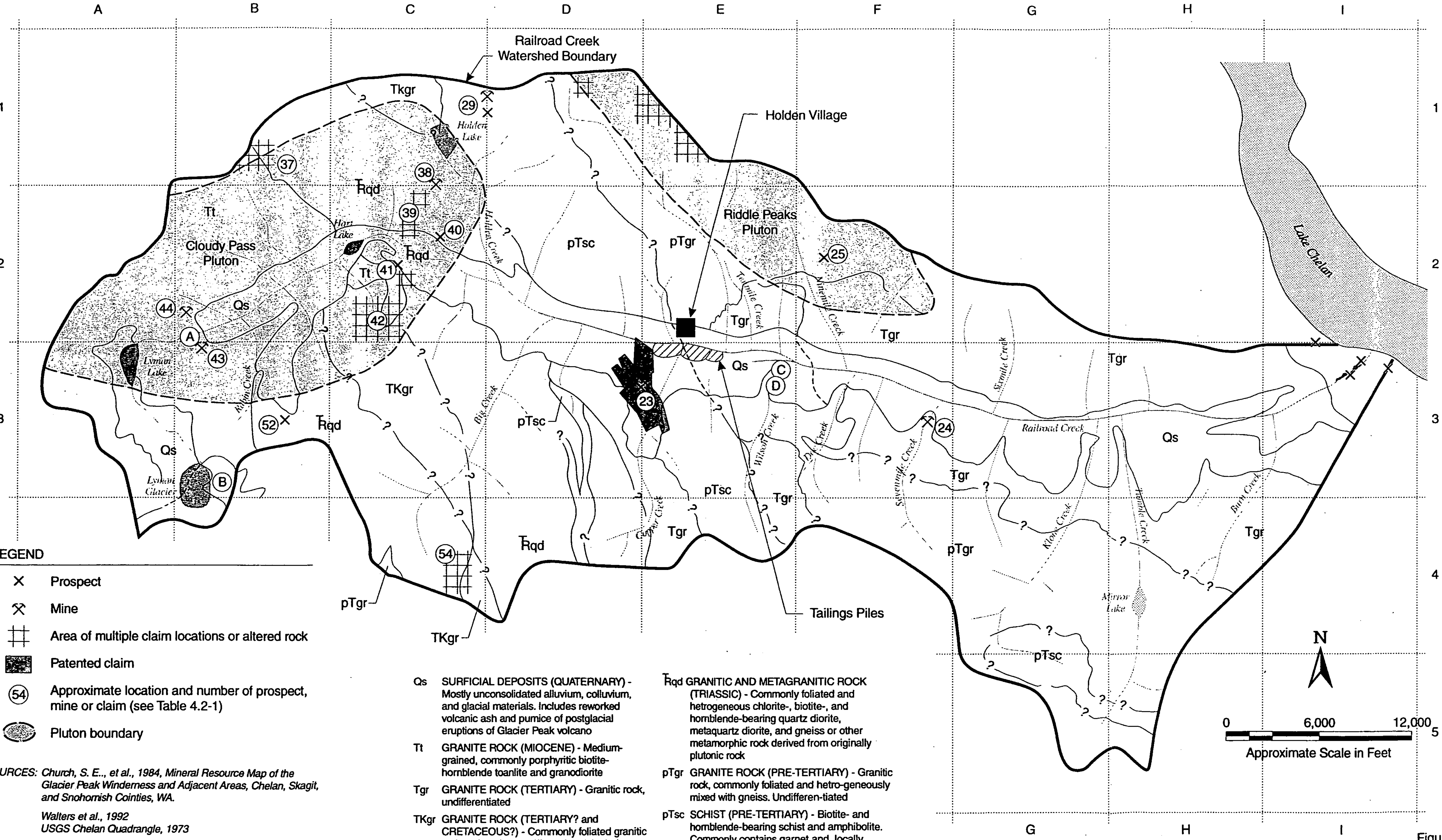
Church, S.E., et al., 1984, Mineral Resource Potential Map of the Glacier Peak Wilderness and Adjacent Areas, Chelan, Skagit, and Snohomish Counties, WA, US Geological Survey, misc. Field Studies Map MF 1652-A.

Miller, R. B., 1987, Geologic Map of the Twisp River-Chelan Divide Region, North Cascades, Washington

Miller, R. B., 1987, Geologic Map of Part of the McAlaster Mountain Quadrangle, Washington

Figure 4.2-3
NORTH LAKE CHELAN BASIN GEOLOGY MAP WITH HISTORIC MINING ACTIVITY

17693B11.CDR



LEGEND

× Prospect

⚒ Mine

\# Area of multiple claim locations or altered rock

▨ Patented claim

(54) Approximate location and number of prospect, mine or claim (see Table 4.2-1)

◌ Pluton boundary

Qs	SURFICIAL DEPOSITS (QUATERNARY) - Mostly unconsolidated alluvium, colluvium, and glacial materials. Includes reworked volcanic ash and pumice of postglacial eruptions of Glacier Peak volcano
Tt	GRANITE ROCK (MIOCENE) - Medium-grained, commonly porphyritic biotite-hornblende toanlite and granodiorite
Tgr	GRANITE ROCK (TERTIARY) - Granitic rock, undifferentiated
TKgr	GRANITE ROCK (TERTIARY? and CRETACEOUS?) - Commonly foliated granitic rock and gneiss, undifferentiated. Includes quartz diorite, tonalite, grandiorite, and minor diorite
Ŧqd	GRANITIC AND METAGRANITIC ROCK (TRIASSIC) - Commonly foliated and hetrogeneous chlorite-, biotite-, and hornblende-bearing quartz diorite, metaquartz diorite, and gneiss or other metamorphic rock derived from originally plutonic rock
pTgr	GRANITE ROCK (PRE-TERTIARY) - Granitic rock, commonly foliated and hetro-geneously mixed with gneiss. Undifferen-tiated
pTsc	SCHIST (PRE-TERTIARY) - Biotite- and hornblende-bearing schist and amphibolite. Commonly contains garnet and, locally, chlorite, staurolite, kyanite, and sillimanite. In places mixed with gneiss and granite rock

SOURCES: *Church, S. E.., et al., 1984, Mineral Resource Map of the Glacier Peak Winderness and Adjacent Areas, Chelan, Skagit, and Snohomish Cointies, WA.*

Walters et al., 1992
USGS Chelan Quadrangle, 1973

Figure 4.2-4

RAILROAD CREEK WATERSHED GEOLOGY MAP WITH SURFICIAL GEOLOGY AND HISTORIC MINING ACTIVITY

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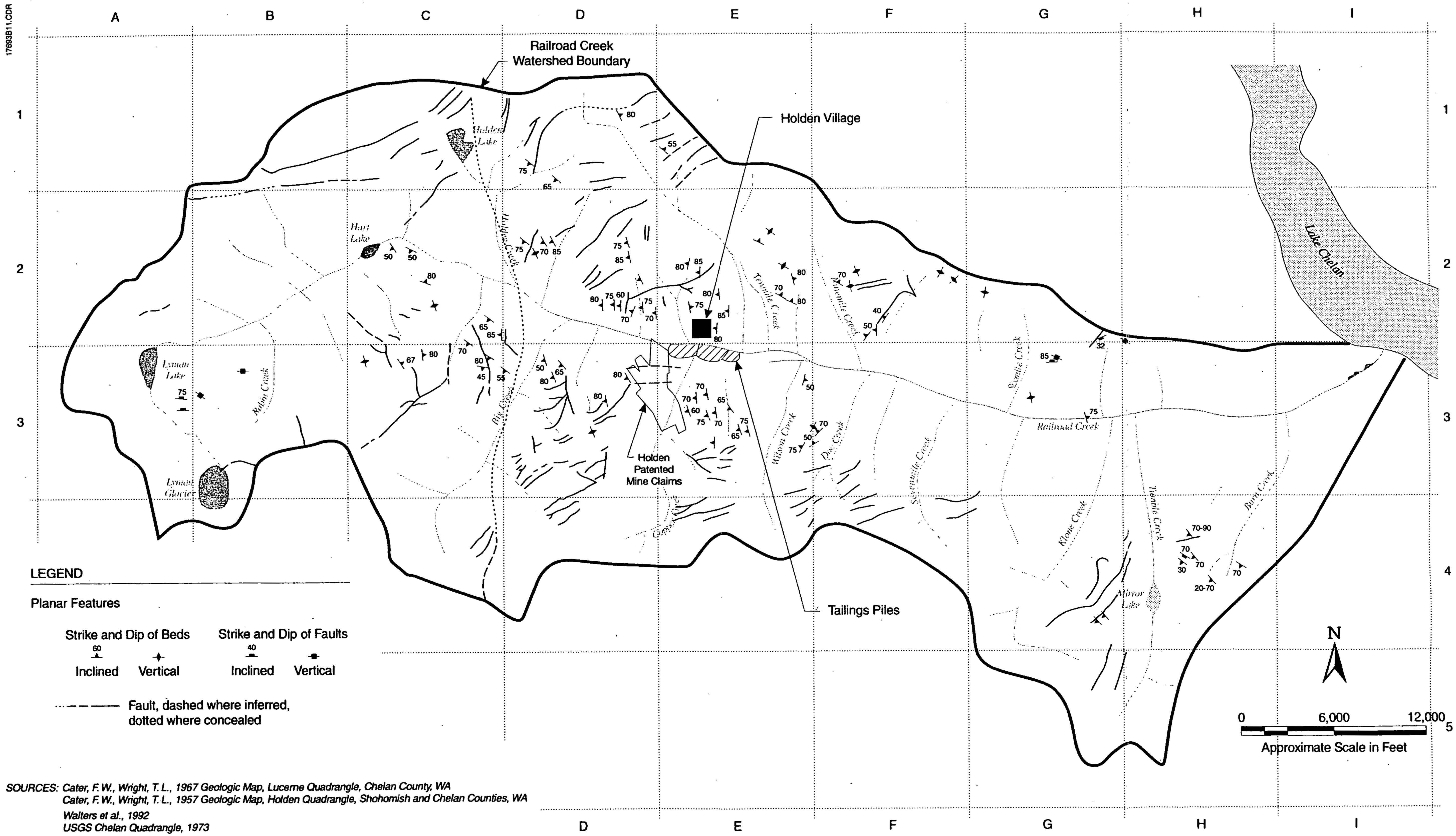

SOURCES: *Cater, F. W., Wright, T. L., 1967 Geologic Map, Lucerne Quadrangle, Chelan County, WA*
Cater, F. W., Wright, T. L., 1957 Geologic Map, Holden Quadrangle, Shohomish and Chelan Counties, WA
Walters et al., 1992
USGS Chelan Quadrangle, 1973

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Figure 4.2-5
RAILROAD CREEK WATERSHED STRUCTURAL GEOLOGY MAP

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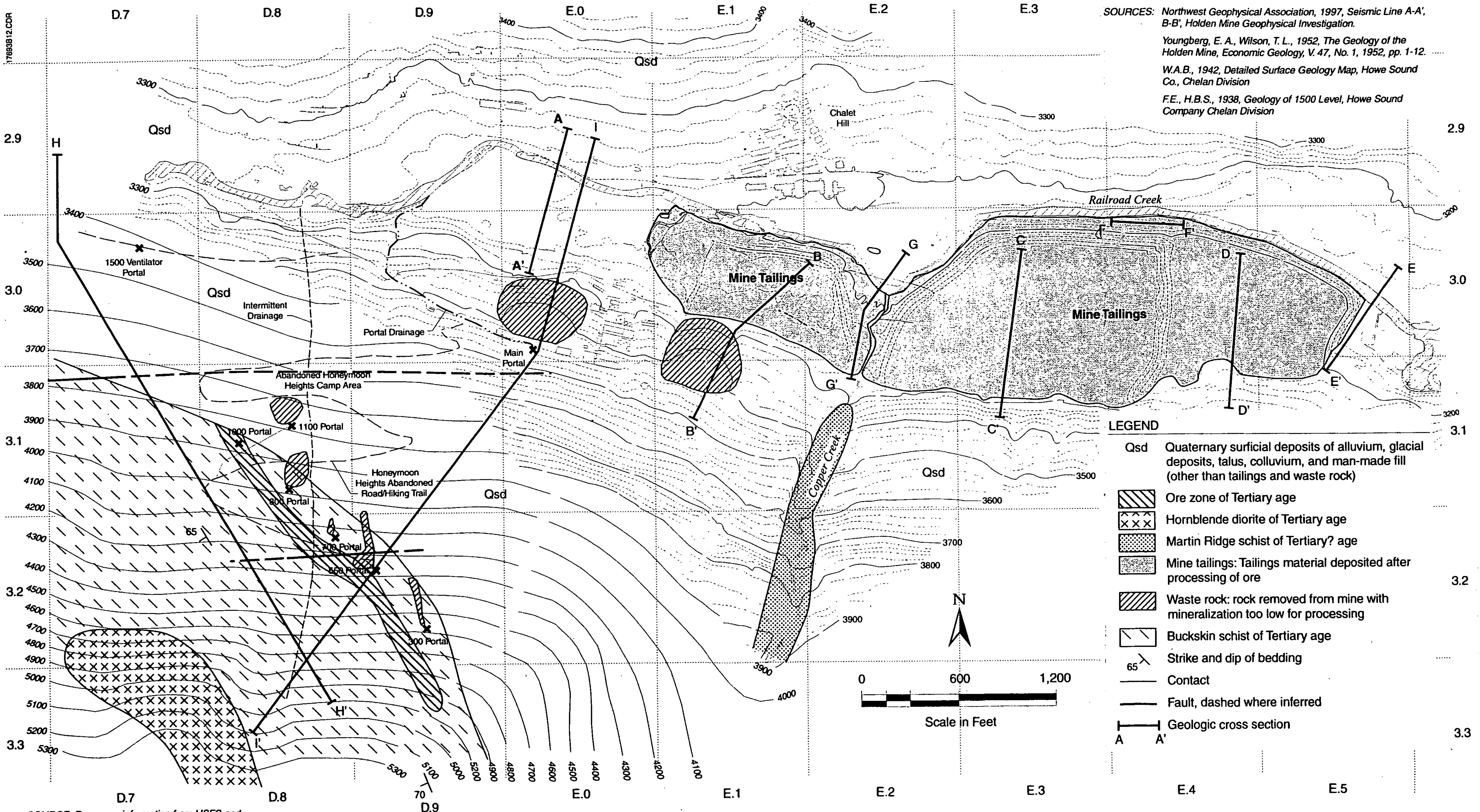

SOURCES: Northwest Geophysical Association, 1997, Seismic Line A-A', B-B', Holden Mine Geophysical Investigation.

Youngberg, E. A., Wilson, T. L., 1952, The Geology of the Holden Mine, Economic Geology, V. 47, No. 1, 1952, pp. 1-12.

W.A.B., 1942, Detailed Surface Geology Map, Howe Sound Co., Chelan Division

F.E., H.B.S., 1938, Geology of 1500 Level, Howe Sound Company Chelan Division

SOURCE: Base map information from USFS and Washington DNR, DEM CD ROM

Figure 4.2-6a

HOLDEN MINE SITE GEOLOGIC MAP

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Holden Mine RI/FS
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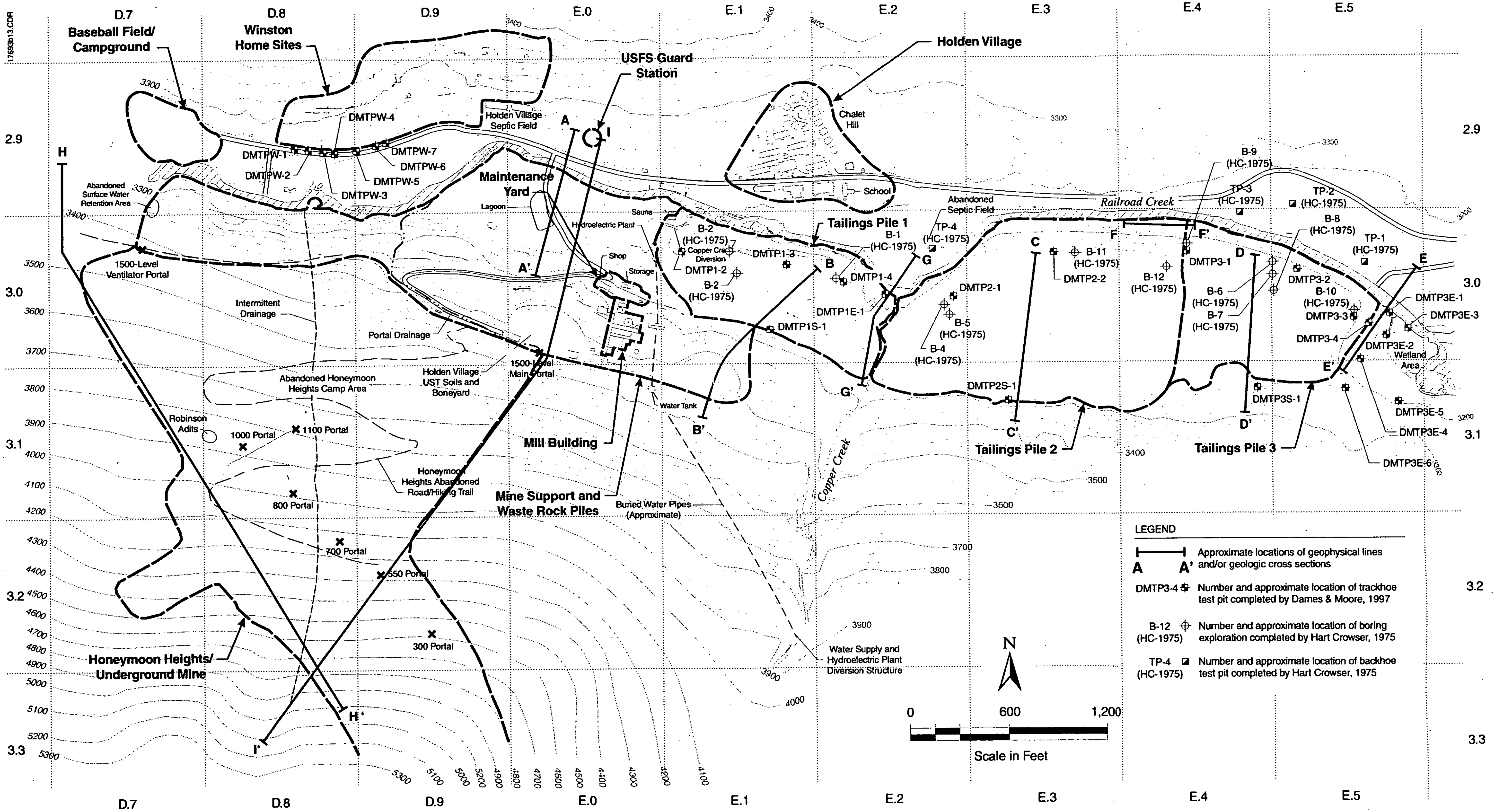

SOURCE: Base map information from USFS and Washington DNR, DEM CD ROM

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Figure 4.2-6b

RI GEOLOGIC INVESTIGATION LOCATIONS

Holden Mine RI/FS
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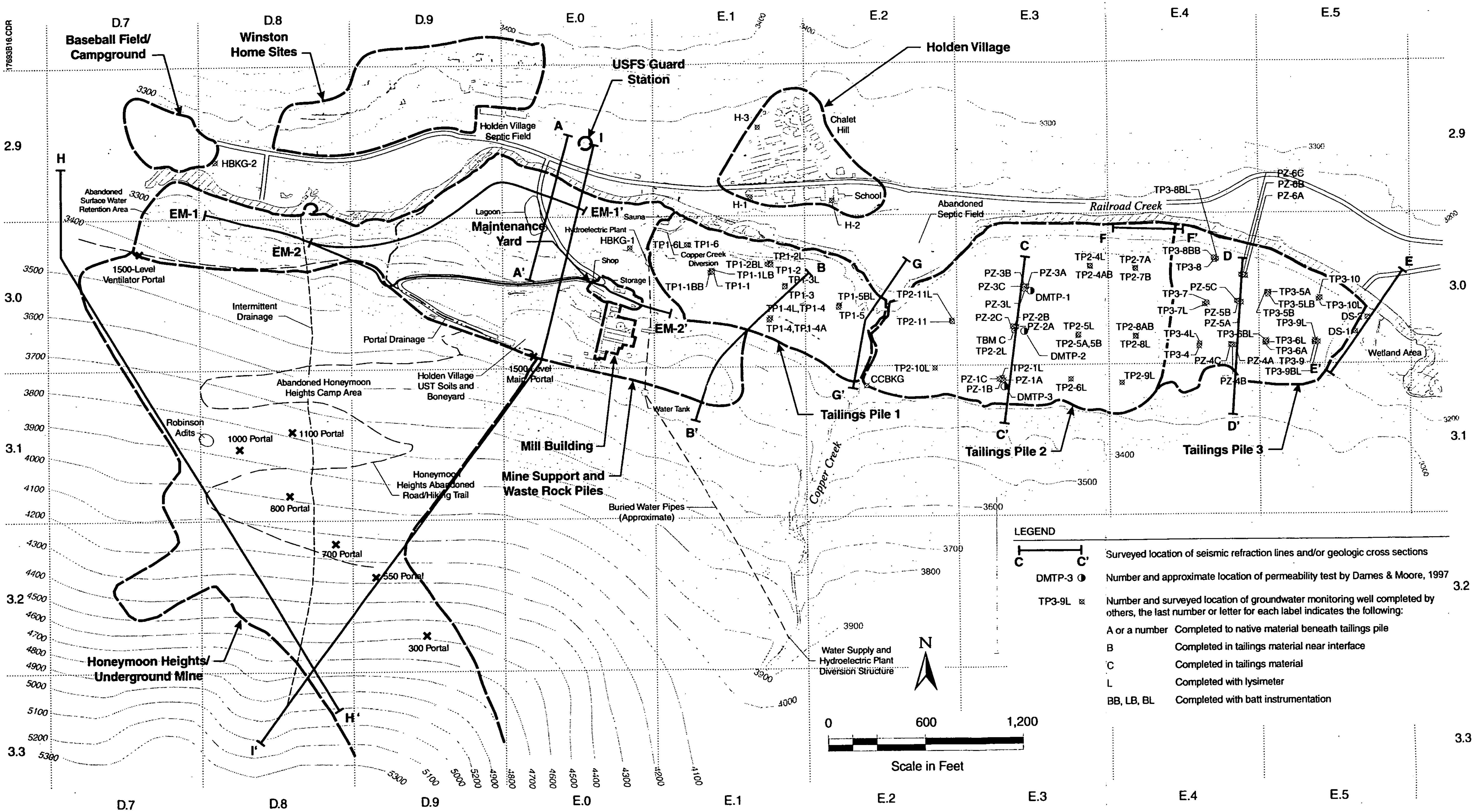

LEGEND

C —— C'	Surveyed location of seismic refraction lines and/or geologic cross sections
DMTP-3 ◑	Number and approximate location of permeability test by Dames & Moore, 1997
TP3-9L ⊠	Number and surveyed location of groundwater monitoring well completed by others, the last number or letter for each label indicates the following:

A or a number	Completed to native material beneath tailings pile
B	Completed in tailings material near interface
C	Completed in tailings material
L	Completed with lysimeter
BB, LB, BL	Completed with batt instrumentation

SOURCE: Base map information from USFS and Washington DNR, DEM CD ROM

4.2-6c

SITE GEOLOGICAL DATA COLLECTED DURING HYDROGEOLOGIC INVESTIGATIONS

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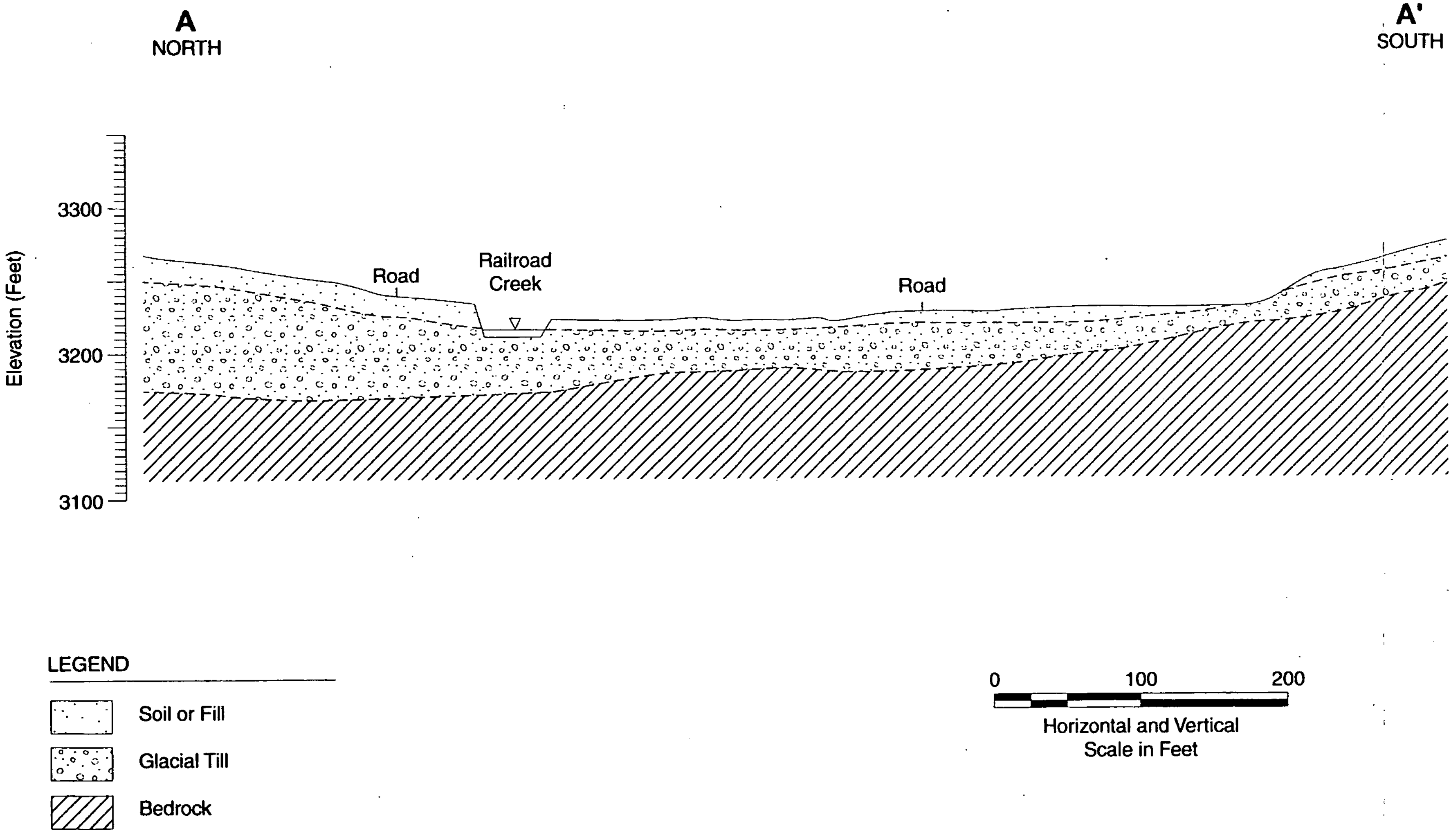
17693B14.CDR



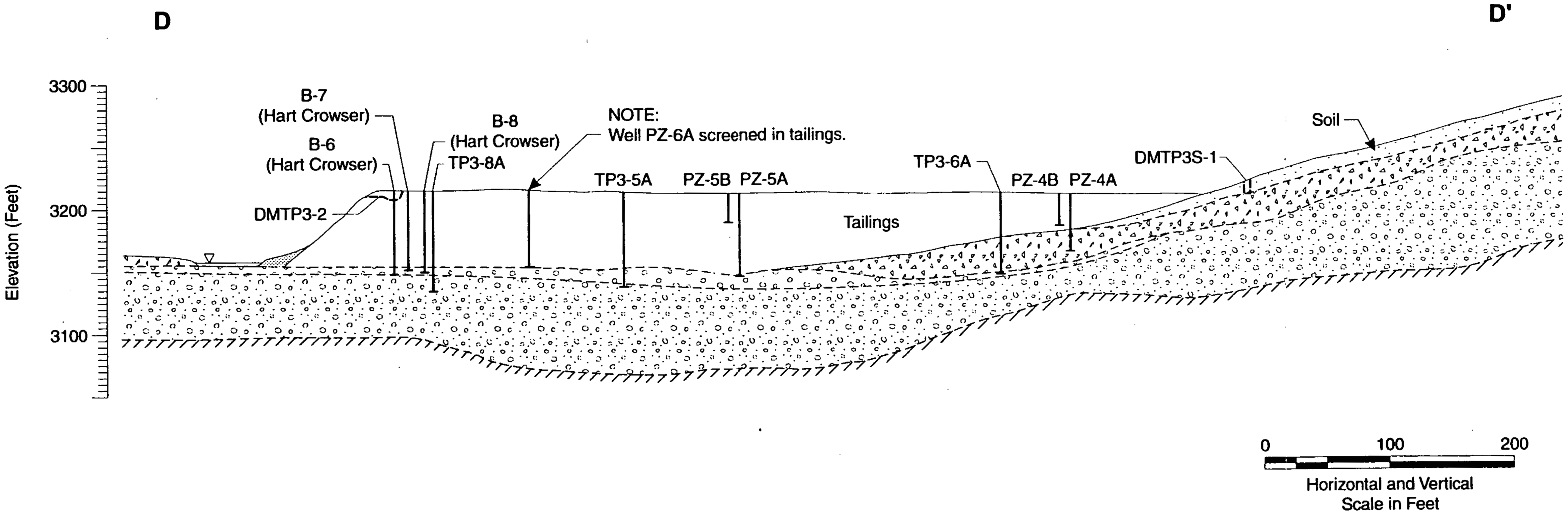
NJB notes Figs
4.2-8 & 4.2-9
missing 3.10.3

SOURCE: Northwest Geophysical Association, 1997, Seismic Line A-A', Holden Mine Geophysical Investigation

Figure 4.2-7

HOLDEN MINE SITE
GEOLOGIC CROSS SECTION A-A'

17693B18.CDR



NOTE:
Well PZ-6A screened in tailings.

LEGEND

▨	Colluvium	▨	Dense till
▨	Alluvium/reworked till	▨	Colluvium – tailings
▨	Soil	▨	Bedrock

B-6	Number and approximate location of boring completed by Hart Crowser, 1975.
PZ-6A	Number and approximate location of groundwater monitoring well installed by PNL, 1991.
TP3-5A	Number and approximate location of groundwater monitoring well installed by USBM, 1995.
DMTP3-2	Number and approximate location of test pit completed by Dames & Moore, 1997.

SOURCE: Northwest Geophysical Association, 1997, Seismic Line D-D',
Holden Mine Geophysical Investigation

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Figure 4.2-10

HOLDEN MINE SITE
GEOLOGIC CROSS SECTION D-D'

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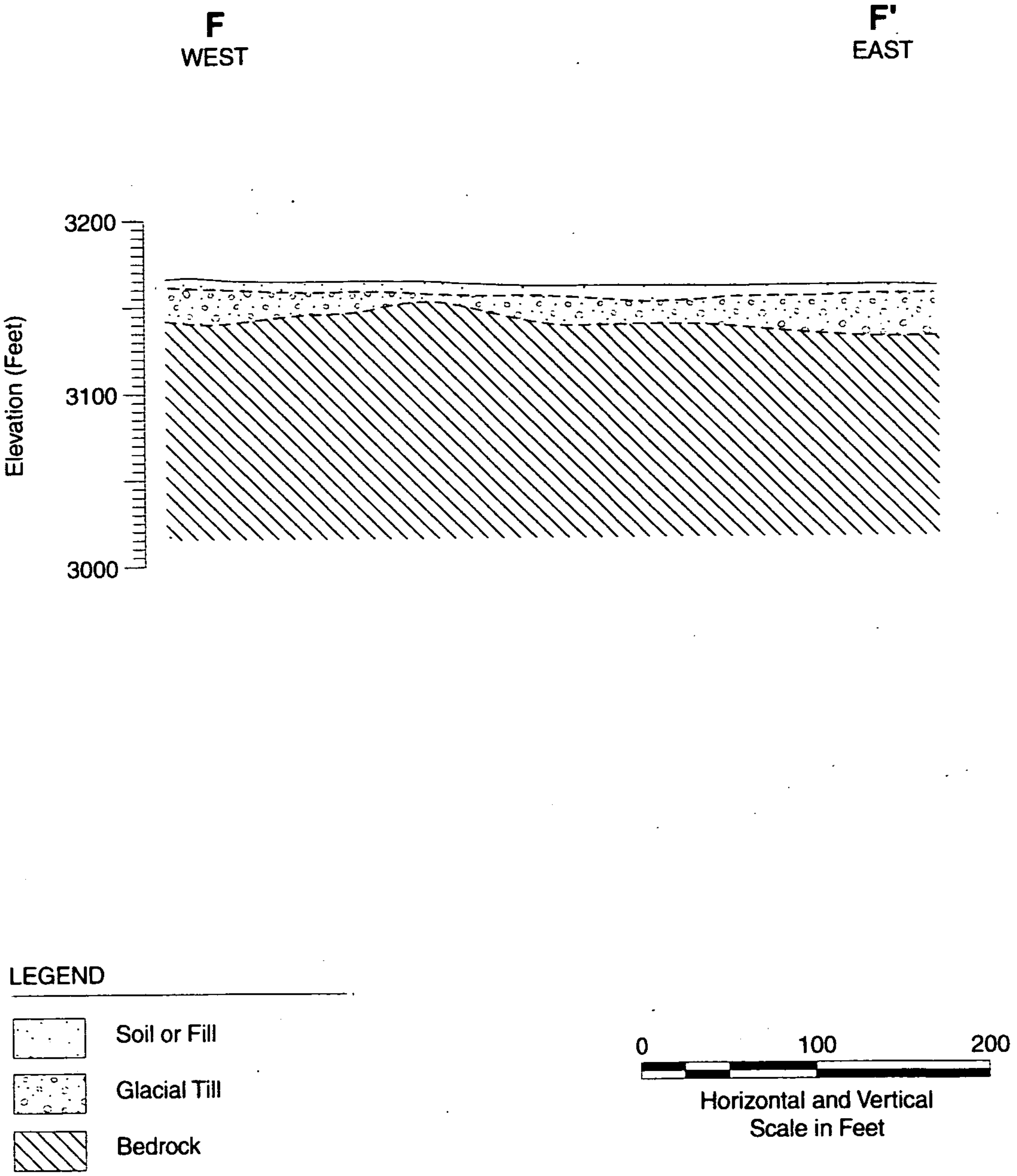

SOURCE: *Northwest Geophysical Association, 1997, Seismic Line F-F', Holden Mine Geophysical Investigation*

Figure 4.2-12

HOLDEN MINE SITE
GEOLOGIC CROSS SECTION F-F'

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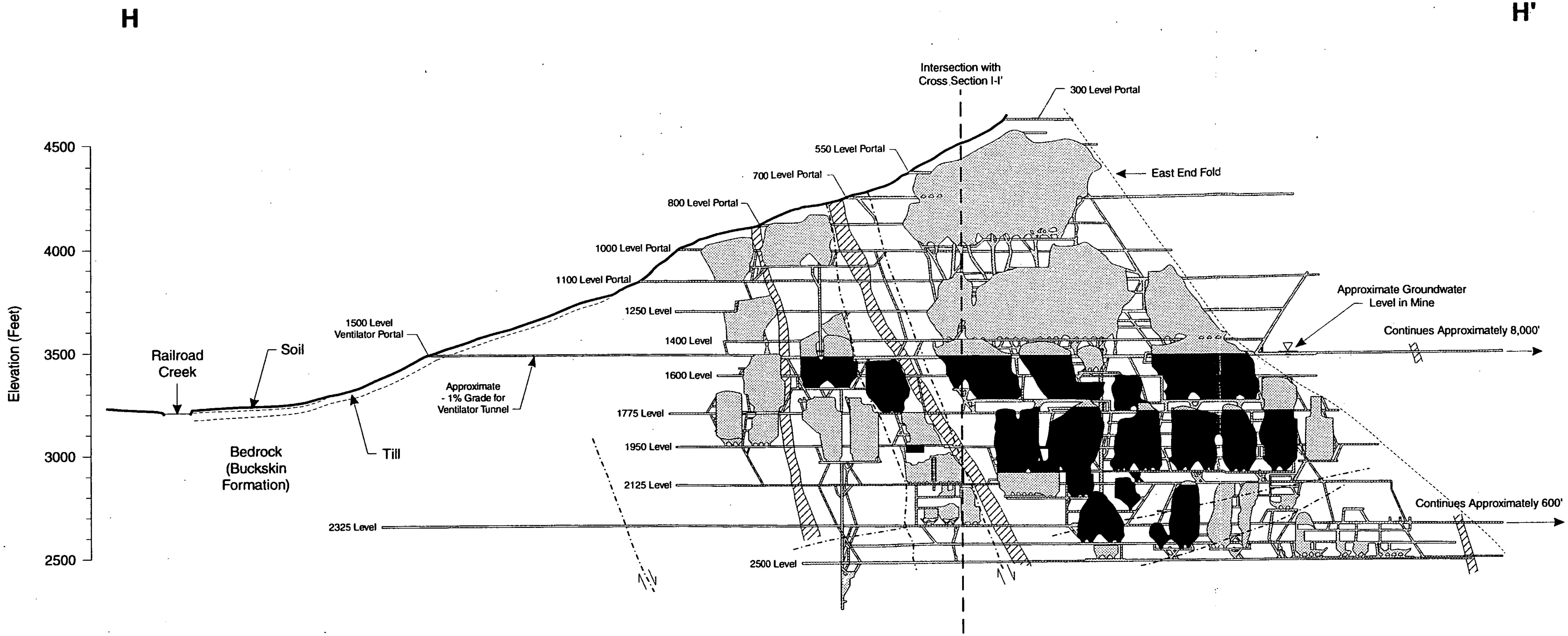

NOTE: This cross section is generally parallel to ore body and 1500 level ventilator tunnel

SOURCES: *Northwest Geophysical Associates, 1997, Seismic Line A-A', B-B', Holden Mine Geophysical Investigation.*

Youngberg, E. A., Wilson, T. L., 1952, The Geology of the Holden Mine, Economic Geology, V. 47, No. 1, 1952, pp. 1-12.

W.A.B., 1942, Detailed Surface Geology Map, Howe Sound Co., Chelan Division

F.E., H.B.S., 1938, Geology of 1500 Level, Howe Sound Company Chelan Division

Howe Sound Co, 1957, Holden Mine, East West Section

LEGEND

- ░ Open stope
- ■ Backfilled stope
- ▨ Dike
- -·-·- Transform fault

0 500 1,000

Approximate
Horizontal and Vertical
Scale in Feet

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Figure 4.2-14

HOLDEN MINE SITE
GEOLOGIC CROSS SECTION H-H'

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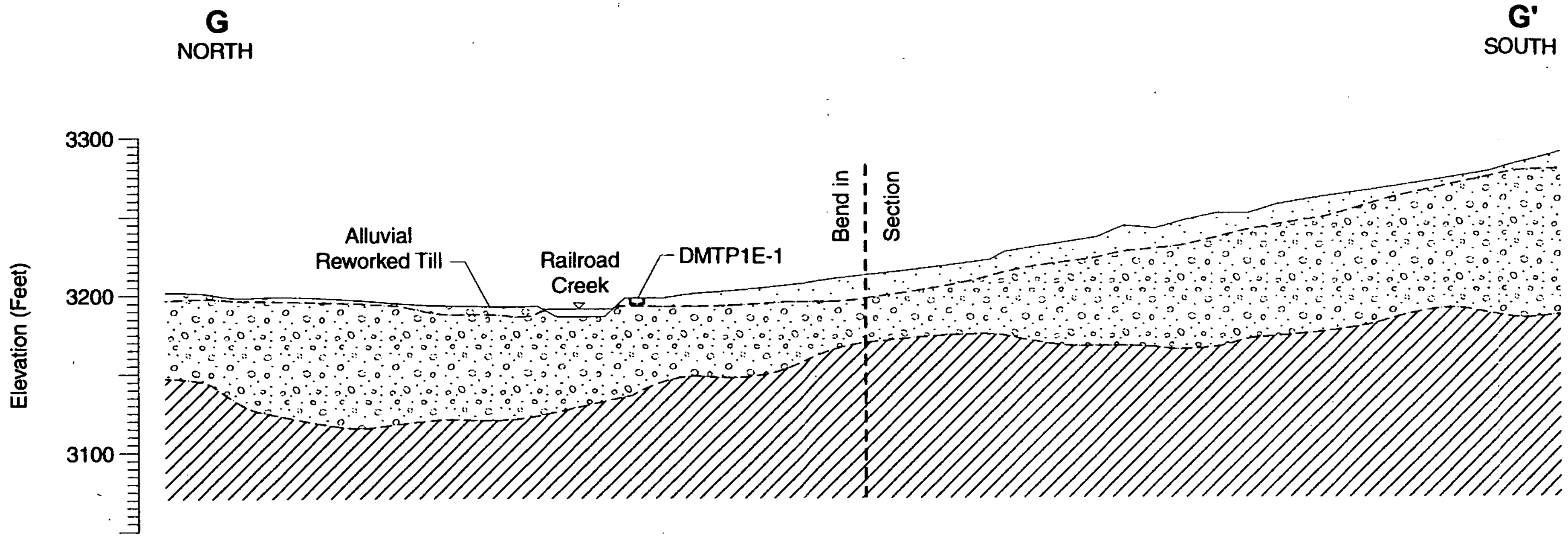


LEGEND

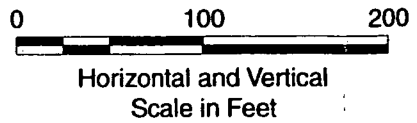
⋯ Soil or Fill

○ Alluvial Reworked Till

⁘ Glacial Till

▨ Bedrock

DMTP1E-1 Number and approximate location of test pit completed by Dames & Moore, 1997.



Horizontal and Vertical Scale in Feet

SOURCE: Northwest Geophysical Association, 1997, Seismic Line G-G', Holden Mine Geophysical Investigation

Figure 4.2-13

HOLDEN MINE SITE
GEOLOGIC CROSS SECTION G-G'

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17693B25.CDR

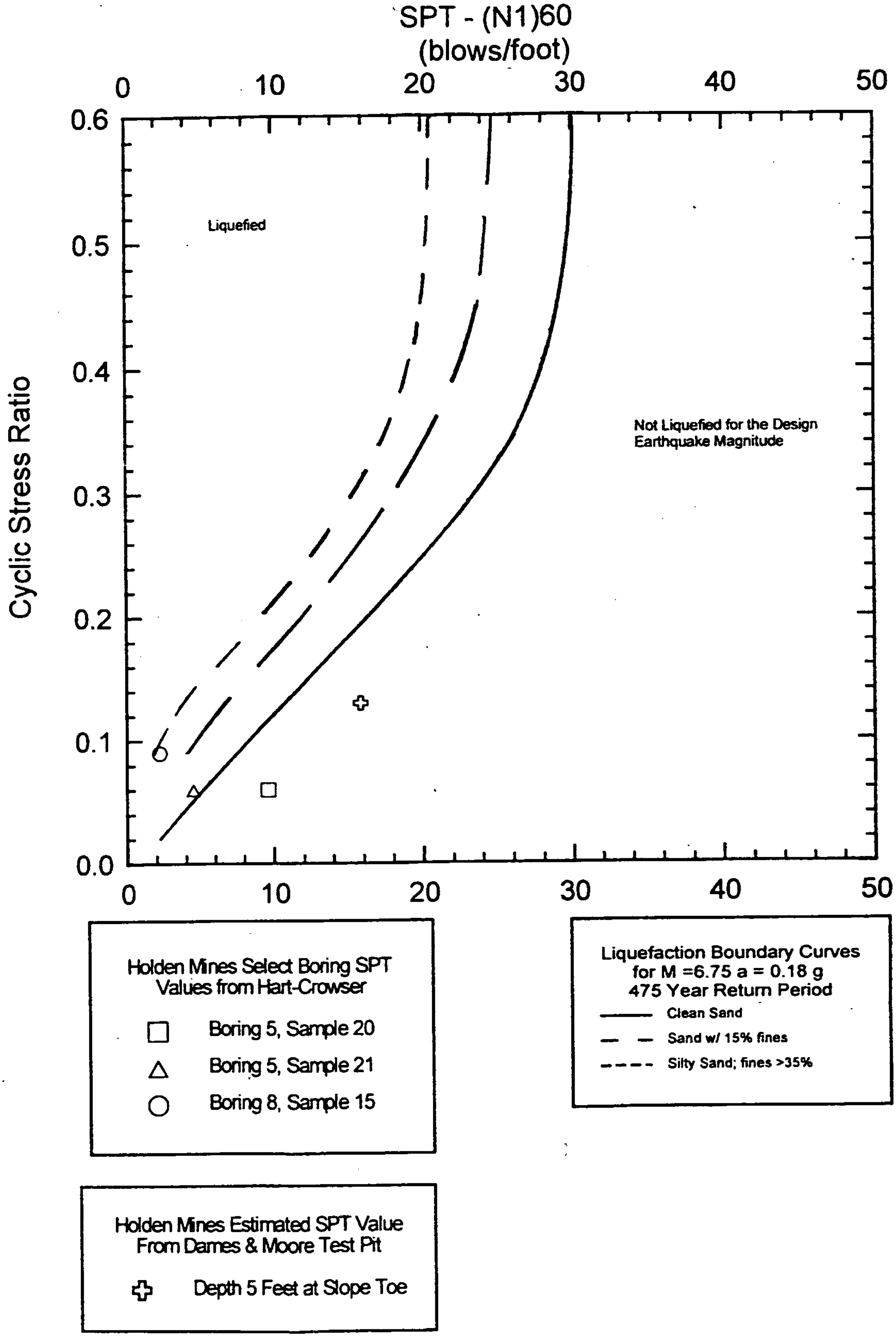

Figure 4.2-16

HOLDEN MINE SITE EQUIVALENT SPT AND LIQUEFACTION POTENTIAL

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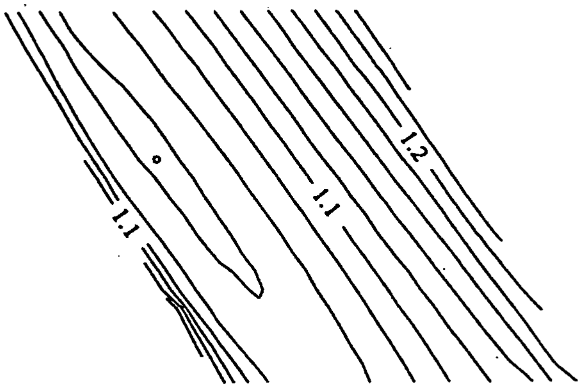

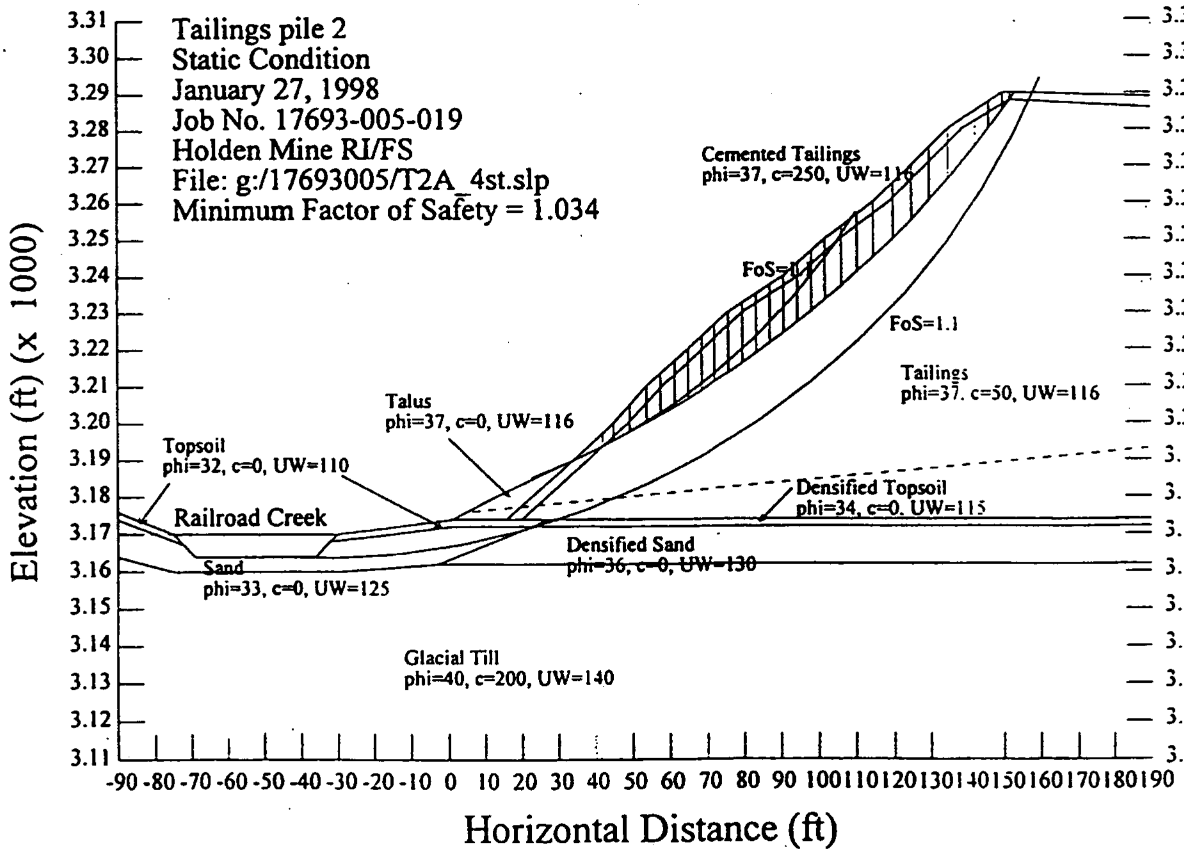

Figure 4.2-17

HOLDEN MINE SITE SLOPE STABILITY CROSS SECTION C-C' STATIC CONDITIONS

17693B64.CDR

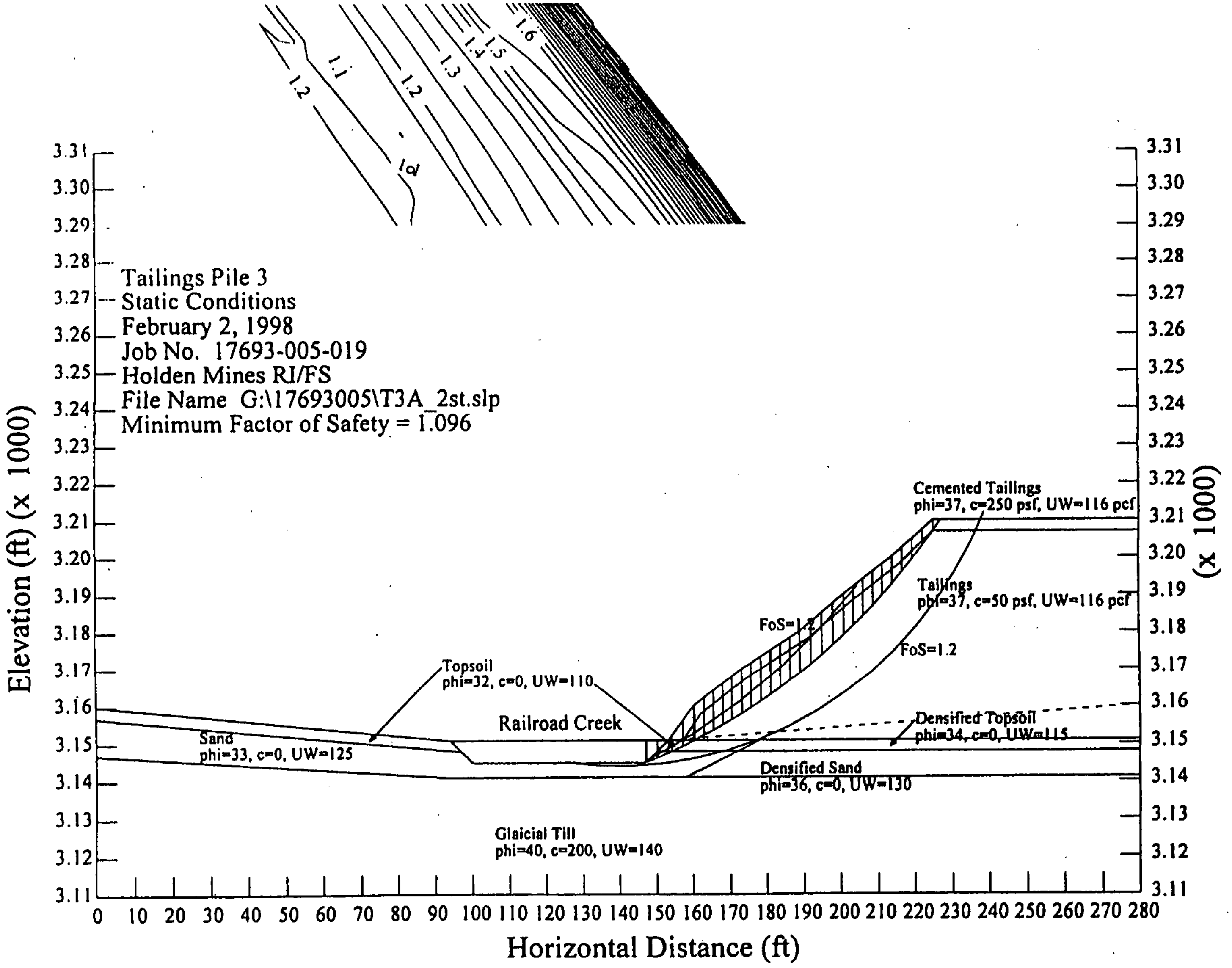

Figure 4.2-18

HOLDEN MINE SITE SLOPE STABILITY CROSS SECTION D-D' STATIC CONDITIONS

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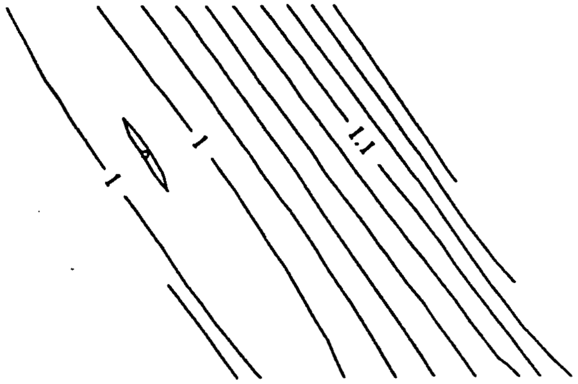
17693B65.CDR



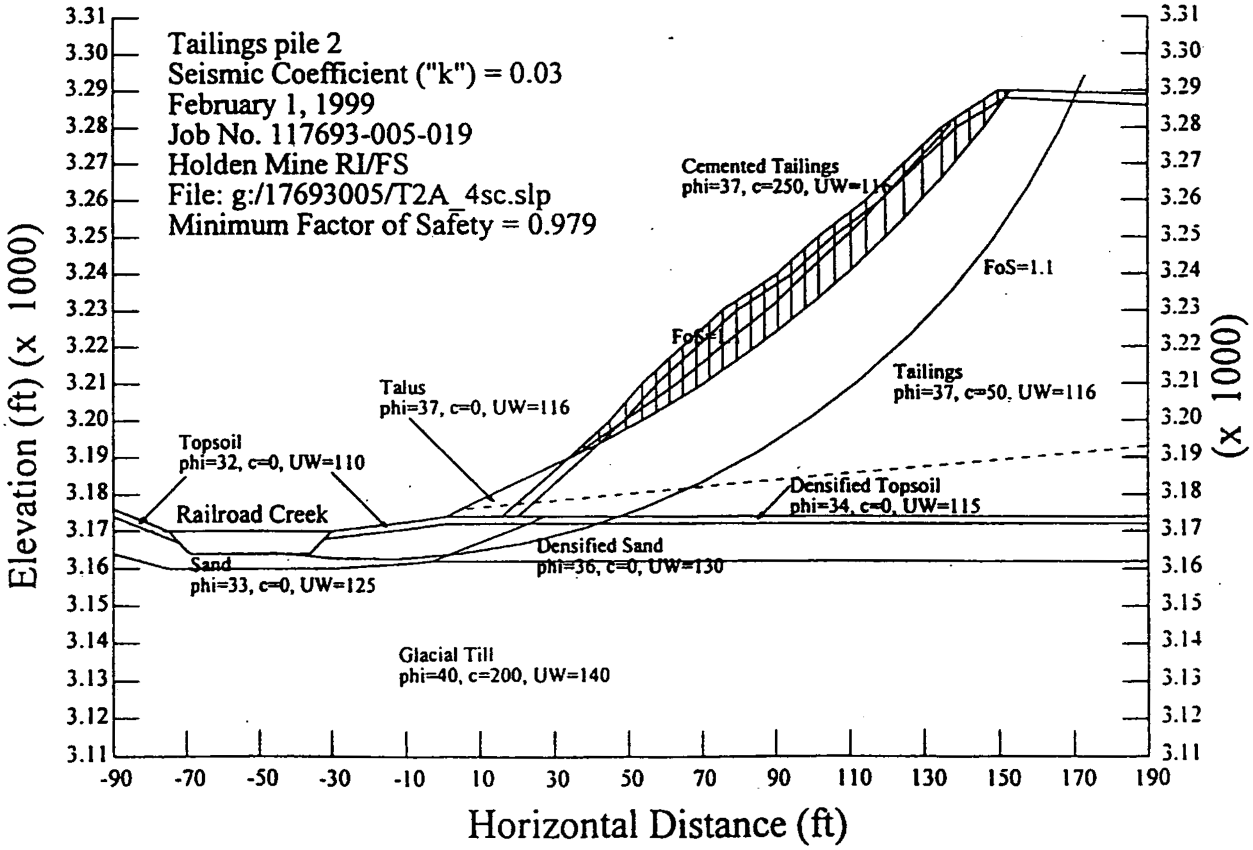


Figure 4.2-19

HOLDEN MINE SITE SLOPE STABILITY
CROSS SECTION C-C'
SEISMIC CONDITIONS

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17693B64.CDR

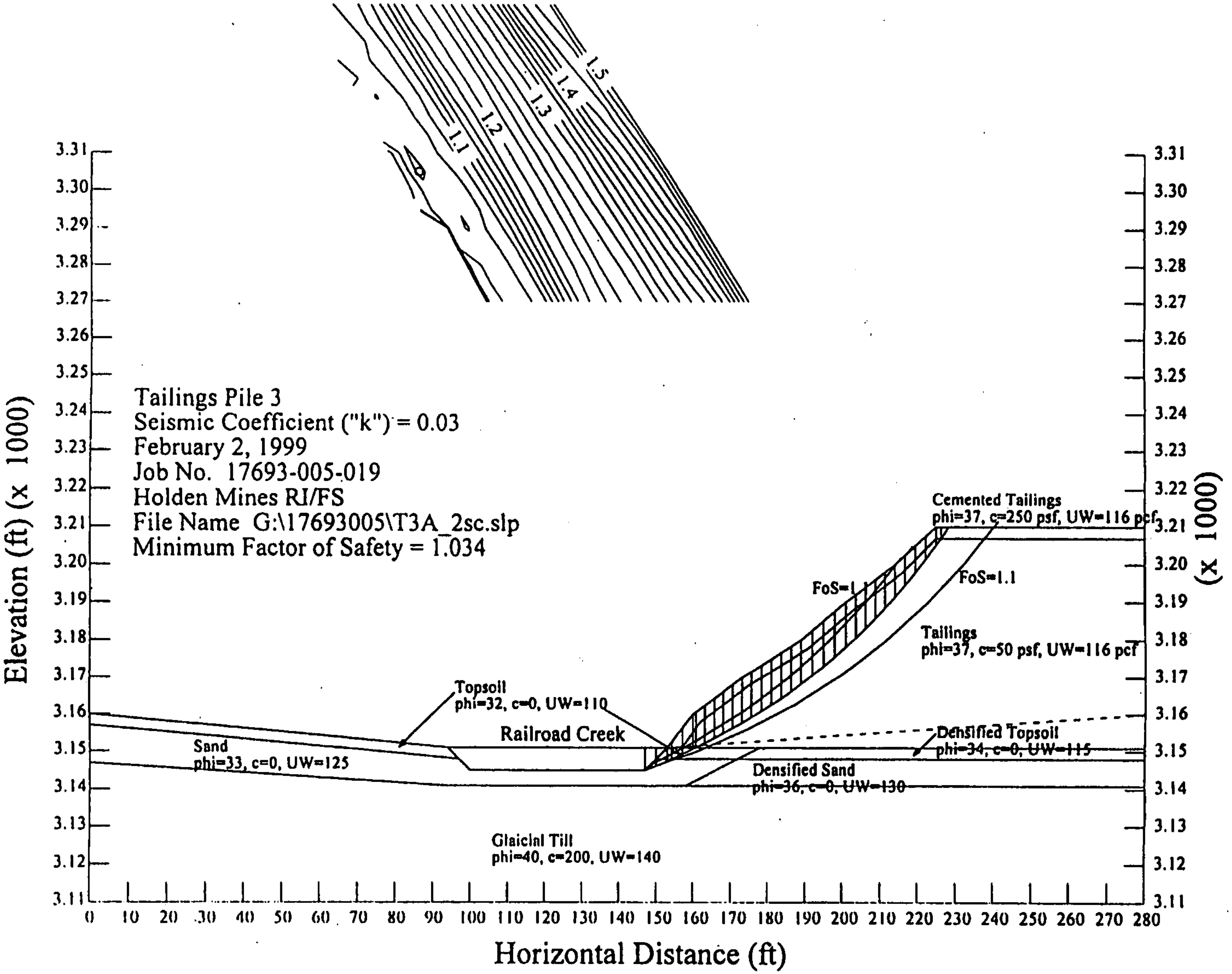
Tailings Pile 3
Seismic Coefficient ("k") = 0.03
February 2, 1999
Job No. 17693-005-019
Holden Mines RI/FS
File Name G:\17693005\T3A_2sc.slp
Minimum Factor of Safety = 1.034

Figure 4.2-20

HOLDEN MINE SITE SLOPE STABILITY CROSS SECTION D-D' SEISMIC CONDITIONS

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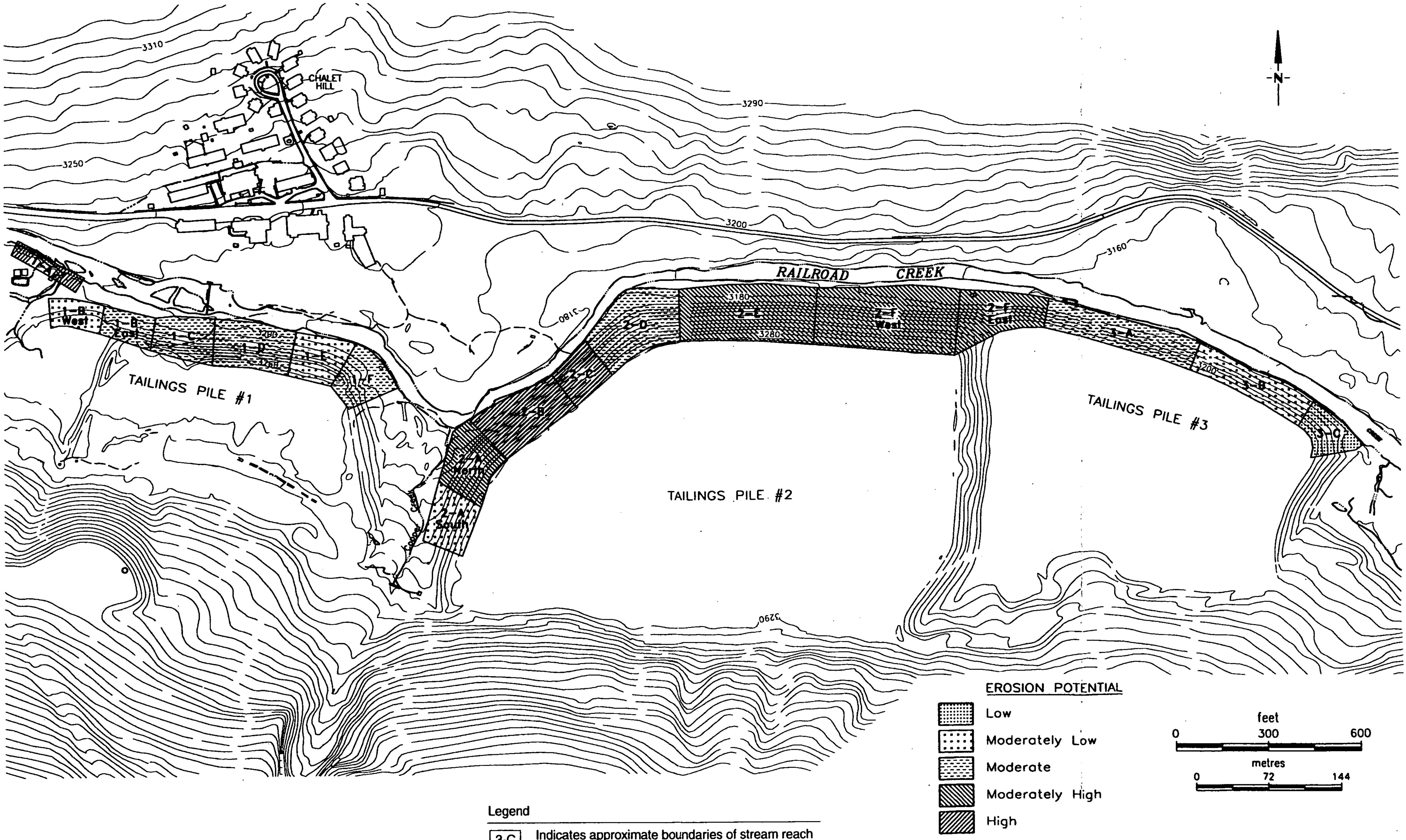
17693B23.CDR



Legend

3-C Indicates approximate boundaries of stream reach erosion potential areas based on field observations

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Figure 4.2-21

HOLDEN MINE SITE EROSION POTENTIAL MAP

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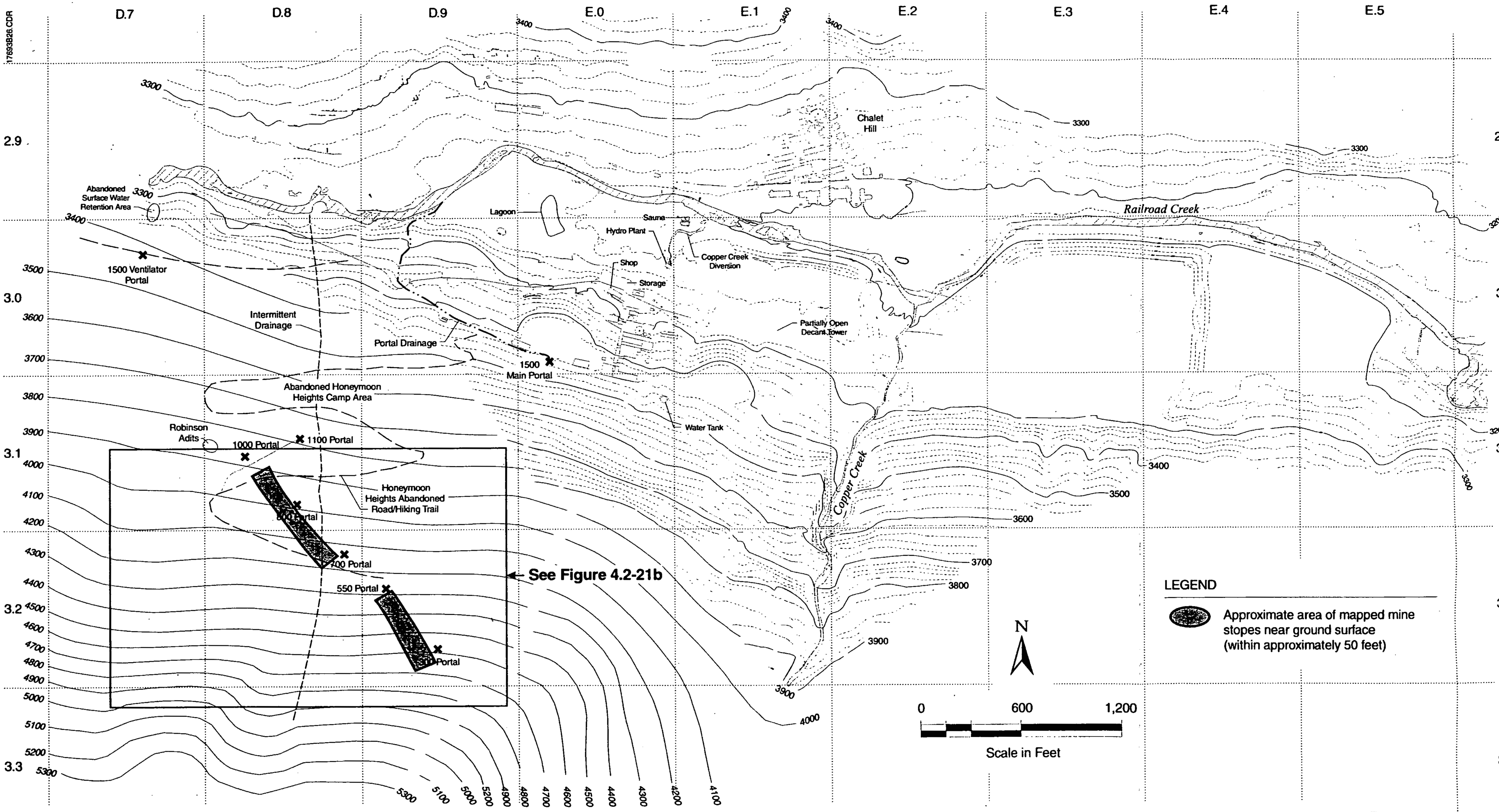

SOURCE: Base map information from USFS and Washington DNR, DEM CD ROM

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Figure 4.2-21a

HOLDEN MINE AREAS OF NEAR-SURFACE MINE WORKINGS

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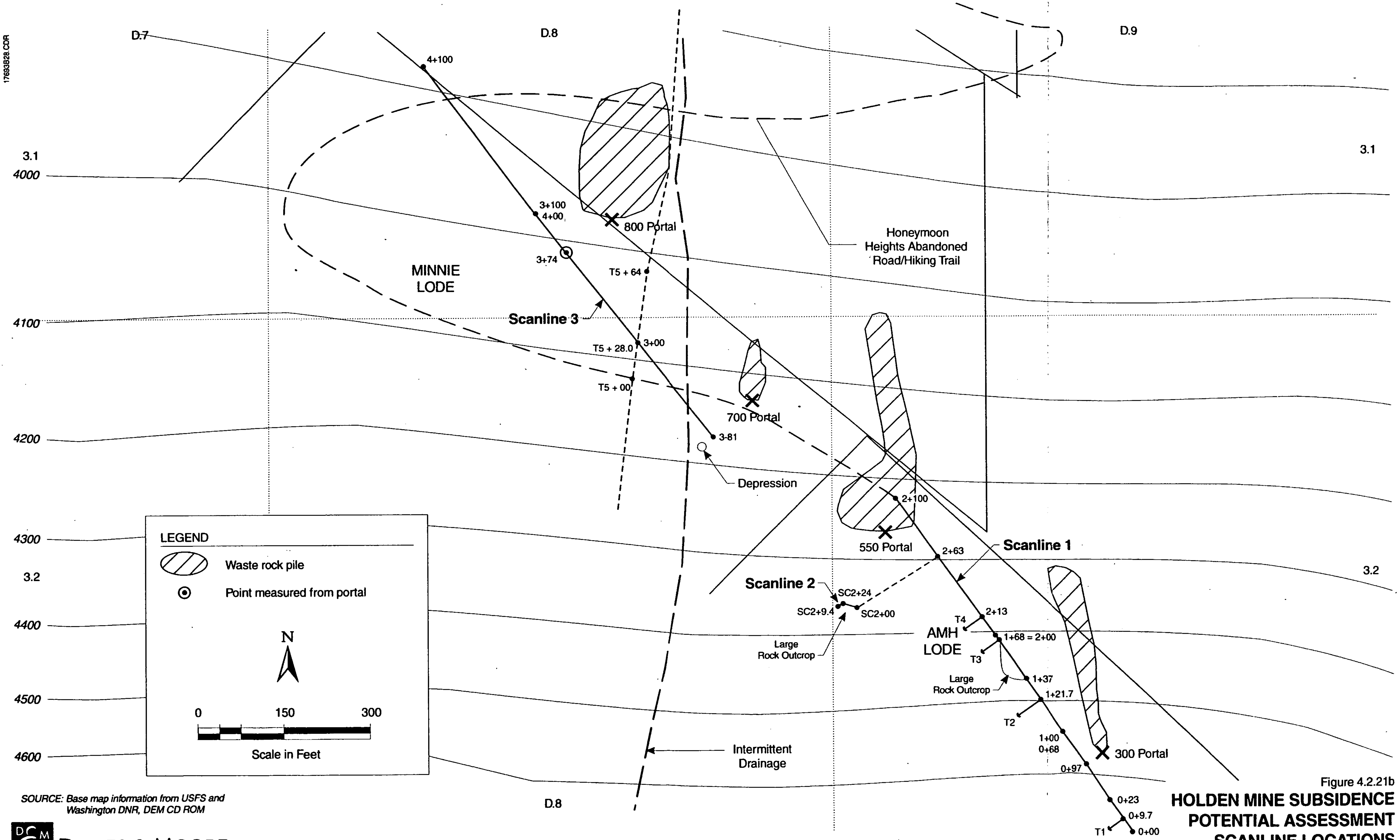

SOURCE: *Base map information from USFS and Washington DNR, DEM CD ROM*

Figure 4.2.21b

HOLDEN MINE SUBSIDENCE POTENTIAL ASSESSMENT SCANLINE LOCATIONS

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17693B29.CDR

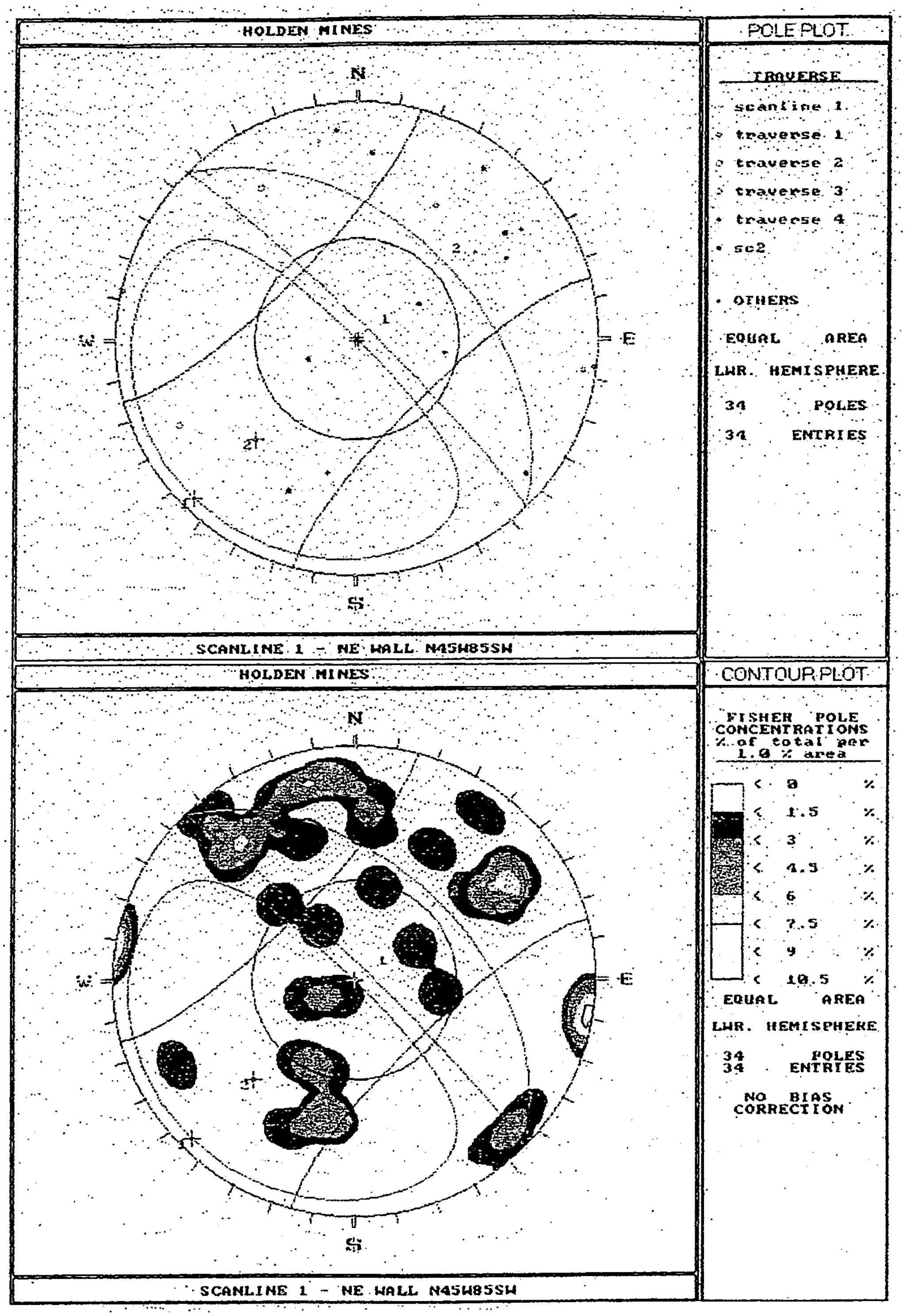

Figure 4.2-21c

HOLDEN MINE SUBSIDENCE POTENTIAL ASSESSMENT SCANLINE 1 – NE WALL STEREONET

17693B28.CDR

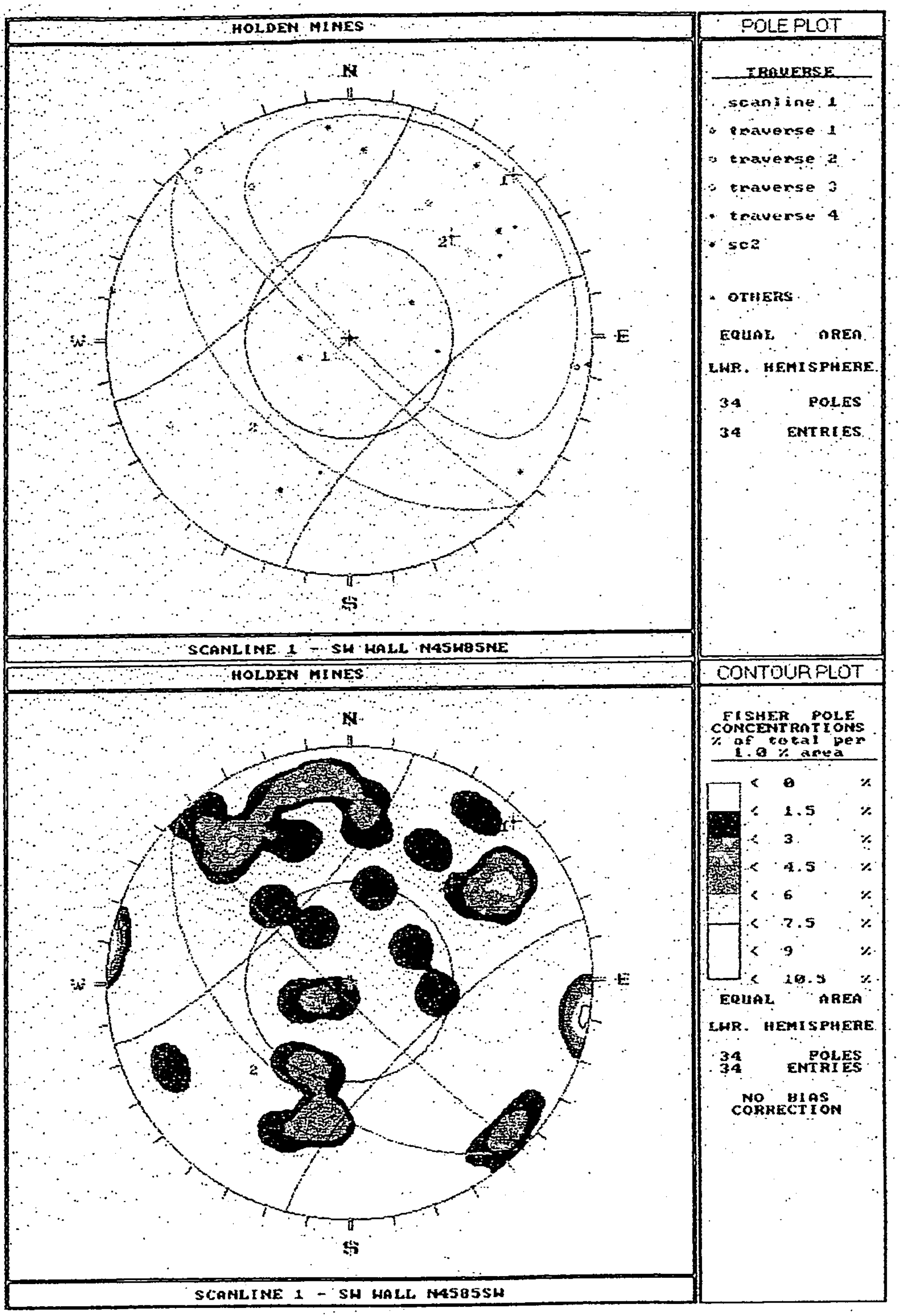

Figure 4.2-21d

HOLDEN MINE SUBSIDENCE POTENTIAL ASSESSMENT

SCANLINE 1 – SW WALL STEREONET

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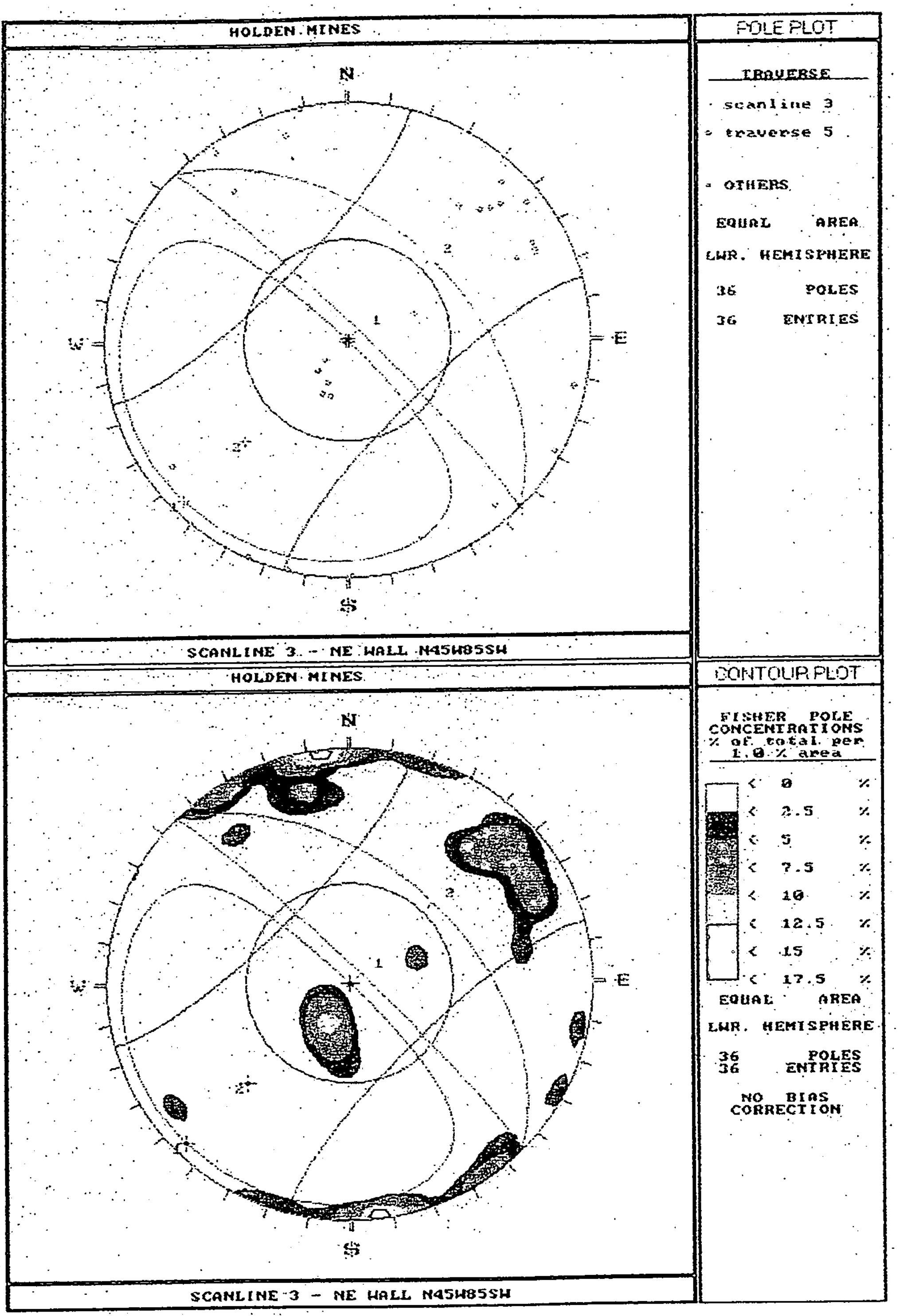

Figure 4.2-21e

HOLDEN MINE SUBSIDENCE POTENTIAL ASSESSMENT SCANLINE 3 – NE WALL STEREONET

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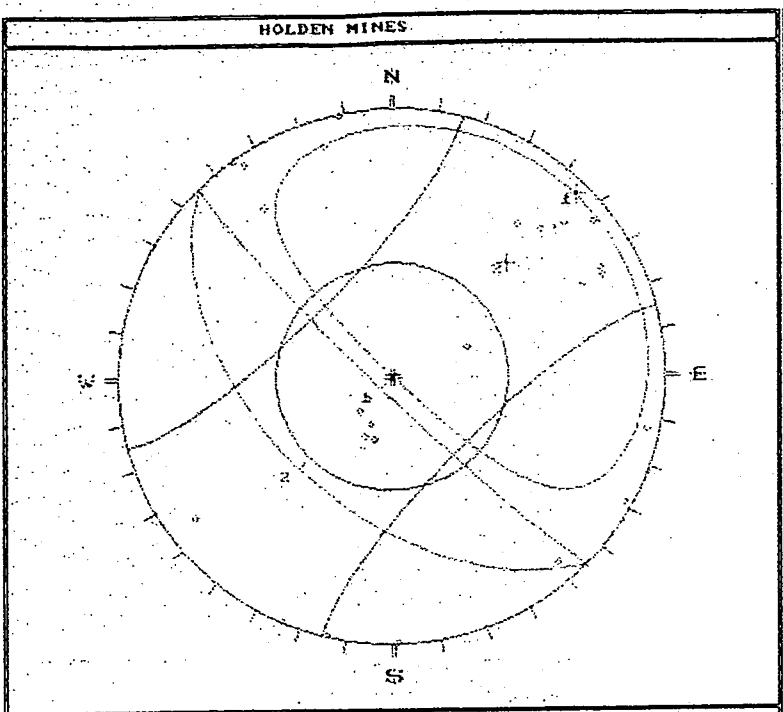
17693B29.CDR

HOLDEN MINES



SCANLINE 3 - SW WALL N45W85SW

POLE PLOT

TRAVERSE

scanline 3

traverse 5

OTHERS

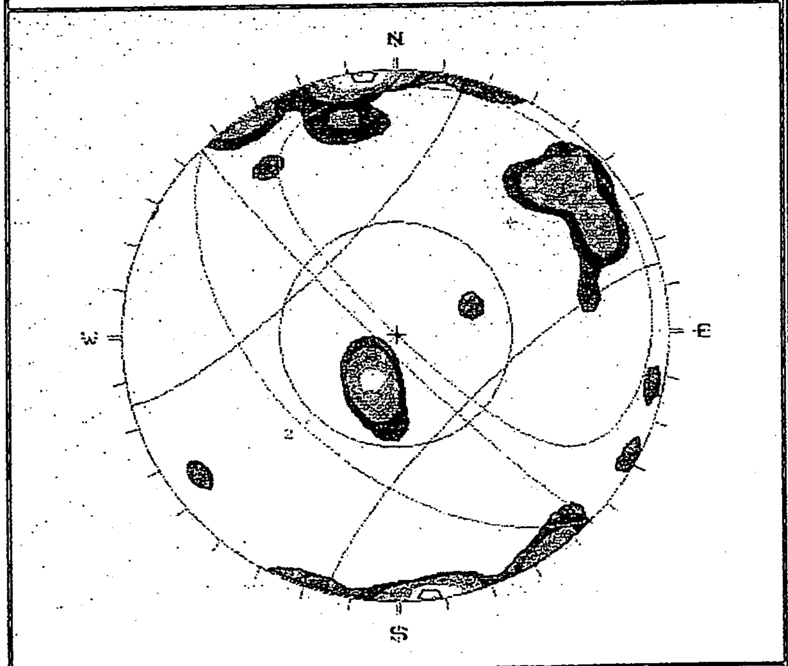
EQUAL AREA

LWR. HEMISPHERE

36 POLES

36 ENTRIES

HOLDEN MINES



SCANLINE 3 - SW WALL N45W85SW

CONTOUR PLOT

FISHER POLE CONCENTRATIONS
% of total per 1.0 % area

< 0 %
< 2.5 %
< 5 %
< 7.5 %
< 10 %
< 12.5 %
< 15 %
< 17.5 %

EQUAL AREA

LWR. HEMISPHERE

36 POLES
36 ENTRIES

NO BIAS CORRECTION

Figure 4.2-21f

HOLDEN MINE SUBSIDENCE POTENTIAL ASSESSMENT SCANLINE 3 – SW WALL STEREONET

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17693B29.CDR

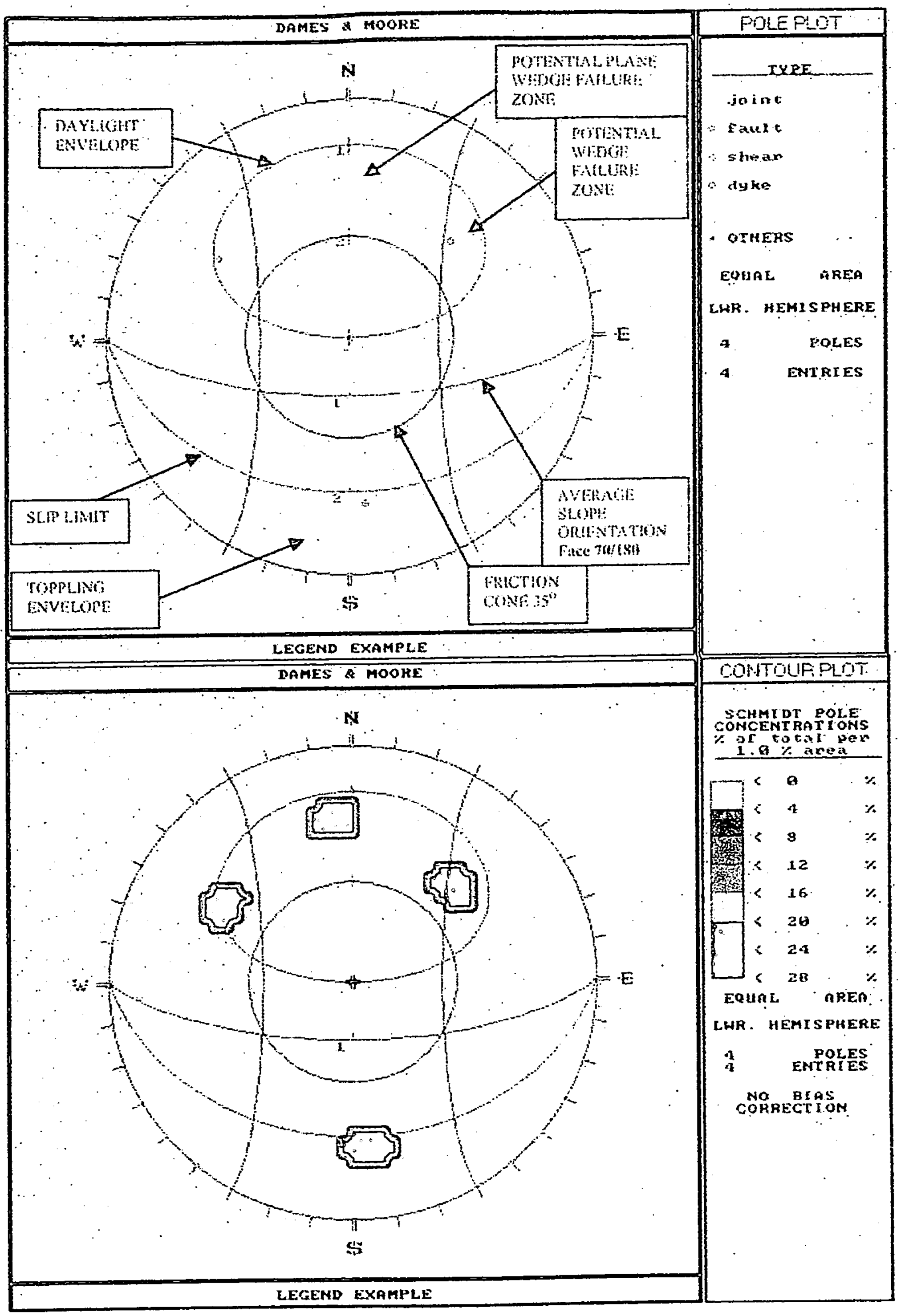

Figure 4.2-21g

HOLDEN MINE SUBSIDENCE POTENTIAL ASSESSMENT STEREOGRAPHIC PROJECTION LEGEND

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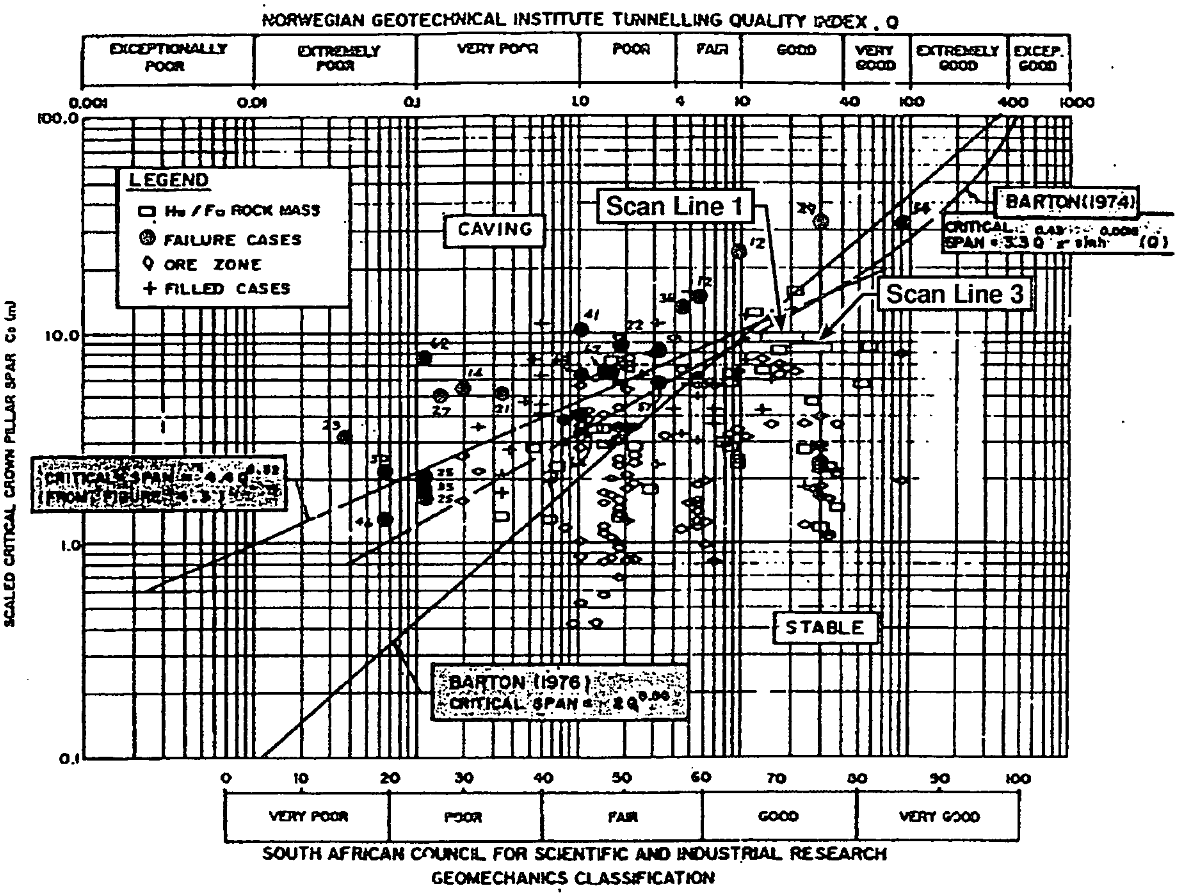
17693B30.CDR



$$C_s = L\left[\frac{\gamma_r}{t\,(1 + L/S)(1 - 0.4\cos\psi)}\right]^{0.5}$$

SOURCE: Golder and Associates, 1990

Figure 4.2-21h

CRITICAL EMPIRICAL SPAN/THICKNESS FOR SURFACE CROWN PILLARS

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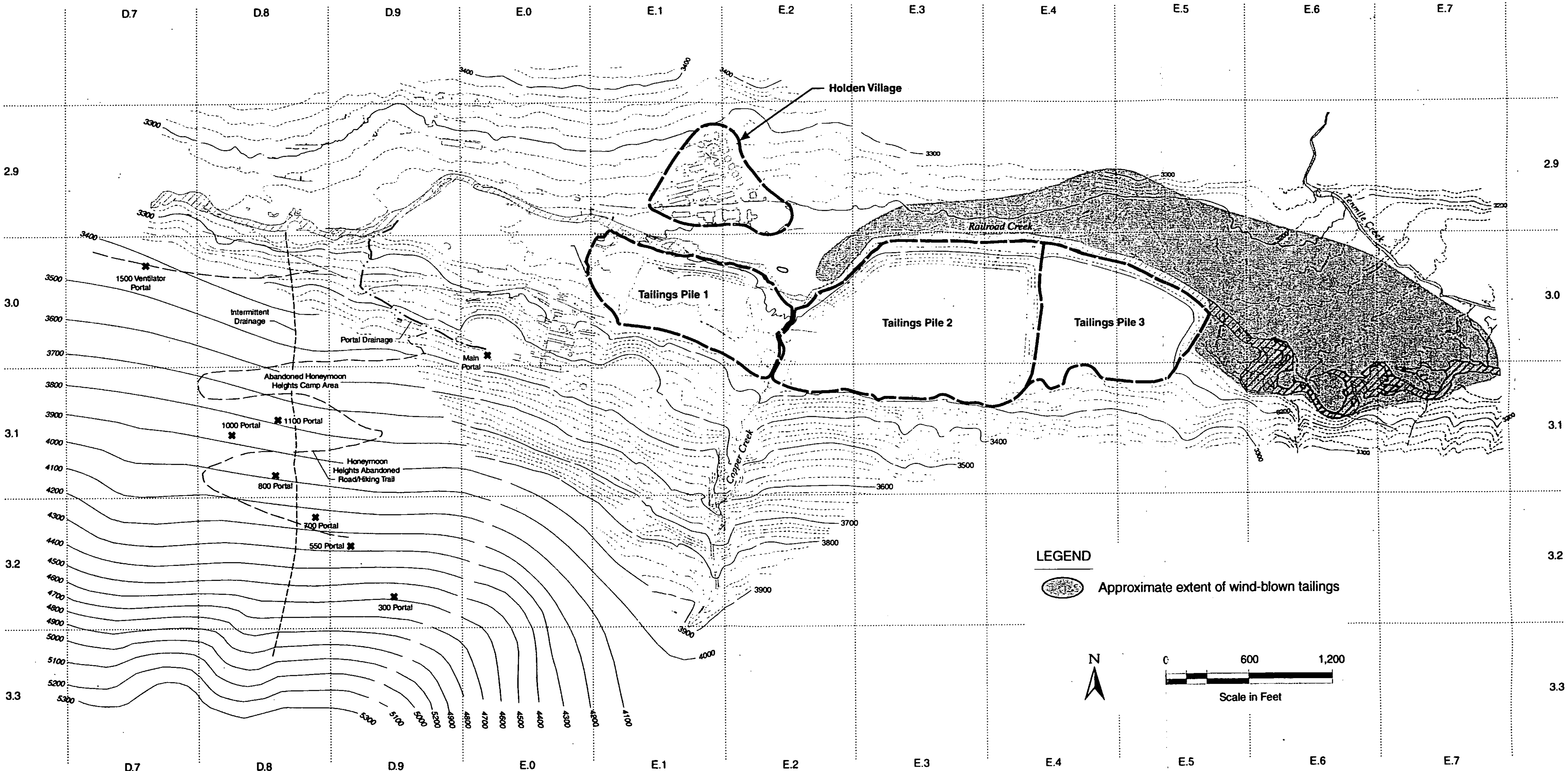
17693B31.CDR



SOURCE: Base map information from USFS and Washington DNR, DEM CD ROM

Figure 4.2-22

APPROXIMATE EXTENT OF WIND-BLOWN TAILINGS

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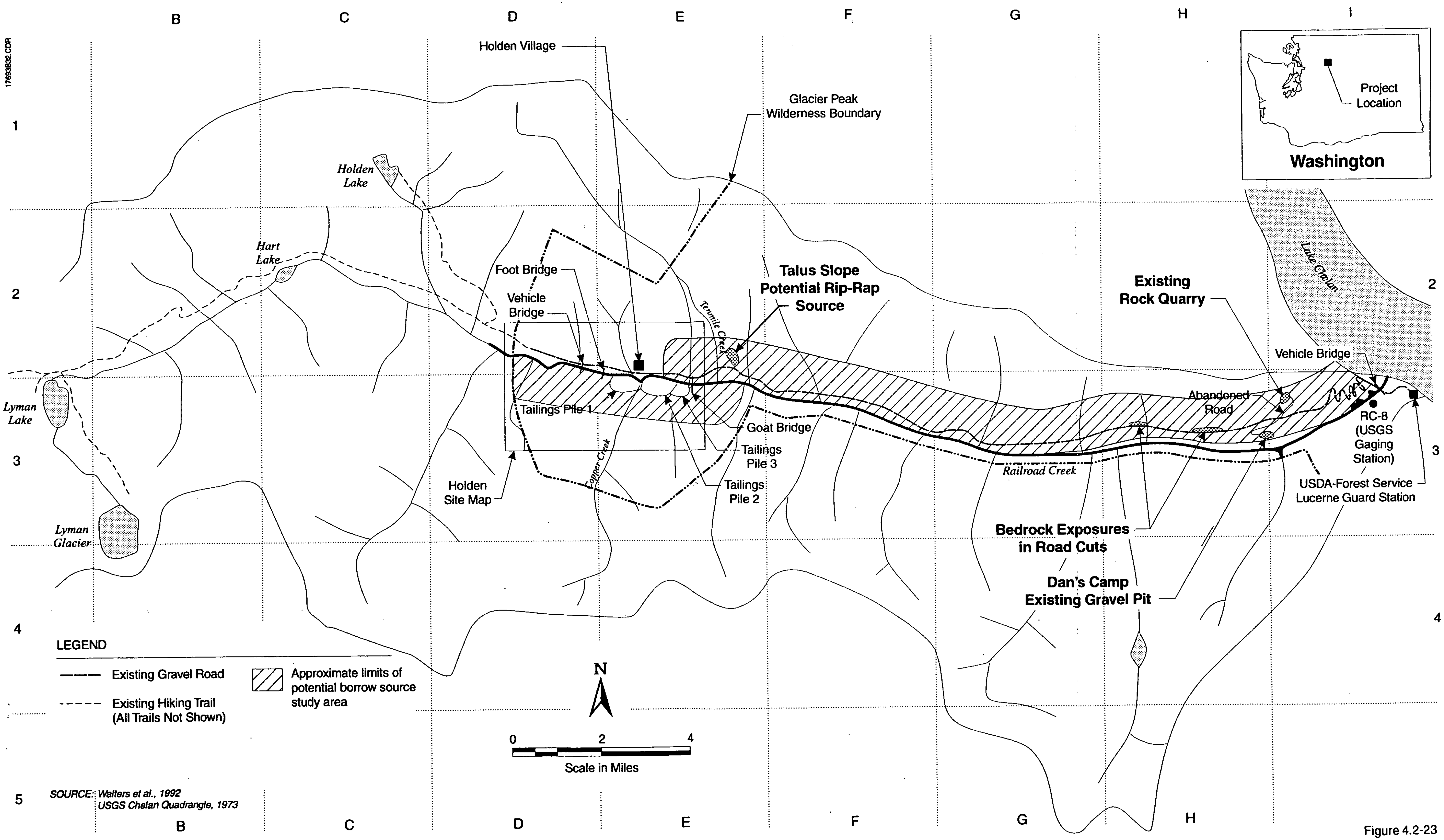

SOURCE: Walters et al., 1992
USGS Chelan Quadrangle, 1973

Figure 4.2-23

RAILROAD CREEK
EXISTING AND POTENTIAL BORROW SOURCE STUDY AREAS MAP

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17693B27.CDR

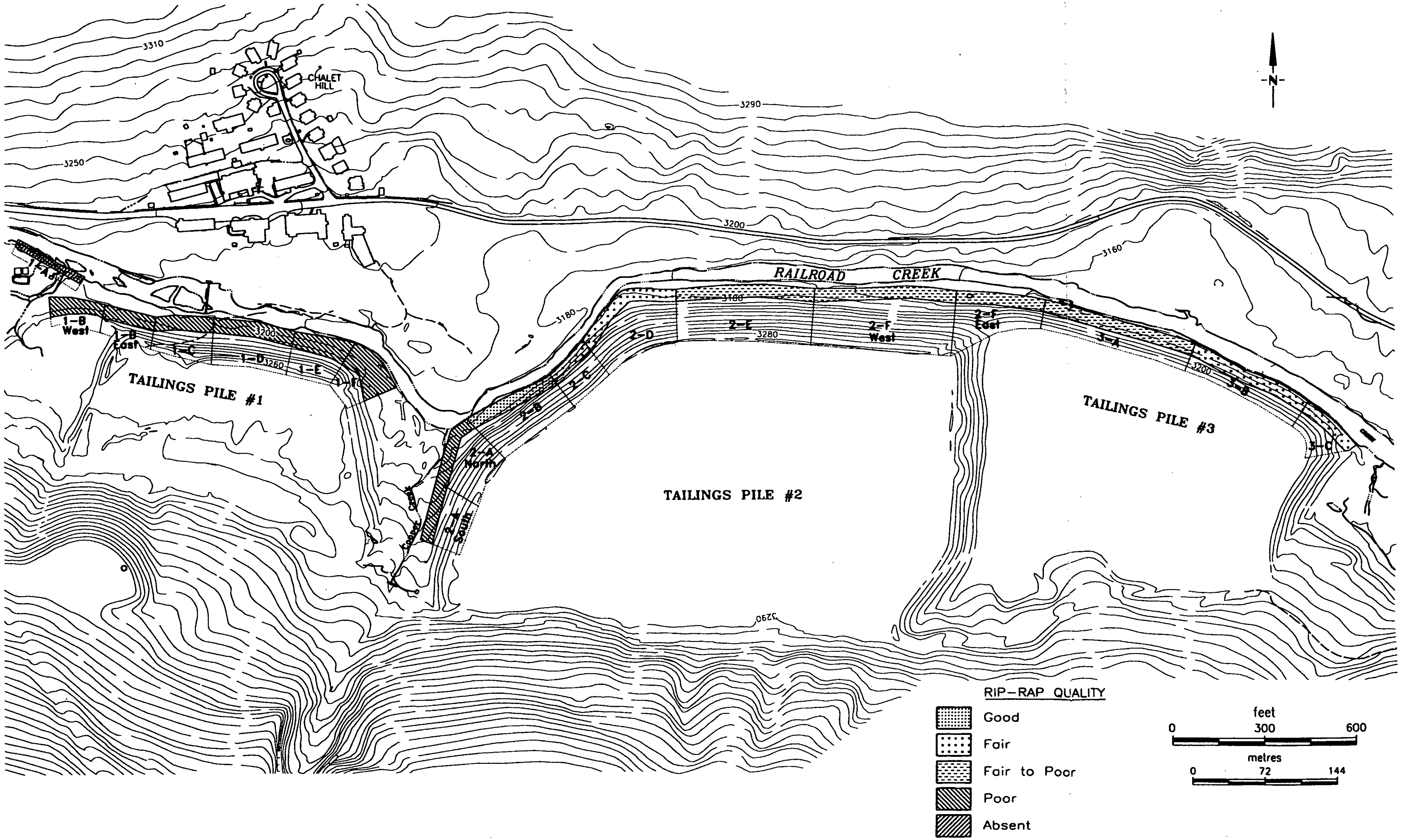

Figure 4.2-24

HOLDEN MINE SITE RIP-RAP CONDITION MAP

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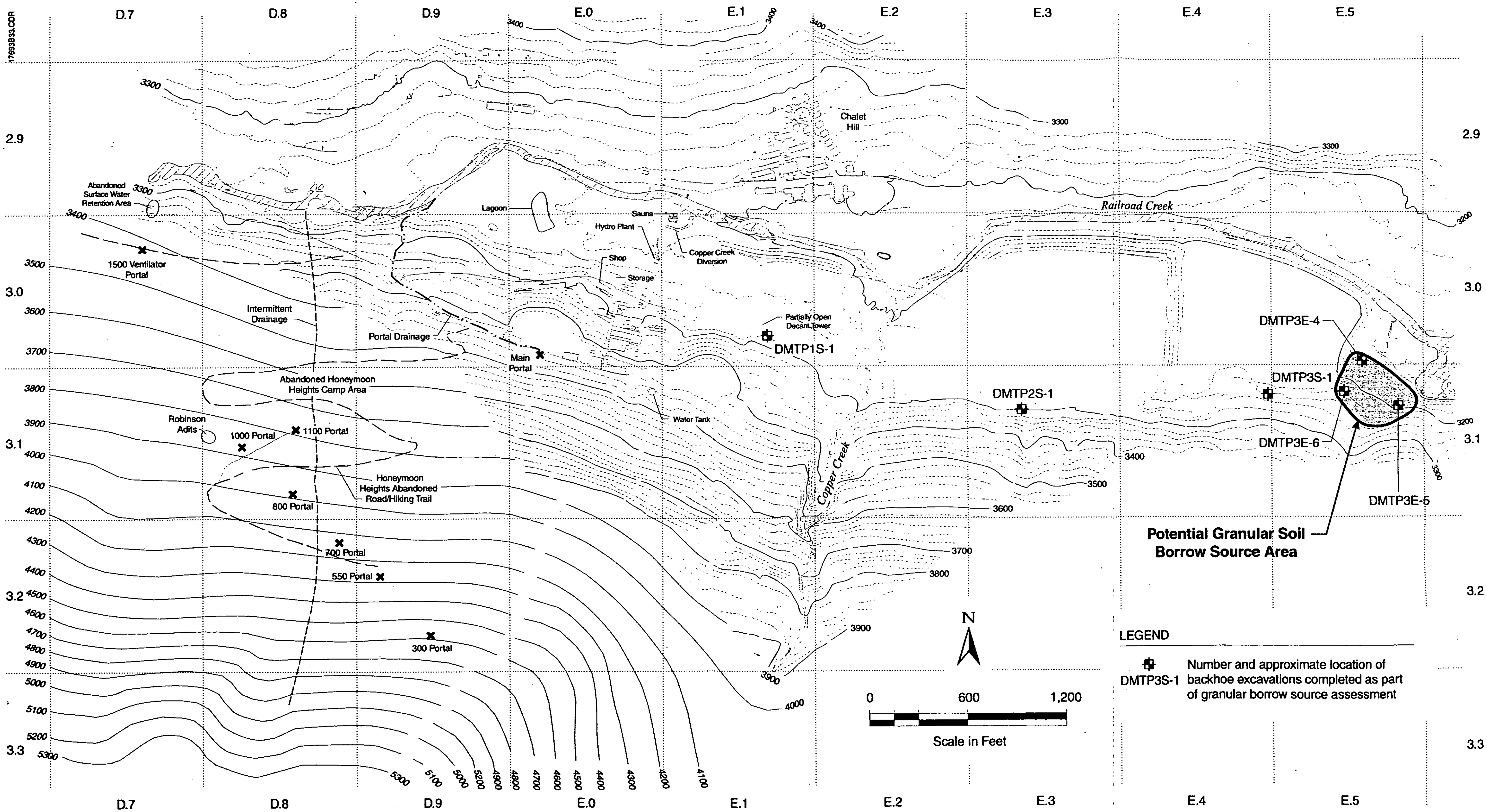

SOURCE: Base map information from USFS and Washington DNR, DEM CD ROM

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Figure 4.2-25

HOLDEN MINE SITE
POTENTIAL BORROW SOURCE AREAS MAP

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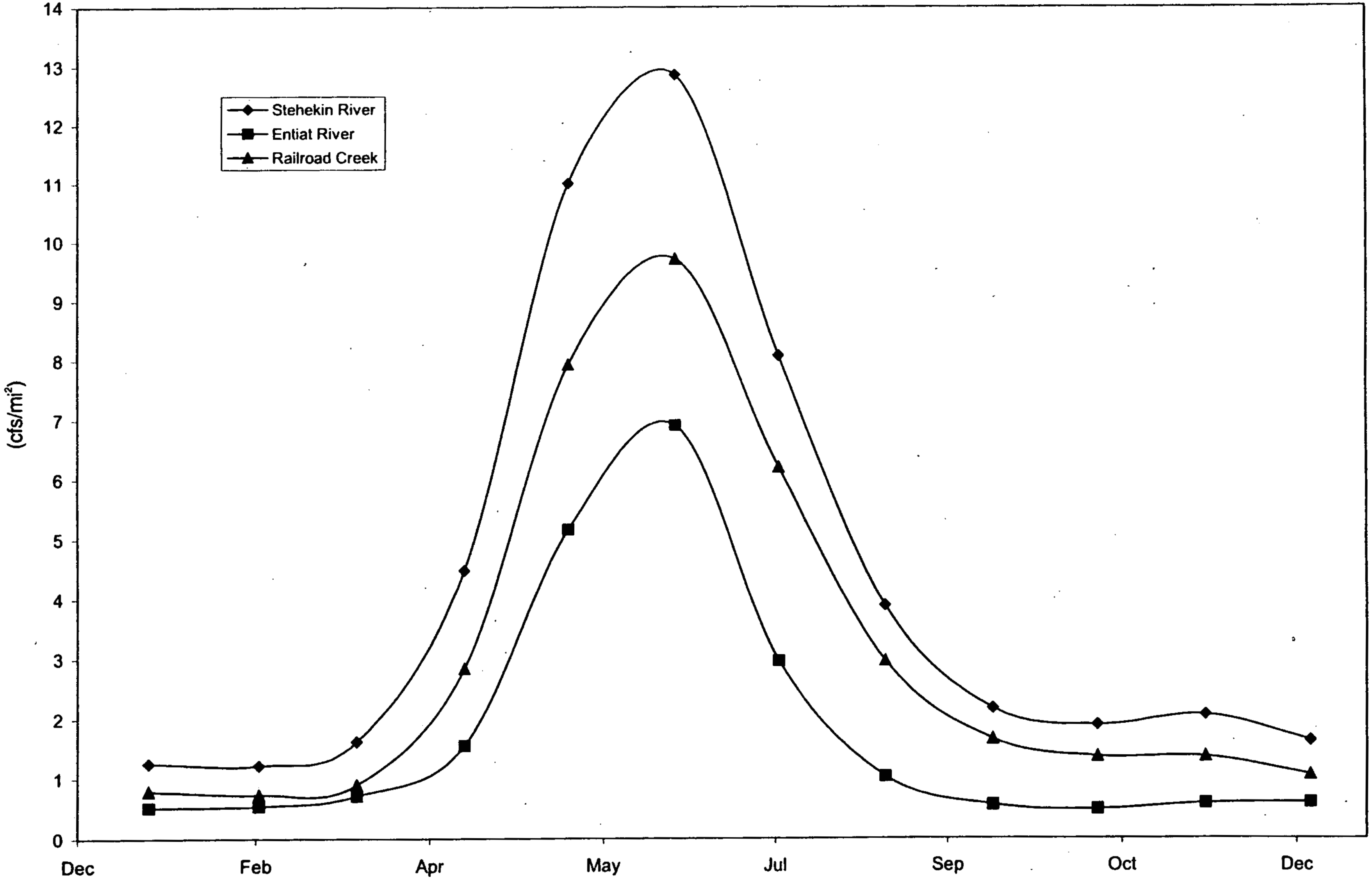

Source: USGS, 1997.

Figure 4.3-1

AVERAGE MONTHLY FLOW PER UNIT AREA OF WATERSHED RAILROAD CREEK, STEHEKIN RIVER AND ENTIAT RIVER, 1997

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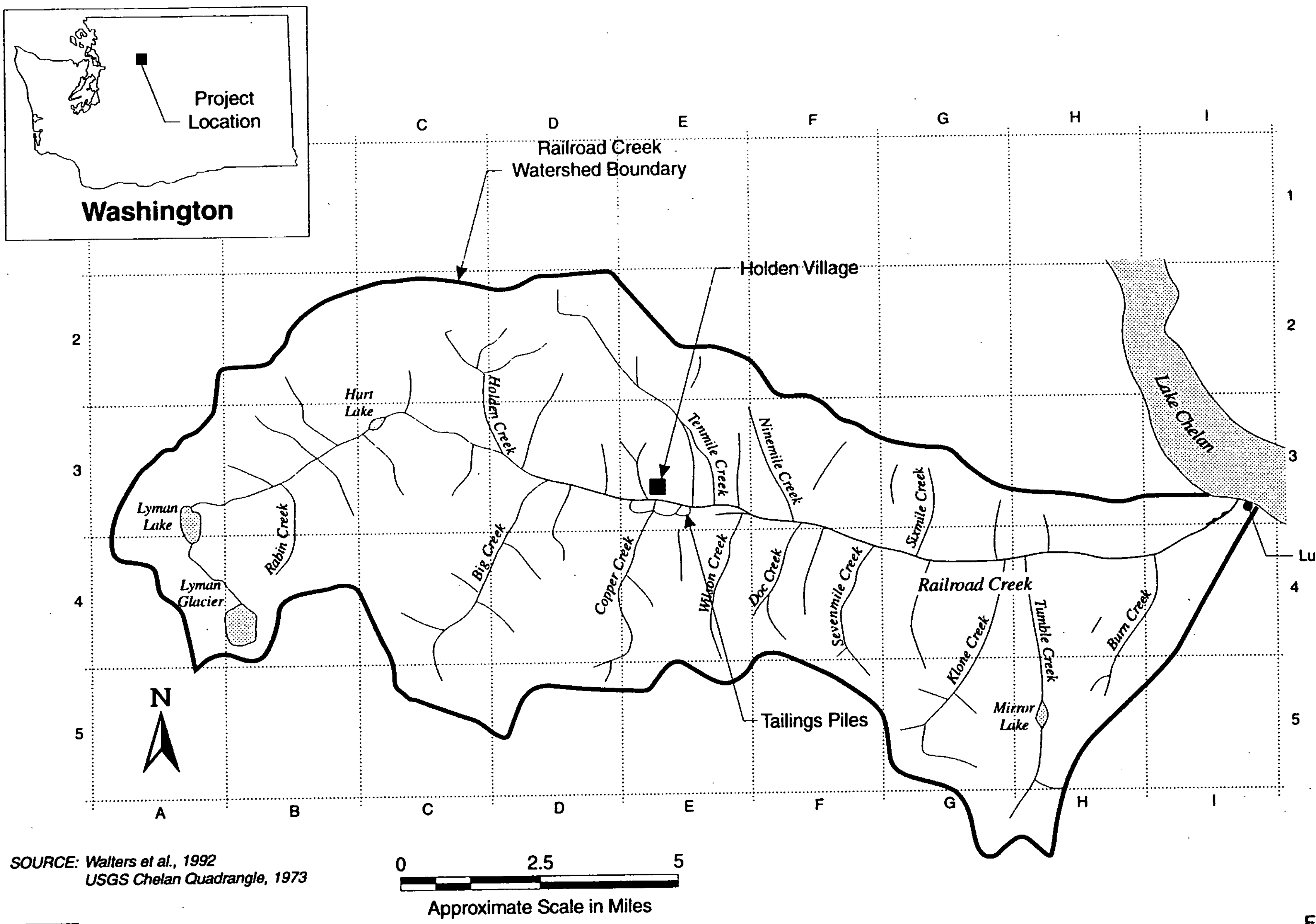
17693B35.CDR



SOURCE: *Walters et al., 1992*
USGS Chelan Quadrangle, 1973

Figure 4.3-2

RAILROAD CREEK WATERSHED

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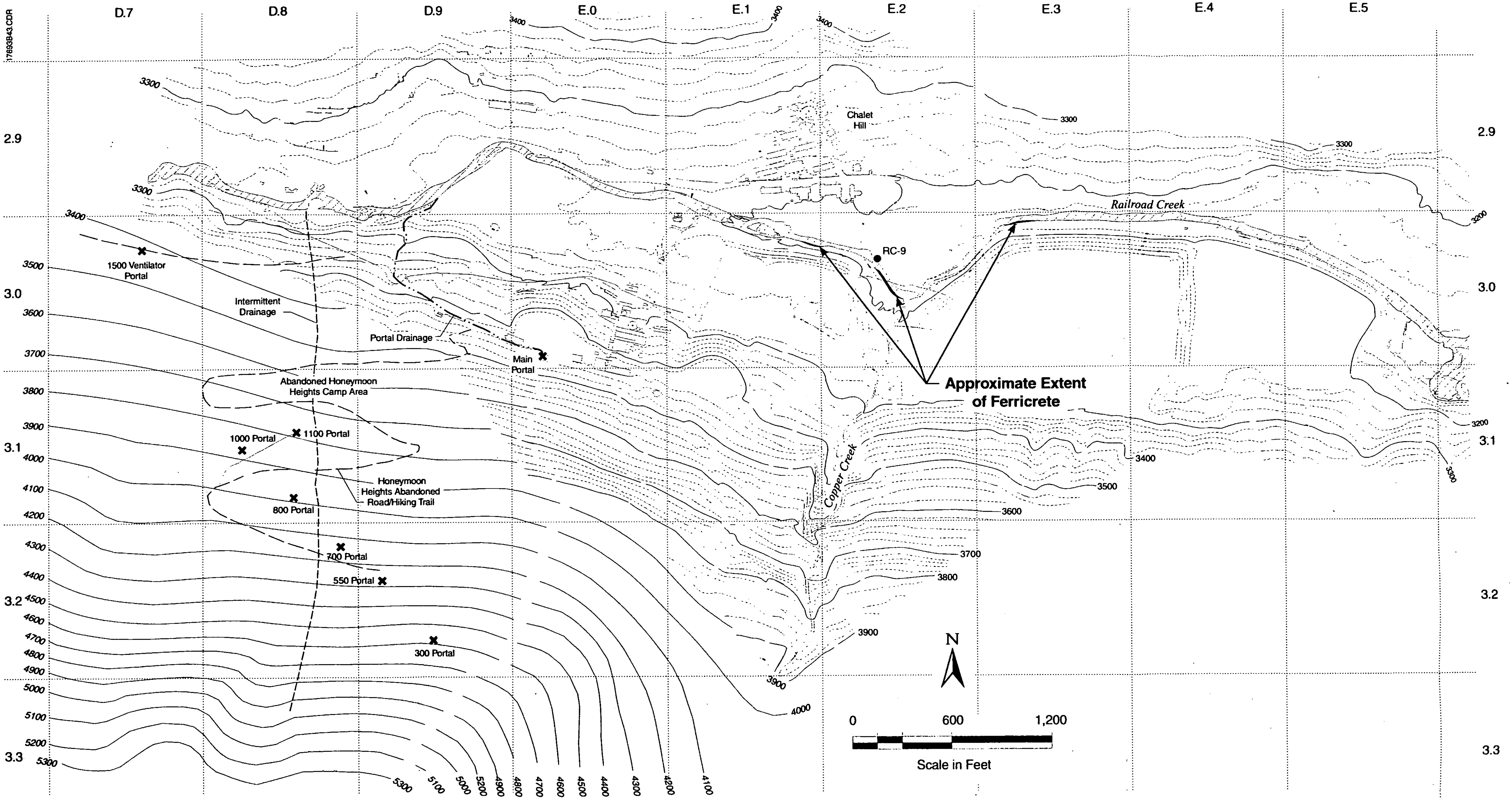

SOURCES: *Base map information from USFS and Washington DNR, DEM CD ROM*
USBM (unpublished), 1994
Dames & Moore RI, 1997

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Figure 4.3-3d
APPROXIMATE EXTENT OF EXPOSED FERRICRETE IN RAILROAD CREEK

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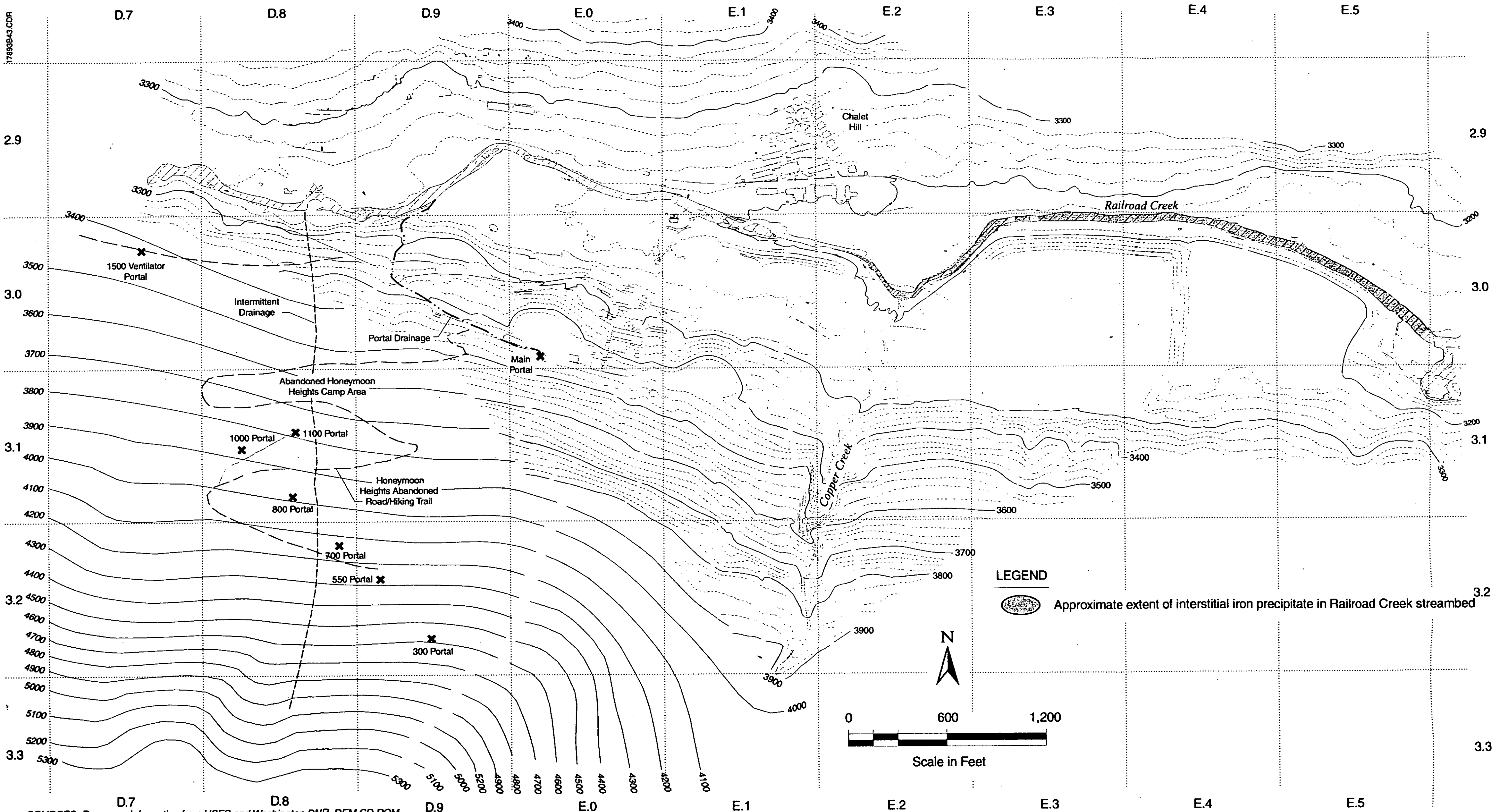

SOURCES: Base map information from USFS and Washington DNR, DEM CD ROM
USBM (unpublished), 1994
Dames & Moore RI, 1997
U.S.B.M., 1994, Unpublished map provided by Robert Lambeth

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Figure 4.3-3c

APPROXIMATE EXTENT OF INTERSTITIAL IRON OXIDE PRECIPITATE IN RAILROAD CREEK

Holden Mine RI/FS
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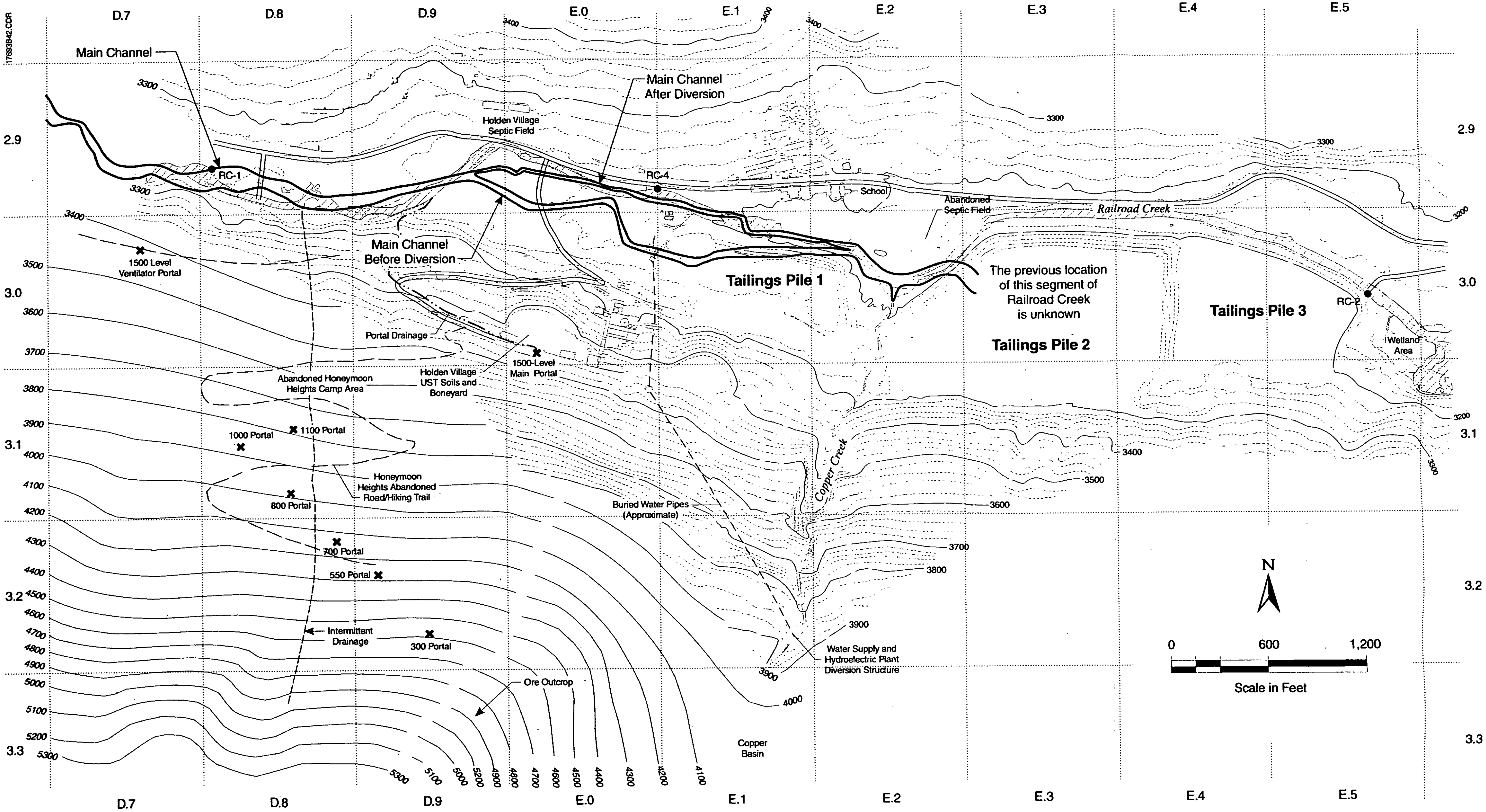

SOURCES: *Base map information from USFS and Washington DNR, DEM CD ROM. Relocation of Railroad Creek based on Howe Saund Co. map dated 1937.*

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Figure 4.3-3b

HOLDEN MINE SITE MAP
RAILROAD CREEK CHANNEL - 1937

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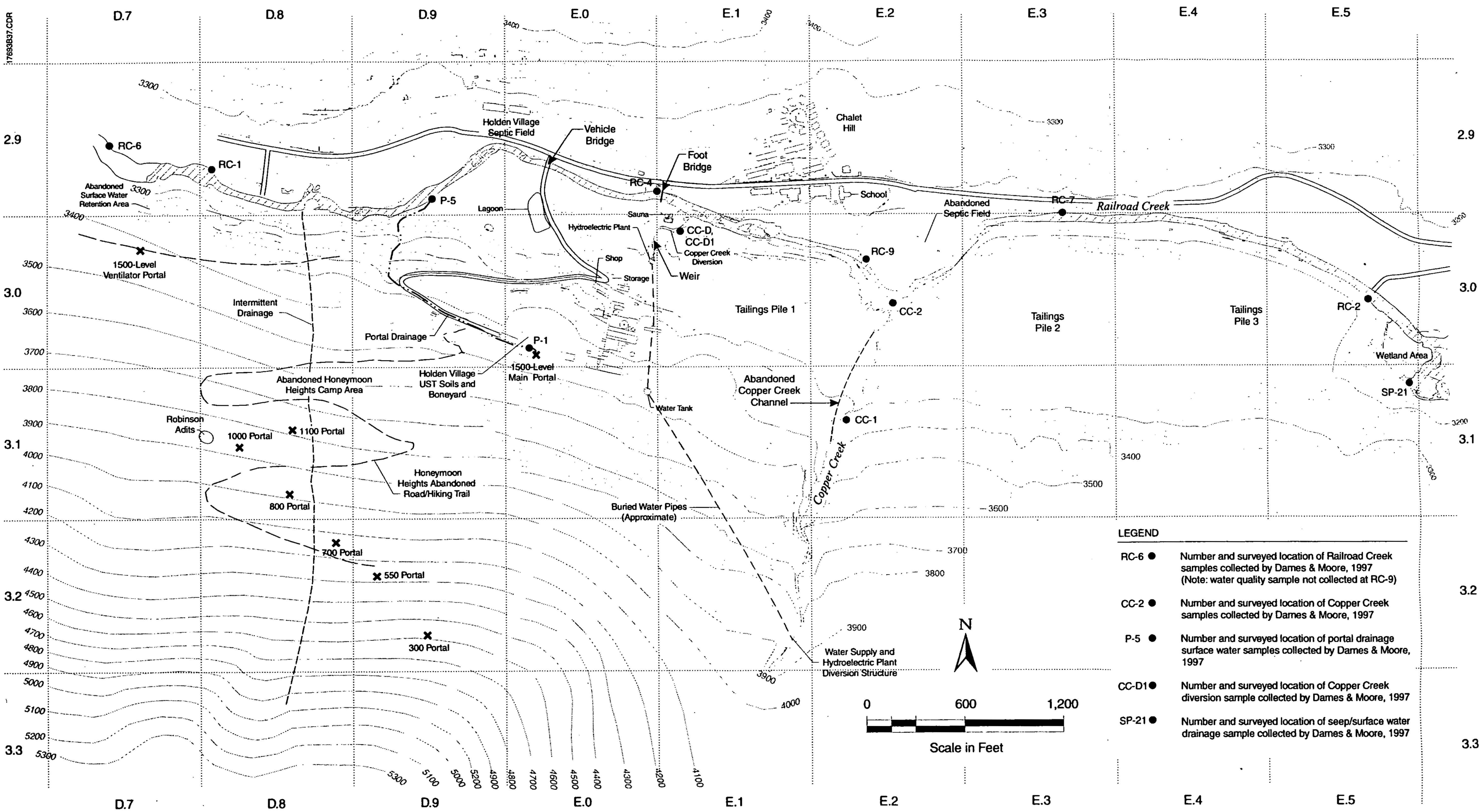
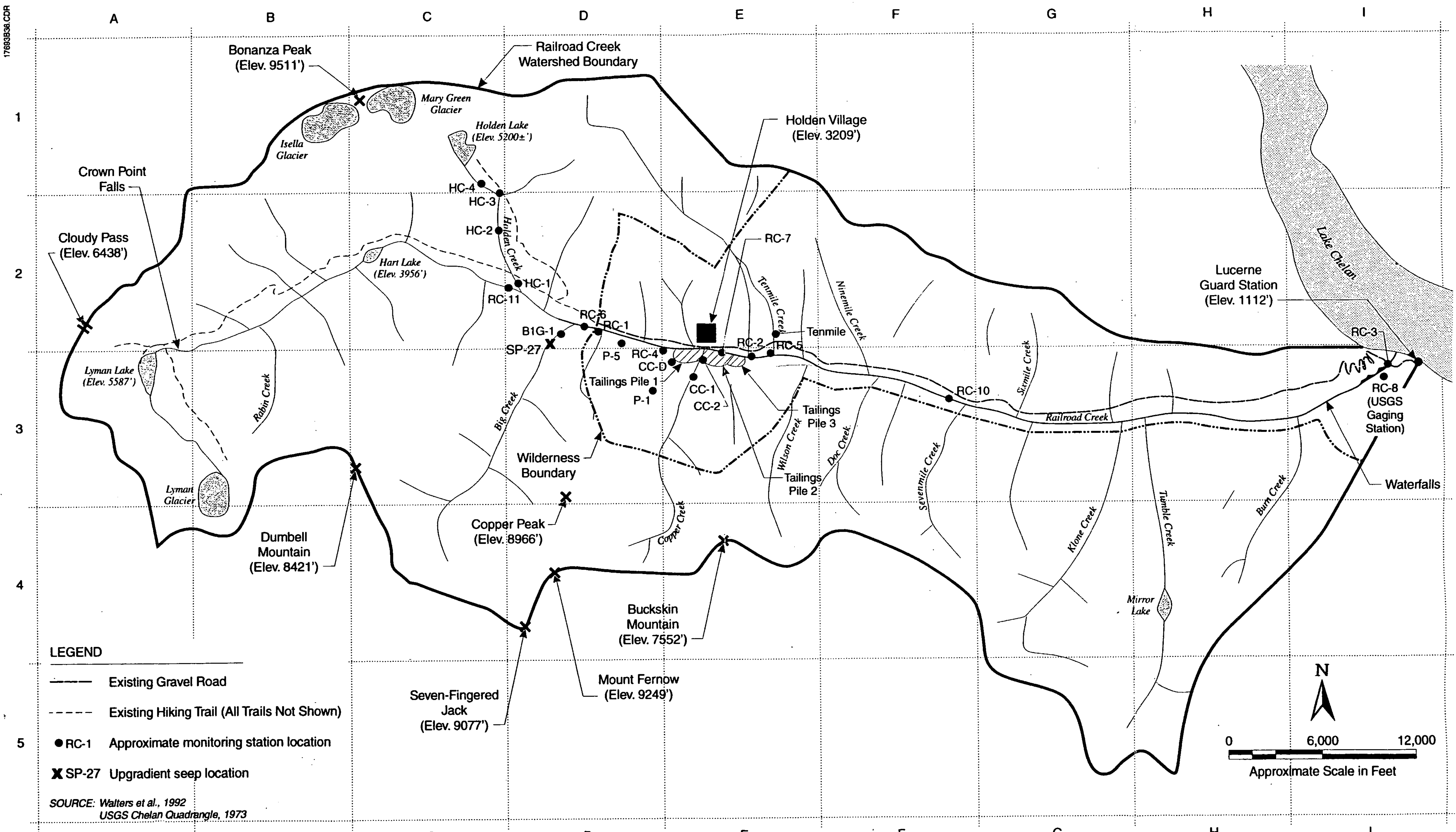


SOURCE: Base map information from USFS and Washington DNR, DEM CD ROM

Figure 4.3-3a

STREAM FLOW AND WATER QUALITY MONITORING STATIONS - SITE

17693B38.CDR



SOURCE: Walters et al., 1992
USGS Chelan Quadrangle, 1973

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Figure 4.3-3

STREAMFLOW AND WATER QUALITY MONITORING STATIONS - RAILROAD CREEK

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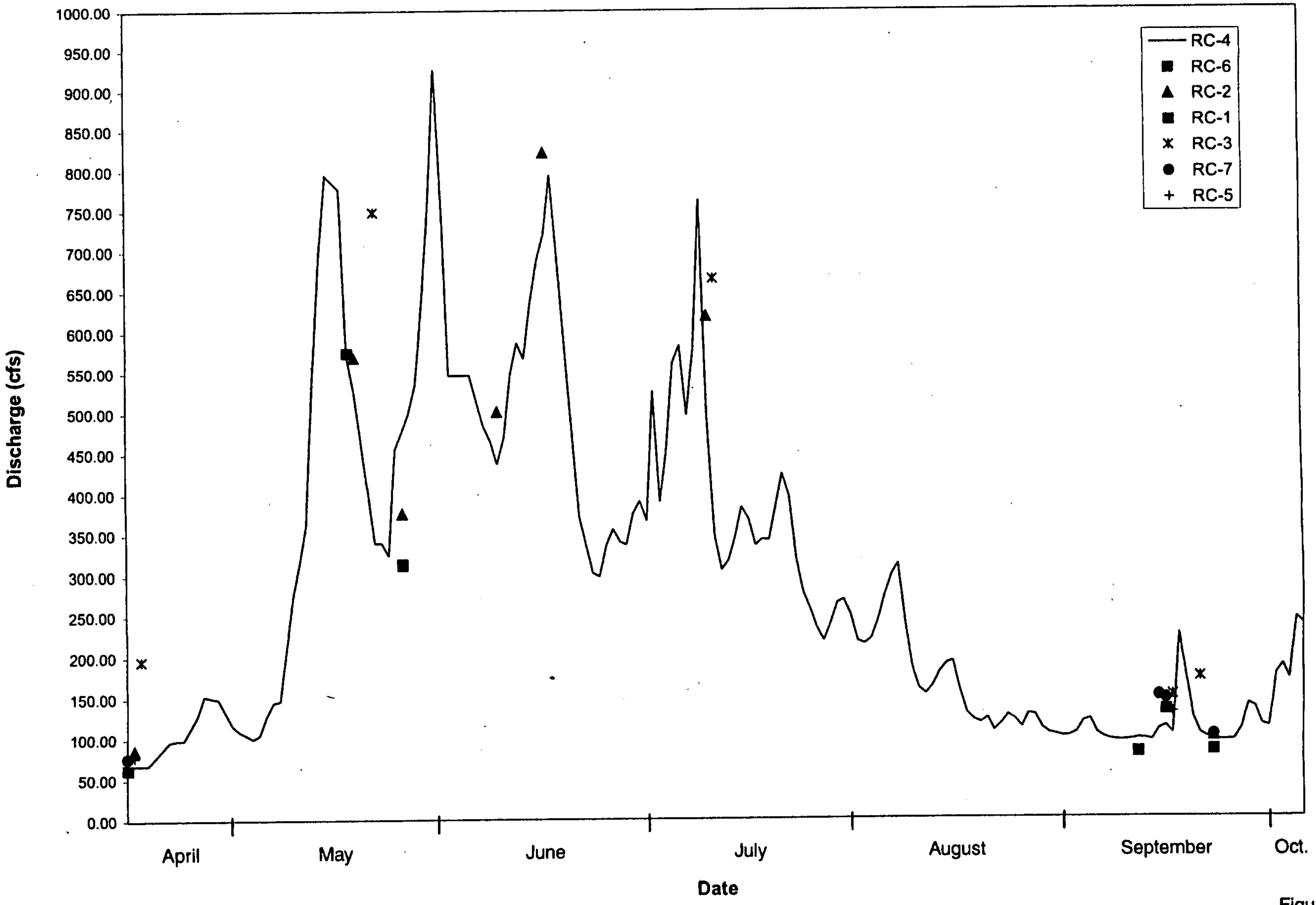

Figure 4.3-4

RC-4 DAILY AVERAGE FLOW FOR APRIL THROUGH OCTOBER 1997

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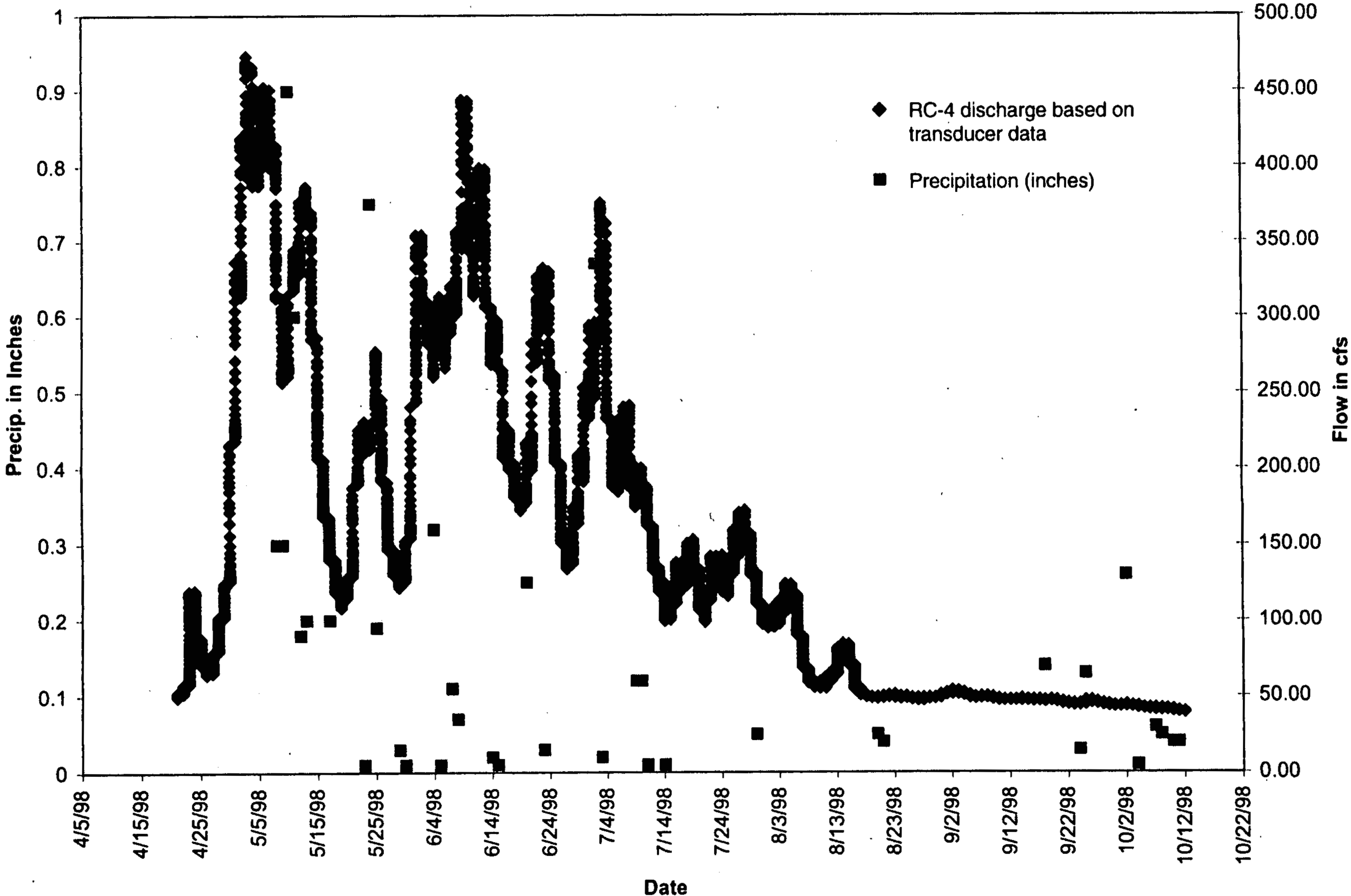
17693B34.CDR



SOURCE: RC-4 discharge data from Dames & Moore transducer precipitation data from Holden Village (see Appendix H)

Figure 4.3-4a

RC-4 DAILY AVERAGE FLOW FOR APRIL THROUGH OCTOBER 1998

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Job No. 17693-005-019

17693B34.CDR

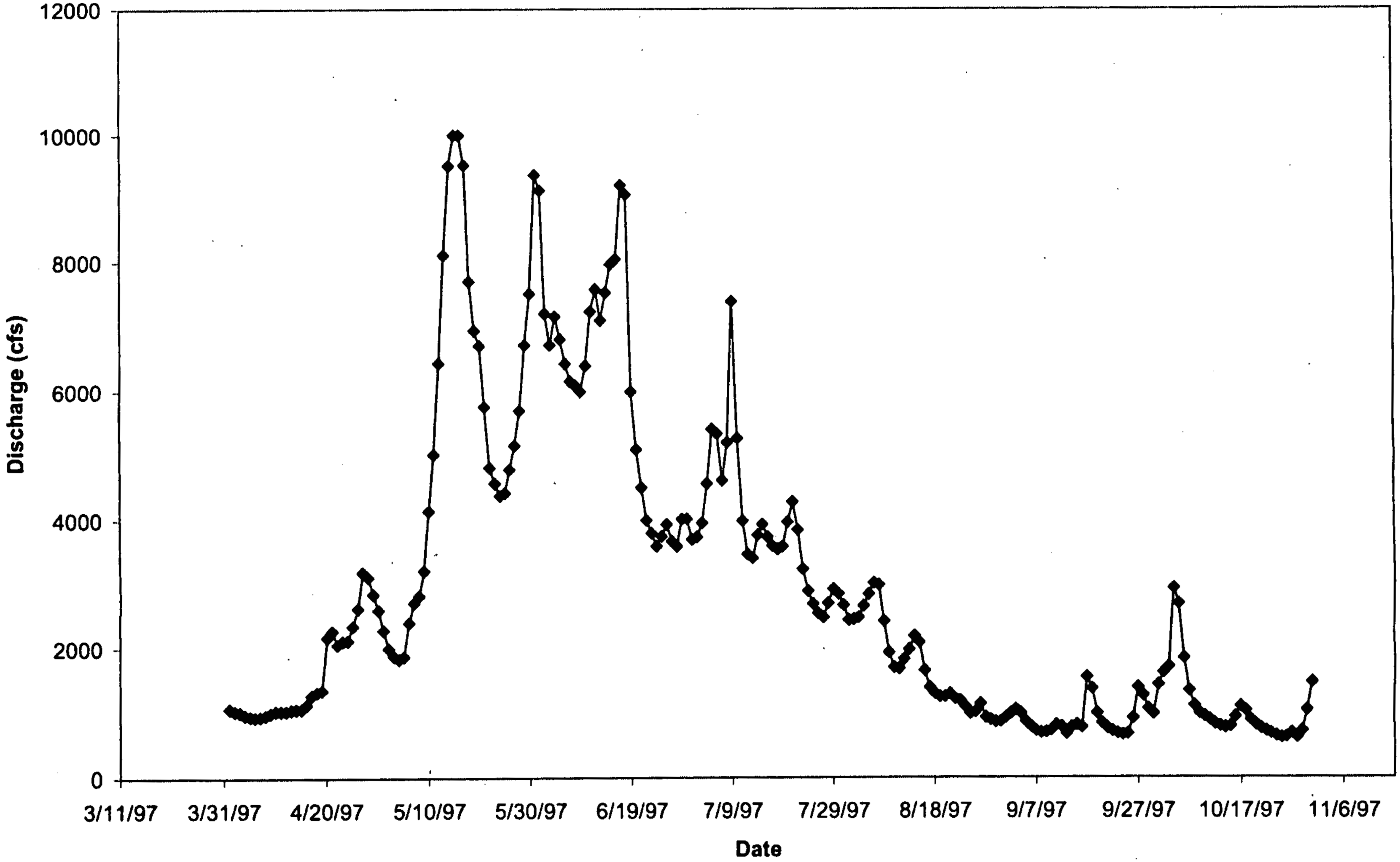

Figure 4.3-5

STEHEKIN RIVER DAILY HYDROGRAPH
FOR APRIL 1 THROUGH NOVEMBER 1, 1997

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17693B34.CDR

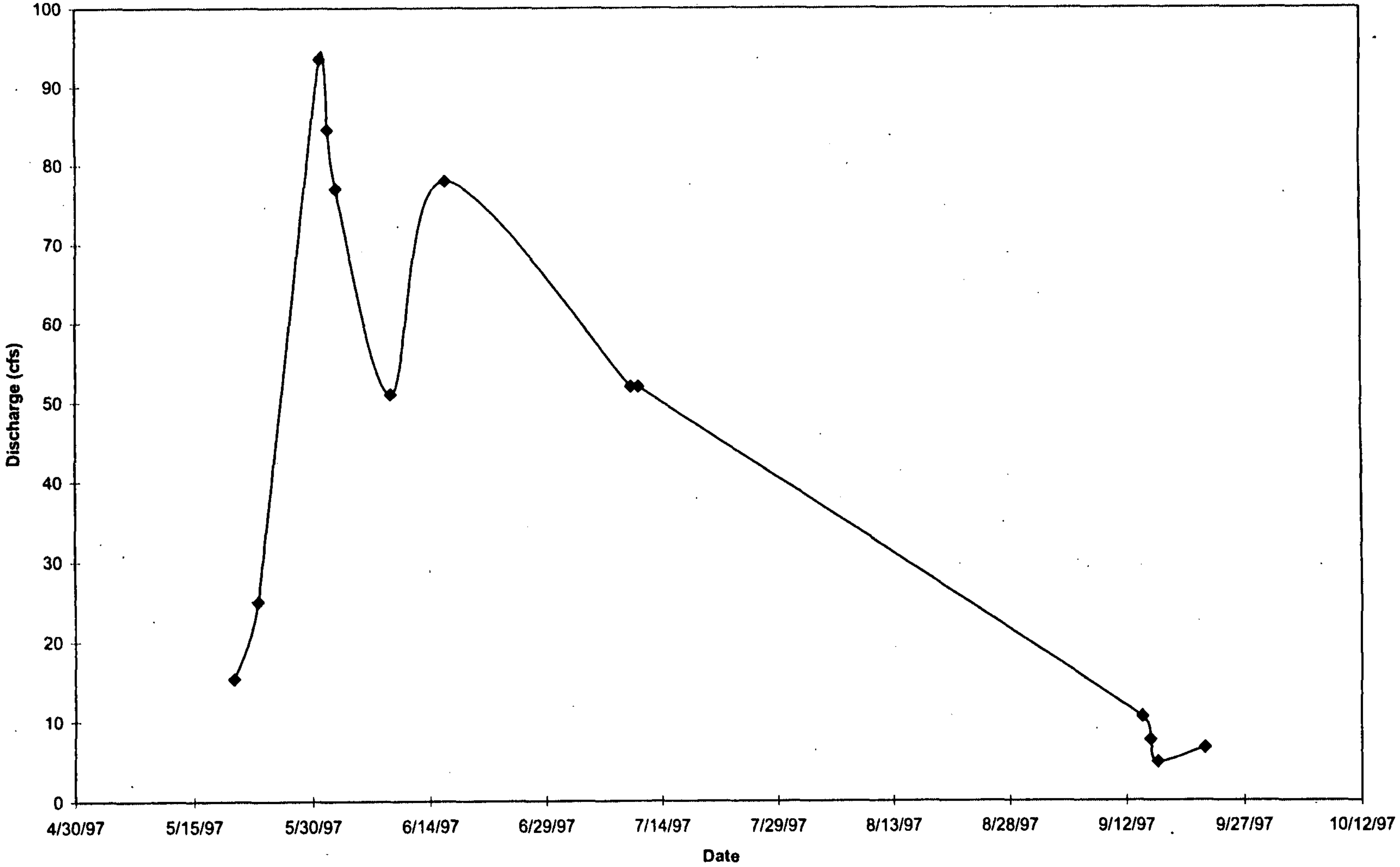

Figure 4.3-6

COPPER CREEK HYDROGRAPH FOR MAY 18 THROUGH SEPTEMBER 15, 1997

DAMES & MOORE
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Job No. 17693-005-019

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Draft Final RI Report

17693B34.CDR

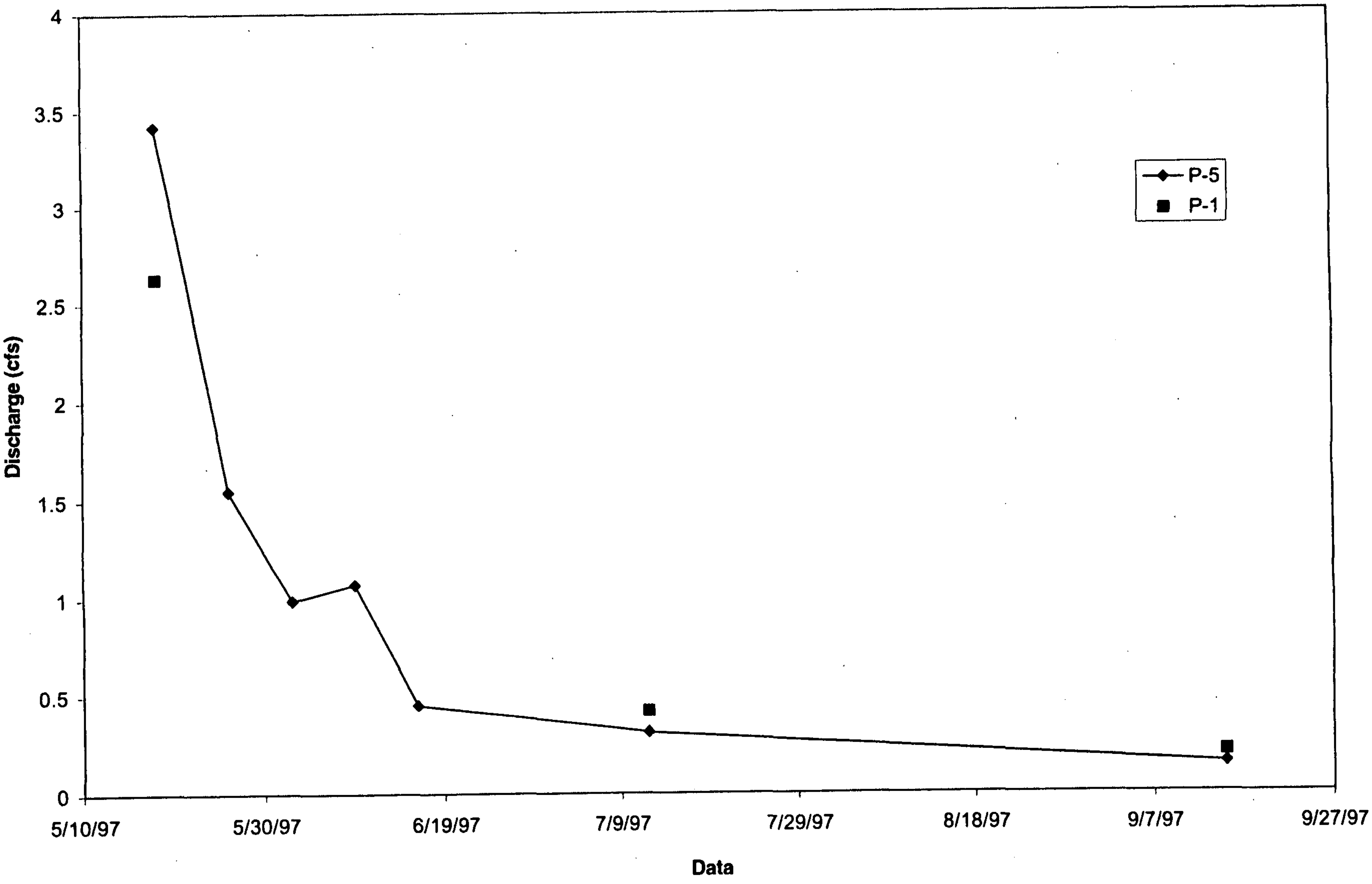

Figure 4.3-7

P-1 AND P-5 HYDROGRAPH FOR MAY 17 THROUGH SEPTEMBER 20, 1997

DAMES & MOORE
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Holden Mine RI/FS
Draft Final RI Report

17693B63.CDR

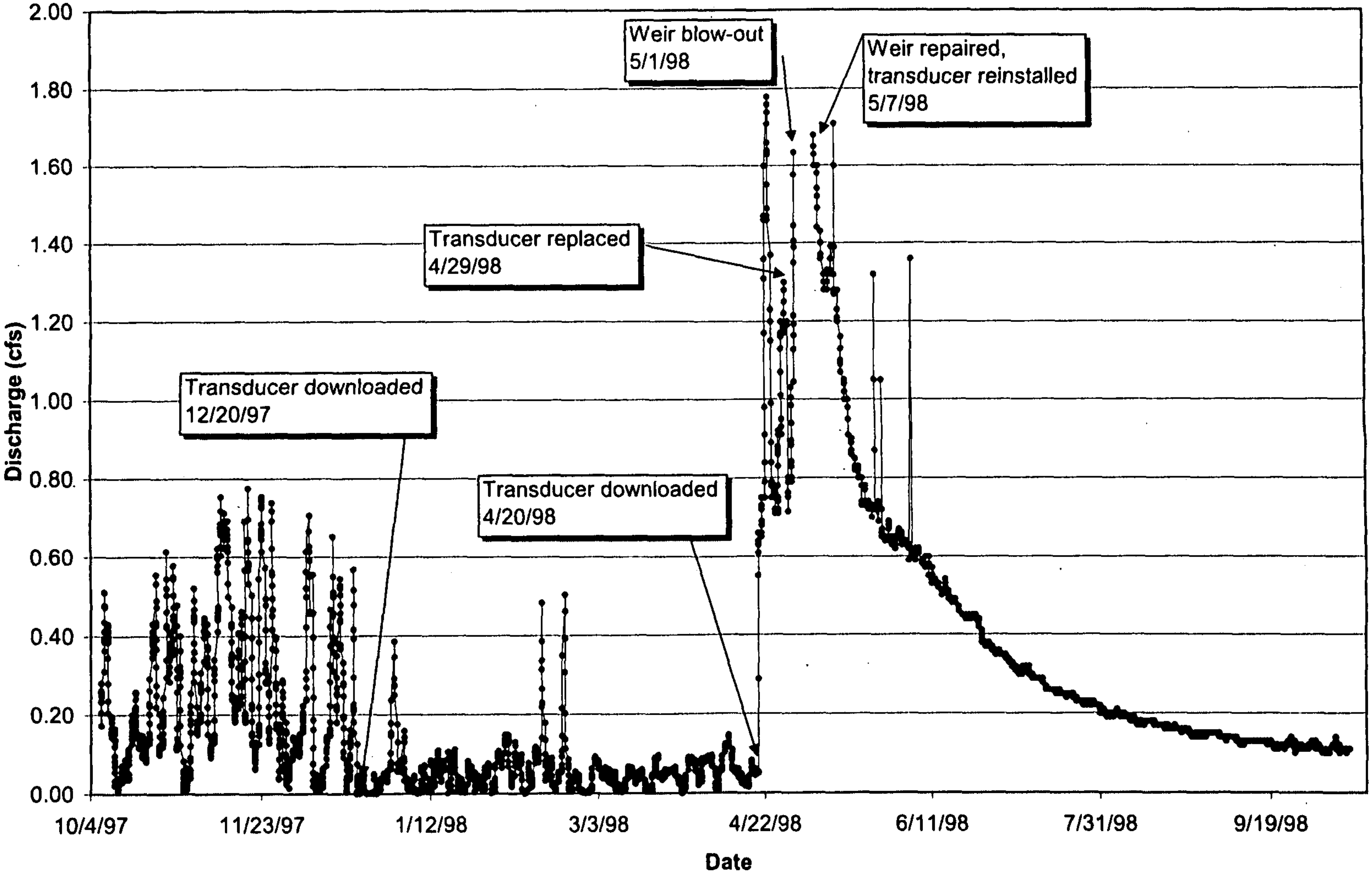

Figure 4.3-7a

DISCHARGE VS. TIME, PORTAL DRAINAGE OCTOBER 1997 THROUGH OCTOBER 1998

DAMES & MOORE
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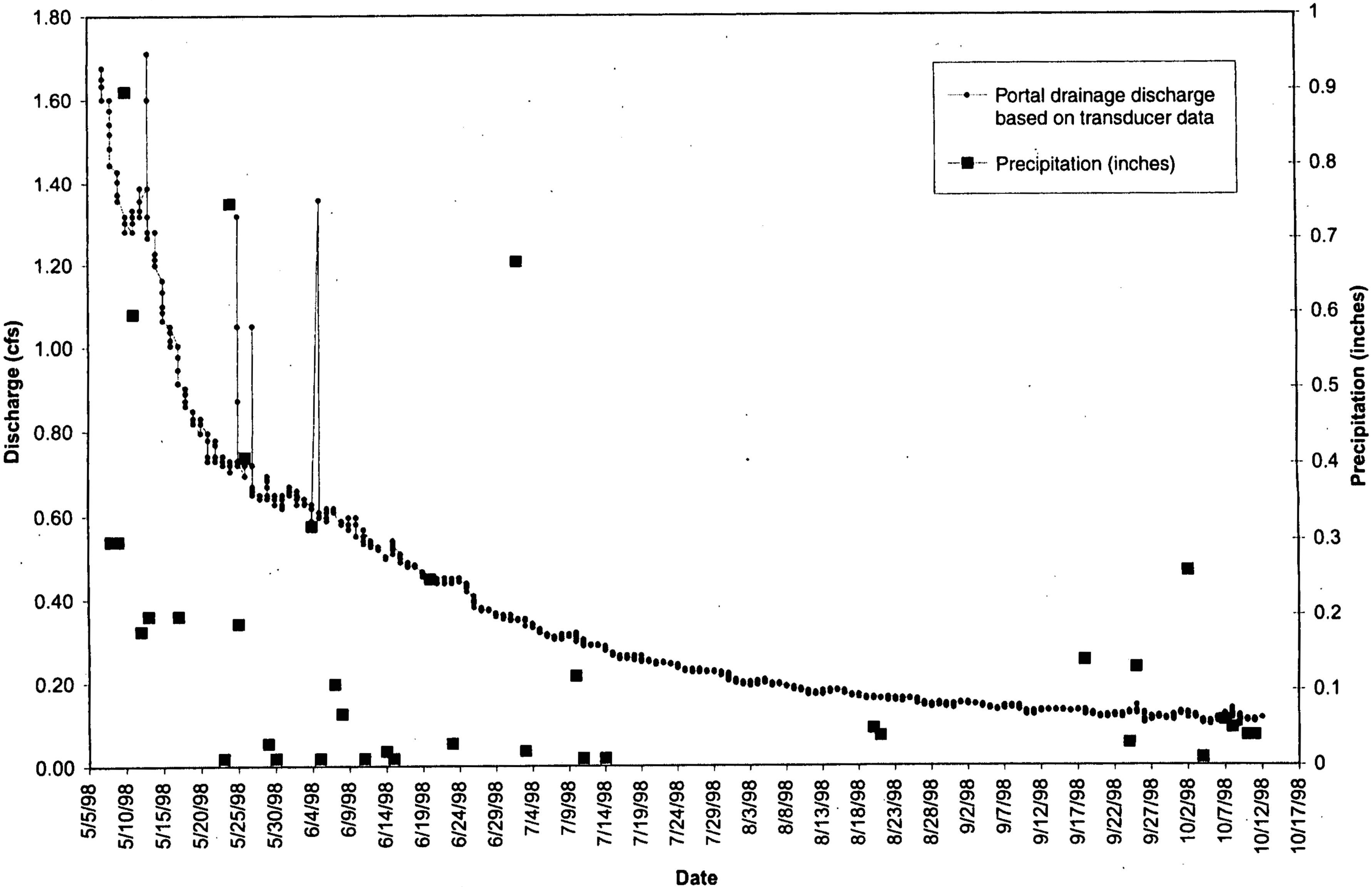
Job No. 17693-005-019

Holden Mine RI/FS
Draft Final RI Report

17693B44.CDR



SOURCE: Portal drainage discharge data from Dames & Moore transducer
Precipitation data from Holden Village (see Appendix H)

Figure 4.3-7b

PORTAL DISCHARGE VS. PRECIPITATION
MAY 1998 THROUGH OCTOBER 1998

DAMES & MOORE
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Draft Final RI Report

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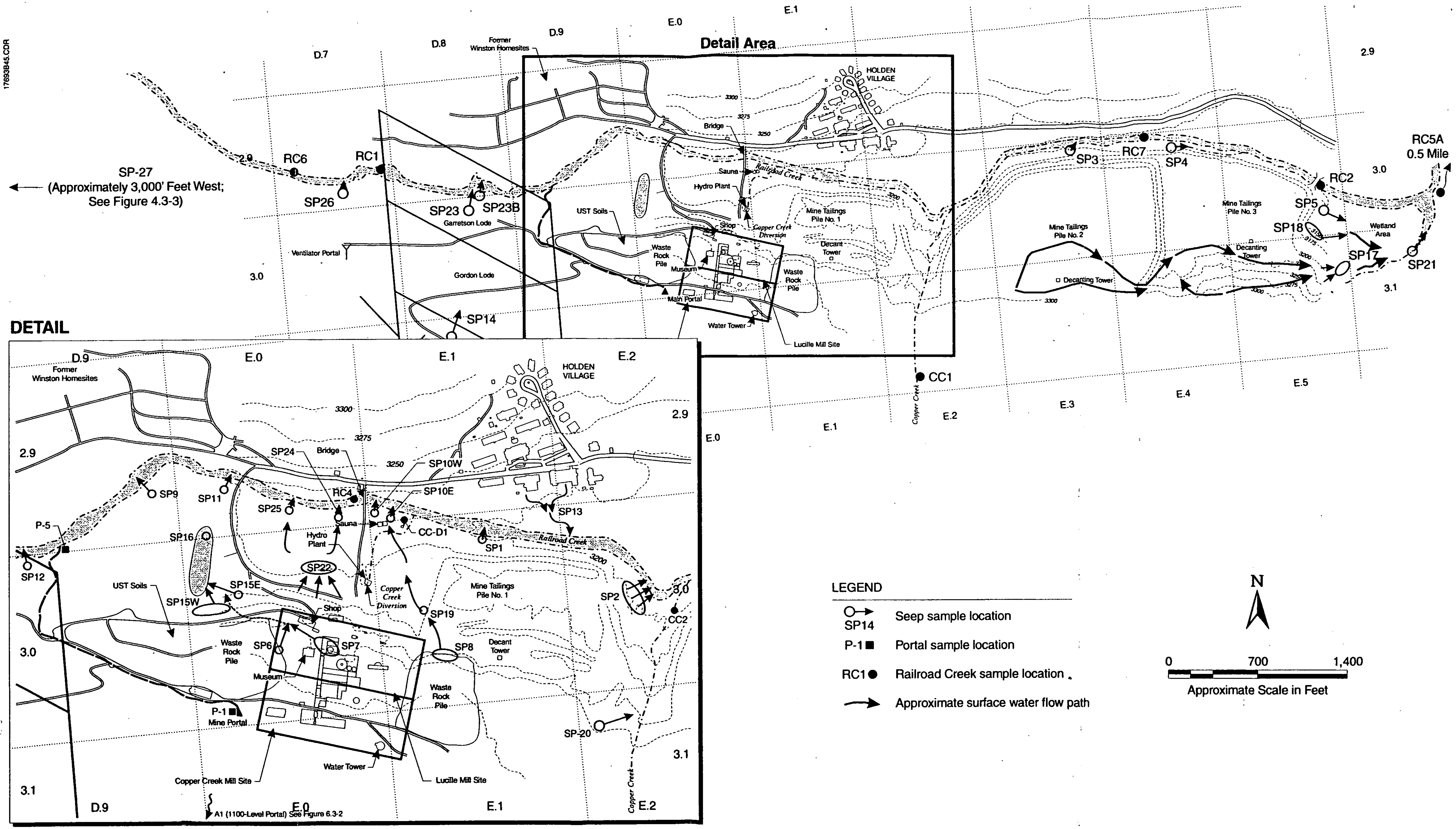
17693B45.CDR



SOURCE: ORB, 1975

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Job No. 17693-005-019

Figure 4.3-8
APPROXIMATE LOCATIONS OF SURFACE WATER RUNON AND RUNOFF - SITE

Holden Mine RI/FS
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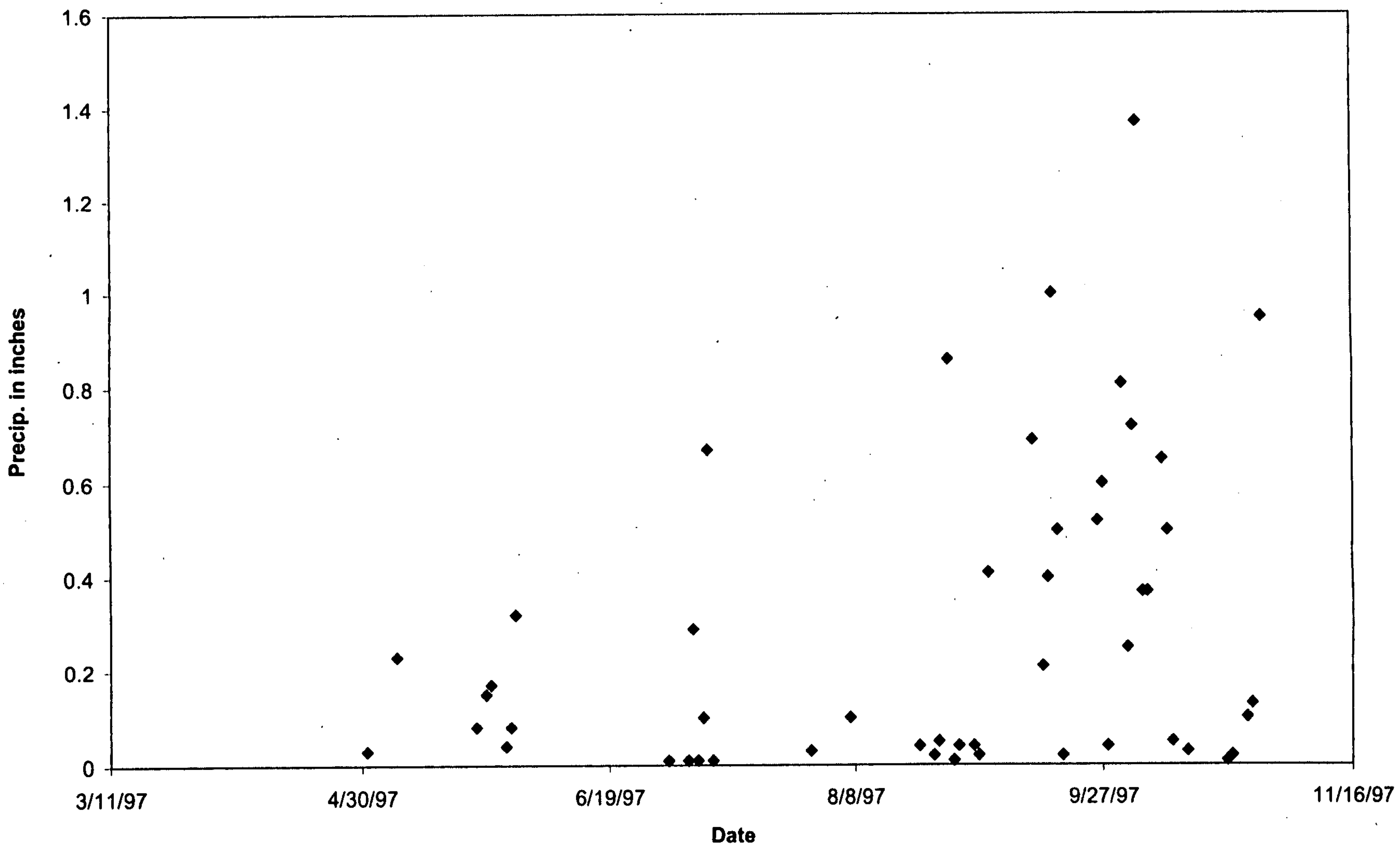
17693B34.CDR



Note: No data available for June 1997

Figure 4.3-9a

HOLDEN VILLAGE PRECIPITATION RECORD
MAY THROUGH OCTOBER 1997

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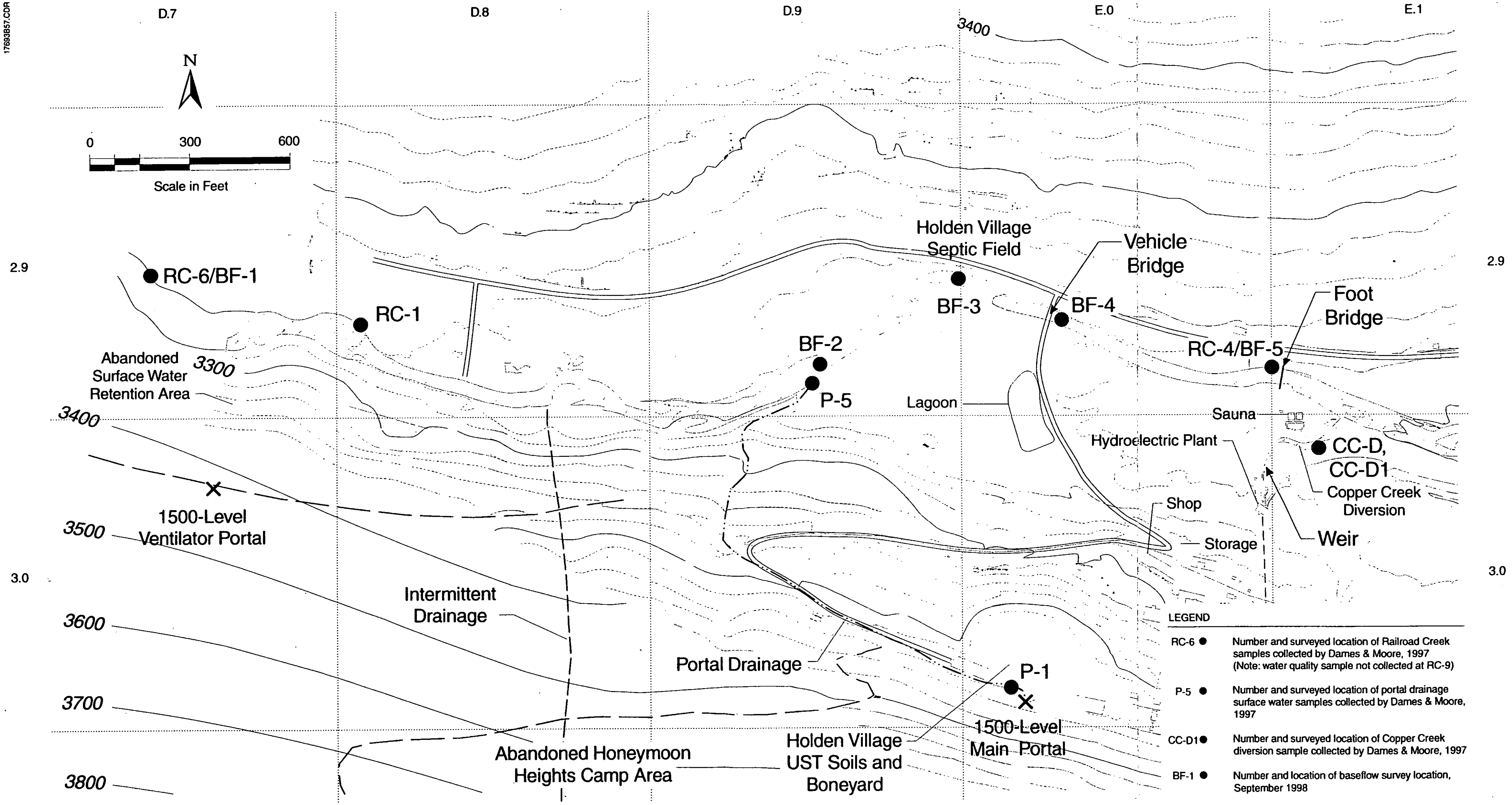
17693B57.CDR



LEGEND

RC-6 ●	Number and surveyed location of Railroad Creek samples collected by Dames & Moore, 1997 (Note: water quality sample not collected at RC-9)
P-5 ●	Number and surveyed location of portal drainage surface water samples collected by Dames & Moore, 1997
CC-D1●	Number and surveyed location of Copper Creek diversion sample collected by Dames & Moore, 1997
BF-1 ●	Number and location of baseflow survey location, September 1998

SOURCE: Base map information from USFS and Washington DNR, DEM CD ROM

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Figure 4.3-10

SEPTEMBER 1998 BASEFLOW SURVEY – RC-6 TO RC-4

Holden Mine RI/FS
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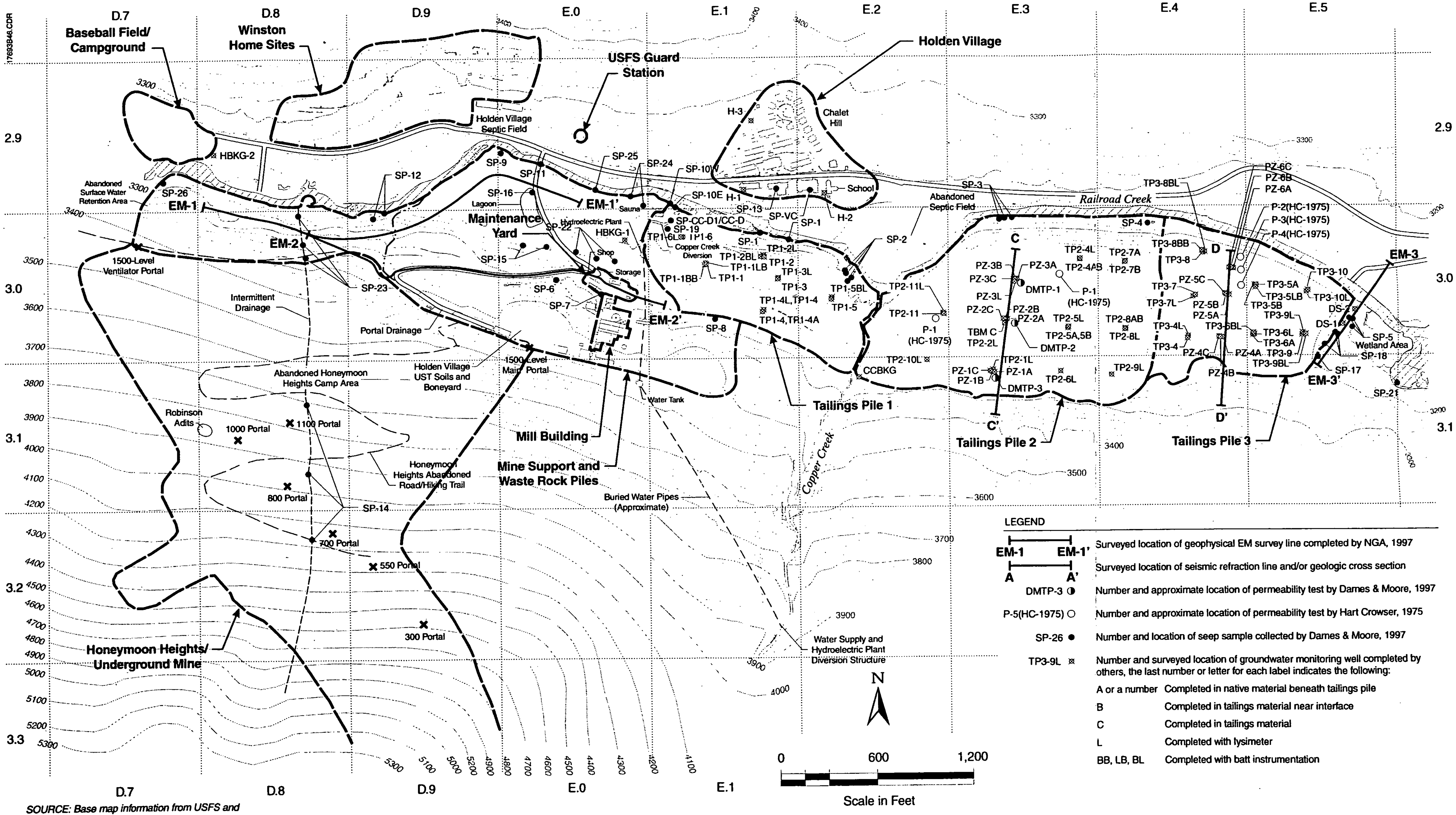

SOURCE: Base map information from USFS and Washington DNR, DEM CD ROM

Figure 4.4-1

SITE HYDROGEOLOGIC INVESTIGATION LOCATIONS

DAMES & MOORE
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17693B38.CDR

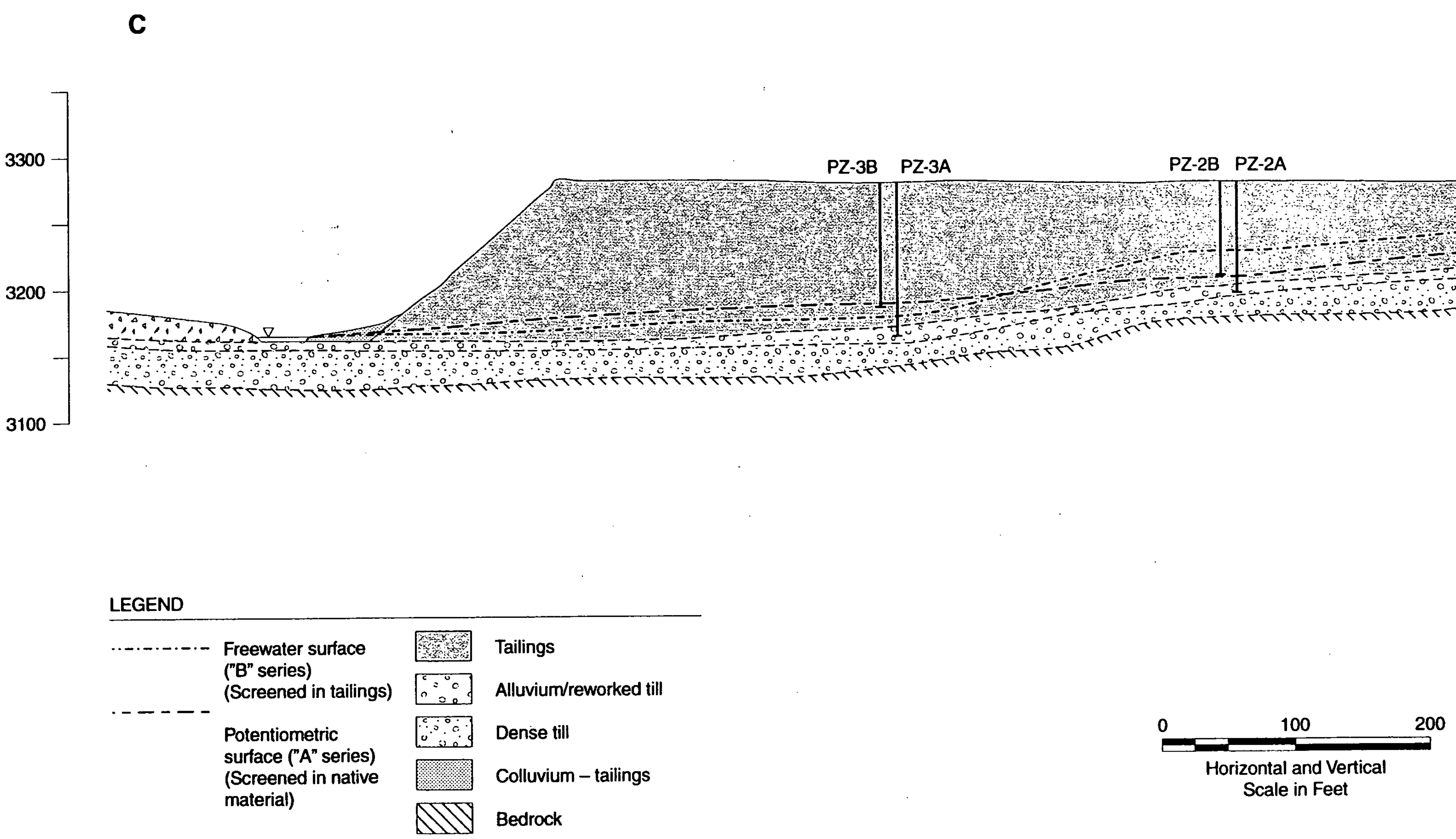

Figure 4.4-2

INTERPRETIVE HYDROGEOLOGIC CROSS SECTION TAILINGS PILE #2 ALONG GEOPHYSICS CROSS SECTION C-C' INCLUDING MAY 1997 WATER LEVELS

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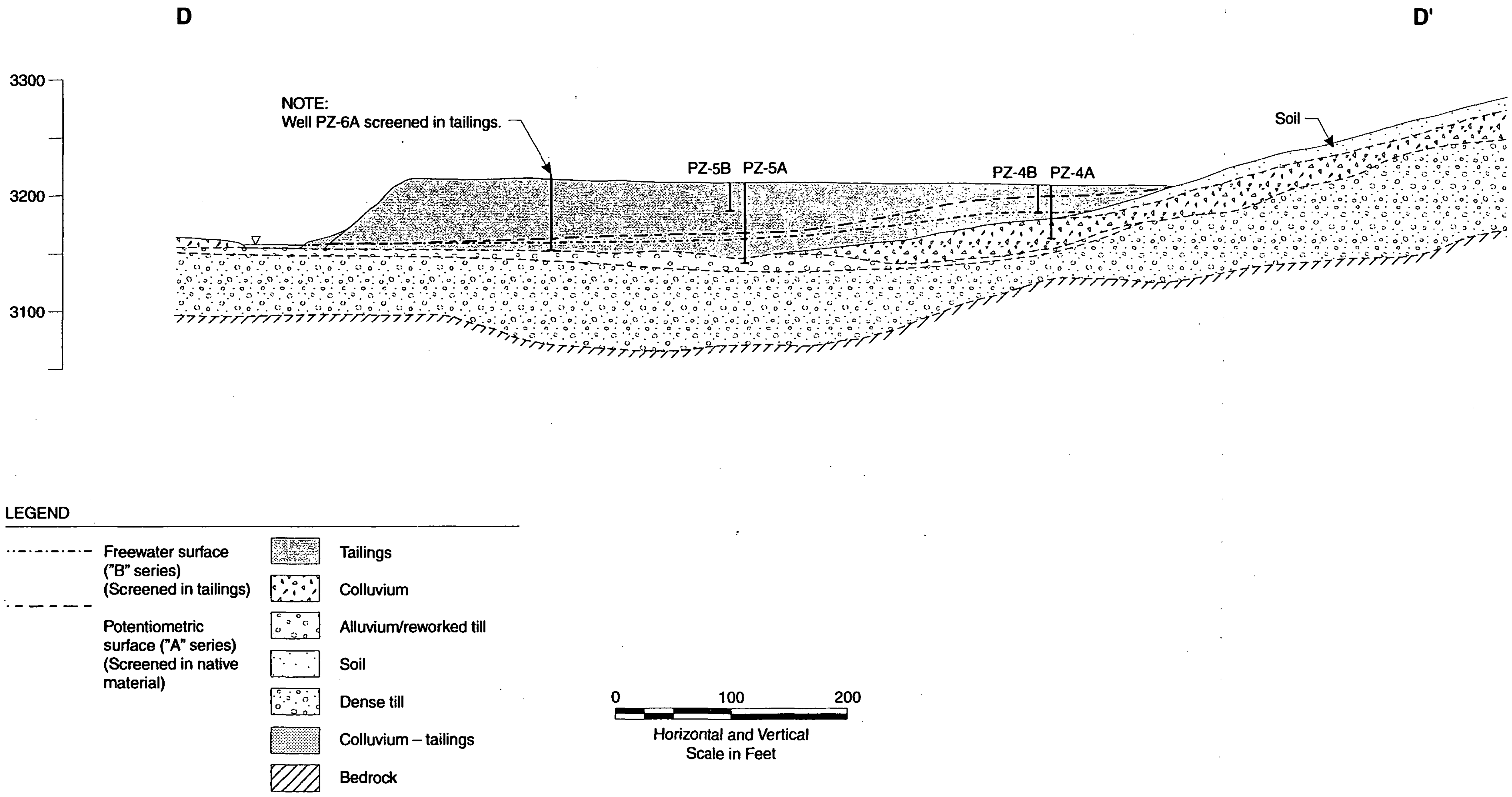

Figure 4.4-3

INTERPRETIVE HYDROGEOLOGIC CROSS SECTION TAILINGS PILE #3 ALONG GEOPHYSICS CROSS SECTION D-D' INCLUDING MAY 1997 WATER LEVELS

DAMES & MOORE
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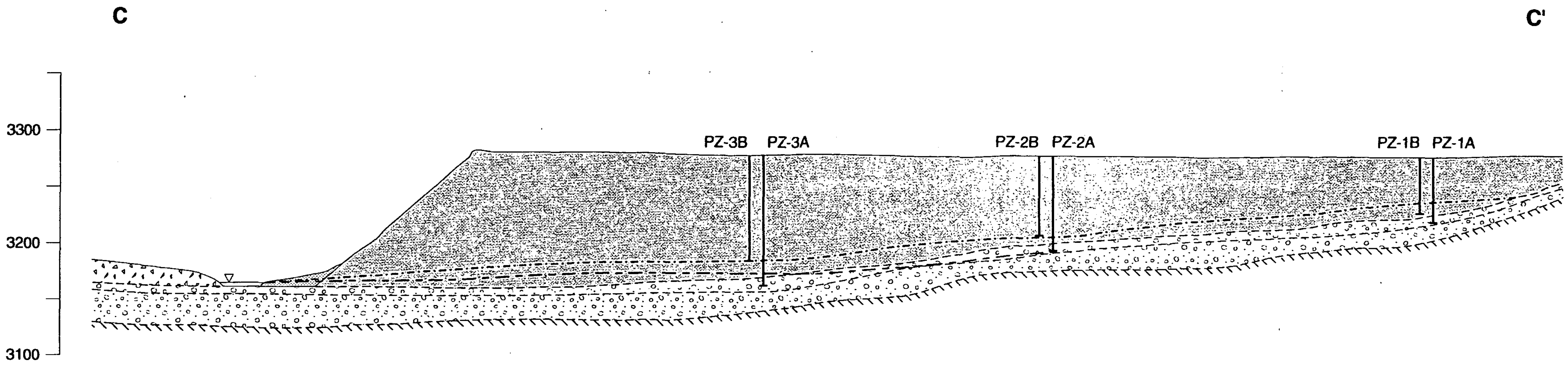
17693B38.CDR



LEGEND

- ·-·-·-·- Freewater surface ("B" series) (Screened in tailings)
- -·——-—- Potentiometric surface ("A" series) (Screened in native material)
- ▨ Tailings
- ○ Alluvium/reworked till
- ○ Dense till
- ▨ Colluvium – tailings
- ▧ Bedrock

0 100 200

Horizontal and Vertical
Scale in Feet

Figure 4.4-4

INTERPRETIVE HYDROGEOLOGIC CROSS SECTION TAILINGS PILE #2 ALONG GEOPHYSICS CROSS SECTION C-C' INCLUDING SEPTEMBER 1997 WATER LEVELS

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17693B39.CDR

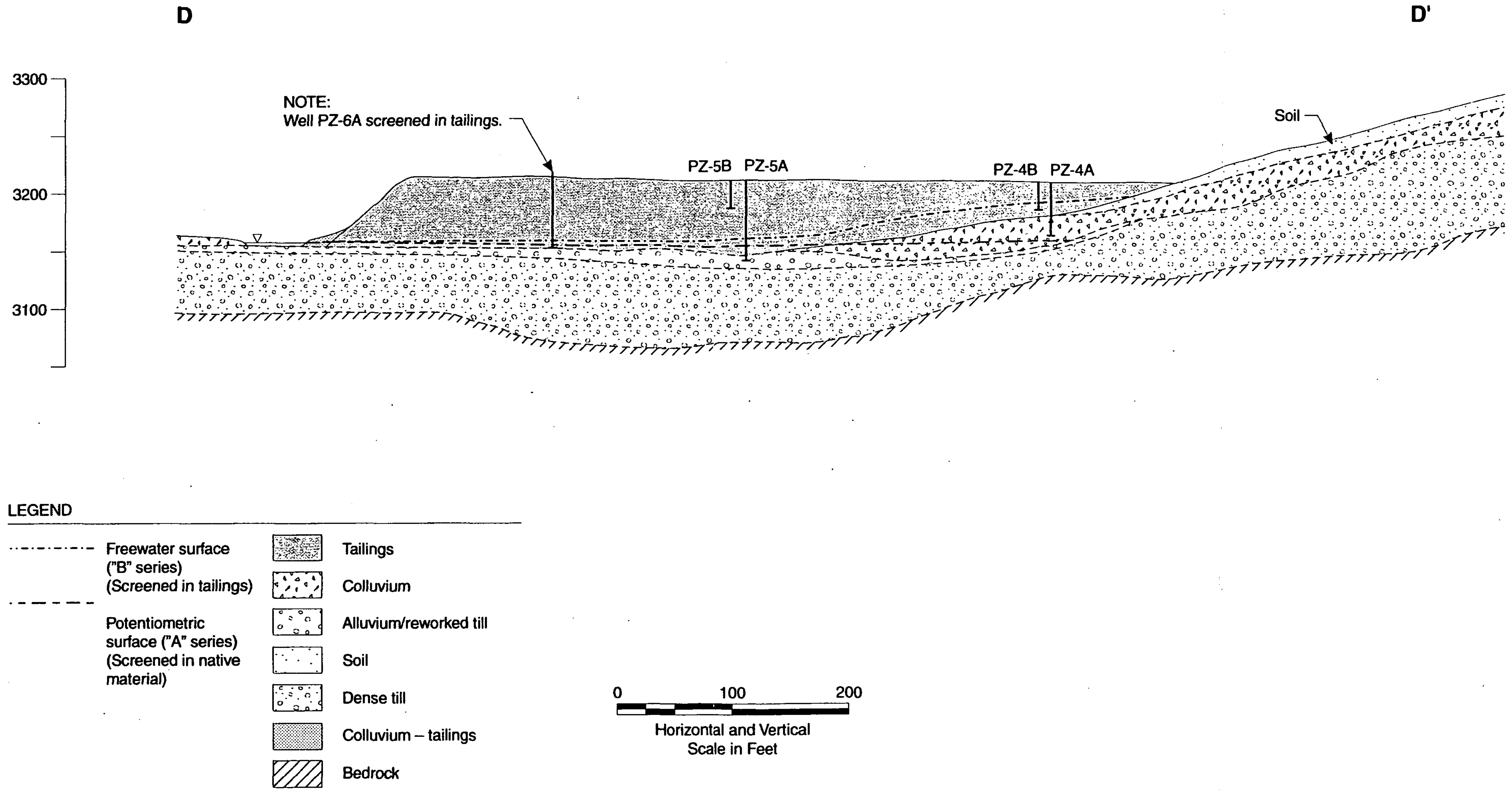

Figure 4.4-5

INTERPRETIVE HYDROGEOLOGIC CROSS SECTION
TAILINGS PILE #3 ALONG GEOPHYSICS CROSS SECTION D-D'
INCLUDING SEPTEMBER 1997 WATER LEVELS

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Job No. 17693-005-019

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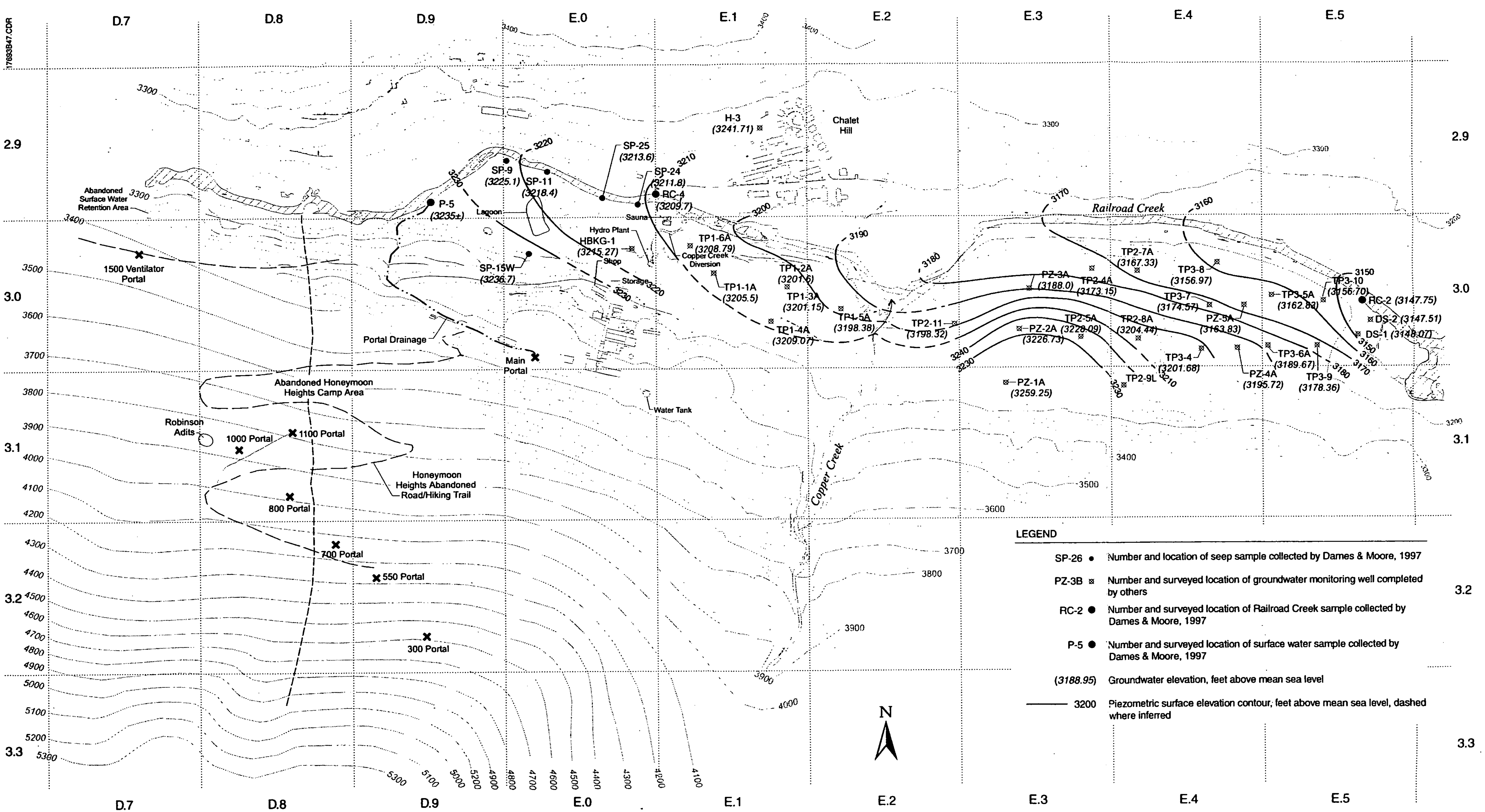

SOURCE: Base map information from USFS and Washington DNR, DEM CD ROM

0 600 1,200

Scale in Feet

Figure 4.4-6

WATER LEVELS IN SITE WELLS COMPLETED IN NATIVE MATERIALS MAY 1997

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Job No. 17693-005-019

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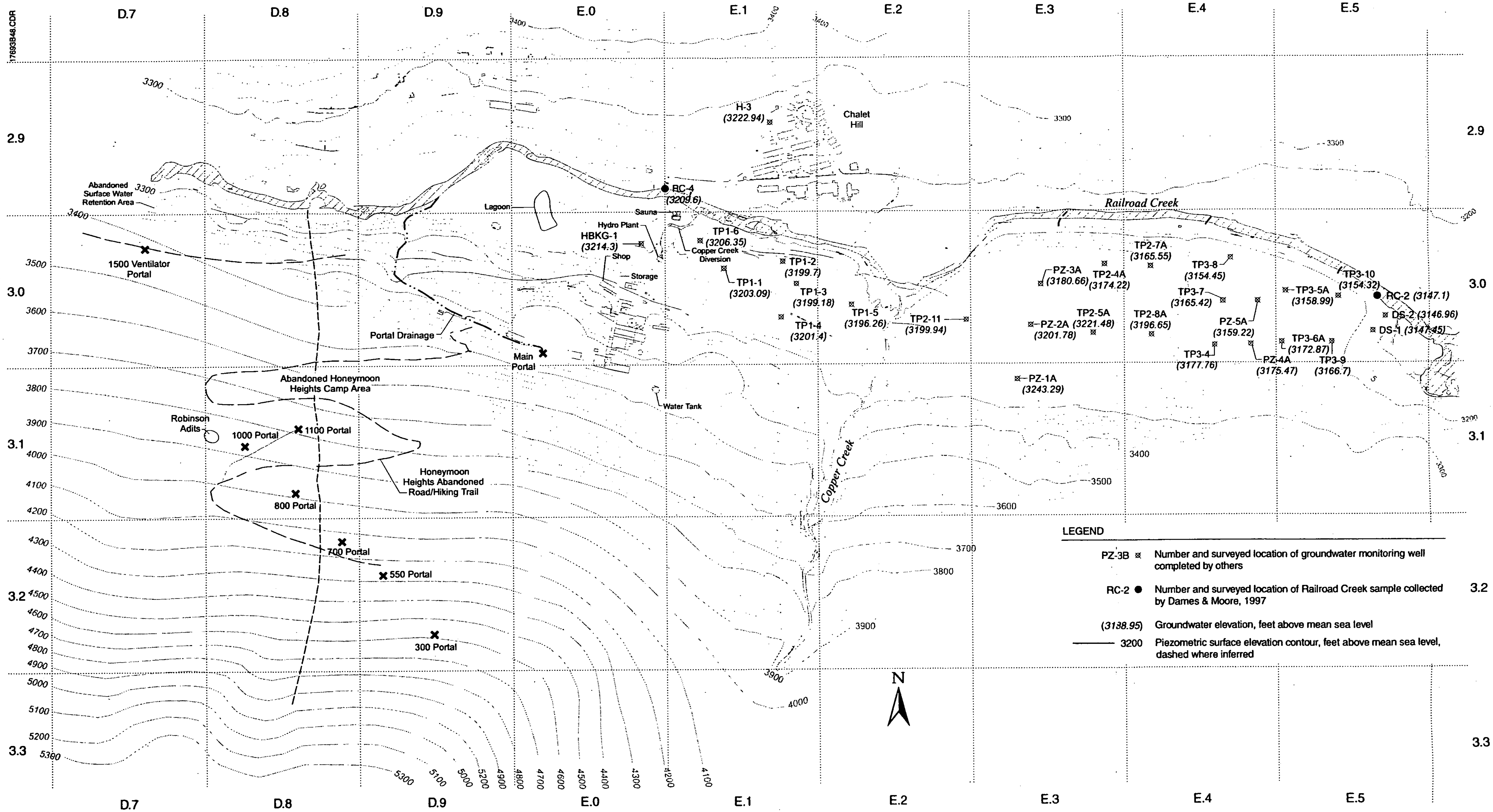
Draft Final RI Report



SOURCE: *Base map information from USFS and Washington DNR, DEM CD ROM*

Figure 4.4-7

WATER LEVELS IN SITE WELLS COMPLETED IN NATIVE MATERIALS JUNE 1997

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Job No. 17693-005-019

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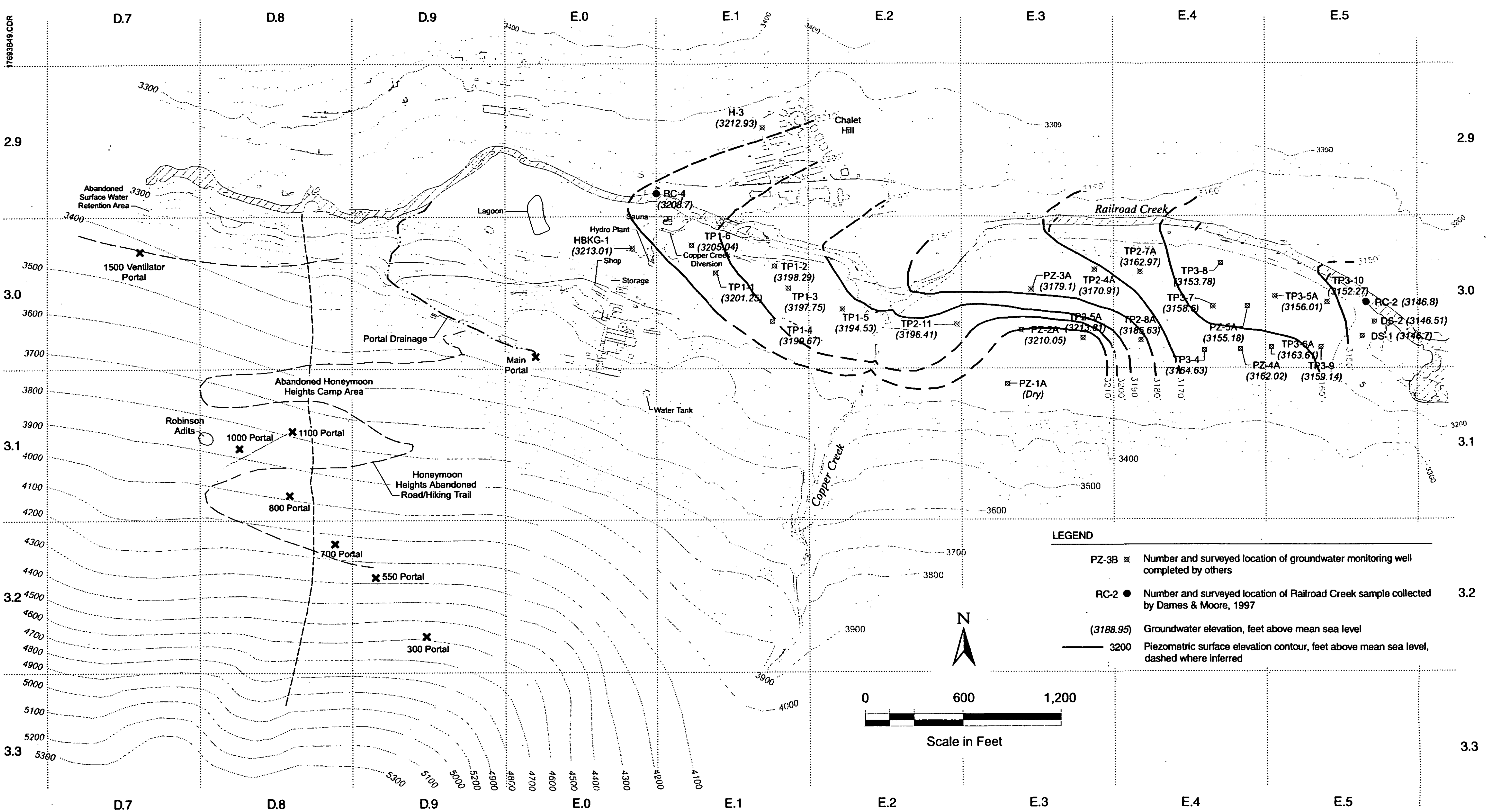

SOURCE: Base map information from USFS and Washington DNR, DEM CD ROM

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Figure 4.4-8

WATER LEVELS IN SITE WELLS COMPLETED IN NATIVE MATERIALS JULY 1997

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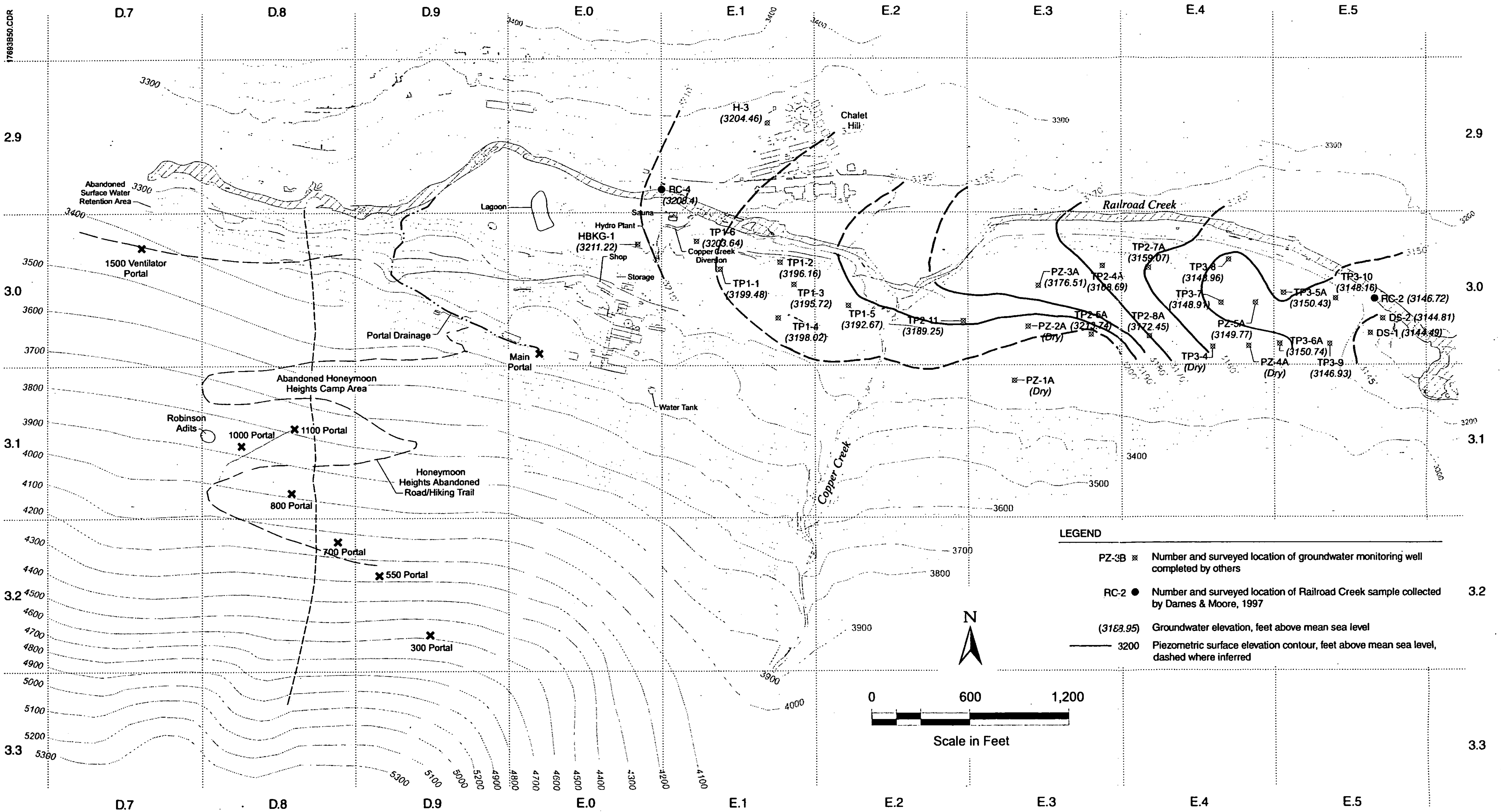
Draft Final RI Report



SOURCE: Base map information from USFS and Washington DNR, DEM CD ROM

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Figure 4.4.9

WATER LEVELS IN SITE WELLS COMPLETED IN NATIVE MATERIALS SEPTEMBER 1997

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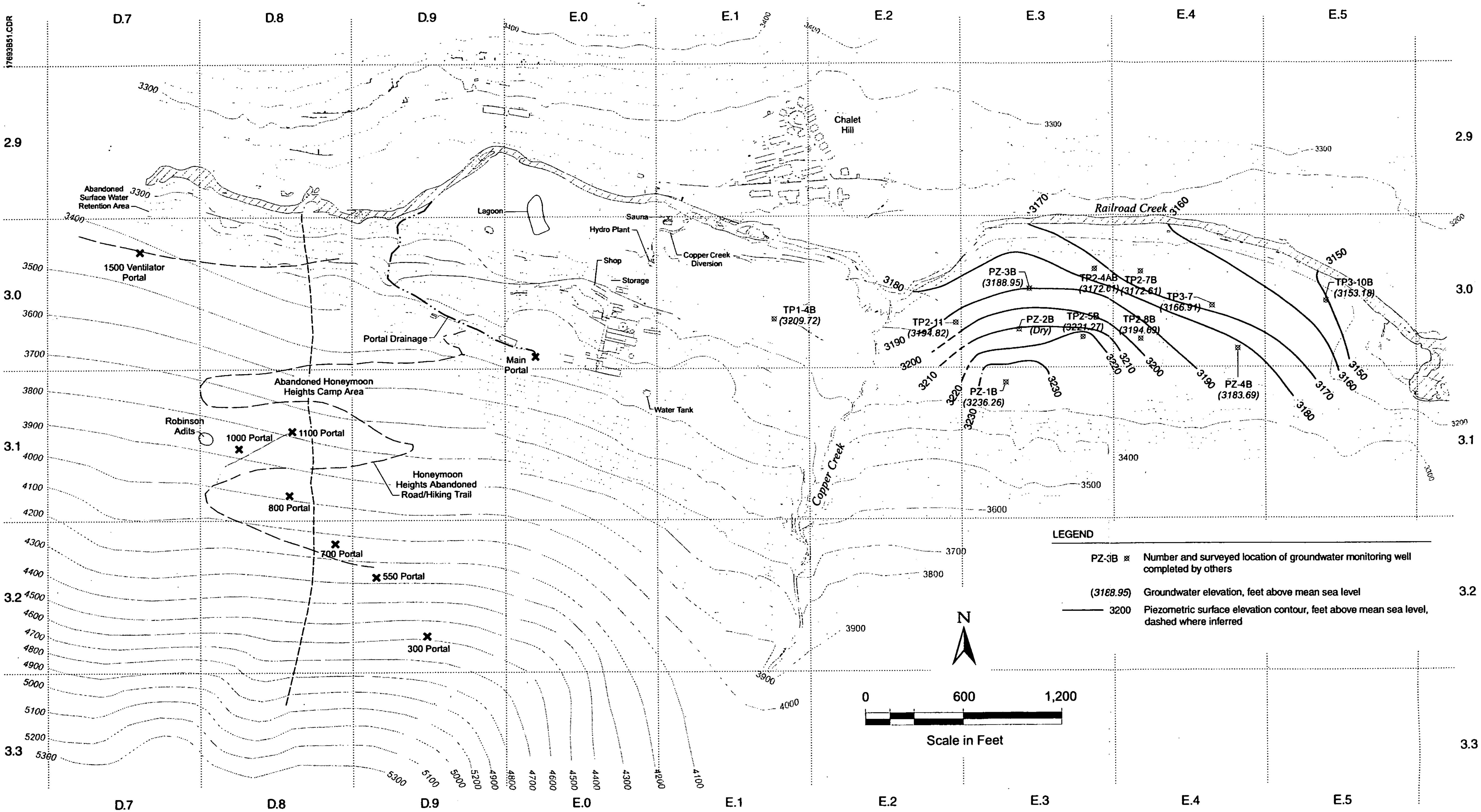
Draft Final RI Report



SOURCE: Base map information from USFS and Washington DNR, DEM CD ROM

Figure 4.4-10

WATER LEVELS IN SITE WELLS COMPLETED IN TAILINGS MAY 1997

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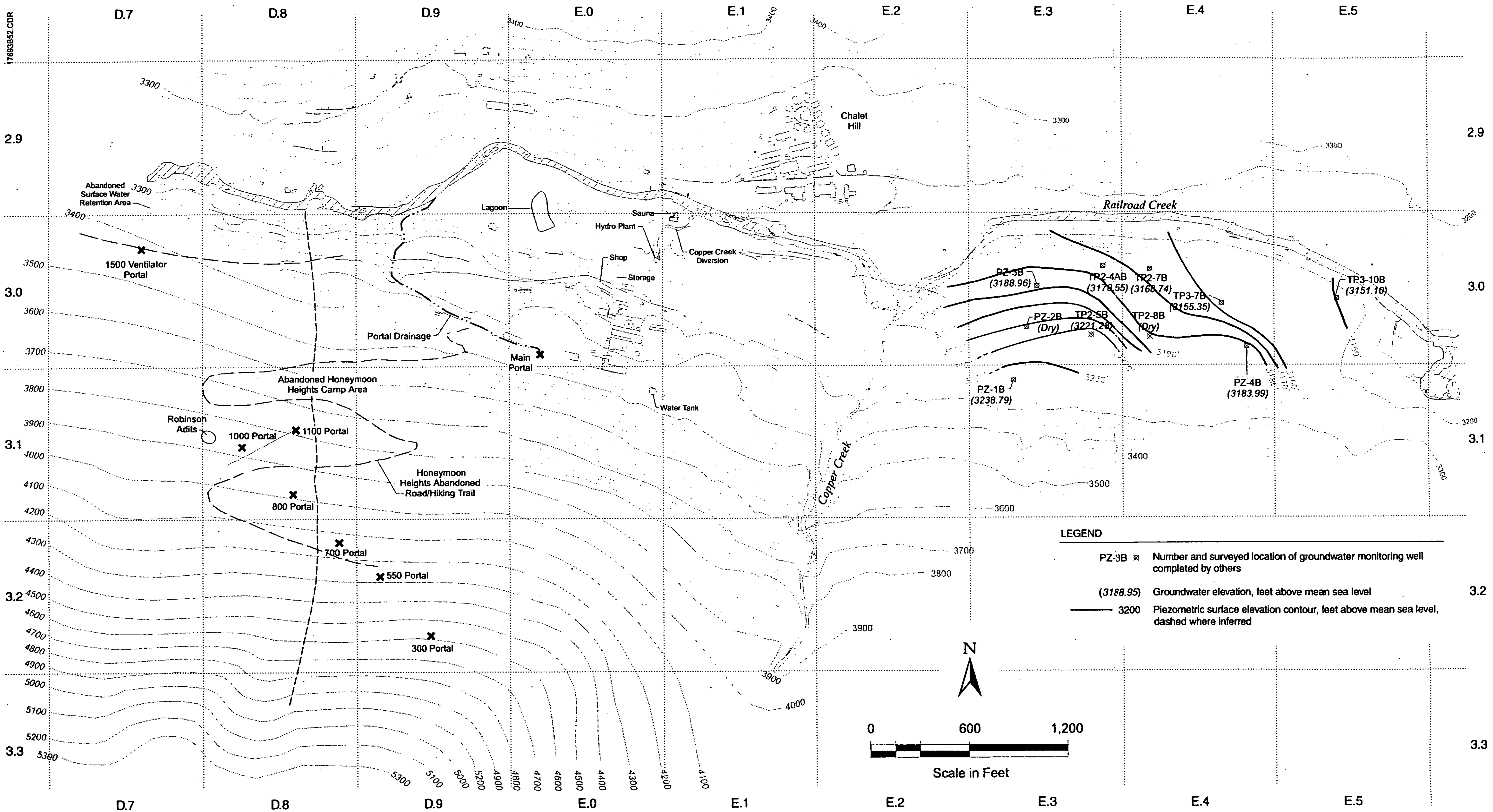

SOURCE: Base map information from USFS and Washington DNR, DEM CD ROM

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Figure 4.4-11
WATER LEVELS IN SITE WELLS COMPLETED IN TAILINGS SEPTEMBER 1997

Holden Mine RI/FS
Draft Final RI Report

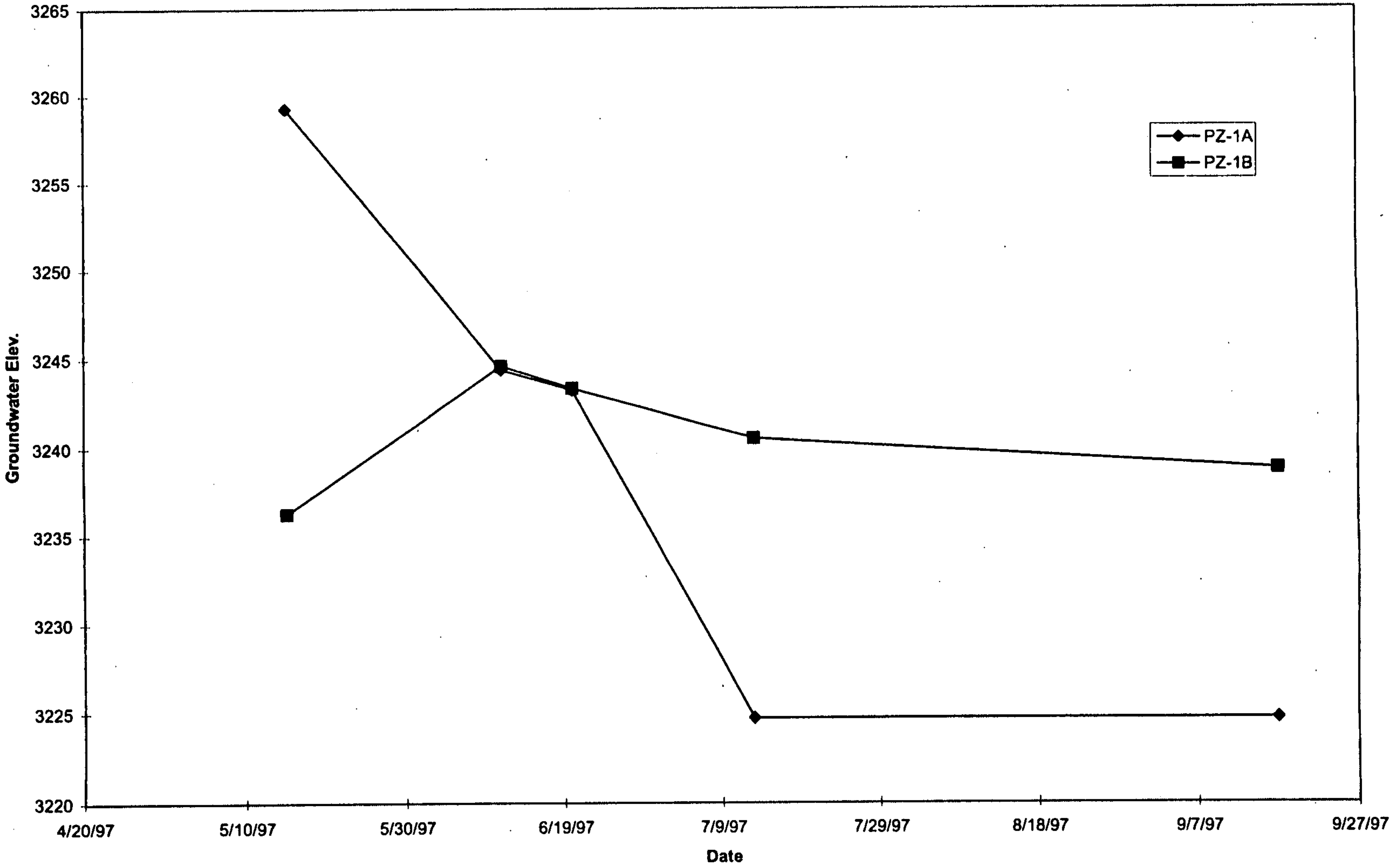

Figure 4.4-12

GROUNDWATER ELEVATIONS
PZ-1 LOCATION

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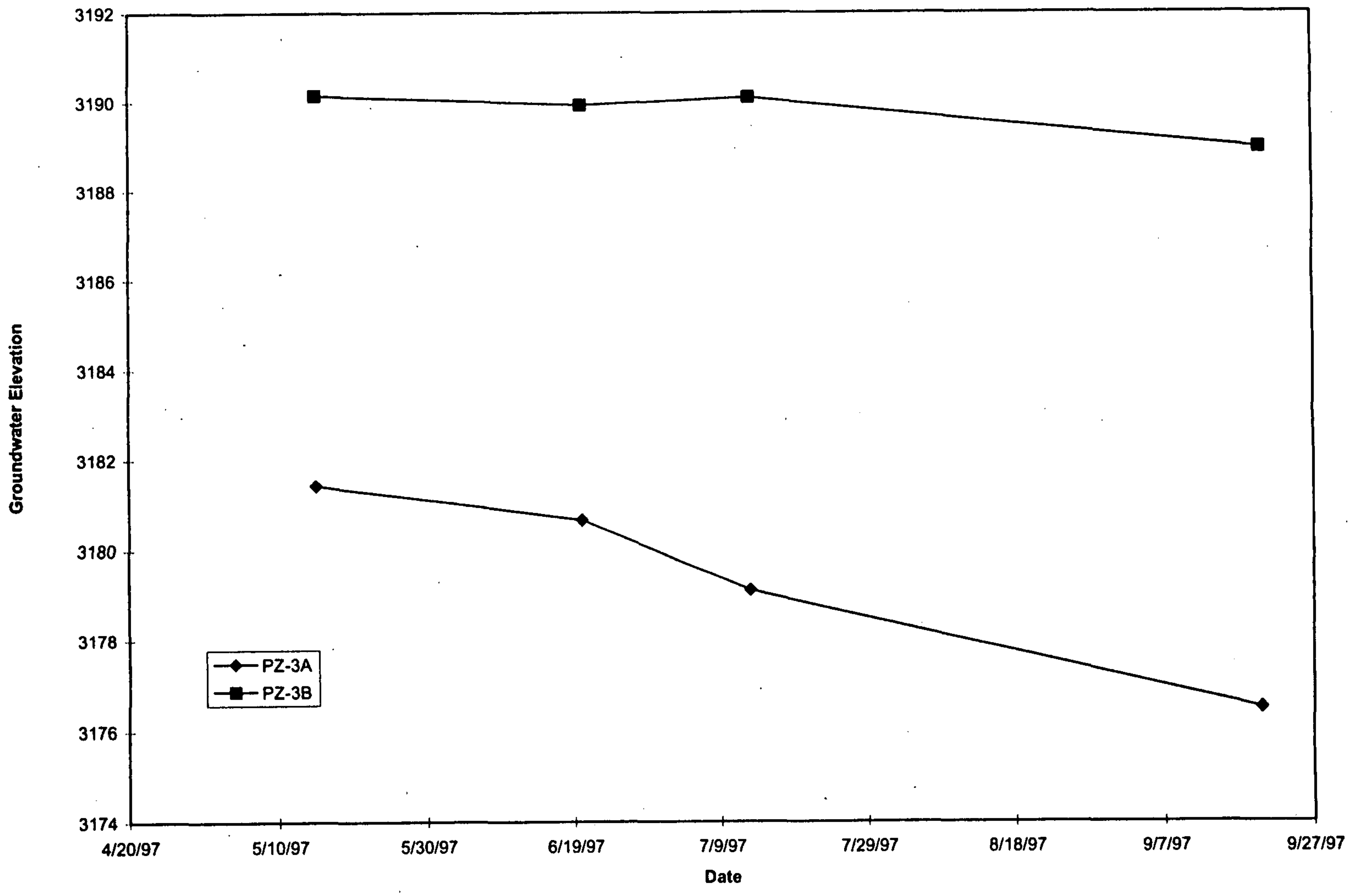

Figure 4.4-13
GROUNDWATER ELEVATIONS
PZ-3 LOCATION

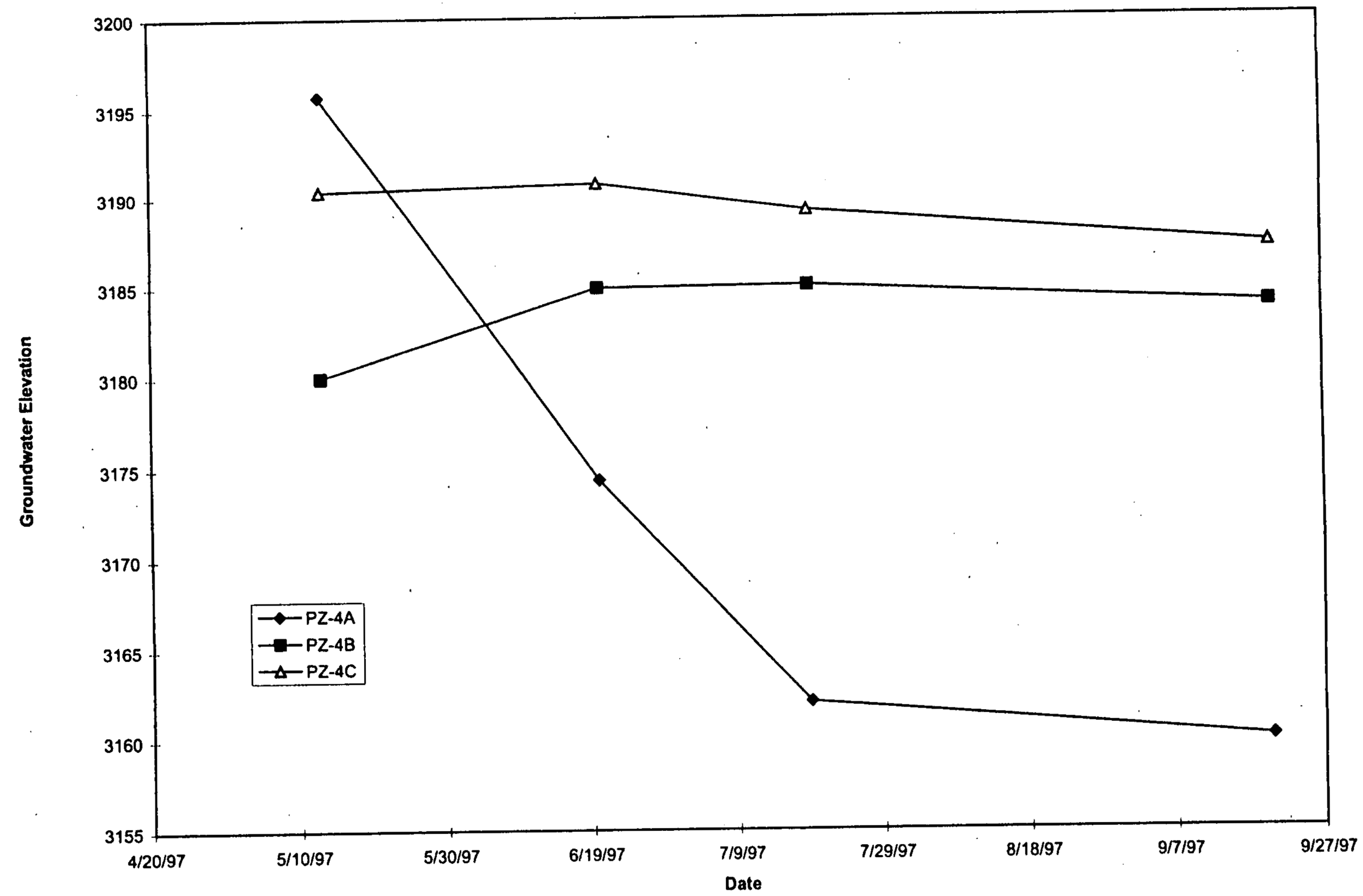

Figure 4.4-14

GROUNDWATER ELEVATIONS
PZ-4 LOCATION

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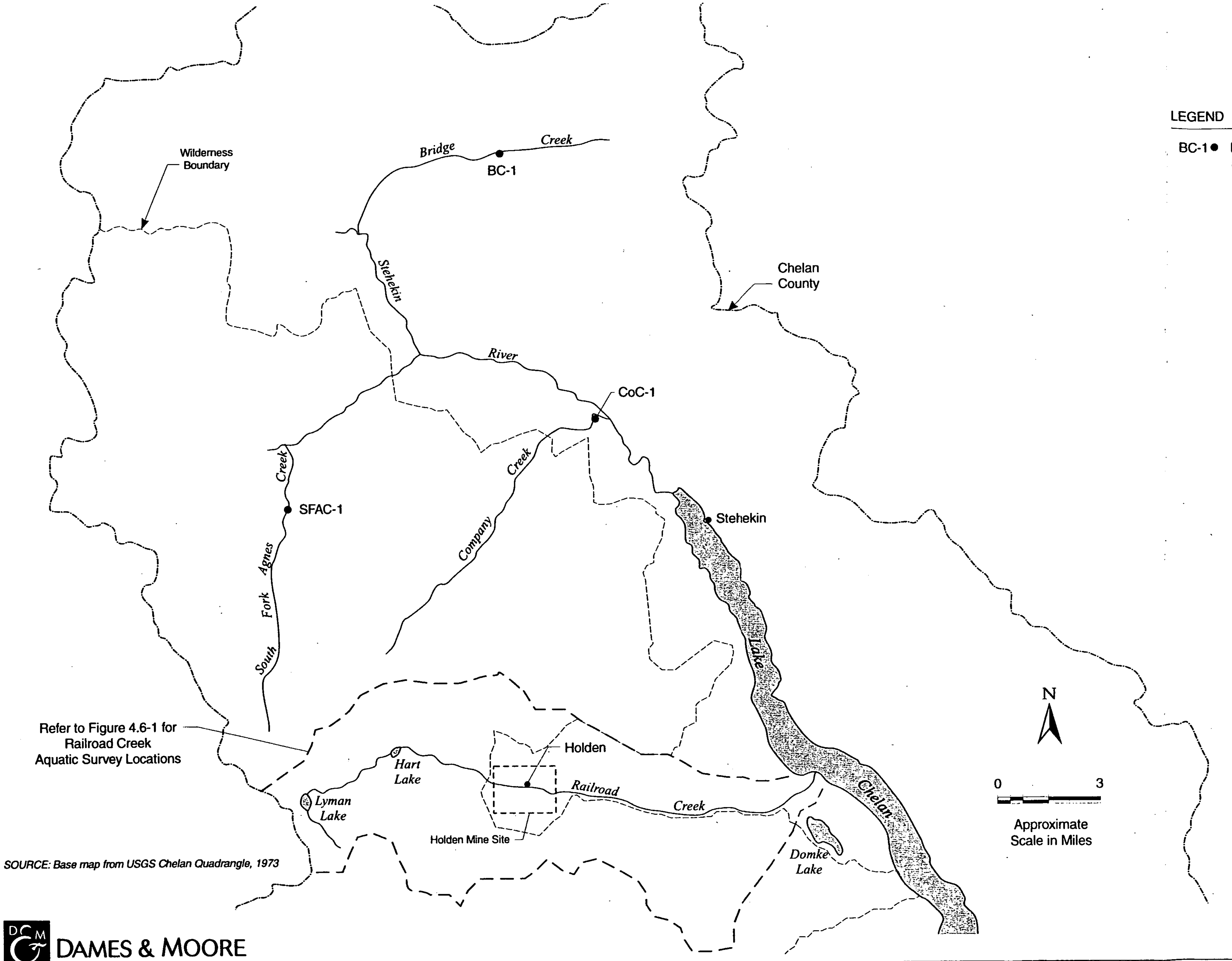
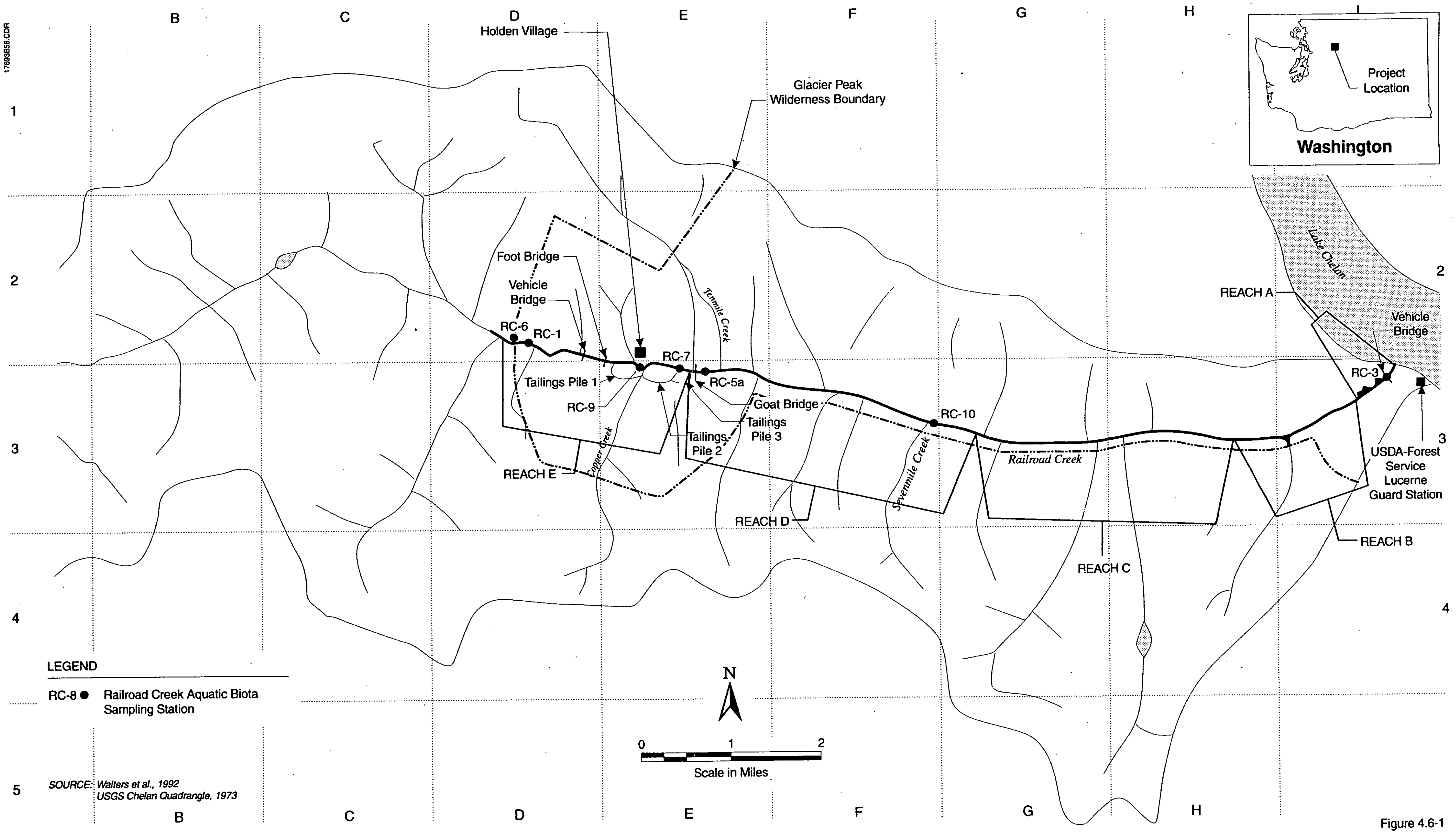


SOURCE: Base map from USGS Chelan Quadrangle, 1973

Figure 4.6-2

STEHEKIN RIVER WATERSHED— AQUATIC SAMPLING LOCATIONS



SOURCE: Walters et al., 1992
USGS Chelan Quadrangle, 1973

Figure 4.6-1

AQUATIC SAMPLING LOCATIONS
RAILROAD CREEK

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Job No. 17693-005-019

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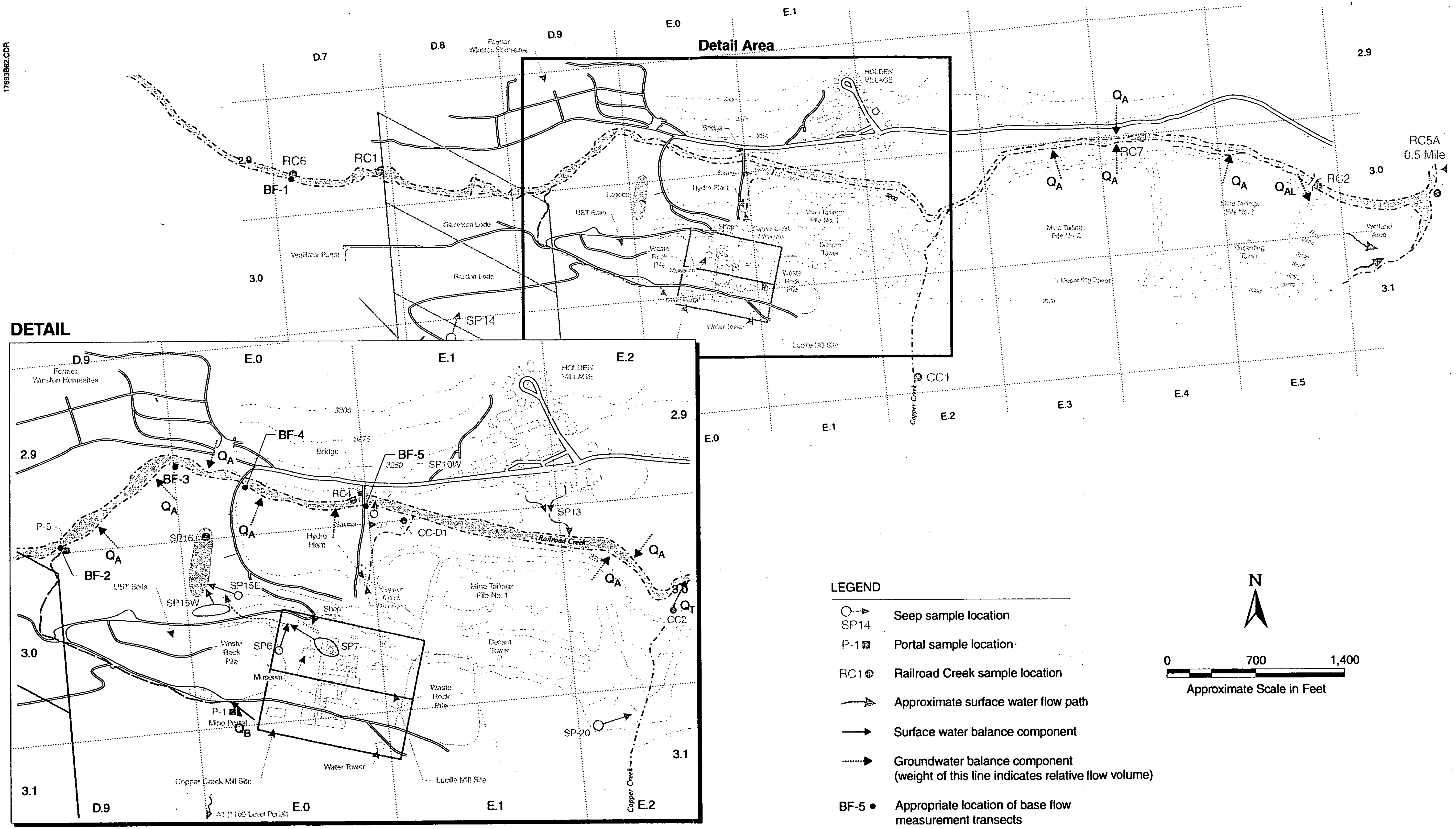
17693862.CDR



SOURCE: ORB, 1975

Figure 4.4-21

SITE-SPECIFIC WATER BALANCE SCHEMATIC OF FLOW PATHS
SEPTEMBER 1997

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17693a78.CDR

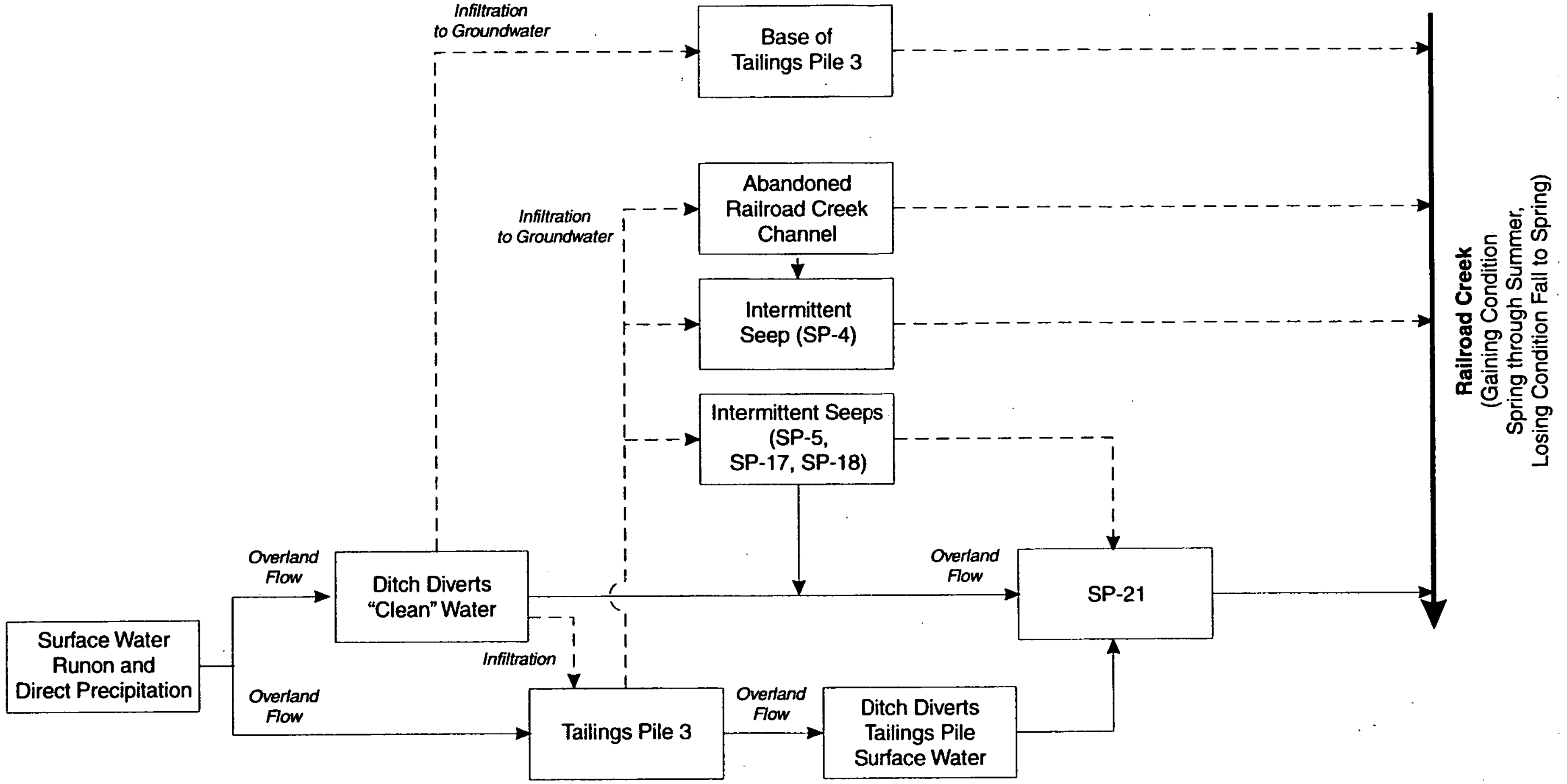

Figure 4.4-20d

TAILINGS PILE 3 CONCEPTUAL TRANSPORT PATHWAYS

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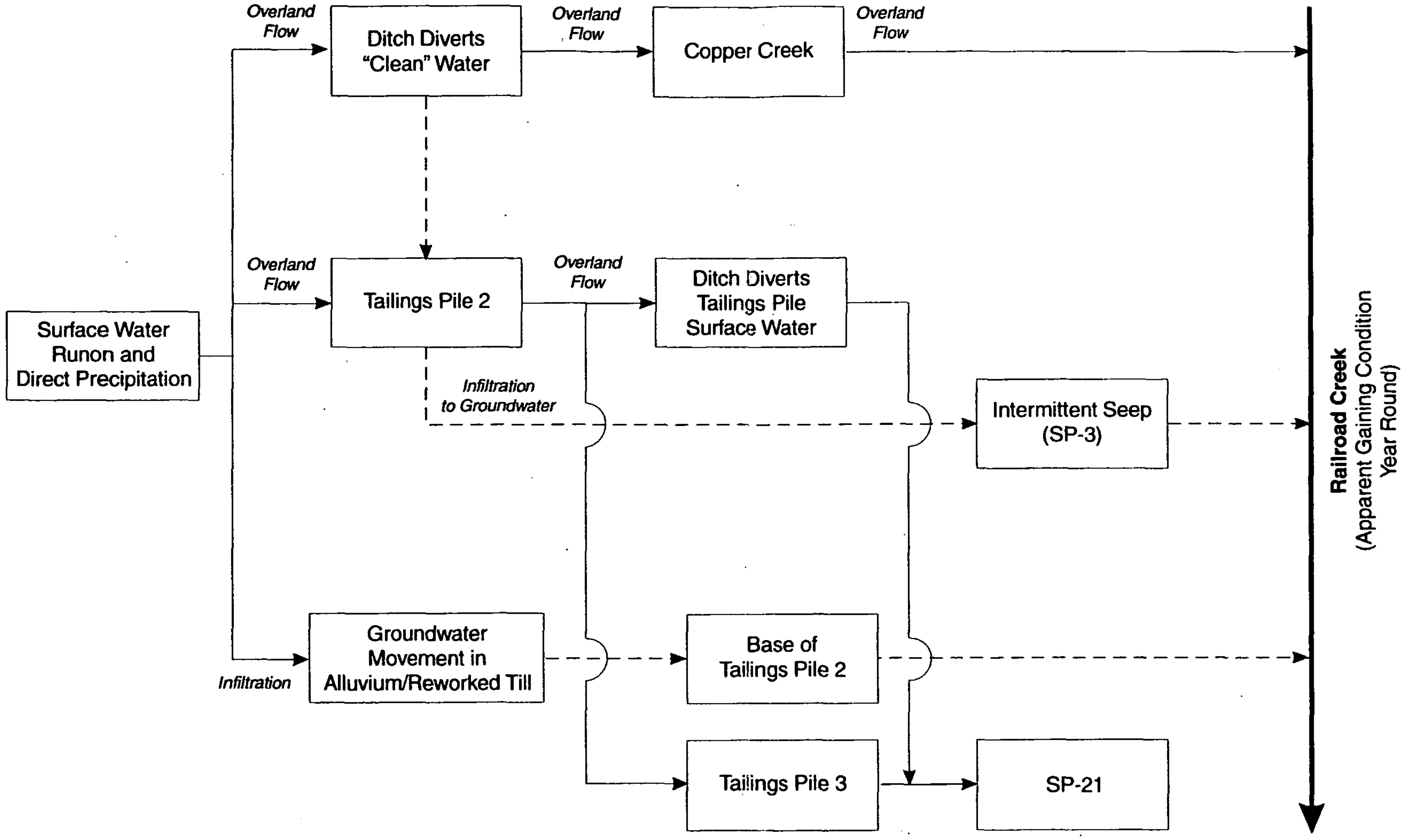

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Figure 4.4-20c
TAILINGS PILE 2
CONCEPTUAL TRANSPORT PATHWAYS

17693a74.CDR

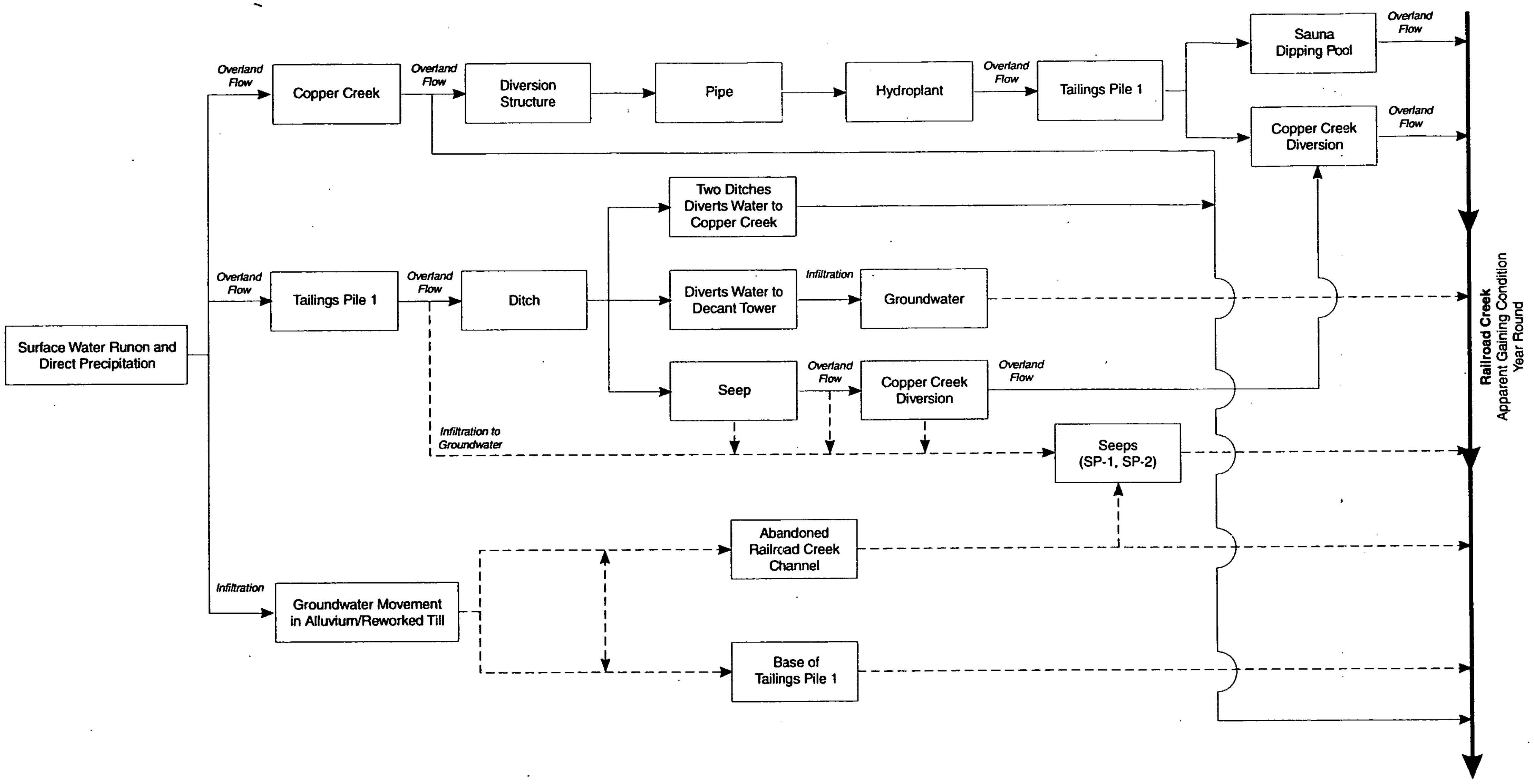

Figure 4.4-20b

TAILINGS PILE 1
CONCEPTUAL TRANSPORT PATHWAYS

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GROUP
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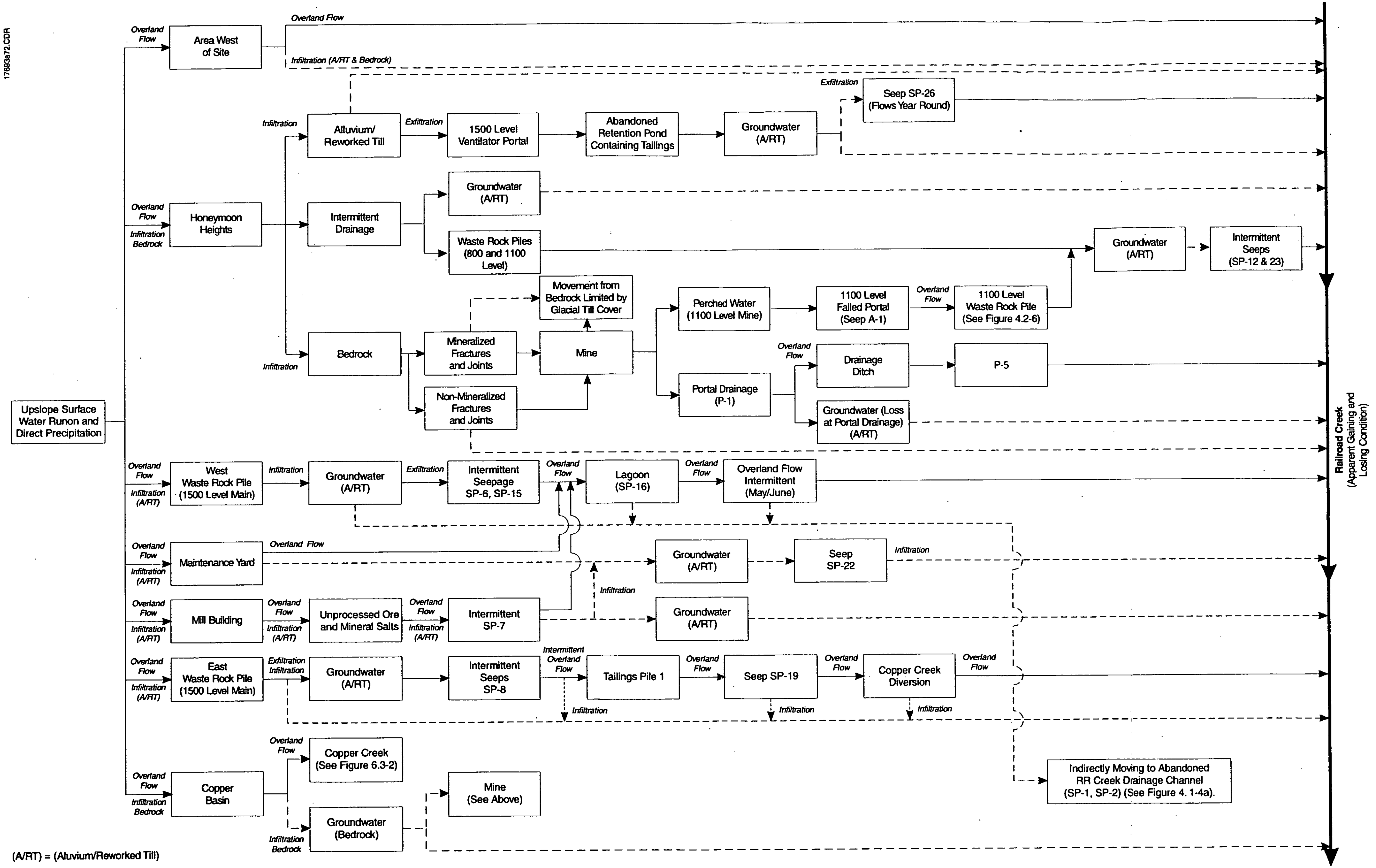
Job No. 17693-005-019

17693a72.CDR



(A/RT) = (Aluviuum/Reworked Till)

Figure 4.4-20a

HONEYMOON HEIGHTS AND MINE SUPPORT AREAS CONCEPTUAL TRANSPORT PATHWAYS

DAMES & MOORE
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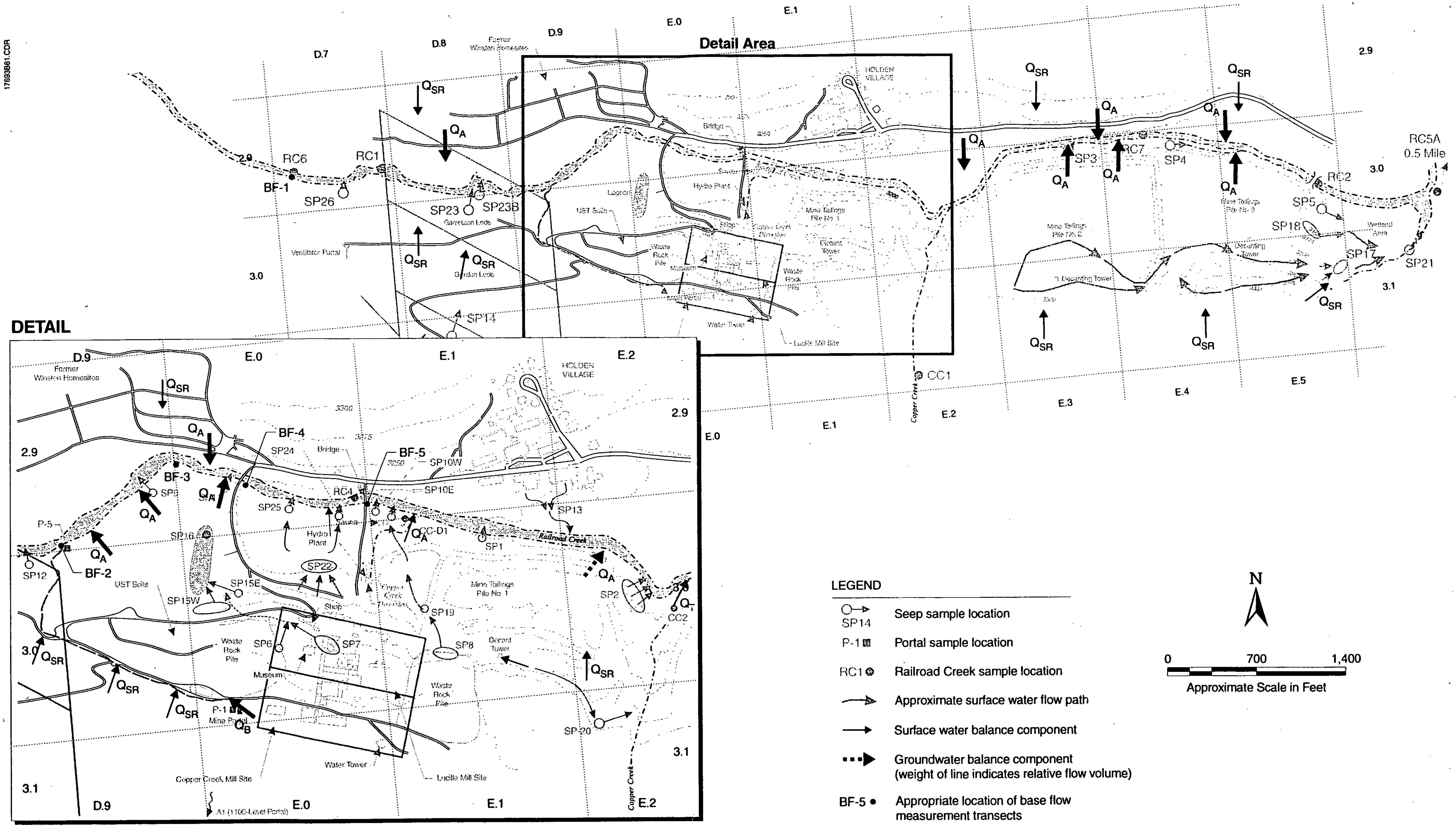
Job No. 17693-005-019

17693B61.CDR



SOURCE: ORB, 1975

Figure 4.4-20

SITE-SPECIFIC WATER BALANCE SCHEMATIC OF FLOW PATHS MAY/JUNE 1997

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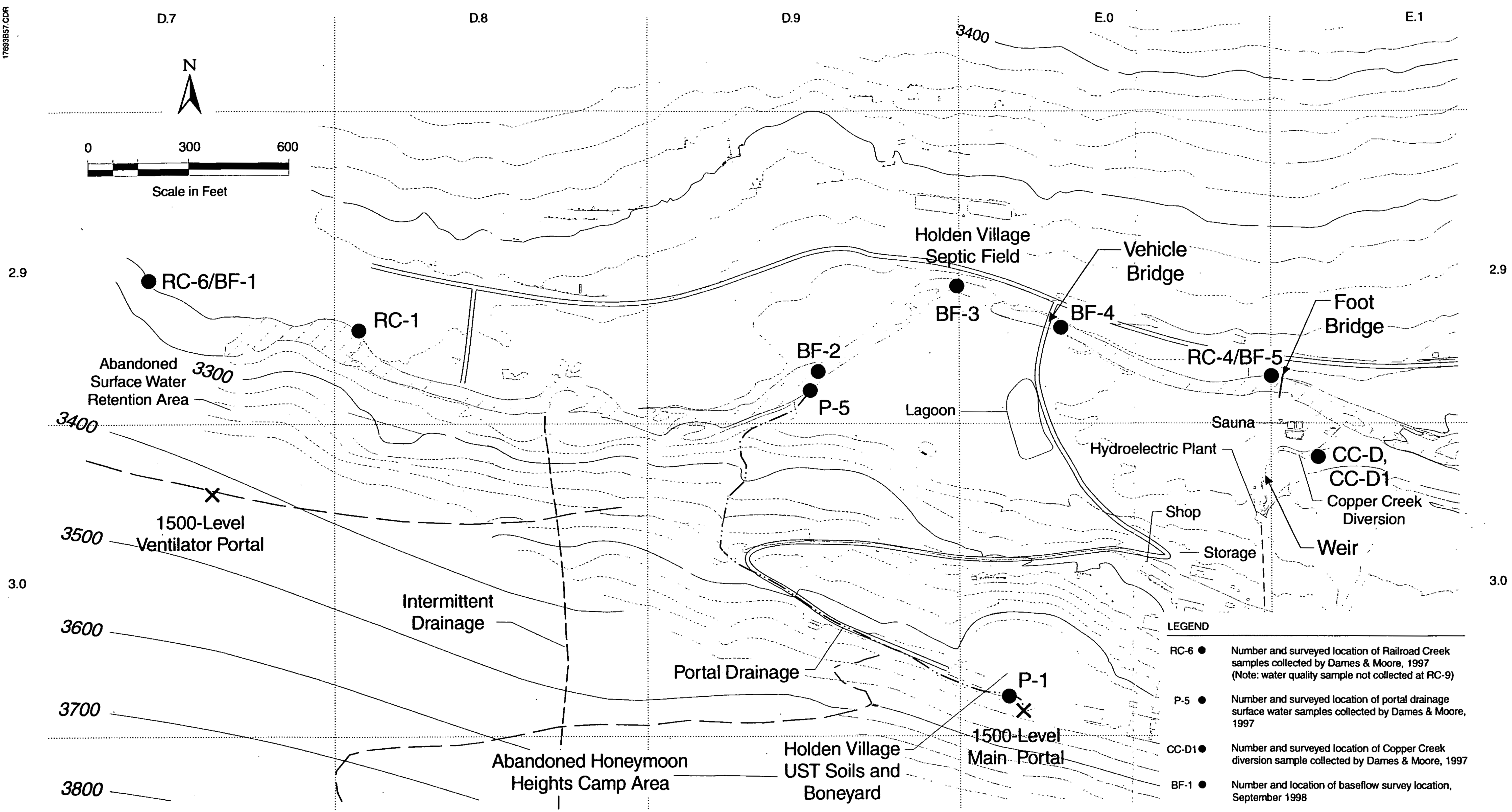
17693857.CDR



LEGEND

RC-6 ●	Number and surveyed location of Railroad Creek samples collected by Dames & Moore, 1997 (Note: water quality sample not collected at RC-9)
P-5 ●	Number and surveyed location of portal drainage surface water samples collected by Dames & Moore, 1997
CC-D1●	Number and surveyed location of Copper Creek diversion sample collected by Dames & Moore, 1997
BF-1 ●	Number and location of baseflow survey location, September 1998

SOURCE: Base map information from USFS and Washington DNR, DEM CD ROM

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Figure 4.4-19

SEPTEMBER 1998 BASEFLOW SURVEY – RC-6 TO RC-4

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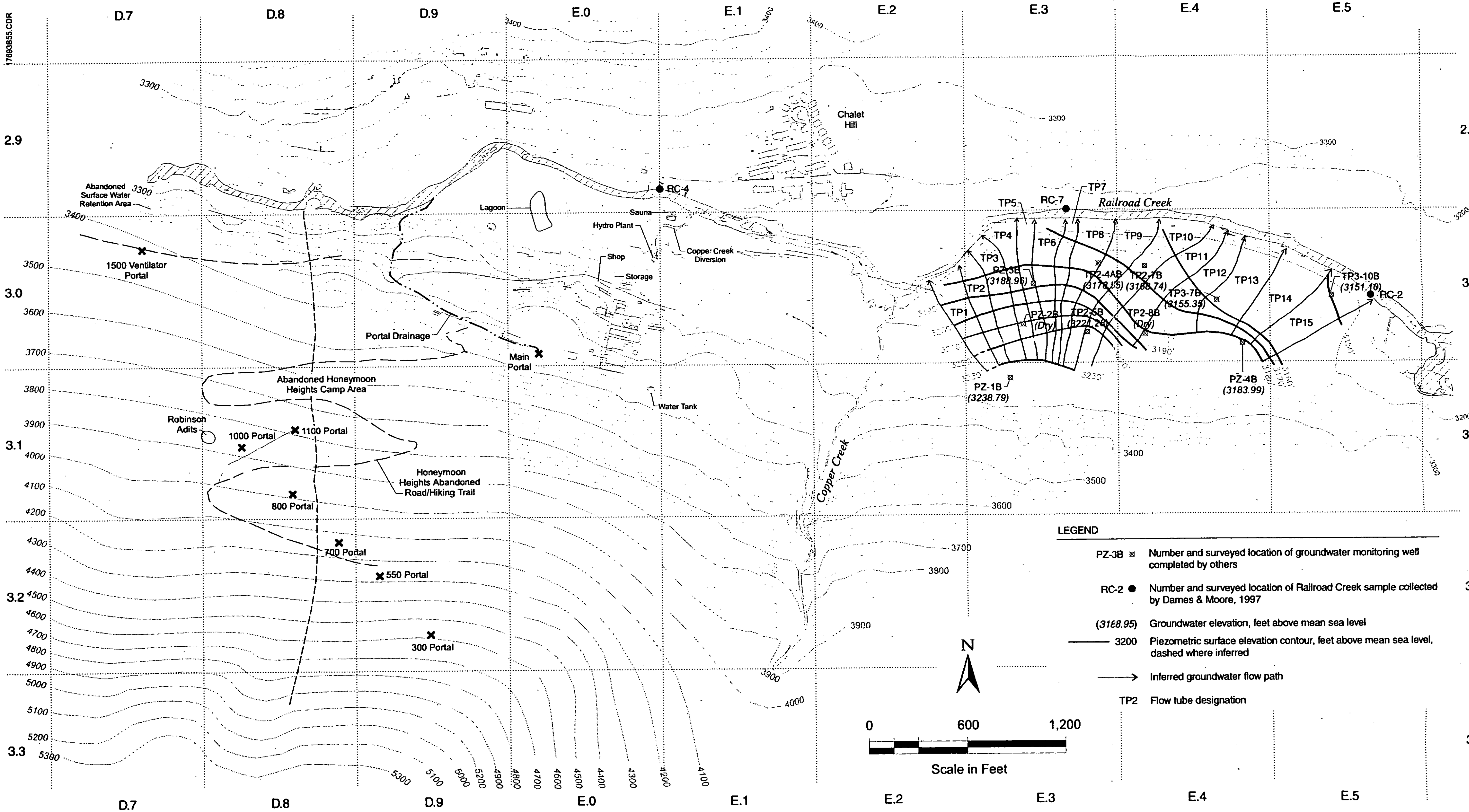

LEGEND

PZ-3B ⊠	Number and surveyed location of groundwater monitoring well completed by others
RC-2 ●	Number and surveyed location of Railroad Creek sample collected by Dames & Moore, 1997
(3188.95)	Groundwater elevation, feet above mean sea level
—— 3200	Piezometric surface elevation contour, feet above mean sea level, dashed where inferred
——→	Inferred groundwater flow path
TP2	Flow tube designation

SOURCE: Base map information from USFS and Washington DNR, DEM CD ROM

Figure 4.4-18

FLOW NET FOR SITE WELLS COMPLETED IN TAILINGS SEPTEMBER 1997

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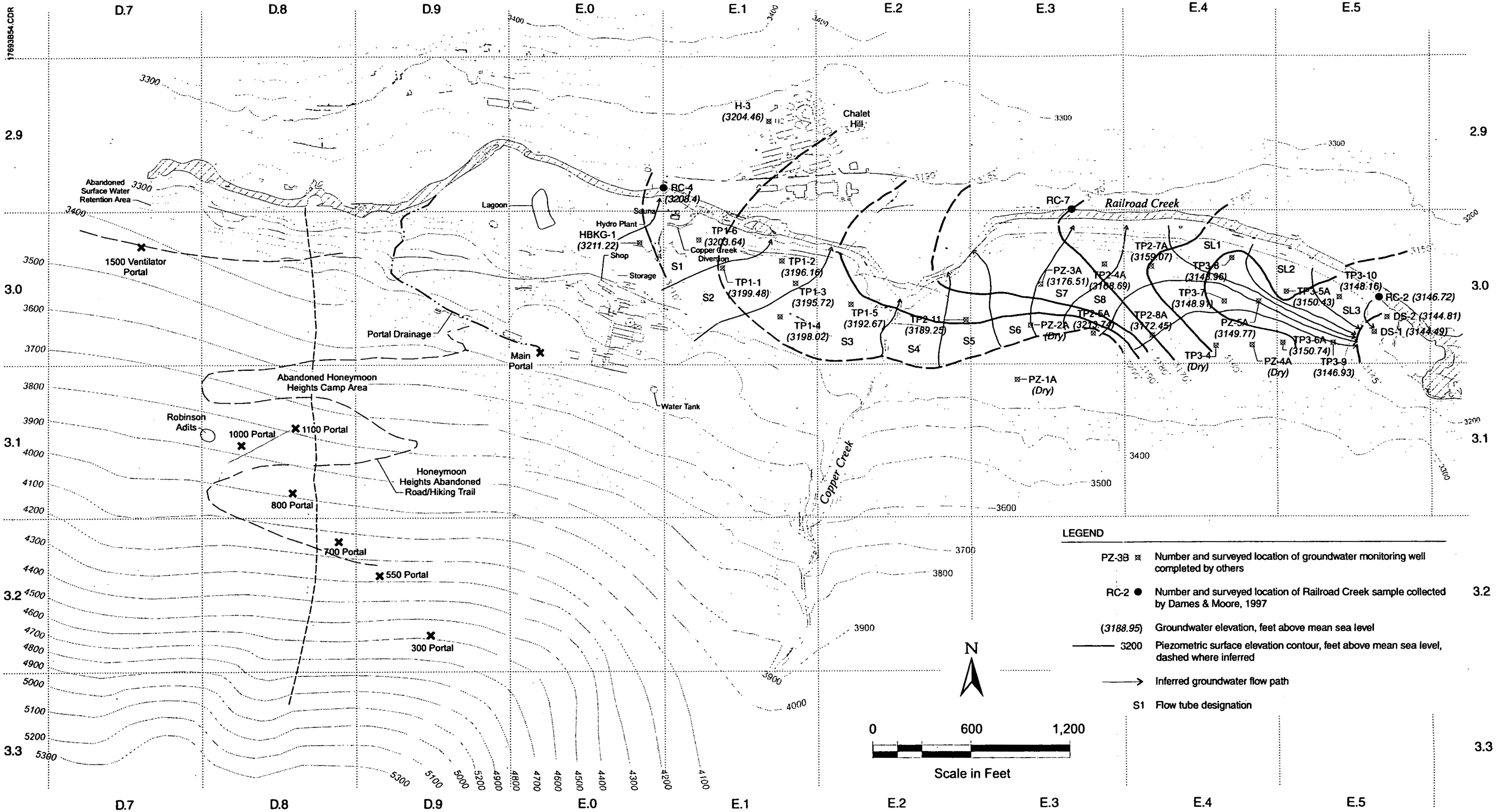

SOURCE: *Base map information from USFS and Washington DNR, DEM CD ROM*

Figure 4.4-17

FLOW NET FOR SITE WELLS COMPLETED IN NATIVE MATERIALS SEPTEMBER 1997

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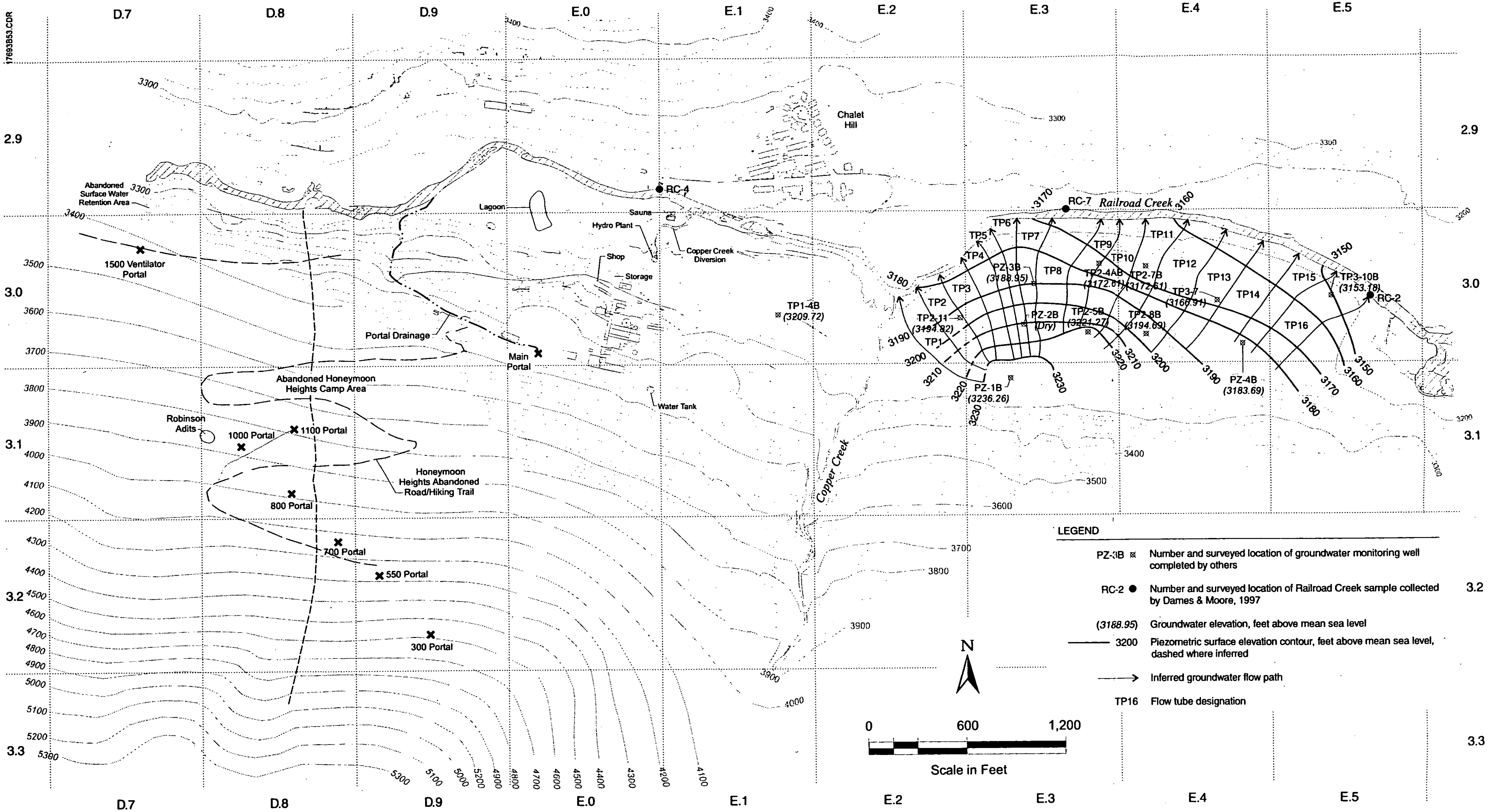

SOURCE: *Base map information from USFS and Washington DNR, DEM CD ROM*

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Figure 4.4-16

FLOW NET FOR SITE WELLS COMPLETED IN TAILINGS MAY 1997

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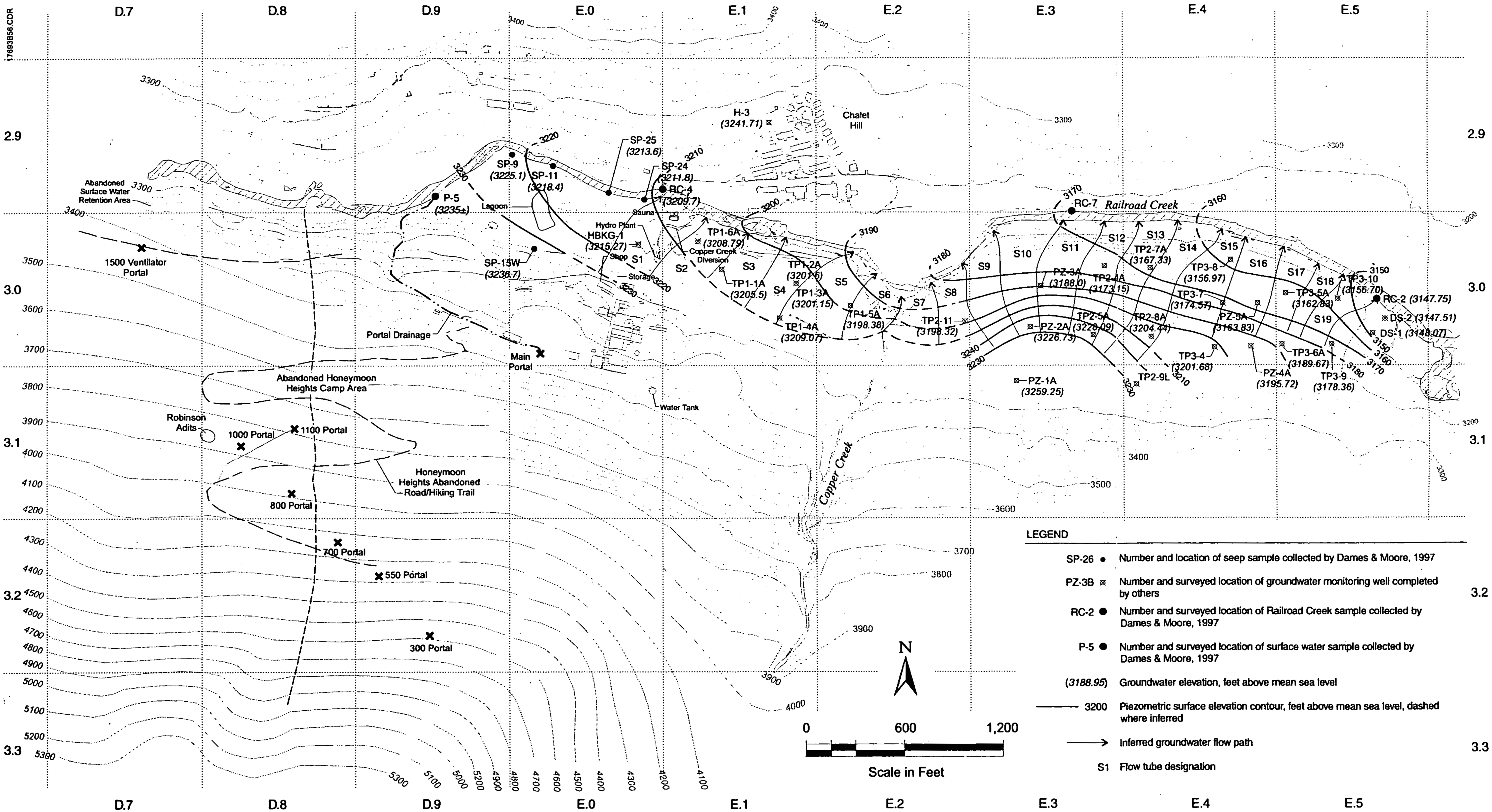

SOURCE: *Base map information from USFS and Washington DNR, DEM CD ROM*

Figure 4.4-15

FLOW NET FOR SITE WELLS COMPLETED IN NATIVE MATERIALS MAY 1997

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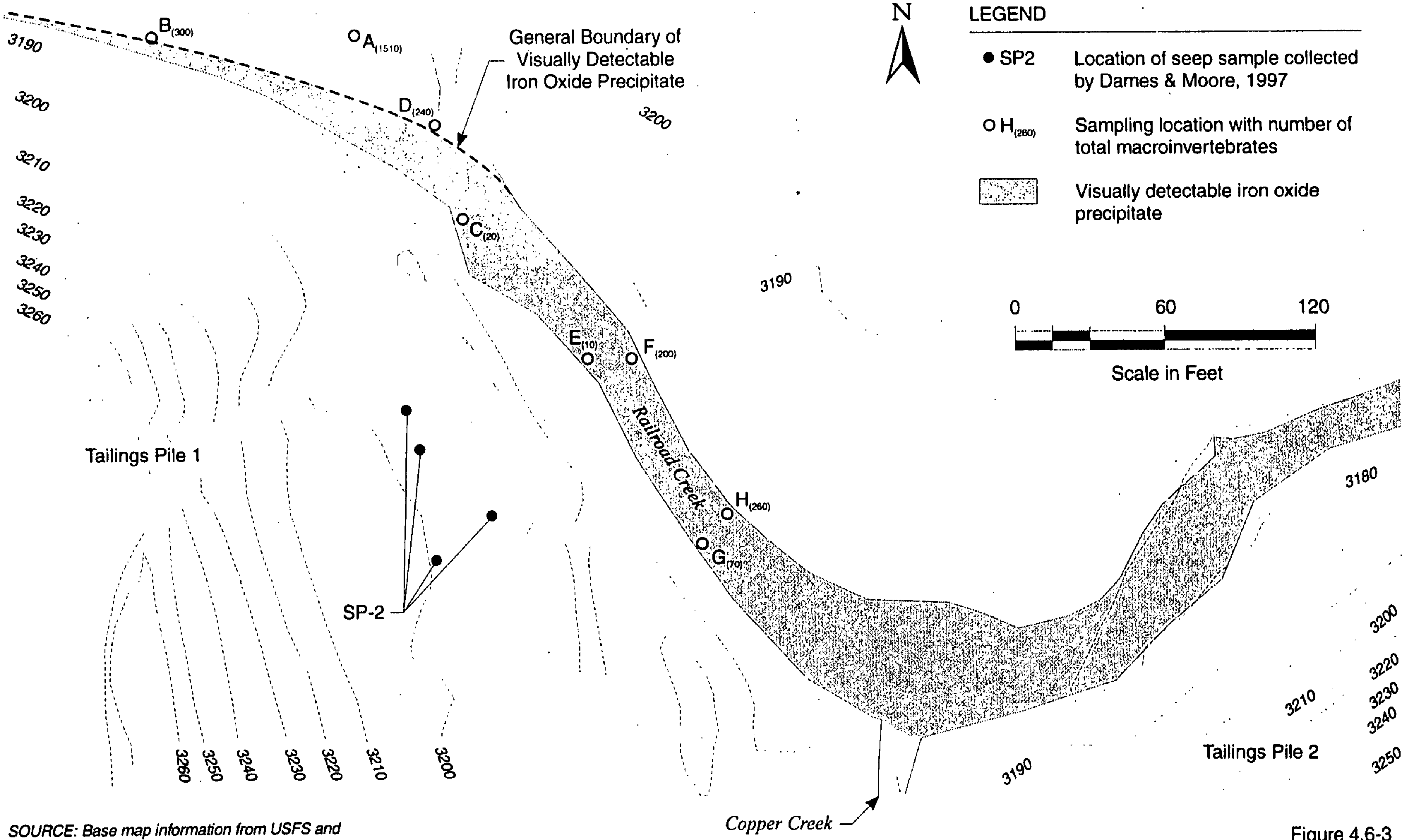
Holden Mine RI/FS
Draft Final RI Report

17693B59.CDR



SOURCE: Base map information from USFS and Washington DNR, DEM CD ROM

Figure 4.6-3

RC-9 BENTHIC MACROINVERTEBRATE REPLICATE RESULTS (NUMBER OF ORGANISMS/m²)

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Job No. 17693-005-019

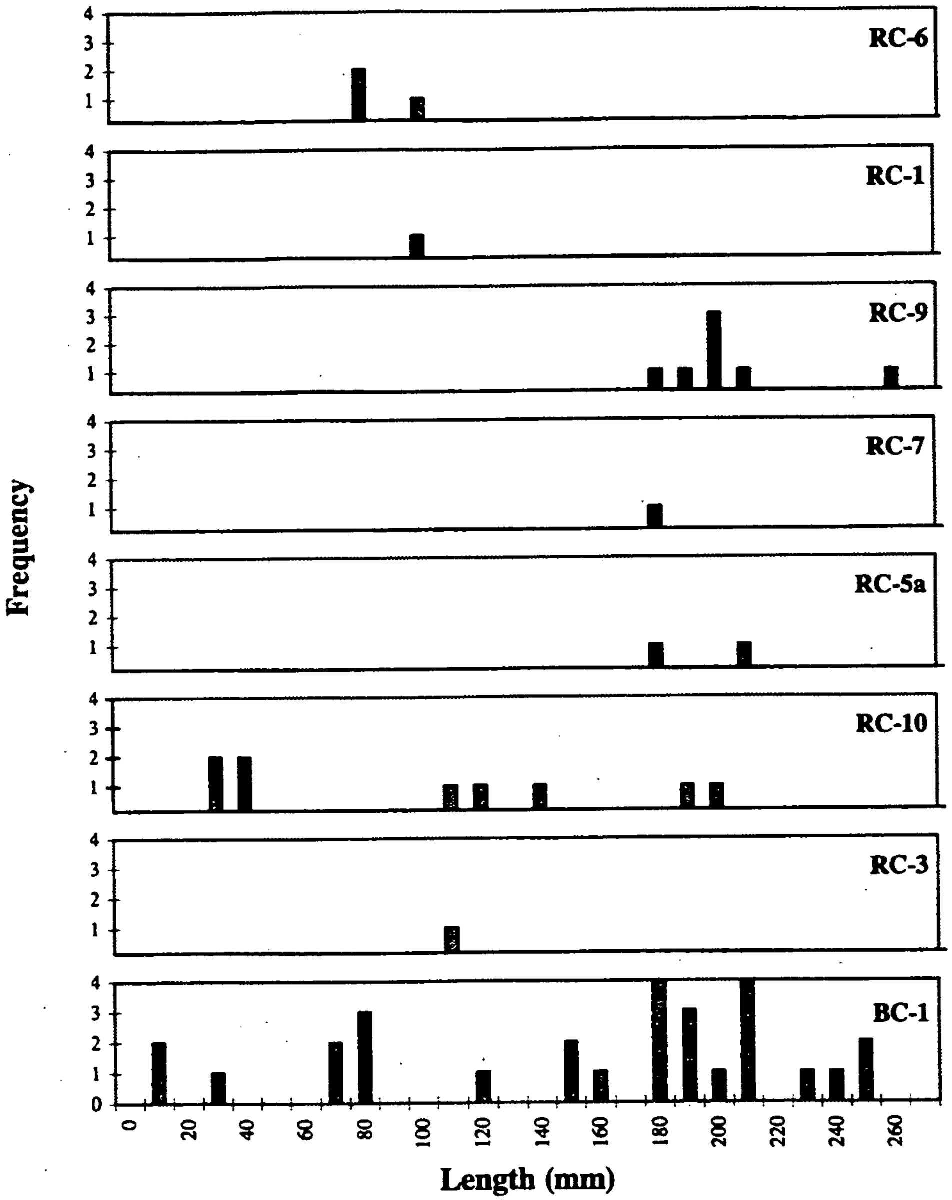

Figure 4.6-4

HOLDEN MINE
CUTTHROAT LENGTH FREQUENCY

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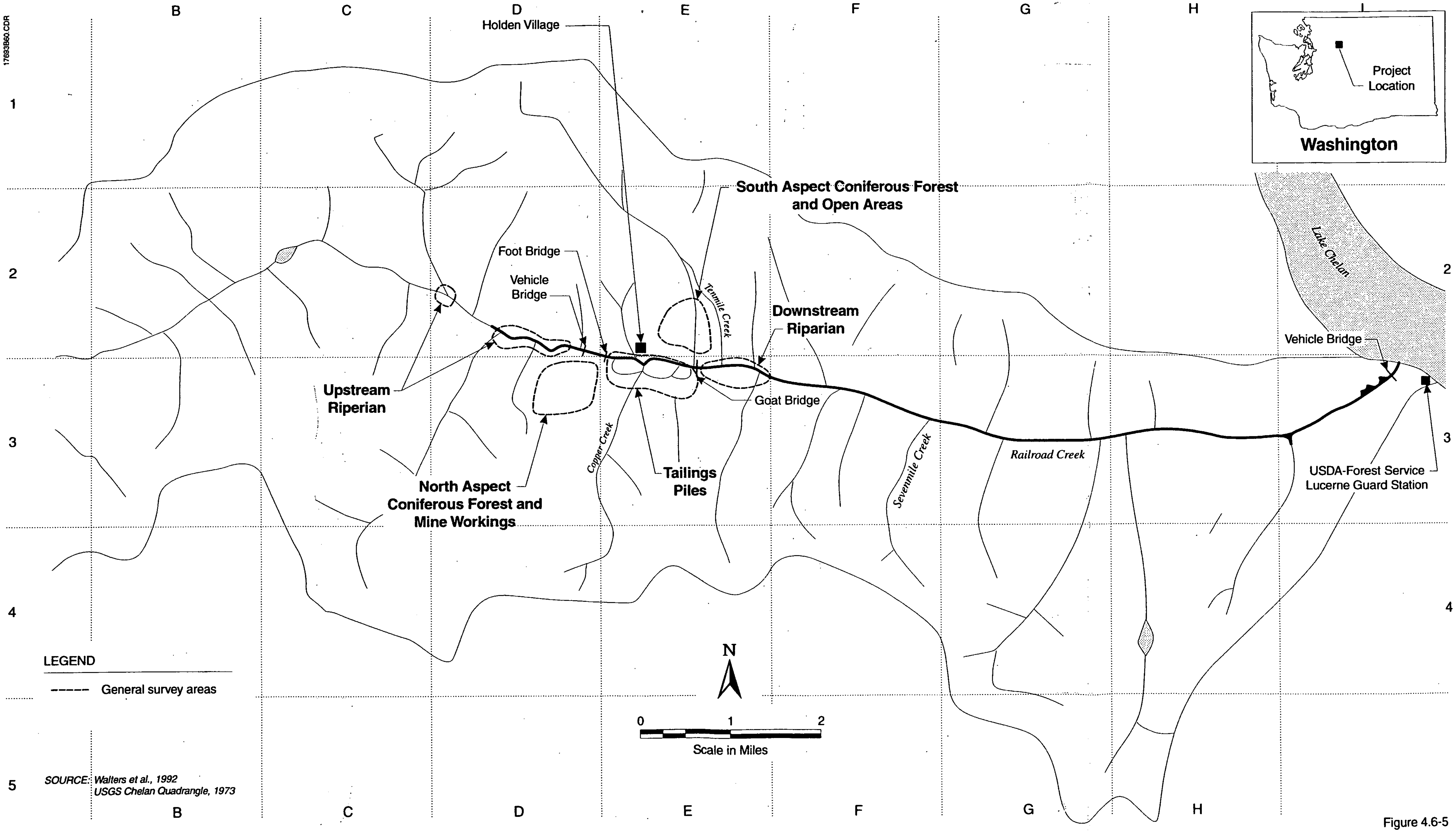
17693B60.CDR



SOURCE: *Walters et al., 1992*
USGS Chelan Quadrangle, 1973

Figure 4.6-5

ECOLOGICAL SURVEY LOCATIONS - TERRESTRIAL - SITE

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Draft Final RI Report

DAMES & MOORE
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Job No. 17693-005-019

DRAFT FINAL
Remedial Investigation Report
Holden Mine Site

Volume 1B – Report

prepared for
Alumet, Inc.

prepared by
Dames & Moore
Seattle, Washington

July 28, 1999

DAMES & MOORE
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DRAFT FINAL
Remedial Investigation Report
Holden Mine Site

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5.0 NATURE AND EXTENT OF CONTAMINATION

This section discusses the nature and extent of contamination identified in the surface water of Railroad Creek, Copper Creek, and associated tributaries, groundwater in the mine-affected area, soil in Holden Village and maintenance yard areas, sediment in Railroad Creek and Lake Chelan, and other media associated with the Site. The discussion is based on analytical results collected historically from previous investigations at the Site and data collected during the RI conducted in 1997 and 1998. Included in this section are field measurements and laboratory analytical data collected in accordance with the approved draft RI Work Plan, SAPs, and QAPPs for the RI as presented in Section 1.0. Issues that were identified during data validation reviews that resulted in data qualification affecting data interpretation are incorporated in the analytical discussions for each media.

5.1 BACKGROUND AND CHEMICAL SPECIFIC ARARS AND TBCS

Background conditions were assessed for Site media where feasible to assess chemical constituents that exist in the area but are not related to mining activities at the Site. Assessment of background conditions included the collection and analysis of samples from areas in and near the Railroad Creek drainage where mining activities by Howe Sound Company are believed not too have occurred. Statistical analyses of the data were performed using the statistical methods established under MTCA and associated other published statistical guidance. The MTCA statistical methods utilized adequately address background conditions assessed under CERCLA. The establishment of cleanup levels under MTCA considers Site-specific characteristics under certain circumstances. Site-specific cleanup levels may be established based on background concentrations of compounds of concern (COCs) at a site provided that adequate data are available to appropriately calculate background concentrations as specified in the Washington Administrative Code (WAC) 173-340-708(11).

Two types of background are defined by MTCA. Natural background is defined as the concentration of hazardous substances consistently present in the environment which has not been influenced by localized human activities. Area background is defined as the concentration of hazardous substances that are consistently in the environment in the vicinity of the Site which are the result of human activities unrelated to releases on the Site. Natural background was not evaluated due to the physical characteristics of the Site and historical prospecting and mining-related activities that have occurred in the area unrelated to the Howe Sound Company and the Holden Mine. Area background was assessed for media where feasible.

Site data were compared to background constituent levels to assess if Site-specific sample concentrations are above area background values. A preliminary list of chemical specific Applicable or Relevant and Appropriate Requirements (ARARs) and To Be Considered (TBC) numerical chemical guidance for surface water, groundwater, soil, and sediment are presented and discussed and are for identifying potential compounds of concern (PCOCs) for the Site. The PCOCs identified are further evaluated in the ecological and human health risk assessments.

The intent of this section is to present and compare available background data and chemical-specific ARARs and TBC guidance for compounds identified in surface water, groundwater, soil, and sediment. A more detailed discussion of ARARs and TBC values will be provided in the Remedial Action Objectives

(RAOs) section of the Feasibility Study. This section is not intended to substitute or replace discussion on establishing RAOs at the Site, which are established as cleanup goals for protection of human health and the environment. The purpose of the comparison is to focus the discussion of laboratory results on specific areas related to the Site where background influences are considered and where chemicals occur at concentrations that are above background and preliminary chemical-specific ARARs. The background data and chemical-specific ARARs used in the evaluation of each media are provided in the following sections.

5.1.1 Soil

Soil samples were collected in the fall of 1998 from the Railroad Creek drainage generally upvalley of mining activities associated with the Holden Mine Site to assess area background metal concentrations. These data are discussed in Section 5.2. Site data were compared to area background concentrations as an initial step in the assessment of PCOCs.

Published background soil data for the Yakima Basin (Ecology, 1994) is also available for comparison to Site data, where constituent background levels are not available. The MTCA (WAC 173-340) cleanup levels were also used for comparison. The preliminary chemical specific ARARs and TBCs for soils are shown in Table 5.1-1 and include:

- Railroad Creek drainage area background values
- Background values for the Yakima Basin published by Ecology
- MTCA Method A and Method B soil cleanup levels, where available

MTCA establishes procedures for calculating cleanup levels at sites where releases of hazardous substances pose a threat to human health or the environment. MTCA Method A involves comparing measured compound of concern concentrations to cleanup standards developed for a limited number of compounds. Method A is intended to provide protective cleanup levels at sites undergoing routine actions or for sites with a limited number of compounds of potential concern. Method A values derived by Ecology were based on considerations of technical feasibility and aesthetics, as well as other considerations, and are not strictly based on toxicological properties. The Interim Interpretive and Policy Statement for total petroleum hydrocarbons (TPH) published by Ecology in 1997 allows the calculation of revised TPH cleanup levels that are site-specific and protective of groundwater and human health.

MTCA Method B presents cleanup levels for individual compounds of potential concern using applicable state and federal laws or algorithms as specified in WAC 173-340-720 through 173-340-750. For remediation of potentially carcinogenic substances, cleanup levels are based on the upper bound of the estimated excess lifetime cancer risk of 1.0E-06. For individual non-carcinogenic substances, cleanup levels are set at concentrations which are expected to result in no acute or chronic toxic effects to human health or the environment. Calculated cleanup levels are based on the most recent available reference doses and carcinogenic potency factors, in addition to standardization exposure parameters established by Ecology.

Site soil was initially compared to area background levels. If the concentration was above background, the data were then compared to MTCA Method A if available. Where MTCA Method A levels were unavailable, Method B levels were used.

Area background values for arsenic, cadmium, copper, lead, manganese, and zinc are above the Yakima Basin background values published by Ecology. Additionally, area background arsenic and cadmium levels are above MTCA Method B and MTCA Method A cleanup levels, respectively.

5.1.2 Surface Water

The assessment of background surface water quality conditions for Railroad Creek is complex due to the presence of a number of tributaries that enter Railroad Creek upstream and downstream of the Site. Additionally, historic prospecting and mine activities in the area unrelated to the Howe Sound Company and the Holden Mine preclude the assessment of natural background as defined under MTCA. Area background related to Railroad Creek was evaluated by collecting water quality data from Railroad Creek and various tributaries upstream and downstream of the Site and from creeks located in the Stehekin valley that have similar characteristics to Railroad Creek.

The specific sampling locations are further described in Section 5.3. Area background data were compared to federal freshwater acute and chronic water quality criteria (AWQC and CWQC, respectively) specified in 40 CFR Part 131.36 and Washington State freshwater criteria (WAC 173-201A) to assess if background metal concentrations were above the criteria. Site data collected from reaches that appeared to be influenced by the Site were then compared to the background data and the ARARs described below.

Table 5.1-1 presents preliminary ARARs and TBCs for surface water. The table includes:

- Area background surface water concentrations
- Washington State freshwater acute/chronic criteria as described in WAC 173-201A
- Federal freshwater acute/chronic criteria as described in 40 CFR Part 131.36
- MTCA Method B Surface Water Cleanup Levels, CLARCII update, February 1996

The federal freshwater AWQC and CWQC focus specifically on the protection of aquatic life. Freshwater AWQC and CWQC are established for arsenic, cadmium, chromium, copper, lead, nickel, and zinc and are based on dissolved concentrations. The AWQC and CWQC for selenium are based on total recoverable concentrations. The AWQC for mercury is based on dissolved concentrations, however the CWQC is based on total recoverable concentrations. Only an AWQC (no CWQC) is established for silver and is based on dissolved concentrations. The criteria for cadmium, chromium, copper, lead, nickel, silver, and zinc are corrected for water hardness.

The State of Washington criteria for surface water generally adopted the federal criteria; however, actual hardness values for metal-specific criteria calculations are used as compared to the use of 25 ppm minimum hardness for federal criteria where actual hardness measurements are less than 25 ppm. The comparison of Site surface water data to the AWQC and CWQC is considered to be a conservative assessment as the AWQC is based on short-term exposure of 1-hour average and the CWQC is based on a 4-day average.

In addition to the metals discussed above, criteria for beryllium and iron are specified in WAC 173-201A by reference to an EPA document "Quality Criteria for Water, 1986." As with the metals criteria specifically identified in WAC 173-201A, the criteria specified for beryllium and iron is derived primarily for the protection of aquatic life.

Also included in WAC 173-201A are parameters that are not metals but which are measured and assessed in surface water bodies. These include chloride, cyanide, dissolved oxygen, temperature, pH, and turbidity. Site data were compared to the criteria for these parameters as well as the WQC for metals.

Freshwater AWQC and CWQC have not been established for other metals including: aluminum, barium, calcium, magnesium, manganese, molybdenum, potassium, sodium, thallium, and uranium. Calcium, magnesium, potassium, and sodium are considered nutrient metals and were not considered as part of the PCOC evaluation. Area background metal concentrations for the remaining metals were used to assess downstream Railroad Creek surface water concentrations of these metals.

MTCA Method B surface water levels are also available and are derived for protection of human health rather than the protection of aquatic life. In general, metal concentrations for aquatic life criteria are more conservative than the MTCA criteria; therefore, the MTCA Method B levels were considered further for PCOC assessment only for those metals where aquatic life criteria were not available. Evaluation of the MTCA Method B levels are addressed in the human health risk assessment in Section 7.0.

5.1.3 Groundwater

Groundwater in and around the Site is not used as a source of potable water. The Holden Village community water source is supplied by Copper Creek upgradient of Holden Mine–related mining influences. The use of groundwater beneath the tailings as a potable source is not anticipated in the future due to readily available surface water in Copper Creek as a potable water supply source. Currently, in the Railroad Creek drainage, the use of groundwater as a potable water supply is limited to Lucerne at the mouth of Railroad Creek.

It was not possible to fully assess representative background groundwater quality at the Site due to the complex hydrogeologic conditions and physical characteristics of the area. Groundwater occurs in both bedrock and the overlying glacial soil and alluvium. Groundwater was collected from wells and seeps located outside of the observed influence of the Holden Mine and believed to be representative of background groundwater quality. The majority of groundwater data collected was from wells and seeps located directly within the influence of the Holden Mine and/or in direct contact with tailings material. Background water quality and Site data are discussed in Section 5.4.

Groundwater quality data were compared to MTCA Method A and Method B groundwater cleanup levels (Table 5.1-1). Groundwater collected at Lucerne was also compared to EPA maximum and secondary MCLs. Additionally, groundwater data were compared to conventional and field parameter criteria specified in Washington State groundwater standards (WAC 173-200) for nitrate, chloride, sulfate, total dissolved solids, pH, and color.

5.1.4 Sediment

Limited background sediment data from 1994 is available upstream of the Site in Railroad Creek and in Holden Creek (USGS, 1994). Sediment samples were collected during the RI from the Lucerne Bar in Lake Chelan and from a reference location in Stehekin. Additionally, solid samples not characteristic of sediments were collected at the Site during the RI and historically. These matrices included flocculent, ferricrete, portal film, and concentrate.

There are no promulgated federal or State of Washington regulations regarding freshwater sediment chemical criteria or criteria related to other accumulated solid materials. In 1997, Ecology published a guidance document, "Creation and Analysis of Freshwater Sediment Quality Values in Washington State," which provides guidance information on possible sediment threshold levels and suggests "possible" proposed guidelines (Ecology, 1997). The Ecology Freshwater Sediment Quality Values (FSQVs) are provided in Table 5.1-1. The only current regulatory citation for freshwater sediments is specified in WAC 173-204 Section 340 for freshwater sediment quality standards and states "the department shall determine on a case-by-case basis the criteria, methods, and procedures necessary to meet the intent of this chapter." Currently, proposed changes are under review regarding this regulation but have not been promulgated.

Guidelines for freshwater sediments have been developed by Long & Morgan (1990, 1995) and the Canadian Council of Ministers of the Environment (CCMI, 1991) and are considered TBCs that may also be used for comparison; however, these guidelines are not further discussed in this section. It is understood that these guidance have limitations and uncertainties associated with them. The FSQVs available for comparison to historical and RI sediment data are considered to be preliminary as the "possible" guidance levels do not reflect Site-specific conditions.

5.2 SOIL

Surface soil samples were collected during the RI from locations throughout the Railroad Creek drainage and in Holden Village, the baseball field near Winston home sites, the maintenance yard, the lagoon area, the surfaces of the three tailings piles, and downwind of the Site area for windblown tailings. Subsurface soil samples were collected from the maintenance yard, the lagoon area, and the tailings piles.

Samples were analyzed for metals (aluminum, arsenic, barium, beryllium, cadmium, calcium, chromium, copper, iron, lead, magnesium, manganese, molybdenum, nickel, potassium, silver, sodium, thallium, uranium, and zinc). Samples collected in the maintenance yard and the lagoon area were also analyzed for total petroleum hydrocarbons and PCBs. The samples were submitted for analyses to Analytical Resources Incorporated (ARI) in Seattle, Washington.

The following sections discuss the data collected during the RI for each of the geographic locations, as well as historical data reported by the USBM and USGS. The historical data are assumed to be of adequate quality to include in the RI for comparative purposes and for evaluating PCOCs except where noted. Sampling procedures and analytical methodology used historically may differ from procedures and methods used during the RI. These differences may result in data that are inappropriate or not beneficial to use for Site assessment due to increased detection limits, different sample locations, and different analytical parameters. Where appropriate, historical data are discussed with the RI data. RI and historical sample locations are shown on Figures 5.2-1 through 5.2-5. Analytical data are summarized in Tables 5.2-1 through 5.2-5. A summary of the PCOCs identified in the soil matrix at the Site is provided in Table 5.2-6.

5.2.1 Background

Area background was statistically calculated from analytical data collected for this purpose. The Site sample data were compared initially to the area background values.

MTCA defines the methods and describes the criteria for determining background concentrations (WAC 173-340-708). A total of 20 samples are required to define area background and were collected from areas that appeared not to have been influenced by releases from Howe Sound Company or Site activities.

Two surface soil samples (DMSS-26 and DMSS-27) were collected in 1997 west of the Wilderness Area boundary to preliminarily evaluate background concentrations. The sample locations are shown in Figure 5.2-1 and the data are summarized in Table 5.2-1. Additional historic information was discovered during the RI that indicated that road building activities utilizing waste rock materials may have occurred at or near these sample locations prior to the establishment of the Glacier Peak Wilderness, precluding these data from background evaluation.

Area background metal concentrations were calculated from sample data collected in the fall of 1998. Twenty samples were collected within the Railroad Creek watershed but outside of areas suspected to be affected by mine activities associated with the Howe Sound Company and the Holden Mine. The analytical data are summarized in Table 5.2-2. The sample locations are shown on Figure 5.2-2.

The results of the 20 area background samples collected in 1998 were statistically analyzed. Samples DMSS-26 and DMSS-27 were not included in the statistical calculations due to potential affects in terms of the reported use of waste rock for road construction at these locations. Statistical calculation methods to determine background concentrations are outlined in WAC 173-340-708(11) and in Ecology's statistical guidance (1992). The statistical guidance and Ecology's MTCAStat program were used to perform the analyses. The MTCAStat program is recommended for background and site cleanup calculations. The background module of the MTCAStat program was used to determine the distribution of data. Based on the data distribution, the 90th percentile, mean, standard deviation, median, minimum, and maximum were calculated. The results of the statistical analysis are summarized with the data in Table 5.2-2.

The 90th percentile value is a default value for the MTCAStat background evaluation. A 90th percentile was calculated for all of the metals evaluated. Generally, distribution was lognormal or normal. There were some data sets that were distribution free (non-parametric). These included arsenic, beryllium, calcium, chromium, lead, molybdenum, nickel, silver, and thallium. The non-parametric distribution generally results from data sets that include a wide range of detected concentrations or data sets with concentrations that are similar and whose distribution tend to bunch rather than spread.

The calculated area background values (90th percentile) were compared to the Yakima Basin published background values (Ecology) where available. Area background values for aluminum, beryllium, chromium, iron, and nickel were below Yakima Basin values. Arsenic, cadmium, copper, lead, manganese, and zinc were above Yakima Basin values. Higher concentrations of copper and zinc in native soil in the area are consistent with the natural mineralization in the Railroad Creek valley. Area background values were also compared to MTCA Methods A and B cleanup levels. Background values were below the cleanup levels with the exception of arsenic and cadmium which were above MTCA Method B and MTCA Method A cleanup levels, respectively.

Site data were compared to the area background concentrations. For purposes of this discussion, "above background" refers to the statistically calculated area background. Per MTCA (Chapter 173-303-740), if background concentrations are used as cleanup levels, no single sample concentration in a data set may be greater than two times the 90th percentile value (background) and less than ten percent of the sample concentrations may be above the 90th percentile value in a data set. PCOCs were identified where metal concentrations were (1) greater than 2 times background, or (2) more than 10% of the sample concentrations in a data set were above background, and (3) concentrations were above MTCA Method A cleanup levels or MTCA Method B cleanup levels if Method A levels were not available. Exceptions to the PCOC assessment were cations (calcium, magnesium, potassium, and sodium), aluminum, and iron as there are no available cleanup levels provided for these metals. Calcium, magnesium, potassium, and sodium are considered nutrient metals and were not considered as PCOCs. Iron and aluminum were considered PCOCs if the results were above background as noted above.

5.2.2 Holden Village

5.2.2.1 Historical Soil Samples

Seven surficial soil samples (HV-1A, HV-2A, HV-3A, HV-4A, HV-5A, HV-6A, HV-7) were collected in 1994 by the USBM in Holden Village. One surface soil sample (HW-1A) was collected in the area near the current USFS guard station west of Holden Village. Sample locations are shown in Figure 5.2-3 and the data are provided in Table 5.2-3.

Concentrations of aluminum, beryllium, chromium, copper, iron, lead, mercury, nickel, silver, and zinc were above background levels in several samples, however with the exception of beryllium, all were below MTCA cleanup levels. Beryllium concentrations were slightly above background (0.2 mg/kg) and the MTCA Method B level (0.23 mg/kg) in samples HV-4A (0.32 mg/kg) and HV-6A (0.29 mg/kg). Iron concentrations above background (24,100 mg/kg) ranged from 26,200 to 28,400 mg/kg and were detected in samples HW-1A, HV-3A, HV-4A, and HV-6A. Aluminum concentrations ranged from 21,400 mg/kg to 25,100 mg/kg and were above background (20,900 mg/kg) in samples HV-1A, HV-3A, HV-4A, and HV-6A.

Sample HW-1A contained arsenic (25.2 mg/kg) above background and the MTCA Method A (20 mg/kg) level.

5.2.2.2 RI Soil Samples

Seven surficial soil samples (DMSS-1, DMSS-2, DMSS-3, DMSS-4, DMSS-5, DMSS-6, DMSS-7) and a field duplicate (DMSS-6X) were collected in September 1997 in and around Holden Village. The samples were analyzed for metals. Sample locations are shown in Figure 5.2-1 and analytical data are summarized in Table 5.2-1.

Concentrations of aluminum, barium, beryllium, chromium, copper, iron, lead, molybdenum, nickel, silver, and zinc were detected in one or more samples above background concentrations. However, with the exception of beryllium, the concentrations were below MTCA levels. Beryllium concentrations were slightly above background (0.2 mg/kg) and the MTCA Method B level (0.23 mg/kg) in samples DMSS-1 (0.3 mg/kg), DMSS-3 (0.3 mg/kg), DMSS-6 (0.3 mg/kg), and DMSS-6X (0.3 mg/kg). Iron concentrations above background (24,100 mg/kg) ranged from 24,600 to 29,600 mg/kg and were detected in samples DMSS-2, DMSS-3, DMSS-4, DMSS-5, DMSS-6, and DMSS-6X. Aluminum was above background (20,900 mg/kg) in samples DMSS-3, DMSS-6, and DMSS-6X and ranged from 23,500 mg/kg to 26,300 mg/kg.

The historical data for samples collected in Holden Village were compared to the data collected during the RI. The soil samples collected in 1994 were not analyzed for molybdenum and uranium, and mercury and selenium were not analyzed in 1997; therefore, comparisons were not performed for these metals. The analytical data for the comparable list of analytes were well within an order of magnitude.

The PCOCs in soil in Holden Village appear to be: arsenic at historical location HW-1A; beryllium at historical locations HV-4A and HV-6A, and RI locations DMSS-1, DMSS-3, and DMSS-6; and iron at historical locations HW-1A, HV-3A, HV-4A, HV-6A and RI locations DMSS-2, DMSS-3, DMSS-4, DMSS-5, and DMSS-6; and aluminum at historical locations HV-1A, HV-3A, HV-4A, HV-6A and RI locations DMSS-3 and DMSS-6.

5.2.3 Baseball Field

One surficial soil sample (DMSS-25) was collected from within the baseball field area in October 1997 (Figure 5.2-1). Analytical results are summarized in Table 5.2-1. Copper (63 mg/kg) and iron (26,600 mg/kg) were detected above background (57.4 mg/kg and 24,100 mg/kg, respectively). The concentration of silver (0.5 mg/kg) in the sample was equal to background. Copper and silver were below the MTCA Method B levels (2,960 mg/kg and 400 mg/kg, respectively). Iron was identified as a PCOC for this area.

5.2.4 Maintenance Yard

Four surface soil samples (DMSS-8, DMSS-9, Storage, and DMSS-10), a field duplicate (DMSS-10X) and three subsurface samples (DMSS-8, DMSS-9, and DMSS-10) collected at 2 feet bgs were collected during the RI. Sample locations are shown in Figure 5.2-1 and the analytical data are summarized in Table 5.2-1. Samples were analyzed for metals and organics (TPH, PCBs).

5.2.4.1 Inorganic Results

Arsenic, barium, cadmium, copper, iron, lead, molybdenum, nickel, silver, and zinc concentrations were above background in one or more surface samples. Concentrations were below MTCA levels with the exception of arsenic, cadmium, copper, and lead. The arsenic concentration detected in surface sample "Storage" (60 mg/kg) was above background and the MTCA Method A (20 mg/kg) cleanup level. Cadmium (9.4 to 21.6 mg/kg) was detected in samples DMSS-8, DMSS-9, and "Storage" above background (5.4 mg/kg) and MTCA Method A (2 mg/kg) level. Copper (3,160 mg/kg) detected in sample DMSS-9 was above background (57.4 mg/kg) and MTCA Method B (2,960 mg/kg) level. Lead (1,070 and 392 mg/kg) was detected in samples DMSS-8 and DMSS-9 above background (20.6 mg/kg) and MTCA Method A (250 mg/kg) level. Iron ranged from 22,400 mg/kg to 60,300 mg/kg. Concentrations detected in samples DMSS-8, DMSS-9 and "Storage" were above background (24,100 mg/kg).

Metal concentrations for aluminum, copper, lead, and zinc were above background in one or more subsurface samples. Concentrations for copper, lead and zinc were below MTCA levels. Aluminum (23,900 mg/kg) detected in subsurface sample DMSS-10 was above background (20,900 mg/kg). Generally, the data from surface and subsurface samples indicated that metal concentrations decreased with depth.

PCOCs in soil at the maintenance yard include copper, lead, cadmium, and iron in surface soil. Arsenic is a PCOC in surface soil only at the "Storage" location. Aluminum is considered a PCOC in subsurface soil at DMSS-10.

5.2.4.2 Organic Results

The surface and subsurface samples collected in the maintenance yard were analyzed for PCBs and total petroleum hydrocarbons (as gasoline, diesel, and heavier than diesel). PCBs were detected in surface soil collected at DMSS-9, DMSS-10, and "Storage" and ranged from 17 to 46 µg/kg. These levels are well below the MTCA Method A level (1000 µg/kg). PCBs were not detected in subsurface soils.

TPH concentrations (diesel and heavier than diesel) were above the MTCA Method A level (200 mg/kg) at all sample locations with the exception of subsurface sample DMSS-9 collected at 2 feet bgs. TPH concentrations in the gasoline range were above the MTCA Method A cleanup level at DMSS-10 and DMSS-10 2' (surface and subsurface).

TPH as diesel, heavier than diesel, and gasoline are considered PCOCs in the maintenance yard.

5.2.5 Lagoon Area

A surface soil sample (Lagoon 6,") and a subsurface sample (Lagoon 2'), were collected in 1997 from the surface and 2 ft bgs, respectively. The samples were analyzed for metals and organic compounds (TPH and PCBs). Based on the analytical data collected in 1997 and summarized in Table 5.2-1, additional test pits (DMLG-1, DMLG-2, DMLG-3, DMLG-4, and DMLG-5) were completed in the lagoon in 1998 to assess the vertical and lateral extent of specific chemical constituents. Samples collected in 1998 were analyzed for cadmium, copper, lead, and total petroleum hydrocarbons (TPH diesel and heavier) based on the PCOCs preliminarily identified from the 1997 RI data. The sample and test pit locations are shown on Figures 5.2-1 and 5.2-4 and the analytical data are summarized in Table 5.2-1.

5.2.5.1 Inorganic Results

Aluminum, barium, beryllium, copper, iron, lead, molybdenum, silver, uranium, and zinc were above background in the surface sample Lagoon 6". Concentrations were below MTCA levels with the exception of beryllium (0.3 mg/kg) which was slightly above the MTCA Method B level (0.23 mg/kg). Aluminum (33,500 mg/kg) and iron (36,200 mg/kg) were above background (20,900 mg/kg and 36,200 mg/kg, respectively).

Aluminum, cadmium, copper, iron, lead, molybdenum, silver, thallium, uranium, and zinc were above background in the subsurface samples collected from the lagoon. Concentrations were below MTCA levels with the exception of cadmium, copper, and lead. Aluminum (31,300 mg/kg) and iron (101,000 mg/kg) were above background (20,900 mg/kg and 24,100 mg/kg, respectively). The vertical and lateral extent of cadmium, copper, and lead was evaluated based on the test pit samples collected in 1998.

The data show that concentrations of cadmium, copper, and/or lead are above MTCA levels in the soil from 2 to 4 feet bgs at test pit locations DMLG-2, DMLG-4, and DMLG-5. The highest concentrations of metals detected in the lagoon samples are found in samples from these three test pits. At 7 ½ ft bgs in test pit DMLG-2, cadmium and copper are above MTCA levels. Test pits were not extended deeper as groundwater was encountered at approximately 4 ft bgs at locations DMLG-4 and DMLG-5 and at 7 ½ ft bgs at DMLG-2. Concentrations of copper and lead were above background but below MTCA levels in samples collected from test pits DMLG-1 and DMLG-3 located at the southern and northern ends of the lagoon area. Cadmium was detected but was below background at locations DMLG-1 and DMLG-3.

PCOCs identified in the surface lagoon soil include beryllium, aluminum, and iron. PCOCs identified in the subsurface soil include cadmium, copper, and lead at depths of 2 to 7 ½ ft bgs within and adjacent to the perimeter of locations DMLG-2, DMLG-4, and DMLG-5. Iron and aluminum were identified as PCOCs in subsurface soil based on the single sample result from 1997 (Lagoon 2'); however, the vertical and lateral extent of these metals in the lagoon was not assessed. Additional PCOCs were not identified at testpits DMLG-1 and DMLG-3 located on the southern and northern ends of the lagoon.

5.2.5.2 Organic Results

PCBs were not detected in the surface or subsurface lagoon samples. Total petroleum hydrocarbons (diesel and heavier) were detected in surface and subsurface samples. Concentrations ranged from 230 to 2,200 mg/kg, which is above the MTCA Method A level (200 mg/kg). TPH (diesel and heavier than diesel) are retained as PCOCs in subsurface soils in the lagoon. Soil to a depth of 4ft bgs in the area bounded by test pits DMLG-2, DMLG-4, and DMLG-5 and to a depth of 2ft bgs in the area surrounding test pits DMLG-1 and DMLG-3 of the lagoon is affected.

5.2.6 Tailings Piles

5.2.6.1 Historical Tailings Samples

Historical surface tailings samples were collected by USBM (1995) and USGS (1994 and 1995). The following historical surface sample locations are associated with each tailings pile:

Tailings Pile 1	Tailings Pile 2	Tailings Pile 3
HT1-2A	HT2-2A	HT3-2A
HT1-2B	HT2-2B	HT3-2B
503T	TP2-4 (subsurface)	4 chc 360
504T	502T	500T
505TA		501T
505TB		

The sample locations are provided in Figure 5.2-3.

The samples were analyzed for a similar suite of metals, with some exceptions. The USGS samples were not analyzed for mercury, nickel, selenium, or thallium. Tailings samples collected by the USBM were not analyzed for molybdenum and uranium. The data are summarized in Table 5.2-4.

Aluminum, barium, copper, iron, lead, molybdenum, silver, thallium, and zinc concentrations were above area background in the majority of surface tailings. Mercury was detected in several samples above the Yakima Basin background value (Ecology). The Yakima Basin published background value for mercury was used for data evaluation as mercury was not included in the area background assessment. Metal concentrations were not above MTCA levels. Iron ranged from 54,000 mg/kg to 85,300 mg/kg, above background (24,100 mg/kg). Aluminum ranged from 32,000 mg/kg to 44,000 mg/kg.

A subsurface tailings sample, TP2-4 (5 to 10 ft bgs), was collected by the USBM in 1994. Barium, cadmium, copper, iron, lead, mercury, thallium, and zinc concentrations were above background; however MTCA levels were not exceeded with the exception of cadmium. Cadmium (16.2 mg/kg) was above the MTCA Method A level (2 mg/kg). Iron (61,400 mg/kg) was above background (24,100 mg/kg).

Aluminum concentrations were significantly greater in the samples collected by the USGS than those collected by the USBM. It was determined that the USGS samples were collected from the surface tailings at the toes of the tailings piles whereas the USBM and RI samples were collected on the top of the tailings piles. Additional metals detected at the toe of the slopes were above concentrations detected on the tops of the tailings piles. However, both of the data sets were considered when reviewing the data for PCOCs and comparing to the RI data.

5.2.6.2 RI Tailings Samples

Surface and subsurface samples were collected during the RI from each tailings pile. The samples associated with each tailings pile is provided below.

	Tailings Pile 1	Tailings Pile 2	Tailings Pile 3
Surface	DMSS-11	DMSS-14	DMSS-17
	DMSS-12	DMSS-15	DMSS-18
	DMSS-13	DMSS-16	DMSS-19
Subsurface	DMTP1-2		DMTP3-1
	DMTP1-3A	DMTP2-1A	DMTP3-2
	DMTP1-3B	DMTP2-1B	DMTP3-3A
	DMTP1-4	DMTP2-2	DMTP3-3B
			DMTP3-4A (7 feet bgs)
			DMTP3-4AX (Duplicate)
			DMTP3-4B (10 feet bgs)

Sample locations are provided on Figure 5.2-1 and analytical data are summarized in Table 5.2-5. Samples were analyzed for metals only.

Copper, iron, lead, molybdenum, and silver were above background in the surface samples collected; however, all concentrations were below available MTCA levels. Barium and zinc were above background in a limited number of samples, but well below MTCA levels. Iron ranged from 53,400 mg/kg to 73,700 mg/kg. The USBM data from surface samples collected from the tops of the tailings piles was compared to RI data. The data were similar in concentration and were well within an order of magnitude.

The subsurface samples were collected between 2.5 and 5 feet bgs from test pits completed in tailings piles 1, 2, and 3, with the exception of sample DMTP3-4A that was collected at 7 feet bgs and sample DMTP3-4B that was collected at 10 feet bgs in tailings pile 3.

Aluminum, barium, cadmium, chromium, copper, iron, lead, molybdenum, nickel, silver, thallium, uranium, and zinc were above background in one or more subsurface samples collected. Concentrations were below MTCA levels with the following exceptions: cadmium (21 mg/kg) and copper (12,400 mg/kg) in sample DMTP1-3B and cadmium (147 mg/kg) and copper (16,500 mg/kg) in sample DMTP2-1A. Iron ranged from 26,800 mg/kg to 87,500 mg/kg. Aluminum (29,700 mg/kg) was above background (20,900 mg/kg) at one location (DMTP2-1A).

The subsurface historical data (TP2-4 collected 5 to 10 ft bgs) was compared to the data collected at location DMTP2-2 (4 to 5 feet bgs) during the RI. Generally, the data were within an order of magnitude; however, concentrations of cadmium, lead, and zinc reported in the USBM sample were 20 to 40 times greater than the concentrations detected in the RI samples. Only cadmium levels in the USBM samples were above MTCA levels.

Aluminum and iron are considered PCOCs in surface and subsurface tailings as it is above background; a MTCA level is not currently established. Cadmium and copper are considered PCOCs in subsurface tailings only.

5.2.7 Wind-Blown Tailings

Five surface soil samples (DMSS-20 through DMSS-24) that contained visual evidence of tailings were collected downwind of RC-2 during the RI and were analyzed for metals only. Sample locations are shown in Figure 5.2-5 and the data are summarized in Table 5.2-5.

Barium, copper, iron, lead, molybdenum, silver, and zinc were above background levels in one or more samples collected. However, none of the concentrations were above available MTCA levels. Iron concentrations ranged from 24,100 mg/kg to 66,200 mg/kg.

Iron is identified as a PCOC as it is above background and a MTCA level is not currently established.

5.2.8 Summary

Site-specific background values for metal concentrations were statistically calculated from surface soil samples collected specifically for area background assessment. Metals data collected from Holden Village, the baseball field, maintenance yard, lagoon, tailings piles, and windblown tailings were compared initially to background values. If concentrations were above background, the data were then compared to available MTCA A or MTCA B cleanup levels. Metal concentrations above background and MTCA cleanup levels were preliminarily selected as PCOCs and are summarized by location in Table 5.2-6. Exceptions to the PCOC assessment were cations (calcium, magnesium, potassium, and sodium), aluminum and iron. The cations are generally considered nutrient metals and MTCA does not provide cleanup levels for these metals. Aluminum and iron were considered PCOCs if the results were above background as MTCA does not provide guidance for these metals.

Organic analytical data from the surface and subsurface soil samples collected from the lagoon and maintenance yard were compared to MTCA Method A and Method B cleanup levels. Total petroleum hydrocarbon concentrations above MTCA cleanup levels were considered PCOCs in subsurface soil in the maintenance yard in a localized area and in surface/subsurface lagoon soils. Organic PCOCs are also summarized in Table 5.2-6.

PCOCs in soil and tailings are further addressed in the human health and ecological risk assessments in Section 7.0.

5.3 SURFACE WATER

Surface water sample results evaluated in the RI include historical sample data collected by the USGS, USFS, and Ecology as well as data collected by Dames & Moore during three RI phases conducted in 1997 and 1998. Surface water quality upstream of Holden Mine influences within Railroad Creek was evaluated using historical data collected by others and through a statistical sampling program completed during the RI. Samples were collected upstream of the Holden Mine in Railroad Creek, from tributaries to Railroad Creek including Holden Creek, Big Creek, Copper Creek, and TenMile Creek, and from reference streams, Bridge Creek, South Fork Agnes Creek, and Company Creek, in the Stehekin watershed to assess area background surface water quality; the Holden Creek samples were collected in order to evaluate potential effects of historic prospects reportedly completed by the Howe Sound Company during the period of operation of the Holden Mine.

The surface water samples were collected for Site assessment historically and during the RI from reaches of Railroad Creek adjacent to the Holden Mine and from reaches downstream of potential mine influences. Tributaries and other areas of inflow to Railroad Creek near the mine and mine area including Copper Creek, Copper Creek diversion, and the portal drainage were sampled historically and during the RI as part of the Site assessment. Samples from Railroad Creek, Copper Creek, Copper Creek diversion, Holden Creek, and the portal drainage were also collected during several sampling events to evaluate water chemistry in relation to seasonal and event-related variations. Sample locations are shown on Figures 5.3-1 through 5.3-4. Sampling locations for the RI were located to maintain continuity with historical sampling efforts where possible.

The samples collected during the RI were analyzed for total recoverable and dissolved metals and conventional parameters including all or a subset of the following: aluminum, arsenic, barium, beryllium, cadmium, calcium, chromium, copper, iron, lead, magnesium, manganese, mercury, molybdenum, nickel, potassium, selenium, silver, sodium, thallium, uranium, zinc, ortho/total phosphorous, total/amenable cyanide, total dissolved solids, total suspended solids, chloride, nitrate/nitrite, sulfate, alkalinity, color, and hardness as outlined in the Sampling and Analysis Plan (SAP) and the Quality Assurance Project Plan (QAPP) associated with each RI phase. Three Railroad Creek stations were also analyzed for polychlorinated biphenyls (PCBs) and total petroleum hydrocarbons (gasoline, diesel, and heavier than diesel range). Metal and organic analyses were performed by Analytical Resources, Incorporated (ARI), low-level mercury analysis was performed by Brooks Rand, Ltd., and low-level lead analysis was performed by Frontier GeoSciences. All three laboratories are located in Seattle, Washington. Field measurements for pH, specific conductivity, temperature, oxidation/reduction potential, turbidity, and dissolved oxygen were collected for each sample as outlined in the SAP and QAPP.

A copy of laboratory reports and associated data validation and related memoranda are included in Appendix L.

The data were reviewed and validated as outlined in the QAPP. Generally, the data were acceptable and met the project objectives. Qualifiers of data were assigned in some cases resulting in estimation of the data. Assigned qualifiers are shown with the summarized data. During the April, May/June, and July 1997 sampling rounds, the field filter blank results suggested that barium and zinc were artificially introduced during the filtration process. Other metals (aluminum, calcium, copper, manganese, silver, and sodium) were also detected at levels near the detection limits; however, these detections did not impact data usability. Concentrations detected in the filter blank for barium (18.7 µg/L) and zinc (6 to 16 µg/L) were considered during the data evaluation as these potential introductions did impact the assessment of the data when compared to water quality criteria.

As previously described in Section 5.1.2, Site surface water data was initially compared to the federal and state acute (AWQC) and chronic (CWQC) aquatic life criteria established. Where WQC were not established, Site data were compared to area surface water background concentrations and MTCA Method B cleanup levels for surface water. AWQC and CWQC is established for dissolved concentrations of arsenic, cadmium, chromium, copper, lead, nickel, and zinc. Only an AWQC is available for dissolved silver concentrations. AWQC and CWQC for selenium are based on total concentrations. The AWQC for mercury is based on dissolved concentrations; however, the CWQC is based on the total recoverable concentration. Criteria for cadmium, chromium, copper, lead, nickel, silver, and zinc are corrected based on water hardness. The federal AWQC and CWQC specifies the use of a 25 ppm hardness value for metals requiring hardness correction when measured hardness is less than 25 ppm. The State of Washington specifies the use of actual hardness measurements. The data tables provide both the use of 25 ppm hardness and measured hardness corrected criteria. For discussion purposes, the measured hardness corrected criteria is discussed.

Criteria for the protection of aquatic life is provided for beryllium and iron by reference to the EPA document "Quality Criteria for Water, 1986" in the Washington State regulatory guidance WAC 173-201A. These criteria are shown in Table 5.1-1 and are assumed to be based on dissolved analysis.

The analytical methods used to measure surface water metal concentrations were selected to provide the lowest technically achievable detection limits in an attempt to be at or below the AWQC/CWQC. As the RI data collection and data evaluation progressed, analytical methods were adjusted to facilitate recognized data needs such as reducing detection limits to clearly evaluate exceedances as compared to water quality criteria. The method changes were documented in the SAPs and QAPPs associated with each field phase.

The detection limits for lead and mercury were above the aquatic life chronic criteria (CWQC) in April 1997. Following this round, the lead and mercury methods were revised to provide lower detection limits. During subsequent sampling rounds in May/June and July 1997, mercury and selenium were not detected or were detected at concentrations that were orders of magnitude below WQC. These analyses were then eliminated from future sampling events. The lead concentrations detected in surface water samples collected during 1997 were suspect due to intermittent problems with laboratory method blank contamination. Additionally, the detection limit provided by the method selected was often at or above the CWQC. The method was reevaluated prior to 1998 sample collection and revised to a draft low-level EPA method. The revised method resulted in detection limits well below the CWQC for lead. The May 1998 data allowed data evaluation to clearly determine if exceedances for lead were apparent in surface water in Railroad Creek during the spring.

The surface water discussion is organized and presented beginning with a discussion on the assessment of area background surface water quality. Following the background discussion, individual sections discuss the chemical data collected from the Stehekin River watershed, Railroad Creek, portal drainage, Copper

Creek diversion, and Copper Creek. The data is compared to WQC where available and appropriate. Where WQC were not available, the data were compared to statistically calculated area background and MTCA Method B cleanup levels for surface water. Calcium, magnesium, sodium, and potassium concentrations were not individually evaluated as these metals are considered nutrient metals. Water hardness was considered in the discussions as WQC for several metals is based on hardness.

The discussions incorporate historical data (where appropriate) and RI data. The surface water quality discussion primarily focuses on the RI data collected; however, historical water quality and stream flow data is available for Stations RC-1, RC-2, and RC-3 and at other locations sampled by USFS, PNL, USGS and Ecology. Due to the varied analyte list per historical sampling event and variable detection limits, the comparability and usability of historical data is discussed in appropriate sections. The data are assumed to be of adequate quality to include in the RI for comparative purposes unless otherwise noted. Historical data for Railroad Creek, Copper Creek, Copper Creek diversion, and the portal drainage are available and summarized in tables referenced in the appropriate sections. These data were collected over several studies and were previously evaluated by Dames & Moore (1996). Additional data collected by the USGS and Ecology in 1996 have been evaluated as well.

The intent of the discussion is to identify data trends and PCOCs that will be further evaluated in the compounds of concern fate and transport discussion and the human health and ecological risk assessments. PCOCs were identified if concentrations were above WQC or above statistically calculated area background concentrations or MTCA Method B cleanup levels where WQC are not available. Statistics were used in the human health and ecological risk assessments and the calculations incorporate both RI and select historical data as appropriate.

5.3.1 Background Surface Water Quality in Railroad Creek

5.3.1.1 Background Data Sets and Statistical Methods

Metals data collected from the 1997 and 1998 RI data sets and historically from stations upstream of the Site were compiled to assess area background surface water quality in Railroad Creek. RI and select historical background surface water data from the following stations were used in the area background assessment:

- Railroad Creek (RC-11, RC-1, RC-6)
- Holden Creek (HC-1, HC-2, HC-3, HC-4, Holden Creek)
- Big Creek (Big-1)
- Copper Creek (CC-1, upstream of the Site)
- Ten Mile Creek
- Reference reaches in the Stehekin watershed from South Fork Agnes Creek (SF Agnes Creek) and Company Creek (Both of these creeks originate from the same headwaters as Railroad Creek)
- Historical data collected from Railroad Creek by the USGS from 1994 through 1996 (USGS 367, USGS 546, USGS 600, USGS 707)

- Department of Ecology samples collected June 1996 and September 1996 were also considered.

Sample station locations are shown on Figures 5.3-1 through 5.3-4.

Calculation methods to determine background concentrations are outlined in WAC 173-340-708(11) and in Ecology's statistical guidance (1992). The statistical guidance and Ecology's MTCAStat statistical program were used to perform the analyses. Statistical analysis was performed for total and dissolved concentrations for aluminum, arsenic, barium, beryllium, cadmium, calcium, chromium, copper, iron, lead, magnesium, manganese, mercury, molybdenum, nickel, potassium, selenium, silver, sodium, thallium, uranium, and zinc. The data were compiled into a total data set that included all data points listed above without regard to season or time collected. The number of and specific data points included in the analysis are shown in Table 5.3-1.

For a select list of dissolved metals including: aluminum, arsenic, beryllium, cadmium, chromium, copper, iron, lead, magnesium, manganese, selenium, silver, and zinc, the total data set was subdivided into two seasonal data sets, spring and fall. These metals represent the broad suite of PCOCs and other metals of interest related to the Holden Mine. The number of data points for each seasonal data set is shown below. Specific data points used are shown in Tables 5.3-2 to 5.3-14.

Eight data points were considered a minimum data set for performing statistical calculations, with one exception (seven points for the arsenic fall data set).

Metal	Seasonal Set – Spring # Data Points	Seasonal Set-Fall # Data Points
Aluminum	19	13
Arsenic	10	7
Beryllium	19	11
Cadmium	20	12
Chromium	17	12
Copper	17	12
Iron	19	11
Lead	18	12
Magnesium	18	11
Manganese	17	11
Selenium	*	*
Silver	19	11
Zinc	20	13

* Insufficient data points available for statistical analysis

Two other data sets, Sets 1A and 1B, were evaluated to assess the comparability of Railroad Creek background stations with Railroad Creek tributaries and other reference stations and to verify that pooling of the data are appropriate. As with the seasonal data sets, only dissolved aluminum, arsenic, beryllium, cadmium, chromium, copper, iron, lead, magnesium, manganese, selenium, silver, and zinc were included in the analysis. The stations included in each set are as follows:

- *Set 1A:* Select historical and RI stations RC-1, RC-6, and RC-11 were pooled.

- *Set 1B:* RI stations located in Holden Creek, Big Creek, Copper Creek, Ten Mile Creek and Stehekin were pooled.

The number of data points for Sets 1A and 1B are shown below. The specific data points used for the analyses are shown in Tables 5.3-2 through 5.3-14.

Metal	**Set 1A** **Railroad Creek** **# Data Points**	**Set 1B** **Other Background** **# Data Points**
Aluminum	30	13
Arsenic	11	8
Beryllium	21	13
Cadmium	28	13
Chromium	22	12
Copper	21	12
Iron	27	13
Lead	22	13
Magnesium	27	13
Manganese	27	9
Selenium	10	6
Silver	28	13
Zinc	31	13

The Ecology guidance notes that MTCA has no provisions for excluding statistical outliers that have not resulted from apparent errors. For this reason, all results for the selected sample points that were reported above the detection limit were included in the statistical calculations. However, due to the wide range of detection limits reported historically and during the RI, some data points (reported as not detected) were omitted if the detection limits reported were due to apparent methodology differences that resulted in high detection limits that were well above the other reported data. Historically and during the RI, method changes were made in an effort to reduce detection limits so that the data were more meaningful when compared to water quality criteria (WQC). Tables 5.3-1 through 5.3-14 show the data points actually used for each analysis as well as those considered for analysis but omitted.

During RI data collection in 1997, lead results in upstream stations were generally at or just above the detection limit of the method used for analysis. Due to continuous method blank contamination in the laboratory, detected surface water sample lead results were artificially influenced. This, in combination with the need to clearly delineate lead concentrations above chronic water quality criteria, resulted in a revision to the lead method in 1998 to reduce the detection limit by an order of magnitude. Detection limits ranged from 0.011 to 1 µg/L in sample data collected during the RI. Due to the wide range of concentrations representing the detection limit, the 90th percentile calculated for lead in all three data sets did not include detection limits greater than or equal to 1.0 µg/L. Inclusion of these detection limits skewed the 90th percentile lead concentration. Table 5.3-9 provides a list of sample data points that were considered but were omitted from the statistical calculations.

An additional item considered during the statistical analysis for zinc was the impact of field filtration during April, May, June, and July 1997. During this timeframe, it was determined that field filtration had potentially artificially enhanced the zinc results. For statistical purposes, the total results were used where the data for dissolved zinc clearly indicated artificially introduced zinc. These instances include only the data sets where the total value was not detected but the dissolved result was above the detection limit. The total zinc results in these instances are assumed to be more representative of actual dissolved zinc concentrations. Table 5.3-14 lists these specific data points.

The background module of the MTCAStat program was used to determine the distribution of data. Based on the data distribution, the 90th percentile, mean, standard deviation, median, minimum, and maximum were calculated.

The results of the statistical analysis for the total data set, the spring seasonal set and the fall seasonal data set are summarized in Tables 5.3-1, 5.3-15 and 5.3-16, respectively. The statistical summary for Sets 1A and B are summarized in Table 5.3-17.

The 90th percentile value is a default value for the MTCAStat background evaluation. The data distribution allowed the calculation of a 90th percentile, with few exceptions. Statistical analysis was not performed for dissolved beryllium, chromium, selenium, silver, and thallium data sets because these metals were not detected. A 90th percentile was not calculated for arsenic in the fall data set due to a limited number of data points. Generally, data distribution was lognormal with an occasional normal distribution. There were several data sets that were distribution free (non-parametric). The non-parametric distribution generally results from data sets that include a wide range of detected concentrations or data sets with concentrations (detects and/or non-detects) that are similar and tend to bunch rather than spread. The 90th percentiles for the total data set are summarized in Table 5.3-1. The 90th percentiles for the seasonal data sets and sets 1A and 1B are summarized below.

			90th Percentiles **(µg/L)**		
Metal (Dissolved)	**Total**	**Spring**	**Fall**	**Set 1A Railroad Creek**	**Set 1B Other Background**
Aluminum	37.4	48	26	39	36
Arsenic	0.9	0.84	0.82 (50th %)	0.92	0.97
Cadmium	0.07	0.06	0.08	0.07	0.07
Copper	1.06	1.02	0.9	1.13	0.81
Iron	40	30	56	44	26
Lead	0.54	0.31	0.56	0.53	1.2
Magnesium	626	540	744	660	703
Manganese	2.42	2.64	2.9	2.47	2.57
Zinc	7.81	4.84	13	8.1	9.4

The 90th percentile concentrations of metals in the total data set include spring, summer, fall and winter data points. The spring and fall data sets generally bracket the range of 90th percentile concentrations for the total data set. Limited variation exists between the 90th percentile metal concentrations in the total data set as compared to the spring and fall seasonal data sets for dissolved aluminum, arsenic, cadmium, copper, iron, lead, magnesium, manganese, and zinc. Additionally, limited variation exists between area background Sets 1A (Railroad Creek stations) and 1B (other background stations). Based on the statistical analysis, it is appropriate to use the 90th percentile values in the total data set for area background assessment. The data also justify using the upstream Railroad Creek station(s), RC-1, RC-6, and/or RC-11, to monitor area background surface water quality in Railroad Creek.

5.3.1.2 Area Background Compared to WQC

The area background concentrations (as determined by the total data set) for arsenic, beryllium, cadmium, chromium, copper, iron, lead, mercury, nickel, selenium, silver, and zinc were compared to WQC. For those metals requiring hardness correction, background values were compared to the WQC using a minimum hardness of 6.7 ppm. This value was selected as it is representative of the lower hardness values obtained in the RI data and provides the most conservative WQC levels. Hardness concentration in Railroad Creek varied from 6.7 to 31 mg/L dependent upon the station location and sampling event. The lowest hardness values generally occurred in stations upstream of the Holden Mine. The background values were also compared to WQC based on 25 ppm hardness as this is the minimum hardness allowed for WQC under the federal guidance when actual hardness values are below 25 ppm. The WQC and background values are summarized below.

Metal	**Background Concentration (μg/L)**	**WQC (μg/L) (hardness 6.7 ppm)**		**WQC (μg/L) (hardness 25 ppm)**	
		AWQC	CWQC	AWQC	CWQC
Arsenic	0.9	360	190	360	190
Beryllium	<0.04	130	5.3	130	5.3
Cadmium	0.07	0.20	0.14	0.82	0.37
Chromium	<0.2	60	19	180	57
Copper	1.06	1.3	1.1	4.6	3.5
Iron	40	1000	1000	1000	1000
Lead	0.54	3.1	0.12	14	0.54
Mercury*	0.00066/0.05	2.4	0.012	2.4	0.012
Nickel	0.39	144	16	440	49
Selenium	<0.2	20	5	20	5
Silver	<0.04	0.030	NE	0.32	NE
Zinc	7.81	12	11	35	32

* CWQC is based on total metals (0.00066 μg/L). AWQC is based on dissolved metals (0.05 μg/L).

Based on 6.7 ppm hardness, lead and silver background concentrations (0.54 μg/L and <0.04 μg/L) may exceed the WQC. The lead background value of 0.54 μg/L is likely enhanced due to the suspected laboratory contamination previously discussed. However, if 0.54 μg/L is considered background, the value exceeds the CWQC of 0.12 μg/L if hardness is 6.7 ppm. In the case of silver, the detection limit currently achievable by modification of standard methods is 0.04 μg/L. With a hardness of 6.7 ppm, this detection limit will exceed the AWQC of 0.030 μg/L. Based on a minimum hardness of 25 ppm, the statistically derived background values are below acute and chronic WQC.

The 90th percentile values derived for the seasonal data sets and sets 1A and 1B were also compared to WQC. The values do not exceed WQC for either seasonal data set with the exception of lead and silver as discussed above and zinc during the fall (13 μg/L vs. conservative criteria, 11μg/L). For those metals where WQC are not established, data were compared to available MTCA Method B cleanup levels. Calculated background values did not exceed MTCA Method B cleanup levels.

5.3.1.3 Summary

Based on the statistical analysis performed, sufficient area background surface water data points exist for determining background surface water quality in Railroad Creek. Limited variation exists between the 90th percentile metal concentrations in the total data set as compared to the spring and fall seasonal data sets for dissolved aluminum, arsenic, cadmium, copper, iron, lead, magnesium, manganese, and zinc. Additionally, limited variation exists between area background Sets 1A (Railroad Creek stations) and 1B (other background stations). This provides justification for using the upstream Railroad Creek station(s), RC-1, RC-6, and/or RC-11, to monitor area background surface water quality in Railroad Creek.

The 90th percentile values calculated for the total data set are provided for total and dissolved metals (aluminum, arsenic, barium, beryllium, cadmium, calcium, chromium, copper, iron, lead, magnesium, manganese, mercury, molybdenum, nickel, potassium, selenium, silver, sodium, thallium, uranium, and zinc) in Table 5.3-1. For the purposes of the following discussion, the area background is defined as the 90th percentile values derived for the total data set. Surface water data are compared to WQC where available and area background and MTCA Method B cleanup levels for those metals without WQC.

5.3.2 Stehekin River Watershed

The Stehekin River Watershed was considered a part of the reference area evaluation for comparative fish population studies to Railroad Creek due to similarities in climate, topography, geology, hydrology, and natural mineralization; however, the prospecting and mining activities in the Stehekin River watershed were not as extensive as in the Railroad Creek watershed. Water quality and benthic macroinvertebrate RI sample collection was performed concurrent with the ecological surveys conducted during the RI in Bridge Creek, South Fork Agnes Creek, and Company Creek. The data collected were compared to data collected in Railroad Creek to assess similarities and differences between the Railroad Creek and Stehekin River drainages. The locations are shown on Figure 5.3-3. Available water quality data are discussed below and include historical data collected from the Stehekin River.

5.3.2.1 Stehekin River

Harper Owes (Patmont, 1989) collected samples from the Stehekin River on a monthly basis from December 1986 to November 1987 and analyzed the samples for total recoverable arsenic, iron, and zinc. The mean concentrations for the metals were 0.41 ± 0.18 μg/L, 98.7 ± 89.8 μg/L, and 1.0 ± 0.4 μg/L, respectively. The data are assumed to be of acceptable quality, however, only the mean concentration for each metal was provided in the 1989 report. The mean concentration is the result of averaging all of the data collected and does not account for the significant seasonal flow differences. Thus, the data collected from the Stehekin River watershed during the RI were not compared to the Harper Owes data.

Data were not collected from the Stehekin River during the RI, but were collected from Bridge Creek, South Fork Agnes Creek, and Company Creek in the Stehekin River watershed.

5.3.2.2 Bridge, South Fork Agnes, and Company Creeks

Samples were collected during the RI at one station each on Bridge Creek, South Fork Agnes Creek, and Company Creek in September/October 1997. A field duplicate was collected at Bridge Creek. Laboratory results and field data are summarized in Table 5.3-18. Sample locations are shown in Figure 5.3-3.

The water quality data collected from South Fork Agnes Creek and Company Creek were included in the area surface water quality background assessment discussed previously in Section 5.3.1. Both of these creeks originate from the same general headwaters as Railroad Creek. The arsenic concentration (2.56 µg/L) in South Fork Agnes Creek was an order of magnitude above the concentration detected in Company Creek (0.13 µg/L). The arsenic concentration may be the result of historical prospecting and mining activities in the Stehekin River area and was not included in the background surface water quality assessment. The arsenic concentration is well below CWQC (190 µg/L) and AWQC (360 µg/L).

The data collected from Bridge Creek was compared to WQC or background and MTCA Method B cleanup levels if WQC were not available. Metal concentrations were below WQC. The remaining metals were below background and MTCA Method B cleanup levels with the exception of molybdenum. Molybdenum (1.02 mg/L) was above background (0.78 µg/L). The elevated molybdenum concentration may be related to mining activities in the Stehekin area.

The field sample data for Bridge Creek were compared to additional parameters specified in WAC 173-201A. Where data were available, criteria were not exceeded with the exception of pH. The measured pH at Bridge Creek was 6.4 SU just below the criterion of 6.5 to 8.5 SU.

5.3.3 Railroad Creek

Samples were collected from Railroad Creek upstream of the Site (RC-1, RC-6, and RC-11), adjacent to the tailings piles (RC-4, RC-7, and RC-2), and downstream of the Site (RC-5, RC-5A, RC-10, RC-8, and RC-3) to assess the influence of the Holden Mine on the water quality of Railroad Creek.

5.3.3.1 Historical Data

Historical data were compiled for RC-1, RC-2, and RC-3 from studies conducted from 1982 to 1983 (USFS 1983) and 1989 to 1995 (PNL, 1989 to 1992; USFS, 1993 to 1995). In addition, the USGS collected samples near RC-1, and in proximity of the RC-2 and RC-3 stations in 1994, 1995, and 1996, and Ecology collected samples in 1996 at RC-1, RC-2, and RC-3. The data are summarized in Tables 5.3-19 through 5.3-21. Sample locations are shown on Figures 5.3-1 and 5.3-4.

The list of metals analyzed varied with sampling event and sampling agency. The bulk of the metals data is total recoverable with the exception of the USGS and Ecology data which included dissolved data. Hardness values were available for some data points, but not all, and the omission precluded calculation of hardness corrected criteria. Detection limits for most of the data are higher than assumed WQC and higher than detection limits achieved during the RI. Due to the number of results reported as not detected, trends were difficult to assess and direct comparison to the RI data or assumed WQC was not feasible. In addition, the historical data collected by the USGS, USFS, and PNL in the Railroad Creek reach adjacent to the Site indicated high variability of chemical concentrations. Each agency collected samples from a different portion of the creek span.

The USGS samples were collected from near the south bank of Railroad Creek, USFS/PNL samples were collected from the north bank, and Ecology samples were collected midstream. Samples were collected as grab samples. Samples collected during the RI specifically to address whether differences of chemical concentrations occurred within the creek channel indicated that samples from the south bank in the reach adjacent to the Site were not necessarily representative of the channel chemistry. The pH and specific conductivity measurements collected historically indicate that the creek water is generally neutral (5 to 8 SU) and conductivity is low regardless of stream flow or season. In general, copper and zinc were not detected at RC-1. Copper and zinc were detected at RC-2 and RC-3. Concentrations were generally lower at RC-3 as compared to RC-2. Available stream flow data indicated that copper and zinc are affected by seasonal flow variations. Iron was detected at all stations. The highest concentrations were detected at RC-2. The data are inconsistent when comparing analytical data to streamflow variations. The inconsistencies may be related to the total recoverable analyses versus dissolved analyses.

Patmont (1989) presented the results of sampling and analysis of surface water from Railroad Creek near Lucerne, at the mouth of Railroad Creek. Mean concentrations of arsenic, iron, and zinc were noted to be 0.46, 976, and 70.2 μg/L, respectively. The mean concentration for each of the metals is the result of averaging data collected monthly from December 1986 to November 1987. The mean concentrations do not account for the significant seasonal flow differences.

The historical data for Railroad Creek collected by the USGS and Ecology in Railroad Creek from stations upstream of the Holden Mine were used for background surface water quality assessment as discussed in Section 5.3.1. The data collected from reaches in Railroad Creek adjacent to and downstream of the mine influenced area generally were not compiled with the RI data for PCOC evaluation due to the limitations noted above.

5.3.3.2 Upstream Railroad Creek Stations (RC-1, RC-6, and RC-11)

Stations RC-1, RC-6, and RC-11 were considered to be upstream of mine influences (Figure 5.3-1). Station RC-1 was historically considered as background, i.e., unaffected by mining activities. Historical data for RC-1 area available from two studies conducted between 1982 and 1983 (USFS, 1983) and between 1989 to 1995 (PNL); however, the possible use of tailings and/or waste rock as fill along the banks and at the ballfield near RC-1 during mine operations was discovered and resulted in the establishment during the RI of station RC-6 several hundred yards upstream near the Glacier Peak Wilderness boundary. RC-11 was located upstream of RC-6, above the confluence of Holden Creek and within the Glacier Peak Wilderness boundary.

During the RI, samples were collected at RC-6 and RC-1 during four sampling events (April, May/June, July, and September) in 1997 and one sampling event in May 1998. RC-1 was sampled across the width of Railroad Creek as well as near the north and south banks during May 1997 and September 1997 to determine if localized differences of metal concentrations exist across the channel. Station RC-6 was sampled weekly from May 19, 1997, to June 16, 1997, to assess event-related variability. Station RC-11 was sampled during two sampling events, October 1997 and May 1998.

Inorganics

As previously discussed in Section 5.3.1, the data collected from stations in Railroad Creek upstream of the mine influence were included in the background surface water quality assessment including samples collected across the width of the creek and samples collected on the banks. At the upstream stations, metal concentrations did not indicate variability based on sample location in the span of the creek. The background surface water quality assessment showed that seasonal variability of metal concentrations was minimal. The data also justified the use of upstream Railroad Creek stations, RC-1, RC-6, and/or RC-11 to monitor area background surface water quality in Railroad Creek.

Statistically derived background values are provided in Table 5.3-1. Complete analytical and field data for upstream Railroad Creek stations are summarized in Table 5.3-22. Background values were compared to WQC and discussed in Section 5.3.1. For metals without WQC, the data were compared to MTCA Method B cleanup levels as discussed in section 5.3.1. The WQC by individual stations and event are summarized in Tables 5.3.23 through 5.3.27 for informational purposes only.

The data from upstream Railroad Creek for parameters other than metals and organic compounds were compared to criteria specified in WAC 173-201A. pH measurements ranged from 5 to 8 SU and were outside of the criteria (6.5 to 8.5 SU) in several instances. Turbidity measurements in the field were collected, however readings appeared to be erratic and the accuracy of these measurements questionable, therefore, turbidity was not evaluated further. Dissolved oxygen and temperature were within the criteria designated in WAC 173-201A.

Organics

Samples were collected at RC-6 in May and July 1997 for TPH (gasoline, diesel, and heavier than diesel range) and PCBs. TPHs and PCBs were not detected. PCB analyses were eliminated from future sampling events.

A sample was collected at RC-6 for TPH in September 1997. TPH was not detected. TPH analyses were eliminated from future sampling events.

5.3.3.3 Railroad Creek Stations Adjacent to Tailings Pile

Three water quality sampling stations, RC-4, RC-7, and RC-2, were established adjacent to the tailings piles during the RI (Figure 5.3-1 and 5.3-2). RC-4 is located at the footbridge upstream of the tailings piles. RC-7 is located downstream of Copper Creek and adjacent to tailings pile 2, and RC-2 is located at the eastern end of tailings pile 3. Historical data for RC-2 were discussed in Section 5.3.3.1.

Samples were collected at RC-4, RC-7, and RC-2 during four sampling events in 1997 (April, May/June, July, and September/October) and one sampling event in May 1998. Samples were also collected weekly at RC-2 from May 19, 1997, to June 16, 1997, to assess event-related variability. Samples were collected from the south bank at stations RC-4 and RC-2 to evaluate potential localized differences in metal concentrations across the width of the channel. Laboratory analytical results and field data are summarized in Table 5.3-28. The sample data for each event and associated AWQC and CWQC are summarized in Tables 5.3-23 through 5.3-27.

Inorganics

The data collected adjacent to the tailings pile were compared to WQC where available and to area background concentrations (Table 5.3-1) and MTCA Method B cleanup levels when WQC were not available. Metal concentrations were then assessed in a downstream trend.

RC-4

RC-4 is located downstream of the portal drainage inflow to Railroad Creek, as shown in Figure 5.3-2. The comparison of RC-4 data to area background concentrations indicates that dissolved aluminum was above background in May 1998 (60 µg/L vs. 37.4 µg/L). Dissolved manganese was detected above background (2.42 µg/L) in April 1997 (3 to 4 µg/L), May 1997 (2.94 µg/L), and May 1998 (4.83 µg/L). Metal concentrations for those metals without WQC were also compared to MTCA Method B cleanup levels. Concentrations were not above cleanup levels. Comparison of RC-4 data to WQC is discussed in the following paragraphs.

Dissolved copper concentrations during April through July 1997 ranged from 3.4 to 26.4 µg/L which were above hardness corrected AWQC (1.8 to 4.3 µg/L) and CWQC (1.5 to 3.2 µg/L). Dissolved zinc concentrations ranged from 17 to 73 µg/L during the first three sampling rounds (April, May, July 1997) and were above AWQC (15 to 33 µg/L) and CWQC (14 to 30 µg/L). Cadmium and lead were the only other metals that contained levels above AWQC and/or CWQC, but were not consistently above the criteria. Hardness, alkalinity, pH, and specific conductivity were similar to upstream locations. The measured pH at RC-4 was 5.5 to 7.8, within the range noted for the upstream stations, but in some cases below the criteria specified in WAC 173-201A (6.5 to 8.5 SU). Concentrations of copper, zinc, cadmium, and lead were highest during the May sampling event that corresponds to the highest flow observed in Railroad Creek in 1997. Data collected at RC-4 in May 1998 generally supports the data collected in May 1997; however, dissolved concentrations of aluminum, cadmium, copper, manganese, and zinc were 1.5 to 2 times higher in 1998 than 1997. The use of the low level lead technique in 1998 indicates that lead concentrations do not exceed CWQC as previously indicated during 1997.

Bank samples collected on the south side of Railroad Creek at RC-4 in 1997 were compared to WQC and to the results from samples collected across the creek. Dissolved copper concentrations during all three sampling events ranged from 58.5 µg/L in May 1997 to 3.9 µg/L in September 1997, which were above hardness corrected AWQC (1.8 to 2.8 µg/L) and CWQC (1.5 to 2.2 µg/L). Dissolved zinc concentrations ranged from 191 µg/L in May 1997 to 20 µg/L in September 1997, which were above AWQC (15 to 23 µg/L) and CWQC (14 to 21 µg/L). Cadmium detected at the south bank only in May (1.1 µg/L) was above the AWQC (0.47 µg/L) and the CWQC (0.25 µg/L). Dissolved lead concentrations in May 1997 (0.6 µg/L) were above the CWQC (0.3 µg/L) but below AWQC (7.8 µg/L). The south bank data was compared to samples collected across the width of the creek. During May, July, and September 1997, copper concentrations were approximately two times greater on the south bank. Cadmium and zinc were approximately two times greater on the south bank in May, but were similar to the creek width results in July and September. Field parameters collected from the bank and across the creek width were comparable. All other metals were below established AWQC and CWQC. Metals that do not have established water quality criteria were compared to background and MTCA Method B cleanup levels. Results were below area background and MTCA levels with the exception of manganese in May 1997 (7.46 µg/L vs. 2.42 µg/L) which was above background.

RC-7

RC-7 is located downstream of the inflow from Copper Creek to Railroad Creek and is adjacent to tailings pile 2 (Figure 5.3-2). Dissolved metal concentrations measured at RC-7 were similar to concentrations detected at RC-4 with the exception of manganese and iron which increased significantly from RC-4 to RC-7. The comparison of RC-7 data collected during the RI to area background concentrations indicate that aluminum was above background (37.4 µg/L) in May 1997 (60 µg/L), September 1997 (40 µg/L), and May 1998 (90 µg/L). Manganese was detected above background (2.42 µg/L) during each sampling event and ranged from 5.48 µg/L to 27 µg/L. Data for metals without WQC were also compared to MTCA Method B levels. Metal concentrations were below MTCA levels. Comparison of RC-7 data to WQC is discussed in the following paragraphs.

Metal concentrations measured at RC-7 were similar to those observed at RC-4. Dissolved cadmium concentrations during April 1997 (0.5 µg/L) and May 1997 (0.58 µg/L) were above the CWQC only in April (0.39 µg/L) and the AWQC and CWQC in May (0.44 µg/L and 0.24 µg/L, respectively) (Tables 5.3-23 and 5.3-24). Dissolved cadmium was below the criteria in subsequent rounds collected in July and September 1997. Cadmium results at RC-7 collected in May 1998 were similar to May 1997. The concentration of dissolved cadmium (0.67 µg/L) was above both the AWQC (0.40 µg/L) and the CWQC (0.23 µg/L).

In May and July 1997, dissolved copper (23 µg/L and 2.6 µg/L, respectively) concentrations were above the AWQC (2.7 and 1.9 µg/L, respectively) and the CWQC (2.1 µg/L and 1.6 µg/L, respectively), but were below the criteria in April and September/October 1997 (Tables 5.3-23 through 5.3-27). The copper result (37.5 µg/L) from the May 1998 sampling event was above AWQC (2.5 µg/L) and CWQC (2.0 µg/L). The concentration was also above the May 1997 result (23 µg/L).

Dissolved zinc concentrations during the first three rounds in 1997 ranged from 20 to 90 µg/L which were above the AWQC (16 to 38 µg/L) and the CWQC (15 to 34 µg/L). The July zinc level (20 µg/L) may be related to the artificial introduction of zinc during field filtration. Zinc was below both criteria in September/October 1997. The zinc concentration measured in May 1998 was 115 µg/L, above the May 1997 concentration (85 µg/L). The 1998 result was also above the AWQC (20 µg/L) and the CWQC (19 µg/L).

In May, July, and September 1997, dissolved lead (0.5 µg/L, 0.5 µg/L, and 0.4 µg/L, respectively) was above the CWQC (0.28 µg/L, 0.19 µg/L, and 0.28 µg/L, respectively), but below the AWQC (7.2 µg/L, 4.9 µg/L, 7.2 µg/L, respectively). The May 1998 lead data (performed by low level lead technique) indicates that lead (0.126 µg/L) is below the CWQC (0.26 µg/L). Iron was above WQC (1000 µg/L) in April and September 1997 (1,680 µg/L and 1,150 µg/L, respectively). Other metal concentrations were below AWQC and CWQC.

Silver detected in May 1997 at RC-7 was 0.54 µg/L. The result was qualified as not detected during data validation due to method blank contamination. The AWQC (0.12 µg/L) is below the revised detection limit. Silver was not above AWQC at RC-7 during any other sampling event including May 1998.

Dissolved iron during 1997 was highest in April, decreased in May and July, and increased in September, indicating an inverse relationship with flow. Specific conductivity, pH, hardness, and alkalinity were similar to the upstream locations. Field measured pH at RC-7 in 1997 ranged from 5.8 to 7.6 SU, similar to upstream measurements.

RC-2

RC-2 is located immediately downstream of tailings pile 3 (Figure 5.3-2). The comparison of RC-2 data collected during the RI to area background concentrations indicate that dissolved aluminum was above background (37.4 µg/L) in May 1997 (90 µg/L), September 1997 (40 µg/L), and May 1998 (100 µg/L). Manganese was detected above background (2.42 µg/L) during each sampling event and ranged from 5.52 µg/L to 26 µg/L. For metals without WQC, data were below MTCA Method B cleanup levels. Comparison of RC-2 data to WQC is discussed in the following paragraphs.

Cadmium at station RC-2 was above the CWQC in April 1997 (0.40 µg/L vs. 0.38 µg/L) and the CWQC and AWQC (0.25 µg/L and 0.47 µg/L, respectively) in May 1997. In May and July, copper (23.6 and 2.3 µg/L, respectively) was above AWQC (2.8 and 1.9, respectively) and CWQC (2.2 and 1.6 µg/L, respectively). In April, May and July 1997, zinc concentrations (77, 84, and 24, respectively) were above AWQC (37, 23, and 16, respectively) and CWQC (33, 21, and 15 µg/L, respectively). The concentration in September 1997 was 23 µg/L, just above CWQC (21 µg/L) and equal to AWQC (23 µg/L). The result in July is a potential anomaly related to zinc introduction during field filtration of the sample. Data collected in May 1998 show concentrations similar to those detected in May 1997. Iron was above WQC (1000 µg/L) in April (1,430 µg/L) and September (1,080 µg/L). Other metals were below the AWQC and CWQC.

Near bank samples were collected on the south side of Railroad Creek at RC-2. Metal concentrations near the south bank at RC-2 were comparable to concentrations detected in samples collected across the creek width. Cadmium, copper, and zinc concentrations exceeded AWQC in May 1997. Copper and zinc exceeded AWQC in July 1997. In September 1997, zinc (23 µg/L) was above the CWQC (21 µg/L) and equal to the AWQC (23 µg/L). Iron (1,150 µg/L) was above WQC (1,000 µg/L) in September. Field parameters (pH and specific conductivity) were comparable between bank and creek width samples as well. The measured pH at RC-2 ranged from 5.7 to 8.2 SU. Measurements collected at the south bank ranged from 6.2 to 7.7 SU. The measurements are within the range of the upstream stations (5 to 8 SU).

In summary, the water quality at stations RC-7 and RC-2 were higher in iron and zinc relative to upstream locations. Iron concentrations at RC-7 and RC-2 were also higher than RC-4 concentrations. RC-7 showed higher iron than RC-2 during all of the sampling events in 1997. RC-2 showed higher aluminum than RC-7 during the May 1997 event. The pH at RC-4, RC-7 and RC-2 were all similar to upstream measurements. Samples collected at RC-4, RC-7, and RC-2 in May 1998 generally confirm the trends indicated in the 1997 data.

Seasonal variability in metals concentrations at RC-7 and RC-2 are similar to RC-4. Zinc, copper, lead and cadmium in 1997 were all highest during the May/June sampling event followed by April, July and September. Aluminum, however, was lowest in April, highest in May/June and decreased in July and September indicating that this metal may be directly correlated with Railroad Creek flow. Iron, along with specific conductance, alkalinity and hardness exhibited the opposite relationship, and was inversely correlated with streamflow. Hardness and concentrations of aluminum, cadmium, copper, iron, manganese, and zinc at RC-2 are plotted against stream flow measured at RC-4 on Figures 5.3-5 to 5.3-9.

Organics

TPH and PCBs were analyzed only at RC-2 and were not detected. PCBs were not included in the list of analytes for the September 1997 and later sampling events based on the results from the previous 1997 sampling rounds.

5.3.3.4 Downstream of Tailings Piles

Surface water sampling locations downstream of the tailings piles included RC-5 and RC-5A, RC-10, RC-8 and RC-3 (Figure 5.3-1). RC-5 was sampled approximately 500 feet downstream of RC-2 during the April 1997 sampling round. RC-5A was established in May 1997 just above the confluence of Tenmile Creek, the next downstream tributary to Railroad Creek. Station RC-10 was established as an aquatic habitat station downstream of Tenmile Creek, and was sampled for water quality only once in September 1997. Stations RC-8 and RC-3 are both near Lucerne. RC-8 was located near the old USGS gauging station at Lucerne upstream of RC-3 (Figure 5.3-1). Samples were collected at stations RC-5(A) and RC-3 during all four sampling events in 1997 (April, May/June, July, September) and one sampling event in May 1998. Station RC-10 was sampled in September 1997 and May 1998. Station RC-8 was established as a comparison to RC-3, and was sampled during April and September 1997 only because high stream flows created accessibility and safety issues at this location during the May/June and July events.

Laboratory analytical results and field data are summarized in Table 5.3-29 and the data are compared to the AWQC/CWQC for each sampling event in Tables 5.3-23 through 5.3-27.

Inorganics

The metals data associated with RC-5, RC-10, RC-8, and RC-3 are described below.

<u>RC-5</u>

The comparison of RC-5 data collected during the RI to area background concentrations indicate that dissolved aluminum was above background (37.4 μg/L) on May 20, 1997 at RC-5 (70 μg/L) and at RC-5A in September 1997 (50 μg/L) and May 1998 (90 μg/L). Manganese was detected above background (2.42 μg/L) during each sampling event and ranged from 7.04 μg/L to 26 μg/L. The concentrations of aluminum and manganese at RC-5 and RC-5A are similar to concentrations of these metals detected at stations RC-7 and RC-2. Metal concentrations were not above MTCA Method B cleanup levels for those metals without WQC. Comparison of RC-5 data to WQC is discussed in the following paragraphs.

Cadmium, copper, and zinc were the only metals that were above WQC in one or more sampling events. Silver was not detected at RC-5 on May 20, 1997, however, the detection limit (0.14 μg/L) was just above the AWQC (0.13 μg/L). Silver was not detected at RC-5A on May 22, 1997. The detection limit (0.04 μg/L) was well below the AWQC (0.18 μg/L). In April 1997, cadmium (0.4 μg/L) was above the CWQC (0.38 μg/L). On May 20, 1997, cadmium (0.5 μg/L) was above the CWQC (0.25 μg/L) and slightly above the AWQC (0.47 μg/L). The RC-5 station was relocated further downstream (RC-5A) and resampled on May 22, 1997. The cadmium concentration (0.4 μg/L) at RC-5A was also above the CWQC (0.29 μg/L) and below the AWQC (0.58 μg/L). A sample was collected from this station in May 1998. The cadmium concentration (0.58 μg/L) was above CWQC (0.25 μg/L) and AWQC (0.47 μg/L).

In May 1997, copper (21.5 µg/L) in the sample collected at RC-5 was above CWQC (2.2 µg/L) and AWQC (2.8 µg/L). Copper concentration (7 µg/L) at the RC-5A location sampled on May 22, 1997 was above CWQC (2.6 µg/L) and AWQC (3.4 µg/L). Copper (2.4 µg/L) was detected in July 1997 above the CWQC (1.7 µg/L) and AWQC (2.1 µg/L). Copper was below WQC in the sample collected in September 1997. A sample was collected at this location in May 1998. The concentration of copper (26.9 µg/L) was above CWQC (2.2 µg/L) and AWQC (2.8 µg/L).

Zinc ranged from 24 to 98 µg/L, which was above AWQC and CWQC during all sampling events (Tables 5.3-23 through 5.3-27). The July 1997 zinc result may be due to the introduction of zinc during field filtration. In general, station RC-5 and RC-5A data indicated similar water quality as RC-2.

Iron (1,290 µg/L) was above WQC (1000 µg/L) at RC-5 sampled in April 1997 and at RC-5A sampled in September 1997 (1,250 µg/L). Field pH measurements ranged from 6.1 to 7.6 SU, similar to upstream measurements.

RC-10

RC-10 data collected during the RI was compared to area background concentrations. Dissolved aluminum and manganese concentrations are above background. Aluminum ranged from 40 to 80 µg/L. Manganese ranged from 9.29 to 13.5 µg/L. Area background concentrations for aluminum and manganese are 37.4 µg/L and 2.42 µg/L, respectively. The concentration of aluminum at RC-10 is similar to the concentration detected at station RC-5. In the spring, the data indicates a decrease in concentration of cadmium, copper, iron, manganese and zinc from RC-5A to RC-10. In the fall, iron significantly decreases from RC-5A to RC-10.

Metal concentrations detected at RC-10 in September 1997 were below WQC. Cadmium, copper, and zinc concentrations detected in the sample collected in May 1998 were above WQC. Cadmium (0.4 µg/L) was above CWQC (0.27 µg/L) but below the AWQC (0.51 µg/L). Copper (18.5 µg/L) was above CWQC and AWQC (2.4 and 3.0 µg/L, respectively). Zinc (69 µg/L) was above CWQC and AWQC (22 and 24 µg/L, respectively).

RC-8

RC-8 data collected during the RI was compared to area background. Dissolved aluminum and manganese concentrations are above background. Aluminum (50 µg/L) was just above background (37.4 µg/L). Manganese (9.97 to 15 µg/L) was above background (2.42 µg/L). Generally, the concentration of metals at this station did not indicate seasonal fluctuation with the possible exceptions of manganese and zinc which decreased from the spring to the fall. Additionally, the fall data for RC-8 compared to the RC-10 data collected during the same timeframe are similar with the exceptions of iron and manganese which decrease.

The RC-8 data was compared to WQC. Dissolved cadmium (0.72 µg/L) at RC-8 was above the AWQC (0.65 µg/L) and CWQC (0.31 µg/L) in September 1997; however this result appears to be an anomaly. The dissolved result (0.72 µg/L) is higher than the total result (0.10 µg/L) and locations sampled upstream of

RC-8 during September did not contain cadmium concentrations near this concentration. Lead (0.5 µg/L) was just above the CWQC (0.42 µg/L) in September 1997.

RC-3

The comparison of RC-3 data collected during the RI to area background concentrations indicate that dissolved aluminum and manganese concentrations are above background for these metals during most of the sampling events. Aluminum ranged from 40 to 70 µg/L. Manganese ranged from 6.48 to 15 µg/L. Area background concentrations for aluminum and manganese are 37.4 µg/L and 2.42 µg/L, respectively. The concentrations of aluminum and manganese at RC-3 during the fall are similar to RC-10 for aluminum, but the concentration of manganese decreases from RC-10 to RC-3. Metal concentrations were not above MTCA Method B cleanup levels for those metals without WQC. Comparison of RC-3 data to WQC is discussed in the following paragraphs.

Copper (10 µg/L) was above AWQC (3.4 µg/L) and CWQC (2.6 µg/L) in May 1997. The data from May 1998 indicated similar results. The concentration of copper (12.6 µg/L) was above CWQC (2.4 µg/L) and AWQC (3.0 µg/L). Zinc was above WQC in April and May 1997 and May 1998. The concentration of zinc (41 µg/L) in April was just above CWQC (39 µg/L) and just below the AWQC (42 µg/L). However, this may be related to the potential introduction of zinc during the field filtration process. The concentration of zinc (38 µg/L) in May 1997 was above CWQC and AWQC (24 and 27 µg/L, respectively). In May 1998, the zinc concentration (45 µg/L) was above the CWQC and AWQC (22 and 24 µg/L, respectively).

Iron concentrations continue to decrease from RC-5 to RC-3. Dissolved copper, cadmium, iron, and zinc concentrations also generally decreased from RC-5 (RC-5A) to RC-3. The pH, specific conductance, and alkalinity remained similar between downstream stations and stations adjacent to the mine. Measured pH ranged from 5.8 to 8.1 SU, similar to upstream measurements.

Seasonal water quality and flow relationships also remained similar at downstream stations compared to stations adjacent to the mine, with trace metals showing a general increase in spring, and iron, alkalinity, hardness and specific conductance decreasing with increasing flow.

Organics

TPH and PCBs were analyzed at RC-3 and were not detected. PCB analysis was eliminated from sampling events after July 1997 based on the results of the previous sampling events. TPH was analyzed in September 1997 and not detected. This analysis was eliminated for future sampling rounds.

5.3.3.5 Railroad Creek Summary

Samples were collected from Railroad Creek upstream (RC-1, RC-6, and RC-11), adjacent to (RC-4, RC-7, and RC-2), and downstream (RC-5, RC-5A, RC-10, RC-8, and RC-3) of the Site to evaluate area background surface water quality in Railroad Creek and assess the influence of the mine on the water quality in Railroad Creek.

Data collected from upstream stations in Railroad Creek were compiled with data collected from other tributaries unaffected by the mine to assess area background surface water quality. The water quality data from Railroad Creek stations adjacent to and downstream of the Holden Mine were compared to WQC for Washington state using actual hardness values as prescribed in the state regulation and to federal WQC using a minimum hardness of 25 ppm or actual hardness if greater than 25 ppm. The results of the comparisons are tabulated below.

Listed below are the dissolved metals that were above the State of Washington AWQC and CWQC, which are based on actual hardness values during the RI sampling events in 1997 and 1998.

Station[1]	April 1997 >AWQC/>CWQC	May/June 1997 >AWQC/>CWQC	July 1997 >AWQC/>CWQC	September/October 1997 >AWQC/>CWQC	May 1998 >AWQC/>CWQC
RC-4	Cu, Zn/ Cu, Zn	Cd, Cu, Zn/Cd, Cu, Pb, Zn	Cu, Zn*/Cu, Pb, Zn*	None/Pb	Cd, Cu, Zn/Cd, Cu, Zn
RC-7	(Fe) Zn/Cd, Zn	Cd, Cu, Zn/Cd, Cu, Pb, Zn	Cu, Zn*/Cu, Pb, Zn*	(Fe) None/Pb	Cd, Cu, Zn/Cd, Cu, Zn
RC-2	(Fe) Zn/Cd, Zn	Cd, Cu, Zn/Cd, Cu, Zn	Cu, Zn*/Cu, Zn*	(Fe) Zn/Zn	Cd, Cu, Zn/Cd, Cu, Zn
RC-5	(Fe) Zn/Cd, Zn	Cd, Cu, Zn/Cd, Cu, Zn	Cu, Zn*/Cu, Zn*	(Fe) Zn/Zn	Cd, Cu, Zn/Cd, Cu, Zn
RC-10	Not Sampled	Not Sampled	Not Sampled	None	Cu, Zn/Cd, Cu, Zn
RC-8	None	Not Sampled	Not Sampled	Cd/Cd, Pb	Not Sampled
RC-3	None/Zn*	Cu, Zn*/Cu, Zn*	None	None	Cu, Zn/Cu, Zn

[1] South bank samples not included

(Fe) – Iron criteria is not designated as AWQC or CWQC. If (Fe) is listed, it means the sample result was above the iron criteria of 1000 µg/L.

Listed below are the dissolved metals above federal AWQC and CWQC that use minimum hardness value of 25 ppm where actual hardness was below 25 ppm.

Station[1]	April 1997 >AWQC/>CWQC	May/June 1997 >AWQC/>CWQC	July 1997 >AWQC/>CWQC	September/October 1997 >AWQC/>CWQC	May 1998 >AWQC/>CWQC
RC-4	Cu, Zn/ Cu, Zn	Cu, Zn/Cd, Cu, Pb, Zn	None	None	Cu, Zn/Cd, Cu, Zn
RC-7	(Fe) Zn/Cd,Zn	Cu, Zn/Cd, Cu, Zn	None	(Fe)	Cu, Zn/Cd, Cu, Zn
RC-2	(Fe) Zn/Cd,Zn	Cu, Zn/Cd, Cu, Zn	None	(Fe)	Cu, Zn/Cd, Cu, Zn
RC-5	(Fe) Zn/Cd,Zn	Cu, Zn/Cd, Cu, Zn	None	(Fe)	Cu, Zn/Cd, Cu, Zn
RC-10	Not Sampled	Not Sampled	Not Sampled	None	Cu, Zn/Cd, Cu, Zn
RC-8	None	Not Sampled	Not Sampled	Cd/Cd	Not Sampled
RC-3	None/Zn*	Cu, Zn*/Cu, Zn*	None	None	Cu, Zn/Cu, Zn

[1] South bank samples not included

(Fe) – Iron criteria is not designated as AWQC or CWQC. If (Fe) is listed, it means the sample result was above the iron criteria of 1000 µg/L.

Where zinc is marked with an asterisk (Zn*) in the above tables, the exceedance of WQC could have been affected by the introduction of zinc during the field filtration process. Therefore, zinc concentrations at RC-3 and zinc concentrations detected in July 1997 should only be considered "apparent" exceedances.

The cadmium concentrations shown for RC-8 in September/October 1997 are apparently an anomalous result, described previously in Section 5.3.3.4, and should not be considered an actual exceedance.

In general, concentrations in the upstream stations did not fluctuate with seasonal or stream flow variations. Iron and hardness were inversely proportional to stream flow. Metal concentrations at the adjacent and downstream stations were generally higher than the upstream locations. The widest variation occurred in May. Concentrations were often similar by September. Concentrations for most metals increased downstream of RC-1 at RC-4. Concentrations from RC-4 to RC-2 were similar or slightly decreased with the exception of iron, which increased substantially at RC-7. Concentrations generally decreased from RC-2 down to RC-3. Cadmium, copper, iron, and zinc concentrations are plotted from upstream station RC-6 to downstream station RC-3 on Figures 5.3-10 through 5.3-13. Field measurements for pH, specific conductance, and dissolved oxygen were similar from upstream to downstream stations in Railroad Creek.

Samples collected from the south banks at RC-4 and RC-2 in 1997 were compared to samples collected across the width of the creek. Concentrations of aluminum, cadmium, copper, manganese, and zinc detected on the south bank of RC-4 during May 1997 were above concentrations detected across the creek width. Concentrations in July and September were similar between the bank and creek width samples, with the exception of copper. Data collected from the south bank at RC-2 were similar to data collected from the width of the creek.

The south bank results from RC-4 and RC-2 were compared to state and federal WQC. Metals above WQC in May, June, and July were generally comparable to the metals above WQC in samples collected across the creek width. The September 1997 data compared to state WQC indicates that copper and zinc at RC-4 and zinc at RC-2 are above WQC. The data from RC-4 indicates that copper is also above federal WQC during this timeframe.

The weekly sampling performed at RC-2 indicated a continued decrease for most metals over time and with decreasing stream flows.

Copper, cadmium, iron and zinc were identified as PCOCs in surface water in Railroad Creek at the stations adjacent to and downstream of the Site. Aluminum and manganese concentrations were greater than background concentrations at stations adjacent to and downstream of the Site. The highest concentrations of metals in 1997 correlated with the highest flow in Railroad creek measured in May/June 1997. In several cases, metal concentrations measured in 1998 in stations adjacent and downstream of the Site were higher than concentrations detected in 1997. The higher concentrations are likely related to the sampling event occurring nearer the initial hydrograph rise (Section 4.0). Metal concentrations did not exceed MTCA Method B cleanup levels (for constituents without WQC) at any stations on Railroad Creek.

5.3.4 Portal Drainage

Samples were collected from the 1500-level main portal drainage at two stations, P-1 and P-5. P-1 is located at the exit of the mine portal and P-5 is located at the confluence with Railroad Creek and upstream of RC-4 (Figure 5.3-1 and 5.3-2). The data is summarized in Table 5.3-30. Additionally, one sample (VP-1) was collected from the 1500-level ventilator portal located west of the portal. Data are summarized on Table 5.3-30a.

5.3.4.1 Exit of Mine Portal (P-1)

Surface water grab samples were collected from the mine drainage at the 1500-level main portal opening (P-1) during May, July, and September 1997 and May 1998 to assess the water quality and seasonal variations of water exiting from the portal. Samples were submitted for total recoverable and dissolved metals analyses and conventional parameters. Field measurements (pH, specific conductivity, temperature, oxidation/reduction potential, and ferrous iron) were collected and recorded in the field.

The data at P-1 were compared to WQC and for those metals where WQC is not available, to surface water background and MTCA Method B cleanup levels for surface water. Additionally, as the water exiting the portal is indicative of groundwater from the bedrock aquifer, the data were compared to the Washington State groundwater criteria as provided in WAC 173-200 and under MTCA Method B cleanup levels for groundwater. The following PCOCs were identified at P-1.

Regulatory Guidance	May 1997	July 1997	September 1997	May 1998
Surface Water Criteria	Cd, Cu, Pb, Zn, pH	Cd, Cu, Pb, Zn, pH	Cd, Cu, Zn	Cd, Cu, Pb, Zn, pH
Groundwater Criteria	As, Be, Cd, Cu, Pb, Zn, SO_4, pH	Cd, Cu, Pb, Zn, SO_4, pH	Cd, SO_4, TDS	Cd, Cu, Fe, Pb, Zn, SO_4, TDS, pH

Dissolved aluminum, barium, thallium, and uranium concentrations are above surface water background in May. Aluminum and barium continue to exceed background concentrations in July. Manganese is above background from May to September. Concentrations were not above available MTCA Method B levels. Cadmium, copper, and zinc consistently are above surface water WQC in May. Lead is above WQC in May and July.

The PCOCs identified based on groundwater criteria are similar to those identified for surface water. Cadmium, copper, and zinc are above criteria in May and July. Arsenic and beryllium indicate a single exceedance in May 1997. Sulfate is consistently above criteria from May through September. Cadmium is the only metal that is above criteria in September.

Concentrations of dissolved aluminum, cadmium, copper, iron, lead, manganese, and zinc decreased from May to September 1997. Dissolved cation concentrations (calcium, potassium and sodium) increased during the same timeframe. Field measurements indicated that pH values changed from acidic (4.8 SU) in May to neutral (7.0 SU) in September.

Increased concentrations of dissolved aluminum, cadmium, copper, iron, manganese, and zinc were detected in the sample collected in May 1998 as compared to May 1997 data. The increased concentrations are likely related to the timing of the sampling event and position on the hydrograph. Stream flow measurements were similar for each of the sampling events in 1997 and 1998 with flows of 2.63 cfs in 1997 and 2.54 cfs in 1998.

5.3.4.2 Confluence with Railroad Creek (P-5)

Grab samples were collected from the 1500-level main portal drainage prior to the confluence with Railroad Creek at location P-5 during May/June, July, and September 1997 and in May 1998 to evaluate source loading and transport to Railroad Creek. Samples were also collected weekly from May 18, 1997 to June 16, 1997. The samples were submitted for the same suite of analyses as the portal opening (P-1). Field measurements were also collected. The data is summarized in Table 5.3-30.

The data collected at P-5 were compared to WQC and for those metals where WQC is not available, to surface water background and MTCA Method B cleanup levels for surface water. The following PCOCs were identified at P-5:

May 1997	July 1997	September 1997	May 1997
Cd, Cu, Pb, Zn, pH	Cd, Cu, Pb, Zn, pH	Cd, Zn	Cd, Cu, Pb, Zn, pH

Similar to P-1, dissolved aluminum, barium, thallium and uranium concentrations are above surface water background in May. Aluminum and barium continue to exceed background concentrations in July. Manganese is above background from May to September. Concentrations were not above available MTCA Method B levels.

Cadmium and zinc consistently are above WQC from May to September. Copper and lead is above WQC in May and July. The PCOCs identified match PCOCs identified at several Railroad Creek stations downstream of P-5.

The concentrations of dissolved metals at P-5 generally were lower than concentrations at P-1 in May due to surface water run on into the drainage from snowmelt. In July, concentrations were similar with the exception of dissolved iron which decreased. In September, dissolved metal concentrations at P-5 were similar to P-1 with the exception of copper, iron, and zinc which decreased.

At P-5, dissolved aluminum, cadmium, copper, iron, lead, and zinc decreased from May to September 1997 similar to the trend identified at P-1. The cation concentrations (calcium, potassium and sodium) increased during the same timeframe. Field measurements indicated that pH values changed from acidic (4.9 SU) in May to neutral (6.7 SU) in September.

Increased concentrations of dissolved aluminum, cadmium, copper, manganese, and zinc at P-5 were detected in 1998 as compared to May 1997. The increased concentrations are likely related to the timing of the sampling event and position on the hydrograph. Stream flows were slightly higher in 1998 (3.8 cfs) than 1997 (3.42 cfs).

The data collected weekly from May 18, 1997 to June 16, 1997 indicated a steady decline of dissolved aluminum, cadmium, copper, and zinc. Dissolved aluminum and copper decreased significantly (50 to 70%) from June 16, 1997 to July 12, 1997. Lead and iron concentrations from May 18 to June 16 were relatively stable. Stream flows continually decreased during the timeframe of the weekly sampling.

The data from May 1997 and May 1998 both indicated similar trends of metal concentrations decreasing and increasing from P-1 to P-5 (trend is metal dependent). The data from P-5 also shows that the influx of surface water from the portal drainage to Railroad Creek introduces concentrations of aluminum, cadmium, copper, lead, manganese, and zinc that are above background or WQC with the actual concentration dependent upon season and stream flow. The portal drainage is a recognized source for metals into Railroad Creek. Comparison to WQC shows that metals that exceed WQC for surface water in the portal drainage at P-1 and P-5, primarily cadmium, copper, and zinc in May and July, coincide with WQC exceedances in downstream Railroad Creek stations. The fate and transport of metals in and from the portal drainage are further discussed in Section 6.0.

5.3.4.3 Historical Portal Drainage Data

Surface water samples associated with the 1500-level main portal drainage were collected intermittently at two locations (P-1 and P-5) between 1982 and 1991 and again between 1992 and 1996. Only a few concurrent monitoring dates were conducted for both stations. A summary of the data is presented in Table 5.3-31.

Historical concentrations of copper, lead, iron, and cadmium at P-1 and P-5 were generally within the same order of magnitude as the RI data during similar seasonal dates. Copper, zinc, and lead appeared to have a direct relationship with flow, i.e., their concentrations were higher during high stream flow than during low flow conditions at P-1.

The USGS collected samples from the P-1 and P-5 locations concurrently in July 1994, July 1995, May 1996, and September 1996. The trends noted in this historical data were comparable to the trends detected in the RI data. Concentration of dissolved aluminum, copper, iron, manganese, and zinc decreased from P-1 to P-5 in May and September. Concentrations of these metals remained constant between the two stations in July. Measurements for pH were acidic in the spring and neutral by fall.

5.3.4.4 Ventilator Portal

A grab sample (VP-1) was collected from water discharging from the 1500-level ventilator portal. The concentrations of dissolved metals were orders of magnitude lower than the corresponding portal drainage samples. The pH was neutral (6.4 SU). The data appeared to indicate that the sample collected was more indicative of meteoric water possibly resulting from snowmelt. The data were not compared to WQC. However, the metal concentrations were compared to surface water background for dissolved metals. Metal concentrations in the sample were below background.

5.3.5 Copper Creek Diversion

Samples were collected from the Copper Creek diversion (CC-D, CC-D1) during April, May, July, and September 1997 and May 1998 (Figure 5.3-1). The sample identification was originally designated as CC-D in April and revised to CC-D1 for the remainder of the RI. There are no specific background water quality conditions for the diversion; however, water quality at the point of diversion in Copper Creek is assumed to be similar to CC-1. Data were compared to the Copper Creek upgradient station (CC-1) and to WQC. The data are summarized in Table 5.3-32.

Water quality in the diversion was similar to CC-1 for all constituents except cadmium (1.76 µg/L), copper (145.8 µg/L), iron (230 µg/L), manganese (7.95 µg/L), and zinc (172 µg/L) during the 1997 May/June sampling round which were one or more orders of magnitude above concentrations detected at CC-1. In addition, the results for these metals from the May/June round were higher than results from the July and September 1997 sampling events. This is explained by the inflow of seeps and site runoff into the Copper Creek diversion during the May/June period.

The data were compared to WQC. Cadmium, copper and zinc were above AWQC and CWQC in May. The data were also compared to MTCA Method B cleanup levels for those metals without WQC. MTCA Method B levels were not exceeded. The measured pH in the field ranged from 5.5 to 7.15 SU, with a one time event (September) where pH was outside of the water quality criteria for pH (6.5 to 8.5 SU).

The data collected at CC-D1 during May 1998 indicated similar trends detected in May 1997. Cadmium, copper, manganese, and zinc concentrations were greater than concentrations at CC-1. Concentrations of cadmium, copper, manganese, and zinc in 1998 were above 1997. Iron decreased from 230 µg/L in May 1997 to not detected (< 20 µg/L) in May 1998.

Historic data for the Copper Creek diversion is limited to two samples collected by the USGS in 1994 and 1996; however, this data generally indicates that metals were not detected and provides little comparative information (Table 5.3-33).

The Copper Creek diversion is primarily used to supply water to the sauna used by residents and guests of Holden Village. The water quality is included in the human health risk discussion in Section 7.0.

5.3.6 Copper Creek

Samples were collected at two locations, CC-1 and CC-2, within Copper Creek (Figure 5.3-2). Station CC-1 is located upstream and outside of the mine influence. Station CC-2 is located in Copper Creek prior to the confluence with Railroad Creek. The data is discussed below. The data collected at CC-1 was included in the area background surface water quality assessment previously discussed (Section 5.3.1).

5.3.6.1 Historical Data

Water samples were collected at CC-1 and CC-2 during 1982 to 1983 (USFS 1983). The samples were analyzed for total metals and conventional parameters. Specific conductivity, pH, and temperature were measured in the field. Samples were collected by the USGS in 1994, 1995, and in the spring and fall of 1996. Two samples were collected at a location near CC-2 by Ecology in June and September 1996. The samples were analyzed for total recoverable and dissolved metals, conventional parameters, and field parameters. The analytical parameters were not consistent between sampling events. Sample data are summarized in Table 5.3-35.

The 1982/1983 data were not compared to WQC or RI data due to the limited list of metals reported, detection limit differences, and unavailability of hardness values for criteria correction.

The data collected by the USGS from 1994 through 1996 was not compared to WQC due to unavailable hardness values. Calcium and magnesium were available; however, in several instances the results are noted as not detected at high detection limits precluding hardness calculations. The data indicated that metal concentrations for CC-1 and CC-2 were relatively similar and did not tend to fluctuate with seasonal variations. Specific conductivity was generally low (20 to 40 µs); however, a 50% increase at both stations occurred in July 1995 (80 µs, 100 µs). The USGS data were compared to appropriate RI data. Where metals were detected, the data were relatively consistent. Field parameters were relatively consistent between historical and RI data.

The data collected by Ecology was compared to WQC. Dissolved cadmium, copper, lead, and zinc concentrations did not exceed WQC. In general, the data from the two sampling events indicated that concentrations at this location do not fluctuate with seasonal differences. An increase in dissolved copper (1.2 µg/L) in September 1996 appears to be anomalous as the total result was lower (0.23 µg/L). Field parameters did not indicate seasonal differences. The data were compared to RI data where appropriate and were relatively consistent between historical data and the RI.

5.3.6.2 Upstream Data

Samples were collected during the RI at CC-1 in May, July, and September 1997 to assess seasonal variability of metal concentrations and in May 1998. The data were included in the background surface water quality assessment discussed in Section 5.3.1. Summarized sample data are provided in Table 5.3-34. Sample data and associated WQC are summarized for each sampling event in Tables 5.3-23 through 5.3-27. Background values are summarized in Table 5.3-1.

The metal concentrations at CC-1 do not appear to increase or decrease in response to seasonal variations. Field measurements did not indicate significant variability between sampling events.

5.3.6.3 Adjacent to Tailings Piles

Samples were collected in Copper Creek at station CC-2 prior to the confluence with Railroad Creek during May, July, and September 1997 and May 1998. Samples were analyzed for the same analytical suite as the CC-1 samples. Comparison of CC-2 data to WQC indicated that metal concentrations were below the AWQC and CWQC, with the exception of lead. The detection limit for lead (7 μg/L) during May 1997 was above the AWQC (6.6 μg/L) and CWQC (0.26 μg/L) in the dissolved fraction. The result was qualified as not detected during data validation due to laboratory contamination. The result for lead in the total fraction in May 1997 showed that lead was not detected in this fraction above the chronic or acute criteria. The comparison of total to the dissolved concentrations indicate that lead results for May 1997 are not above the criteria. The lead result in September 1997 was slightly above the chronic criteria (0.3 vs. 0.21 μg/L). Dissolved lead in May 1998 was below AWQC and CWQC. Generally data from 1998 were similar to data collected in 1997. Concentrations of total aluminum, iron, and manganese were 5 times greater in 1998 than 1997; however, the dissolved concentrations were similar. For those metals that do not currently have water quality criteria assigned, concentrations were below background values and MTCA B levels. Measurements for pH at CC-2 ranged from 6.1 to 8.1 SU, similar to measurements at CC-1 (6.0 to 8.0 SU).

The results of CC-2 are comparable to the CC-1 results. In addition, the metal concentrations between stations do not indicate seasonal variations. PCOCs were not identified for Copper Creek.

5.3.7 Other Railroad Creek Tributaries

Samples were collected from Holden Creek, Big Creek, and TenMile Creek and the data were incorporated into the background surface water quality assessment discussed in Section 5.3.1. The statistically derived background values are summarized in Table 5.3.1. Detailed data summaries for Holden Creek, Big Creek, and TenMile Creek are included in Tables 5.3-36 through 5.3-38.

5.3.8 Lake Chelan

5.3.8.1 Historical Data

Surface water data were not collected from Lake Chelan during the RI; however, in 1989, Patmont reported the results of an assessment of water quality conducted in Lake Chelan for Ecology in 1986. The report noted that the "observed in-lake concentrations of total recoverable arsenic, iron, and zinc exhibited temporal or spatial variations over the study period, and averaged 0.22 ± 0.01μg/L, 3.6 ± 1.4 μg/L, and 2.0 ± 0.1 μg/L, respectively. The only discernable variation in metals was observed in the iron data, as in-lake levels peaked (6-12 μg/L) in lake surface waters during the spring, probably as a result of runoff inputs." Also noted in the report was that concentrations detected were below the applicable aquatic life, water quality criteria and drinking water standards (EPA, 1986).

5.3.9 Surface Water Quality Summary

Data collected from upstream stations in Railroad Creek were compiled with data collected from tributaries to Railroad Creek (Holden Creek, Big Creek, Copper Creek, and Tenmile Creek) and reference streams in the Stehekin area (South Fork Agnes Creek and Company Creek) to assess area background surface water quality. Background values were statistically derived under the MTCA guidance and compared to both Washington State and federal WQC where available. Where WQC were hardness corrected, a conservative value of 6.7 ppm was used for the state criteria as well as a minimum hardness value of 25 ppm for the federal criteria. The statistically derived background values are below state and federal WQC with the exception of lead (0.54 μg/L) and silver (< 0.04 μg/L) which are above state CWQC and AWQC, respectively. Lead and silver are below the federal WQC.

Site data collected from Railroad Creek adjacent to and downstream of the mine-affected area were compared to WQC where established and background concentrations and MTCA Method B cleanup levels if WQC were not available. PCOCs were identified if concentrations were above WQC or MTCA Method B cleanup levels. Metal concentrations that were above background concentrations were identified as compounds of interest to assess with PCOCs in the fate and transport and risk assessment discussions in Sections 6.0 and 7.0.

Copper, cadmium, iron, and zinc were identified as PCOCs in surface water in Railroad Creek at the stations adjacent to and downstream of the Site dependent upon sample location and sampling event. A summary table listing the sample station and sampling event with the PCOCs identified in Railroad Creek is located in Section 5.3.3.5. Aluminum and manganese concentrations were above background at stations adjacent to and downstream of the Site dependent upon sample location and sampling event. Parameters such as pH, dissolved oxygen, and specific conductance were generally similar at stations upstream, adjacent to, and downstream of the site. The highest concentrations of metals in 1997 correlated with the highest flow in Railroad Creek measured in May 1997. Concentrations for most metals increased downstream of RC-1 at RC-4. Concentrations from RC-4 (downstream of the portal drainage) to RC-2 (downstream of tailings pile 3) were similar or slightly decreased with the exception of iron which increased significantly at RC-7 (adjacent to tailings pile 2). Concentrations generally decrease from RC-2 to RC-3 at Lucerne. At several stations adjacent to and downstream of the mine area, metal concentrations measured in 1998 were above 1997 concentrations. The difference in concentrations is likely related to the time and position of the sampling event on the hydrograph (Section 4.0).

The portal drainage was sampled at the 1500-level main portal (P-1) and directly prior to the portal drainage confluence with Railroad Creek (P-5). Dissolved aluminum, cadmium, copper, iron, and zinc decreased from spring to fall. Manganese decreased slightly at P-1 and increased slightly at P-5. The pH was acidic in the spring and neutral in the fall. During the same sampling event, concentrations of dissolved aluminum, cadmium, copper, iron, manganese, and zinc generally decreased from P-1 to P-5 in the spring, remained constant in the summer, and were constant or decreased in the fall. The data from P-5 indicate that the portal drainage introduces concentrations of aluminum, cadmium, copper, iron, lead, manganese, and zinc into Railroad Creek that are above background with the actual concentration dependent upon season and stream flow. The data for P-1 and P-5 were compared to surface water quality criteria (WQC and MTCA Method B cleanup levels). P-1 was compared to groundwater quality criteria (WAC 173-200 and MTCA Method B cleanup levels) as well. PCOCs identified based on surface water comparison included cadmium, copper, lead, zinc and pH. PCOCs identified at P-1 based on groundwater quality criteria included arsenic, beryllium, cadmium, copper, iron, lead, zinc, sulfate, total dissolved solids, and pH. The PCOCs are summarized by sampling event in Section 5.3.4. The fate and transport of metals in and from the portal drainage are further discussed in Section 6.0.

A grab sample (VP-1) was collected from water discharging from the 1500-level ventilator portal. Generally, the concentrations of dissolved metals were orders of magnitude lower than the corresponding portal drainage samples. The pH was neutral (6.4 SU). The data appeared to indicate that the sample collected was more indicative of meteoric water possibly resulting from snowmelt.

Water quality in the Copper Creek diversion was assessed. The Copper Creek diversion is the outflow from the hydroelectric plant and is used as a source of water for a dipping pond associated with a sauna utilized intermittently by residents and guests of Holden Village. Concentrations of cadmium, copper, iron, manganese, and zinc during the spring were above upstream Copper Creek concentrations. The data were compared to WQC. Cadmium, copper and zinc were identified as PCOCs in May (spring). Water quality at the diversion is included in the human health risk discussion in Section 7.0.

Water quality in Copper Creek upstream of apparent Holden Mine influences and adjacent to the tailings piles was assessed. The data from the upstream location was compiled with other data in the background surface water quality assessment. The data collected from CC-2 (adjacent to the tailings piles) was compared to WQC and background values. Metals detected at CC-2 were not above WQC or background. Additionally, concentrations between upstream and downstream stations on Copper Creek do not indicate seasonal variations. PCOCs were not identified in Copper Creek.

5.4 GROUNDWATER

Groundwater samples were collected from groundwater monitoring wells located in Holden Village, west of Holden Village near the baseball field, on the Site downgradient of the maintenance yard, in tailings piles 1, 2, and 3, downgradient of tailings pile 3, and from a single well located at Lucerne. Samples were also collected from lysimeters located in tailings piles 1 and 3. The samples were collected during two sampling events conducted in May 1997 and September 1997. Sample locations are shown on Figure 5.4-1.

As part of the groundwater quality assessment, samples were also collected from seeps located on the Site and along Railroad Creek upgradient, adjacent to, and downgradient of the Holden Mine. The seeps were considered as part of the groundwater system based on the apparent underground source of water at most of the seep locations. Additionally, a limited number of seeps were more indicative of surface water flow, but were considered seeps based on their apparent connection with seeps resulting from underground flow. Seep locations are shown on Figure 5.4-1. Samples were collected in 1997 during sampling events conducted in May/June, July, and September. Seep samples were collected during each sampling event if measurable flow and volume were available for sample collection. Additionally, samples were collected at select seeps in May 1998.

Groundwater samples collected from monitoring wells and seep samples were analyzed for dissolved metals (aluminum, arsenic, barium, beryllium, cadmium, calcium, chromium, copper, iron, lead, magnesium, manganese, mercury, molybdenum, nickel, potassium, selenium, silver, sodium, thallium, uranium, and zinc), ortho/total phosphorus, total/amenable cyanide, total dissolved solids, total suspended solids, chloride, nitrate/nitrite, sulfate, alkalinity, color, and hardness as outlined in the SAPs and QAPPs associated with each field effort (see Section 1.0). Additionally, a limited number of samples were analyzed for organic constituents, i.e., polychlorinated biphenyls (PCBs), and TPH (gasoline, diesel, and heavier than diesel range). The samples were analyzed by Analytical Resources Incorporated (ARI) located in Seattle, Washington. Field measurements for pH, specific conductivity, temperature, oxidation/reduction potential, and ferrous iron were collected for each sample as outlined in the associated SAP and QAPP.

RI analytical data are summarized in Tables 5.4-1 and 5.4-2. A copy of laboratory reports and associated data validation and related memoranda are included in Appendix L. The data were reviewed and validated as outlined in the associated QAPPs. Generally, the data were acceptable and met the project objectives. Due to the total dissolved solids concentration in several samples, the metals analytical methodology originally selected and approved in the SAPs and QAPPs for groundwater was revised to allow analyses to proceed. Method adjustments resulted in raised detection limits for certain metals. Generally, the increased detection limits did not affect evaluation of the data as compared to MTCA cleanup levels or data usability for site assessment with the exception of beryllium and thallium. Detection limits for beryllium ranged from 0.04 μg/L to 20 μg/L compared to the MTCA Method B cleanup level of 0.0203 μg/L. Thallium detection limits ranged from 0.80 μg/L to 50 μg/L compared to the MTCA Method B cleanup level of 1.12 μg/L. Beryllium and thallium were generally not detected. Neither metal was identified as a compound of concern in surface water. The sample analyses were performed such that the lowest detection limit reasonably achievable given the individual sample matrix was obtained.

Site groundwater data collected from monitoring wells were compared to MTCA values and applicable criteria designated in WAC 173-200 as the groundwater underneath and in the surrounding area of Holden Mine is not currently used as a drinking water source and is not anticipated to become a drinking water source in the foreseeable future. Groundwater collected from a drinking water well located at Lucerne at the USFS Guard Station was compared to MTCA and the federal maximum contaminant levels (MCLs) for drinking water as the well supplies water for USFS volunteers and occasional visitors.

To assess PCOCs, the Site groundwater data collected from groundwater monitoring wells were compared to the MTCA Method A cleanup levels for groundwater. If MTCA Method A levels were not available, data were compared to MTCA Method B cleanup levels. Constituent concentrations detected above MTCA cleanup levels were considered PCOCs in groundwater. Calcium, magnesium, potassium, and sodium were not evaluated as these metals are considered nutrient metals and MTCA levels are not established. MTCA also does not include a groundwater value for iron, aluminum, or barium. For those constituents where MTCA criteria are not available, concentrations were compared to criteria designated under WAC 173-200. The data collected from the well at Lucerne were compared to MTCA and federal MCLs. If metal concentrations were above MTCA or the MCLs, the analyte was considered a PCOC.

The chemistry discussion for seeps focuses on the PCOCs identified for surface water in Section 5.3 as the primary concern is due to the interaction of seeps with surface water. The PCOCs and other compounds of interest identified for surface water include aluminum, cadmium, copper, iron, manganese, and zinc. Seep data were compared to groundwater quality criteria to determine if exceedances were apparent and if so, the locations where they occurred. The comparison and assessment of PCOCs was identical to the process for data collected from the groundwater monitoring wells.

Individual metal concentrations are plotted on concentration maps by each metal designated as a PCOC in Railroad Creek. These metals include aluminum, cadmium, copper, iron, manganese, and zinc. All discussions refer to dissolved concentrations. Discussions of constituent variability between May 1997 and September 1997 focus on monitoring well results, as most seeps were not flowing during the September 1997 sampling event. Samples collected from seeps in May 1998 are compared to the 1997 data where appropriate.

Regional and Site groundwater quality are described in the following sections. The RI groundwater data discussion includes background groundwater quality, and water quality from Site wells, lysimeters, and seeps. The groundwater discussion is organized and presented beginning with a discussion on the assessment of regional groundwater quality followed by Site groundwater quality. The Site groundwater quality discussion includes a historical summary of previous groundwater and seep data collected on the Site and in the area. The historical data summary is followed by background water quality based on the results of the RI. Following the background water quality section, individual sections address groundwater quality based on monitoring wells, lysimeters, and seeps by geographic area; Honeymoon Heights, waste rock piles, maintenance yard, tailings pile 1, tailings pile 2, and tailings pile 3. Historical data were compared to the RI data where station locations are considered compatible. At the end of the section is a summary that identifies the occurrence of PCOCs by geographic area. Human health and ecological risks associated with groundwater and seeps in the area are further assessed in Section 7.0.

5.4.1 Regional Groundwater Quality

A water-quality assessment was completed historically by others in the Lake Chelan Basin; the assessment included the installation of groundwater monitoring wells at 26 locations in the lower Lake Chelan basin as part of a Lake Chelan water quality assessment (Patmont, 1989). Metals analyses were not completed on samples collected. pH and specific conductance ranged from 6.8 to 7.5 SU and 99 to 490 μmhos/cm^2 in background wells completed in surficial materials. One well in the basin was completed in bedrock; four samples were collected from the well with a mean pH of 7.0 SU and mean specific conductance of 590 μmhos/cm^2 (Patmont, 1989).

5.4.2 Site Groundwater Quality

The distribution and concentrations of metals and other chemical constituents from samples collected during the RI from Site monitoring wells, lysimeters, and seeps is described in the following sections. Topics discussed include distribution of concentrations and seasonal variability of results. As described in Section 4.4, two groundwater systems occur at the Site, one within the tailings, and the other in the alluvial/reworked till unit.

Groundwater monitoring wells are identified based on geologic unit in which the wells were screened during installation. "A" series wells monitor groundwater from the alluvial/reworked till unit (TP1-1A, TP1-2A, TP1-3A, TP1-4A, TP1-5A, TP1-6A, PZ-1A, PZ-3A, TP2-4A, TP2-5A, TP2-8A, TP2-11A, PZ-6A, TP3-6A, TP3-10A) and "B" and "C" series wells are screened within the tailings (PZ-1B). Additional wells without a series designation (HV-3, HBKG-1, HBKG-2, TP3-4, TP3-8, TP3-9, DS-1, DS-2) monitor the alluvial/reworked till unit or other native materials.

Lysimeter results are reflective of tailings groundwater chemistry in the unsaturated portion of the tailings piles. Samples collected from lysimeters are identified with an “L” suffix (TP1-2L, TP1-3L, TP1-4L, TP1-6L, TP3-4L, TP3-6L, TP3-10L). Seep discharge from the tailings piles is assumed to represent tailings groundwater discharge along either fractures in cemented tailings or water perched on a lower permeability layer at the base of the tailings. Seep discharge from the waste rock piles or the banks of Railroad Creek other than the tailings piles is assumed to be indicative of water percolating through the piles or alluvial/reworked till. Seeps are identified by a “SP” prefix. Samples were numbered based on sequencing in the field. The relationship of surface water and groundwater interaction with respect to seeps was previously described in Sections 4.3 and 4.4.

5.4.2.1 Historical Groundwater and Seep Data

Groundwater

Groundwater samples were collected from groundwater monitoring wells during three previous sampling events completed by others at the Site. In June and August 1991, the USBM collected samples from selected wells on tailings piles 2 and 3. In 1995, the USBM collected samples from wells and lysimeters on tailings pile 2, and from wells HBKG-1 and HBKG-2. The results are summarized on Table 5.4-3. In general, aluminum, copper, lead, and zinc concentrations in samples collected in 1991 and 1995 are higher than were found in samples from the RI sampling at the same locations.

The USBM groundwater data were found to have limited use in the RI due to: (1) the limited list of metals analyzed when compared to those metals analyzed for the RI; (2) relatively high detection limits; (3) the limited number of wells sampled by USBM when compared to the RI; (4) analytical data that were suspect due to concentrations being significantly higher than those analyzed during the R-I (i.e., copper and zinc); and (5) the absence of quality assurance/quality control documentation for the USBM data. Therefore, the USBM data are not included in the RI groundwater discussion presented hereafter.

Seeps

Seep samples were collected by the USGS in July 1994 (Kilburn, et al., 1994), July 1995 (Kilburn and Sutley, 1996), May 1996 (Kilburn and Sutley, 1997), and September 1996 (Kilburn and Sutley, preliminary report 1997). Sample locations are shown on Figure 5.4-2. Analytical data are summarized in Table 5.4-4. These studies identified the general character of the seeps and delineated two distinct seep chemistries: (1) acidic to highly acidic, iron-dominant seeps from the base of the tailings piles, and (2) chemically discriminate seeps of low iron concentrations and high zinc and copper concentrations (Kilburn and Sutley, 1996). In general, water chemistry results for seeps sampled by the USGS are comparable to data collected during the RI.

5.4.2.2 Background Groundwater Quality

As stated previously in Section 5.1.3, evaluation of representative background groundwater quality at the Site is a difficult component to assess due to the relatively complex hydrogeologic conditions. Groundwater occurs in both bedrock and the overlying glacial soil and alluvium. Groundwater movement within the bedrock in the watershed is anticipated to be limited to fractures in the bedrock. The intent of the RI was to collect background data from wells and seeps located outside of the observed influence of the Holden Mine. Samples were collected from monitoring wells HV-3 located in Holden Village, HBKG-1, and HBKG-2 during May and September 1997 to assess background groundwater quality. Two seeps were sampled to assess background, SP-26 in July and September 1997 and SP-27 in May 1998.

Monitoring well HV-3 (H-3) is located on the north side of Railroad Creek and topographically above Holden Village (Figure 5.4-1). The well monitors either glacial till or colluvium. Metal concentrations detected in samples collected from well HV-3 in May and September 1997 were below MTCA Method A and B levels. Beryllium was not detected in the samples, but the detection limits (0.2 to 1 μ/L) reported were above the MTCA Method B level (0.0203 μg/L). Metal concentrations did not appear to fluctuate seasonally with the exception of potassium and sodium, which decreased from the spring to the fall. The pH was neutral (6.6 and 6.5 SU).

Well HBKG-1 was originally installed as a background well, however, its location is directly downgradient of the maintenance yard and water chemistry indicates that the groundwater at this location is affected. This well was not considered further for background groundwater quality assessment. The data collected from this well is discussed in the maintenance yard section.

Monitoring well HBKG-2 is located to the east of the ball field and campground, adjacent to a road that historically crossed Railroad Creek during the operation of the Holden Mine. However, it has been reported that waste rock was used as fill material to construct the road. Therefore, groundwater samples collected from this well may not be representative of background water chemistry. Cadmium, copper, and zinc concentrations were below MTCA levels; however, in May, the concentrations were elevated 3 to 15 times above those detected in HV-3 indicating that the groundwater collected at HBKG-2 may be affected. Concentrations were similar in September 1997. The data from HBKG-2 was not considered further for assessment of background groundwater quality.

A reconnaissance was performed on the south side of Railroad Creek upvalley between the Site and Big Creek to locate seeps that may be indicative of groundwater quality in the area unaffected by mining activities at the Holden Mine. Two seeps, SP-26 and SP-27, were identified to assess background groundwater quality. SP-26 is located adjacent to Railroad Creek near sampling station RC-6, west of the Site (Figure 5.4-1). Samples were collected from seep SP-26 in July 1997 and September 1997. A sample was not collected during the spring melt due to safety concerns resulting from high stream flow in Railroad Creek. Aluminum, copper, iron, and zinc concentrations in SP-26 ranged from <20 to 30 µg/L, 22 to 28 µg/L, <20 µg/L, and 22 to 32 µg/L respectively (Table 5.4-2). Cadmium was detected at 0.3 µg/L during both sampling periods. Manganese was not detected. pH ranged from approximately 6.0 to 8.3 SU.

Due to slightly elevated concentrations of copper and zinc, it appears that the seep SP-26 water may be affected by historic mining activities associated with the Holden Mine. Seep SP-26 was noted in the field to be immediately downslope of an abandoned retention pond that was reportedly used during the backfilling of the underground mine with tailings. A relatively thin layer of tailings was observed on the ground surface of the pond feature. It is possible that meteoric water percolating through the surface of the pond becomes affected and flows eventually into groundwater that emanates as seep SP-26. See Section 4.4 for further discussion.

In May 1998, a sample was collected at seep SP-27 (Figure 5.3-1). Metals concentrations at SP-27 were similar to SP-26 results collected in July and September 1997 with the following exceptions. Zinc was not detected at SP-27. Total dissolved solids (350 mg/L) detected at SP-27 were above that detected at SP-26 (30 to 39 mg/L), but this potentially may be due to timing of sampling. It is possible that the water sampled was surface water runoff and not reflective of groundwater conditions.

In summary, it appears that groundwater samples collected from monitoring wells HBKG-1 and HBKG-2 were affected by Holden Mine–related activities. Seep SP-26 is suspected to be slightly affected by a Holden Mine–related Site feature (abandoned retention pond). Seep SP-27 may be meteoric in nature and not reflective of groundwater conditions. Groundwater monitoring well HV-3 appears to represent background groundwater quality, but is situated on the north side of Railroad Creek.

5.4.2.3 Honeymoon Heights

Seep samples (SP-14-Upper, SP-14, SP-14 Lower, SP-23Up, SP-23 Vent Rd, SP-23, SP-23B, and SP-12) were collected in the Honeymoon Heights drainage at various locations from above the surface expression of the ore body and mine workings to Railroad Creek (Figure 5.4-1). Also included as part of the Honeymoon Heights assessment was a sample (A-1) collected from water ponded at the 1100-level mine portal. Data are summarized in Tables 5.4-1 and 5.4-2.

SP-14

Seep samples were collected in the intermittent drainage flowing down through the Honeymoon Heights area; the samples were designated SP-14-Upper (collected above the surface expression of the ore body and mine workings), SP-14 (collected immediately downslope and adjacent to the 800-level waste rock pile), and SP-14-Lower (collected immediately downslope and adjacent to the 1100-level waste rock pile).

Seep samples were collected at SP-14 in May and September 1997. Concentrations of aluminum, cadmium, copper, manganese, and zinc decreased from May to September. Iron increased during the same time frame. Samples at SP-14 Upper (above the surface expression of the ore body) and SP-14 Lower were collected in October 1997. The concentrations of aluminum, cadmium, copper, manganese, and zinc at SP-14 Upper were below concentrations at SP-14 and SP-14 Lower during the same sampling time frame. The concentration of each of these metals increased from SP-14 Upper, to SP-14, and finally to SP-14 Lower with the exception of iron. Iron at SP-14 Lower (30 μg/L) was similar to SP-14 Upper (<20 μg/L). The iron concentration at SP-14 (480 μg/L) was above the samples collected at SP-14 Upper and SP-14 Lower. Field pH readings ranged from 4.5 to 6.1 SU. The lowest pH (4.5 SU) was recorded at SP-14 Lower. Minor seepage was observed flowing from the 800-level waste rock pile and into the intermittent drainage during a Site visit in June 1998.

SP-23

Samples were collected from the lower portion of the Honeymoon Heights drainage at seeps SP-23 and SP-23B in May 1997, SP-23 UP in July 1997, and SP-23 and SP-23 Vent Road in October 1997. Additionally, samples were collected weekly at SP-23 from May 23, 1997 to June 16, 1997 to assess event-related variability. SP-23 was also sampled in May 1998. SP-23 Up is located on the upside of the 1500-level ventilator portal road in line with the SP-23 drainage. Sample SP-23 Vent Rd. is located in the drainage as it crosses the portal ventilator road. Sample locations are shown on Figure 5.4-1.

Seeps SP-23 and SP-23B were both sampled originally on May 23, 1997. Concentrations of aluminum, cadmium, copper, manganese, and zinc at SP-23 were generally above SP-23B concentrations but within an order of magnitude. Iron was not detected at either location. Aluminum, cadmium, copper, manganese, and zinc continually decreased at SP-23 from May 23 through June 16, 1997. This location was not sampled during the July 1997 field effort as it was not flowing. A sample was collected in October 1997 after a precipitation event. Concentrations of aluminum, cadmium, copper, and zinc in October were similar to those detected on June 16, 1997. Manganese increased from 79 μg/L to 128 μg/L. Iron was not detected at SP-23 during any of the 1997 field sampling events. A sample was collected at SP-23 in May 1998. Concentrations for aluminum, cadmium, copper, manganese, and zinc were slightly below concentrations detected in May 1997. Iron was not detected.

SP-23 Up was sampled in July 1997. Seeps lower in the drainage were not flowing during this sampling event. Concentrations of aluminum, cadmium, copper, manganese, and zinc at SP-23 Up were above concentrations detected at SP-23 but within the same of order of magnitude. Iron was not detected.

SP-23 Vent Rd. was sampled in October 1997. Concentrations of aluminum, cadmium, copper, manganese, and zinc were similar to those detected at SP-23 Up in July and to SP-23 in October. Iron was not detected at SP-23 Vent Rd.

Field pH measurements at the SP-23 locations (SP-23, SP-23B, SP-23 Up, and SP-23 Vent Rd.) ranged from 4.2 to 5 SU.

SP-12

SP-12 is located adjacent to Railroad Creek, downstream of SP-23 and upstream of the mouth of the portal drainage. Samples were collected in May and July 1997. Aluminum, cadmium, copper, and zinc concentrations were similar during both sampling events. Manganese increased from 53 μg/L in May to 93 μg/L in July. Iron was not detected at SP-12. Field pH measurements ranged from 5.03 to 5.48 SU. SP-12 was not flowing during the fall 1997 field event and was not sampled.

Concentrations of aluminum, cadmium, copper, manganese, and zinc at SP-23 in May were 2 to 6 times above concentrations detected at SP-12. The two locations were sampled on the same day during the May field event.

A-1

A sample (A-1) was collected from ponded water behind the partially collapsed opening at the 1100 level portal in July 1997. Aluminum and iron were not detected. Cadmium (2.32 µg/L), copper (120 µg/L), manganese (27.8 µg/L), and zinc (257 µg/L) were detected. A field pH measurement was collected and indicated a neutral pH (8 SU). The concentrations of aluminum, cadmium, copper, manganese, and zinc at A-1 in July were below concentrations detected at SP-14 Lower in October 1997 and at the SP-23 locations sampled in May, June, July, and October 1997.

Comparison to Groundwater Quality Criteria

The data were compared to criteria designated in MTCA and WAC 173-200. The following PCOCs were identified based on this evaluation.

	Spring	Summer	Fall
SP-14 Upper	Not Sampled	Not Sampled	pH (storm event)
SP-14	Cu, pH	Not Sampled	Fe, pH
SP-14 Lower	Not Sampled	Not Sampled	Cd, Cu, pH (storm event)
SP-23 UP	Not Sampled	Cd, Cu	Not Sampled
SP-23 Vent Rd	Not Sampled	Not Sampled	Cd, Cu, pH (storm event)
SP-23	Cd, Cu, Zn, pH	Not Sampled	Cd, Cu, pH (storm event)
SP-23B	Cd, Cu, pH	Not Sampled	Not Sampled
SP-12	Cd, Cu, pH	Cd, Cu, pH	Not Sampled
A-1	Not Sampled	None	Not Sampled

Summary

Samples were collected in the Honeymoon Heights Drainage from above the ore body (SP-14 Upper) to Railroad Creek (SP-23, SP-12). A sample (A-1) was also collected from ponded water at the 1100 portal located in the drainage. Concentrations of aluminum, cadmium, copper, manganese, and zinc increased from SP-14 Upper to SP-14 Lower and again from SP-14 Lower to SP-23. Iron was not detected or detected at or near the detection limit at all sample locations during each field event with one exception. Iron was detected at SP-14 in September 1997 at a concentration of 480 µg/L.

Concentrations of aluminum, cadmium, copper, manganese, and zinc detected at SP-12 were 2 to 6 times below concentrations at SP-23. Iron was not detected. Concentrations of these metals detected at A-1 were below those detected at SP-23 and SP-14 Lower.

Cadmium, copper and zinc were identified as PCOCs at various sample locations in the Honeymoon Heights drainage. Additionally, pH was identified as a PCOC at some locations as the measured values ranged from 4.5 to 6.1 SU, outside of the 6.5 to 8.5 SU criteria (WAC 173-200). Samples collected in the fall were generally the result of a precipitation event.

5.4.2.4 Waste Rock Piles

Seep samples associated with the two waste rock piles adjacent to (east and west of) the abandoned mill building were sampled in 1997. Sample locations are shown on Figure 5.4-1, and analytical data is summarized in Table 5.4-2.

West Waste Rock Pile

Seep SP-6 originates from the base of the west waste rock pile. A sample was collected in May 1997. Concentrations of aluminum (14,600 µg/L), cadmium (173 µg/L), copper (12,700 µg/L), manganese (1,160 µg/L), and zinc (22,100 µg/L) were above concentrations detected in additional seep or pond areas associated with the waste rock pile, as discussed below. Iron was detected at 30 µg/L. pH was acidic (4.2 SU). The seep was not flowing during sampling events in June, July, and September 1997, thus only one sample was collected during the spring snowmelt in May.

The inferred flow path of water exiting the west waste rock pile at SP-6 indicates that seeps SP-15W and SP-15E followed by SP-16 (lagoon) are related. Samples were collected at SP-15W in May 1997 and at SP-15E and SP-16 in May, July, and October 1997. Additionally, samples were collected at SP-15E weekly from May 22 to June 16, 1997 to assess event-related variability.

Concentrations of aluminum, cadmium, copper, iron, manganese, and zinc at locations SP-15W, SP-15E, and SP-16 ranged from <20 to 3,490 µg/L, 9.37 to 74 µg/L, 206 to 4,930 µg/L, <20 to 500 µg/L, 37 to 2,030 µg/L, and 2,260 to 9,810 µg/L, respectively. The lowest concentrations of cadmium, copper, iron, manganese, and zinc were detected at SP-15W. Aluminum was 30 µg/L at SP-15W.

Concentrations of aluminum, cadmium, copper, iron, manganese, and zinc generally increased at SP-15E from May 22 to June 16, 1997. Concentrations decreased from June to July. Aluminum and iron were not detected in July. A sample was collected in October 1997 after a rainfall event. The concentrations of cadmium, copper, manganese, and zinc increased 2 to 5 times compared to July. Aluminum (680 µg/L) and iron (170 µg/L) were detected. Field pH measurements ranged from 5.5 to 4.7 SU in May and June. In July, pH was neutral (7 SU). In October, pH was acidic, 4.9 SU.

Metal concentration trends at SP-16 varied dependent upon the metal. Aluminum and manganese increased from May to September. Cadmium, copper, and zinc generally decreased. Iron was similar in May and September (60 and 80 µg/L, respectively) but increased to 500 µg/L in July. Field pH measurements ranged from 5.4 SU in May to 4.4 SU in September.

The concentration of metals at SP-15E and SP-16 were similar in May, higher at SP-16 in July, and varied in the fall. Aluminum and manganese were higher at SP-16 in the fall, but cadmium, copper, iron, and zinc were lower at SP-16. The higher concentrations of cadmium, copper, iron, and zinc at SP-15E in the fall may be due to overland flow from seep SP-7 at the base of the abandoned mill building. The overland flow was apparently associated with a rainfall event that occurred during the time that SP-15E was sampled. The chemistry of SP-7 is discussed in the maintenance yard section.

Seeps SP-9 and SP-11 are geographically located below the west waste rock pile and lagoon (SP-16) and at the base of Railroad Creek. Both seeps were sampled in May 1997. Additional samples were not

The data from seeps SP-1 and SP-2 were compared to groundwater quality criteria as well as the monitoring wells. The following PCOCs were identified in monitoring wells and seeps associated with tailings pile 1.

	Spring	Summer	Fall
TP1-1A	Fe, Mn, TDS, SO_4, pH	Not Sampled	Fe, Mn, TDS, SO_4, pH
TP1-2A	Be, Fe, Mn, TDS, SO_4, pH	Not Sampled	Fe, Mn ,TDS, SO_4, pH
TP1-3A	Fe, Mn, Zn, TDS, SO_4, pH	Not Sampled	Fe, Mn, TDS, SO_4, pH
TP1-4A	None	Not Sampled	SO_4
TP1-5A	Fe, Mn, Zn, TDS, SO_4, pH	Not Sampled	Fe, Mn, TDS, SO_4, pH
TP1-6A	Cd, Cu, Fe, Mn, Zn, TDS, SO_4, pH	Not Sampled	Cd, Cu, Fe, TDS, SO_4, pH
SP-1	Be, Cd, Cu, Fe, Mn, TDS, SO_4, pH	Cd, Fe, Mn, TDS, SO_4, pH	Not Sampled
SP-2	As, Be, Cd, Cu, Fe, Mn, Zn, TDS, SO_4, color, pH	Cd, Cu, Fe, Mn, TDS, SO_4, color, pH	Fe, Mn, TDS, SO_4, pH

Tailings Pile 2

Groundwater samples were collected from monitoring wells (PZ-1A, PZ-1B, PZ-3A, TP2-4A, TP2-5A, TP2-8A, and TP2-11A), and seeps (SP-3 and SP-4) at the base of the tailings pile.

Samples from monitoring wells PZ-1B, PZ-3A, TP2-4A, TP2-5A, TP2-8A, and TP2-11A were collected during two sampling events in the spring and fall of 1997. PZ-1A was sampled only in the spring as the well was dry in the fall. With the exception of PZ-1B, these wells were screened in the alluvial material underneath the tailings pile. PZ-1B was screened within the tailings. The data were compared to MTCA Method A and Method B cleanup levels. Metal concentrations were below MTCA levels with the exception of arsenic at PZ-3A, cadmium in the spring at TP2-8A, and manganese at wells PZ-1B, and TP2-8A. Arsenic at PZ-3A was 5 to 6 µg/L, just above the MTCA Method A level (5 µg/L). Cadmium was 7 µg/L at TP2-8A, just above the MTCA Method A level (5 µg/L). Manganese ranged from 1,120 to 2,910 µg/L, above the MTCA Method B cleanup level of 747 µg/L. Iron concentrations ranged from <20 µg/L to 70,800 µg/L. Field pH measured at the wells on Tailing Pile 2 ranged from 5.0 to 7.2 SU. Concentration plots for various metals and pH measured in monitoring wells on tailings pile 2 are provided on Figures 5.4-3 through 16. Generally, metal concentrations in wells located at tailings pile 2 were below concentrations detected in wells located at tailings pile 1.

Seep samples were collected from seeps SP-3 and SP-4 at the base of the tailings pile. Samples were collected at both locations in May and July 1997 and at SP-3 in September 1997. Concentrations of aluminum, cadmium, copper, iron, manganese, and zinc ranged from 3,920 to 33,400 µg/L, 2 to 40.3 µg/L, 90 to 1,280 µg/L, 53,000 to 263,000 µg/L, 1,710 to 3,850 µg/L, and 611 to 4,030 µg/L, respectively. Concentrations of these metals were higher at SP-3 compared to SP-4 in May. In July, aluminum and cadmium were similar but copper, iron, manganese, and zinc tended to decrease from SP-3 to SP-4. At SP-3, concentrations of these metals decreased from May to September with the exception of iron, which increased from May to July then stabilized. Field pH at SP-3 and SP-4 ranged from 3.5 to 3.6 SU.

SP-4 was sampled in May 1998. The data were compared to the sample collected in May 1997. Aluminum, cadmium, copper, iron, manganese, and zinc concentrations in 1998 were 3 to 8 times lower than concentrations detected in 1997.

Seep data were compared to MTCA groundwater levels and water quality criteria provided in WAC 173-200. The PCOCs identified for seeps and monitoring wells associated with tailings pile 2 are summarized below.

	Spring	Summer	Fall
PZ-1A	Fe, pH	Not Sampled	Not Sampled
PZ-1B	Fe, Mn, TDS, SO_4	Not Sampled	Fe, Mn, TDS, SO_4, pH
PZ-3A	As, color, Fe, TDS, SO_4	Not Sampled	As, Fe, TDS, SO_4
TP2-4A	Fe, TDS, SO_4	Not Sampled	Fe, TDS, SO_4
TP2-5A	SO_4, pH	Not Sampled	Not Sampled
TP2-8A	Mn, TDS, SO_4, pH	Not Sampled	Mn, TDS, SO_4, pH
TP2-11A	pH	Not Sampled	TDS, SO_4, pH
SP-3	As, Be, Cd, Cu, Fe, Mn, TDS, SO_4, pH	Cd, Fe, Mn, TDS, SO_4, pH	Fe, Mn, TDS, SO_4, pH
SP-4	Cd, Fe, Mn, TDS, SO_4, pH	Cd, Fe, Mn, TDS, SO_4, pH	Not Sampled

Tailings Pile 3

Groundwater samples were collected from monitoring wells (PZ-6A, TP3-4, TP3-6A, TP3-8, TP3-9, and TP3-10A), lysimeters (TP3-4L, TP3-6L, TP3-10L), and seeps SP-5, SP-17, and SP-18. Samples were also collected from monitoring wells DS-1 and DS-2 and seep SP-21 east of tailings pile 3. Sample locations are shown on Figure 5.4-1 and analytical data are summarized on Tables 5.4-1 and 5.4-2.

Sample data from monitoring wells screened underneath tailings pile 3 were collected in the spring and fall of 1997 with the exception of TP3-4 which was sampled only in the spring. Data were compared to MTCA Method A and B cleanup levels. Metals were below MTCA with the exception of lead at TP3-4 in the spring and manganese at PZ-6A and TP3-9 in the spring and fall, and at TP3-8 and TP3-10A in the fall. Cadmium at TP3-4 was 14 µg/L compared to the MTCA Method A cleanup level of 5 µg/L. Manganese concentrations ranged from 1,370 to 3,490 µg/L, above the MTCA Method B cleanup level of 747 µg/L. Lead and manganese are identified as PCOCs in the wells noted. Iron concentration in wells on tailings pile 3 ranged from <20 µg/L to 274,000 µg/L. Field pH ranged from 3.8 to 6.5 SU.

Sample data collected from lysimeters (TP3-4L, TP3-6L, TP3-102) completed within tailings material in tailings pile 3 were compared to monitoring well data at the same location. Generally, metal concentrations were lower in the monitoring wells as compared to the lysimeters. However, aluminum, copper, and zinc were higher in the monitoring wells as compared to the lysimeters. Iron was significantly higher (one or more orders of magnitude) in the lysimeters than monitoring wells. Field pH ranged from 5.7 to 6.8 SU.

Sample data from the monitoring wells (DS-1 and DS-2) east of tailings pile 3 were collected in the spring and fall of 1997. The data were compared to MTCA cleanup levels. Metal concentrations were below MTCA levels with the exception of beryllium at DS-2 in the spring and manganese at DS-2 in the spring and the fall. Beryllium was 0.8 µg/L compared to the MTCA Method B level of 0.0203 µg/L, and manganese was 1,860 µg/L compared to the MTCA Method B level of 747 µg/L. Iron concentrations ranged from <20 µg/L at DS-1 to 72,300 µg/L in the fall at DS-2. Field pH ranged from 4.0 to 5.4 SU.

In the spring, a sample was collected at DS-2 for analysis of PCBs and TPH. PCBs and TPH were not detected.

collected as these seeps were not flowing in July or September. The concentrations of aluminum, cadmium, copper, and zinc at SP-11 were approximately 5 to 150 times the concentrations detected at SP-9. Iron was not detected at either location. Manganese was not detected at SP-9 and was detected at a concentration of 37.3 µg/L at SP-11. Field pH measurements at the two locations ranged from 5.8 to 6.4 SU.

The concentrations of aluminum, cadmium, copper, manganese, and zinc detected at seep SP-11 were well below concentrations at SP-16 detected in May. Iron was similar.

Samples were collected from SP-16 in May and July 1997 for analysis of PCBs and total petroleum hydrocarbons (TPH). PCBs were not detected and this analysis was eliminated in the fall 1997 sampling event. TPH in the motor oil range was detected in July 1997. A sample was collected in September 1997 and analyzed for TPH. TPH was not detected.

The data for seeps associated with the west waste rock pile were compared to groundwater quality criteria. The following PCOCs were identified.

	Spring	Summer	Fall
SP-6	Cd, Cu, Mn, Zn, TDS, SO_4, pH	Not Sampled	Not Sampled
SP-15E	Be, Cd, Cu, Zn, pH	Cd, Cu	Cd, Cu, Zn, pH (storm event)
SP-15W	Cd	Not Sampled	Not Sampled
SP-16	Cd, Cu, Zn, pH	Cd, Cu, Fe, Mn, Zn, pH	Cd, Cu, Mn, pH
SP-9	pH	Not Sampled	Not Sampled
SP-11	As, Cd, pH	Not Sampled	Not Sampled

TDS – Total Dissolved Solids

East Waste Rock Pile

Seep SP-8 originates from the base of the east waste rock pile. A single sample was collected in May 1997. Concentrations of aluminum (9,620 µg/L), cadmium (87.8 µg/L), copper (7,880 µg/L), manganese (419 µg/L), and zinc (11,200 µg/L) were above concentrations detected in seeps associated with SP-8 as discussed below. Iron was detected at a low concentration of 30 µg/L. pH was acidic, 4.6 SU. The seep was not flowing during sampling events in June, July, and September 1997, thus only one sample was collected during the spring snowmelt in May.

The inferred flow path of water exiting the waste rock pile at SP-8 indicates that overland seep SP-19 and seeps SP-10W and SP-10E are related. Samples were collected at SP-19, SP-10E, and SP-10W in May 1997 and additionally at SP-10W in July 1997. Concentrations of aluminum, cadmium, copper, manganese, and zinc continually decrease in May from SP-8 to SP-19 and finally to SP-10E and SP-10W located at Railroad Creek. Iron ranges from 30 to 70 µg/L at SP-8, SP-19 and SP-10W. Iron (14,100 µg/L) at SP-10E is significantly above concentrations in the other related seeps including SP-8 and appears to be influenced by tailings pile 1. Field pH measurements at SP-19 and SP-10W ranged from 4.2 to 4.7 SU. The pH measured at SP-10E was 3.3 SU.

The data for seeps associated with the east waste rock pile were compared to groundwater quality criteria. The following PCOCs were identified.

	Spring	Summer	Fall
SP-8	Cd, Cu, Zn, pH	Not Sampled	Not Sampled
SP-19	Cd, Cu, Zn, pH	Not Sampled	Not Sampled
SP-10W	Cd, Cu, pH	Cd, Cu, pH	Not Sampled
SP-10E	Cd, Cu, Fe, pH	Not Sampled	Not Sampled

5.4.2.5 Maintenance Yard

Samples were collected from seeps (SP-7, SP-22, SP-24, and SP-25) and a groundwater monitoring well (HBKG-1) associated directly or indirectly to the maintenance yard. Seep samples were collected in May 1997 at each seep and well. Additional samples were collected at SP-7 in July and September and at HBKG-1 in September. Sample locations are shown on Figure 5.4-1. Analytical data are summarized in Tables 5.4-1 and 5.4-2.

SP-7

Aluminum, cadmium, copper, iron, manganese, and zinc concentrations ranged from 20 to 1,790 µg/L, 26 to 48 µg/L, 1,930 to 7,560 µg/L, 120 to 710 µg/L, 116 to 451 µg/L, and 3,470 to 6,430 µg/L, respectively. The lowest concentrations were detected in July, followed by May then September with the exception of manganese which was lowest in May, followed by July then September. Field pH measurements ranged from 4.7 to 6.9 SU. The lowest pH (4.7 SU) was measured in September, followed by May (5.6 SU) and July (6.9 SU).

SP-22

One sample was collected in May 1997. Additional samples were not collected as the seep was not flowing in July or September. Concentrations of aluminum, cadmium, copper, iron, manganese, and zinc at SP-22 were 190 µg/L, 47.5 µg/L, 2,140 µg/L, <20 µg/L, 264 µg/L, and 7,350 µg/L, respectively. The concentrations detected were generally similar to those detected at SP-7. Manganese and zinc were elevated 1.5 to 2 times higher at SP-22 than SP-7. Field pH was 6 SU.

A sample was collected in May for analysis of PCBs and TPH (diesel and heavier range hydrocarbons). PCBs and TPH were not detected.

SP-24

One sample was collected in May 1997. Additional samples were not collected as the seep was not flowing in July or September. Concentrations of aluminum, cadmium, copper, iron, manganese, and zinc at SP-24 were 2,410 µg/L, 47.7 µg/L, 3,660 µg/L, 220 µg/L, 270 µg/L, and 7,560 µg/L, respectively. Concentrations of cadmium, manganese, and zinc at SP-24 were similar to SP-22. Aluminum increased an order of magnitude and copper approximately 2 times at SP-24 above SP-22. Iron was detected at SP-24 and had not been detected at SP-22. Field pH at SP-24 was more acidic than SP-22 (4.9 vs. 6 SU).

SP-25

One sample was collected in May 1997. Additional samples were not collected as the seep was not flowing in July or September. Concentrations of aluminum, cadmium, copper, iron, manganese, and zinc at SP-25 were 890 µg/L, 34.1 µg/L, 1,880 µg/L, <20 µg/L, 157 µg/L, and 5,550 µg/L, respectively. Cadmium, copper, iron, manganese, and zinc concentrations at SP-25 were below or similar to those detected at SP-22 and SP-24. Aluminum at SP-25 was above SP-22 but below SP-24. Field pH was 5.5 SU.

HBKG-1

Groundwater monitoring well HBKG-1 is located directly downgradient of the maintenance yard area and SP-22. Samples were collected in May and September 1997. The data collected were compared to MTCA cleanup levels. Cadmium, copper, and zinc concentrations were above MTCA A or B cleanup levels in May and September. Data for both sampling rounds were similar. Lead (5 µg/L) detected in May was equal to the MTCA Method A cleanup level (5 µg/L) and below MTCA levels in September. Field pH was 5.1 SU. The concentrations of cadmium, copper, and zinc detected at HBKG-1 are similar to concentrations detected in seep sample SP-22.

Groundwater samples collected from HBKG-1 were also analyzed for organic constituents (TPH and PCBs). PCBs were not detected in samples collected in May and this analysis was omitted from the analytical requirements in September. Total petroleum hydrocarbons in the diesel range were detected just above the detection limit but well below the MTCA cleanup level of 1 mg/L. TPH were not detected in the sample collected in September.

Comparison to Groundwater Quality Criteria

The data from seeps SP-7, SP-22, SP-24, SP-25 and monitoring well HBKG-1 were compared to groundwater quality criteria (MTCA and WAC 173-200). The following PCOCs were identified.

	Spring	Summer	Fall
SP-7	Cd, Cu, pH	Cd, Cu	Cd, Cu, Fe, Zn, TDS, SO_4, pH
SP-22	Cd, Cu, Zn, pH	Not Sampled	Not Sampled
SP-24	Cd, Cu, Zn, pH	Not Sampled	Not Sampled
SP-25	Cd, Cu, Zn, pH	Not Sampled	Not Sampled
HBKG-1	Cd, Cu, Zn, pH	Not Sampled	Cd, Cu, Zn, pH

5.4.2.6 Tailings Piles

Tailings Pile 1

Groundwater samples were collected from monitoring wells TP1-1A, TP1-2A, TP1-3A, TP1-4A, TP1-5A, and TP1-6A completed in the alluvial and reworked till underneath tailings pile 1 (Figure 5.4-1) during two sampling rounds conducted in May and September of 1997. The data were compared to MTCA Method A and B cleanup levels. Cadmium was above the MTCA Method A cleanup level (5 µg/L) in the spring and fall samples collected from monitoring well TP1-6A. Copper was above the MTCA Method B cleanup level in samples collected in the spring and the fall round from monitoring well TP1-6A. Manganese was above the MTCA Method B (747 µg/L) during both the spring and fall rounds in wells TP1-1A, TP1-2A, TP1-3A, TP1-5A and during the spring round only in monitoring well TP1-6A. Zinc was above the MTCA Method B cleanup level (4800 µg/L) in samples collected in the spring and fall from monitoring well TP1-3A and in the spring from wells TP1-5A and TP1-6A. All other metals were below MTCA cleanup levels where established. Iron concentrations in the wells screened below tailings pile 1 ranged from not detected (< 20 µg/L) at TP1-4A in fall 1997 to 1,690,000 µg/L at TP1-2A in fall 1997. With the exception of TP1-4A, concentrations of iron were greater than 79,500 µg/L. Field pH ranged from 4.1 to 5.5 SU. Concentrations plots for pH, aluminum, cadmium, copper, iron, manganese, and zinc are shown on Figures 5.4-3 through 5.4-16.

Groundwater samples were collected from lysimeters (TP1-2L, TP1-3L, TP1-4L, and TP1-6L) completed within the tailings in tailings pile 1. Sample results for dissolved metals were collected in the spring and fall of 1997. Generally, dissolved metal concentrations for lysimeter and groundwater monitoring wells were similar at the same locations. Exceptions were aluminum, copper, cadmium, iron, manganese, and zinc, which showed increases and decreases dependent upon location and may be indicative of the varying material deposited in the tailings pile, as well as the level of saturation.

Seep samples were collected from SP-1 and SP-2 at the base of tailings pile 1. SP-1 was sampled in May and July 1997. SP-2 was sampled in May, July, and September 1997. Additionally, samples were collected at SP-2 weekly from May 18 to June 16 to assess event-related variability and after a rain event in October 1997. Concentrations of aluminum, cadmium, copper, iron, manganese, and zinc ranged from 27,100 to 121,000 µg/L, 6 to 22.8 µg/L, 101 to 914 µg/L, 487,000 to 1,260,000 µg/L, 3,380 to 6,310 µg/L, and 2,050 to 6,120 µg/L, respectively. pH ranged from 2.9 to 3.9 SU. Concentrations of cadmium and iron were similar at SP-1 and SP-2. Aluminum, copper, manganese, and zinc generally were higher at SP-2 than SP-1, but within an order of magnitude.

The concentration of aluminum, cadmium, copper, manganese and zinc generally decreased at SP-2 during the weekly sampling from May 18 to June 16, 1997. Iron increased during the same timeframe. pH ranged from 2.9 to 3.2. Concentrations for aluminum, copper, iron, and manganese increased in July and then decreased in September. pH was 2.9 to 3.1 SU. The sample collected after the rain event in October 1997 contained concentrations of metals similar to those detected in September.

SP-1 and SP-2 were sampled in May 1998. Concentrations of aluminum, manganese, and zinc are similar to 1997 results. Cadmium and copper appeared to decrease in 1998 and iron increased, but results were well within an order of magnitude compared to 1997.

Samples were collected from SP-1 and SP-2 in May and July for analysis for PCBs and TPH. PCBs and TPH were not detected. A sample was collected from SP-2 in September for TPH analysis. TPH was not detected.

Seep samples were collected at SP-5, SP-17, SP-18, and SP-21 east of tailings pile 3 in May and July 1997. Additionally, a sample was collected at SP-21 in September and after a rain event in October 1997.

Metal concentrations (aluminum, cadmium, copper, iron, manganese, and zinc) decreased significantly from May to July. At seep locations SP-17, and SP-18, concentrations of aluminum, cadmium, copper, iron, manganese, and zinc tended to be similar in May and July. At SP-21, concentrations were similar or decreased slightly from May to July. July and September concentrations were similar at SP-21 with the exception of iron and manganese, which increased approximately 2 times. The data collected at SP-21 after the rain event in October was similar to the September sampling with the exception of slight increases in aluminum and iron.

The concentrations of metals at SP-17 were significantly below the concentrations at SP-5, SP-18 and SP-21. Concentrations at SP-5 were similar to those detected at SP-18 in May. In July, SP-5 was significantly below SP-18. The concentrations of metals at SP-21 were an order of magnitude below SP-5 and SP-18 in May. The pH measured at SP-17 ranged from 6.4 to 7.4 SU. The pH at locations SP-5, SP-18, and SP-21 ranged from 3.4 to 5.4 SU with the lowest pH readings occurring at SP-18 and SP-5.

Seep samples SP-5, SP-17 and SP-18 were compared to MTCA groundwater levels and groundwater quality criteria designated in WAC 173-200. Seep SP-21 was compared to surface water quality criteria instead of groundwater criteria as this seep is more indicative of surface water and available for aquatic habitat. The following PCOCs are identified in monitoring wells and seeps associated with the east side of tailings pile 3.

	Spring	Summer	Fall
PZ-6A	Fe, Mn, TDS, SO_4, pH	Not Sampled	Fe, Mn, TDS, SO_4, pH
TP3-4	Pb, pH	Not Sampled	Not Sampled
TP3-6A	pH	Not Sampled	pH
TP3-8	Fe, TDS, SO_4, pH	Not Sampled	Fe, Mn, TDS, SO_4, pH
TP3-9	Be, Fe, Mn, pH	Not Sampled	Fe, Mn, TDS, SO_4, pH
TP3-10A	pH	Not Sampled	Fe, Mn, TDS, SO_4, pH
DS-1	SO_4, pH	Not Sampled	pH
DS-2	Be, pH	Not Sampled	Fe, Mn, TDS, SO_4, pH
SP-5	Be, Cd, Cu, Fe, Mn, TDS, SO_4, pH	Fe, pH	Not Sampled
SP-17	pH	None	Not Sampled
SP-18	Be, Cd, Cu, Fe, Mn, SO_4, pH	Be, Cd, Cu, Fe, Mn, TDS, SO_4, pH	Not Sampled
SP-21	Cd, Cu, Zn, pH	Cd, Cu, Zn, pH	Cu, pH

5.4.2.7 Holden Village

A sample was collected from seep SP-13, which originates as drainage from beneath two of the buildings in the southern portion of Holden Village and was noted to flow only during the snowmelt runoff period. Analytical data are summarized in Table 5.4-2. Aluminum and copper were not detected. Concentrations of cadmium, iron, manganese, and zinc were 0.31 µg/L, 330 µg/L, 74 µ/L, and 71 µg/L, respectively. Field pH was 6 SU. The data were compared to groundwater quality criteria. Iron (330 µg/L) and pH were outside of water quality criteria (300 µg/L and 6.5 SU, respectively).

5.4.2.8 Lucerne Well

The well at the Lucerne USFS guard station was sampled in both May and September 1997. The data collected were compared to MTCA cleanup levels and federal MCLs. Metal concentrations detected were not above MTCA cleanup levels. Iron (310 µg/L) detected in the sample collected in June 1997 was just above the secondary federal MCL (300 µg/L). The concentration detected in October 1997 decreased to 200 µg/L. Iron was identified as a PCOC at Lucerne. Measured pH (5.25 to 5.49 SU) was below groundwater quality criteria (6.5 to 8.5 SU).

5.4.3 Interstitial Pore Water Data and Mill Building Drip Water

5.4.3.1 Interstitial Pore Water

Samples of interstitial pore water (BKG, TP1-2, TP2-1, TP2-2, TP3-1, TP3-2, and DG) were collected in April 1994 from locations shown on Figure 5.4-1 (USBM, 1994). Samples were reportedly collected by pushing a syringe fitted with a Teflon tip into the streambed and withdrawing the water from between the particles of the streambed. Due to potential problems with sample collection technique and unavailability of quality assurance information related to sample data, these data are considered useful for screening purposes only. Analytical results are summarized on Table 5.4-5.

Results from sample location BKG, upstream of the tailings piles, indicate neutral pH (7.3) and low metal concentrations. Aluminum and copper concentrations were below detection limits and iron and zinc concentrations were 20 µg/L.

Generally, metal concentrations increased at TP1-2 relative to BKG data. The highest interstitial iron concentration (95,000 µg/L) was present at TP1-2. The pH from sample TP1-2 was 3.4 SU.

Sample TP2-1 also contained low pH and higher iron, aluminum, and copper concentrations than detected at BKG. pH for sample TP2-1 was 4.0 SU. Aluminum (17,000 µg/L) and copper (250 µ/L) concentrations measured at TP2-1 were higher by at least an order of magnitude than in the additional samples collected.

Samples downstream of location TP2-1 indicate that pH becomes less acidic and dissolved metal concentrations decrease from TP2-1 downstream to TP3-2, with the exception of lead.

Sample DG-1 was collected downstream of the northeast corner of tailings pile 3. Iron (22,000 µg/L) and zinc (6,000 µg/L) concentrations detected in sample DG-1 were higher than concentrations at TP3-2 by 100 times or greater.

5.4.3.2 Mill Building Drip Water

Two samples of water dripping off surfaces within the mill building were collected in 1995 (Kilburn and Sutley, 1996) and an additional seven samples were collected in 1996 (Kilburn and Sutley, 1997). These samples contained concentrations of aluminum, cadmium, copper, iron, manganese, and zinc, ranging from 32 to 76,000 µg/L, 22 to 3000 µg/L, 450 to 650,000 µg/L, not detected to >500,000 µg/L, 56 to 33,000 µg/L, and 3,200 to 350,000 µg/L, respectively. Dissolved metals results for the samples are summarized in Table 5.4-6.

5.4.4 Groundwater Summary

Groundwater samples were collected from monitoring wells located in Holden Village, west of Holden Village near the baseball field, on the Site downgradient of the maintenance yard, in tailings piles 1, 2, and 3, east of tailings pile 3, and from a single well located at Lucerne. Samples were also collected from lysimeters completed within tailings piles 1 and 3. Seep samples were included as part of the groundwater quality assessment based on the apparent relationship to underground water sources. Samples were collected from seeps located on the Site and on the banks of Railroad Creek upgradient, adjacent to, and downgradient of the Holden Mine.

Samples were collected during sampling events in the spring, summer, and fall of 1997. The samples were analyzed for dissolved metals, conventional parameters, and field parameters as outlined in the SAPs and QAPPs. Select groundwater and seep samples were analyzed for organic constituents (PCBs and TPH).

The data collected from monitoring wells and seeps were compared to MTCA cleanup levels and WAC 173-200 to assess PCOCs. The sample collected at Lucerne was also compared to federal MCLs as the water from this well is a current drinking water source for the Lucerne community. PCOCs were identified if metal concentrations were above MTCA cleanup levels, outside of WAC 173-200 criteria, or above MCLs. Data collected at SP-21 were compared to surface water quality criteria rather than groundwater criteria as this location is available to support aquatic life. Arsenic, beryllium, cadmium, copper, iron, lead, manganese, and zinc were identified as PCOCs at one or more monitoring well locations. Arsenic, beryllium, cadmium, copper, iron, manganese, and zinc were above groundwater criteria at various seeps in the west and east portions of the site. Additionally, pH, sulfate, and total dissolved solids were commonly assessed as PCOCs at both monitoring well and seep locations. The PCOCs at seeps were generally similar to PCOCs identified in monitoring wells in the same geographic areas. Cadmium, copper, and zinc were identified as PCOCs at SP-21. A summary of PCOCs by individual sample location is provided at the end of each subsection in Section 5.4.2. A general summary of PCOCs is tabulated in Table 5.4-7.

The primary potential concern regarding seeps at the Site and in the Site area is the relation to surface water quality in Railroad Creek. Aluminum, cadmium, copper, iron, manganese, and zinc concentrations were evaluated at each seep location. Additionally, the relationship of seeps within each geographical area as designated in Section 4.0 were discussed based on metal results. The relationship of the seeps to surface water quality is discussed in Section 6.0 as part of the fate and transport discussion.

Lysimeter data were compared to monitoring well data at each location sampled. These data were not used to assess PCOCs.

5.5 SEDIMENT

5.5.1 Railroad Creek

Sediment in Railroad Creek consists primarily of large grain size, including boulder, cobble and large gravel. Previous evaluations of sediment grain size completed by PNL (1992) upstream and adjacent to the Site indicate that the cobble and boulder fraction of streambed sediment is on the order of 90%. PNL (1992) further reports that the boulder/cobble fraction diminishes to 70% downstream of the Site (and upstream of

Ninemile Creek) with a corresponding increase in gravel/sand and silt fraction. The change in substrate size is related to channel slope and overall geomorphologic conditions (Section 4.3).

Assessment of sediment chemical characteristics as it relates to mining activities is difficult because of the generally large grain sizes encountered. Therefore, previous sediment quality investigations have tended to focus on the smaller grain size fraction. None of the investigations attempted to evaluate the depositional environment or how representative the sediment samples that were collected are to typical conditions in Railroad Creek. Sediment samples were not collected from Railroad Creek or tributaries to Railroad Creek during the RI. Historical sediment data is described below.

Stream sediment samples were previously collected by USGS (1994), U.S. Bureau of Mines (1995), and Ecology (1997). The historical data is summarized in Table 5.5-1. Historical samples did not include ferricrete or flocculent media. The locations of historic sediment samples are shown on Figures 5.5-1 and 5.5-1a. Metal concentrations in samples collected upstream of the Site (USGS, 1994) and tributaries to Railroad Creek were all below Ecology's proposed Freshwater Sediment Quality Values (FSQV, 1997), with the exception of copper at USGS station 346, which was 1,000 mg/kg compared to the FSQV (340 mg/kg).

Sediment samples were collected at stations adjacent to and downstream of the Holden Mine. The data were compared to upstream concentrations and FSQVs. Generally, metals were below upstream concentrations with the exception of cadmium, copper, iron, lead, and silver, which were above upstream concentrations in a limited number of samples. Cadmium, copper, and silver were below FSQVs. An FSQV is not established for iron. Iron was above upstream concentrations at only one location, station 350, which is located east of Tailings Pile 3 in the area near location SP-18.

Ecology (1997) compared metals concentrations in sediment samples collected from Railroad Creek to assumed background levels for stream sediments in Washington, and sediment quality guidelines. The comparison indicates that sediments in Railroad Creek upstream of the Site contained concentrations of zinc, copper and lead at or below expected background levels, and were below concentrations for FSQVs. Concentrations of zinc and copper were reported to be above typical background conditions in sediment samples collected in Railroad Creek adjacent to the Site; however, they were also below FSQVs.

5.5.2 Lake Chelan-Lucerne Bar and Stehekin

Sediment samples were collected in the fall of 1998 from Lake Chelan at Lucerne bar and at Stehekin near the mouth of the Stehekin River in Lake Chelan. Data collected from Stehekin were used to assess reference concentrations. Data collected at Lucerne were compared to the reference concentrations and to Ecology's FSQVs. The samples were analyzed for a limited list of metals (aluminum, arsenic, cadmium, copper, iron, lead, manganese, and zinc) based on PCOCs identified in Railroad Creek. Additionally, the samples were analyzed for total solids, total organic carbon, total volatile solids, and acid volatile solids. The data are summarized with the statistical analysis in Tables 5.5-2 and 5.5-3. Sample locations are shown on Figures 5.5-2 and 5.5-3.

The Stehekin reference concentrations were statistically analyzed to calculate a 90th percentile value which is considered the reference concentration. The reference concentrations were compared to

Ecology's FSQVs. The reference concentrations as well as individual sample concentrations did not exceed the FSQVs.

The concentration of metals detected at Lucerne were compared to reference concentrations and FSQVs. Concentrations of cadmium, copper, iron, and zinc were above reference concentrations. Cadmium and copper were below FSQVs. Zinc was below the FSQV at all sample locations with the exception of one. The zinc concentration (426 mg/kg) at LUC-SED-101598-5-1 was just above the FSQV (410 mg/kg).

Iron concentrations ranged from 15,400 to 52,800 mg/kg. Iron detected at sample locations LUC-SED-101598-3-2 and LUC-SED-101598-5-1 was 33,200 mg/kg and 52,800 mg/kg, respectively. The reference concentration was 32,297 mg/kg.

5.5.3 Summary

Metal concentrations detected in sediment collected from Railroad Creek, tributaries to Railroad Creek, and from Lake Chelan at the Lucerne bar and Stehekin were compared to FSQVs and upstream or reference concentrations as appropriate. Concentrations were above FSQVs at only one station located in the Copper Creek diversion for copper only, and at one sample location at Lucerne bar for zinc only.

In Railroad Creek, metal concentrations of cadmium, copper, iron, lead, and silver in sediment samples adjacent to and downstream of the Site were above upstream concentrations at limited locations, but were not above FSQVs. Iron concentrations were relatively consistent in Railroad Creek from upstream to downstream stations with a single exception located adjacent to the Site that was above upstream concentrations.

Cadmium, copper, iron and zinc in sediment samples collected at Lucerne bar were above reference concentrations but below FSQVs with a single exception for zinc.

Zinc in Railroad Creek sediments increased from upstream stations to stations adjacent to the Site, stabilized downstream of the Site and then increased in Railroad Creek at Lucerne. USGS station 354 is the furthest downstream station and located at Lucerne. Zinc at this location was 330 mg/kg, similar to the concentrations detected in Lake Chelan sediments.

5.6 OTHER MEDIA

During the 1997 investigation, other media present in the creek bed were sampled and included: flocculent and precipitate from the portal drainage (portal film), flocculent and precipitate in Railroad Creek adjacent to the tailings piles (flocculent), and samples of the cemented iron-oxide ferricrete accumulated along the south bank of the creek adjacent to tailings pile 1 and tailings pile 2. The flocculent and film that were collected consisted of a coating on the larger substrate materials, and also included small size particles deposited within the interstices of the larger grain sizes. The ferricrete samples were obtained by breaking up large solidified blocks of the material that had formed on the south bank adjacent to tailings pile 1. Only the flocculent and precipitate are assumed potentially transportable downstream.

The analytical results for the ferricrete, flocculent and portal film samples collected in 1997 during the RI are presented on Table 5.6-1. Sample locations are shown on Figure 5.6.1.

5.6.1 Ferricrete

Three ferricrete samples, DMTP1E-1, DMTP1W-1A, and DMTP1W-1B, were collected in October 1997. Metal concentrations varied between samples. Iron concentrations were highest in sample DMTP1E-1 (111,000 mg/kg). Iron concentrations in samples DMTP1W-1A (45,000 mg/kg) and DMTP1W-1B (37,500 mg/kg) were similar. Copper in sample DMTP1W-1B (2,340 mg/kg) was higher than concentrations detected in samples DMTP1E-1 (101 mg/kg) and DMTP1W-1A (90.8 mg/kg). Zinc was also detected at the highest concentration in sample DMTP1W-1B (404 mg/kg).

5.6.2 Flocculent

Three flocculent samples, Floc1-RC-2, Floc2-RC-5, Floc3-RC-9, were collected from Railroad Creek in October 1997. Metal concentrations were highest at Floc3-RC-9 followed by Floc2-RC-5 then Floc1-RC-2 (Table 5.6-1).

5.6.3 Portal Film

Two portal film samples were collected from the portal drainage in July 1997 and October 1997. Aluminum and manganese were two times higher in July compared to October. Zinc and copper were highest by approximately two times in October as compared to July. Iron concentrations were similar in July and October.

5.6.4 Concentrate

Concentrate samples were collected in 1994 by the USGS upstream, adjacent to, and downstream of the Site in Railroad Creek. Samples were also collected from Copper Creek and Holden Creek. The samples were collected to maximize the heavy metal content of the matrix by collecting from areas of the streambed where material would naturally accumulate. Concentrate was collected simultaneously with sediments. The samples were analyzed for metals. Sample locations are shown in Figures 5.5-1 and 5.5-1a and data are summarized in Table 5.5-1.

Generally, concentrate data adjacent to and downstream of the Site in Railroad Creek was similar to upstream data. The upstream concentrate in Railroad Creek was similar to Holden Creek and Copper Creek. Concentrate data compared to sediment data in Railroad Creek generally detected higher concentrations of chromium, copper, and zinc in concentrate samples. Iron concentrations generally were lower in concentrate samples compared to the associated sediment samples.

5.7 AIR

A dust bucket study of dry deposition rates was conducted in 1974, 1975 and 1976 (Bureau of Mines, 1974), and air quality monitoring was conducted in 1994 by the USFS at the request of the EPA Region X facilities assessment manager (EPA, 1994; Air Resource Specialists, 1995).

The dust bucket study was conducted in order to evaluate dry deposition rates of tailings materials at several locations within the Railroad Creek watershed. The data did indicate that significant amounts of dust were being deposited downwind of the tailings piles, however, the dust was not chemically characterized.

During the mine reclamation activities at the Site which included covering much of the tailings deposits with gravel and introduction of vegetation, an air quality study at the Site was conducted by the USFS in 1994 to provide the EPA with additional data required for the Preliminary Assessment of the Site conducted in the same year. The study was completed by Air Resource Specialists under contract with the USFS and audited by the Washington State Department of Ecology. The results of that study along with associated quality assurance data were presented to the USFS in a preliminary data transmittal report in December 1994 (Air Resource Specialists, 1994). The study consisted of eight particulate monitoring stations: (1) one up-valley background monitoring site; (2) three on tailings piles; (3) one between tailings piles; (4) two in the community of Holden Village; and, (5) one down-valley from the village and tailings piles, to the east. Monitoring began on July 31 and ended October 15, 1994.

The results of the particulate sampling indicated that maximum particulate concentrations were detected in downwind sampling locations the majority of the time. The wind direction was predominantly from the west, down the valley toward Lake Chelan. However, during the morning and evening transitional periods winds from the east toward the west were not uncommon. The highest concentrations of particulates were detected in the monitoring stations near the tailings piles. Selected particulate samples collected at seven of the eight monitoring stations on September 23 and 29 were analyzed using EPA SW-846 methodology for metals (aluminum, barium, calcium, copper, iron, lead, magnesium, manganese, potassium, sodium, and zinc). A summary of the results of these analyses is provided in Table 5.7-1. These data are evaluated in the Human Health Risk Assessment in Section 7.0.

Additional air monitoring data were not collected during the RI.

5.8 ASBESTOS

Three samples were collected in October 1997 from the mill building wall insulation material to determine if asbestos-containing materials were present. Two samples were collected of the insulation, and one sample was collected of the mortar covering the insulation material. The samples were submitted to EMSL Analytical, Inc., in Seattle, Washington, for bulk asbestos analysis by polarized light microscopy (PLM). Asbestos was not detected in any of the samples. The data are provided in Appendix L.

5.9 WINSTON HOMESITE UNDERGROUND STORAGE TANKS

A reconnaissance of the Winston home site area was performed to determine the number of remaining underground storage tanks in the area. Approximately 38 USTs were observed in the area. Fuel product is suspected to be present in some of the USTs. However, it is understood that the majority of fuel may have been removed for use in Holden Village. A more thorough discussion of the results of tank inventory was provided previously in Section 4.2.

Seven testpits were completed from 3.5 to 8 feet below ground surface (bgs) on the south perimeter of the home site area to assess the potential presence of petroleum hydrocarbons related to the USTs in the Winston area. Information related to the test pits was provided previously in Section 4.2. No indications of petroleum hydrocarbons were noted in the test pits; thus, samples were not collected for chemical analyses.

TABLE 5.0-1
KEY OF SITE FEATURES & MEDIA SAMPLING/DATA COLLECTION LOCATIONS
HOLDEN MINE RI/FS
DAMES & MOORE JOB NO. 17693-005-019

Feature/Area or Media	Station No.	Location by Area	Coordinate	Comments
Feature/Area				
1500-Level Main Portal	N/A	Mine Support & Waste Rock	E.0-3.0	Near southern boundary
1500-Level Ventilator Portal	N/A	Mine Support & Waste Rock	D.7-3.0	Near western boundary
1100-Level Portal	N/A	Honeymoon Heights	D.8-3.1	
1000-Level Portal	N/A	Honeymoon Heights	D.8-3.1	
800-Level Portal	N/A	Honeymoon Heights	D.8-3.1	
700-Level Portal	N/A	Honeymoon Heights	D.8-3.2	
550-Level Portal	N/A	Honeymoon Heights	D.9-3.2	
300-Level Portal	N/A	Honeymoon Heights	D.9-3.2	
Abandoned Septic Field	N/A	SE of Holden Village	E.2-3.0	
Abandoned Surface Water Ret.	N/A	Mine Support & Waste Rock	D.7-2.9	
Baseball Field/Campground	N/A	Baseball Field/Campground	D.7-2.9, D.8-2.9	
Copper Creek	N/A	S. of Tailings Piles 1 & 2	E.1-3.1, E.1-3.2, E.2-3.0, E.3-3.1	
Copper Creek Diversion	N/A	W. of Tailings Pile 1	E.0-3.0, E.1-3.0	
East Waste Rock Pile	N/A	Mine Support & Waste Rock	E.1-3.0, E.1-3.1	
Holden Village	N/A	Holden Village	E.1-2.9, E.2-2.9	
Holden Village Septic Field	N/A	SE of Winston Home Sites	D.9-2.9, E.0-2.9	
Honeymoon Heights	N/A	Honeymoon Heights	D.7-3.0, 3.1, 3.2; D.8-3.0, 3.1, 3.2, 3.3; D.9-3.0, 3.1, 3.2, 3.3	
Hydroelectric Plant	N/A	W. of Tailings Pile 1	E.0-3.0	
Intermittent Drainage	N/A	Honeymoon Heights	D.8-3.0, D.8-3.1, D.8-3.2, D.8-3.3	
Lagoon	N/A	Mine Support & Waste Rock	E.0-2.9, E.0-3.0	
Lucerne Bar	N/A	Lucerne		
Lucerne Guard Station	N/A	Lucerne	I-3	
Maintenance Yard	N/A	Maintenance Yard	E.0-3.0	
Mill Building	N/A	Mill Building	E.0-3.0	
Mine Support and Waste Rock	N/A	Mine Support & Waste Rock	D.7-2.9, 3.0; D.8-2.9, 3.0; D.9-2.9, 3.0; E.0-2.9, 3.0, 3.1; E.1-3.0, 3.1, 2.9	
Portal Museum	N/A	Mine Support & Waste Rock	E.0-3.0	
Sauna	N/A	NW of Tailings Pile 1	E.1-3.0	
Shop	N/A	Maintenance Yard	E.0-3.0	
Storage	N/A	Maintenance Yard	E.0-3.0	
Tailings Pile 1	N/A	Tailings Pile 1	E.1-3.0, E.2-3.0, E.2-3.1	
Tailings Pile 2	N/A	Tailings Pile 2	E.2-3.0, E.2-3.1, E.3-3.0, E.3-3.1, E.4-3.0, E.4-3.1	
Tailings Pile 3	N/A	Tailings Pile 3	E.4-3.0, E.4-3.1, E.5-3.0, E.5-3.1	
USFS Guard Station	N/A	USFS Guard Station	E.0-2.9	
West Waste Rock Pile	N/A	Mine Support & Waste Rock	E.0-3.0	
Winston Home Sites	N/A	Winston Home Sites	D.8-2.9; D.9-2.8, 2.9; E.0-2.8, 2.9	
Geophysical Survey Lines				
A-A'	N/A	North of West Waste Rock Pile	E.0-2.9, E.0-3.0	
B1-B1'	N/A	Tailings Pile 1	E.1-3.0	
B2-B2'	N/A	East Waste Rock Pile	E.1-3.1	
C-C'	N/A	Tailings Pile 2	E.3-3.0, E.3-3.1	
D-D'	N/A	Tailings Pile 3	E.4-3.0, E.4-3.1	
E-E'	N/A	East of Tailings Pile 3	E.5-3.0, E.5-3.1	

Feature/Area or Media	Station No.	Location by Area	Coordinate	Comments
EM1-EM1'	N/A	Western Mine Support Area	D.8-2.9, D.8-3.0, D.9-2.9, D.9-3.0, E.0-2.9	
EM2-EM2'	N/A	Western Mine Support Area	D.8-3.0, D.9-3.0, E.0-3.0, E.1-3.0	
EM3-EM3'	N/A	East of Tailings Pile 3	E.5-3.0, E.5-3.1	
F-F'	N/A	North of Tailings Piles 2 & 3	E.4-3.0	
G-G'	N/A	Between Tailings Piles 1 & 2	E.2-3.0, E.2-3.1	
Sample Locations				
Groundwater Monitoring Wells				
	HBKG-1	W. of Tailings Pile 1	E.0-3.0	Potential background
	HBKG-2	E. of Baseball Field/Campgr.	D.8-2.9	Potential background
	CC-BKG	SW Tailings Pile 2	E.2-3.1	Background
	H-1	Holden Village	E.1-2.9	
	H-2	Holden Village	E.2-2.9	
	HV-3/H-3	Holden Village	E.1-2.9	Background
	DS-1	East of Tailings Pile 3	E.5-3.0	Downstream Wells:
	DS-2	East of Tailings Pile 3	E.5-3.0	Downstream Wells:
	TP1-1A	Tailings Pile 1	E.1-3.0	
	TP1-2A	Tailings Pile 1	E.1-3.0	
	TP1-2L	Tailings Pile 1	E.1-3.0	
	TP1-3A	Tailings Pile 1	E.1-3.0	
	TP1-3L	Tailings Pile 1	E.1-3.0	
	TP1-4A	Tailings Pile 1	E.1-3.0	
	TP1-4L	Tailings Pile 1	E.1-3.0	
	TP1-5A	Tailings Pile 1	E.2-3.0	
	TP1-6A	Tailings Pile 1	E.1-3.0	
	TP1-6L	Tailings Pile 1	E.1-3.0	
	PZ-1A	Tailings Pile 2	E.3-3.1	
	PZ-1B	Tailings Pile 2	E.3-3.1	
	PZ-1C	Tailings Pile 2	E.3-3.1	
	PZ-2A	Tailings Pile 2	E.3-3.0	
	PZ-2B	Tailings Pile 2	E.3-3.0	
	PZ-2C	Tailings Pile 2	E.3-3.0	
	PZ-3A	Tailings Pile 2	E.3-3.0	
	PZ-3B	Tailings Pile 2	E.3-3.0	
	PZ-3C	Tailings Pile 2	E.3-3.0	
	TP2-1L	Tailings Pile 2	E.3-3.1	
	TP2-2L	Tailings Pile 2	E.3-3.0	
	TP2-4A	Tailings Pile 2	E.3-3.0	
	TP2-4B	Tailings Pile 2	E.3-3.0	
	TP2-5A	Tailings Pile 2	E.3-3.0	
	TP2-5B	Tailings Pile 2	E.3-3.0	
	TP2-6L	Tailings Pile 2	E.3-3.1	
	TP2-7N&S	Tailings Pile 2	E.4-3.0	
	TP2-8A	Tailings Pile 2	E.4-3.0	
	TP2-8B	Tailings Pile 2	E.4-3.0	
	TP2-9L	Tailings Pile 2	E.4-3.1	
	TP2-10L	Tailings Pile 2	E.2-3.1	
	TP2-11	Tailings Pile 2	E.2-3.0	
	TP2-11L	Tailings Pile 2	E.2-3.0	
	TP3-4	Tailings Pile 3	E.4-3.0	

Feature/Area or Media	Station No.	Location by Area	Coordinate	Comments
	TP3-4L	Tailings Pile 3	E.4-3.0	
	TP3-5A	Tailings Pile 3	E.5-3.0	
	TP3-6A	Tailings Pile 3	E.5-3.0	
	TP3-6BL	Tailings Pile 3	E.5-3.0	
	TP3-7	Tailings Pile 3	E.4-3.0	
	TP3-8	Tailings Pile 3	E.4-3.0	
	TP3-9	Tailings Pile 3	E.5-3.0	
	TP3-10	Tailings Pile 3	E.5-3.0	
	TP3-10L	Tailings Pile 3	E.5-3.0	
	PZ-4A	Tailings Pile 3	E.4-3.0	
	PZ-4B	Tailings Pile 3	E.4-3.0	
	PZ-4C	Tailings Pile 3	E.4-3.0	
	PZ-5A	Tailings Pile 3	E.4-3.0	
	PZ-5B	Tailings Pile 3	E.4-3.0	
	PZ-5C	Tailings Pile 3	E.4-3.0	
	PZ-6A	Tailings Pile 3	E.4-3.0	
	PZ-6B	Tailings Pile 3	E.4-3.0	
	PZ-6C	Tailings Pile 3	E.4-3.0	
	Lucerne Well	Lucerne	I-3	Lucerne Guard Station
Subsurface/Surface Soil				
	DMSS-1	Holden Village	E.2-2.9	Surface soil
	DMSS-2	Holden Village	E.2-2.9	Surface soil
	DMSS-3	Holden Village	E.1-2.9	Surface soil
	DMSS-4	Holden Village	E.1-2.9	Surface soil
	DMSS-5	Holden Village	E.1-2.9	Surface soil
	DMSS-6	Holden Village	E.2-2.9	Surface soil
	DMSS-7	Holden Village	E.1-2.9	Surface soil
	DMSS-8	Maintenance Yard	E.0-3.0	Surface soil
	DMSS-9	Maintenance Yard	E.0-3.0	Surface soil
	DMSS-10	Maintenance Yard	E.0-3.0	Surface soil
	DMSS-11	Tailings Pile 1	E.1-3.0	Surface soil
	DMSS-12	Tailings Pile 1	E.1-3.0	Surface soil
	DMSS-13	Tailings Pile 1	E.2-3.0	Surface soil
	DMSS-14	Tailings Pile 2	E.2-3.0	Surface soil
	DMSS-15	Tailings Pile 2	E.3-3.0	Surface soil
	DMSS-16	Tailings Pile 2	E.4-3.0	Surface soil
	DMSS-17	Tailings Pile 3	E.4-3.0	Surface soil
	DMSS-18	Tailings Pile 3	E.4-3.0	Surface soil
	DMSS-19	Tailings Pile 3	E.5-3.0	Surface soil
	DMSS-20	East of Tailings Pile 3	E.5-3.0	Windblown tailings
	DMSS-21	East of Tailings Pile 3	E.6-3.0	Windblown tailings
	DMSS-22	East of Tailings Pile 3	E.6-3.0	Windblown tailings
	DMSS-23	East of Tailings Pile 3	E.7-3.0	Windblown tailings
	DMSS-24	East of Tailings Pile 3	E.5-3.0	Windblown tailings
	DMSS-25	Baseball Field	D.7-2.9	Surface soil
	DMSS-26	Wilderness Area	D.7-2.9	Surface soil
	DMSS-27	Wilderness Area	D.7-2.9	Surface soil
	Lagoon 6"	Lagoon	E.0-2.9	Surface soil
	Lagoon 2'	Lagoon	E.0-2.9	Subsurface soil sample
	DMLG1	Lagoon	E.0-3.0	Subsurface soil sample
	DMLG2	Lagoon	E.0-2.9	Subsurface soil sample
	DMLG3	Lagoon	E.0-2.9	Subsurface soil sample

TABLE 5.0-1
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HOLDEN MINE RI/FS
DAMES & MOORE JOB NO. 17693-005-019

Feature/Area or Media	Station No.	Location by Area	Coordinate	Comments
	DMLG4	Lagoon	E.0-3.0	Subsurface soil sample
	DMLG5	Lagoon	E.0-2.9	Subsurface soil sample
	DMBG1	Approximately 1-mile West of Site	D-2	Background surface soil
	DMBG2	Holden Creek Drainage	D-2	Background surface soil
	DMBG3	Between Holden Creek & Hart Lake	C-2	Background surface soil
	DMBG4	East of Hart Lake	C-2	Background surface soil
	DMBG5	Between Hart Lake & Crown Point	B-2	Background surface soil
	DMBG6	Lyman Lakes	A-3	Background surface soil
	DMBG7	West of Hart Lake	B-2	Background surface soil
	DMBG8	West of Holden Creek	C-2	Background surface soil
	DMBG9	West of Big Creek	D-2	Background surface soil
	DMBG10	Copper Basin	E-3	Background surface soil
	DMBG11	Southwest of Site	D-3	Background surface soil
	DMBG12	South of Site	D-3	Background surface soil
	DMBG13	Near South Site Boundary	E-3	Background surface soil
	DMBG14	Near Holden Creek	D-2	Background surface soil
	DMBG15	Near Holden Creek	D-2	Background surface soil
	DMBG16	West of Site Boundary	D-2	Background surface soil
	DMBG17	Near Winston Home Sites	D-2	Background surface soil
	DMBG18	Northeast of Site	E-2	Background surface soil
	DMBG19	North of Holden Village	E-2	Background surface soil
	DMTP1-2	Tailings Pile 1	E.1-3.0	Test pit excavation
	DMTP1-3	Tailings Pile 1	E.1-3.0	Test pit excavation
	DMTP1-4	Tailings Pile 1	E.1-3.0	Test pit excavation
	DMTP1S-1	Tailings Pile 1	E.1-3.0	Test pit excavation
	DMTP2-1	Tailings Pile 2	E.2-3.0	Test pit excavation
	DMTP2-2	Tailings Pile 2	E.3-3.0	Test pit excavation
	DMTP2S-1	Tailings Pile 2	E.3-3.1	Test pit excavation
	DMTP3-1	Tailings Pile 3	E.4-3.0	Test pit excavation
	DMTP3-2	Tailings Pile 3	E.5-3.0	Test pit excavation
	DMTP3-3	Tailings Pile 3	E.5-3.0	Test pit excavation
	DMTP3-4	Tailings Pile 3	E.5-3.0	Test pit excavation
	DMTP3S-1	Tailings Pile 3	E.4-3.1	Test pit excavation
	DMTP3E-1	Immed. east of Tailings Pile 3	E.5-3.0	Test pit excavation
	DMTP3E-2	Immed. east of Tailings Pile 3	E.5-3.0	Test pit excavation
	DMTP3E-3	Immed. east of Tailings Pile 3	E.5-3.0	Test pit excavation
	DMTP3E-4	Immed. east of Tailings Pile 3	E.5-3.0	Test pit excavation
	DMTP3E-5	Immed. east of Tailings Pile 3	E.5-3.1	Test pit excavation
	DMTP3E-6	Immed. east of Tailings Pile 3	E.5-3.1	Test pit excavation
	DMTPW-1	Winston home sites	D.8-2.9	Test pit excavation
	DMTPW-2	Winston home sites	D.8-2.9	Test pit excavation
	DMTPW-3	Winston home sites	D.8-2.9	Test pit excavation
	DMTPW-4	Winston home sites	D.8-2.9	Test pit excavation
	DMTPW-5	Winston home sites	D.9-2.9	Test pit excavation
	DMTPW-6	Winston home sites	D.9-2.9	Test pit excavation
	DMTPW-7	Winston home sites	D.9-2.9	Test pit excavation
Surface Water				
	RC-1	Railroad Creek	D.7-2.9	
	RC-1 North Bank	Railroad Creek	D.7-2.9	
	RC-1 South Bank	Railroad Creek	D.7-2.9	
	RC-2	Railroad Creek	E.5-3.0	
	RC-2 South Bank	Railroad Creek	E.5-3.0	

TABLE 5.0-1
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HOLDEN MINE RI/FS
DAMES & MOORE JOB NO. 17693-005-019

Feature/Area or Media	Station No.	Location by Area	Coordinate	Comments
	RC-3	Railroad Creek	I-3	
	RC-4	Railroad Creek	E.0-2.9	
	RC-4 South Bank	Railroad Creek	E.0-2.9	
	RC-5	Railroad Creek	E-3	
	RC-5A	Railroad Creek	E-3	
	RC-6	Railroad Creek	D.7-2.9	
	RC-6 North Bank	Railroad Creek	D.7-2.9	
	RC-7	Railroad Creek	E.4-3.0	
	RC-8	Railroad Creek	I-3	
	RC-8 North Bank	Railroad Creek	I-3	
	RC-10	Near Seven Mile Creek	F-3	
	RC-11	Upstream of Holden Creek	D-2	
	CC-1	Copper Creek	E.2-3.1	
	CC-2	Copper Creek	E.2-3.0	
	CC-D	Copper Creek Diversion	E.1-3.0	
	CC-D1	Copper Creek Diversion	E.1-3.0	
	P-1	Mine Support & Waste Rock	E.0-3.0	Portal Drainage/1500 Main
	P-5	Mine Support & Waste Rock	D.9-2.9	Portal Drainage/RR Creek
	HC-1	Holden Creek	D-2	
	HC-2	Holden Creek	C-2	
	HC-3	Holden Creek	C-2	
	HC-4	Holden Creek	C-1	
	Big-1	Big Creek	D-2	
	Tenmile Creek	Tenmile Creek	E-2	
Seeps				
	A1	Honeymoon Heights	D.B-3.1	1100 Level Portal
	SP1	Tailings Pile 1	E.1-3.0	
	SP2	Tailings Pile 1	E.2-3.0	
	SP3	Tailings Pile 2	E.3-3.0	
	SP4	Tailings Pile.3	E.4-3.0	
	SP5	East of Tailings Pile 3	E.5-3.0	
	SP6	West Waste Rock Pile	E.0-3.0	
	SP7	West Waste Rock Pile	E.0-3.0	
	SP8	East Waste Rock Pile	E.1-3.0	
	SP9	Between P-5 & RC-4	D.9-2.9	
	SP10W	River Sauna	E.1-2.9	
	SP10E	River Sauna	E.1-2.9	
	SP11	West of Vehicle Bridge	E.0-2.9	
	SP12	West of P-5	D.9-3.0	
	SP13	South of Holden Village	E.1-2.9, 3.0; E.2-2.9, 3.0	"Black Seep"
	SP14	Honeymoon Heights	D.8-3.1	
	SP15W	North of West Waste Rock Pile	E.0-3.0	
	SP15E	North of West Waste Rock Pile	E.0-3.0	
	SP16	Lagoon	E.0-2.9	
	SP17	East of Tailings Pile 3	E.5-3.1	
	SP18	East of Tailings Pile 3	E.5-3.0	Bank sample
	SP19	Tailings Pile 1	E.1-3.0	
	SP20	Tailings Pile 1 (Near Copper Creek)		
	SP21	East of Tailings Pile 3	2.6-3.1	
	SP22	North of Maintenance Yard	E.0-3.0	
	SP23	Between RC-1 and P-5	D.8-3.0	
	SP23B	Between RC-1 and P-5	D.8-3.0	

TABLE 5.0-1
KEY OF SITE FEATURES & MEDIA SAMPLING/DATA COLLECTION LOCATIONS
HOLDEN MINE RI/FS
DAMES & MOORE JOB NO. 17693-005-019

Feature/Area or Media	Station No.	Location by Area	Coordinate	Comments
	SP24	West of RC-4	E.0-2.9	
	SP25	Between Vehicle Bridge & RC-4	E.0-2.9	
	SP26	Between RC-1 and RC-6	D.7-2.9	
	SP-27	Near Big Creek	D-2	
	CC-D1	Copper Creek Diversion	E.1-2.9	
Sediment - Lake Chelan				
	1-1	Lucerne	N/A	
	1-2	Lucerne	N/A	
	2-1	Lucerne	N/A	
	2-2	Lucerne	N/A	
	3-1	Lucerne	N/A	
	3-1A	Lucerne	N/A	
	3-1B	Lucerne	N/A	
	3-1C	Lucerne	N/A	
	3-2	Lucerne	N/A	
	3.5-1	Lucerne	N/A	
	3.5-2	Lucerne	N/A	
	5-1	Lucerne	N/A	
	5-2	Lucerne	N/A	
	1	Stehekin	N/A	
	2	Stehekin	N/A	
	3A	Stehekin	N/A	
	3B	Stehekin	N/A	
	3C	Stehekin	N/A	
	4	Stehekin	N/A	
USGS Select Samples				
	344	Ten Mile Creek	E.6-2.9	
	345	Railroad Creek near RC-2	E.5-3.0	
	346	Copper Creek Diversion	E.1-3.0	
	347	Railroad Creek at Vehicle Bridge	E.0-2.9	
	350	East of Tailings Pile 3	E.5-3.0	
	351	Nine Mile Creek	F-3	
	352	Railroad Creek near Seven Mile Creek	F-3	
	353	Seven Mile Creek	F-3	
	354	Railroad Creek at Lucerene	N/A	
	355	Holden Creek	D-2	
	356	Railroad Creek West of Site	D-2	
	MP-7	Railroad Creek at Mile Post 7	G-3	
USBM Select Samples				
	BKG 1/2	Downstream of Vehicle Bridge	E.0-2.9	
	DG-1	Downstream of Tailings Pile 3	E.6-3.0	
	TP1-2	Adjacent to Tailings Pile1	E.1-3.0	
	TP2-1	Downstream of Copper Creek	E.2-3.0	
	TP2-2	Adjacent to Tailings Pile 2	E.3-3.0	
	TP3-1	Adjacent to Tailings Pile 3	E.4-3.0	
	RC-2	At Railroad Creek RC-2 Station	E.5-3.0	

TABLE 5.1-1
PRELIMINARY CHEMICAL SPECIFIC ARARs (APPLICABLE AND REGULATORY)
HOLDEN MINE RI/FS
DAMES & MOORE JOB NO. 17693-005-019

Parameters	Soil				Surface Water					Groundwater			Sediment		
	Area Background [1]	Yakima Basin Background Values [2]	MTCA Method A [3]	MTCA Method B [4]	Area Background [5] (μg/L)		Surface Water Quality Criteria [6] (μg/L)		MTCA Method B [4]	MTCA [3] Method A	MTCA [4] Method B	Federal MCLs [7]	Reference Concentrations [9]	FSQV [11]	Screening Levels [12] ER-M / ER-L
	(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)	Total	Dissolved	Acute	Chronic	(μg/L)	(μg/L)	(μg/L)	(μg/L)	(mg/kg)	(mg/kg)	(mg/kg)
Metals															
Aluminum	20,900	33,400	NE	NE	144	37.4	NE	NE	NE	NE	NE	50 to 200 [8]	21,193	NE	NA
Arsenic	11.6	5	20	1.67	1.44	0.9	360	190	0.0982	5	0.0583	50	20.6	57	70/ 8.2
Barium	310	NE	NE	5,600	6.24	17.5	NE	NE	NE	NE	NE	2,000	NE	NE	NA
Beryllium	0.2	2	NE	0.23	< 0.04	< 0.04	130 [13]	5.3 [13]	0.0793	NE	0.0203	4	NE	NE	NA
Cadmium	5.4	1	2	80	0.10	0.07	0.82	0.37	20.3	5	8	5	0.5 [10]	5.1	9.6/ 1.2
Calcium	12,100	NE	NE	NE	6,814	6,703	NE	NE	NE	NE	NE	NE	NE	NE	NA
Chromium	37.2	38	100	80,000 (Cr^{+3})	0.46	< 0.2	180	57	162,000 (Cr^{+3})	50	16,000 (Cr^{+3})	100	NE	260	NA
Copper	57.4	27	NE	2,960	1.83	1.06	4.6	3.5	2,660	NE	592	1,300	48 [10]	390	270/ 34
Iron	24,100	51,500	NE	NE	177	40	1000 [13]	1000 [13]	NE	NE	NE	300 [8]	32,297	NE	40,000/ 20,000
Lead	20.6	11	250	NE	0.3	0.54	14	0.54	NE	5	NE	15	15.2	450	218/ 46.7
Magnesium	9,200	NE	NE	NE	647	626	NE	NE	NE	NE	NE	NE	NE	NE	NA
Manganese	1,430	1,100	NE	3,730	5.06	2.42	NE	NE	NE	NE	747	50 [8]	420	NE	1,100/ 460
Mercury	NE	0.05	1	24	0.00066	0.05	2.4	0.012	NE	2	4.8	2	NE	0.4	0.71/ 0.15
Molybdenum	1.2	NE	NE	400	0.79	0.78	NE	NE	NE	NE	80	NE	NE	NE	NA
Nickel	22.7	46	NE	1,600	0.4	0.39	440	49	1,100	NE	320	100	NE	NE	51.6/ 20.9
Potassium	1,260	NE	NE	NE	672	660	NE	NE	NE	NE	NE	NE	NE	NE	NA
Selenium	NE	NE	NE	400	< 0.2	< 0.2	20	5	NE	NE	80	50	NE	NE	NA
Silver	0.5	NE	NE	400	0.1	< 0.04	0.32	NE	25,900	NE	80	100 [8]	NE	6.1	3.7/ 1.0
Sodium	827	NE	NE	NE	1,034	1,078	NE	NE	NE	NE	NE	NE	NE	NE	NA
Thallium	0.4	NE	NE	5.6	< 0.04	< 0.04	NE	NE	1.56	NE	1.12	2	NE	NE	NA
Uranium	1.0	NE	NE	240	0.06	0.172	NE	NE	NE	NE	48	20	NE	NE	NA
Zinc	253	79	NE	24,000	5	7.81	35	32	16,500	NE	4,800	5000 [8]	113 [10]	410	410/ 150
Polychlorinated Biphenyls (PCBs)*	NE	NE	1	0.13	NE	NE	NE	0.014 **	0.000027	0.1	0.0114	0.5	NE	NE	NA
Total Petroleum Hydrocarbons															
Gasoline Range	NE	NE	100	NE	NE	NE	NE	NE	NE	1,000	NE	NE	NE	NE	NA
Diesel Range	NE	NE	200	NE	NE	NE	NE	NE	NE	1,000	NE	NE	NE	NE	NA
Heavier Than Diesel Range	NE	NE	200	NE	NE	NE	NE	NE	NE	1,000	NE	NE	NE	NE	NA

Notes:
* PCBs - Polychlorinated Biphenyls as total (seven arochlors)
**Individual Arochlors
NE - Not Established
NA - Not Available
1 - Area Background values based on Statistical Analysis per MTCA using data collected from Railroad Creek drainage in 1998.
2 - Yakima Basin 90th Percentile Values, Washington Department of Ecology "Natural Background Soil Metals Concentrations in Washington State", October 1994
3 - Model Toxics Control Act (MTCA) Method A, Toxics Cleanup Program, amended 1/96 (Chapter 173-340 WAC)
4 - Model Toxics Control Act Cleanup Levels and Risk Calculation (CLARCII), 2/96, Method B
5 - Area background values based on Statistical Analysis per MTCA using data collected from the Railroad Creek and Stehekin watersheds, historically and during the RI.
Values for dissolved chromium, selenium, silver, and thallium and total selenium and thallium are provided as < values as these metals were not detected above this level. The value for total uranium is based on the maximum concentration.
6 - Based on Toxics Criteria for Those States Not Complying with Clean Water Act Section 303(c)(2)(B), at 40 CFR Part 131.36 (b)(1)
Cadmium, chromium, copper, lead, nickel, silver (acute only), and zinc are hardness corrected for actual hardness values per sample. For purposes of this table, the values are based on a 25 ppm hardness value.
7 - MCLs (Maximum Contaminant Levels), Drinking Water Regulations and Health Advisories, Office of Water, US EPA, 10/96
8 - Secondary MCLs (Maximum Contaminant Levels), Drinking Water Regulations and Health Advisories, Office of Water, US EPA, 10/96
9 - Reference concentrations based on Statistical Analysis per MTCA using data collected from the Stehekin area during 1998.
10 - Value shown is maximum concentration as the 90th percentile was not calculable.
11 - Washington Department of Ecology, 1997 Creation and Analysis of Freshwater Sediment Quality Values in Washington State: Freshwater Sediment Quality Value based on SMS values.
12 - Long et al. (1995)with the exceptions of iron and manganese which are from Persaud et al. (1993)
13 - Values are referenced in WAC 173-201A as part of the EPA "Quality Criteria for Water 1986" publication EPA 44015-86-001, May 1, 1986.
ER-M Effects ratio- median (occasionally causes adverse effects).
ER-M Effects ratio- low (rarely causes adverse effects).

TABLE 5.2-1
SUMMARY OF RI SOIL ANALYTICAL RESULTS
HOLDEN MINE RI/FS
DAMES & MOORE JOB NO. 17693-005-019

Parameters	Sampling Location	MTCA Method A[1]	MTCA Method B[2]	Area Background[3]	Wilderness Boundary		Holden Village								Baseball Field
	Station No.				DMSS-26	DMSS-27	DMSS-1	DMSS-2	DMSS-3	DMSS-4	DMSS-5	DMSS-6	DMSS-6X*	DMSS-7	DMSS-25
	Sampling Date				10/5/97	10/5/97	9/20/97	9/20/97	9/20/97	9/20/97	9/20/97	9/20/97	9/20/97	9/20/97	10/5/97
Total Metals (mg/kg)															
Aluminum		-	-	20,900	15,200	17,500	19,100	16,800	23,500	16,200	17,900	25,900	26,300	15,500	20,300
Arsenic		*20*	*1.67*	11.6	10.7	11.4	2.1J	3.3J	1.6J	5.1J	1.3J	3.5J	3.7J	2.3J	10.8
Barium		-	*5,600*	310	93.1	72.5	102	380	156	333	136	104	104	116	101
Beryllium		-	*0.23*	0.2	0.1	0.2	0.3	0.2	0.3	0.2	0.2	0.3	0.3	0.2	0.2
Cadmium		*2*	*80*	5.4	3.1	0.9	0.8	1.5	0.9	2.1	1.4	1.6	1.2	0.7	1.3
Calcium		-	-	12,100	5,160	6,440	4,480J	5,320J	6,070J	12,400J	4,020J	8,310J	8,790J	4,360J	5,770
Chromium		*100*	*80,000 (Cr^{+3})*	37.2	20.8	27.8	39.4	23.8	48.3	28.7	29.1	26.3	26.5	24.0	29.4
Copper		-	*2,960*	57.4	147	81.4	83.0	523	86.2	155	412	216	245	112	63.0
Iron		-	-	24,100	24,200	26,500	24,000	29,600	28,200	26,300	26,100	25,200	24,600	22,600	26,600
Lead		*250*	-	20.6	37	16	21	103	12	61	34	10	11	45	15
Magnesium		-	-	9,200	7,470	8,980	8,450	7,200	10,800	5,860	8,040	8,980	9,230	6,750	7,640
Manganese		-	*3,730*	1,430	365	455	435	315	542	613	637	427	419	317	537
Mercury		*1*	*24*	*0.05*[4]											
Molybdenum		-	*400*	1.2	1.5	2.4	0.9	4.5	0.9	5.0	2.4	0.6U	0.6U	1.9	1.0
Nickel		-	*1,600*	22.7	12	17	22	13	27	16	17	18	18	14	18
Potassium		-	-	1,260	1,290	940	1,300	1,740	1,430	2,110	1,660	1,710	1,590	1,360	1,270
Selenium		-	*400*	NE											
Silver		-	*400*	0.5	0.5	0.6	0.4U	1.2	0.4U	2.0	0.4	0.3U	0.3U	0.3	0.5
Sodium		-	-	827	647	573	612	728	531	777	600	1,080	1,090	533	605
Thallium		-	*5.6*	0.4	0.6U	0.6U	0.1U	0.6U	0.1U	0.8U	0.1U	0.1U	0.1U	0.6U	0.6 U
Uranium		-	*240*	1.0	2U	4	2U	2U	3U	3U	2U	2U	2U	2U	2U
Zinc		-	*24,000*	253	303	121	132	284	112	356	137	201	161	145	129
Polychlorinated Biphenyls (µg/kg)															
Aroclor 1016		-	*5,600*	*NE*											
Aroclor 1221		-	-	*NE*											
Aroclor 1232		-	-	*NE*											
Aroclor 1242		-	-	*NE*											
Aroclor 1248		-	-	*NE*											
Aroclor 1254		-	*1,600*	*NE*											
Aroclor 1260		-	-	*NE*											
Total PCBs		*1,000*	*130*	*NE*											
Total Petroleum Hydrocarbons (mg/kg)															
Gasoline		*100*	-	*NE*											
Diesel		*200*	-	*NE*											
Motor Oil		*200*	-	*NE*											

Notes:
J - Estimated value.
NE - Not Established
U - Parameter was analyzed for, but not detected above the reporting limit shown.
UJ - Parameter was analyzed for but not detected. Detection limit is an estimated value.
X - Pattern profile does not match typical standard profile. In the case of PCBs, pattern was more indicative of Arochlor 1262.
Y - Pattern profile is more indicative of motor oil range hydrocarbons.
* 'X' after the sample ID is an indication of field duplicate
Grey Shading indicates the concentration of analyte was not established, therefore not reported nor analyzed.
1 - Model Toxics Control Act (MTCA) Method A, Toxics Cleanup Program, amended 1/96 (Chapter 173-340 WAC)
2 - Model Toxics Control Act Cleanup Levels and Risk Calculation (CLARC II), 2/96, Method B
3 - Area Background values based on Statistical Analysis per MTCA using data collected from Railroad Creek drainage in 1998.
4 - Mercury value is based on Yakima Basin 90th percentile values, Washington Department of Ecology "*Natural Background Soil Metals Concentrations in Washington State*" October 1994

TABLE 5.2-1
SUMMARY OF RI SOIL ANALYTICAL RESULTS
HOLDEN MINE RI/FS
DAMES & MOORE JOB NO. 17693-005-019

Parameters	Sampling Location	MTCA Method A[1]	MTCA Method B[2]	Area Background[3]	Maintenance Yard							
	Station No.				DMSS-8	DMSS-8 2'	DMSS-9	DMSS-9 2'	DMSS-10	DMSS-10X*	DMSS-10 2'	Storage
	Sampling Date				10/3/97	10/3/97	10/3/97	10/3/97	10/3/97	10/3/97	10/3/97	10/3/97
Total Metals (mg/kg)												
Aluminum		-	-	20,900	15,000	19,700	17,200	17,100	17,500	17,100	23,900	14,700
Arsenic		*20*	*1.67*	11.6	2.7	1.7	4.3	2.6	3.0	2.8	4.1	60
Barium		-	*5,600*	310	321	34.1	717	58.2	161	133	163	192
Beryllium		-	*0.23*	0.2	0.1	0.2	0.2U	0.1	0.1	0.1	0.2	0.2
Cadmium		*2*	*80*	5.4	11.6	5.0	21.6	0.9	3.7	4.3	1.3	9.4
Calcium		-	-	12,100	5,790	4,460	5,130	6,230	5,070	4,370	6,730	6,830
Chromium		*100*	*80,000 (Cr^{+3})*	37.2	22.5	19.1	33	16.6	21.6	22	23.4	18.5
Copper		-	*2,960*	57.4	1,780	514	3,160	260	748	753	306	1,520
Iron		-	-	24,100	35,000	15,100	60,300	14,500	22,400	20,800	22,300	28,200
Lead		*250*	-	23.6	1,070	22	392	7	129	125	31	217
Magnesium		-	-	9,200	8,490	4,680	11,400	5,240	5,670	5,590	7,750	5,400
Manganese		-	*3,730*	1,430	334	150	426	223	203	186	267	230
Mercury		*1*	*24*	0.05[4]	▨	▨	▨	▨	▨	▨	▨	▨
Molybdenum		-	*400*	1.2	7.3	0.6U	16	0.6U	2.4	2.1	0.6U	4.4
Nickel		-	*1,600*	22.7	11	22	23	14	11	12	14	20
Potassium		-	-	1,260	3,460	640	4,600	950	1,290	1,180	1,330	1,750
Selenium		-	*400*	NE	▨	▨	▨	▨	▨	▨	▨	▨
Silver		-	*400*	0.5	2.4	0.3U	5.0	0.3U	1.1	0.8	0.4	2.9
Sodium		-	-	827	590	766	620	872	794	612	864	657
Thallium		-	*5.6*	0.4	2U	2U	2U	0.6U	2U	2U	2U	2U
Uranium		-	*240*	1.0	2U	2U	2U	2U	2U	2U	2U	2U
Zinc		-	*24,000*	253	1,860	576	3,240	147	550	584	170	1,440
Polychlorinated Biphenyls (µg/kg)												
Aroclor 1016		-	*5,600*	*NE*	36U	36U	39U	37U	38U	38U	41U	39U
Aroclor 1221		-	-	*NE*	72U	72U	77U	73U	77U	75U	82U	78U
Aroclor 1232		-	-	*NE*	36U	36U	39U	37U	38U	38U	41U	39U
Aroclor 1242		-	-	*NE*	36U	36U	39U	37U	38U	38U	41U	39U
Aroclor 1248		-	-	*NE*	36U	36U	39U	37U	38U	38U	41U	39U
Aroclor 1254		-	*1,600*	*NE*	36U	36U	39U	37U	38U	38U	41U	39U
Aroclor 1260		-	-	*NE*	36U	36U	17JX	37U	46X	36JX	41U	18JX
Total PCBs		*1,000*	*130*	*NE*								
Total Petroleum Hydrocarbons (mg/kg)												
Gasoline		*100*	-	*NE*	5.9U	140X	29X	5.9U	1,200X	1,700	200X	▨
Diesel		*200*	-	*NE*	520X	9,300J	3,100XJ	5.5U	12,000J	8,400J	480	390X
Motor Oil		*200*	-	*NE*	870X	1,100U	3,400XJ	11U	9,800J	8,900J	950	1,000X

Notes:

J - Estimated value.

NE - Not Established

U - Parameter was analyzed for, but not detected above the reporting limit shown.

UJ - Parameter was analyzed for but not detected. Detection limit is an estimated value.

X - Pattern profile does not match typical standard profile. In the case of PCBs, pattern was more indicative of Arochlor 1262.

Y - Pattern profile is more indicative of motor oil range hydrocarbons.

* 'X' after the sample ID is an indication of field duplicate

▨ Grey Shading indicates the concentration of analyte was not established, therefore not reported nor analyzed.

1 - Model Toxics Control Act (MTCA) Method A, Toxics Cleanup Program, amended 1/96 (Chapter 173-340 WAC)

2 - Model Toxics Control Act Cleanup Levels and Risk Calculation (CLARC II), 2/96, Method B

3 - Area Background values based on Statistical Analysis per MTCA using data collected from Railroad Creek drainage in 1998.

4 - Mercury value is based on Yakima Basin 90th percentile values, Washington Department of Ecology "Natural Background Soil Metals Concentrations in Washington State" October 1994

TABLE 5.2-1
SUMMARY OF RI SOIL ANALYTICAL RESULTS
HOLDEN MINE RI/FS
DAMES & MOORE JOB NO. 17693-005-019

Parameters	Sampling Location Station No.	MTCA Method A[1]	MTCA Method B[2]	Area Background[3]	Lagoon 6"	Lagoon 2'	DMLG-1-2'	DMLG-1-4'	DMLG-2-4'	DMLG-2-7 1/2'	DMLG-3-2'	DMLG-3-4'	DMLG-4-2'	DMLG-4-4'	DMLG-5-2'	DMLG-5-4'
	Sampling Date				10/3/97	10/3/97	10/15/98	10/15/98	10/14/98	10/15/98	10/15/98	10/15/98	10/14/98	10/14/98	10/14/98	10/15/98
Total Metals (mg/kg)																
Aluminum		-	-	20,900	33,500	31,300	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨
Arsenic		*20*	*1.67*	11.6	3.7	5.0	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨
Barium		-	*5,600*	310	343	287	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨
Beryllium		-	*0.23*	0.2	0.3	1U	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨
Cadmium		*2*	*80*	5.4	1.9	184	2.5	4.3	175	28	2.3	0.7	150	135	173	25
Calcium		-	-	12,100	5,150	6,120	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨
Chromium		*100*	*80,000 (Cr^{+3})*	37.2	20.6	21	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨
Copper		-	*2,960*	57.4	1,190	24,100	1,390	1,120	22,500	3,610	1,020	294	17,300	22,100	23,900	4,000
Iron		-	-	24,100	36,200	101,000	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨
Lead		*250*	-	20.6	129	620	132	73	560	110	153	52	730	800	580	190
Magnesium		-	-	9,200	6,760	18,100	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨
Manganese		-	*3,730*	1,430	255	625	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨
Mercury		*1*	*24*	0.05[4]	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨
Molybdenum		-	*400*	1.2	6.6	74	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨
Nickel		-	*1,600*	22.7	13	10U	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨
Potassium		-	-	1,260	1,840	4,370	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨
Selenium		-	*400*	NE	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨
Silver		-	*400*	0.5	2.0	27	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨
Sodium		-	-	827	931	900	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨
Thallium		-	*5.6*	0.4	3U	3	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨
Uranium		-	*240*	1.0	7	6	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨
Zinc		-	*24,000*	253	387	23,700	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨
Polychlorinated Biphenyls (μg/kg)																
Aroclor 1016		-	*5,600*	*NE*	51U	46U	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨
Aroclor 1221		-	-	*NE*	100U	92U	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨
Aroclor 1232		-	-	*NE*	51U	46U	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨
Aroclor 1242		-	-	*NE*	51U	46U	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨
Aroclor 1248		-	-	*NE*	51U	46U	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨
Aroclor 1254		-	*1,600*	*NE*	51U	46U	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨
Aroclor 1260		-	-	*NE*	51U	46U	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨
Total PCBs		*1,000*	*130*	*NE*												
Total Petroleum Hydrocarbons (mg/kg)																
Gasoline		*100*	-	*NE*	11.0U	9.0U	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨
Diesel		*200*	-	*NE*	98X	230X	2,200 X	140 JY	520 Y	150 JY	520 JY	86 JY	540 Y	1,200 Y	280 Y	170 JY
Motor Oil		*200*	-	*NE*	310	440	1,900 X	170 J	960	170 J	800 J	120 J	850	1,700	500	330 J

Notes:

J - Estimated value.
NE - Not Established
U - Parameter was analyzed for, but not detected above the reporting limit shown.
UJ - Parameter was analyzed for but not detected. Detection limit is an estimated value.
X - Pattern profile does not match typical standard profile. In the case of PCBs, pattern was more indicative of Arochlor 1262.
Y - Pattern profile is more indicative of motor oil range hydrocarbons.
* 'X' after the sample ID is an indication of field duplicate
▨ Grey Shading indicates the concentration of analyte was not established, therefore not reported nor analyzed.
1 - Model Toxics Control Act (MTCA) Method A, Toxics Cleanup Program, amended 1/96 (Chapter 173-340 WAC)
2 - *Model Toxics Control Act Cleanup Levels and Risk Calculation (CLARC II), 2/96, Method B*
3 - Area Background values based on Statistical Analysis per MTCA using data collected from Railroad Creek drainage in 1998.
4 - Mercury value is based on Yakima Basin 90th percentile values, Washington Department of Ecology "Natural Background Soil Metals Concentrations in Washington State" October 1994

TABLE 5.2-2
SUMMARY OF 1998 BACKGROUND SOIL DATA AND AREA BACKGROUND STATISTICS
HOLDEN MINE RI/FS
DAMES & MOORE JOB NO. 17693-005-019

Sample ID	DMBG-1	DMBG-2	DMBG-3	DMBG-4	DMBG-5	DMBG-6	DMBG-7	DMBG-8	DMBG-9	DMBG-10	DMBG-10X	DMBG-11	DMBG-12	DMBG-13	DMBG-14	DMBG-15	DMBG-16	DMBG-17	DMBG-18	DMBG-19	Statistical Calculations [1]							
Date Collected	10/15/98	10/15/98	10/13/98	10/13/98	10/13/98	10/13/98	10/13/98	10/13/98	10/15/98	10/12/98	10/12/98	10/17/98	10/17/98	10/17/98	10/17/98	10/17/98	10/17/98	10/17/98	10/17/98	10/17/98	Minimum Concentration	Maximum Concentration	Approximate Distribution	Distribution Mean	Median	Standard Deviation	90th %
Metals, Total (mg/kg)																											
Aluminum	16,800	18,800	7,010	11,000	14,900	3,430	13,700	11,300	22,100	11,000	10,000	21,700	15,900	16,800	12,300	21,700	11,200	16,200	9,310	17,100	3,430	22,100	Normal	14,113	14,300	5,006	20,870
Arsenic	0.6	3.7	3.3	5.2	12.3	0.5	98	1.2	4	0.7	0.8	0.8	0.9	1.2	1.8	2	0.8	1.2	1.3	0.9	0.5	98	Nonparametric	7.06	1.2	21.6	11.59
Barium	48.4	120	194	205	29.5	26.1	94.7	117	76.3	68.8	76	31.6	31.1	40.2	85.8	127	250	526	237	350	26.1	526	Lognormal	140	90.25	127.3	310
Beryllium	0.2	0.2	0.1	0.1	0.2	0.1U	0.2	0.1U	0.2	0.2	0.2	0.2	0.2	0.2	0.1	0.3	0.2	0.2	0.2	0.1	0.1	0.3	Nonparametric	0.18	0.2	0.05	0.2
Cadmium	0.8	0.8	4.1	1.8	0.3	0.3U	2.7	0.8	0.5	0.2U	0.2	0.2U	0.2U	0.2U	0.6	3.8	17.4	3.6	0.5	0.7	0.2	17.4	Lognormal	2.45	0.8	4.32	5.41
Calcium	2,380	2,380	7,460	10,400	2,630	894	5,480	10,900	3,880	2,190	2,330	3,330	2,500	2,410	3,550	11,600	11,000	12,200	12,300	10,500	894	12,300	Nonparametric	6,016	3,715	4,198	12,140
Chromium	7.5 J	18.9 J	5.6 J	9.9 J	5 J	4.2 J	5 J	9.3 J	16 J	6.2 J	5.8 J	4.7	6.5	7.6	8.1	12.5	8.4	39.2	8	41.5	4.2	41.5	Nonparametric	11.5	7.8	10.56	37.17
Copper	13.3	36.2	6.2	27.5	8.8	7.7	39.3	21.7	42.2	11	11.1	5.2	7.2	6.8	17	59.5	24.8	65	30.2	62.6	5.2	65	Lognormal	26.07	19.35	19.76	57.45
Iron	11,900	36,300	8,230	11,600	12,900	5,510	15,900	15,400	24,500	10,400	10,500	10,100	10,500	10,600	12,400	17,800	10,500	22,300	9,290	23,900	5,510	36,300	Lognormal	14,504	11,750	7,280	24,098
Lead	4	10	21	13	17	4	56	6	6	3	4	3	3	4	5	10	7	7	6	7	3	56	Nonparametric	9.8	6	11.89	20.6
Magnesium	1,740	7,640	998	4,780	1,190	197	3,070	5,760	7,580	1,190	1,240	528	1,290	628	2,580	5,440	2,220	8,530	2,160	9,750	197	9,750	Lognormal	3,833	2,190	3,000	9,199
Manganese	309	433	1,340	448	244	343	577	279	297	383	344	71.3 J	79.4 J	97.1 J	436 J	534 J	1,160 J	2,970 J	702 J	1,030 J	71.3	2,970	Lognormal	619.6	408.0	654.7	1,425
Molybdenum	0.5U	0.7	0.7	0.7U	0.7	0.7U	2.1	0.9	0.5U	0.5U	0.5U	0.5U	0.6U	0.6U	0.5U	0.9	0.9	1.2	0.8	0.5U	0.7	2.1	Nonparametric	0.99	0.9	0.45	1.17
Nickel	7	9	6	8	4	4	5	6	12	5	5	5	7	6	6	20	12	23	5	23	4	23	Nonparametric	8.9	6	6.09	22.7
Potassium	600	770	430	560	280	310	1,150	850	560	480	480	220	360	270	500	1,010	1,160	1,080	610	2,020	220	2;020	Lognormal	687.5	560	432	1,263
Silver	0.3U	0.4	0.4U	0.4U	0.4U	0.5	0.5	0.4U	0.3	0.3U	0.3U	0.3U	0.3U	0.3U	0.3U	0.3U	0.4U	0.3U	0.3U	0.3U	0.3	0.5	Nonparametric	0.43	0.45	0.1	0.49
Sodium	595	306	641	428	607	336	622	235	563	517	528	903	746	724	725	605	557	439	510	499	235	903	Lognormal	558	560	159.5	827
Thallium	0.1U	0.1	0.1U	0.1U	0.1U	0.1U	0.2U	0.1U	0.1U	0.1U	0.1U	0.5U	0.6U	0.6	0.5U	0.6U	0.7U	0.5U	0.5U	0.6U	0.1	0.6	Nonparametric	0.35	0.35	0.35	0.35
Uranium	1.3	0.2U	0.3U	0.3U	1	0.3U	2	0.3U	0.2U	0.2U	0.2U	0.4	0.3	0.3	0.2U	0.5	0.3	0.2	0.3	0.6	0.2	2	Lognormal	0.65	0.4	0.56	1.04
Zinc	110	75.8	139	90.9	38.5	19.5	134	42.2	105	32.5	34.8	12.5	19.7	22.3	93.4	518	298	215	57.3	94.1	12.5	518	Lognormal	110	83.4	120.1	253.4

Notes:

U - Parameter was analyzed for, but not detected above the reporting limit shown.

J - Estimated Value

"X" after sample ID is an indication of field duplicate

[1] Statistical analyses including approximating sample distributions, means, standard deviations, medians and background 90th percentile were calculated using an Excel version 5.0 macro designed by the Washington Department of Ecology and their guidance found in *Statistical Guidance for Ecology Site Managers*, Toxics Cleanup Program (August, 1992).

TABLE 5.2-3
SUMMARY OF HISTORICAL SOIL ANALYTICAL DATA
HOLDEN MINE RI/FS
DAMES & MOORE JOB NO. 17693-005-019

Parameters	Sampling Location	MTCA Method A[1]	MTCA Method B[2]	Area Background [3]	USFS GS [5]	HOLDEN VILLAGE [5]						
	Station No.				HW-1A	HV-1A	HV-2A	HV-3A	HV-4A	HV-5A	HV-6A	HV-7
	Sampling Date				6/1/94	6/1/94	6/1/94	6/1/94	6/1/94	6/1/94	6/1/94	11/94
Total Metals (mg/kg)												
Aluminum		-	-	20,900	20,100	21,400	18,400	21,600	22,300	15,300	25,100	10,100
Arsenic		20	1.67	11.6	25.2	3	3.1	2	4.5	1.3	1.1	1.7
Barium		-	5,600	310	80.4	124	126	161	102	171	127	297
Beryllium		-	0.23	0.2	0.22	0.19	0.16	0.23	0.32	0.22	0.29	0.11
Cadmium		2	80	5.4	2.1	2	1.1	1.2	0.97	0.77	1.5	1.6
Calcium		-	-	12,100	4,260	6,090	5,090	5,370	6,670	3,380	4,210	2,370
Chromium		100	80,000 (Cr^{+3})	37.2	21.7	14.5	10.7	57.7	30.5	21.3	36.6	4.3
Copper		-	2,960	57.4	61.8	210	150	53.4	33.6	49	47.5	229
Iron		-	-	24,100	27,600	23,600	24,100	26,200	26,400	17,400	28,400	19,800
Lead		250	-	20.6	84.1	23	21	18	14	23	5	99
Magnesium		-	-	9,200	8,930	7,950	6,610	10,200	8,620	5,770	10,500	4,950
Manganese		-	3,730	1,430	580	363	301	562	463	1,270	621	205
Mercury		1	24	0.05 [4]	0.02	0.03	0.06	0.02	0.03	▨	0.02	0.08
Molybdenum		-	400	1.2	▨	▨	▨	▨	▨	▨	▨	▨
Nickel		-	1,600	22.7	18.2	15	11	27	26	17	27	6
Potassium		-	-	1,260	997	1,830	1,380	1,060	813	748	1,050	1,660
Selenium		-	400	NE	0.94 U	0.99 U	1.0 U	1.0 U	1 U	1.1 U	0.95 U	1.1 U
Silver		-	400	0.5	0.55 U	0.69 U	0.58 U	0.76 U	0.79 U	0.68	0.58 U	0.56 U
Sodium		-	-	827	448	652	711	522	841	471	450	303
Thallium		-	5.6	0.4	0.11	0.13	0.32	0.10 U	0.10	0.11 U	0.10	0.35
Uranium		-	240	1	▨	▨	▨	▨	▨	▨	▨	▨
Zinc		-	24,000	253	125	204	171	169	106	456	90	184

Notes:
U - Parameter was analyzed for, but not detected above the reporting limit shown.
▨ Grey Shading ▨ indicates the concentration of analyte was not established, therefore not reported nor analyzed.
1 - Model Toxics Control Act (MTCA) Method A, Toxics Cleanup Program, amended 1/96 (Chapter 173-340 WAC)
2 - Model Toxics Control Act Cleanup Levels and Risk Calculation (CLARC II), 2/96, Method B
3 - Area Background values based on statistical analysis per MTCA using data collected from Railroad Creek drainage in 1998.
4 - Yakima Basin 90th percentile values, Washington Department of Ecology "Natural Background Soil Metals Concentrations in Washington State", October 1994
5 - Lambeth, R.H. 1995. Transmittal of laboratory data from samples collected at Holden Mine site by the US Bureau of Mines. (Data collected in 1994).

TABLE 5.2-4
SUMMARY OF HISTORICAL TAILINGS ANALYTICAL DATA
HOLDEN MINE RI/FS
DAMES & MOORE JOB NO. 17693-005-019

Parameters	Sampling Location Station No. Sampling Date	MTCA Method A[1]	MTCA Method B[2]	Area Background [3]	Surface Samples from Tailings Pile (TP-1)					
					HT1-2A	HT1-2B	503T	504T	505TA	505TB
					6/1/94[5]	6/1/94[5]	7/95[6]	7/95[5]	7/95[6]	7/95[6]
Total Metals (mg/kg)										
Aluminum		-	-	*20,900*	5,280	5,410	39,000	32,000	37,000	37,000
Arsenic		*20*	*1.67*	*11.6*	5.5	5.8	3.2	6.5	3.1	2.6
Barium		-	*5,600*	*310*	361	450	860	790	780	850
Beryllium		-	*0.23*	*0.2*	0.09	0.08	1 U	1 U	1 U	1 U
Cadmium		*2*	*80*	*5.4*	0.95	1.3	0.14	0.08U	0.08U	0.08U
Calcium		-	-	*12,100*	1,910	1,940	12,000	11,000	11,000	11,000
Chromium		*100*	*80,000* (Cr^{+3})	*37.2*	19.6U	13.6U	13	10	12	10
Copper		-	*2,960*	*57.4*	423	436	260	230	330	240
Iron		-	-	*24,100*	54,500	59,800	62,000	74,000	73,000	59,000
Lead		*250*	-	*20.6*	112	110	97	140	100	100
Magnesium		-	-	*9,200*	3,170	3,220	9,800	7,100	8,400	7,600
Manganese		-	*3,730*	*1,430*	113	117	470	420	460	420
Mercury		*1*	*24*	*0.05*[4]	0.35	0.33	▨	▨	▨	▨
Molybdenum		-	*400*	*1.2*	▨	▨	26	25	30	25
Nickel		-	*1,600*	*22.7*	1.3	1.3	▨	▨	▨	▨
Potassium		-	-	*1,260*	2,180	2,360	8,800	7,300	8,100	8,000
Selenium		-	*400*	*NE*	28	19.8	▨	▨	▨	▨
Silver		-	*400*	*0.5*	1.6	2	2	3.4	2.8	2.3
Sodium		-	-	*827*	750	820	11,000	10,000	11,000	11,000
Thallium		-	*5.6*	*0.4*	1.2	1.1	▨	▨	▨	▨
Uranium		-	*240*	*1*	▨	▨	100 U	100 U	100 U	100 U
Zinc		-	*24,000*	*253*	76.1	82.6	260	200	200	220

Notes:
U - Parameter was analyzed for, but not detected above the reporting limit shown.
▨ Grey Shading indicates the concentration of analyte was not established, therefore not reported nor analyzed.
1 - Model Toxics Control Act (MTCA) Method A, Toxics Cleanup Program, amended 1/96 (Chapter 173-340 WAC)
2 - Model Toxics Control Act Cleanup Levels and Risk Calculation (CLARC II), 2/96, Method B
3 - Area Background values based on statistical analysis per MTCA using data collected from Railroad Creek drainage in 1998.
4 - Yakima Basin 90th percentile values, Washington Department of Ecology "Natural Background Soil Metals Concentrations in Washington State", October 1994
5 - Lambeth, R.H. 1995. Transmittal of laboratory data from samples collected at Holden Mine site by the US Bureau of Mines. (Data collected in 1994).
6 - Kilburn, J.E. & S.J. Sutley. 1996. *Characterization of acid mine drainage at the Holden mine, Chelan, Washington*. USGS Open File Report 96-531. (Data collected in 1995).
7 - Kilburn, et al. 1994. *Geochemical data and sample locality maps for stream-sediment, heavy-mineral-concentrate, mill tailing, water, and precipitate samples collected in and around the Holden mine, Chelan County, Washington.* USGS Open File Report 94-680A Paper Version, 94-680B Diskette version (Data Collected in 1994).

TABLE 5.2-4
SUMMARY OF HISTORICAL TAILINGS ANALYTICAL DATA
HOLDEN MINE RI/FS
DAMES & MOORE JOB NO. 17693-005-019

Parameters	Sampling Location	MTCA Method A[1]	MTCA Method B[2]	Area Background [3]	Surface and Subsurface Samples from Tailings Pile 2 (TP-2)				Surface Samples from Tailings Pile 3 (TP-3)				
	Station No.				HT2-2A	HT2-2B	TP2-4	502T	HT3-2A	HT3-2B	4chc360	500T	501T
	Sampling Date				6/1/94 [5]	6/1/94 [5]	8/23/94 [5]	7/95 [6]	6/1/94 [5]	6/1/94 [5]	7/94 [7]	7/95 [6]	7/95 [6]
Total Metals (mg/kg)													
Aluminum		-	-	*20,900*	9,750	10,900	16,000	38,000	6,210	7,000	44,000	44,000	43,000
Arsenic		*20*	*1.67*	*11.6*	0.5	0.5	0.95	1.5U	0.44	0.37	1U	1.5U	1.5U
Barium		-	*5,600*	*310*	239	275	480	1,200	220	301	172	900	680
Beryllium		-	*0.23*	*0.2*	0.1	0.11	0.2	1 U	0.11	0.1	1 U	1 U	1 U
Cadmium		*2*	*80*	*5.4*	0.85	1.3	16.2	0.08 U	1	1	0.05 U	0.08U	0.08U
Calcium		-	-	*12,100*	1,110	1,250	6,090	11,000	568	753	16,000	16,000	14,000
Chromium		*100*	*80,000 (Cr^{+3})*	*37.2*	23 U	10.7 U	11.4 U	8	11.3 U	50.4 U	24	24	19
Copper		-	*2,960*	*57.4*	226	261	774	250	294	355	110	110	86
Iron		-	-	*24,100*	60,400	68,700	61,400	54,000	64,000	85,300	47,000	50,000	45,000
Lead		*250*	-	*20.6*	34.1	39	88.6	83	41.8	55.9	75	76	74
Magnesium		-	-	*9,200*	6,710	7,390	8,770	11,000	4,040	4,180	8,800	8,900	7,700
Manganese		-	*3,730*	*1,430*	230	257	320	430	166	175	480	500	390
Mercury		*1*	*24*	*0.05* [4]	0.23	0.25	0.13	▨	0.27	0.25	▨	▨	▨
Molybdenum		-	*400*	*1.2*	▨	▨	▨	8	▨	▨	20	23	16
Nickel		-	*1,600*	*22.7*	2.4	2.4	8.3	▨	0.99	1.8	3	▨	▨
Potassium		-	-	*1,260*	3,650	4,020	3,820	8,100	3,240	4,600	7,400	7,100	7,500
Selenium		-	*400*	*NE*	17.9	16.8	15.4	▨	17.1	13.3	▨	▨	▨
Silver		-	*400*	*0.5*	0.66 U	0.61 U	0.65 U	1.2	0.65 U	0.58 U	0.91	1.1	1
Sodium		-	-	*827*	433	479	783	10,000	497	684	14,000	14,000	13,000
Thallium		-	*5.6*	*0.4*	0.73	0.74	0.89	▨	0.51	0.86	▨	▨	▨
Uranium		-	*240*	*1*	▨	▨	▨	100 U	▨	▨	100 U	100 U	100 U
Zinc		-	*24,000*	*253*	216	249	2,070	270	569	767	123	147	78.3

Notes:
U - Parameter was analyzed for, but not detected above the *reporting limit shown.*
Gray Shading indicates the concentration of analyte was not established, therefore not reported nor analyzed.
1 - Model Toxics Control Act (MTCA) Method A, Toxics Cleanup Program, amended 1/96 (Chapter 173-340 WAC)
2 - Model Toxics Control Act Cleanup Levels and Risk Calculation (CLARC II), 2/96, Method B
3 - Area Background values based on statistical analysis per MTCA using data collected from Railroad Creek drainage in 1998.
4 - Yakima Basin 90th percentile values, Washington Department of Ecology "Natural Background Soil Metals Concentrations in Washington State", October 1994
5 - Lambeth, R.H. 1995. Transmittal of laboratory data from samples collected at Holden Mine site by the US Bureau of Mines. (Data collected in 1994).
6 - Kilburn, J.E. & S.J. Sutley. 1996. *Characterization of acid mine drainage at the Holden mine, Chelan, Washington*. USGS Open File Report 96-531. (Data collected in 1995).
7 - Kilburn, et al. 1994. *Geochemical data and sample locality maps for stream-sediment, heavy-mineral-concentrate, mill tailing, water, and precipitate samples collected in and around the Holden mine, Chelan County, Washington.* USGS Open File Report 94-680A Paper Version, 94-680B Diskette version (Data Collected in 1994).

TABLE 5.2-5
SUMMARY OF RI TAILINGS ANALYTICAL RESULTS
HOLDEN MINE RI/FS
DAMES & MOORE JOB NO. 17693-005-019

Parameters	Sample Location	MTCA Method A[1]	MTCA Method B[2]	Area Background [3]	Surface Samples from TP-1			Surface Samples from TP-2			Surface Samples from TP-3		
	Station No.				DMSS-11	DMSS-12	DMSS-13	DMSS-14	DMSS-15	DMSS-16	DMSS-17	DMSS-18	DMSS-19
	Sampling Date				9/20/97	9/20/97	9/20/97	9/21/97	9/21/97	9/21/97	9/21/97	9/21/97	9/21/97
Total Metals (mg/kg)													
Aluminum		-	-	20,900	8,220	8,700	7,350	8,450	17,300	11,000	10,500	12,800	7,210
Arsenic		20	1.67	11.6	3.3J	4.0J	5.0J	1.4J	1.0J	2.8J	1.7J	2.9J	1.0J
Barium		-	5,600	310	395	394	375	339	535	286	272	397	302
Beryllium		-	0.23	0.2	0.2U	0.1	0.2U	0.2U	0.1U	0.2	0.2	0.2U	0.2U
Cadmium		2	80	5.4	0.5	0.6	0.4U	0.5	0.3	0.4	0.3	0.5U	0.5U
Calcium		-	-	12,100	1,180J	1,820J	1,310J	1,290J	1,920J	2,200J	2,100J	1,870J	1,090J
Chromium		100	80,000 (Cr^{+3})	37.2	8	9.5	6	8	15.5	19.1	18.2	17	11
Copper		-	2,960	57.4	382	239	442	199	299	161	154	147	154
Iron		-	-	24,100	65,100	58,500	63,700	71,100	53,400	56,800	54,300	64,900	73,700
Lead		250	-	20.6	83	59	95	41	51	80	77	77	70
Magnesium		-	-	9,200	4,910	4,910	3,960	5,340	11,700	6,810	6,480	8,690	4,730
Manganese		-	3,730	1,430	169	167	148	208	385	220	210	277	156
Mercury		1	24	0.05 [4]	▨	▨	▨	▨	▨	▨	▨	▨	▨
Molybdenum		-	400	1.2	27	21.4	26	16	17.3	25.9	24.6	26	30
Nickel		-	1,600	22.7	2U	4	2U	2	3	5	5	4	3
Potassium		-	-	1,260	3,280	2,710	3,000	3,810	5,040	3,930	3,730	3,580	3,430
Selenium		-	400	NE	▨	▨	▨	▨	▨	▨	▨	▨	▨
Silver		-	400	0.5	3.1	2.0	3.3	2.2	2.0	2.5	2.3	2.3	2.6
Sodium		-	-	827	790	795	700	570	652	551	525	550	500
Thallium		-	5.6	0.4	2U	1U	2U	2U	1U	1U	1U	1U	2U
Uranium		-	240	1	2U	2U	2U	2U	2U	3U	2U	3U	2U
Zinc		-	24,000	253	157	187	124	190	163	176	169	283	305

Notes:
J - Estimated value.
U - Parameter was analyzed for, but not detected above the reporting limit shown.
UJ - Parameter was analyzed for but not detected. Detection limit is an estimated value.
▨ Grey Shading ▨ indicates the concentration of analyte was not established, therefore not reported nor analyzed.
1 - Model Toxics Control Act (MTCA) Method A, Toxics Cleanup Program, amended 1/96 (Chapter 173-340 WAC)
2 - Model Toxics Control Act Cleanup Levels and Risk Calculation (CLARC II), 2/96, Method B
3 - Area Background values based on statistical analysis per MTCA using data collected from Railroad Creek drainage in 1998.
4 - Yakima Basin 90th percentile values, Washington Department of Ecology "Natural Background Soil Metals Concentrations in Washington State", October 1994

TABLE 5.2-5
SUMMARY OF RI TAILINGS ANALYTICAL RESULTS
HOLDEN MINE RI/FS
DAMES & MOORE JOB NO. 17693-005-019

Parameters	Sample Location	MTCA Method A[1]	MTCA Method B[2]	Area Background [3]	Subsurface Samples from TP-1				Subsurface Samples from TP-2		
	Station No.				DMTP1-2	DMTP1-3A	DMTP1-3B	DMTP1-4	DMTP2-1A	DMTP2-1B	DMTP2-2
	Sampling Date				9/25/97	9/25/97	9/25/97	9/25/97	9/29/97	9/29/97	9/29/97
Total Metals (mg/kg)											
Aluminum		-	-	*20,900*	6,530	6,620	19,400	7,570	29,700	11,600	19,600
Arsenic		20	*1.67*	*11.6*	1.9	3.3	3.3	3.3	0.6	0.9	1.1
Barium		-	*5,600*	*310*	851J	301J	180J	320J	401J	494J	101J
Beryllium		-	*0.23*	*0.2*	0.2U	0.1U	1.0U	0.2U	0.1U	0.1U	0.2
Cadmium		2	*80*	*5.4*	0.5	0.9	21	0.5	147	0.7	0.4
Calcium		-	-	*12,100*	5,430J	7,850J	7,940J	8,020J	11,100J	7,990J	4,110J
Chromium		*100*	*80,000 (Cr^{+3})*	*37.2*	8	5.1	5	6	17	10.2	49.9
Copper		-	*2,960*	*57.4*	525	1,260	12,400	551	16,500	160	141
Iron		-	-	*24,100*	87,500	49,800	74,700	69,100	45,700	54,100	26,800
Lead		*250*	-	*20.6*	114	93	70	83	40	37	4
Magnesium		-	-	*9,200*	3,590	3,330	7,610	3,620	18,100	7,890	9,450
Manganese		-	*3,730*	*1,430*	124	130	291	141	657	250	350
Mercury		*1*	*24*	*0.05* [4]	▨	▨	▨	▨	▨	▨	▨
Molybdenum		-	*400*	*1.2*	24	32.5	25	24	16	28.6	1.0
Nickel		-	*1,600*	*22.7*	2U	2	20	2U	70	1	36
Potassium		-	-	*1,260*	4,200	2,150	2,760	3,020	6,560	5,540	1,680
Selenium		-	*400*	*NE*	▨	▨	▨	▨	▨	▨	▨
Silver		-	*400*	*0.5*	3.3	4.7	6	4.0	6	4.4	0.5
Sodium		-	-	*827*	960	900	680	930	1,050	1,060	619
Thallium		-	*5.6*	*0.4*	3	2U	2U	2U	3U	2U	0.5U
Uranium		-	*240*	*1*	2U	2U	3	2U	3U	2U	2U
Zinc		-	*24,000*	*253*	216	74.5	2,350	481	2,750	191	85.0

Notes:

J - Estimated value.
U - Parameter was analyzed for, but not detected above the reporting limit shown.
UJ - Parameter was analyzed for but not detected. Detection limit is an estimated value.
▨ Grey Shading indicates the concentration of analyte was not established, therefore not reported nor analyzed.
1 - Model Toxics Control Act (MTCA) Method A, Toxics Cleanup Program, amended 1/96 (Chapter 173-340 WAC)
2 - Model Toxics Control Act Cleanup Levels and Risk Calculation (CLARC II), 2/96, Method B
3 - Area Background values based on statistical analysis per MTCA using data collected from Railroad Creek drainage in 1998.
4 - Yakima Basin 90th percentile values, Washington Department of Ecology "Natural Background Soil Metals Concentrations in Washington State", October 1994

TABLE 5.2-5
SUMMARY OF RI TAILINGS ANALYTICAL RESULTS
HOLDEN MINE RI/FS
DAMES & MOORE JOB NO. 17693-005-019

Parameters	Sample Location	MTCA Method A[1]	MTCA Method B[2]	Area Background [3]	Subsurface Samples from TP-3							Windblown Tailings				
	Station No.				DMTP3-1	DMTP3-2	DMTP3-3A	DMTP3-3B	DMTP3-4A	DMTP3-4AX*	DMTP3-4B	DMSS-20	DMSS-21	DMSS-22	DMSS-23	DMSS-24
	Sampling Date				9/29/97	9/29/97	9/29/97	9/29/97	9/30/97	9/30/97	9/30/97	10/4/97	10/4/97	10/4/97	10/4/97	10/4/97
Total Metals (mg/kg)																
Aluminum		-	-	*20,900*	6,840	14,200	10,700	17,800	9,560	10,300	8,660	6,510	9,740	20,700	12,900	8,330
Arsenic		*20*	*1.67*	*11.6*	1.3	0.7	0.3	1.1	1.3	1.4	6.0	1.9	2.2	2.3	2.0	3.1
Barium		-	*5,600*	*310*	494J	365J	357J	99.5J	1,180J	1,570J	137J	321	327	79.0	388	380
Beryllium		-	*0.23*	*0.2*	0.2U	0.1U	0.2U	0.1	0.2U	0.3U	0.2U	0.2U	0.1U	0.2	0.1U	0.1U
Cadmium		*2*	*80*	*5.4*	0.4	0.4	0.5U	0.3	0.5U	0.5U	0.5U	0.5	0.5	0.4	0.6	0.5
Calcium		-	-	*12,100*	1,130J	5,700J	6,320J	4,780J	1,550J	1,620J	2,490J	1,190	2,140	5,870	3,880	1,790
Chromium		*100*	*80,000 (Cr^{+3})*	*37.2*	6	13.7	16	62.0	15	16	18	10	14.7	29.0	18.2	11.8
Copper		-	*2,960*	*57.4*	249	244	195	107	159	209	96.7	107	151	159	332	149
Iron		-	-	*24,100*	61,400	45,100	62,200	29,500	62,900	81,700	75,900	65,000	63,500	24,100	40,400	66,200
Lead		*250*	-	*20.6*	89	29	28	4	141	178	23	49	52	7	62	59
Magnesium		-	-	*9,200*	4,110	8,730	7,270	8,660	6,950	7,530	5,630	3,810	5,840	6,070	6,570	4,860
Manganese		-	*3,730*	*1,430*	139	282	237	245	179	199	169	135	197	292	203	165
Mercury		*1*	*24*	*0.05* [4]	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨
Molybdenum		-	*400*	*1.2*	24	10.4	10	1.3	23	21	3	30	31.7	0.7U	10.7	29.4
Nickel		-	*1,600*	*22.7*	2	4	4	39	3	4	9	3	6	17	9	4
Potassium		-	-	*1,260*	3,080	5,620	6,040	1,990	4,900	6,260	5,050	2,850	2,990	580U	1,340	3,510
Selenium		-	*400*	*NE*	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨
Silver		-	*400*	*0.5*	2.8	1.6	1.9	0.5	3.2	3.5	1.3	2.8	2.3	0.4U	1.2	2.4
Sodium		-	-	*827*	540	694	1,050	578	610	700	850	550	597	1,130	611	774
Thallium		-	*5.6*	*0.4*	2U	2U	2U	0.5	3U	3U	2U	2U	3U	0.7U	2U	3U
Uranium		-	*240*	*1*	2U	2U	2U	2U	3U	3U	2U	2U	3U	3U	2U	3U
Zinc		-	*24,000*	*253*	144	302	96.2	78.7	123	147	78.3	246	256	75.3	107	260

Notes:
J - Estimated value.
U - Parameter was analyzed for, but not detected above the reporting limit shown.
UJ - Parameter was analyzed for but not detected. Detection limit is an estimated value.
* 'X' after the sample ID is an indication of field duplicate
▨ Grey Shading ▨ indicates the concentration of analyte was not established, therefore not reported nor analyzed.
1 - Model Toxics Control Act (MTCA) Method A, Toxics Cleanup Program, amended 1/96 (Chapter 173-340 WAC)
2 - Model Toxics Control Act Cleanup Levels and Risk Calculation (CLARC II), 2/96, Method B
3 - Area Background values based on statistical analysis per MTCA using data collected from Railroad Creek drainage in 1998.
4 - Yakima Basin 90th percentile values, Washington Department of Ecology "Natural Background Soil Metals Concentrations in Washington State", October 1994

TABLE 5.2-6
POTENTIAL COMPOUNDS OF CONCERN (PCOC) FOR SOIL & TAILINGS
HOLDEN MINE RI/FS
DAMES & MOORE JOB NO. 17693-005-019

Area		Analytes Above Area Background	Analytes Above MTCA-A/ MTCA-B	PCOC's	Samples Containing PCOC's
Holden Village		Aluminum, Arsenic, Barium, Beryllium, Chromium, Copper, Iron, Lead,Mercury, Molybdenum, Nickel, Silver, Zinc	Arsenic, Beryllium	Aluminum, Arsenic*, Beryllium, Iron	HW-1A*, HV-1A, HV-3A, HV-4A, HV-6A, DMSS-1, DMSS-2, DMSS-3, DMSS-4, DMSS-5, DMSS-6, DMSS-6X
Baseball Field		Copper, Iron, Silver	None	Iron	DMSS-25
Maintenance Yard	**Surface**	Arsenic, Barium, Cadmium, Copper, Iron, Lead, Molybdenum, Nickel, Silver, Zinc	Arsenic, Cadmium, Copper, Lead, Total Petroleum Hydrocarbons	Arsenic*, Cadmium, Copper, Lead, Iron, Total Petroleum Hydrocarbons	DMSS-8, DMSS-9, DMSS-10, DMSS-10X, Storage*
	Subsurface	Aluminum, Copper, Lead, Zinc	Total Petroleum Hydrocarbons	Aluminum, Total Petroleum Hydrocarbons	DMSS-8-2', DMSS-10-2'
Lagoon	**Surface**	Aluminum, Barium, Beryllium, Copper, Iron, Lead, Molybdenum, Silver, Uranium, Zinc	Beryllium, Total Petroleum Hydrocarbons	Aluminum, Beryllium, Iron, Total Petroleum Hydrocarbons	Lagoon 6"
	Subsurface	Aluminum, Cadmium, Copper, Iron, Lead, Molybdenum, Silver, Thallium, Uranium, Zinc	Cadmium, Copper, Lead, Total Petroleum Hydrocarbons	Aluminum, Cadmium, Copper, Lead, Iron, Total Petroleum Hydrocarbons	Lagoon 2, DMLG1-2', DMLG2-4', DMLG2-71/2', DMLG3-2', DMLG4-2', DMLG4-4', DMLG5-2', DMLG5-4'
Tailings Pile	**Surface**	Aluminum, Barium, Copper, Iron, Lead, Molybdenum, Mercury, Silver, Thallium, Zinc	None	Aluminum, Iron	Iron - All Samples Aluminum - 503T, 504T, 505TA, 505TB, 502T, 4chc360, 500T, 501T
	Subsurface	Aluminum, Barium, Cadmium, Chromium, Copper, Iron, Lead, Mercury, Molybdenum, Nickel, Silver, Thallium, Uranium, Zinc	Cadmium, Copper	Aluminum, Cadmium, Copper, Iron	All Samples for Iron, TP2-4 (Cd), DMTP1-3B (Cd, Cu), DMTP2-1A (Al,Cd, Cu)
Windblown Tailings		Barium, Copper, Iron, Lead, Molybdenum, Silver, Zinc	None	Iron	All Samples

Notes:
* Arsenic is considered as a PCOC at sample locations HW-1A and "Storage" only.

All samples listed under "Samples Containing PCOCs" do not necessarily contain all PCOCs listed unless otherwise noted.

TABLE 5.3-1
SURFACE WATER AREA BACKGROUND STATISTICAL ANALYSIS
HOLDEN MINE RI/FS
DAMES & MOORE JOB NO. 17693-005-019

Parameters	DAMES & MOORE RI DATA										
	Holden Creek	**HC-1**	**HC-2**	**HC-3**	**HC-4**	**Big-1**	**CC-1**	**CC-1**	**CC-1**	**CC-1**	**Ten-Mile Creek**
	10/4/97	**5/1/98**	**4/30/98**	**4/30/98**	**4/30/98**	**5/2/98**	**5/23/97**	**7/11/97**	**9/15/97**	**5/2/98**	**9/16/97**
Total Metals (ug/L)											
Aluminum	40U	80U	240	70U	50U	30U	20U	40	20	100J	30
Arsenic	0.54	0.52	0.65	0.78	1.33	0.33				0.04U	0.14
Barium	4.27	5.04	6.17	5.76	6.82	7.09	6	4.99	4.61	5.64	6.17
Beryllium	0.08U	0.04U	0.04U	0.04U	0.04U	0.04U	0.04U	0.04U	0.04U	0.04U	0.04U
Cadmium	0.05	0.04U	0.07U	0.07U	0.06U	0.04U	0.04U	0.04U	0.04U	0.04U	0.04U
Calcium	3,600	5,180	5,690	5,010	4,150	7,050	4,400	3,110	3,720	3,980	10,200
Chromium	1U	0.2U	0.3	0.2U	0.2U	0.2U	5U	0.2U	0.2U	0.3	0.2U
Copper	0.7	1.2U	1.6J	1U	0.9U	0.5U	2U	0.3	0.3	0.6U	0.4
Iron	50	70	230	100	100	20U	20U	30	20U	100	20U
Lead	0.3	0.054	0.129	0.067	0.069	0.011U	0.4U	0.3UJ	0.2UJ	0.06	0.2UJ
Magnesium	330	560	670	580	260	360	550	410	450	490	760
Manganese	3.5	2.69	6.8	3.95	2.87	0.73	1U	0.63	0.22	2.96	0.31
Mercury											
Molybdenum	0.43	0.5	0.53	0.45	0.69	0.35				0.49	0.69
Nickel	0.2	0.2U	0.5	0.2U	0.2U	0.2U	10U	0.2	0.2	0.4	0.3
Potassium	500U	500U	500U	600	500U	500U	530	710	500U	500U	500U
Selenium											
Silver	0.04U	0.04U	0.04U	0.04U	0.04U	0.04U	0.04U	0.04U	0.04U	0.04U	0.04U
Sodium	630U	850	880	880	640	660	740	540	610	640	740
Thallium											0.04U
Uranium											0.06
Zinc	4U	5	5	4U	4	4U	4U	4U	4U	5	4U
Dissolved Metals (ug/L)											
Aluminum	30U	50	30	20	20U	30	20U	20U	20U	20U	20U
Arsenic	0.5	0.39	0.45	0.61	1	0.29				0.04U	0.14
Barium	4.19	4.27	4.56	4.88	6.19	6.51	23	13.6	4.73	4.96	6.42
Beryllium	0.04U	0.04U	0.04U	0.04U	0.04U	0.04U	0.04U	0.04U	0.04U	0.04U	0.04U
Cadmium	0.05	0.04U	0.05	0.04U	0.06	0.04U	0.04U	0.08	0.04U	0.04U	0.04U
Calcium	3,550	4,980	5,340	5,030	3,990	6,730	4,390	3,110	3,780	3,790	10,600
Chromium	0.2U	0.2U	0.2U	0.2U	0.2U	0.2U	5U	0.2U	0.2U	0.2U	0.2U
Copper	0.9	0.6	0.7	0.6	0.5	0.3	2U	0.3	0.2	0.5	0.3
Iron	20U	20U	20U	20	30	20U	20U	20U	20U	20U	20U
Lead	0.3	0.018	0.011U	0.011U	0.011U	0.011U	0.4U	1.8J	0.2U	0.011U	0.2U
Magnesium	330	520	580	570	230	350	550	390	470	430	790
Manganese	1.80	0.78	2.91	1.32	1.05	0.29U	1U	0.13	0.13U	0.82	0.14U
Mercury											
Molybdenum	0.5	0.46	0.49	0.43	0.64	0.33				0.48	0.70
Nickel	0.2U	0.2U	0.2	0.2U	0.2U	0.2U	10U	0.2U	0.2U	0.3	0.4
Potassium	500U	500U	500U	500U	500U	500U	650	500U	630	500U	500U
Selenium											
Silver	0.04U	0.04U	0.04U	0.04U	0.04U	0.04U	0.04U	0.04U	0.04U	0.04U	0.04U
Sodium	640U	850	820	880	610	640	800	570	620	600	790
Thallium											0.04U
Uranium											0.06
Zinc	6	4U	4U	4U	4U	4U	12	10	4U	4U	4U

Data Notes:

U - Parameter was analyzed for, but not detected above the reporting limit shown.

J - Estimated Value.

UJ - Parameter was analyzed for, but not detected. Detection limit is an estimated value.

* indicates that highest value from range of replicated samples were represented.

Shading	Indicates that this value was not included in the statistical analysis
Blank Cell	Indicates that the data was not available for this parameter

Data Source:

(a) Walters, et al. 1992. *Holden Mine Reclamation Project Final Report.* Pacific Northwest Laboratories,Richland, WA. (Data collected in 1991).

(b) Kilburn, et al. 1994. *Geochemical data and sample locality maps for stream-sediment, heavy-mineral-concentrate, mill tailing, water, and precipitate samples collected in and around the Holden mine, Chelan County, Washington.* USGS Open File Report 94-680A Paper Version, 94-680B Diskette version (Data Collected in 1994).

(c) Anderson, Keith A. (USFS Chelan Ranger District). Compilation of Data for Preliminary Assessment of the Holden Mine Site.

(d) Kilburn, J.E. & S.J. Sutley. 1996. *Characterization of acid mine drainage at the Holden mine, Chelan, Washington*. USGS Open File Report 96-531. (Data collected in 1995).

(e) Kilburn, J.E. & S.J. Sutley. 1997. *Analytical results and comparative overview of geochemical studies conducted at the Holden Mine*, spring 1996. USGS Open File Report 97-128 (Data collected in Spring 1996).

(f) Kilburn, J.E. & S.J. Sutley. 1997. Preliminary data (*no report attached, data collected in Fall 1996*).

(g) Johnson, A., et al. 1997. *Effects of Holden Mine on the Water, Sediments and Benthic Invertebrates of Railroad Creek (Lake Chelan).* Environmental Investigations and Laboratory Services Program. Water Body No. WA-47-1020. Publication No. 97-330 (data collected in Spring and Fall 1996).

TABLE 5.3-1
SURFACE WATER AREA BACKGROUND STATISTICAL ANALYSIS
HOLDEN MINE RI/FS
DAMES & MOORE JOB NO. 17693-005-019

							DAMES & MOORE RI DATA				
Parameters	367	546	600	DEPT. OF ECOLOGY (RC-STATION SAMPLES) [g]		707	RC-11		RC-6A	RC-6B	RC-6C
	USGS 7/94[b]	USGS 7/95[d]	USGS 5/96[e]	6/12/96	9/10/96	USGS 1996[f]	10/4/97	5/1/98	4/15/97	4/15/97	4/15/97
Total Metals (ug/L)											
Aluminum				13	32	46	140U	70U	20U	20U	20
Arsenic				0.69	0.88		1.56	1.12	1U	1U	1U
Barium						5.4	4.13	4.14	3	3	4
Beryllium						10 U	0.08U	0.04U	1U	1U	1U
Cadmium				0.02 U	0.1 U	10 U	0.04U	0.04U	0.2U	0.2U	0.2U
Calcium						5,900	2,540	2,410	6,720	6,660	6,740
Chromium						10 U	0.2U	0.2U	5U	5U	5U
Copper				1.4	3.7	10 U	1.2	1	2U	2U	2U
Iron				71	77	110	220	90	70	70	70
Lead				0.13	0.12	50 U	0.4	0.139	1U	1U	1U
Magnesium						1000 U	290	240	680	670	670
Manganese				1.3	1.9	10 U	6.02	3.83	2	2	2
Mercury				0.001 U					0.1U	0.1U	0.1U
Molybdenum						20 U	0.66	0.65			
Nickel				0.34		10 U	0.4	0.3	10U	10U	10U
Potassium						1000 U	500U	500U	600	810	650
Selenium					0.4 U				1U	1U	1U
Silver				0.02			0.04U	0.04U	0.2U	0.2U	0.2U
Sodium						1,100	540U	670	1,120	1,120	1,140
Thallium									1U	1U	1U
Uranium											
Zinc				3.7	3	10 U	5	4U	4U	4U	4U
Dissolved Metals (ug/L)											
Aluminum	20	20	20 U		7.4 *	11	40U	30	20	40	20U
Arsenic	2 U	1 U	4 U				0.94	0.73	1U	1U	1U
Barium	4.1	3.8	6.5			5.1	3.42	3.61	5	5	5
Beryllium	1 U	0.3 U	0.4 U			10 U	0.04U	0.04U	1U	1U	1U
Cadmium	1 U	1 U	0.7 U	0.05	0.02 *	10 U	0.04U	0.04U	0.2U	0.2U	0.2U
Calcium	6000 U	3900	5900			5,800	2,520	2,310	6,750	6,810	6,490
Chromium	1 U	0.9 U	0.5 U			10 U	0.2U	0.2U	5U	5U	5U
Copper	0.62	3	6.5	0.96	0.26 *	10 U	1.1	0.7	2U	2U	2U
Iron	100 U	40	91			100 U	60	30	30	40	40
Lead	0.2 U	0.3 U	0.2	0.02	0.02 *	50 U	0.2U	0.5J	1U	1U	1U
Magnesium	270	280	1000 U			1000 U	260	230	640	650	660
Manganese	2	1.6	3 U			10 U	3.17	2.88	2	1	1
Mercury									0.1UJ	0.1UJ	0.1UJ
Molybdenum	0.5	0.3	0.6			20 U	0.67	0.59			
Nickel	3 U	0.5	1 U	0.22		0.01 U	0.3	0.3	10U	10U	10U
Potassium	200 U					1000 U	500U	500U	780	660	500U
Selenium									1U	1U	1U
Silver	0.1 U	0.1 U	0.2 U	0.02			0.04U	0.04U	0.2U	0.2U	0.2U
Sodium	300	500				1000 U	560U	630	1,100	1,160	1,120
Thallium	0.1 U	0.6 U	4 U						1U	1U	1U
Uranium	0.1 U	0.1 U	0.4 U								
Zinc	4	10	3.4	1.3	0.85 *	10 U	5	4U	6	6	5

Data Notes:

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TABLE 5.3-1
SURFACE WATER AREA BACKGROUND STATISTICAL ANALYSIS
HOLDEN MINE RI/FS
DAMES & MOORE JOB NO. 17693-005-019

Parameters	DAMES & MOORE RI DATA								
	RC-6							RC-6 N.Bank	RC-6 N.Bank X
	5/19/97	5/26/97	6/2/97	6/9/97	6/16/97	7/10/97	5/3/98	9/15/97	9/15/97
Total Metals (ug/L)									
Aluminum	90	40J	160	80J	180	150	150J	60	60
Arsenic	0.80					0.76	1.07	1.07	1.09
Barium	4.92	4.43	4.87	4.43J	5	4.61	5.1	4.38	4.52
Beryllium	0.04U	0.2U	0.04U	0.04U	0.2U	0.04U	0.04U	0.04U	0.04U
Cadmium	0.04U	0.04U	0.04	0.04U	0.2U	0.04U	0.04U	0.04U	0.04U
Calcium	3,820	4,020	3,430	3,530J	2,820	3,030	3,800	4,100	4,020
Chromium	0.2U	0.2U	0.2U	0.2U	5U	0.2U	0.2U	0.2U	0.2U
Copper	0.9U	0.7	1.3	0.8J	4	1.1	1.8J	0.6	1.0
Iron	140	80J	150	70J	170	150	180	110	120
Lead	0.3U	0.3	4.8	0.3J	1U	0.3UJ	0.124	0.2UJ	0.3UJ
Magnesium	360	400	340	340J	310	310	360	360	360
Manganese	3.7	1.67	4.41	1.95J	5	3.90	6.52	3.02	3.53
Mercury	0.00046J					0.00064			
Molybdenum	0.49					0.39	0.53	0.74	0.74
Nickel	0.3J	0.4	0.4	0.2U	10U	0 3	0.3	0.2	0.3
Potassium	500U	500U	500U	510J	500U	500U	500U	500U	500U
Selenium	0.2U					0.2U			
Silver	0.04U	0.04U	0.04U	0.04UJ	0.2U	0.04U	0.04U	0.04U	0.04U
Sodium	760	810	610	610J	600	700	690	580	570
Thallium	0.04U					0.04U		0.04U	0.04U
Uranium	0.04U					0.04U		0.04U	0.04U
Zinc	4U	4U	4U	4U	11	4U	4U	5	4U
Dissolved Metals (ug/L)									
Aluminum	30U	20	60	40J	30	30U	40	30	20U
Arsenic	0.50					0.52	0.54	0.81	0.82
Barium	15.4J	24.3	17.6	16.0J	14	10.9	4.14	4.33	4.33
Beryllium	0.04U	0.04U	0.04U	0.04U	0.04U	0.04U	0.04U	0.04U	0.04U
Cadmium	0.04U	0.04U	0.04U	0.04U	0.04U	0.04U	0.08	0.04U	0.08
Calcium	3,870	3,780	3,510	3,480J	2,800	3,000	3,630	4,170	4,150
Chromium	0.2U	0.2U	0.2U	0.2U	5U	0.2U	0.2U	0.2U	0.2U
Copper	0.7	1.0	0.9	1.2U	2U	0.6	0.6	0.4	0.5
Iron	30	30J	30	20U	20U	20U	30	40	40
Lead	0.9U	0.3U	1.8U	0.2U	0.2U	0.2J	0.011U	0.2U	0.9
Magnesium	360	370	340	310J	250	260	320	350	350
Manganese	1.94	1.40	1.23	0.96J	1	1.18	2.08	1.74	1.72
Mercury	0.00003J					0.00033J			
Molybdenum	0.51					0.41	0.48	0.73	0.73
Nickel	0.3	0.6	0.4	0.2U	10U	0.2U	0.2U	0.2	0.2
Potassium	500U	500U	710	500U	500U	500U	500U	500U	500U
Selenium	0.2U					0.2U			
Silver	0.04U	0.04U	0.04UJ	0.04UJ	0.04U	0.04U	0.04U	0.04U	0.04U
Sodium	800J	820	660	660J	570U	490	700	600	610
Thallium	0.04U					0.04U		0.04U	0.04U
Uranium	0.04U					0.04U		0.04U	0.04U
Zinc	16	14U	13U	16U	12	6	4U	16	4

Data Notes:

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TABLE 5.3-1
SURFACE WATER AREA BACKGROUND STATISTICAL ANALYSIS
HOLDEN MINE RI/FS
DAMES & MOORE JOB NO. 17693-005-019

Parameters	DAMES & MOORE RI DATA												
	RC-1A	**RC-1B**	**RC-1C**	**RC-1**				**RC-1 North Bank**		**RC-1 South Bank**		**SF Agnes Creek**	**Company Creek**
	4/16/97	**4/16/97**	**4/16/97**	**5/19/97**	**7/10/97**	**9/15/97**	**5/3/98**	**5/19/97**	**9/15/97**	**5/19/97**	**9/15/97**	**9/30/97**	**10/2/97**
Total Metals (ug/L)													
Aluminum	20	20U	20U	90	160	70	100J	100	40	100U	60	110U	30U
Arsenic	1	1	2	0.72	0.76	1.07	0.86					2.84	0.14
Barium	3	3	4	4.98	4.62	4.42	4.91	5.02	4.40	4.80	4.39	4.91	6.27
Beryllium	1U	1U	1U	0.04U	0.04U	0.04U	0.04U	0.04U	0.04U	0.04U	0.04U	0.04U	0.08U
Cadmium	0.2U	0.2U	0.2U	0.04U	0.04U	0.04U	0.04U	0.05	0.04U	0.04U	0.04U	0.04U	0.04U
Calcium	6,480	6,480	6,470	3,800	3,050	4,080	3,860	3,850	4,060	3,840	4,100	2,420	6,980
Chromium	5U	5U	5U	0.2U	0.2U	0.2U	0.2U	0.2U	0.2U	0.2U	0.2U	0.2U	1U
Copper	2U	2U	2U	1.1U	1.0	0.6	1.1	1.2U	0.6	1.1U	0.7	0.4	0.4
Iron	70	90	70	120	160	110	110	130	100	140	110	90	20U
Lead	1U	1U	1U	0.2U	0.3UJ	0.2UJ	0.103	0.3U	0.3UJ	0.4U	0.2UJ	0.2U	0.3
Magnesium	650	640	650	360	320	350	360	370	360	390	360	340	570
Manganese	2	2	2	4.70	3.87	3.09	4.45	3.49	2.70	3.30	3.20	1.79	0.9
Mercury	0.1U	0.1U	0.1U	0.00039	0.00032J								
Molybdenum				0.49	0.39	0.74	0.52					0.98	0.60
Nickel	10U	10U	10U	0.3J	0.3	0.2	0.3	0.3J	0.2	0.3J	0.2	0.2U	0.3
Potassium	780	630	730	500U	500U	500U	500U	500U	500U	610	500U	500U	500U
Selenium	1U	1U	1U	0.2U	0.2U								
Silver	0.2U	0.2U	0.2U	0.14U	0.04U	0.04U	0.04U	0.12U	0.12	0.05U	0.04U	0.15J	0.04U
Sodium	1,090	1,090	1,090	780	490	580	730	750	590	800	590	610U	840U
Thallium	1U	1U	1U	0.04U	0.04U	0.04U							
Uranium				0.04U	0.04U	0.04U							
Zinc	4U	4U	4U	4U	5	4U	4U	4U	4U	5	4U	4U	4U
Dissolved Metals (ug/L)													
Aluminum	20	20U	20	30	20U	20U	30	30U	20U	30	20U	20U	20U
Arsenic	1U	1U	1U	0.50	0.51	0.82	0.53					2.56	0.13
Barium	5	6	6	22.0J	10.4	4.32	4.38	17.2J	4.30	15.0J	4.29	4.36	6.14
Beryllium	1U	1U	1U	0.04U	0.04U	0.04U	0.04U	0.04U	0.04U	0.04U	0.04U	0.08U	0.04U
Cadmium	0.2U	0.2U	0.2U	0.04U	0.04U	0.04U	0.04U	0.06	0.04U	0.04	0.09	0.04U	0.04U
Calcium	6,430	6,430	6,400	3,770	3,120	4,120	3,730	3,800	4,150	3,760	4,180	2,350	6,890
Chromium	5U	5U	5U	0.2U	0.2U	0.2U	0.2U	0.2U	0.2U	0.2U	0.2U	0.2U	0.2U
Copper	2U	2U	2U	1.1	0.6	0.4	0.8	1.0	0.6	1.0	0.6	0.5	0.4
Iron	40	40	40	30	20U	40	20	20U	40	20U	40	20U	20U
Lead	1U	1U	1U	0.2U	0.3J	0.5	0.011U	1.1U	0.2U	0.7U	0.2	0.2U	0.2U
Magnesium	660	660	660	360	270	350	330	360	340	360	350	300	560
Manganese	2	1	1	1.82	1.13	1.65	2	1.86	1.67	1.83	1.68	0.62	0.29
Mercury	0.1UJ	0.1UJ	0.1UJ	0.00031J	0.00028J								
Molybdenum				0.49	0.40	0.82	0.49					1.02	0.61
Nickel	10U	10U	10U	0.2	0.2U	0.2	0.2U	0.3	0.2	0.2	0.2	0.2	0.2
Potassium	690	500	500	500U	500U	500U	500U	500U	500U	500U	500U	560	500U
Selenium	1U	1U	1U	0.2U	0.2U								
Silver	0.2U	0.2U	0.2U	0.04U	0.04U	0.04U	0.04U	0.04U	0.04U	0.04U	0.04U	0.04U	0.04U
Sodium	1,240	1,220	1,280	810J	490	620	690	850J	600	780U	630	590U	880U
Thallium	1U	1U	1U	0.04U	0.04U	0.04U							
Uranium				0.04U	0.04U	0.04U							
Zinc	5	5	4U	13	6	4U	4U	16	9	13	4U	11	7

Data Notes:

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TABLE 5.3-1
SURFACE WATER AREA BACKGROUND STATISTICAL ANALYSIS
HOLDEN MINE RI/FS
DAMES & MOORE JOB NO. 17693-005-019

Parameters	STATISTICAL CALCULATIONS									
	# Analyses	# of Detections	Maximum Conc.	Minimum Conc.	Range of RL	Approximate Distribution	Mean	Standard Deviation	Median	90th Percentile
Total Metals (ug/L)										
Aluminum	41	26	240	13	20-140	Lognormal	86.1	58.9	65	144
Arsenic	25	24	2	0.14	0.04	Normal	0.87	0.415	0.83	1.44
Barium	39	39	7.09	3	None	Lognormal	4.8	0.97	4.8	6.24
Beryllium	32	0	NA	NA	0.04 - 0.2	NA	NA	NA	NA	NA
Cadmium	40	3	0.05	0.04	0.02 - 0.2	Non-Parametric	0.047	0.006	0.05	0.10
Calcium	39	39	10200	2410	None	Lognormal	4589	1659	4020	6814
Chromium	31	2	0.3	0.3	0.2-10	Non-Parametric	0.3	0	0.3	0.46
Copper	33	24	4	0.3	0.5-1.2	Lognormal	1.1	0.936	0.9	1.83
Iron	41	36	230	30	20	Lognormal	110	44.5	100	177
Lead	33	16	4.8	0.054	0.2-0.4	Non-Parametric	0.46	1.16	0.1295	0.3
Magnesium	38	38	760	240	None	Lognormal	443	144.5	360	647
Manganese	39	39	6.8	0.22	None	Normal	2.95	1.59	2.96	5.06
Mercury	11	4	0.00064	0.000032	0.001-0.1	Lognormal	0.00046	0.00014	0.000425	0.00066
Molybdenum	21	21	0.98	0.35	None	Lognormal	0.57	0.154	0.53	0.79
Nickel	31	25	0.5	0.2	0.2	Non-Parametric	0.3	0.08	0.3	0.4
Potassium	38	11	810	510	500	Lognormal	652	96.7	630	672
Selenium	10	0	NA	NA	0.2-1	NA	NA	NA	NA	NA
Silver	38	2	0.15	0.12	0.04-0.2	Non-Parametric	0.135	0.021	0.135	0.1
Sodium	39	35	1140	490	540-840	Lognormal	767	196.7	730	1034
Thallium	14	0	NA	NA	0.04-1	NA	NA	NA	NA	NA
Uranium	8	1	0.06	0.06	0.04	Non-Parametric	0.06	NA	0.06	NA
Zinc	41	11	11	3	4-10	Non-Parametric	5.2	2.1	5	5
Dissolved Metals (ug/L)										
Aluminum	43	22	60	7.4	20 - 40	Lognormal	29	12.2	30	37.4
Arsenic	19	19	1	0.13	None	Normal	0.565	0.242	0.52	0.9
Barium	42	42	24.3	3.42	None	Non-Parametric	8.22	5.9	5	17.5
Beryllium	34	0	NA	NA	0.04 - 0.4	NA	NA	NA	NA	NA
Cadmium	41	11	0.09	0.02	0.04 -0.7	Lognormal	0.061	0.021	0.06	0.07
Calcium	42	41	10600	2310	6000	Lognormal	4564	1653	3990	6703
Chromium	34	0	NA	NA	0.2 -10	NA	NA	NA	NA	NA
Copper	32	31	1.1	0.2	1.2	Lognormal	0.64	0.26	0.6	1.06
Iron	40	23	91	20	20	Non-Parametric	37.87	14.3	40	40
Lead	35	12	1.8	0.018	0.011 - 0.9	Lognormal	0.602	0.505	0.25	0.54
Magnesium	40	40	790	230	None	Lognormal	417	151	355	626
Manganese	39	36	3.17	0.13	0.13 - 0.29	Normal	1.507	0.677	1.625	2.42
Mercury	10	4	0.00033	0.00003	0.1	Non-Parametric	0.00024	0.00014	0.000295	0.05
Molybdenum	24	24	1.02	0.3	None	Lognormal	0.56	0.16	0.5	0.78
Nickel	32	20	0.6	0.2	0.2	Lognormal	0.28	0.11	0.21	0.39
Potassium	39	9	780	500	200 - 500	Non-Parametric	631	95	650	660
Selenium	10	0	NA	NA	0.2 - 1	NA	NA	NA	NA	NA
Silver	41	0	NA	NA	0.04	NA	NA	NA	NA	NA
Sodium	41	34	1280	300	560-1000	Lognormal	759	237	675	1078
Thallium	17	0	NA	NA	0.04-4	NA	NA	NA	NA	NA
Uranium	11	1	0.06	0.06	0.04-0.4	Non-Parametric	0.06	NA	0.06	0.172
Zinc	44	15	16	0.85	4	Lognormal	7.184	4.203	5	7.81

Statistical Notes: (Statistical calculations were performed using Washington Department of Ecology's MTCAStat Excel V.5 Macro (Background Module 2.1), *downloaded from their web site.*)

Maximum and minimum concentrations are based on detected values only.

Range of reporting limits (RL) are based on results reported as not detected.

Distribution is determined based on the MTCA stat program by analyzing the data through the "Distribution Decision Probability Plot". Where data is not lognormally nor normally distributed, the distribution is noted as "Non-parametric".

The mean is an arithmetic mean if data are normally distributed or if distribution is indicated as "non-parametric". The reported mean for lognormally distributed data is a lognormal mean.

NA indicates that the data set contained too many results reported as not detected to perform a statistical analysis for background concentrations.

TABLE 5.3-2
Aluminum Data Points, Background Assessment
Holden Mine RI/FS
Dames & Moore Job No. 17693-005-019

Sample	Date Collected	Metal	Result (ug/L)	Total Set	Seasonal		Railroad Creek	Other Bkg
					Spring	Fall	Set 1A	Set 1B
Holden Creek								
Holden Creek	04-Oct-97	Aluminum	<30	X		X		X
HC-1	01-May-98	Aluminum	50	X	X			X
HC-2	30-Apr-98	Aluminum	30	X	X			X
HC-3	30-Apr-98	Aluminum	20	X	X			X
HC-4	30-Apr-98	Aluminum	<20	X	X			X
Big Creek								
BIG-1	02-May-98	Aluminum	30	X	X			X
Railroad Creek								
RC-11	04-Oct-97	Aluminum	<40	X		X	X	
RC-11	01-May-98	Aluminum	30	X	X		X	
RC-6A	15-Apr-97	Aluminum	20	X			X	
RC-6B	15-Apr-97	Aluminum	40	X			X	
RC-6C	15-Apr-97	Aluminum	<20	X			X	
RC-6	19-May-97	Aluminum	<30	X	X		X	
RC-6	26-May-97	Aluminum	20	X	X		X	
RC-6	02-Jun-97	Aluminum	60	X	X		X	
RC-6	09-Jun-97	Aluminum	40	X	X		X	
RC-6	16-Jun-97	Aluminum	30	X	X		X	
RC-6	10-Jul-97	Aluminum	<30	X			X	
RC-6	03-May-98	Aluminum	40	X	X		X	
RC-6 * North Bank	15-Sep-97	Aluminum	<20	X		X	X	
RC-6 North Bank	15-Sep-97	Aluminum	30	X		X	X	
RC-1A	16-Apr-97	Aluminum	20	X			X	
RC-1B	16-Apr-97	Aluminum	<20	X			X	
RC-1C	16-Apr-97	Aluminum	20	X			X	
RC-1	19-May-97	Aluminum	30	X	X		X	
RC-1	10-Jul-97	Aluminum	<20	X			X	
RC-1	15-Sep-97	Aluminum	<20	X		X	X	
RC-1	03-May-98	Aluminum	30	X	X		X	
RC-1 North Bank	19-May-97	Aluminum	<30	X	X		X	
RC-1 North Bank	15-Sep-97	Aluminum	<20	X		X	X	
RC-1 South Bank	19-May-97	Aluminum	30	X	X		X	
RC-1 South Bank	15-Sep-97	Aluminum	<20	X		X	X	
Historical Railroad Creek								
USGS 367	01-Jul-94	Aluminum	20	X			X	
USGS 546	01-Jul-95	Aluminum	20	X			X	
USGS 600	01-May-96	Aluminum	<20	X	X		X	
Dept of Ecology	10-Sep-96	Aluminum	7.4	X		X	X	
USGS 707	01-Sep-96	Aluminum	11	X		X	X	
Copper Creek								
CC-1	23-May-97	Aluminum	<20	X	X			X
CC-1	11-Jul-97	Aluminum	<20	X				X
CC-1	15-Sep-97	Aluminum	<20	X		X		X
CC-1	02-May-98	Aluminum	<20	X	X			X
Ten Mile Creek	16-Sep-97	Aluminum	<20	X		X		X
Stehekin Area								
SF Agnes Creek	30-Sep-97	Aluminum	<20	X		X		X
Company Creek	02-Oct-97	Aluminum	<20	X		X		X

X - Data point was used for statistical analysis.

TABLE 5.3-3
Arsenic Data Points, Background Assessment
Holden Mine RI/FS
Dames & Moore Job No. 17693-005-019

Sample	Date Collected	Metal	Result (ug/L)	Total Set	Seasonal		Railroad Creek	Other Bkg
					Spring	Fall	Set 1A	Set 1B
Holden Creek								
Holden Creek	04-Oct-97	Arsenic	0.5	X		X		X
HC-1	01-May-98	Arsenic	0.39	X	X			X
HC-2	30-Apr-98	Arsenic	0.45	X	X			X
HC-3	30-Apr-98	Arsenic	0.61	X	X			X
HC-4	30-Apr-98	Arsenic	1	X	X			X
Big Creek								
BIG-1	02-May-98	Arsenic	0.29	X	X			X
Railroad Creek								
RC-11	04-Oct-97	Arsenic	0.94	X		X	X	
RC-11	01-May-98	Arsenic	0.73	X	X		X	
RC-6A	15-Apr-97	Arsenic	<1					
RC-6B	15-Apr-97	Arsenic	<1					
RC-6C	15-Apr-97	Arsenic	<1					
RC-6	19-May-97	Arsenic	0.5	X	X		X	
RC-6	10-Jul-97	Arsenic	0.52	X			X	
RC-6	03-May-98	Arsenic	0.54	X	X		X	
RC-6 * North Bank	15-Sep-97	Arsenic	0.82	X		X	X	
RC-6 North Bank	15-Sep-97	Arsenic	0.81	X		X	X	
RC-1A	16-Apr-97	Arsenic	<1					
RC-1B	16-Apr-97	Arsenic	<1					
RC-1C	16-Apr-97	Arsenic	<1					
RC-1	19-May-97	Arsenic	0.5	X	X		X	
RC-1	10-Jul-97	Arsenic	0.51	X			X	
RC-1	15-Sep-97	Arsenic	0.82	X		X	X	
RC-1	03-May-98	Arsenic	0.53	X	X		X	
Historical Railroad Creek								
USGS 367	01-Jul-94	Arsenic	<2					
USGS 546	01-Jul-95	Arsenic	<1					
USGS 600	01-May-96	Arsenic	<4					
Copper Creek								
CC-1	02-May-98	Arsenic	<0.04	X	X			X
Ten Mile Creek	16-Sep-97	Arsenic	0.14	X		X		X
Stehekin Area								
SF Agnes Creek	30-Sep-97	Arsenic	2.56					
Company Creek	02-Oct-97	Arsenic	0.13	X		X		X

X - Data point was used for statistical analysis.

TABLE 5.3-4
Beryllium Data Points, Background Assessment
Holden Mine RI/FS
Dames & Moore Job No. 17693-005-019

Sample	Date Collected	Metal	Result (ug/L)	Total Set	Seasonal		Railroad Creek	Other Bkg
					Spring	Fall	Set 1A	Set 1B
Holden Creek								
Holden Creek	04-Oct-97	Beryllium	<0.04	X		X		X
HC-1	01-May-98	Beryllium	<0.04	X	X			X
HC-2	30-Apr-98	Beryllium	<0.04	X	X			X
HC-3	30-Apr-98	Beryllium	<0.04	X	X			X
HC-4	30-Apr-98	Beryllium	<0.04	X	X			X
Big Creek								
BIG-1	02-May-98	Beryllium	<0.04	X	X			X
Railroad Creek								
RC-11	04-Oct-97	Beryllium	<0.04	X		X	X	
RC-11	01-May-98	Beryllium	<0.04	X	X		X	
RC-6A	15-Apr-97	Beryllium	<1					
RC-6B	15-Apr-97	Beryllium	<1					
RC-6C	15-Apr-97	Beryllium	<1					
RC-6	19-May-97	Beryllium	<0.04	X	X		X	
RC-6	26-May-97	Beryllium	<0.04	X	X		X	
RC-6	02-Jun-97	Beryllium	<0.04	X	X		X	
RC-6	09-Jun-97	Beryllium	<0.04	X	X		X	
RC-6	16-Jun-97	Beryllium	<0.04	X	X		X	
RC-6	10-Jul-97	Beryllium	<0.04	X			X	
RC-6	03-May-98	Beryllium	<0.04	X	X		X	
RC-6 * North Bank	15-Sep-97	Beryllium	<0.04	X		X	X	
RC-6 North Bank	15-Sep-97	Beryllium	<0.04	X		X	X	
RC-1A	16-Apr-97	Beryllium	<1					
RC-1B	16-Apr-97	Beryllium	<1					
RC-1C	16-Apr-97	Beryllium	<1					
RC-1	19-May-97	Beryllium	<0.04	X	X		X	
RC-1	10-Jul-97	Beryllium	<0.04	X			X	
RC-1	15-Sep-97	Beryllium	<0.04	X		X	X	
RC-1	03-May-98	Beryllium	<0.04	X	X		X	
RC-1 North Bank	19-May-97	Beryllium	<0.04	X	X		X	
RC-1 North Bank	15-Sep-97	Beryllium	<0.04	X		X	X	
RC-1 South Bank	19-May-97	Beryllium	<0.04	X	X		X	
RC-1 South Bank	15-Sep-97	Beryllium	<0.04	X		X	X	
Historical Railroad Creek								
USGS 367	01-Jul-94	Beryllium	<1					
USGS 546	01-Jul-95	Beryllium	<0.3	X			X	
USGS 600	01-May-96	Beryllium	<0.4	X	X		X	
Dept of Ecology	10-Sep-96	Beryllium	NA					
USGS 707	01-Sep-96	Beryllium	<10					
Copper Creek								
CC-1	23-May-97	Beryllium	<0.04	X	X			X
CC-1	11-Jul-97	Beryllium	<0.04	X				X
CC-1	15-Sep-97	Beryllium	<0.04	X		X		X
CC-1	02-May-98	Beryllium	<0.04	X	X			X
Ten Mile Creek	16-Sep-97	Beryllium	<0.04	X		X		X
Stehekin Area								
SF Agnes Creek	30-Sep-97	Beryllium	<0.08	X		X		X
Company Creek	02-Oct-97	Beryllium	<0.04	X		X		X

X - Data point was used for statistical analysis.
NA - Not Analyzed

TABLE 5.3-5
Cadmium Data Points, Background Assessment
Holden Mine RI/FS
Dames & Moore Job No. 17693-005-019

Sample	Date Collected	Metal	Result (ug/L)	Total Set	Seasonal		Railroad Creek	Other Bkg
					Spring	Fall	Set 1A	Set 1B
Holden Creek								
Holden Creek	04-Oct-97	Cadmium	0.05	X		X		X
HC-1	01-May-98	Cadmium	<0.04	X	X			X
HC-2	30-Apr-98	Cadmium	0.05	X	X			X
HC-3	30-Apr-98	Cadmium	<0.04	X	X			X
HC-4	30-Apr-98	Cadmium	0.06	X	X			X
Big Creek								
BIG-1	02-May-98	Cadmium	<0.04	X	X			X
Railroad Creek								
RC-11	04-Oct-97	Cadmium	<0.04	X		X	X	
RC-11	01-May-98	Cadmium	<0.04	X	X		X	
RC-6A	15-Apr-97	Cadmium	<0.2	X			X	
RC-6B	15-Apr-97	Cadmium	<0.2	X			X	
RC-6C	15-Apr-97	Cadmium	<0.2	X			X	
RC-6	19-May-97	Cadmium	<0.04	X	X		X	
RC-6	26-May-97	Cadmium	<0.04	X	X		X	
RC-6	02-Jun-97	Cadmium	<0.04	X	X		X	
RC-6	09-Jun-97	Cadmium	<0.04	X	X		X	
RC-6	16-Jun-97	Cadmium	<0.04	X	X		X	
RC-6	10-Jul-97	Cadmium	<0.04	X			X	
RC-6	03-May-98	Cadmium	0.08	X	X		X	
RC-6 North Bank	15-Sep-97	Cadmium	0.08	X		X	X	
RC-6 North Bank	15-Sep-97	Cadmium	<0.04	X		X	X	
RC-1A	16-Apr-97	Cadmium	<0.2	X			X	
RC-1B	16-Apr-97	Cadmium	<0.2	X			X	
RC-1C	16-Apr-97	Cadmium	<0.2	X			X	
RC-1	19-May-97	Cadmium	<0.04	X	X		X	
RC-1	10-Jul-97	Cadmium	<0.04	X			X	
RC-1	15-Sep-97	Cadmium	<0.04	X		X	X	
RC-1	03-May-98	Cadmium	<0.04	X	X		X	
RC-1 North Bank	19-May-97	Cadmium	0.06	X	X		X	
RC-1 North Bank	15-Sep-97	Cadmium	<0.04	X		X	X	
RC-1 South Bank	19-May-97	Cadmium	0.04	X	X		X	
RC-1 South Bank	15-Sep-97	Cadmium	0.09	X		X	X	
Historical Railroad Creek								
USGS 367	01-Jul-94	Cadmium	<1					
USGS 546	01-Jul-95	Cadmium	<1					
USGS 600	01-May-96	Cadmium	<0.7	X	X		X	
Dept of Ecology	12-Jun-96	Cadmium	0.05	X	X		X	
Dept of Ecology	10-Sep-96	Cadmium	0.02	X		X	X	
USGS 707	01-Sep-96	Cadmium	<10					
Copper Creek								
CC-1	23-May-97	Cadmium	<0.04	X	X			X
CC-1	11-Jul-97	Cadmium	0.08	X				X
CC-1	15-Sep-97	Cadmium	<0.04	X		X		X
CC-1	02-May-98	Cadmium	<0.04	X	X			X
Ten Mile Creek	16-Sep-97	Cadmium	<0.04	X		X		X
Stehekin Area								
SF Agnes Creek	30-Sep-97	Cadmium	<0.04	X		X		X
Company Creek	02-Oct-97	Cadmium	<0.04	X		X		X

X - Data point was used for statistical analysis.

TABLE 5.3-6
Chromium Data Points, Background Assessment
Holden Mine RI/FS
Dames & Moore Job No. 17693-005-019

Sample	Date Collected	Metal	Result (ug/L)	Total Set	Seasonal		Railroad Creek	Other Bkg
					Spring	Fall	Set 1A	Set 1B
Holden Creek								
Holden Creek	04-Oct-97	Chromium	<0.2	X		X		X
HC-1	01-May-98	Chromium	<0.2	X	X			X
HC-2	30-Apr-98	Chromium	<0.2	X	X			X
HC-3	30-Apr-98	Chromium	<0.2	X	X			X
HC-4	30-Apr-98	Chromium	<0.2	X	X			X
Big Creek								
BIG-1	02-May-98	Chromium	<0.2	X	X			X
Railroad Creek								
RC-11	04-Oct-97	Chromium	<0.2	X		X	X	
RC-11	01-May-98	Chromium	<0.2	X	X		X	
RC-6A	15-Apr-97	Chromium	<5					
RC-6B	15-Apr-97	Chromium	<5					
RC-6C	15-Apr-97	Chromium	<5					
RC-6	19-May-97	Chromium	<0.2	X	X		X	
RC-6	26-May-97	Chromium	<0.2	X	X		X	
RC-6	02-Jun-97	Chromium	<0.2	X	X		X	
RC-6	09-Jun-97	Chromium	<0.2	X	X		X	
RC-6	16-Jun-97	Chromium	<5					
RC-6	10-Jul-97	Chromium	<0.2	X			X	
RC-6	03-May-98	Chromium	<0.2	X	X		X	
RC-6 North Bank	15-Sep-97	Chromium	<0.2	X		X	X	
RC-6 North Bank	15-Sep-97	Chromium	<0.2	X		X	X	
RC-1A	16-Apr-97	Chromium	<5					
RC-1B	16-Apr-97	Chromium	<5					
RC-1C	16-Apr-97	Chromium	<5					
RC-1	19-May-97	Chromium	<0.2	X	X		X	
RC-1	10-Jul-97	Chromium	<0.2	X			X	
RC-1	15-Sep-97	Chromium	<0.2	X		X	X	
RC-1	03-May-98	Chromium	<0.2	X	X		X	
RC-1 North Bank	19-May-97	Chromium	<0.2	X	X		X	
RC-1 North Bank	15-Sep-97	Chromium	<0.2	X		X	X	
RC-1 South Bank	19-May-97	Chromium	<0.2	X	X		X	
RC-1 South Bank	15-Sep-97	Chromium	<0.2	X		X	X	
Historical Railroad Creek								
USGS 367	01-Jul-94	Chromium	<1	X			X	
USGS 546	01-Jul-95	Chromium	<0.9	X			X	
USGS 600	01-May-96	Chromium	<0.5	X	X		X	
Dept of Ecology	10-Sep-96	Chromium	NA					
USGS 707	01-Sep-96	Chromium	<10	X		X	X	
Copper Creek								
CC-1	23-May-97	Chromium	<5					
CC-1	11-Jul-97	Chromium	<0.2	X				X
CC-1	15-Sep-97	Chromium	<0.2	X		X		X
CC-1	02-May-98	Chromium	<0.2	X	X			X
Ten Mile Creek	16-Sep-97	Chromium	<0.2	X		X		X
Stehekin Area								
SF Agnes Creek	30-Sep-97	Chromium	<0.2	X		X		X
Company Creek	02-Oct-97	Chromium	<0.2	X		X		X

X - Data point was used for statistical analysis.
NA - Not Analyzed

TABLE 5.3-7
Copper Data Points, Background Assessment
Holden Mine RI/FS
Dames & Moore Job No. 17693-005-019

Sample	Date Collected	Metal	Result (ug/L)	Total Set	Seasonal		Railroad Creek	Other Bkg
					Spring	Fall	Set 1A	Set 1B
Holden Creek								
Holden Creek	04-Oct-97	Copper	0.9	X		X		X
HC-1	01-May-98	Copper	0.6	X	X			X
HC-2	30-Apr-98	Copper	0.7	X	X			X
HC-3	30-Apr-98	Copper	0.6	X	X			X
HC-4	30-Apr-98	Copper	0.5	X	X			X
Big Creek								
BIG-1	02-May-98	Copper	0.3	X	X			X
Railroad Creek								
RC-11	04-Oct-97	Copper	1.1	X		X	X	
RC-11	01-May-98	Copper	0.7	X	X		X	
RC-6A	15-Apr-97	Copper	<2					
RC-6B	15-Apr-97	Copper	<2					
RC-6C	15-Apr-97	Copper	<2					
RC-6	19-May-97	Copper	0.7	X	X		X	
RC-6	26-May-97	Copper	1	X	X		X	
RC-6	02-Jun-97	Copper	0.9	X	X		X	
RC-6	09-Jun-97	Copper	<1.2	X	X		X	
RC-6	16-Jun-97	Copper	<2					
RC-6	10-Jul-97	Copper	0.6	X			X	
RC-6	03-May-98	Copper	0.6	X	X		X	
RC-6 * North Bank	15-Sep-97	Copper	0.5	X		X	X	
RC-6 North Bank	15-Sep-97	Copper	0.4	X		X	X	
RC-1A	16-Apr-97	Copper	<2					
RC-1B	16-Apr-97	Copper	<2					
RC-1C	16-Apr-97	Copper	<2					
RC-1	19-May-97	Copper	1.1	X	X		X	
RC-1	10-Jul-97	Copper	0.6	X			X	
RC-1	15-Sep-97	Copper	0.4	X		X	X	
RC-1	03-May-98	Copper	0.8	X	X		X	
RC-1 North Bank	19-May-97	Copper	1	X	X		X	
RC-1 North Bank	15-Sep-97	Copper	0.6	X		X	X	
RC-1 South Bank	19-May-97	Copper	1	X	X		X	
RC-1 South Bank	15-Sep-97	Copper	0.6	X		X	X	
Historical Railroad Creek								
USGS 367	01-Jul-94	Copper	0.62	X			X	
USGS 546	01-Jul-95	Copper	3					
USGS 600	01-May-96	Copper	6.5					
Dept of Ecology	12-Jun-96	Copper	0.96	X	X		X	
Dept of Ecology	10-Sep-96	Copper	0.26	X		X	X	
USGS 707	01-Sep-96	Copper	<10					
Copper Creek								
CC-1	23-May-97	Copper	<2					
CC-1	11-Jul-97	Copper	0.3	X				X
CC-1	15-Sep-97	Copper	0.2	X		X		X
CC-1	02-May-98	Copper	0.5	X	X			X
Ten Mile Creek	16-Sep-97	Copper	0.3	X		X		X
Stehekin Area								
SF Agnes Creek	30-Sep-97	Copper	0.5	X		X		X
Company Creek	02-Oct-97	Copper	0.4	X		X		X

X - Data point was used for statistical analysis.

TABLE 5.3-8
Iron Data Points, Background Assessment
Holden Mine RI/FS
Dames & Moore Job No. 17693-005-019

Sample	Date Collected	Metal	Result (ug/L)	Total Set	Seasonal		Railroad Creek	Other Bkg
					Spring	Fall	Set 1A	Set 1B
Holden Creek								
Holden Creek	04-Oct-97	Iron	<20	X		X		X
HC-1	01-May-98	Iron	<20	X	X			X
HC-2	30-Apr-98	Iron	<20	X	X			X
HC-3	30-Apr-98	Iron	20	X	X			X
HC-4	30-Apr-98	Iron	30	X	X			X
Big Creek								
BIG-1	02-May-98	Iron	<20	X	X			X
Railroad Creek								
RC-11	04-Oct-97	Iron	60	X		X	X	
RC-11	01-May-98	Iron	30	X	X		X	
RC-6A	15-Apr-97	Iron	30	X			X	
RC-6B	15-Apr-97	Iron	40	X			X	
RC-6C	15-Apr-97	Iron	40	X			X	
RC-6	19-May-97	Iron	30	X	X		X	
RC-6	26-May-97	Iron	30	X	X		X	
RC-6	02-Jun-97	Iron	30	X	X		X	
RC-6	09-Jun-97	Iron	<20	X	X		X	
RC-6	16-Jun-97	Iron	<20	X	X		X	
RC-6	10-Jul-97	Iron	<20	X			X	
RC-6	03-May-98	Iron	30	X	X		X	
RC-6 * North Bank	15-Sep-97	Iron	40	X		X	X	
RC-6 North Bank	15-Sep-97	Iron	40	X		X	X	
RC-1A	16-Apr-97	Iron	40	X			X	
RC-1B	16-Apr-97	Iron	40	X			X	
RC-1C	16-Apr-97	Iron	40	X			X	
RC-1	19-May-97	Iron	30	X	X		X	
RC-1	10-Jul-97	Iron	<20	X			X	
RC-1	15-Sep-97	Iron	40	X		X	X	
RC-1	03-May-98	Iron	20	X	X		X	
RC-1 North Bank	19-May-97	Iron	<20	X	X		X	
RC-1 North Bank	15-Sep-97	Iron	40	X		X	X	
RC-1 South Bank	19-May-97	Iron	<20	X	X		X	
RC-1 South Bank	15-Sep-97	Iron	40	X		X	X	
Historical Railroad Creek								
USGS 367	01-Jul-94	Iron	<100					
USGS 546	01-Jul-95	Iron	40	X			X	
USGS 600	01-May-96	Iron	91	X	X		X	
USGS 707	01-Sep-96	Iron	<100					
Copper Creek								
CC-1	23-May-97	Iron	<20	X	X			X
CC-1	11-Jul-97	Iron	<20	X				X
CC-1	15-Sep-97	Iron	<20	X		X		X
CC-1	02-May-98	Iron	<20	X	X			X
Ten Mile Creek	16-Sep-97	Iron	<20	X		X		X
Stehekin Area								
SF Agnes Creek	30-Sep-97	Iron	<20	X		X		X
Company Creek	02-Oct-97	Iron	<20	X		X		X

X - Data point was used for statistical analysis.

TABLE 5.3-9
Lead Data Points, Background Assessment
Holden Mine RI/FS
Dames & Moore Job No. 17693-005-019

Sample	Date Collected	Metal	Result (ug/L)	Total Set	Seasonal		Railroad Creek	Other Bkg
					Spring	Fall	Set 1A	Set 1B
Holden Creek								
Holden Creek	04-Oct-97	Lead	0.3	X		X		X
HC-1	01-May-98	LL Lead	0.018	X	X			X
HC-2	30-Apr-98	LL Lead	<0.011	X	X			X
HC-3	30-Apr-98	LL Lead	<0.011	X	X			X
HC-4	30-Apr-98	LL Lead	<0.011	X	X			X
Big Creek								
BIG-1	02-May-98	LL Lead	<0.011	X	X			X
Railroad Creek								
RC-11	04-Oct-97	Lead	<0.2	X		X	X	
RC-11	01-May-98	Lead	0.5	X	X		X	
RC-6A	15-Apr-97	Lead	<1					
RC-6B	15-Apr-97	Lead	<1					
RC-6C	15-Apr-97	Lead	<1					
RC-6	19-May-97	Lead	<0.9	X	X		X	
RC-6	26-May-97	Lead	<0.3	X	X		X	
RC-6	02-Jun-97	Lead	<1.8					
RC-6	09-Jun-97	Lead	<0.2	X	X		X	
RC-6	16-Jun-97	Lead	<0.2	X	X		X	
RC-6	10-Jul-97	Lead	0.2	X			X	
RC-6	03-May-98	LL Lead	<0.011	X	X		X	
RC-6 North Bank	15-Sep-97	Lead	0.9	X		X	X	
RC-6 North Bank	15-Sep-97	Lead	<0.2	X		X	X	
RC-1A	16-Apr-97	Lead	<1					
RC-1B	16-Apr-97	Lead	<1					
RC-1C	16-Apr-97	Lead	<1					
RC-1	19-May-97	Lead	<0.2	X	X		X	
RC-1	10-Jul-97	Lead	0.3	X			X	
RC-1	15-Sep-97	Lead	0.5	X		X	X	
RC-1	03-May-98	LL Lead	<0.011	X	X		X	
RC-1 North Bank	19-May-97	Lead	<1.1					
RC-1 North Bank	15-Sep-97	Lead	<0.2	X		X	X	
RC-1 South Bank	19-May-97	Lead	<0.7	X	X		X	
RC-1 South Bank	15-Sep-97	Lead	0.2	X		X	X	
Historical Railroad Creek								
USGS 367	01-Jul-94	Lead	<0.2	X			X	
USGS 546	01-Jul-95	Lead	<0.3	X			X	
USGS 600	01-May-96	Lead	0.2	X	X		X	
Dept of Ecology	12-Jun-96	Lead	0.02	X	X		X	
Dept of Ecology	10-Sep-96	Lead	0.02	X		X	X	
USGS 707	01-Sep-96	Lead	<50					
Copper Creek								
CC-1	23-May-97	Lead	<0.4	X	X			X
CC-1	11-Jul-97	Lead	1.8	X				X
CC-1	15-Sep-97	Lead	<0.2	X		X		X
CC-1	02-May-98	LL Lead	<0.011	X	X			X
Ten Mile Creek	16-Sep-97	Lead	<0.2	X		X		X
Stehekin Area								
SF Agnes Creek	30-Sep-97	Lead	<0.2	X		X		X
Company Creek	02-Oct-97	Lead	<0.2	X		X		X

X - Data point was used for statistical analysis.

TABLE 5.3-10
Magnesium Data Points, Background Assessment
Holden Mine RI/FS
Dames & Moore Job No. 17693-005-019

Sample	Date Collected	Metal	Result (ug/L)	Total Set	Seasonal		Railroad Creek	Other Bkg
					Spring	Fall	Set 1A	Set 1B
Holden Creek								
Holden Creek	04-Oct-97	Magnesium	330	X		X		X
HC-1	01-May-98	Magnesium	520	X	X			X
HC-2	30-Apr-98	Magnesium	580	X	X			X
HC-3	30-Apr-98	Magnesium	570	X	X			X
HC-4	30-Apr-98	Magnesium	230	X	X			X
Big Creek								
BIG-1	02-May-98	Magnesium	350	X	X			X
Railroad Creek								
RC-11	04-Oct-97	Magnesium	260	X		X	X	
RC-11	01-May-98	Magnesium	230	X	X		X	
RC-6A	15-Apr-97	Magnesium	640	X			X	
RC-6B	15-Apr-97	Magnesium	650	X			X	
RC-6C	15-Apr-97	Magnesium	660	X			X	
RC-6	19-May-97	Magnesium	360	X	X		X	
RC-6	26-May-97	Magnesium	370	X	X		X	
RC-6	02-Jun-97	Magnesium	340	X	X		X	
RC-6	09-Jun-97	Magnesium	310	X	X		X	
RC-6	16-Jun-97	Magnesium	250	X	X		X	
RC-6	10-Jul-97	Magnesium	260	X			X	
RC-6	03-May-98	Magnesium	320	X	X		X	
RC-6 * North Bank	15-Sep-97	Magnesium	350	X		X	X	
RC-6 North Bank	15-Sep-97	Magnesium	350	X		X	X	
RC-1A	16-Apr-97	Magnesium	660	X			X	
RC-1B	16-Apr-97	Magnesium	660	X			X	
RC-1C	16-Apr-97	Magnesium	660	X			X	
RC-1	19-May-97	Magnesium	360	X	X		X	
RC-1	10-Jul-97	Magnesium	270	X			X	
RC-1	15-Sep-97	Magnesium	350	X		X	X	
RC-1	03-May-98	Magnesium	330	X	X		X	
RC-1 North Bank	19-May-97	Magnesium	360	X	X		X	
RC-1 North Bank	15-Sep-97	Magnesium	340	X		X	X	
RC-1 South Bank	19-May-97	Magnesium	360	X	X		X	
RC-1 South Bank	15-Sep-97	Magnesium	350	X		X	X	
Historical Railroad Creek								
USGS 367	01-Jul-94	Magnesium	270	X			X	
USGS 546	01-Jul-95	Magnesium	280	X			X	
USGS 600	01-May-96	Magnesium	<1000					
Dept of Ecology	10-Sep-96	Magnesium	NA					
USGS 707	01-Sep-96	Magnesium	<1000					
Copper Creek								
CC-1	23-May-97	Magnesium	550	X	X			X
CC-1	11-Jul-97	Magnesium	390	X				X
CC-1	15-Sep-97	Magnesium	470	X		X		X
CC-1	02-May-98	Magnesium	430	X	X			X
Ten Mile Creek	16-Sep-97	Magnesium	790	X		X		X
Stehekin Area								
SF Agnes Creek	30-Sep-97	Magnesium	300	X		X		X
Company Creek	02-Oct-97	Magnesium	560	X		X		X

X - Data point was used for statistical analysis.

TABLE 5.3-11
Manganese Data Points, Background Assessment
Holden Mine RI/FS
Dames & Moore Job No. 17693-005-019

Sample	Date Collected	Metal	Result (ug/L)	Total Set	Seasonal		Railroad Creek	Other Bkg
					Spring	Fall	Set 1A	Set 1B
Holden Creek								
Holden Creek	04-Oct-97	Manganese	1.8	X		X		X
HC-1	01-May-98	Manganese	0.78	X	X			X
HC-2	30-Apr-98	Manganese	2.91	X	X			X
HC-3	30-Apr-98	Manganese	1.32	X	X			X
HC-4	30-Apr-98	Manganese	1.05	X	X			X
Big Creek								
BIG-1	02-May-98	Manganese	<0.29	X	X			X
Railroad Creek								
RC-11	04-Oct-97	Manganese	3.17	X		X	X	
RC-11	01-May-98	Manganese	2.88	X	X		X	
RC-6A	15-Apr-97	Manganese	2	X			X	
RC-6B	15-Apr-97	Manganese	1	X			X	
RC-6C	15-Apr-97	Manganese	1	X			X	
RC-6	19-May-97	Manganese	1.94	X	X		X	
RC-6	26-May-97	Manganese	1.4	X	X		X	
RC-6	02-Jun-97	Manganese	1.23	X	X		X	
RC-6	09-Jun-97	Manganese	0.96	X	X		X	
RC-6	16-Jun-97	Manganese	1	X	X		X	
RC-6	10-Jul-97	Manganese	1.18	X			X	
RC-6	03-May-98	Manganese	2.08	X	X		X	
RC-6 North Bank	15-Sep-97	Manganese	1.72	X		X	X	
RC-6 North Bank	15-Sep-97	Manganese	1.74	X		X	X	
RC-1A	16-Apr-97	Manganese	2	X			X	
RC-1B	16-Apr-97	Manganese	1	X			X	
RC-1C	16-Apr-97	Manganese	1	X			X	
RC-1	19-May-97	Manganese	1.82	X	X		X	
RC-1	10-Jul-97	Manganese	1.13	X			X	
RC-1	15-Sep-97	Manganese	1.65	X		X	X	
RC-1	03-May-98	Manganese	2	X	X		X	
RC-1 North Bank	19-May-97	Manganese	1.86	X	X		X	
RC-1 North Bank	15-Sep-97	Manganese	1.67	X		X	X	
RC-1 South Bank	19-May-97	Manganese	1.83	X	X		X	
RC-1 South Bank	15-Sep-97	Manganese	1.68	X		X	X	
Historical Railroad Creek								
USGS 367	01-Jul-94	Manganese	2	X			X	
USGS 546	01-Jul-95	Manganese	1.6	X			X	
USGS 600	01-May-96	Manganese	<3					
USGS 707	01-Sep-96	Manganese	<10					
Copper Creek								
CC-1	23-May-97	Manganese	<1					
CC-1	11-Jul-97	Manganese	0.13	X				X
CC-1	15-Sep-97	Manganese	<0.13	X		X		X
CC-1	02-May-98	Manganese	0.82	X	X			X
Ten Mile Creek	16-Sep-97	Manganese	<0.14	X		X		X
Stehekin Area								
SF Agnes Creek	30-Sep-97	Manganese	0.62	X		X		X
Company Creek	02-Oct-97	Manganese	0.29	X		X		X

X - Data point was used for statistical analysis.

TABLE 5.3-12
Selenium Data Points, Background Assessment
Holden Mine RI/FS
Dames & Moore Job No. 17693-005-019

Sample	Date Collected	Metal	Result (ug/L)	Total Set	Seasonal		Railroad Creek	Other Bkg
					Spring	Fall	Set 1A	Set 1B
Holden Creek								
Holden Creek	04-Oct-97	Selenium	NA					
HC-1	01-May-98	Selenium	NA					
HC-2	30-Apr-98	Selenium	NA					
HC-3	30-Apr-98	Selenium	NA					
HC-4	30-Apr-98	Selenium	NA					
Big Creek								
BIG-1	02-May-98	Selenium	NA					
Railroad Creek								
RC-11	04-Oct-97	Selenium	NA					
RC-11	01-May-98	Selenium	NA					
RC-6A	15-Apr-97	Selenium	<1	X			X	
RC-6B	15-Apr-97	Selenium	<1	X			X	
RC-6C	15-Apr-97	Selenium	<1	X			X	
RC-6	19-May-97	Selenium	<0.2	X	X		X	
RC-6	26-May-97	Selenium	NA					
RC-6	02-Jun-97	Selenium	NA					
RC-6	09-Jun-97	Selenium	NA					
RC-6	16-Jun-97	Selenium	NA					
RC-6	10-Jul-97	Selenium	<0.2	X			X	
RC-6	03-May-98	Selenium	NA					
RC-6 North Bank	15-Sep-97	Selenium	NA					
RC-6 North Bank	15-Sep-97	Selenium	NA					
RC-1A	16-Apr-97	Selenium	<1	X			X	
RC-1B	16-Apr-97	Selenium	<1	X			X	
RC-1C	16-Apr-97	Selenium	<1	X			X	
RC-1	19-May-97	Selenium	<0.2	X	X		X	
RC-1	10-Jul-97	Selenium	<0.2	X			X	
RC-1	15-Sep-97	Selenium	NA					
RC-1	03-May-98	Selenium	NA					
RC-1 North Bank	19-May-97	Selenium	NA					
RC-1 North Bank	15-Sep-97	Selenium	NA					
RC-1 South Bank	19-May-97	Selenium	NA					
RC-1 South Bank	15-Sep-97	Selenium	NA					
Historical Railroad Creek								
USGS 367	01-Jul-94	Selenium	NA					
USGS 546	01-Jul-95	Selenium	NA					
USGS 600	01-May-96	Selenium	NA					
Dept of Ecology	10-Sep-96	Selenium	NA					
USGS 707	01-Sep-96	Selenium	NA					
Copper Creek								
CC-1	23-May-97	Selenium	NA					X
CC-1	11-Jul-97	Selenium	NA					X
CC-1	15-Sep-97	Selenium	NA					X
CC-1	02-May-98	Selenium	NA					
Ten Mile Creek	16-Sep-97	Selenium	NA					X
Stehekin Area								
SF Agnes Creek	30-Sep-97	Selenium	NA					X
Company Creek	02-Oct-97	Selenium	NA					X

X - Data point was used for statistical analysis.
NA - Not Analyzed
Note: Statistical analysis was not performed for seasonal due to limited sample results.

TABLE 5.3-13
Silver Data Points. Background Assessment
Holden Mine RI/FS
Dames & Moore Job No. 17693-005-019

Sample	Date Collected	Metal	Result (ug/L)	Total Set	Seasonal		Railroad Creek	Other Bkg
					Spring	Fall	Set 1A	Set 1B
Holden Creek								
Holden Creek	04-Oct-97	Silver	<0.04	X		X		X
HC-1	01-May-98	Silver	<0.04	X	X			X
HC-2	30-Apr-98	Silver	<0.04	X	X			X
HC-3	30-Apr-98	Silver	<0.04	X	X			X
HC-4	30-Apr-98	Silver	<0.04	X	X			X
Big Creek								
BIG-1	02-May-98	Silver	<0.04	X	X			X
Railroad Creek								
RC-11	04-Oct-97	Silver	<0.04	X		X	X	
RC-11	01-May-98	Silver	<0.04	X	X		X	
RC-6A	15-Apr-97	Silver	<0.2	X			X	
RC-6B	15-Apr-97	Silver	<0.2	X			X	
RC-6C	15-Apr-97	Silver	<0.2	X			X	
RC-6	19-May-97	Silver	<0.04	X	X		X	
RC-6	26-May-97	Silver	<0.04	X	X		X	
RC-6	02-Jun-97	Silver	<0.04	X	X		X	
RC-6	09-Jun-97	Silver	<0.04	X	X		X	
RC-6	16-Jun-97	Silver	<0.04	X	X		X	
RC-6	10-Jul-97	Silver	<0.04	X			X	
RC-6	03-May-98	Silver	<0.04	X	X		X	
RC-6 * North Bank	15-Sep-97	Silver	<0.04	X		X	X	
RC-6 North Bank	15-Sep-97	Silver	<0.04	X		X	X	
RC-1A	16-Apr-97	Silver	<0.2	X			X	
RC-1B	16-Apr-97	Silver	<0.2	X			X	
RC-1C	16-Apr-97	Silver	<0.2	X			X	
RC-1	19-May-97	Silver	<0.04	X	X		X	
RC-1	10-Jul-97	Silver	<0.04	X			X	
RC-1	15-Sep-97	Silver	<0.04	X		X	X	
RC-1	03-May-98	Silver	<0.04	X	X		X	
RC-1 North Bank	19-May-97	Silver	<0.04	X	X		X	
RC-1 North Bank	15-Sep-97	Silver	<0.04	X		X	X	
RC-1 South Bank	19-May-97	Silver	<0.04	X	X		X	
RC-1 South Bank	15-Sep-97	Silver	<0.04	X		X	X	
Historical Railroad Creek								
USGS 367	01-Jul-94	Silver	<0.1	X			X	
USGS 546	01-Jul-95	Silver	<0.1	X			X	
USGS 600	01-May-96	Silver	<0.6	X	X		X	
Dept of Ecology	10-Sep-96	Silver	NA					
USGS 707	01-Sep-96	Silver	NA					
Copper Creek								
CC-1	23-May-97	Silver	<0.04	X	X			X
CC-1	11-Jul-97	Silver	<0.04	X				X
CC-1	15-Sep-97	Silver	<0.04	X		X		X
CC-1	02-May-98	Silver	<0.04	X	X			X
Ten Mile Creek	16-Sep-97	Silver	<0.04	X		X		X
Stehekin Area								
SF Agnes Creek	30-Sep-97	Silver	<0.04	X		X		X
Company Creek	02-Oct-97	Silver	<0.04	X		X		X

X - Data point was used for statistical analysis.
NA - Not Analyzed

TABLE 5.3-14
Zinc Data Points, Background Assessment
Holden Mine RI/FS
Dames & Moore Job No. 17693-005-019

Sample	Date Collected	Metal	Dissolved Result (ug/L)	Total Result (ug/L)	Total Set	Seasonal		Railroad Creek	Other Bkg
						Spring	Fall	Set 1A	Set 1B
Holden Creek									
Holden Creek	04-Oct-97	Zinc	6		X		X		X
HC-1	01-May-98	Zinc	<4		X	X			X
HC-2	30-Apr-98	Zinc	<4		X	X			X
HC-3	30-Apr-98	Zinc	<4		X	X			X
HC-4	30-Apr-98	Zinc	<4		X	X			X
Big Creek									
BIG-1	02-May-98	Zinc	<4		X	X			X
Railroad Creek									
RC-11	04-Oct-97	Zinc	5		X		X	X	
RC-11	01-May-98	Zinc	<4		X	X		X	
RC-6A	15-Apr-97	Zinc	6	<4	X			X	
RC-6B	15-Apr-97	Zinc	6	<4	X			X	
RC-6C	15-Apr-97	Zinc	5	<4	X			X	
RC-6	19-May-97	Zinc	16	<4	X	X		X	
RC-6	26-May-97	Zinc	<14	<4	X	X		X	
RC-6	02-Jun-97	Zinc	<13	<4	X	X		X	
RC-6	09-Jun-97	Zinc	<16	<4	X	X		X	
RC-6	16-Jun-97	Zinc	12		X	X		X	
RC-6	10-Jul-97	Zinc	6	<4	X			X	
RC-6	03-May-98	Zinc	<4		X	X		X	
RC-6 * North Bank	15-Sep-97	Zinc	4		X		X	X	
RC-6 North Bank	15-Sep-97	Zinc	16		X		X	X	
RC-1A	16-Apr-97	Zinc	5	<4	X			X	
RC-1B	16-Apr-97	Zinc	5	<4	X			X	
RC-1C	16-Apr-97	Zinc	<4	<4	X			X	
RC-1	19-May-97	Zinc	13	<4	X	X		X	
RC-1	10-Jul-97	Zinc	6	5	X			X	
RC-1	15-Sep-97	Zinc	<4		X		X	X	
RC-1	03-May-98	Zinc	<4		X	X		X	
RC-1 North Bank	19-May-97	Zinc	16	<4	X	X		X	
RC-1 North Bank	15-Sep-97	Zinc	9		X		X	X	
RC-1 South Bank	19-May-97	Zinc	13	5	X	X		X	
RC-1 South Bank	15-Sep-97	Zinc	<4		X		X	X	
Historical Railroad Creek									
USGS 367	01-Jul-94	Zinc	4		X			X	
USGS 546	01-Jul-95	Zinc	10		X			X	
USGS 600	01-May-96	Zinc	3.4		X	X		X	
Dept of Ecology	12-Jun-96	Zinc	1.3		X	X		X	
Dept of Ecology	10-Sep-96	Zinc	0.85		X		X	X	
USGS 707	01-Sep-96	Zinc	<10		X		X	X	
Copper Creek									
CC-1	23-May-97	Zinc	12	<4	X	X			X
CC-1	11-Jul-97	Zinc	10	<4	X				X
CC-1	15-Sep-97	Zinc	<4		X		X		X
CC-1	02-May-98	Zinc	<4		X	X			X
Ten Mile Creek	16-Sep-97	Zinc	<4		X		X		X
Stehekin Area									
SF Agnes Creek	30-Sep-97	Zinc	11		X		X		X
Company Creek	02-Oct-97	Zinc	7		X		X		X

X - Data point was used for statistical analysis.

TABLE 5.3-15
Statistical Summary - Spring Data Set, Background Assessment[1]
Holden Mine RI/FS
Dames & Moore Job No. 17693-005-019

Metal	# data pts	# detects	# nondetects	Distribution	90th %[2]	mean[3]	std dev	median	min	max
Aluminum	19	12	7	Normal	47.74	34.167	11.645	30	20	60
Arsenic	10	10	0	Lognormal	0.84	0.557	0.196	0.515	0.29	1
Cadmium	20	6	14	Lognormal	0.06	0.057	0.014	0.055	0.04	0.08
Copper	18	17	1	Lognormal	1.02	0.754	0.228	0.7	0.3	1.1
Iron	19	10	9	Non-Parametric	30	34.1	20.42	30	20	91
Lead	18	4	14	Lognormal	0.31	0.311	0.227	0.11	0.018	0.5
Magnesium	18	18	0	Lognormal	540	380	110	360	230	580
Manganese	17	16	1	Lognormal	2.64	1.628	0.665	1.61	0.78	2.91
Zinc	20	4	16	Non-Parametric	4.84	5.425	4.638	4.2	1.3	12

Notes:

[1] Statistical analysis calculated using MTCA Stat Background Module (an Excel 5.0 macro), designed by the Washington Department of Ecology.

[2] 90th percentile values are in ug/L.

[3] The mean value is based on lognormal except where data distribution is normal or non-parametric.

TABLE 5.3-16
Statistical Summary -Fall Data Set, Background Assessment[1]
Holden Mine RI/FS
Dames & Moore Job No. 17693-005-019

Metal	# data pts	# detects	# nondetects	Distribution	90th %[2]	mean[3]	std dev	median	min	max
Aluminum	13	3	10	Non-Parametric	26	16.133	12.143	11	7.4	30
Arsenic	8	8	0	Non-Parametric	N/A	0.84	0.763	0.815	0.13	2.56
Cadmium	12	4	8	Lognormal	0.08	0.065	0.032	0.065	0.02	0.09
Copper	12	12	0	Lognormal	0.90	0.518	0.262	0.45	0.2	1.1
Iron	11	6	5	Non-Parametric	56	43.33	8.165	40	40	60
Lead	12	5	7	Lognormal	0.56	0.644	0.337	0.3	0.02	0.9
Magnesium	11	11	0	Non-Parametric	744	405	152	350	260	790
Manganese	11	9	2	Non-Parametric	2.9	1.593	0.808	1.68	0.29	3.17
Zinc	13	8	5	Lognormal	12.95	8.468	4.657	6.5	0.85	16

Notes:

[1] Statistical analysis calculated using MTCA Stat Background Module (an Excel 5.0 macro), designed by the Washington Department of Ecology

[2] 90th percentile values are in ug/L.

[3] The mean value is based on lognormal except where data distribution is normal or non-parametric.

TABLE 5.3-17
Statistical Summary - Set 1A (Railroad Creek) and Set 1B (Other Background), Background Assessment[1]
Holden Mine RI/FS
Dames & Moore Job No. 17693-005-019

Metal	Data Sets	# data pts	# detects	# nondetects	Distribution	90th %[2]	mean[3]	std dev	median	min	max
Aluminum	Set 1A	30	18	12	lognormal	39.23	28.194	12.309	30	7.4	60
	Set 1B	13	4	9	lognormal	36.82	33.048	12.583	30	20	50
Arsenic	Set 1A	11	11	0	non-parametric	0.92	0.656	0.168	0.54	0.5	0.94
	Set 1B	8	8	0	lognormal	0.97	0.461	0.282	0.42	0.13	1
Cadmium	Set 1A	28	7	21	lognormal	0.07	0.062	0.025	0.06	0.02	0.09
	Set 1B	13	4	9	lognormal	0.07	0.06	0.014	0.055	0.05	0.08
Copper	Set 1A	21	20	1	lognormal	1.13	0.729	0.248	0.66	0.26	1.1
	Set 1B	12	12	0	lognormal	0.81	0.489	0.199	0.5	0.2	0.9
Iron	Set 1A	27	21	6	non-parametric	44	39.095	14.29	40	20	91
	Set 1B	13	2	11	non-parametric	26	25	7.071	25	20	30
Lead	Set 1A	22	9	13	lognormal	0.53	0.453	0.279	0.2	0.02	0.9
	Set 1B	13	3	10	non-parametric	1.20	0.706	0.958	0.3	0.018	1.8
Magnesium	Set 1A	27	27	0	non-parametric	660	393	148	350	230	660
	Set 1B	13	13	0	lognormal	703	467	150	470	230	790
Manganese	Set 1A	27	27	0	lognormal	2.47	1.653	0.556	1.68	0.96	3.17
	Set 1B	12	9	3	lognormal	2.57	1.213	0.853	0.82	0.13	2.91
Zinc	Set 1A	31	12	19	lognormal	8.1	6.86	4.536	5	0.85	16
	Set 1B	13	3	10	non-parametric	9.4	8	2.646	7	6	11

Notes:

[1] Statistical analysis calculated using MTCA Stat Background Module (an Excel 5.0 macro), designed by the Washington Department of Ecology.

[2] 90th percentile values are in ug/L.

[3] The mean value is based on lognormal except where data distribution is normal or non-parametric.

TABLE 5.3-18
SUMMARY OF RI SURFACE WATER ANALYTICAL RESULTS
STEHEKIN REFERENCE STREAMS
HOLDEN MINE RI/FS
DAMES & MOORE JOB NO. 17693-005-019

Parameter	Sample ID Sampling Date	Bridge Creek 9/28/97	Bridge Creek X* 9/28/97	SF Agnes Creek 9/30/97	Company Creek 10/2/97
Total Metals, (µg/L)					
Aluminum		50U	30U	110U	30U
Arsenic		0.25	0.24	2.84	0.14
Barium		5.07	5.38	4.91	6.27
Beryllium		0.04U	0.08U	0.04U	0.08U
Cadmium		0.04U	0.04U	0.04U	0.04U
Calcium		4,790	4,750	2,420	6,980
Chromium		0.2U	0.2U	0.2U	1U
Copper		0.3	0.4	0.4	0.4
Iron		20U	20U	90	20U
Lead		0.2U	0.2	0.2U	0.3
Magnesium		470	470	340	570
Manganese		0.54	0.47	1.79	0.9
Molybdenum		1.24	1.23	0.98	0.60
Nickel		0.2U	0.2U	0.2U	0.3
Potassium		500U	500U	500U	500U
Silver		0.08J	0.09J	0.15J	0.04U
Sodium		750U	760U	610U	840U
Zinc		4U	4U	4U	4U
Dissolved Metals, (µg/L)					
Aluminum		30U	30U	20U	20U
Arsenic		0.24	0.24	2.56	0.13
Barium		5.30	5.25	4.36	6.14
Beryllium		0.08U	0.08U	0.08U	0.04U
Cadmium		0.04U	0.04U	0.04U	0.04U
Calcium		4,750	4,750	2,350	6,890
Chromium		0.2U	0.2U	0.2U	0.2U
Copper		0.4	1.4	0.5	0.4
Iron		20U	20U	20U	20U
Lead		0.2	0.3	0.2U	0.2U
Magnesium		460	460	300	560
Manganese		0.31	0.26	0.62	0.29
Molybdenum		1.24	1.26	1.02	0.61
Nickel		0.2	0.2U	0.2	0.2
Potassium		500U	500U	560	500U
Silver		0.04U	0.04U	0.04U	0.04U
Sodium		740U	740U	590U	880U
Zinc		7	7	11	7
Conventional Analyses (mg/L)					
Total Dissolved Solids		21J	27J	24J	45J
Total Suspended Solids		1.0UJ	1.0UJ	1.1UJ	1.1U
Sulfate		2.5U	2.5U	2.5U	4.6
Alkalinity		15	14	7.1	15
Hardness, Dissolved		14	14	7	20
Field Measurements					
pH		6.4	▨	6.5	6.1
Specific Conductivity (µS)		31	▨	16	60
Temperature (°C)		8.9	▨	8.3	7.3
Dissolved Oxygen (mg/L)		11.06	▨	11.62	11.75

Notes:
J - Estimated Value.
U - Parameter was analyzed for, but not detected above the reporting limit shown.
UJ - Parameter was analyzed for but not detected. Detection limit is an estimated value.
* 'X' after sample ID is an indication of field sample duplicate.
▨ **Grey shading** indicates the concentration of analyte was not established, therefore not reported nor analyzed.

TABLE 5.3-19
STATION RC-1 AND PROXIMITY SUMMARY OF HISTORICAL RAILROAD CREEK ANALYTICAL DATA (1982-1996)
HOLDEN MINE RI/FS
DAMES & MOORE JOB NO. 17693-005-019

Parameters Sample ID	1982 USFS WATER QUALITY DATA [a]						1983 USFS WATER QUALITY DATA [a]						1991 BATTELLE WATER QUALITY MONITORING DATA [b]							
Sampling Date	5/12/82	6/10/82	6/23/82	7/14/82	8/25/82	9/29/82	6/1/83	6/22/83	7/20/83	8/11/83	8/31/83	9/28/83	5/10/91	5/18/91	6/3/91	6/18/91	7/2/91	7/16/91	8/6/91	9/17/91
Total Metals (µg/L)																				
Aluminum																				
Arsenic	TR	TR	30 U	30 U	30 U	30 U	4	1 U	1 U	23	1 U	1 U								
Barium																				
Beryllium																				
Cadmium																				
Calcium													5517	4632	4320	4894	3578	3435	3594	4603
Chromium																				
Copper	5 U	5 U	5 U	5 U	5 U	5 U	10 U	10 U	10 U	10 U	10 U	10 U	1.1 U	13	6	3	1.1 U	1.1 U	1.1 U	1.1 U
Iron	230	110	50	130	140	120	40	10	20	50	100	80								
Lead	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10.4 U	10.4 U	10.4 U	17	11	18	10.4 U	10.4 U
Magnesium													516	445	400	463	319	302	305	342
Manganese																				
Mercury																				
Molybdenum																				
Nickel																				
Potassium																				
Selenium																				
Silver																				
Sodium													880	772	656	729	482	441	497	756
Thallium																				
Uranium																				
Zinc	5 U	10 U	10 U	10 U	60 U	10 U	5 U	5 U	5 U	5 U	5 U	5 U	0.7 U	11	9	2	0.7 U	0.7 U	1 U	0.7 U
Dissolved Metals (µg/L)																				
Aluminum																				
Arsenic																				
Barium																				
Beryllium																				
Cadmium																				
Calcium																				
Chromium																				
Copper																				
Iron																				
Lead																				
Magnesium																				
Manganese																				
Mercury																				
Molybdenum																				
Nickel																				
Potassium																				
Selenium																				
Silver																				
Sodium																				
Thallium																				
Uranium																				
Zinc																				
Conventional Analyses:																				
Alkalinity (mg/L)	15.7	13.2	9.8	12.8	10.8	13	7.0	9.5	9.3	9.2	8.4	11								
Chloride (mg/L)													0.48	0.22	0.36	0.17	0.09 U	0.16	0.17	0.31
Cyanide (mg/L)	3.3 U	3.3 U	3.3 U	3.3 U	3.3 U	3.3 U	TR	3.3 U	TR	3.3 U	TR	3.3 U								
Dissolved Organic Carbon (mg/L)													2.77	1.14	1.2	3.37	1.09	1.66	0.78	1.29
Fluoride (mg/L)															0.03	0.03 U	0.02 U	0.06	0.08 U	0.02 U
Hardness (mg/L)													16	13.5	12.5	14.2	10.3	9.9	10.3	13
NO_2 & NO_3 (mg/L)													0.67	0.69	0.71	0.49	0.22	0.33	0.24	0.2
Sulfate (mg/L)													3.39	2.94	2.91	3.06	2.22	2.28	2.69	3.56
Total Suspended Solids (mg/L)	TR	TR	TR	TR	TR	TR	26.1	TR	5.3											
Field Measurements:																				
Conductivity (µS/cm)	37	20	21	23	27	32	23	31	40	29	29	38								
pH	7.25	7.07	6.85	7.11	7.37	7.09	6.85	6.86	7.32	6.92	6.93	6.92	5.5	7.3	6.3	7.1	7.6	7.6	5.7	7.8
Stream Flow (cfs)	209.1	194.4	776.3	481	183.3	67.4	818.7	240.1	375.6	352.6	163	55.8	180	350	325	210	420	340	285	125
Temperature (°C)																				
Turbidity (NTU)	2	3.2	4.9	1.3	3.4	2.6	4.6	1.9	6.2	8.4	6.0	3.9								

Data Notes:
J - Estimated value.
TR- Trace; indicates compound detectable, but not quantifiable.
U - Parameter was analyzed for, but not detected above the reporting limit shown.
UJ - Parameter was analyzed for, but not detected. Detection limit is an estimated value.
* indicates that highest value from range of replicated samples were represented
▨ **Grey shading** indicates the concentration of analyte was not established, therefore not reported and analyzed.

Data Source:
(a) Anderson, Keith A. (USFS Chelan Ranger District). Compilation of Data for Preliminary Assessment of the Holden Mine Site.
(b) Walters, et al. 1992. *Holden Mine Reclamation Project Final Report.* Pacific Northwest Laboratories,Richland, WA. (Data collected in 1991).
(c) Kilburn, et al. 1994. *Geochemical data and sample locality maps for stream-sediment, heavy-mineral-concentrate, mill tailing, water, and precipitate samples collected in and around the Holden mine, Chelan County, Washington.* USGS Open File Report 94-680A Paper Version, 94-680B Diskette version (Data Collected in 1994).
(d) Kilburn, J.E. & S.J. Sutley. 1996. *Characterization of acid mine drainage at the Holden mine, Chelan, Washington*. USGS Open File Report 96-531. (Data collected in 1995)
(f) Kilburn, J.E. & S.J. Sutley. 1997. *Analytical results and comparative overview of geochemical studies conducted at the Holden Mine*, spring 1996. USGS Open File Report 97-128 (Data collected in Spring 1996).
(g) Kilburn, J.E. & S.J. Sutley. 1997. Preliminary data (no report attached, data collected in Fall 1996).
(h) Johnson, A., et al. 1997. *Effects of Holden Mine on the Water, Sediments and Benthic Invertebrates of Railroad Creek (Lake Chelan).* Environmental Investigations and Laboratory Services Program. Water Body No. WA-47-1020. Publication No. 97-330 (data collected in Spring and Fall 1996).

TABLE 5.3-19
STATION RC-1 AND PROXIMITY SUMMARY OF HISTORICAL RAILROAD CREEK ANALYTICAL DATA (1982-1996)
HOLDEN MINE RI/FS
DAMES & MOORE JOB NO. 17693-005-019

Parameters	Sample ID	1992 USFS WATER QUALITY MONITORING DATA [a]								1993 USFS WATER QUALITY MONITORING DATA [a]						
	Sampling Date	5/14/92	6/2/92	6/16/92	7/1/92	7/14/92	7/29/92	8/11/92	9/8/92	5/21/93	6/9/93	6/23/93	7/7/93	7/21/93	8/4/93	9/1/93
Total Metals (µg/L)																
Aluminum																
Arsenic																
Barium																
Beryllium																
Cadmium																
Calcium		6310	3060	3282	3454	3997	3899	3866	3850	3500	4000	4600	4700	4000	4300	5900
Chromium																
Copper		8 U	8 U	0.8 U	1 U	1 U	1 U	0.9 U	15 U	10	10	10	10	10 U	10 U	10 U
Iron										240	100	80	100	680	190	110
Lead		30 U	30 U	16.5 U	10.4 U	10.4 U	10.4 U	11.7 U	85.5 U	10	10	10	10	10 U	10 U	10 U
Magnesium		590	180	274	285	329	337	354	47.5 U	340	360	390	410	390	370	560
Manganese																
Mercury																
Molybdenum																
Nickel																
Potassium																
Selenium																
Silver																
Sodium		1060	430	1503	504	576	503	494	480	1500	560	1100	1200	840	820	1400
Thallium																
Uranium																
Zinc		10	20	3	2.8 U	2.8 U	2.8 U	0.8 U	10	10	10	10	10	10 U	10 U	110
Dissolved Metals (µg/L)																
Aluminum																
Arsenic																
Barium																
Beryllium																
Cadmium																
Calcium																
Chromium																
Copper																
Iron																
Lead																
Magnesium																
Manganese																
Mercury																
Molybdenum																
Nickel																
Potassium																
Selenium																
Silver																
Sodium																
Thallium																
Uranium																
Zinc																
Conventional Analyses:																
Alkalinity (mg/L)																
Chloride (mg/L)																
Cyanide (mg/L)																
Dissolved Organic Carbon (mg/L)																
Fluoride (mg/L)			0.02 U	0.07	0.02 U	0.02 U	0.02 U	0.01 U	0.01 U							
Hardness (mg/L)																
NO_2 & NO_3 (mg/L)		0.54	0.28	0.19	0.24	0.14	0.13	0.14	0.21							
Sulfate (mg/L)			2.41	2.46	2.71	3.11	3.25	3.21	3.1	2	2	1.2	4.9	2	3	2
Total Suspended Solids (mg/L)																
Field Measurements:																
Conductivity (µS/cm)																
pH		7.5	7.8	7.8	8.7	8	7.6	7.8	8.1	7.5	10.2	9.2	7.9	8.7	6.3	9.3
Stream Flow (cfs)		165	218	263	260	198	165	145	182	345	145	85	20	30	10	4
Temperature (°C)		8	9	9	10.7	12.8	15.7	14.1	9.6							
Turbidity (NTU)																

Data Notes:
J - Estimated value.
TR- Trace; indicates compound detectable, but not quantifiable.
U - Parameter was analyzed for, *but not detected above the reporting limit shown.*
UJ - Parameter was analyzed for, but not detected. Detection limit is an estimated value.
* indicates that highest value from range of replicated samples were represented
▨ Grey shading ▨ indicates the concentration of analyte was not established, therefore not reported and analyzed.

Data Source:
(a) Anderson, Keith A. (USFS Chelan Ranger District). Compilation of Data for Preliminary Assessment of the Holden Mine Site.
(b) Walters, et al. 1992. *Holden Mine Reclamation Project Final Report.* Pacific Northwest Laboratories,Richland, WA. (Data collected in 1991).
(c) Kilburn, et al. 1994. *Geochemical data and sample locality maps for stream-sediment, heavy-mineral-concentrate, mill tailing, water, and precipitate samples collected in and around the Holden mine, Chelan County, Washington.* USGS Open File Report 94-680A Paper Version, 94-680B Diskette version (Data Collected in 1994).
(d) Kilburn, J.E. & S.J. Sutley. 1996. *Characterization of acid mine drainage at the Holden mine, Chelan, Washington.* USGS Open File Report 96-531 (Data collected in 1995).
(f) Kilburn, J.E. & S.J. Sutley. 1997. *Analytical results and comparative overview of geochemical studies conducted at the Holden Mine*, spring 1996. USGS Open File Report 97-128 (Data collected in Spring 1996).
(g) Kilburn, J.E. & S.J. Sutley. 1997. Preliminary data (no report attached, data collected in Fall 1996).
(h) Johnson, A., et al. 1997. *Effects of Holden Mine on the Water, Sediments and Benthic Invertebrates of Railroad Creek (Lake Chelan).* Environmental Investigations and Laboratory Services Program. Water Body No. WA-47-1020. Publication No. 97-330 (data collected in Spring and Fall 1996)

TABLE 5.3-19
STATION RC-1 AND PROXIMITY SUMMARY OF HISTORICAL RAILROAD CREEK ANALYTICAL DATA (1982-1996)
HOLDEN MINE RI/FS
DAMES & MOORE JOB NO. 17693-005-019

Parameters / Sample ID	USFS 1994[a]	USGS	1994 USFS WATER QUALITY MONITORING DATA[a]						USFS 1995[a]	USGS	1995 USFS WATER QUALITY MONITORING DATA			USGS	DEPT. OF ECOLOGY[h]		USGS
		367[c]								546[d]				600[f]	RC STATION		707[g]
Sampling Date	6/8/94	7/94	7/5/94	7/19/94	8/3/94	8/29/94	9/14/94	9/28/94	6/20/95	7/95	7/26/95	8/9/95	8/23/95	5/96	6/12/96	9/10/96	9/96
Total Metals (µg/L)																	
Aluminum															13	32	46
Arsenic															0.69	0.88	
Barium																	5.4
Beryllium																	10 U
Cadmium															0.02 U	0.1 U	10 U
Calcium	4200		3600	3800	4100	4500	5200	4800	4200		3000	3500	4800				5,900
Chromium																	10 U
Copper	10 U		10 U	10 U	10 U	10 U	10 U	10 U	10 U		10 U	10 U	10 U		1.4	3.7	10 U
Iron	50		140	80	60	70	10	80	70		130	100	70		71	77	110
Lead	10 U		10 U	10 U	10 U	10 U	10 U	10 U	10 U		10 U	10 U	10 U		0.13	0.12	50 U
Magnesium	460		420	360	290	390	440	410	280		310	390	420				1000 U
Manganese															1.3	1.9	10 U
Mercury															0.001 U		
Molybdenum																	20 U
Nickel															0.34		10 U
Potassium																	1000 U
Selenium																0.4 U	
Silver															0.02		
Sodium	730		600	700	330	590	480	540	850		440	440	600				1,100
Thallium																	
Uranium																	
Zinc	10		10 U	10 U	10 U	10	10 U	10	10		10 U	10 U	10 U		3.7	3	10 U
Dissolved Metals (µg/L)																	
Aluminum		20								20				20 U		7.4 *	11
Arsenic		2 U								1 U				4 U			
Barium		4.1								3.8				6.5			5.1
Beryllium		1 U								0.3 U				0.4 U			10 U
Cadmium		1 U								1 U				0.7 U	0.05	0.02 *	10 U
Calcium		6000 U								3900				5900			5,800
Chromium		1 U								0.9 U				0.5 U			10 U
Copper		0.62								3				6.5	0.96	0.26 *	10 U
Iron		100 U								40				91			100 U
Lead		0.2 U								0.3 U				0.2	0.02	0.02 *	50 U
Magnesium		270								280				1000 U			1000 U
Manganese		2								1.6				3 U			10 U
Mercury																	
Molybdenum		0.5								0.3				0.6			20 U
Nickel		3 U								0.5				1 U	0.22		0.01 U
Potassium		200 U															1000 U
Selenium																	
Silver		0.1 U								0.1 U				0.2 U	0.01 U		
Sodium		300								500							1000 U
Thallium		0.1 U								0.6 U				4 U			
Uranium		0.1 U								0.1 U				0.4 U			
Zinc		4								10				3.4	1.3	0.85 *	10 U
Conventional Analyses:																	
Alkalinity (mg/L)															10		
Chloride (mg/L)	0.7	0.18	0.7	0.7	0.7	0.9	0.9	0.9	0.9	0.3	0.9	0.9	0.9	0.8			
Cyanide (mg/L)															0.01 U		
Dissolved Organic Carbon (mg/L)																	
Fluoride (mg/L)	0.05	0.05 U	0.07	0.05	0.06	0.05	0.01	0.03	0.07	0.1	0.06	0.05	0.11	0.1 U			
Hardness (mg/L)															11	14	
NO_2 & NO_3 (mg/L)	0.07	0.1 U	0.04	0.06	0.07	0.02	0.01 U	0.02	0.09	0.02 U	0.02	0.04	0.04	0.1 U	0.09		
Sulfate (mg/L)	3.7	2.7	0.4	0.8	2.5	4.9	2.9	4.9	2.1	3	3.7	4.9	5.8	4	2.2	3.4	
Total Suspended Solids (mg/L)															1	1 U	
Field Measurements:																	
Conductivity (µS/cm)		20								100				43	28	32	
pH	7.4	7.02	7.1	8.2				8.7	8.1	7.17	8.8	8.4	8.2	5.52	7.4	7.3	
Stream Flow (cfs)	8.5		11	14	12		10	10	6.5		10.8	7.7	8.5		277	55.3	
Temperature (°C)		13												4	5.1	10.4	
Turbidity (NTU)															1.5	1.6	

Data Notes:
J - Estimated value.
TR- Trace; indicates compound detectable, but not quantifiable.
U - Parameter was analyzed for, but not detected above the reporting limit shown.
UJ - Parameter was analyzed for, but not detected. Detection limit is an estimated value.
* indicates that highest value from range of replicated samples were represented
▨ Grey shading indicates the concentration of analyte was not established, therefore not reported and analyzed.

Data Source:
(a) Anderson, Keith A. (USFS Chelan Ranger District). Compilation of Data for Preliminary Assessment of the Holden Mine Site.
(b) Walters, et al. 1992 *Holden Mine Reclamation Project Final Report.* Pacific Northwest Laboratories,Richland, WA. (Data collected in 1991).
(c) Kilburn, et al. 1994. *Geochemical data and sample locality maps for stream-sediment, heavy-mineral-concentrate, mill tailing, water, and precipitate samples collected in and around the Holden mine, Chelan County, Washington.* USGS Open File Report 94-680A Paper Version, 94-680B Diskette version (Data Collected in 1994)
(d) Kilburn, J.E. & S.J. Sutley. 1996. *Characterization of acid mine drainage at the Holden mine, Chelan, Washington.* USGS Open File Report 96-531. (Data collected in 1995)
(f) Kilburn, J.E. & S.J. Sutley. 1997. *Analytical results and comparative overview of geochemical studies conducted at the Holden Mine*, spring 1996. USGS Open File Report 97-128 (Data collected in Spring 1996).
(g) Kilburn, J.E. & S.J. Sutley. 1997. Preliminary data (no report attached, data collected in Fall 1996).
(h) Johnson, A., et al. 1997. *Effects of Holden Mine on the Water, Sediments and Benthic Invertebrates of Railroad Creek (Lake Chelan).* Environmental Investigations and Laboratory Services Program. Water Body No. WA-47-1020. Publication No. 97-330 (data collected in Spring and Fall 1996).

TABLE 5.3-20
STATION RC-2 AND PROXIMITY SUMMARY OF HISTORICAL RAILROAD CREEK ANALYTICAL DATA (1982-1996)
HOLDEN MINE RI/FS
DAMES & MOORE JOB NO. 17693-005-019

Parameters	Sample ID	1982 BATTELLE WATER QUALITY MONITORING DATA[a]						1983 BATTELLE WATER QUALITY MONITORING DATA[a]						1991 BATTELLE WATER QUALITY MONITORING DATA[b]							
	Sampling Date	5/12/82	6/10/82	6/23/82	7/14/82	8/25/82	9/29/82	6/1/83	6/22/83	7/20/83	8/11/83	8/31/83	9/28/83	5/10/91	5/18/91	6/3/91	6/18/91	7/2/91	7/16/91	8/6/91	9/17/91
Total Metals (µg/L)																					
Aluminum																					
Arsenic		TR	25 U	TR	TR	25 U	25 U	35	30 U	9	23	15	30 U								
Barium																					
Beryllium																					
Cadmium																					
Calcium														7246	4818	4535	5180	3484	3443	3573	5487
Chromium																					
Copper		40	15	10	5 U	5 U	5 U	10 U	10 U	10 U	10 U	10 U	10 U	1.1 U	34	14	9	1.1 U	1.1 U	1.1 U	1.1 U
Iron		1210	340	130	310	690	1100	70	200	130	20	300	260								
Lead		0.24	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10.4 U	10.4 U	10.4 U	10.4 U	10.4 U	15	10.4 U	10.4 U
Magnesium														926	600	507	596	359	382	373	626
Manganese																					
Mercury																					
Molybdenum																					
Nickel																					
Potassium														658	516	503	581	110	189	521	506
Selenium																					
Silver																					
Sodium														1006	746	747	720	465	463	494	811
Thallium																					
Uranium																					
Zinc		200	47	20	10	10	30	22	40	19	5 U	5 U	5 U	79	98	54	47	0.7 U	0.7 U	14	25
Dissolved Metals (µg/L)																					
Aluminum																					
Arsenic																					
Barium																					
Beryllium																					
Cadmium																					
Calcium																					
Chromium																					
Copper																					
Iron																					
Lead																					
Magnesium																					
Manganese																					
Mercury																					
Molybdenum																					
Nickel																					
Potassium																					
Selenium																					
Silver																					
Sodium																					
Thallium																					
Uranium																					
Zinc																					
Conventional Analyses:																					
Alkalinity (mg/L)		16.5	12.2	9.4	9.7	9.6	11.5	6.7	11.5	7.8	6.7	8.1	9.2								
Chloride (mg/L)														0.55	0.31	0.23	0.15	0.19	0.05 U	0.18	0.27
Cyanide (mg/L)		0.003 U	0.003 U	0.003 U	0.003 U	0.005	0.003 U	TR	TR	TR	TR	TR	TR								
Dissolved Organic Carbon (mg/L)														4.29	1.15	1.34	1.19	1.05	2.22	1.13	0.87
Fluoride (mg/L)														0.07	0.65	0.03	0.01 U	0.04	0.01 U	0.01 U	0.01 U
Hardness (mg/L)														22.1	14.6	13.5	15.5	10.3	10.3	10.5	16.4
NO_2 & NO_3 (mg/L)														0.67	0.76	0.62	0.54	0.31	0.35	0.21	0.26
Sulfate (mg/L)														12.89	7.12	5.65	6.43	3.91	3.61	4.57	9.84
Total Suspended Solids (mg/L)		23	8.3	10.2	7.2	1.3	6	15.6	12.1	6.7	7.7	3.9	2.9								
Field Measurements:																					
Conductivity (µS/cm)		50	37	28	26	34	47	29	40	36	32	36	56								
pH		7.03	7.04	6.88	6.95	7.12	7.01	6.83	6.8	6.75	6.65	6.93	6.68	5.3	7.1	6.7	7.2	7.4	8.1	4.9	7.8
Stream Flow (cfs)		210.43	413.29	913.01	521.72	192.08	75.09	935.9	258.0	394.3				195	377	354	229	487	380	317	140
Temperature (°C)		10	6	9	7			7	7	9	9	11	6								
Turbidity (NTU)		11.5	2.2	5.6	1.6	3.2	4.5	5.4	1.3	6.4	11.3	5.6	10								

Data Notes:
J - Estimated value.
NR - Not Reported
TR- Trace; indicates compound detectable, but not quantifiable.
U - Parameter was analyzed for, but not detected above the reporting limit shown.
UJ - Parameter was analyzed for, but not detected. Detection limit is an estimated value.
* indicates that highest value from range of replicated samples were represented
▨ Grey shading ▨ indicates the concentration of analyte was not established, therefore not reported and analyzed.

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(a) Anderson, Keith A. (USFS Chelan Ranger District). Compilation of Data for Preliminary Assessment of the Holden Mine Site.
(b) Walters, et al. 1992. *Holden Mine Reclamation Project Final Report.* Pacific Northwest Laboratories,Richland, WA. (Data collected in 1991)
(c) Kilburn, et al. 1994. *Geochemical data and sample locality maps for stream-sediment, heavy-mineral-concentrate, mill tailing, water, and precipitate samples collected in and around the Holden mine, Chelan County, Washington.* USGS Open File Report 94-680A Paper Version, 94-680B Diskette version (Data Collected in 1994).
(d) Kilburn, J.E. & S.J. Sutley. 1996. *Characterization of acid mine drainage at the Holden mine, Chelan, Washington.* USGS Open File Report 96-531. (Data collected in 1995).
(f) Kilburn, J.E. & S.J. Sutley. 1997. *Analytical results and comparative overview of geochemical studies conducted at the Holden Mine*, spring 1996. USGS Open File Report 97-128 (Data collected in Spring 1996).
(g) Kilburn, J.E. & S.J. Sutley. 1997. Preliminary data (no report attached, data collected in Fall 1996).
(h) Johnson, A., et al. 1997. *Effects of Holden Mine on the Water, Sediments and Benthic Invertebrates of Railroad Creek (Lake Chelan)* Environmental Investigations and Laboratory Services Program. Water Body No. WA-47-1020 Publication No. 97-330 (data collected in Spring and Fall 1996).

TABLE 5.3-20
STATION RC-2 AND PROXIMITY SUMMARY OF HISTORICAL RAILROAD CREEK ANALYTICAL DATA (1982-1996)
HOLDEN MINE RI/FS
DAMES & MOORE JOB NO. 17693-005-019

Parameters	1992 USFS WATER QUALITY MONITORING DATA[a]								1993 USFS WATER QUALITY MONITORING DATA[b]							USFS 1994[a]	USGS[c]		1994 USFS WATER QUALITY MONITORING DATA[a]					
Sample ID																	345	347						
Sampling Date	5/14/92	6/2/92	6/16/92	7/1/92	7/14/92	7/29/92	8/11/92	9/8/92	5/21/93	6/9/93	6/23/93	7/7/93	7/21/93	8/4/93	9/1/93	6/8/94	7/94	7/94	7/5/94	7/19/94	8/3/94	8/29/94	9/14/94	9/28/94
Total Metals (µg/L)																								
Aluminum																								
Arsenic																								
Barium																								
Beryllium																								
Cadmium																								
Calcium	5522	3290	3891	3847	4487	4544	4631	4530	3800	4500	5100	5500	4400	4900	6500	5100			4000	4600	4800	5800	6400	5900
Chromium																								
Copper	4 U	8 U	0.8 U	1 U	1 U	1 U	0.9 U	10.5 U	10	10	10	10	10 U	10	10 U	10 U			10 U	10 U	10 U	10 U	10 U	10 U
Iron																440			340	390	320	1500	10 U	1500
Lead	14.9 U	30 U	16.5 U	10.4 U	10.4 U	10.4 U	11.7 U	85.5 U	10	10	10	10	10 U	10 U	10 U	10 U			10 U	10 U	10 U	10 U	10 U	10 U
Magnesium	674	240	400	384	472	505	549	47.5 U	410	530	570	590	480	520	810	640			500	480	440	640	710	700
Manganese																								
Mercury																								
Molybdenum																								
Nickel																								
Potassium	520	124 U	464	328	317	300	317	533.5 U	210	450	500	520	420	480	220	500			280	280	370	460	490	490
Selenium																								
Silver																								
Sodium	760	500	621	478	640	560	675	480	1700	590	1300	1300	890	840	1600	830			600	800	460	590	630	770
Thallium																								
Uranium																								
Zinc	68	30	18	7	9	8	0.8 U	20	40	30	40	30	20	30	130	60			20	10	20	30	40	40
Dissolved Metals (µg/L)																								
Aluminum																	20	10						
Arsenic																	2 U	2 U						
Barium																	4.4	4.2						
Beryllium																	1 U	1 U						
Cadmium																	1 U	1 U						
Calcium																	6000 U	6000 U						
Chromium																	1 U	1 U						
Copper																	2.3	5						
Iron																	320	100 U						
Lead																	0.2 U	0.2 U						
Magnesium																	360	320						
Manganese																	5.4	3						
Mercury																								
Molybdenum																	0.5	0.5						
Nickel																	3 U	3 U						
Potassium																	200	200 U						
Selenium																								
Silver																	0.1 U	0.1 U						
Sodium																	400	400						
Thallium																	0.1 U	0.1 U						
Uranium																	0.1 U	0.1 U						
Zinc																	18	37						
Conventional Analyses:																								
Alkalinity (mg/L)																								
Chloride (mg/L)	0.28	0.2	0.32	0.22	0.21	0.28	0.3	0.88	3	2	3	4	1	1	1 U	0.7	3	0.21	0.7	0.7	0.7	0.9	0.9	0.9
Cyanide (mg/L)																								
Dissolved Organic Carbon (mg/L)																								
Fluoride (mg/L)	0.01 U	0.01 U	0.01 U	0.01 U	0.01 U	0.01 U	0.01 U	0.01 U	50	20	10	10	10	50	50	60	50	0.05 U	70	60	60	50	10 U	20
Hardness (mg/L)																								
NO_2 & NO_3 (mg/L)	0.57	0.32	0.23	0.38	0.17	0.14	0.14	0.28	0.11	0.13	0.08	0.04	0.03	0.04	0.04	0.09	0.11	0.1 U	0.04	0.04	0.06	0.03	0.03	0.03
Sulfate (mg/L)	8.97	3.9	4.41	4.72	6.13	6.79	7.43	5.44	5	4	6.6	7.8	6	6	8	5.8	5	4.8	1.6	3.3	5.8	9.5	9.9	10.7
Total Suspended Solids (mg/L)																								
Field Measurements:																								
Conductivity (µS/cm)													20					30						
pH	7.9	8	7.6		8.2	7.5	7.5	8.2	8.3	14.2	9	7.7	9.7	7	8.2	6.6	8.3	7.29	7.3	7.5	7.8		8.9	8.7
Stream Flow (cfs)	179		276	295	213	179	158	190	141.58	170.93	99.43	37.54	54.52	32.89	28.13		414.58							
Temperature (°C)	9	8	9	10	11.7	13.6	13.7	9.3	5.9	7	6.7	8.5	9.1	11.5	9.8	9	5.9	10		14	13		10	10
Turbidity (NTU)																								

Data Notes:
J - Estimated value.
NR - Not Reported
TR - Trace; indicates compound detectable, but not quantifiable.
U - Parameter was analyzed for, but not detected above the reporting limit shown.
UJ - Parameter was analyzed for, but not detected. Detection limit is an estimated value.
* indicates that highest value from range of replicated samples were represented
▨ Grey shading ▨ indicates the concentration of analyte was not established, therefore not reported and analyzed.

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TABLE 5.3-20

STATION RC-2 AND PROXIMITY SUMMARY OF HISTORICAL RAILROAD CREEK ANALYTICAL DATA (1982-1996)

HOLDEN MINE RI/FS

DAMES & MOORE JOB NO. 17693-005-019

Parameters	USFS 1995[a]	USGS 7/95[d]												1995 WATER QUALITY MONITORING DATA[a]		
Sample ID		510	513	517	519	522	526	530	531	532	540	544	545			
Sampling Date	6/20/95	7/95	7/95	7/95	7/95	7/95	7/95	7/95	7/95	7/95	7/95	7/95	7/95	7/26/95	8/9/95	9/27/95
Total Metals (µg/L)																
Aluminum																
Arsenic																
Barium																
Beryllium																
Cadmium																
Calcium	5000													3100	4400	5500
Chromium																
Copper	10 U													10 U	10 U	10 U
Iron	430													480	400	1300
Lead	10 U													10 U	10 U	10 U
Magnesium	480													350	540	690
Manganese																
Mercury																
Molybdenum																
Nickel																
Potassium	310													300	710	500
Selenium																
Silver																
Sodium	960													520	800	770
Thallium																
Uranium																
Zinc	50													10 U	20	30
Dissolved Metals (µg/L)																
Aluminum		30	51	3000	86	40	40	40	10	61	20	30	30			
Arsenic		1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1	1 U	1 U	1 U			
Barium		4.1	4.3	3.9	4.1	4.1	4.4	4.4	4	4.6	4.3	4.3	4			
Beryllium		0.3 U	0.3 U	0.3 U	0.3 U	0.3 U	0.3 U	0.3 U	0.3 U	0.3 U	0.3 U	0.3 U	0.3 U			
Cadmium		1 U	1 U	1	1 U	1 U	1 U	1 U	1 U	5	1 U	1 U	1 U			
Calcium		4900	5400	11000	6400	7300	5000	3600	3600	20000	4200	4000	4400			
Chromium		0.9 U	0.9 U	0.9 U	0.9 U	0.9 U	0.9 U	0.9 U	0.9 U	0.9 U	0.9 U	0.9 U	0.9 U			
Copper		3	4	48	5	3	4	7.4	4	160	3	3	3			
Iron		560	1200	35000	13000	20000	3200	140	240	30	600	680	760			
Lead		0.3 U	0.3 U	0.3 U	0.3 U	0.3 U	0.3 U	0.3 U	0.3 U	2	0.3 U	0.3 U	0.3 U			
Magnesium		390	490	4000	1200	1600	620	290	260	1800	380	390	420			
Manganese		6.4	9.7	240	68	88	19	3.5	2.4	59	6.2	7.3	7.6			
Mercury																
Molybdenum		0.3	0.3	0.1 U	0.2	0.2	0.2	0.2	0.4	0.2	0.3	0.2	0.1 U			
Nickel		0.3	0.7	4.8	1	0.5	0.5	0.3	0.4	1.2	0.4	0.3	0.8			
Potassium																
Selenium																
Silver		0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U			
Sodium		580	700	1200	650	780	660	470	480	2900	520	510	540			
Thallium		0.6 U	0.6 U	0.6 U	0.6 U	0.6 U	0.6 U	0.6 U	0.6 U	0.6 U	0.6 U	0.6 U	0.6 U			
Uranium		0.1 U	0.1 U	0.6	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1	0.1 U	0.1 U	0.1 U			
Zinc		22	30	690	90	60	60	30	10	1200	260	20	20			
Conventional Analyses:																
Alkalinity (mg/L)																
Chloride (mg/L)	0.9	0.3	0.8	0.3	0.4	0.4	0.4	0.4	0.3	1.2	0.3	0.4	0.4	0.9	0.9	0.9
Cyanide (mg/L)																
Dissolved Organic Carbon (mg/L)																
Fluoride (mg/L)	60	0.2	0.1	NR	NR	2	0.2	0.2	0.2	NR	NR	NR	0.2	50	50	100
Hardness (mg/L)																
NO_2 & NO_3 (mg/L)	0.11	0.2 U	0.2 U	0.3	0.3	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.3	0.3	0.2 U	0.01	0.06	0.05
Sulfate (mg/L)	5.4	5	6	80	60	40	16	860	3	60	80	60	40	5.8	9.1	11.9
Total Suspended Solids (mg/L)																
Field Measurements:																
Conductivity (µS/cm)		140	160	400	340	240	140	80	80	240	400	340	240			
pH	8.3	6.6	7.1	7.1	6.7	6.59	6.7	7.07	7.12	6.38	3.91	4.97	6.59	6.6	7.1	7.1
Stream Flow (cfs)																
Temperature (°C)	7	4.5	5	7.5	7.5	4.5	6	5	3	3	7.5	4.5	4.5	11.4	9	8
Turbidity (NTU)																

Data Notes:

J - Estimated value.

NR - Not Reported

TR- Trace; indicates compound detectable, but not quantifiable.

U - Parameter was analyzed for, but not detected above the reporting limit shown.

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* indicates that highest value from range of replicated samples were represented

▨ Grey shading ▨ indicates the concentration of analyte was not established, therefore not reported and analyzed.

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TABLE 5.3-20
STATION RC-2 AND PROXIMITY SUMMARY OF HISTORICAL RAILROAD CREEK ANALYTICAL DATA (1982-1996)
HOLDEN MINE RI/FS
DAMES & MOORE JOB NO. 17693-005-019

Parameters	USGS[f]								DEPT. OF ECOLOGY (RC-STATION SAMPLES)[h]		USGS[g]					
Sample ID	602	603	604	613	618	628	635	636			700	705	708	709	722	727
Sampling Date	5/96	5/96	5/96	5/96	5/96	5/96	5/96	5/96	6/12/96	9/10/96	9/96	9/96	9/96	9/96	9/96	9/96
Total Metals (µg/L)																
Aluminum									44	96 *	140	72	86	52	190	300
Arsenic									0.63	0.68						
Barium											5.7	5.5	5.5	5.4	6.0	6.2
Beryllium											10 U	10 U	10 U	10 U	10 U	10 U
Cadmium									0.21	0.12 *	10 U	10 U	10 U	10 U	10 U	10 U
Calcium											7,400	6,000	8,500	6,200	8,500	10,000
Chromium											10 U	10 U	10 U	10 U	10 U	10 U
Copper									14	2.4 *	10 U	10 U	10 U	10 U	10 U	10 U
Iron									599	1970 *	3,500	140	120	110	5,200	7,000
Lead									0.21	0.10 U	50 U	50 U	50 U	50 U	50 U	50 U
Magnesium											1,100	1000 U	1000 U	1000 U	1,400	1,900
Manganese									8.2	20 *	37	10 U	10	10 U	44	65
Mercury									0.001							
Molybdenum											20 U	20 U	20 U	20 U	20 U	20 U
Nickel									0.44		10 U	10 U	10 U	10 U	10 U	10 U
Potassium											1000 U	1000 U	1000 U	1000 U	1000 U	1000 U
Selenium										0.4 U						
Silver									0.01 U							
Sodium											1,200	1,100	1,500	1,100	1,200	1,300
Thallium																
Uranium																
Zinc									36	30	49	10 U	64	14	49	58
Dissolved Metals (µg/L)																
Aluminum	1000	5600	82	45	70	3600	67	62		5.4 *	18	13	15	13	36	40
Arsenic	4 U	4 U	4 U	4U	4U	4 U	4 U	4 U								
Barium	8.1	13	6.5	6.1	5.8	5.7	6.2	6.6			5.4	5.2	5.2	5.1	5.5	6.0
Beryllium	0.4 U	0.4 U	0.4 U	0.4U	0.4U	0.4 U	0.4 U	0.4 U			10 U	10 U	10 U	10 U	10 U	10 U
Cadmium	13	45	5.8	0.7	0.8	2	2	1	0.29	0.13 *	10 U	10 U	10 U	10 U	10 U	10 U
Calcium	13000	32000	7400	5300	5900	14000	5100	5500			7,300	6,000	8,400	6,200	8,700	10,000
Chromium	0.5 U	0.5 U	0.5 U	0.5U	0.5U	0.5 U	0.5 U	0.5 U			10 U	10 U	10 U	10 U	10 U	10 U
Copper	970	3100	320	26	38	73	89	68	10	0.93 *	10 U	10 U	10 U	10 U	10 U	10 U
Iron	51	150	50 U	940	1700	43000	70	55			2,500	100 U	100 U	100 U	3,400	5,000
Lead	6.5	25	2.3	0.3	0.4	0.4	0.4	0.4	0.07	0.06 *	50 U	50 U	50 U	50 U	50 U	50 U
Magnesium	2100	5700	1000	1000 U	1000 U	6100	1000 U	1000 U			1,000	1000 U	1000 U	1000 U	1,300	1,700
Manganese	73	260	32	15	24	380	8	5			36	10 U	10 U	10 U	40	66
Mercury																
Molybdenum	0.5	0.4 U	0.5	0.4	0.5	0.4 U	0.5	0.5			20 U	20 U	20 U	20 U	20 U	20 U
Nickel	2	5.8	1 U	1U	1U	7.8	1	1 U	0.36		0.01 U	0.01 U	0.01 U	0.01 U	0.01 U	0.01 U
Potassium	1000	2200	610	540	660	970	500	500 U			1000 U	1000 U	1000 U	1000 U	1000 U	1000 U
Selenium																
Silver	0.2 U	0.2 U	0.2 U	0.2U	0.2U	0.2 U	0.2 U	0.2 U	0.01 U							
Sodium	2200	5100	1300	1000	1100	1700	1000	1000 U			1,200	1000 U	1,600	1,100	1,000	1,400
Thallium	4 U	4 U	4 U	4U	4U	4 U	4 U	4 U								
Uranium	0.4	2.4	0.4 U	0.4U	0.4U	0.5	0.4 U	0.4 U								
Zinc	2500	8500	1000	110	120	590	260	210	40	30 *	40	10 U	60	11	54	54
Conventional Analyses:																
Alkalinity (mg/L)									10 U							
Chloride (mg/L)	0.8	1.3	0.6	0.4	0.8	1.3	0.4	0.4								
Cyanide (mg/L)									0.01 U							
Dissolved Organic Carbon (mg/L)																
Fluoride (mg/L)	0.2	0.4	0.1	0.1 U	0.2	0.4	0.1 U	0.1 U								
Hardness (mg/L)									14	18						
NO_2 & NO_3 (mg/L)	0.7	0.1	0.7	0.6	0.7	0.1	0.7	0.6								
Sulfate (mg/L)	48	240	19	45	48	240	8	8	5.7	11						
Total Suspended Solids (mg/L)									2	4						
Field Measurements:																
Conductivity (µS/cm)	120	373	70	45	120	373	45	45	34	47						
pH	5.63	4.85	5.64	5.65	5.63	4.85	6.21	6.34	7.3	6.8						
Stream Flow (cfs)										63.8						
Temperature (°C)	4.5	7	6	4	4.5	7	4	4	5.4	11.1						
Turbidity (NTU)									1.6	4.2						

Data Notes:
J - Estimated value.
NR - Not Reported
TR- Trace; indicates compound detectable, but not quantifiable.
U - Parameter was analyzed for, but not detected above the reporting limit shown.
UJ - Parameter was analyzed for, but not detected. Detection limit is an estimated value.
* indicates that highest value from range of replicated samples were represented
▨ Grey shading indicates the concentration of analyte was not established, therefore not reported and analyzed.

Data Source:
(a) Anderson, Keith A. (USFS Chelan Ranger District). Compilation of Data for Preliminary Assessment of the Holden Mine Site.
(b) Walters, et al. 1992. *Holden Mine Reclamation Project Final Report.* Pacific Northwest Laboratories,Richland, WA. (Data collected in 1991).
(c) Kilburn, et al. 1994. *Geochemical data and sample locality maps for stream-sediment, heavy-mineral-concentrate, mill tailing, water, and precipitate samples collected in and around the Holden mine, Chelan County, Washington.* USGS Open File Report 94-680A Paper Version, 94-680B Diskette version (Data Collected in 1994)
(d) Kilburn, J.E. & S.J. Sutley. 1996. *Characterization of acid mine drainage at the Holden mine, Chelan, Washington.* USGS Open File Report 96-531 (Data collected in 1995).
(f) Kilburn, J.E. & S.J. Sutley. 1997. *Analytical results and comparative overview of geochemical studies conducted at the Holden Mine*, spring 1996. USGS Open File Report 97-128 (Data collected in Spring 1996).
(g) Kilburn, J.E. & S.J. Sutley. 1997. Preliminary data (no report attached, data collected in Fall 1996).
(h) Johnson, A., et al. 1997. *Effects of Holden Mine on the Water, Sediments and Benthic Invertebrates of Railroad Creek (Lake Chelan)* Environmental Investigations and Laboratory Services Program. Water Body No. WA-47-1020. Publication No. 97-330 (data collected in Spring and Fall 1996).

TABLE 5.3-21
STATION RC-3 AND PROXIMITY SUMMARY OF HISTORICAL RAILROAD CREEK ANALYTICAL DATA (1982-1996)
HOLDEN MINE RI/FS
DAMES & MOORE JOB NO. 17693-005-019

Parameters / Sample ID	1982 BATTELLE WATER QUALITY MONITORING DATA[a]						1983 BATTELLE WATER QUALITY MONITORING DATA[a]						1991 BATTELLE WATER QUALITY MONITORING DATA[b]							
Sampling Date	5/12/82	6/10/82	6/23/82	7/14/82	8/25/82	9/29/82	6/1/83	6/22/83	7/20/83	8/11/83	8/31/83	9/28/83	5/10/91	5/18/91	6/3/91	6/18/91	7/2/91	7/16/91	8/6/91	9/17/91
Total Metals (µg/L)																				
Aluminum																				
Arsenic	TR	2 U	TR	TR	2 U	2 U	2 U	2 U	2 U	2 U	9	9								
Barium																				
Beryllium																				
Cadmium																				
Calcium													8076	5657	5340	6161	4197	4229	4350	7103
Chromium																				
Copper	30	10	6	5 U	5 U	5 U	10 U	10 U	10 U	10 U	10 U	10 U	1.1 U	9	7	5	1.1 U	1.1 U	1.1 U	1.1 U
Iron	1240	210	60	190	410	430	60	90	90	10 U	220	180								
Lead	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10.4 U	3	10.4 U	10.4 U	10.4 U	11	10.4 U	10.4 U
Magnesium													1047	728	626	747	467	493	481	836
Manganese																				
Mercury																				
Molybdenum																				
Nickel																				
Potassium													703	549	528	570	248	279	510	643
Selenium																				
Silver																				
Sodium													1166	882	798	852	554	557	561	970
Thallium																				
Uranium																				
Zinc	70	23	10 U	10 U	10	50	10	15	15	5 U	5 U	5 U	0.7 U	42	28	28	0.7 U	0.7 U	9	11
Dissolved Metals (µg/L)																				
Aluminum																				
Arsenic																				
Barium																				
Beryllium																				
Cadmium																				
Calcium																				
Chromium																				
Copper																				
Iron																				
Lead																				
Magnesium																				
Manganese																				
Mercury																				
Molybdenum																				
Nickel																				
Potassium																				
Selenium																				
Silver																				
Sodium																				
Thallium																				
Uranium																				
Zinc																				
Conventional Analyses:																				
Alkalinity (mg/L)	20.5	15	12.4	12.2	11.8	14.9	7.5	11.9	9.6	9.4	11.4	14.2								
Chloride (mg/L)													0.29	0.17	0.21	0.16	0.19	0.1	0.16	0.33
Cyanide (mg/L)	0.0026	0.00065	0.0033 U	TR	TR	TR	TR	TR	TR	TR	TR	TR								
Dissolved Organic Carbon (mg/L)													1.91	1.34	1.6	1.43	0.97	1.39	0.97	0.72
Fluoride (mg/L)													0.06		0.03	0.03	0.06	0.05	0.08 U	0.08
Hardness (mg/L)													24.7	17.3	16	18.6	12.5	12.7	12.9	21.4
NO_2 & NO_3 (mg/L)													0.47	0.57	0.48	0.46	0.24	0.35	0.19	0.34
Sulfate (mg/L)													9.77	6.41	4.98	6.01	3.82	3.69	5.2	10.69
Total Suspended Solids (mg/L)	26.3	9.3	39.8	6.9	2.5	0.7	66.1	2.2	6.7	15.3	7.2	2.4								
Field Measurements:																				
Conductivity (µS/cm)	53	39	33	36	41	58	32	43	36	33	44	78								
pH	7.45	7.15	6.91	7.15	7.41	7.13	6.86	6.82	6.84	6.76	6.98	6.69	5.7	7.4	6.8	7.5	7.1	8.1	6.1	8.40
Stream Flow (cfs)	551.2	684.9	1532.8	708.4	215.6	134.9	1385.7	487	584.1	544.1	198	88.6	527	1005	970	665	1110	870	690	107
Temperature (°C)	7	8	8	7	10	7	6	8	8.5	9	9	6								
Turbidity (NTU)	9.6	4.4	10.2	2.9	3.5	3.8	9	1.5	3.5	23	7.1	5.5								

Data Notes:

J - Estimated value.
TR- Trace amount of sample reported.
U - Parameter was analyzed for, but not detected above the reporting limit shown.
UJ - Parameter was analyzed for, but not detected. Detection limit is an estimated value.
* indicates that highest value from range of replicated samples were represented
▨ Grey shading indicates the concentration of analyte was not established, therefore not reported and analyzed.

Data Source:

(a) Anderson, Keith A. (USFS Chelan Ranger District). *Compilation of Data for Preliminary Assessment of the Holden Mine Site.*
(b) Walters, et al. 1992. *Holden Mine Reclamation Project Final Report.* Pacific Northwest Laboratories,Richland, WA. (Data collected in 1991).
(c) Kilburn, et al. 1994. *Geochemical data and sample locality maps for stream-sediment, heavy-mineral-concentrate, mill tailing, water, and precipitate samples collected in and around the Holden mine, Chelan County, Washington.* USGS Open File Report 94-680A Paper Version, 94-680B Diskette version (Data Collected in 1994).
(d) Johnson, A., et al. 1997. *Effects of Holden Mine on the Water, Sediments and Benthic Invertebrates of Railroad Creek (Lake Chelan).* Environmental Investigations and Laboratory Services Program. Water Body No. WA-47-1020. Publication No. 97-330 (data collected in Spring and Fall 1996)

TABLE 5.3-21
STATION RC-3 AND PROXIMITY SUMMARY OF HISTORICAL RAILROAD CREEK ANALYTICAL DATA (1982-1996)
HOLDEN MINE RI/FS
DAMES & MOORE JOB NO. 17693-005-019

Parameters — Sample ID	1992 USFS WATER QUALITY MONITORING DATA[a]								1993 USFS WATER QUALITY MONITORING DATA[b]						
Sampling Date	**5/14/92**	**6/2/92**	**6/16/92**	**7/1/92**	**7/14/92**	**7/29/92**	**8/11/92**	**9/8/92**	**5/21/93**	**6/9/93**	**6/23/93**	**7/7/93**	**7/21/93**	**8/4/93**	**9/1/93**
Total Metals (µg/L)															
Aluminum	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨
Arsenic	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨
Barium	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨
Beryllium	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨
Cadmium	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨
Calcium	6462	4130	4645	4737	5653	5836	6310	6340	4600	5500	6300	6700	5800	6100	8700
Chromium	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨
Copper	*4 U*	*8 U*	*0.8 U*	1 U	1 U	1 U	0.9 U	10.5 U	10	10	10	10	10 U	10 U	10 U
Iron	▨	▨	▨	▨	▨	▨	▨	▨	460	210	260	300	920	330	320
Lead	14.9 U	30 U	16.5 U	10.4 U	10.4 U	10.4 U	11.7 U	85.5 U	10	10	10	10	10 U	10 U	10 U
Magnesium	850	360	504	517	640	672	760	310	550	700	750	780	650	670	1000
Manganese	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨
Mercury	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨
Molybdenum	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨
Nickel	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨
Potassium	694	140	442	419	385	509	473	533.5 U	430	420	570	650	470	530	290
Selenium	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨
Silver	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨
Sodium	1019	930	646	617	705	724	934	610	1800	700	1400	1500	920	920	2100
Thallium	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨
Uranium	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨
Zinc	34	30	9	2.8 U	2.8 U	0.4	0.8 U	4 U	40	20	30	30	20	20	140
Dissolved Metals (µg/L)															
Aluminum	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨
Arsenic	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨
Barium	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨
Beryllium	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨
Cadmium	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨
Calcium	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨
Chromium	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨
Copper	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨
Iron	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨
Lead	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨
Magnesium	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨
Manganese	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨
Mercury	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨
Molybdenum	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨
Nickel	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨
Potassium	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨
Selenium	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨
Silver	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨
Sodium	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨
Thallium	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨
Uranium	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨
Zinc	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨
Conventional Analyses:															
Alkalinity (mg/L)	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨
Chloride (mg/L)	0.28	0.66	0.24	0.27	0.21	0.79	0.35	0.97	2	3	4	1	2.1	1.0 U	0.7
Cyanide (mg/L)	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨
Dissolved Organic Carbon (mg/L)	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨
Fluoride (mg/L)	0.01 U	0.01 U	0.01 U	0.01 U	0.01 U	0.01 U	0.01 U	0.01 U	0.05	0.04	0.01	0.01	0.03	0.05	0.06
Hardness (mg/L)	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨
NO_2 & NO_3 (mg/L)	0.33	0.28	0.21	0.22	0.17	0.16	0.17	0.38	0.12	0.09	0.07	0.03	0.02	0.04	0.04
Sulfate (mg/L)	8.41	4.18	4.98	5.4	6.79	7.74	8.65	7.82	6	6	7.4	7	7	8	9
Total Suspended Solids (mg/L)	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨
Field Measurements:															
Conductivity (µS/cm)	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨
pH	8.6	8	7.8	5.6	8.3	8.3	7.8	6.8	3.8	▨	10.2	11.3	10.4	6.7	7.6
Stream Flow (cfs)	538	670	825	655	418	305	165	365	1160	685	450	310	410	290	38
Temperature (°C)	6	8	9	10.9	11.5	13	12.7	10	7.5	8.6	8.3	10.3	11.1	13.4	10.8
Turbidity (NTU)	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨

Data Notes:
J - Estimated value.
TR- Trace amount of sample reported.
U - Parameter was analyzed for, but not detected above the reporting limit shown.
UJ - Parameter was analyzed for, but not detected. Detection limit is an estimated value.
* indicates that highest value from range of replicated samples were represented
▨ Grey shading indicates the concentration of analyte was not established, therefore not reported and analyzed.

Data Source:
(a) Anderson, Keith A. (USFS Chelan Ranger District). 1992 Compilation of Data for Preliminary Assessment of the Holden Mine Site.
(b) Walters, et al. 1992. *Holden Mine Reclamation Project Final Report.* Pacific Northwest Laboratories,Richland, WA. (Cata collected in 1991).
(c) Kilburn, et al. 1994. *Geochemical data and sample locality maps for stream-sediment, heavy-mineral-concentrate, mill tailing, water, and precipitate samples collected in and around the Holden mine, Chelan County, Washington.* USGS Open File Report 94-680A Paper Version, 94-680B Diskette version (Data Collected in 1994).
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TABLE 5.3-21
STATION RC-3 AND PROXIMITY SUMMARY OF HISTORICAL RAILROAD CREEK ANALYTICAL DATA (1982-1996)
HOLDEN MINE RI/FS
DAMES & MOORE JOB NO. 17693-005-019

Parameters / Sample ID	USFS 1994[a]	USGS[c]			1994 USFS WATER QUALITY MONITORING DATA[a]						1995 USFS WATER QUALITY MONITORING DATA[a]					DEPT. OF ECOLOGY[d]		
		352	353	354												RC-STATION		MP-STATION
Sampling Date	6/8/94	7/94	7/94	7/94	7/5/94	7/19/94	8/3/94	8/29/94	9/14/94	9/28/94	6/20/95	7/26/95	8/9/95	8/23/95	9/27/95	6/12/96	9/10/96	9/10/96
Total Metals (µg/L)																		
Aluminum																37	50	110
Arsenic																0.42	0.32	0.51
Barium																		
Beryllium																		
Cadmium																0.13	0.1 U	0.12
Calcium	6500				5300	4900		7600	9400	8100	5700	3800	5400	6700				
Chromium																		
Copper	10 U				10 U	10 U		10 U	10 U	10 U	10 U	10 U	10 U	10 U		7.9	1.4	1.8
Iron	290				210	220		320	40	510	200	380	320	470		438	684	1240
Lead	10 U				10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U		0.17	0.1 U	0.10 U
Magnesium	830				610	650		640	980	890	630	430	680	890				
Manganese																7.9	13	19
Mercury																0.002		
Molybdenum																		
Nickel																0.43		
Potassium	500				310	370		540	630	600	340	350	530	600				
Selenium																	0.4 U	0.4 U
Silver																0.03		
Sodium	1000				700	800		880	980	860	1100	520	670	920				
Thallium																		
Uranium																		
Zinc	30				10	10 U	10	20	20	30	40	10 U	10 U	20		22	21	28
Dissolved Metals (µg/L)																		
Aluminum		20	6 U	21													6.4 *	3.2 *
Arsenic		2 U	2 U	2 U														
Barium		4.7	6.1	5.3														
Beryllium		1 U	1 U	1 U														
Cadmium		1 U	1 U	1 U												0.16	0.08 *	0.13 *
Calcium		6000 U	6000 U	6000 U														
Chromium		1 U	1 U	1 U														
Copper		1.6	0.1 U	1.4												5.2	0.4 *	0.39 *
Iron		200	100 U	200														
Lead		0.2 U	0.2 U	0.2 U												0.04	0.09 *	0.06 *
Magnesium		480	540	490														
Manganese		5.5	0.9 U	3.5														
Mercury																		
Molybdenum		0.5	0.2	0.4														
Nickel		3 U	3 U	3 U												0.26		
Potassium		200	200	300														
Selenium																		
Silver		0.1 U	0.1 U	0.1 U												0.01 U		
Sodium		400	400	500														
Thallium		0.1 U	0.1 U	0.1 U														
Uranium		0.1 U	0.1 U	0.1 U														
Zinc		13	2 U	14												20	19 *	25 *
Conventional Analyses:																		
Alkalinity (mg/L)																13		
Chloride (mg/L)	0.7	0.21	0.13	0.21	0.7		0.9	0.9	0.9									
Cyanide (mg/L)																0.01 U		
Dissolved Organic Carbon (mg/L)																		
Fluoride (mg/L)	0.07	0.05 U	0.05 U	0.05 U	0.06	0.08		0.05	0.04	0.02								
Hardness (mg/L)																16	22	
NO_2 & NO_3 (mg/L)	0.06	0.11	0.1 U	0.1 U	0.03	0.04		0.02	0.02	0.04	0.08	0.01	0.04	0.04	0	0.09		
Sulfate (mg/L)	6.2	6.4	1.4	6.1	4.5	2.1		11.5	13.6	14.4	4.5	5.8	9.1	12.3		5.2	12	
Total Suspended Solids (mg/L)																3	1	
Field Measurements:																		
Conductivity (µS/cm)		30	30	30												40	55	
pH	7.4	7.38	7.69	7.45	7.8	8.1	7.8	NA	8.9	8.2	7.8	7.4	7.5	7.6	6.4	7.1	6.3	
Stream Flow (cfs)																615	83.4	
Temperature (°C)	10	9.5	9	12.5	11	14	12	12	11	11	8	12.9		10	10	8.1	11.1	
Turbidity (NTU)																2.1	2.8	

Data Notes:

J - Estimated value.
TR- Trace amount of sample reported.
U - Parameter was analyzed for, but not detected above the reporting limit shown.
UJ - Parameter was analyzed for, but not detected. Detection limit is an estimated value.
* indicates that highest value from range of replicated samples were represented
▨ Grey shading indicates the concentration of analyte was not established, therefore not reported and analyzed.

Data Source:

(a) Anderson, Keith A. (USFS Chelan Ranger District). Compilation of Data for Preliminary Assessment of the Holden Mine Site.
(b) Walters, et al. 1992. *Holden Mine Reclamation Project Final Report.* Pacific Northwest Laboratories,Richland, WA. (Data collected in 1991).
(c) Kilburn, et al. 1994. *Geochemical data and sample locality maps for stream-sediment, heavy-mineral-concentrate, mill tailing, water, and precipitate samples collected in and around the Holden mine, Chelan County, Washington.* USGS Open File Report 94-680A Paper Version, 94-680B Diskette version (Data Collected in 1994)
(d) Johnson, A., et al. 1997. *Effects of Holden Mine on the Water, Sediments and Benthic Invertebrates of Railroad Creek (Lake Chelan).* Environmental Investigations and Laboratory Services Program. Water Body No WA-47-1020. Publication No. 97-330 (data collected in Spring and Fall 1996).

TABLE 5.3-22
SUMMARY OF RI WATER QUALITY DATA FOR STATIONS IN RAILROAD CREEK UPSTREAM OF SITE
HOLDEN MINE RI/FS
DAMES & MOORE JOB NO. 17693-005-019

Parameters	RC-11		RC-6 Station												RC-1 Station										
Station No.			RC-6A	RC-6B	RC-6C	RC-6							RC-6 North Bank	RC-6 North Bank X	RC-1A	RC-1B	RC-1C	RC-1				RC-1 North Bank		RC-1 South Bank	
Sampling Date	10/4/97	5/1/98	4/15/97	4/15/97	4/15/97	5/19/97	5/26/97	6/2/97	6/9/97	6/16/97	7/10/97	5/3/98	9/15/97	9/15/97	4/16/97	4/16/97	4/16/97	5/19/97	7/10/97	9/15/97	5/3/98	5/19/97	9/15/97	5/19/97	9/15/97
Total Metals, (ug/L)																									
Aluminum	140U	70U	20U	20U	20	90	40J	160	80J	180	150	150J	60	60	20	20U	20U	90	160	70	100J	100	40	100U	60
Arsenic	1.56	1.12	1U	1U	1U	0.80					0.76	1.07	1.07	1.09	1	1	2	0.72	0.76	1.07	0.86				
Barium	4.13	4.14	3	3	4	4.92	4.43	4.87	4.43J	5	4.61	5.1	4.38	4.52	3	3	4	4.98	4.62	4.42	4.91	5.02	4.40	4.80	4.39
Beryllium	0.08U	0.04U	1U	1U	1U	0.04U	0.2U	0.04U	0.04U	0.2U	0.04U	0.04U	0.04U	0.04U	1U	1U	1U	0.04U	0.04U	0.04U	0.04U	0.04U	0.04U	0.04U	0.04U
Cadmium	0.04U	0.04U	0.2U	0.2U	0.2U	0.04U	0.04U	0.04	0.04U	0.2U	0.04U	0.04U	0.04U	0.04U	0.2U	0.2U	0.2U	0.04U	0.04U	0.04U	0.04U	0.05	0.04U	0.04U	0.04U
Calcium	2,540	2410	6,720	6,660	6,740	3,820	4,020	3,430	3,530J	2,820	3,030	3800	4,100	4,020	6,480	6,480	6,470	3,800	3,050	4,080	3860	3,850	4,060	3,840	4,100
Chromium	0.2U	0.2U	5U	5U	5U	0.2U	0.2U	0.2U	0.2U	5U	0.2U	0.2U	0.2U	0.2U	5U	5U	5U	0.2U	0.2U	0.2U	0.2U	0.2U	0.2U	0.2U	0.2U
Copper	1.2	1	2U	2U	2U	0.9U	0.7	1.3	0.8J	4	1.1	1.8J	0.6	1.0	2U	2U	2U	1.1U	1.0	0.6	1.1	1.2U	0.6	1.1U	0.7
Iron	220	90	70	70	70	140	80J	150	70J	170	150	180	110	120	70	90	70	120	160	110	110	130	100	140	110
Lead	0.4	0.139	1U	1U	1U	0.3U	0.3	4.8	0.3J	1U	0.3UJ	0.124	0.2UJ	0.3UJ	1U	1U	1U	0.2U	0.3UJ	0.2UJ	0.103	0.3U	0.3UJ	0.4U	0.2UJ
Magnesium	290	240	680	670	670	360	400	340	340J	310	310	360	360	360	650	640	650	360	320	350	360	370	360	390	360
Manganese	6.02	3.83	2	2	2	3.7	1.67	4.41	1.95J	5	3.90	6.52	3.02	3.53	2	2	2	4.70	3.87	3.09	4.45	3.49	2.70	3.30	3.20
Mercury			0.1U	0.1U	0.1U	0.00046J					0.00064				0.1U	0.1U	0.1U	0.00039	0.00032J						
Molybdenum	0.66	0.65				0.49					0.39	0.53	0.74	0.74				0.49	0.39	0.74	0.52				
Nickel	0.4	0.3	10U	10U	10U	0.3J	0.4	0.4	0.2U	10U	0.3	0.3	0.2	0.3	10U	10U	10U	0.3J	0.3	0.2	0.3	0.3J	0.2	0.3J	0.2
Potassium	500U	500U	600	810	650	500U	500U	500U	510J	500U	500U	500U	500U	500U	780	630	730	500U	500U	500U	500U	500U	500U	610	500U
Selenium			1U	1U	1U	0.2U					0.2U				1U	1U	1U	0.2U	0.2U						
Silver	0.04U	0.04U	0.2U	0.2U	0.2U	0.04U	0.04U	0.04U	0.04UJ	0.2U	0.04U	0.04U	0.04U	0.04U	0.2U	0.2U	0.2U	0.14U	0.04U	0.04U	0.04U	0.12U	0.12	0.05U	0.04U
Sodium	540U	670	1,120	1,120	1,140	760	810	610	610J	600	700	690	580	570	1,090	1,090	1,090	780	490	580	730	750	590	800	590
Thallium			1U	1U	1U	0.04U					0.04U		0.04U	0.04U	1U	1U	1U	0.04U	0.04U	0.04U					
Uranium						0.04U					0.04U		0.04U	0.04U				0.04U	0.04U	0.04U					
Zinc	5	4U	4U	4U	4U	4U	4U	4U	4U	11	4U	4U	5	4U	4U	4U	4U	4U	.5	4U	4U	4U	4U	5	4U
Dissolved Metals, (ug/L)																									
Aluminum	40U	30	20	40	20U	30U	20	60	40J	30	30U	40	30	20U	20	20U	20	30	20U	20U	30	30U	20U	30	20U
Arsenic	0.94	0.73	1U	1U	1U	0.50					0.52	0.54	0.81	0.82	1U	1U	1U	0.50	0.51	0.82	0.53				
Barium	3.42	3.61	5	5	5	15.4J	24.3	17.6	16.0J	14	10.9	4.14	4.33	4.33	5	6	6	22.0J	10.4	4.32	4.38	17.2J	4.30	15.0J	4.29
Beryllium	0.04U	0.04U	1U	1U	1U	0.04U	0.04U	0.04U	0.04U	0.04U	0.04U	0.04U	0.04U	0.04U	1U	1U	1U	0.04U	0.04U	0.04U	0.04U	0.04U	0.04U	0.04U	0.04U
Cadmium	0.04U	0.04U	0.2U	0.2U	0.2U	0.04U	0.04U	0.04U	0.04U	0.04U	0.04U	0.08	0.04U	0.08	0.2U	0.2U	0.2U	0.04U	0.04U	0.04U	0.04U	0.06	0.04U	0.04	0.09
Calcium	2,520	2310	6,750	6,810	6,490	3,870	3,780	3,510	3,480J	2,800	3,000	3630	4,170	4,150	6,430	6,430	6,400	3,770	3,120	4,120	3730	3,800	4,150	3,760	4,180
Chromium	0.2U	0.2U	5U	5U	5U	0.2U	0.2U	0.2U	0.2U	5U	0.2U	0.2U	0.2U	0.2U	5U	5U	5U	0.2U	0.2U	0.2U	0.2U	0.2U	0.2U	0.2U	0.2U
Copper	1.1	0.7	2U	2U	2U	0.7	1.0	0.9	1.2U	2U	0.6	0.6	0.4	0.5	2U	2U	2U	1.1	0.6	0.4	0.8	1.0	0.6	1.0	0.6
Iron	60	30	30	40	40	30	30J	30	20U	20U	20U	30	40	40	40	40	40	30	20U	40	20	20U	40	20U	40
Lead	0.2U	0.5J	1U	1U	1U	0.9U	0.3U	1.8U	0.2U	0.2U	0.2J	0.011U	0.2U	0.9	1U	1U	1U	0.2U	0.3J	0.5	0.011U	1.1U	0.2U	0.7U	0.2
Magnesium	260	230	640	650	660	360	370	340	310J	250	260	320	350	350	660	660	660	360	270	350	330	360	340	360	350
Manganese	3.17	2.88	2	1	1	1.94	1.40	1.23	0.96J	1	1.18	2.08	1.74	1.72	2	1	1	1.82	1.13	1.65	2	1.86	1.67	1.83	1.68
Mercury			0.1UJ	0.1UJ	0.1UJ	0.00003J					0.00033J				0.1UJ	0.1UJ	0.1UJ	0.00031J	0.00028J						
Molybdenum	0.67	0.59				0.51					0.41	0.48	0.73	0.73				0.49	0.40	0.82	0.49				
Nickel	0.3	0.3	10U	10U	10U	0.3	0.6	0.4	0.2U	10U	0.2U	0.2U	0.2	0.2	10U	10U	10U	0.2	0.2U	0.2	0.2U	0.3	0.2	0.2	0.2
Potassium	500U	500U	780	660	500U	500U	500U	710	500U	500U	500U	500U	500U	500U	690	500	500	500U	500U	500U	500U	500U	500U	500U	500U
Selenium			1U	1U	1U	0.2U					0.2U				1U	1U	1U	0.2U	0.2U						
Silver	0.04U	0.04U	0.2U	0.2U	0.2U	0.04U	0.04U	0.04UJ	0.04UJ	0.04U	0.04U	0.04U	0.04U	0.04U	0.2U	0.2U	0.2U	0.04U	0.04U	0.04U	0.04U	0.04U	0.04U	0.04U	0.04U
Sodium	560U	630	1,100	1,160	1,120	800J	820	660	660J	570U	490	700	600	610	1,240	1,220	1,280	810J	490	620	690	850J	600	780U	630
Thallium			1U	1U	1U	0.04U					0.04U		0.04U	0.04U	1U	1U	1U	0.04U	0.04U	0.04U					
Uranium						0.04U					0.04U		0.04U	0.04U				0.04U	0.04U	0.04U					
Zinc	5	4U	6	6	5	16	14U	13U	16U	12	6	4U	16	4	5	5	4U	13	6	4U	4U	16	9	13	4U
Stream Discharge (cfs)	60-70	--	54.9	--	--	--	314	--	--	--	--	--	131.2	--	63.1	--	--	575	--	132.27	--	--	--	--	--

TABLE 5.3-22
SUMMARY OF RI WATER QUALITY DATA FOR STATIONS IN RAILROAD CREEK UPSTREAM OF SITE
HOLDEN MINE RI/FS
DAMES & MOORE JOB NO. 17693-005-019

Station No.	RC-11		RC-6 Station												RC-1 Station										
Parameters			RC-6A	RC-6B	RC-6C	RC-6							RC-6 North Bank	RC-6 North Bank X	RC-1A	RC-1B	RC-1C	RC-1				RC-1 North Bank		RC-1 South Bank	
Sampling Date	10/4/97	5/1/98	4/15/97	4/15/97	4/15/97	5/19/97	5/26/97	6/2/97	6/9/97	6/16/97	7/10/97	5/3/98	9/15/97	9/15/97	4/16/97	4/16/97	4/16/97	5/19/97	7/10/97	9/15/97	5/3/98	5/19/97	9/15/97	5/19/97	9/15/97
Total Petroleum Hydrocarbon (mg/L)																									
Gasoline Range Hydrocarbons						0.25U					0.25U		0.25U	0.25U											
Diesel Range Hydrocarbons						0.25UJ			0.25U		0.25U		0.25U	0.25U											
Motor Oil						0.50UJ			0.50U		0.50U		0.50U	0.50U											
Polychlorinated Biphenyls (µg/L)																									
Aroclor 1016						0.017U					0.033U														
Aroclor 1221						0.033U					0.067U														
Aroclor 1232						0.017U					0.033U														
Aroclor 1242						0.017U					0.033U														
Aroclor 1248						0.017U					0.033U														
Aroclor 1254						0.017U					0.033U														
Aroclor 1260						0.017U					0.033U														
Conventional Analyses																									
Ortho-Phosphorous (mg/L)						0.004U					0.008J		0.004UJ	0.004UJ				0.004U	0.022J						
Post Chlorination Cyanide (mg/L)						0.004U					0.004U		0.004UJ	0.004UJ				0.004U	0.004U	0.004UJ					
Total Cyanide (mg/L)						0.004					0.004U		0.004UJ	0.004UJ				0.004U	0.004U	0.004UJ					
Total Dissolved Solids (mg/L)	31J	11	33	32	34	16	19J	5.0UJ	15	7.0	15J	22	31J	34J	27	34	24	17	14J	32J	22	910	32J	15	34J
Total Phosphorous (mg/L)						0.019					0.016U		0.016U	0.016U				0.028	0.031						
Total Suspended Solids (mg/L)	3.8	1.3	1.8U	1.0U	1.0U	1.1U	1.0UJ	1.8J	1.1U	3.1	1.2	1.5	1.1U	1.1U	1.0U	1.0U	1.0U	3.7	1.7	1.1U	1.1	1.2	1.1U	1.1U	1.1U
Chloride (mg/L)			1.0U	1.0U	1.0U	1.0U					1.2		1.0U	1.0U	1.0U	1.0U	1.0U	1.0U	1.0U	1.0U					
NO_2 & NO_3 (mg/L)			0.12	0.12	0.12	0.17					0.059		0.023	0.012	0.12	0.10	0.11	0.19	0.062	0.017					
Sulfate (mg/L)	2.5U	2.5U	5.4	4.8	6.9	4.9	3.7	4.2	4.9	7.7	2.5U	2.5U	5.0	4.6	4.4	4.5	4.3	7.7	2.5U	3.6	2.5U	2.5U	3.4	2.5U	4.2
Silicates (mg/L)																									
Alkalinity (mg/L $CaCO_3$)	5.5	6.1	17	17	18	10	10	8.8	10	7.9	7.8	8.6	7.6	12	17	17	17	10	8.6	10	10	8.8	11	8.3	12
Amenable Cyanide (mg/L)						0.004					0.004U		0.004UJ	0.004UJ				0.004U	0.004U	0.004UJ					
Color (Pt-CO)						10					5UJ		10J	5J				5	5UJ						
Hardness, Dissolved (mg/L)	7	6.7	20	20	19	11	11	10	10	8.0	8.6	10	12	12	19	19	19	11	8.9	12	11	11	12	11	12
Field Measurements:																									
pH	6.2	7.6	5.96	5.5	6	5.9	7.1		6.3	5	7.8	5.7	6.1		5.9	5.8	5.8	5.45	8	5.8	7.64	6.1	6.3	5.73	6.3
Specific Conductivity (µS)	15					28	40		35	61	51	20	29		57	56	55	50	22	68	2	29	29	29	29
Temperature (°C)	7	6.6				7.4	5.5		6.9	6.9	7.3	6.8	8.9		4.7	4.6	47	5.9	6.6	9.7	6.3	5.6	8.9	6.2	8.9
Redox (mV)							157		190	208															
Iron (ion)																									
Turbidity (NTU)		1	0.10UJ	0.14J	0.14J				31	210		37	0					111			3	5	0	4	0
Dissolved Oxygen (mg/L)		15.7					15.5		16.06	14.76		10.9 (W)	10.5					15.44			16	15.85	10.3	15.28	10.3

Data Notes:

J - Estimated value.
U - Parameter was analyzed for, but not detected above the reporting limit shown.
UJ - Parameter was analyzed for but not detected. Detection limit is an estimated value.
(W) - Dissolved oxygen performed using field test kit based on Winkler titration.
Sample nomenclature - An "A", "B", and "C" after the station ID indicates that these samples were collected separately at the same station, ie., field replicates. This was changed in later rounds to an "X" to indicate field duplicates.
X - after the sample ID is an indication of field duplicate
▨ Grey shading indicates the concentration of analyte was not established, therefore not reported nor analyzed.
-- indicates no discharge data available or replicate analysis.

TABLE 5.3-23
SUMMARY OF SURFACE WATER MONITORING DATA AND WATER QUALITY CRITERIA FOR RAILROAD CREEK AND TRIBUTARIES (APRIL 1997)
HOLDEN MINE RI/FS
DAMES & MOORE JOB NO. 17693-005-019

Station No.		Parameters	Arsenic, Dissolved (ug/L)	Cadmium, Dissolved (ug/L)	Chromium, Dissolved (ug/L)	Copper, Dissolved (ug/L)	Lead, Dissolved (ug/L)	Mercury, Dissolved (ug/L) *	Nickel, Dissolved (ug/L)	Selenium, Total (ug/L)	Silver, Dissolved (ug/L)	Zinc, Dissolved (ug/L)**	Hardness CaCO3 (mg/L)***
		SWQ Criteria (Acute)	*360*	*0.82*	*180*	*4.6*	*14*	*2.4*	*440*	*20*	*0.32*	*35*	*25*
		SWQ Criteria (Chronic)	*190*	*0.37*	*57*	*3.5*	*0.54*	*0.012*	*49*	*5*	*NE*	*32*	*25*
RAILROAD CREEK:													
UPSTREAM OF SITE		**Specific SWQ Criteria (Acute)**	360	0.63	140	3.7	11	2.4	360	20	0.21	29	-
		Specific SWQ Critieria (Chronic)	190	0.31	47	2.8	0.41	0.012	40	5	NE	26	-
	RC-6A	**4/15/97**	1 U	0.2 U	5 U	2 U	1 U	0.1 UJ	10 U	1U	0.2 U	6	19.67
	RC-6B	**4/15/97**	1 U	0.2 U	5 U	2 U	1 U	0.1 UJ	10 U	1U	0.2 U	6	19.67
	RC-6C	**4/15/97**	1 U	0.2 U	5 U	2 U	1 U	0.1 UJ	10 U	1U	0.2 U	5	19.67
		Specific SWQ Criteria (Acute)	360	0.61	140	3.6	10	2.4	350	20	0.20	28	-
		Specific SWQ Critieria (Chronic)	190	0.30	46	2.7	0.40	0.012	39	5	NE	26	-
	RC-1A	**4/16/97**	1 U	0.2 U	5 U	2 U	1 U	0.1 UJ	10 U	1 U	0.2 U	5	19
	RC-1B	**4/16/97**	1 U	0.2 U	5 U	2 U	1 U	0.1 UJ	10 U	1 U	0.2 U	5	19
	RC-1C	**4/16/97**	1 U	0.2 U	5 U	2 U	1 U	0.1 UJ	10 U	1 U	0.2 U	4 U	19
ADJACENT TO SITE		**Specific SWQ Criteria (Acute)**	360	0.72	160	4.1	12	2.4	390	20	0.26	32	-
		Specific SWQ Critieria (Chronic)	190	0.34	52	3.1	0.47	0.012	44	5	NE	29	-
	RC-4-Grab	**4/16/97**	1 U	0.2	5 U	9	1 U	0.1 UJ	10 U	1 U	0.2 U	39	22
		Specific SWQ Criteria (Acute)	360	0.75	160	4.3	13	2.4	410	20	0.27	33	-
		Specific SWQ Critieria (Chronic)	190	0.35	53	3.2	0.49	0.012	45	5	NE	30	-
	RC-4A	**4/16/97**	1 U	0.3	5 U	11	1 U	0 1 UJ	10 U	1 U	0.2 U	55	23
		Specific SWQ Criteria (Acute)	360	0.89	190	5.0	15	2.4	470	20	0.36	38	-
		Specific SWQ Critieria (Chronic)	190	0.39	61	3.7	0.59	0.012	52	5	NE	34	-
	RC-7A	**4/16/97**	1 U	0.5	5 U	3	1 U	0.1 UJ	10 U	1 U	0.2 U	90	27
		Specific SWQ Criteria (Acute)	360	0.86	180	4.8	15	2.4	450	20	0.34	37	-
		Specific SWQ Critieria (Chronic)	190	0.38	59	3.6	0.57	0.012	50	5	NE	33	-
	RC-2A	**4/17/97**	1 U	0.4	5 U	2	1 U	0.1 UJ	10 U	1 U	0.2 U	77	26
DOWNSTREAM OF SITE		**Specific SWQ Criteria (Acute)**	360	0.86	180	4.8	15	2.4	450	20	0.34	37	-
		Specific SWQ Critieria (Chronic)	190	0.38	59	3.6	0.57	0.012	50	5	NE	33	-
	RC-5A	**4/17/97**	1 U	0.4	5 U	3	1 U	0.1 UJ	10 U	1 U	0.2 U	86	26
		Specific SWQ Criteria (Acute)	360	1.0	210	5 6	18	2.4	530	20	0.46	42	-
		Specific SWQ Critieria (Chronic)	190	0.43	68	4.2	0.69	0.012	58	5	NE	39	-
	RC-8A	**4/18/97**	1 U	0.2 U	5 U	4	1 U	0.1 UJ	10 U	1 U	0.2 U	37	31
	RC-8B	**4/18/97**	1 U	0.2 U	5 U	3	1 U	0.1 UJ	10 U	1 U	0.2 U	32	32
		Specific SWQ Criteria (Acute)	360	1.0	210	5.6	18	2.4	530	20	0.46	42	-
		Specific SWQ Critieria (Chronic)	190	0.43	68	4.2	0.69	0.012	58	5	NE	39	-
	RC-3A	**4/18/97**	1 U	0.2 U	5 U	4	1 U	0.1 UJ	10 U	1 U	0.2 U	41	31

Notes:
J - Estimated value.
U - Parameter was analyzed for, but not detected above the reporting limit shown.
UJ - Parameter was analyzed for but not detected. Detection limit is an estimated value.
NA - Data Not Available
NE - Not Established
* Evaluation of chronic criteria is based on total; acute criteria is based on dissolved.
** Dissolved zinc concentrations potentially increased due to the introduction of zinc during the field filtration procedure. See text for additional information.
*** Value is an average value if water samples were collected more than one time within the specified period.

TABLE 5.3-24
SUMMARY OF SURFACE WATER MONITORING DATA AND WATER QUALITY CRITERIA FOR RAILROAD CREEK AND TRIBUTARIES (MAY/ JUNE 1997)
HOLDEN MINE RI/FS
DAMES & MOORE JOB NO. 17693-005-019

Station No.		Parameters	Arsenic, Dissolved (ug/L)	Cadmium, Dissolved (ug/L)	Chromium, Dissolved (ug/L)	Copper, Dissolved (ug/L)	Lead, Dissolved (ug/L)	Mercury, Dissolved (ug/L)*	Nickel, Dissolved (ug/L)	Selenium, Total (ug/L)	Silver, Dissolved (ug/L)	Zinc, Dissolved (ug/L)**	Hardness $CaCO_3$ (mg/L)
		SWQ Criteria (Acute)	*360*	*0.82*	*180*	*4.6*	*14*	*2.4*	*440*	*20*	*0.32*	*35*	*25*
		SWQ Criteria (Chronic)	*190*	*0.37*	*57*	*3.5*	*0.54*	*0.012*	*49*	*5*	*NE*	*32*	*25*
RAILROAD CREEK:													
UPSTREAM OF SITE	**RC-6**	**Specific SWQ Criteria (Acute)**	360	0.34	90	2.1	5.5	2.4	220	20	0.077	18	-
		Specific SWQ Critieria (Chronic)	190	0.2	29	1.7	0.21	0.012	24	5	NE	16	-
		5/19/97	0.5	0.04 U	0.2 U	0.7	0.9 U	0.00003 J	0.3	0.2 U	0.04 U	16	11
	RC-1	**Specific SWQ Criteria (Acute)**	360	0.34	90	2.1	5.5	2.4	220	20	0.077	18	-
		Specific SWQ Critieria (Chronic)	190	0.2	29	1.7	0.21	0.012	24	5	NE	16	-
		5/19/97	0.5	0.04 U	0.2 U	1.1	0.2 U	0.00031 J	0.2	0.2 U	0.04 U	13	11
	RC-1 North Bank	**Specific SWQ Criteria (Acute)**	360	0.34	90	2.1	5.5	2.4	220	20	0.077	18	-
		Specific SWQ Critieria (Chronic)	190	0.2	29	1.7	0.21	0.012	24	5	NE	16	-
		5/19/97	NA	0.06	0.2 U	1	1.1 U	NA	0.3	NA	0.04 U	16	11
	RC-1 South Bank	**Specific SWQ Criteria (Acute)**	360	0.34	90	2.1	5.5	2.4	220	20	0.077	18	-
		Specific SWQ Critieria (Chronic)	190	0.2	29	1.7	0.21	0.012	24	5	NE	16	-
		5/19/97	NA	0.04	0.2 U	1	0.7 U	NA	0.2	NA	0.04 U	13	11
ADJACENT TO SITE	**RC-4**	**Specific SWQ Criteria (Acute)**	360	0.4	103	2.5	6.6	2.4	250	20	0.1	20	-
		Specific SWQ Critieria (Chronic)	190	0.23	33	2	0.26	0.012	28	5	NE	19	-
		5/21/97	NA	0.44	0.2 U	26.4	0.6 J	NA	0.3	NA	0.08 U	73	13
	RC-4 South Bank	**Specific SWQ Criteria (Acute)**	360	0.47	120	2.8	7.8	2.4	280	20	0.13	23	-
		Specific SWQ Critieria (Chronic)	190	0.25	38	2.2	0.3	0.012	32	5	MD	21	-
		5/21/97	NA	1.1	0.2 U	58.5	0.6 J	NA	1	NA	0.14 U	191	15
	RC-7	**Specific SWQ Criteria (Acute)**	360	0.44	110	2.7	7.2	2.4	270	20	0.12	22	-
		Specific SWQ Critieria (Chronic)	190	0.24	36	2.1	0.28	0.012	30	5	NE	20	-
		5/20/97	NA	0.58	0.2 U	23	0.5 J	NA	0.4	NA	0.54 U	85	14
	RC-2	**Specific SWQ Criteria (Acute)**	360	0.47	120	2.8	7.8	2.4	280	20	0.13	23	-
		Specific SWQ Critieria (Chronic)	190	0.25	38	2.2	0.3	0.012	32	5	NE	21	-
		5/19/97	0.3	0.53	0.4	23.6	1.4 U	0.00047 J	0.9	0.2 U	0.07	84	15
	RC-2 South Bank	**Specific SWQ Criteria (Acute)**	360	0.47	120	2.8	7.8	2.4	280	20	0.13	23	-
		Specific SWQ Critieria (Chronic)	190	0.25	38	2.2	0.3	0.012	32	5	NE	21	-
		5/19/97	0.22	0.55	0.2 U	26	0.6 U	0.00036 J	0.6	0.2 U	0.04 U	97	15

TABLE 5.3-24
SUMMARY OF SURFACE WATER MONITORING DATA AND WATER QUALITY CRITERIA FOR RAILROAD CREEK AND TRIBUTARIES (MAY/ JUNE 1997)
HOLDEN MINE RI/FS
DAMES & MOORE JOB NO. 17693-005-019

Station No.		Parameters	Arsenic, Dissolved (ug/L)	Cadmium, Dissolved (ug/L)	Chromium, Dissolved (ug/L)	Copper, Dissolved (ug/L)	Lead, Dissolved (ug/L)	Mercury, Dissolved (ug/L)*	Nickel, Dissolved (ug/L)	Selenium, Total (ug/L)	Silver, Dissolved (ug/L)	Zinc, Dissolved (ug/L)**	Hardness $CaCO_3$ (mg/L)
		SWQ Criteria (Acute)	*360*	*0.82*	*180*	*4.6*	*14*	*2.4*	*440*	*20*	*0.32*	*35*	*25*
		SWQ Criteria (Chronic)	*190*	*0.37*	*57*	*3.5*	*0.54*	*0.012*	*49*	*5*	*NE*	*32*	*25*
RAILROAD CREEK (continued):													
DOWNSTREAM OF SITE	RC-5	Specific SWQ Criteria (Acute)	360	0.47	120	2.8	7.8	2.4	280	20	0.13	23	-
		Specific SWQ Critieria (Chronic)	190	0.25	38	2.2	0.3	0.012	32	5	NE	21	-
		5/20/97	NA	0.5	0.2 U	21.5	0.2 J	NA	0.6	NA	0.14 U	84	15
	RC-5A	Specific SWQ Criteria (Acute)	360	0.58	130	3.4	9.6	2.4	330	20	0.18	27	-
		Specific SWQ Critieria (Chronic)	190	0.29	44	2.6	0.37	0.012	37	5	NE	24	-
		5/22/97	-	0.4	5 U	7	0.2 U	-	10 U	-	0.04 U	80	18
	RC-3	Specific SWQ Criteria (Acute)	360	0.58	130	3.4	9.6	2.4	330	20	0.18	27	-
		Specific SWQ Critieria (Chronic)	190	0.29	44	2.6	0.37	0.012	37	5	NE	24	-
		5/22/97	0.19	0.24	5 U	10	0.4 U	0.00064	10 U	0.2 U	0.04 U	38	18
COPPER CREEK	CC-1	Specific SWQ Criteria (Acute)	360	0.4	103	2.5	6.6	2.4	250	20	0.1	20	-
		Specific SWQ Critieria (Chronic)	190	0.23	33	2	0.26	0.012	28	5	NE	19	-
		5/23/97	NA	0.04 U	5 U	2 U	0.4 U	NA	10 U	NA	0.04 U	12	13
	CC-2	Specific SWQ Criteria (Acute)	360	0.4	103	2.5	6.6	2.4	250	20	0.1	20	-
		Specific SWQ Critieria (Chronic)	190	0.23	33	2	0.26	0.012	28	5	NE	19	-
		5/23/97	NA	0.04 U	5 U	2 U	7 U	NA	10 U	NA	0.04 U	13	13

Notes:
J - Estimated value.
U - Parameter was analyzed for, but not detected above the reporting limit shown.
UJ - Parameter was analyzed for but not detected. Detection limit is an estimated value.
NA - Data Not Available
NE - Not Established
* Evaluation of chronic criteria is based on total; acute criteria is based on dissolved.
** Dissolved zinc concentrations potentially increased due to the introduction of zinc during the field filtration procedure. See text for additional information.

TABLE 5.3-25
SUMMARY OF SURFACE WATER MONITORING DATA AND WATER QUALITY CRITERIA FOR RAILROAD CREEK AND TRIBUTARIES (JULY 1997)
HOLDEN MINE RI/FS
DAMES & MOORE JOB NO. 17693-005-019

Station No.		Parameters	Arsenic, Dissolved (ug/L)	Cadmium, Dissolved (ug/L)	Chromium, Dissolved (ug/L)	Copper, Dissolved (ug/L)	Lead, Dissolved (ug/L)	Mercury, Dissolved (ug/L)*	Nickel, Dissolved (ug/L)	Selenium, Total (ug/L)	Silver, Dissolved (ug/L)	Zinc, Dissolved (ug/L)**	Hardness CaCO$_3$ (mg/L)
		SWQ Criteria (Acute)	*360*	*0.82*	*180*	*4.6*	*14*	*2.4*	*440*	*20*	*0.32*	*35*	*25*
		SWQ Criteria (Chronic)	*190*	*0.37*	*57*	*3.5*	*0.54*	*0.012*	*49*	*5*	*NE*	*32*	*25*
RAILROAD CREEK:													
UPSTREAM OF SITE	**RC-6**	**Specific SWQ Criteria (Acute)**	360	0.26	74	1.7	4.1	2.4	180	20	0.051	14	-
		Specific SWQ Critieria (Chronic)	190	0.17	24	1.4	0.16	0.012	20	5	NE	13	-
		7/10/97	0.52	0.04 U	0.2 U	0.6	0.2 J	0.00033 J	0.2 U	0.2 U	0.04 U	6	8.6
	RC-1	**Specific SWQ Criteria (Acute)**	360	0.27	76	1.7	4.3	2.4	180	20	0.054	15	-
		Specific SWQ Critieria (Chronic)	190	0.17	25	1.4	0.17	0.012	20	5	NE	13	-
		7/10/97	0.51	0.04 U	0.2 U	0.6	0.3 J	0.00028 J	0.2 U	0.2 U	0.04 U	6	8.9
ADJACENT TO SITE	**RC-4**	**Specific SWQ Criteria (Acute)**	360	0.28	79	1.8	4.6	2.4	190	20	0.059	15	-
		Specific SWQ Critieria (Chronic)	190	0.18	26	1.5	0.18	0.012	21	5	NE	14	-
		7/10/97	NA	0.09	0.2 U	3.4	0.4 J	NA	0.2	NA	0.04 U	17	9.4
	RC-4 South Bank	**Specific SWQ Criteria (Acute)**	360	0.28	78	1.8	4.5	2.4	190	20	0.058	15	-
		Specific SWQ Critieria (Chronic)	190	0.18	25	1.5	0.18	0.012	21	5	NE	14	-
		7/10/97	NA	0.1	0.2 U	5.3	0.2 UJ	NA	0.2 U	NA	0.04 U	24	9.3
	RC-7	**Specific SWQ Criteria (Acute)**	360	0.3	83	1.9	4.9	2.4	202	20	0.066	16	-
		Specific SWQ Critieria (Chronic)	190	0.19	27	1.6	0.19	0.012	22	5	NE	15	-
		7/10/97	NA	0.09	0.2 U	2.6	0.5 J	NA	0.2	NA	0.04 U	20	10
	RC-2	**Specific SWQ Criteria (Acute)**	360	0.3	83	1.9	4.9	2.4	202	20	0.066	16	-
		Specific SWQ Critieria (Chronic)	190	0.19	27	1.6	0.19	0.012	22	5	NE	15	-
		7/10/97	0.33	0.08	0.2 U	2.3	0.2 UJ	0.00053	0.2	0.2 U	0.04 U	24	10
	RC-2 South Bank	**Specific SWQ Criteria (Acute)**	360	0.3	83	1.9	4.9	2.4	202	20	0.066	16	-
		Specific SWQ Critieria (Chronic)	190	0.19	27	1.6	0.19	0.012	22	5	NE	15	-
		7/10/97	0.36	0.09	0.2 U	2.6	0.2 J	0.0003 J	0.2	0.2 U	0.04 U	21	10
DOWNSTREAM OF SITE	**RC-5A**	**Specific SWQ Criteria (Acute)**	360	0.34	90	2.1	5.5	2.4	220	20	0.077	18	-
		Specific SWQ Critieria (Chronic)	190	0.2	29	1.7	0.21	0.012	24	5	NE	16	-
		7/10/97	NA	0.1	0.2 U	2.4	0.2 UJ	NA	0.2	NA	0.04 U	24	11
	RC-3	**Specific SWQ Criteria (Acute)**	360	0.44	110	2.7	7.2	2.4	270	20	0.12	22	-
		Specific SWQ Critieria (Chronic)	190	0.24	36	2.1	0.28	0.012	30	5	NE	20	-
		7/11/97	0.23	0.07	0.2 U	1.9	0.2 UJ	0.00019 J	0.2 U	0.2 U	0.04 U	17	14
COPPER CREEK	**CC-1**	**Specific SWQ Criteria (Acute)**	360	0.28	78	1.8	4.5	2.4	190	20	0.06	15	-
		Specific SWQ Critieria (Chronic)	190	0.18	25	1.5	0.18	0.012	21	5	NE	14	-
		7/11/97	NA	0.08	0.2 U	0.3	1.8 J	NA	0.2 U	NA	0.04 U	10	9.3
	CC-2	**Specific SWQ Criteria (Acute)**	360	0.27	76	1.8	4.3	2.4	180	20	0.055	15	-
		Specific SWQ Critieria (Chronic)	190	0.17	25	1.5	0.17	0.012	21	5	NE	14	-
		7/11/97	NA	0.04 U	0.2 U	0.3	0.2 UJ	NA	0.2 U	NA	0.04 U	8	9

Notes:
J - Estimated value.
U - Parameter was analyzed for, but not detected above the reporting limit shown.
UJ - Parameter was analyzed for but not detected. Detection limit is an estimated value.
NA - Data Not Available
NE - Not Established
* Evaluation of chronic criteria is based on total; acute criteria is based on dissolved.
** Dissolved zinc concentrations potentially increased due to the introduction of zinc during the field filtration procedure. See text for additional information.

TABLE 5.3-26
SUMMARY OF SURFACE WATER MONITORING DATA AND WATER QUALITY CRITERIA FOR RAILROAD CREEK, TRIBUTARIES, AND REFERENCE STREAMS (SEPT/OCT 1997)
HOLDEN MINE RI/FS
DAMES & MOORE JOB NO. 17693-005-019

Station No.		Parameters	Arsenic, Dissolved (ug/L)	Cadmium, Dissolved (ug/L)	Chromium, Dissolved (ug/L)	Copper, Dissolved (ug/L)	Lead, Dissolved (ug/L)	Mercury, Dissolved (ug/L)*	Nickel, Dissolved (ug/L)	Selenium, Total (ug/L)	Silver, Dissolved (ug/L)	Zinc, Dissolved (ug/L)	Hardness $CaCO_3$ (mg/L)
		SWQ Criteria (Acute)	***360***	***0.82***	***180***	***4.6***	***14***	***2.4***	***440***	***20***	***0.32***	***35***	***25***
		SWQ Criteria (Chronic)	***190***	***0.37***	***57***	***3.5***	***0.54***	***0.012***	***49***	***5***	***NE***	***32***	***25***
STEHEKIN REFERENCE STREAMS:													
Bridge Creek		**Specific SWQ Criteria (Acute)**	360	0.44	110	2.7	7.2	2.4	270	20	0.12	22	-
		Specific SWQ Critieria (Chronic)	190	0.24	36	2.1	0.28	0.012	30	5	NE	20	-
		9/28/97	0.24	0.04 U	0.2 U	0.4	0.2	NA	0.2	NA	0.04 U	7	14
SF Agnes Creek		**Specific SWQ Criteria (Acute)**	360	0.21	62	1.4	3.3	2.4	150	20	0.036	12	-
		Specific SWQ Critieria (Chronic)	190	0.14	20	1.2	0.13	0.012	17	5	NE	11	-
		9/30/97	2.56	0.04 U	0.2 U	0.5	0.2 U	NA	0.2	NA	0.04 U	11	7
Company Creek		**Specific SWQ Criteria (Acute)**	360	0.65	150	3.7	11	2.4	360	20	0.22	29	-
		Specific SWQ Critieria (Chronic)	190	0.31	48	2.9	0.42	0.012	40	5	NE	27	-
		10/2/97	0.13	0.04 U	0.2 U	0.4	0.2 U	NA	0.2	NA	0.04 U	7	20
RAILROAD CREEK:													
UPSTREAM OF SITE	**RC-11**	**Specific SWQ Criteria (Acute)**	360	0.21	62	1.4	3.3	2.4	150	20	0.036	12	-
		Specific SWQ Critieria (Chronic)	190	0.14	20	1.2	0.13	0.012	17	5	NE	11	-
		10/4/97	0.94	0.04 U	0.2 U	1.1	0.2 U	NA	0.3	NA	0.04 U	5	7
	RC-6 North Bank	**Specific SWQ Criteria (Acute)**	360	0.37	97	2.3	6	2.4	240	20	0.09	19	-
		Specific SWQ Critieria (Chronic)	190	0.21	31	1.9	0.24	0.012	26	5	NE	17	-
		9/15/97	0.81	0.04 U	0.2 U	0.4	0.2 U	NA	0.2	NA	0.04 U	16	12
	RC-1	**Specific SWQ Criteria (Acute)**	360	0.37	97	2.3	6	2.4	240	20	0.09	19	-
		Specific SWQ Critieria (Chronic)	190	0.21	31	1.9	0.24	0.012	26	5	NE	17	-
		9/15/97	0.82	0.04 U	0.2 U	0.4	0.5	NA	0.2	NA	0.04 U	4 U	12
	RC-1 North Bank	**Specific SWQ Criteria (Acute)**	360	0.37	97	2.3	6	2.4	240	20	0.09	19	-
		Specific SWQ Critieria (Chronic)	190	0.21	31	1.9	0.24	0.012	26	5	NE	17	-
		9/15/97	NA	0.04	0.2 U	0.6	0.2U	NA	0.2	NA	0.04 U	9	12
	RC-1 South Bank	**Specific SWQ Criteria (Acute)**	360	0.37	97	2.3	6	2.4	240	20	0.09	19	-
		Specific SWQ Critieria (Chronic)	190	0.21	31	1.9	0.24	0.012	26	5	NE	17	-
		9/15/97	NA	0.09	0.2 U	0.6	0.2	NA	0.2	NA	0.04 U	4 U	12
ADJACENT TO SITE	**RC-4**	**Specific SWQ Criteria (Acute)**	360	0.37	97	2.3	6	2.4	240	20	0.09	19	-
		Specific SWQ Critieria (Chronic)	190	0.21	31	1.9	0.24	0.012	26	5	NE	17	-
		9/15/97	NA	0.06	0.2 U	1.8	0.3	NA	0.2	NA	0.04 U	11	12
	RC-4 South Bank	**Specific SWQ Criteria (Acute)**	360	0.4	103	2.5	6.6	2.4	250	20	0.1	20	-
		Specific SWQ Critieria (Chronic)	190	0.23	33	2	0.26	0.012	28	5	NE	19	-
		9/15/97	NA	0.14	0.2 U	3.9	0.4	NA	0.3	NA	0.04 U	20	13
	RC-7	**Specific SWQ Criteria (Acute)**	360	0.44	110	2.7	7.2	2.4	270	20	0.12	22	-
		Specific SWQ Critieria (Chronic)	190	0.24	36	2.1	0.28	0.012	30	5	NE	20	-
		9/15/97	NA	0.09	0.2	1.3	0.4	NA	0.4	NA	0.04 U	19	14
	RC-2	**Specific SWQ Criteria (Acute)**	360	0.47	120	2.8	7.8	2.4	280	20	0.13	23	-
		Specific SWQ Critieria (Chronic)	190	0.25	38	2.2	0.3	0.012	32	5	NE	21	-
		9/15/97	0.49	0.1	0.2 U	1.2	0.2 U	NA	0.4	NA	0.04 U	23	15
	RC-2 South Bank	**Specific SWQ Criteria (Acute)**	360	0.47	120	2.8	7.8	2.4	280	20	0.13	23	-
		Specific SWQ Critieria (Chronic)	190	0.25	38	2.2	0.3	0.012	32	5	NE	21	-
		9/15/97	0.52	0.1	0.2 U	1.4	0.2 U	NA	0.4	NA	0.04 U	23	15

TABLE 5.3-26
SUMMARY OF SURFACE WATER MONITORING DATA AND WATER QUALITY CRITERIA FOR RAILROAD CREEK, TRIBUTARIES, AND REFERENCE STREAMS (SEPT/OCT 1997)
HOLDEN MINE RI/FS
DAMES & MOORE JOB NO. 17693-005-019

Station No.		Parameters	Arsenic, Dissolved (ug/L)	Cadmium, Dissolved (ug/L)	Chromium, Dissolved (ug/L)	Copper, Dissolved (ug/L)	Lead, Dissolved (ug/L)	Mercury, Dissolved (ug/L)*	Nickel, Dissolved (ug/L)	Selenium, Total (ug/L)	Silver, Dissolved (ug/L)	Zinc, Dissolved (ug/L)	Hardness $CaCO_3$ (mg/L)
		SWQ Criteria (Acute)	***360***	***0.82***	***180***	***4.6***	***14***	***2.4***	***440***	***20***	***0.32***	***35***	***25***
		SWQ Criteria (Chronic)	***190***	***0.37***	***57***	***3.5***	***0.54***	***0.012***	***49***	***5***	***NE***	***32***	***25***
RAILROAD CREEK (continued):													
DOWNSTREAM OF SITE	**RC-5**	**Specific SWQ Criteria (Acute)**	360	0.54	130	3.2	9	2.4	320	20	0.16	26	-
		Specific SWQ Critieria (Chronic)	190	0.28	42	2.5	0.35	0.012	35	5	NE	23	-
		9/16/97	NA	0.12	0.2 U	1.6	0.2 U	NA	0.4	NA	0.04 U	30	17
	RC-10	**Specific SWQ Criteria (Acute)**	360	0.65	150	3.7	11	2.4	360	20	0.22	29	-
		Specific SWQ Critieria (Chronic)	190	0.31	48	2.9	0.42	0.012	40	5	NE	27	-
		9/16/97	NA	0.12	0.2 U	1.3	0.2	NA	0.4	NA	0.09 J	22	20
	RC-8	**Specific SWQ Criteria (Acute)**	360	0.65	150	3.7	11	2.4	360	20	0.22	29	-
		Specific SWQ Critieria (Chronic)	190	0.31	48	2.9	0.42	0.012	40	5	NE	27	-
		9/16/97	NA	0.72	0.2 U	1.4	0.5	NA	0.5	NA	0.04 U	20	20
	RC-3	**Specific SWQ Criteria (Acute)**	360	0.65	150	3.7	11	2.4	360	20	0.22	29	-
		Specific SWQ Critieria (Chronic)	190	0.31	48	2.9	0.42	0.012	40	5	NE	27	-
		9/16/97	0.31	0.1	0.2 U	1.2	0.2	NA	0.4	NA	0.04 U	20	20
Holden Creek		**Specific SWQ Criteria (Acute)**	360	0.3	83	1.9	4.9	2.4	202	20	0.066	16	-
		Specific SWQ Critieria (Chronic)	190	0.19	27	1.6	0.19	0.012	22	5	NE	15	-
		10/4/97	0.5	0.05	0.2 U	0.9	0.3	NA	0.2 U	NA	0.04 U	6	10
COPPER CREEK	**CC-1**	**Specific SWQ Criteria (Acute)**	360	0.34	90	2.1	5.5	2.4	220	20	0.07	18	-
		Specific SWQ Critieria (Chronic)	190	0.2	29	1.7	0.21	0.012	24	5	NE	16	-
		9/15/97	NA	0.04 U	0.2 U	0.2	0.2 U	NA	0.2 U	NA	0.04 U	4 U	11
	CC-2	**Specific SWQ Criteria (Acute)**	360	0.34	90	2.1	5.5	2.4	220	20	0.077	18	-
		Specific SWQ Critieria (Chronic)	190	0.2	29	1.7	0.21	0.012	24	5	NE	16	-
		9/15/97	NA	0.04 U	0.2 U	0.3	0.3	NA	0.2 U	NA	0.04 U	4 U	11
Ten Mile Creek		**Specific SWQ Criteria (Acute)**	360	1	210	5.5	17	2.4	510	20	0.43	41	-
		Specific SWQ Critieria (Chronic)	190	0.42	66	4.1	0.66	0.012	57	5	NE	38	-
		10/4/97	0.14	0.04 U	0.2 U	0.3	0.2 U	NA	0.4	NA	0.04 U	4 U	30

Notes:
J - Estimated value.
U - Parameter was analyzed for, but not detected above the reporting limit shown.
UJ - Parameter was analyzed for but not detected. Detection limit is an estimated value.
NA - Data Not Available
NE - Not Established
* Evaluation of chronic criteria is based on total; acute criteria is based on dissolved.

TABLE 5.3-27
SUMMARY OF SURFACE WATER MONITORING DATA AND WATER QUALITY CRITERIA FOR RAILROAD CREEK AND TRIBUTARIES (MAY 1998)
HOLDEN MINE RI/FS
DAMES & MOORE JOB NO. 17693-005-019

Station No.		Parameters	*Arsenic, Dissolved (ug/L)*	*Cadmium, Dissolved (ug/L)*	*Chromium, Dissolved (ug/L)*	*Copper, Dissolved (ug/L)*	Lead, Dissolved (ug/L)	Mercury, Dissolved (ug/L)*	Nickel, Dissolved (ug/L)	Selenium, Total (ug/L)	Silver, Dissolved (ug/L)	Zinc, Dissolved (ug/L)**	Hardness $CaCO_3$ (mg/L)
		SWQ Criteria (Acute)	*360*	*0.82*	*180*	*4.6*	*14*	*2.4*	*440*	*20*	*0.32*	*35*	*25*
		SWQ Criteria (Chronic)	*190*	*0.37*	*57*	*3.5*	*0.54*	*0.012*	*49*	*5*	*NE*	*32*	*25*
HOLDEN CREEK	HC-1	Specific SWQ Criteria (Acute)	360	0.47	116	2.8	7.8	2.4	284	20	0.13	23	-
		Specific SWQ Critieria (Chronic)	190	0.25	38	2.2	0.30	0.012	32	5	NE	21	-
		5/1/98	0.39	0.04U	0.2U	0.6	0.018	NA	0.2U	NA	0.04U	4U	15
	HC-2	Specific SWQ Criteria (Acute)	360	0.51	122	3.0	8.4	2.4	300	20	0.15	24	-
		Specific SWQ Critieria (Chronic)	190	0.27	40	2.4	0.33	0.012	33	5	NE	22	-
		4/30/98	0.45	0.05	0.2U	0.7	0.011U	NA	0.2	NA	0.04U	4U	16
	HC-3	Specific SWQ Criteria (Acute)	360	0.47	116	2.8	7.8	2.4	284	20	0.13	23	-
		Specific SWQ Critieria (Chronic)	190	0.25	38	2.2	0.30	0.012	32	5	NE	21	-
		4/30/98	0.61	0.04U	0.2U	0.6	0.011U	NA	0.2U	NA	0.04U	4U	15
	HC-4	Specific SWQ Criteria (Acute)	360	0.34	90	2.1	5.5	2.4	219	20	0.08	18	-
		Specific SWQ Critieria (Chronic)	190	0.20	29	1.7	0.21	0.012	24	5	NE	16	-
		4/30/98	1	0.06	0.2U	0.5	0.011U	NA	0.2U	NA	0.04U	4U	11
BIG CREEK	BIG-1	Specific SWQ Criteria (Acute)	360	0.58	135	3.4	9.6	2.4	330	20	0.18	27	-
		Specific SWQ Critieria (Chronic)	190	0.29	44	2.6	0.37	0.012	37	5	NE	24	-
		5/2/98	0.29	0.04U	0.2U	0.3	0.011U	NA	0.2U	NA	0.04U	4U	18
<u>RAILROAD CREEK:</u>													
UPSTREAM OF SITE	RC-11	Specific SWQ Criteria (Acute)	360	0.20	60	1.3	3.1	2.4	144	20	0.03	12	-
		Specific SWQ Critieria (Chronic)	190	0.14	19	1.1	0.12	0.012	16	5	NE	11	-
		5/1/98	0.73	0.04U	0.2U	0.7	0.5J	NA	0.3	NA	0.04U	4U	6.7
	RC-6	Specific SWQ Criteria (Acute)	360	0.30	83	1.9	4.9	2.4	202	20	0.07	16	-
		Specific SWQ Critieria (Chronic)	190	0.19	27	1.6	0.19	0.012	22	5	NE	15	-
		5/3/98	0.54	0.08	0.2U	0.6	0.011U	NA	0.2U	NA	0.04U	4U	10
	RC-1	Specific SWQ Criteria (Acute)	360	0.34	90	2.1	5.5	2.4	219	20	0.08	18	-
		Specific SWQ Critieria (Chronic)	190	0.20	29	1.7	0.21	0.012	24	5	NE	16	-
		5/3/98	0.53	0.04U	0.2U	0.8	0.011U	NA	0.2U	NA	0.04U	4U	11

TABLE 5.3-27
SUMMARY OF SURFACE WATER MONITORING DATA AND WATER QUALITY CRITERIA FOR RAILROAD CREEK AND TRIBUTARIES (MAY 1998)
HOLDEN MINE RI/FS
DAMES & MOORE JOB NO. 17693-005-019

Station No.		Parameters	Arsenic, Dissolved (ug/L)	Cadmium, Dissolved (ug/L)	Chromium, Dissolved (ug/L)	Copper, Dissolved (ug/L)	Lead, Dissolved (ug/L)	Mercury, Dissolved (ug/L)*	Nickel, Dissolved (ug/L)	Selenium, Total (ug/L)	Silver, Dissolved (ug/L)	Zinc, Dissolved (ug/L)**	Hardness CaCO$_3$ (mg/L)
		SWQ Criteria (Acute)	*360*	*0.82*	*180*	*4.6*	*14*	*2.4*	*440*	*20*	*0.32*	*35*	*25*
		SWQ Criteria (Chronic)	*190*	*0.37*	*57*	*3.5*	*0.54*	*0.012*	*49*	*5*	*NE*	*32*	*25*
RAILROAD CREEK (continued):													
ADJACENT TO SITE	RC-4	Specific SWQ Criteria (Acute)	360	0.37	97	2.3	6.0	2.4	235	20	0.09	19	-
		Specific SWQ Critieria (Chronic)	190	0.21	31	1.9	0.24	0.012	26	5	NE	17	-
		5/3/98	0.46	0.66	0.2U	41.7	0.088	NA	0.5	NA	0.04U	114	12
	RC-7	Specific SWQ Criteria (Acute)	360	0.40	103	2.5	6.6	2.4	252	20	0.10	20	-
		Specific SWQ Critieria (Chronic)	190	0.23	33	2.0	0.26	0.012	28	5	NE	19	-
		5/3/98	0.36	0.67	0.2U	37.5	0.126	NA	0.4	NA	0.04U	115	13
	RC-2	Specific SWQ Criteria (Acute)	360	0.44	110	2.7	7.2	2.4	268	20	0.12	22	-
		Specific SWQ Critieria (Chronic)	190	0.24	36	2.1	0.28	0.012	30	5	NE	20	-
		5/3/98	0.35	0.68	0.2U	35.7	0.107	NA	0.4	NA	0.04U	113	14
DOWNSTREAM OF SITE	RC-5A	Specific SWQ Criteria (Acute)	360	0.47	116	2.8	7.8	2.4	284	20	0.13	23	-
		Specific SWQ Critieria (Chronic)	190	0.25	38	2.2	0.30	0.012	32	5	NE	21	-
		5/4/98	0.28	0.58	0.2U	26.9	0.106	NA	0.4	NA	0.04U	98	15
	RC-10	Specific SWQ Criteria (Acute)	360	0.51	122	3.0	8.4	2.4	300	20	0.15	24	-
		Specific SWQ Critieria (Chronic)	190	0.27	40	2.4	0.33	0.012	33	5	NE	22	-
		5/4/98	0.26	0.4	0.2U	18.5	0.082	NA	0.5	NA	0.04U	69	16
	RC-3	Specific SWQ Criteria (Acute)	360	0.51	122	3.0	8.4	2.4	300	20	0.15	24	-
		Specific SWQ Critieria (Chronic)	190	0.27	40	2.4	0.33	0.012	33	5	NE	22	-
		5/5/98	0.2	0.26	0.2U	12.6	0.053	NA	0.3	NA	0.04U	45	16
COPPER CREEK	CC-1	Specific SWQ Criteria (Acute)	360	0.34	90	2.1	5.5	2.4	219	20	0.08	18	-
		Specific SWQ Critieria (Chronic)	190	0.20	29	1.7	0.21	0.012	24	5	NE	16	-
		5/2/98	0.04U	0.04U	0.2U	0.5	0.011U	NA	0.3	NA	0.04U	4U	11
	CC-2	Specific SWQ Criteria (Acute)	360	0.37	97	2.3	6.0	2.4	235	20	0.09	19	-
		Specific SWQ Critieria (Chronic)	190	0.21	31	1.9	0.24	0.012	26	5	NE	17	-
		5/2/98	0.04U	0.04U	0.2U	0.4	0.011U	NA	0.3	NA	0.04U	4U	12

Notes:
J - Estimated value.
U - Parameter was analyzed for, but not detected above the reporting limit shown.
UJ - Parameter was analyzed for but not detected. Detection limit is an estimated value.
NA - Data Not Available
NE - Not Established
* *Evaluation of chronic criteria is based on total; acute criteria is based on dissolved.*

TABLE 5.3-28
SUMMARY OF RI WATER QUALITY DATA FOR STATIONS IN RAILROAD CREEK ADJACENT TO SITE
HOLDEN MINE RI/FS
DAMES & MOORE JOB NO. 17693-005-019

Parameters	RC-4 Station												RC-7 Station					RC-2 Station												
Station No.	RC-4A	RC-4X	RC-4 Grab	RC-4				RC-4X	RC-4 South Bank			RC-4X South	RC-7A	RC-7				RC-2A	RC-2					RC-2			RC-2X	RC-2 South Bank		
Sampling Date	4/16/97	4/16/97	4/16/97	5/21/97	7/10/97	9/15/97	5/3/98	5/3/98	5/21/97	7/10/97	9/15/97	5/21/97	4/16/97	5/20/97	7/10/97	9/15/97	5/3/98	4/17/97	5/19/97	5/26/97	6/2/97	6/9/97	6/16/97	7/10/97	9/15/97	5/3/98	9/15/97	5/19/97	7/10/97	9/15/97
Total Metals, (ug/L)																														
Aluminum	40	40	40	100	160	50	200J	160J	170	170	50	160	160	180	190	100	220	160	230	160	190	150J	220	210	90	250	90	240	140	90
Arsenic	1U	1U	1				0.93	0.85					1U				0.76	1U	0.61					0.66	0.87	0.83	0.88	0.65	0.58	0.85
Barium	3	4	3	4.90	4.77	4.36	5.48	5.32	5.30	4.75	4.45	5.03	4	5.16	4.91	4.54	5.48	6	5.51	5.08	5.11	4.87J	5	5.04	4.71	5.75	4.71	5.74	4.70	4.61
Beryllium	1U	1U	1U	0.04U	0.04U	0.04U	0.04U	0.04U	0.04U	0.04U	0.04U	0.04U	1U	0.04U	0.04U	0.04U	0.04U	1U	0.04U	0.04U	0.04U	0.04U	0.2U	0.04U	0.04U	0.04U	0.04U	0.04U	0.04U	0.04U
Cadmium	0.2	0.3	0.2	0.47	0.08U	0.07	0.73J	0.75J	1.09	0.12U	0.12	1.08	0.4	0.51	0.10	0.10	0.75J	0.5	0.52	0.44	0.33	0.25J	0.2U	0.10U	0.11	0.77J	0.11	0.55	0.08U	0.14
Calcium	7,490	7,470	7,410	4,350	3,310	4,360	4370	4310	4,870	3,340	4,400	4,980	8,720	4,500	3,550	4,770	4670	8,150	4,800	4,890	4,180	4,260J	3,330	3,510	4,750	4700	4,740	4,800	3,450	4,920
Chromium	5U	5U	5U	0.2U	0.2U	0.2U	0.2U	0.2U	0.2U	0.2U	0.2U	0.2U	5U	0.2U	0.2U	0.2U	0.2U	5U	0.2U	0.2U	0.2U	0.2U	5U	0.2U	0.2U	0.2	0.2U	0.2U	0.2U	0.2U
Copper	12	11	9	32.4	4.4	2.3	56.7	58.6	79	6.8	4.9	77	15	33.7	3.9	2.1	52.8	14	33.2	30.2	23.2	15.0J	10	3.8	2.2	52.3	2.2	38	3.7	2.2
Iron	60	60	60	90	170	90	140	100	90	180	100	90	2,290	650	530	1,280	590	2,250	600	710J	510J	520J	440	500	1,330	630	1,340	620	440	1,350
Lead	1U	1U	1U	0.7J	0.4UJ	0.5UJ	0.276	0.279	0.4J	0.3UJ	0.2UJ	0.4J	1U	0.2U	0.7UJ	0.2UJ	0.295	1U	1.4U	0.3	0.6	1.4J	1U	0.6UJ	0.3UJ	0.284	0.7	0.5U	0.2UJ	0.8UJ
Magnesium	770	770	760	460	350	380	450	450	550	350	380	560	1,190	580	440	540	550	1,170	610	670	550	540J	410	440	540	570	560	640	410	570
Manganese	3	3	3	3.58	4.34	2.75	8.22	7.53	6.08	4.83	3.51	5.86	26	9.44	7.91	10.8	11.8	26	11.6	11.6	9.82	8.06J	9	8.61	12.2	12.7	12.2	12.4	6.82	12.3
Mercury	0.1U	0.1U	0.1U										0.1U					0.1U	0.00039J					0.00029J				0.00066J	0.00021J	
Molybdenum							0.52	0.53									0.52		0.46					0.36	0.73	0.53	0.72	0.48	0.43	0.71
Nickel	10U	10U	10U	0.4	0.3	0.2	0.5	0.5	0.6	0.4	0.3	0.6	10U	0.5	0.4	0.3	0.6	10U	2.3J	0.5	0.6	0.4J	10U	0.4	0.4	0.6	0.4	0.5J	0.4	0.4
Potassium	660	660	880	500U	500U	500U	500U	500U	560	500U	500U	850	1,010	780	590	500U	500U	640	500U	590	770	880J	500U	500U	500U	500U	500U	530	500U	500U
Selenium	1U	1U	1U										1U					1U	0.2U					0.2U				0.2U	0.2U	
Silver	0.2U	0.2U	0.2U	0.04U	0.04U	0.04U	0.04U	0.04U	0.17	0.04U	0.04U	0.12	0.2U	0.06	0.04U	0.04U	0.04U	0.2U	0.04U	0.04U	0.04U	0.04U	0.2U	0.14	0.11	0.04U	0.07	0.04U	0.04	0.04U
Sodium	1,230	1,230	1,210	800	510	650	780	740	910	520	640	890	1,310	810	540	650	770	1,270	840	880	750	820J	590U	530	640	790	670	840	520	660
Thallium	1U	1U	1U										1U					1U	0.2U					0.04U	0.04U		0.04U	0.04U	0.04U	0.04U
Uranium																			0.4U					0.04	0.04U		0.04U	0.05	0.04U	0.04U
Zinc	48	48	34	67	12	18	115	114	177	22	20	185	85	79	15	25	119	76	86	76	52	43J	24	16	21	116	20	87	15	21
Dissolved Metals, (ug/L)																														
Aluminum	30	30	20	30	30U	20U	60	70	50	30U	20U	50	20U	60	40U	40	90	20U	90	60	70	80J	50	50U	40	100	40	60U	50U	40
Arsenic	1U	1U	1U				0.46	0.45					1U				0.36	1U	0.30					0.33	0.49	0.35	0.50	0.22	0.36	0.52
Barium	6	6	6	9.90	13.4	4.37	4.69	4.6	10.2	13.0	4.31	11.2	6	10.7	12.6	4.52	4.88	6	10.6J	18.2	31.1	20.2J	15	17.7	4.55	5.02	4.5	12.1J	14.2	4.56
Beryllium	1U	1U	1U	0.04U	0.04U	0.04U	0.04U	0.04U	0.04U	0.04U	0.04U	0.04	1U	0.04U	0.04U	0.04U	0.04U	1U	0.04U	0.04U	0.04U	0.04U	0.04U	0.04U	0.08U	0.04U	0.04U	0.04U	0.04U	0.04U
Cadmium	0.3	0.3	0.2	0.44	0.09	0.06	0.66	0.67	1.10	0.11	0.14	1.14	0.5	0.58	0.09	0.09	0.67	0.4	0.53	0.45	0.32	0.23J	0.14	0.08	0.10	0.68	0.11	0.55	0.09	0.10
Calcium	7,760	7,550	7,470	4,540	3,260	4,390	4250	4240	5,110	3,230	4,420	5,050	8,880	4,740	3,540	4,720	4520	8,320	4,900	4,800	4,260	4,200J	3,280	3,560	4,940	4680	5,120	4,970	3,420	5,020
Chromium	5U	5U	5U	0.2U	0.2U	0.2U	0.2U	0.2U	0.2U	0.2U	0.2U	0.2	5U	0.2U	0.2U	0.2U	0.2U	5U	0.4	0.2U	0.2U	0.2U	5U	0.2U	0.2U	0.2U	0.2	0.2U	0.2U	0.2U
Copper	11	11	9	26.4	3.4	1.8	41.7	41.9	58.5	5.3	3.9	59.8	3	23.0	2.6	1.3	37.5	2	23.6	19.1	15.1	10.3J	8	2.3	1.2	35.7	1.3	26	2.6	1.4
Iron	40	30	50	20	20U	40	20U	20U	20	20U	40	20U	1,680	480	330	1,150	380	1,430	300	480J	360J	380J	220	270	1,080	350	1,160	420	280	1,150
Lead	1U	1U	1U	0.6J	0.4J	0.3	0.088	0.085	0.6J	0.2UJ	0.4	0.2	1U	0.5J	0.5J	0.4	0.126	1U	1.4U	0.7U	1.4U	0.4J	0.4U	0.2UJ	0.2U	0.107	0.3	0.6U	0.2J	0.2U
Magnesium	810	790	790	470	300	370	420	420	560	290	390	550	1,250	590	380	530	510	1,190	630	640	530	490J	350	370	570	550	590	650	380	580
Manganese	4	3	4	2.94	1.53	1.86	4.83	4.94	7.46	1.81	2.10	7.68	27	11.8	5.48	9.96	9.6	26	12.8	10.9	8.47	7.42J	6	5.52	11.1	9.9	11.4	11.7	5.64	11.4
Mercury	0.1UJ	0.1UJ	0.1UJ										0.1UJ					0.1UJ	0.00047J					0.00053				0.00036J	0.00030J	
Molybdenum							0.49	0.61									0.48		0.47					0.37	0.71	0.48	0.72	0.48	0.41	0.70
Nickel	10U	10U	10U	0.3	0.2	0.2	0.5	0.5	1.0	0.2U	0.3	0.6	10U	0.4	0.2	0.4	0.4	10U	0.9	0.6	0.4	0.4J	10U	0.2	0.4	0.4	0.4	0.6	0.2	0.4
Potassium	690	660	520	520	500U	500U	500U	500U	690	500U	500U	500U	610	530	500U	500U	500U	640	500U	500U	500U	630J	500U	500U	500U	500U	500U	600	500U	500U
Selenium	1U	1U	1U										1U					1U	0.2U					0.2U				0.2U	0.2U	
Silver	0.2U	0.2U	0.2U	0.08U	0.04U	0.04U	0.04U	0.04U	0.14U	0.04U	0.04U	0.10	0.2U	0.54U	0.04U	0.04U	0.04U	0.2U	0.07	0.04U	0.04UJ	0.04U	0.04U	0.04U	0.04U	0.04U	0.04U	0.04U	0.04U	0.04U
Sodium	1,440	1,300	1,380	840	520	650	740	750	910	530	640	890	1,500	860	590	660	760	1,360	1,800J	910	1,010	770J	590U	580	670	800	730	920J	550	690
Thallium	1U	1U	1U										1U					1U	0.04U					0.04U	0.04U		0.04U	0.04U	0.04U	0.04U
Uranium																			0.2U					0.04U	0.04U		0.04U	0.04U	0.04U	0.04U
Zinc	55	50	39	73	17	11	114	114	191	24	20	191	90	85	20	19	115	77	84	84	60	51J	27	24	23	113	28	97	21	23
Stream Discharge (cfs)	60.4	--	--	370	496	123	508	--	--	--	--	--	77.12	--	--	145.8	--	86.4	569	376	605	501	922	619	135.8	647	--	--	--	--

TABLE 5.3-28
SUMMARY OF RI WATER QUALITY DATA FOR STATIONS IN RAILROAD CREEK ADJACENT TO SITE
HOLDEN MINE RI/FS
DAMES & MOORE JOB NO. 17693-005-019

Parameters	RC-4 Station												RC-7 Station					RC-2 Station												
Station No.	RC-4A	RC-4X	RC-4 Grab	RC-4				RC-4X	RC-4 South Bank			RC-4X South	RC-7A	RC-7				RC-2A	RC-2					RC-2			RC-2X	RC-2 South Bank		
Sampling Date	4/16/97	4/16/97	4/16/97	5/21/97	7/10/97	9/15/97	5/3/98	5/3/98	5/21/97	7/10/97	9/15/97	5/21/97	4/16/97	5/20/97	7/10/97	9/15/97	5/3/98	4/17/97	5/19/97	5/26/97	6/2/97	6/9/97	6/16/97	7/10/97	9/15/97	5/3/98	9/15/97	5/19/97	7/10/97	9/15/97
Total Petroleum Hydrocarbon (mg/L)																														
Gasoline Range Hydrocarbons																			0.25U					0.25U	0.25U	0.25U	0.25	0.25U	0.25U	0.25U
Diesel Range Hydrocarbons																			0.25UJ			0.25U		0.25U	0.25U	0.25U	0.25	0.25UJ	0.25U	0.25U
Motor Oil																			0.50UJ			0.50U		0.50U	0.50U	0.5U	0.50	0.25UJ	0.50U	0.50U
Polychlorinated Biphenyls (ug/L)																														
Aroclor 1016																			0.20UJ					0.033U				0.017U	0.033U	
Aroclor 1221																			0.40UJ					0.067U				0.033U	0.067U	
Aroclor 1232																			0.20UJ					0.033U				0.017U	0.033U	
Aroclor 1242																			0.20UJ					0.033U				0.017U	0.033U	
Aroclor 1248																			0.20UJ					0.033U				0.017U	0.033U	
Aroclor 1254																			0.20UJ					0.033U				0.017U	0.033U	
Aroclor 1260																			0.20UJ					0.033U				0.017U	0.033U	
Conventional Analyses																														
Ortho-Phosphorous (mg/L)																			0.004U					0.009J	0.004UJ		0.004UJ	0.004U	0.013J	0.004UJ
Post Chlorination Cyanide (mg/L)																			0.004U					0.004U	0.004UJ		0.004UJ	0.004U	0.004U	0.004UJ
Total Cyanide (mg/L)																			0.004U					0.004U	0.004UJ		0.004UJ	0.004U	0.004U	0.004UJ
Total Dissolved Solids (mg/L)	33	44	40	19	9.0J	39J	24	27	24	11J	24J	23	47	26	13J	20J	23	43	22	30J	17J	29	8.0	12J	26J	23	40J	25	9.0J	40J
Total Phosphorous (mg/L)																			0.034					0.016U	0.016U		0.016U	0.037	0.018	0.016U
Total Suspended Solids (mg/L)	1.0U	1.0U	1.0U	1.1U	1.7	1.1U	1.8	1.8	1.1U	1.6	1.1U	1.1U	6.3	1.1	1.8	3.8	1.7	6.7	2.2U	1.1UJ	1.0UJ	1.1U	3.6	1.6	3.6	3.1	3.3	1.5	1.4	3.3
Chloride (mg/L)	1.0U	1.0U	1.0U										1.0					1.0U	1.0U					1.0	1.0U		1.0U	1.0	1.0U	1.0U
NO_2 & NO_3 (mg/L)	0.13	0.11	0.12										0.14					0.13	0.13					0.072	0.041		0.020	0.14	0.064	0.021
Sulfate (mg/L)	6.5	5.7	5.9	7.0	2.5U	4.0	3	3.4	4.1	2.5U	3.8	5.6	16	4.6	2.5U	6.4	4.8	16	8.3	8.6	6.7	6.7	2.5U	2.5U	6.9	6.2	7.4	7.1	2.5U	6.9
Silicates (mg/L)																														
Alkalinity (mg/L $CaCO_3$)	20	20	20	15	9.0	9.9	9.3	9.3	11	8.6	11	14	13	8.1	7.8	7.7	8.1	13	9.6	8.8	8.4	8.2	7.5	8.3	7.5	8.4	6.5	7.7	6.9	8.4
Amenable Cyanide (mg/L)	1.0U																		0.004U					0.004U	0.004R		0.004UR	0.004U	0.004U	0.004UR
Color (Pt-CO)																			15					5UJ	15J		15J	8	5UJ	15J
Hardness, Dissolved (mg/L)	23	22	22	13	9.4	12	12	12	15	9.3	13	15	27	14	10	14	13	26	15	15	13	12	9.6	10	15	14	15	15	10	15
Field Measurements:																														
pH	5.5	5.7	5.7	7.1	7.7	6.7	7.8		7.3	7.6	6.8		5.8	7.1	7.6	7	6.5	6.2	6.7	7.4	6.9	6	6	8	5.7	8.2		6.8	7.7	6.2
Specific Conductivity (μS)	67	65	85	42	26	32	10		38	24	33		94	42	28	42	30	103	38	51	46	34	27	27	76	12		42	30	
Temperature (°C)	4.2	3.9	6	4.4	9.8	10	7.1		4.2	7.7	9.6		5	6.4	8.7	9.7	8.7	5.7	4.2	6.8	7.9	11.3	9	9.5	10	7.7		4.6	10.4	
Redox (mV)				142					142					151						137	114	170	238						21.8	
Iron (ion)																														
Turbidity (NTU)					3		135		5				4.0J				223	3.4J	4	1	6					20		66	213	
Dissolved Oxygen (mg/L)					13.48		16.8		15.26								15.8		13.1	13.68	14.7				10.4	9.7 (W)		14.1	14.48	

Data Notes:

J - Estimated value.

U - Parameter was analyzed for, but not detected above the reporting limit shown.

UJ - Parameter was analyzed for but not detected. Detection limit is an estimated value.

R - Data is rejected due to quality control concerns.

An "X" after the sample ID indicates field duplicate.

-- Indicates no discharge data available or replicate analysis.

Grey shading indicates the concentration of analyte was not established, therefore not reported nor analyzed.

TABLE 5.3-29
SUMMARY OF RI WATER QUALITY DATA FOR STATIONS IN RAILROAD CREEK DOWNSTREAM OF SITE
HOLDEN MINE RI/FS
DAMES & MOORE JOB NO. 17693-005-019

Parameters	RC-5 Station						RC-10 Station		RC-8 Station			RC-3 Station						
Station No.	RC-5A[1]	RC-5[2]	RC-5A[3]				RC-10		RC-8A	RC-8B	RC-8	RC-3A	RC-3				RC-3X	
Sampling Date	4/17/97	5/20/97	5/22/97	7/10/97	9/16/97	5/4/98	9/16/97	5/4/98	4/18/97	4/18/97	9/16/97	4/18/97	5/22/97	7/11/97	9/16/97	5/5/98	5/22/97	7/11/97
Total Metals, (µg/L)																		
Aluminum	160	210	240	200	120	250	80	300	110		70	100	170	160	70	250	150	150
Arsenic	1U					0.76		0.72	1U			1U	0.35	0.40	0.46	0.5	0.33	0.39
Barium	6	5.68	6	5.27	5.01	6.22	5.60	6.74	10		6.47	10	7	5.62	6.47	7.07	7	5.63
Beryllium	1U	0.04U	0.04U	0.04U	0.04U	0.04U	0.04U	0.04U	1U		0.04U	1U	0.04U	0.04U	0.04U	0.04U	0.04U	0.04U
Cadmium	0.4	0.50	0.54	0.11U	0.13	0.66J	0.11	0.45	0.2		0.10	0.3	0.27	0.07U	0.09	0.37	0.34	0.08U
Calcium	8,280	4,940	6,070	3,840	5,570	5210	6,480	5730	9,950		6,540	9,740	6,350	4,620	6,570	5520	6,420	4,800
Chromium	5U	0.2U	5U	0.2U	0.2U	0.2U	0.2U	0.2	5U		0.2U	5U	5U	0.2U	0.2U	0.2	5U	0.2U
Copper	14	32.3	32	4.2	2.4	43.5	2.3	30.3	7		1.7	6	16	3.2	1.6	19.7	16	3.3
Iron	2,300	580	750	500	1,440	650	990	790	900		640	870	450	330	620	580	430	330
Lead	1U	0.3J	0.5U	0.4UJ	0.2UJ	0.249	0.2UJ	0.201	1U		0.2UJ	1U	0.5U	0.3UJ	0.2UJ	0.159	0.9U	0.3UJ
Magnesium	1,190	660	850	490	690	660	780	720	1,490		800	1,480	850	570	810	700	850	580
Manganese	26	12.3	20	9.72	15.4	15	14.0	13.4	15		10.7	14	11	6.66	10.1	10.7	10	6.46
Mercury	0.1U								0.1U			0.1U	0.00034J	0.00014J			0.00047J	0.00015J
Molybdenum						0.52		0.55				10U	0.55J	0.47	0.68	0.55	0.57J	0.54
Nickel	10U	0.6	10U	0.4	0.4	0.6	0.5	0.6	10U		0.4	640	10U	0.4	0.4	0.5	10U	0.4
Potassium	810	870	560	690	620	500U	500U	500U	850		500U	1U	500U	500U	630	530	590	610
Selenium	1U								1U				0.2U	0.2U			0.2U	0.2U
Silver	0.2U	0.04U	0.20J	0.04U	0.04U	0.04U	0.04U	0.04U	0.2U		0.04U	0.2U	0.04U	0.04U	0.04U	0.04U	0.09J	0.04U
Sodium	1,290	840	910	560	730	820	780	850	1,610		860	1,570	1,070	700	860	930	1,070	750
Thallium	1								1U			1U	0.04U	0.04U	0.04U		0.04U	0.04U
Uranium													0.10	0.06	0.06		0.09	0.05
Zinc	78	81	88	18	33	101	25	75	40		25	36	45	14	22	56	47	13
Dissolved Metals, (µg/L)																		
Aluminum	20U	70	20U	30U	50	90	40	80	50	20U	50	50	70	30U	40	70	80	30U
Arsenic	1U					0.28		0.26	1U	1U		1U	0.19	0.23	0.31	0.2	0.18	0.23
Barium	6	10.8	6	15.9	5.00	5.4	5.56	5.51	9	9	6.43	9	7	16.2	6.95	5.8	7	14.8
Beryllium	1U	0.04U	4U	0.04U	0.04U	0.04U	0.04U	0.04U	1U	1U	0.04U	1U	0.2U	0.04U	0.04U	0.04U	0.2U	0.04U
Cadmium	0.4	0.50	0.51	0.10	0.12	0.58	0.12	0.4	0.2U	0.2U	0.72	0.2U	0.24	0.07	0.10	0.26	0.24	0.08
Calcium	8,370	5,010	5,800	3,830	5,600	5040	6,580	5410	10,000	10,100	6,640	10,100	6,070	4,630	6,690	5250	6,220	4,720
Chromium	5U	0.2U	5U	0.2U	0.2U	0.2U	0.2U	0.2U	5U	5U	0.2U	5U	5U	0.2U	0.2U	0.2U	5U	0.2U
Copper	3	21.5	7	2.4	1.6	26.9	1.3	18.5	4	3	1.4	4	10	1.9	1.2	12.6	11	2.0
Iron	1,290	350	40	250	1,250	300	740	220	430	60	420	370	230	140	420	170	240	140
Lead	1U	0.2J	0.2U	0.2UJ	0.2U	0.106	0.2	0.082	1U	1U	0.5	1U	0.4U	0.2UJ	0.2	0.053	0.6U	0.2UJ
Magnesium	1,210	670	780	420	680	620	800	640	1,510	1,520	800	1,510	800	540	820	620	810	540
Manganese	26	10.9	18	7.04	14.8	12	13.5	9.29	15	14	9.97	15	10	4.96	9.83	6.48	9	4.88
Mercury	0.1UJ								0.1UJ	0.1UJ		0.1UJ	0.00064	0.00019J			0.00040J	0.00007J
Molybdenum						0.45		0.43					0.54J	0.54	0.64	0.51	0.54J	0.54
Nickel	10U	0.6	10U	0.2	0.4	0.4	0.4	0.5	10U	10U	0.5	10U	10U	0.2U	0.4	0.3	10U	0.2U
Potassium	690	700	500U	500U	500U	500U	550	500U	880	930	500U	810	510	500U	500U	500U	500U	520
Selenium	1U								1U	1U		1U	0.2U	0.2U			0.2U	0.2U
Silver	0.2U	0.14U	0.04U	0.04U	0.04U	0.04U	0.09J	0.04U	0.2U	0.2U	0.04U	0.2U	0.04U	0.04U	0.04U	0.04U	0.04U	0.08
Sodium	1,430	860	900	630	700	780	800	810	1,750	1,740	860	1,660	1,020	730	870	870	1,100	740
Thallium	1U								1U	1U		1U	0.04U	0.04U	0.04U		0.04U	0.04U
Uranium													0.07	0.04U	0.04		0.07	0.04U
Zinc	86	84	80	24	30	98	22	69	37	32	20	41	38	17	20	45	40	16
Stream Discharge (cfs)	78.56	--	--	--	129.2	--	126.3	--	est. 186	--	--	195.6	748	665	149.7	1105	--	--

TABLE 5.3-29
SUMMARY OF RI WATER QUALITY DATA FOR STATIONS IN RAILROAD CREEK DOWNSTREAM OF SITE
HOLDEN MINE RI/FS
DAMES & MOORE JOB NO. 17693-005-019

Parameters	RC-5 Station						RC-10 Station		RC-8 Station			RC-3 Station						
Station No.	RC-5A[1]	RC-5[2]	RC-5A[3]				RC-10		RC-8A	RC-8B	RC-8	RC-3A	RC-3				RC-3X	
Sampling Date	4/17/97	5/20/97	5/22/97	7/10/97	9/16/97	5/4/98	9/16/97	5/4/98	4/18/97	4/18/97	9/16/97	4/18/97	5/22/97	7/11/97	9/16/97	5/5/98	5/22/97	7/11/97
Total Petroleum Hydrocarbon (mg/L)																		
Gasoline Range Hydrocarbons													0.25U	0.25U	0.25U		0.25U	0.25U
Diesel Range Hydrocarbons													0.25U	0.25U	0.25U		0.25U	0.25U
Motor Oil													0.50U	0.50U	0.50U		0.50U	0.50U
Polychlorinated Biphenyls (µg/L)																		
Aroclor 1016													0.050U	0.033U			0.050U	0.033U
Aroclor 1221													0.10U	0.067U			0.10U	0.067U
Aroclor 1232													0.050U	0.033U			0.050U	0.033U
Aroclor 1242													0.050U	0.033U			0.050U	0.033U
Aroclor 1248													0.050U	0.033U			0.050U	0.033U
Aroclor 1254													0.050U	0.033U			0.050U	0.033U
Aroclor 1260													0.050U	0.033U			0.050U	0.033U
Conventional Analyses																		
Ortho-Phosphorous (mg/L)													0.004UJ	0.004UJ	0.004UJ		0.004UJ	0.004UJ
Post Chlorination Cyanide (mg/L)													0.004U	0.004U	0.004UJ		0.004U	0.004U
Total Cyanide (mg/L)													0.004U	0.004U	0.004UJ		0.004U	0.004U
Total Dissolved Solids (mg/L)	42	27	32J	12J	36J	20	46J	25	46		38J	48	26J	18J	40J	29	29J	14J
Total Phosphorous (mg/L)													0.016U	0.016U	0.016U		0.016U	0.016U
Total Suspended Solids (mg/L)	7.7	1.4	1.9J	1.4	3.4	2.5	2.4	3.8	1.6		1.1U	1.5	2.2UJ	2.1	1.1U	4.3	1.2J	1.2
Chloride (mg/L)	1.0U								1.0U			1.0U	1.0	1.0U	1.0U		1.0U	1.0U
NO_2 & NO_3 (mg/L)	0.12								0.076			0.078	0.10	0.051	0.028		0.10	0.054
Sulfate (mg/L)	16	8.1	11	3.0	11	5.6	12	5.5	14		10	13	7.7	2.5U	12	5.3	7.6	5.5
Silicates (mg/L)																		
Alkalinity (mg/L $CaCO_3$)	12	8.7	8.6	7.1	1.0U	8.1	11	11	25		9.0	26	14	10	12	12	13	10
Amenable Cyanide (mg/L)													0.004U	0.004U	0.004UJ		0.004U	0.004U
Color (Pt-CO)													5UJ	5UJ	15J		5UJ	5UJ
Hardness, Dissolved (mg/L)	26	15	18	11	17	15	20	16	31	32	20	31	18	14	20	16	19	14
Field Measurements:																		
pH	6.1	7	7.6	7.6	7.1	7.6	7	5.8	6.1	6.2	6.5	6.2	8.1	7.8	6.6	5.8		
Specific Conductivity (µS)	95	50	63	30	53	16	57	38	148	110	60	40	57	37	56	26		
Temperature (°C)	4.3	3.8	6.2	8.4	8.5	9.6	9.8	7.1	6.3	5.7	10.7	5.7	9.8	10.5	10.7	8.5		
Redox (mV)			155										176					
Iron (ion)																		
Turbidity (NTU)						440		33				11				11		
Dissolved Oxygen (mg/L)						18		16.3							11.08	10.9 (W)		

Data Notes:
J - Estimated value.
U - Parameter was analyzed for, but not detected above the reporting limit shown.
UJ - Parameter was analyzed for but not detected. Detection limit is an estimated value.
X - after the sample ID is an indication of field duplicate.
Stations RC-5A collected in April 1997 and RC-5 collected on 5/20/97 are in different locations in the RC-5 sample area. All other RC-5A and RC-5 samples were collected at the same location.
▨ Grey shading indicates the concentration of analyte was not established, therefore not reported nor analyzed.
-- indicates no discharge data available or replicate analysis.
[1] Sample location was upstream of location sampled 5/20/97 and 5/22/97. The "A" attached to sample ID indicates it was the first sample of of a triplicate sample set collected on 4/17/97.
[2] Sample location was upstream of location sampled 5/22/97 and downstream of sample collected on 4/17/97.
[3] Final location for RC-5. Samples collected from 5/22/97 and forward were collected at the same location in Railroad Creek.

TABLE 5.3-30
SUMMARY OF RI PORTAL DRAINAGE WATER QUALITY DATA
HOLDEN MINE RI/FS
DAMES & MOORE JOB NO. 17693-005-019

Parameters	P-1				P-5							
	5/18/97	7/12/97	9/15/97	5/1/98	5/18/97	5/26/97	6/2/97	6/9/97	6/16/97	7/12/97	9/15/97	5/1/98
Total Metals, (µg/L)												
Aluminum	13,400	4,850	2,570	22600	7,290	6,320	8,270	6,650J	6,500	3,790	2,810	13600
Arsenic	0.3	1U	1U	1U	0.2U	▨	▨	▨	▨	1U	1U	1U
Barium	12.1	13	10	12	14.3	13.3	14.4	13.0J	13	13	10	19
Beryllium	0.3	1U	1U	1U	0.2U	0.2U	4U	0.2U	4U	1U	1U	1U
Cadmium	82.2	23	8	170	49.7	40.7	45.4	35.8J	36	23	8	80
Calcium	50,600	70,300	130,000	58400	30,200	37,000	38,300	48,000J	52,000	71,400	128,000	28000
Chromium	1U	5U	5U	5U	1U	1U	1U	1U	5U	5U	5U	5U
Copper	6,350	912	235	10400	4,040	2,620	3,200	2,270J	2,000	914	237	4800
Iron	960	540	930	2030	480	440J	830J	500J	520	390	970	2320
Lead	57J	20	8	64	29J	30	37	29J	30	18	8	36
Magnesium	10,800	8,210	9,820	14500	8,540	6,400	7,020	7,540J	7,590	8,310	9,630	6620
Manganese	444	287	373	703	239	229	259	260J	267	291	365	321
Mercury	0.00313	0.00024J	▨	▨	0.00249	▨	▨	▨	▨	0.00031J	▨	▨
Molybdenum	0.4	5U	5U	5U	0.2U	▨	▨	▨	▨	5U	5U	10
Nickel	8J	10U	10U	10U	5J	5	6	5J	10U	10U	10U	10U
Potassium	2,620	4,100	6,300	3460	2,110	2,480	2,970	3,280J	2,990	4,300	5,810	1920
Selenium	1U	1U	▨	▨	1U	▨	▨	▨	▨	1U	▨	▨
Silver	0.2U	0.2U	0.2U	0.2	0.2U	0.2UJ	0.2U	0.2U	4U	0.2U	0.2U	0 2U
Sodium	5,670	12,600	24,600	6310	3,700	5,380	5,180	7,140J	7,800	12,700	24,200	3310
Thallium	0.3	1U	1U	▨	0.2U	▨	▨	▨	▨	1U	1U	▨
Uranium	4.6	20U	20U	▨	2.4	▨	▨	▨	▨	20U	2U	▨
Zinc	14,900	5,270	3,380	27800	8,620	7,050	7,930	6,790J	6,880	5,380	3,230	12300
Dissolved Metals, (µg/L)												
Aluminum	13,200	1,460	40U	21100	5,840	4,910	7,070	4,860J	4,430	1,360	40U	8960
Arsenic	0.25	1U	1U	1U	0.15	▨	▨	▨	▨	1U	1U	1U
Barium	23.0J	20	11	12	32.6J	26.4	24.4	26.1J	22	20	10	17
Beryllium	0.34	1U	1U	1U	0.4U	0.2U	4U	0.2U	4U	1U	1U	1U
Cadmium	81.2	22	8	160	52.5	41.0	47.0	37.0J	36	22	8	70
Calcium	50,300	73,200	130,000	57300	30,500	36,900	38,700	49,100J	53,800	71,900	131,000	28300
Chromium	0.3	5U	5U	5U	0.2U	1U	1U	1U	5U	5U	5U	5U
Copper	5,780	907	77	10300	2,340	2,570	3,240	2,360J	2,060	901	28	4790
Iron	240	280	110	430	190	130J	140J	150J	170	180	20U	150
Lead	48J	19	5U	58	27J	28	33	28J	30	17	1U	22
Magnesium	10,700	8,430	9,840	14600	9,290	6,350	7,160	7,730J	7,530	8,280	9,850	6650
Manganese	420	299	374	695	255	228	261	267J	274	293	372	314
Mercury	0.00257	0.00038J	▨	▨	0.00069	▨	▨	▨	▨	0.00039J	▨	▨
Molybdenum	0.05	5U	5U	5U	0.09	▨	▨	▨	▨	5U	5U	5U
Nickel	7.7	10U	10U	10U	5 0	5	5	5J	10U	10U	10U	10U
Potassium	3,160	4,420	6,150	3430	1,750	2,640	2,590	3,420J	2,950	4,020	6,400	1880
Selenium	1.1	1U	▨	▨	0.6	▨	▨	▨	▨	1U	▨	▨
Silver	0.04U	0.2U	0.2U	0.2U	0.16	0.2UJ	0.2	0.2U	4U	0.2U	0.2	0.2U
Sodium	5,800	13,000	24,600	6340	3,830	5,380	5,390	7,470J	7,770	12,600	24,800	3290
Thallium	0.29	1U	1U	▨	0 16	▨	▨	▨	▨	1U	1U	▨
Uranium	3.95	20U	20U	▨	2.04	▨	▨	▨	▨	20U	20U	▨
Zinc	14,900	5,440	3,280	27500	8,820	7,020	7,970	6,960J	6,820	5,330	2,980	12700
Stream Discharge cfs	2.63	0.42	0.21	2.54	3.42	1.55	0.99	1.07	0.45	0.31	0.15	3.8

Data Notes:
J - Estimated Value.
U - Parameter was analyzed for, but not detected above the reporting limit shown.
UJ - Parameter was analyzed for but not detected. Detection limit is an estimated value.
▨ Grey shading ▨ indicates the concentration of analyte was not established, therefore not reported nor analyzed.

TABLE 5.3-30
SUMMARY OF RI PORTAL DRAINAGE WATER QUALITY DATA
HOLDEN MINE RI/FS
DAMES & MOORE JOB NO. 17693-005-019

Parameters	P-1				P-5							
	5/18/97	7/12/97	9/15/97	5/1/98	5/18/97	5/26/97	6/2/97	6/9/97	6/16/97	7/12/97	9/15/97	5/1/98
Conventional Analyses:												
Ortho-Phosphorous (mg/L)	0.004UJ	0.011J	▨	▨	0.004UJ	▨	▨	▨	▨	0.009J	▨	▨
Post Chlorination Cyanide	*0.004U*	*0.004U*	*0.004UJ*	▨	*0.004U*	▨	▨	▨	▨	0.004U	0.004UJ	▨
Total Cyanide (mg/L)	0.004U	0.004	0.004UJ	▨	0.004U	▨	▨	▨	▨	0.004U	0.004UJ	▨
Total Dissolved Solids (mg	270	370	630J	540	210	270J	260J	290	320	380	610J	260
Total Phosphorous (mg/L)	0.025	0.018	▨	▨	0.028	▨	▨	▨	▨	0.018	▨	▨
Total Suspended Solids (m	2.0	14	11J	9.1	9.2	9.9J	12J	10	9.6	9.7	14J	39
Chloride (mg/L)	1.0U	4.0	6.5	▨	1.0U	▨	▨	▨	▨	3.3	6.2	▨
NO_2 & NO_3 (mg/L)	0.038	0.050	0.024	▨	0.034	▨	▨	▨	▨	0.025	0.023	▨
Sulfate (mg/L)	270	260	310	310	190	160	190	200	170	260	340	140
Silicates (mg/L)	▨	▨	▨	▨	▨	▨	▨	▨	▨	10	▨	▨
Alkalinity (mg/L $CaCO_3$)	1.0U	1.0U	16	1U	1.0U	1.0U	1.0U	1.0U	1.0U	1.0U	14	1U
Amenable Cyanide (mg/L)	0.004U	0.004	0.004UJ	▨	0.004U	▨	▨	▨	▨	0.004U	0.004UJ	▨
Color (Pt-CO)	12J	5UJ	▨	▨	5J	▨	▨	▨	▨	5UJ	▨	▨
Hardness, Dissolved (mg/	170	220	360	200	120	120	130	150	160	210	370	98
Field Measurements:												
pH	4.8	5.8	7.0	4.3	4.9	5.28	4.4	5.3	4.3	5.56	6.7	4.8
Specific Conductivity (μS)	692	575	*1010*	570	441	379	522	586	610	572	782	292
Temperature (°C)	8.4	10	10.5	9.6	6.3	6.7	7.4	9.7	11.9	12.1	11.1	7.2
Redox (mV)	420	188	▨	▨	346	285	230	182	210	185	▨	▨
Iron (ion)	▨	positive	▨	▨	▨	negative	▨	negative	▨	positive	▨	▨

Data Notes:
J - Estimated Value.
U - Parameter was analyzed for, but not detected above the reporting limit shown.
UJ - Parameter was analyzed for but not detected. Detection limit is an estimated value.
▨ **Grey shading** indicates the concentration of analyte was not established, therefore not reported nor analyzed.

TABLE 5.3-30a
SUMMARY OF RI WATER QUALITY DATA FOR VENTILATOR PORTAL
HOLDEN MINE RI/FS
DAMES & MOORE Job No. 17693-005-019

	Station No.	VP-1
Parameters	**Sampling Date**	**5/2/98**
Total Metals, (ug/L)		
Aluminum		4,400
Arsenic		0.64
Barium		27.6
Beryllium		0.04U
Cadmium		0.09
Calcium		5,400
Chromium		3.0
Copper		9.6
Iron		3,510
Lead		2.9
Lead, low level		1.66
Magnesium		1,870
Manganese		40.6
Molybdenum		0.26
Nickel		3.3
Potassium		870
Silver		0.04U
Sodium		1,360
Zinc		13
Dissolved Metals, (ug/L)		
Aluminum		50U
Arsenic		0.05
Barium		1.15
Beryllium		0.04U
Cadmium		0.04
Calcium		4,120
Chromium		0.2U
Copper		0.7
Iron		20U
Lead		0.6U
Lead, low level		0.015
Magnesium		530
Manganese		0.81
Molybdenum		0.25
Nickel		0.2U
Potassium		500U
Silver		0.04U
Sodium		950
Zinc		4U
Conventional Analyses		
Alkalinity (mg/L $CaCO_3$)		12
Hardness, Dissolved (mg/L)		12
Sulfate (mg/L)		3.5
Total Dissolved Solids (mg/L)		10U
Total Suspended Solids (mg/L)		69
Field Measurements		
Dissolved Oxygen (mg/L)		16.7
pH		6.4
Specific Conductivity (uS)		23
Temperature (C)		4.4
Turbidity (NTU)		346

Data Notes:
J - Estimated Value
U - Parameter was analyzed for, but not detected above the reporting limit shown.
UJ - Parameter was analyzed for, but not detected. Detection limit shown is an estimated value.
X - after the sample ID is an indication of field duplicate
Grey Shading indicates the concentration of analyte was not established, therefore not reported or analyzed.
(W) - Indicates value is based on Winkler Titration.

TABLE 5.3-31
SUMMARY OF HISTORICAL WATER QUALITY DATA FOR PORTAL DRAINAGE (1982-1996)
HOLDEN MINE RI/FS
DAMES & MOORE JOB NO. 17693-005-019

Parameters	Location	P-1																								P-2			
	Sample ID	1982 BATTELLE WATER QUALITY MONITORING DATA[a]					1983 BATTELLE WATER QUALITY MONITORING DATA[a]							1991 BATTELLE WATER QUALITY MONITORING DATA[b]								357[c]	USFS 1995[e]	534[d]	605[e]	702[f]	362-P[c]	535[d]	606[e]	703[f]
	ample Date	5/12/82	6/10/82	6/23/82	7/14/82	8/25/82	9/29/82	6/1/83	6/22/83	7/20/83	8/11/83	8/31/83	9/28/83	5/10/91	5/17/91	6/3/91	6/17/91	7/1/91	7/15/91	8/6/91	9/18/91	7/94	6/20/95	7/95	5/96	9/96	7/94	7/95	5/96	9/96
Total Metals (μg/L)																														
Aluminum																										2400				4700
Arsenic																														
Barium																										10				11
Beryllium																										10 U				10 U
Cadmium																										10 U				10 U
Calcium														59046	58695	61285	68580	73610	88632	106150	125615		73000			150000				150000
Chromium																										10 U				10 U
Copper		3610	4600	2780	1370	710	250	6000	1840	1270	860	670	250	3780	4086	2867	1746	1498	1048	730	75		1900			160				260
Iron		2100	1180	820	1690	3800	3400	610	610	590	810	930	950										570			1100				1800
Lead		30	90	110	160	130	90	10	80	10 U	10 U	10 U	10 U	62	51	46	50	38	58	52	52		30			50 U				50 U
Magnesium														9768	9909	9074	8888	9000	9502	10200	9450		9600			12000				12000
Manganese																										390				380
Mercury																														
Molybdenum																										20 U				20 U
Nickel																										10 U				10 U
Potassium														3510	3285	3529	3834	3704	4254	5505	6250		3500			6300				6400
Selenium																														
Silver																														
Sodium														7392	8081	8373	10190	11212	14818	19345	25700		10000			26000				26000
Thallium																														
Uranium																														
Zinc		17290	12810	10710	8470	6850	4700	13070	6770	5880	4670	5000	3770	13530	11797	9484	7576	7918	7136	6215	3365		7800			3600				3600
Dissolved Metals (μg/L)																														
Aluminum																						1000		2400	7700	44	150000	2200	6600	43
Arsenic																						2 U		1 U	4 U		1 U	1 U	4 U	
Barium																						12		12	11	10	82	11	12	11
Beryllium																						1 U		0.3 U	0.4 U	10 U	1	0.3 U	0.4 U	10 U
Cadmium																						21		29	58	10 U	0.63	29	53	10 U
Calcium																						72000		94000	42000	160000	6500	97000	42000	160000
Chromium																						1 U		0.9 U	0.5 U	10 U	15	0.9 U	0.5 U	10 U
Copper																						570		900	3700	62	710	910	3500	23
Iron																						580		940	230	280	59000	430	230	100 U
Lead																						21		22 U	35	50 U	160	19	31	50 U
Magnesium																						7900		8800	7900	11000	3000	8800	7900	11000
Manganese																						350		320	340	420	190	330	310	400
Mercury																								0.1 U						
Molybdenum																						0.6		0.4	0.4 U	20 U	19	0.2	0.4 U	20 U
Nickel																						4		7.2	5.8	0.01 U	4	6.5	5.9	0.01 U
Potassium																						2000 U			2700	6200	2400		2700	6400
Selenium																														
Silver																						0.1 U		0.1 U	0.2 U		1.6	0.1 U	0.2 U	
Sodium																						> 5000		> 10000	6300	27000	5800	> 10000	6300	28000
Thallium																						0.1		0.6 U	4 U			0.6U	4 U	
Uranium																						2.7		2.5	3.7		100 U	2.4	3	
Zinc																						4800		6000	9600	3600	200	6000	8600	3300
Conventional Analyses:																														
Alkalinity (mg/L)																														
Chloride (mg/L)														2.18	2.04	1.81	2.43	2.94	3.96	5.36	7.47	6.2	3.7	3	1.7			3	1.4	
Cyanide (mg/L)																														
Dissolved Organic Carbon (mg/L)														3.07	1.55	0.83	1.93	0.9	4	0.68	0.59									
Fluoride (mg/L)														0.5	0.48	0.29	0.49	0.58	0.45	0.63	0.85	0.71	0.47		0.6				0.4	
Hardness (mg/L)																														
NO_2 & NO_3 (mg/L)														0.11	0.14	0.24	0.25	0.46	0.28	0.22	0.18	0.11	0.05	0.2 U	0.1			0.2 U	0.1	
Sulfate (mg/L)														265.73	256.84	269.24	275.67	280.94	284.72	345.09	422.49	1.0 U	274.1		290				250	
Total Phosphorous (mg/L)																						410	0.01 U	340				340		
Total Suspended Solids (mg/L)																														
Field Measurements:																														
Conductivity (μS/cm)																						20		840	472			840	412	
pH		4.68	4.52	4.64	4.82	6.11	6.75	4.37	4.96	5.64	4.93	6.36	6.51	4.4	4.4	4.48	5.2	5.7	5.9	5.9	7.6	7.02	5.3	5.07	4.31			5	4.47	
Stream Flow (cfs)		1.04	1.77	1.25	0.66	0.47	0.21	1.81	0.75	0.43	0.3	0.2	0.16	1.11	1.3	0.71	0.67	0.61	0.5	0.4	0.19	13								
Temperature (°C)																							10	4.5	8			6.5	9	
Turbidity (NTU)																														

Data Notes:
J - Estimated value.
NR - Not Reported
TR- Trace amount of sample reported.
U - Parameter was analyzed for, but not detected above the reporting limit shown.
UJ - Parameter was analyzed for, but not detected. Detection limit is an estimated value.
▨ Grey shading indicates the concentration of analyte was not established, therefore not reported and analyzed.
1982-1983 Water Quality data was sampled for P-1 station only.

Data Source:
(a) Walters, et al. 1992. *Holden Mine Reclamation Project Final Report.* Pacific Northwest Laboratories,Richland, WA. (Data collected by Snyder 1982 - 1983).
(b) Walters, et al. 1992. *Holden Mine Reclamation Project Final Report.* Pacific Northwest Laboratories,Richland, WA. (Data collected in 1991).
(c) Kilburn, et al. 1994. *Geochemical data and sample locality maps for stream-sediment, heavy-mineral-concentrate, mill tailing, water, and precipitate samples collected in and around the Holden mine, Chelan County, Washington.* USGS Open File Report 94-680A Paper Version, 94-680B Diskette version (Data Collected in 1994)
(d) Kilburn, J.E. & S.J. Sutley. 1996. *Characterization of acid mine drainage at the Holden mine, Chelan, Washington.* USGS Open File Report 96-531. (Data collected in 1995)
(e) Kilburn, J.E. & S.J. Sutley. 1997. *Analytical results and comparative overview of geochemical studies conducted at the Holden Mine*, spring 1996. USGS Open File Report 97-128 (Data collected in Spring 1996).
(f) Kilburn, J.E. & S.J Sutley. 1997. Preliminary data (no report attached, data collected in Fall 1996).
(g) Johnson, A., et al. 1997. *Effects of Holden Mine on the Water, Sediments and Benthic Invertebrates of Railroad Creek (Lake Chelan).* Environmental Investigations and Laboratory Services Program. Water Body No WA-47-1020. Publication No. 97-330 (data collected in Spring and Fall 1996).

TABLE 5.3-31
SUMMARY OF HISTORICAL WATER QUALITY DATA FOR PORTAL DRAINAGE (1982-1996)
HOLDEN MINE RI/FS
DAMES & MOORE JOB NO. 17693-005-019

Parameters	Location	P-5																			
	Sample ID	1991 BATTELLE WATER QUALITY MONITORING DATA[b]								1995 USFS WATER MONITORING DATA[a]					358[c]	533[d]	DEPT. OF ECOLOGY PORTAL DRAINAGE STATION[g]		601[e]	704[f]	706[f]
	Sample Date	5/9/91	5/17/91	6/3/91	6/17/91	7/1/91	7/15/91	8/6/91	9/18/91	6/20/95	7/26/95	8/9/95	8/23/95	9/27/95	7/94[b]	7/95[c]	6/12/96	9/10/96	5/96	9/96	9/96
Total Metals (µg/L)																					
Aluminum																	6650	3970		9400	3000
Arsenic																	0.23	0.02 U			
Barium																				11	11
Beryllium																				10 U	10 U
Cadmium																	35	7.4 U		10 U	10 U
Calcium		48744	52350	61235	68616	71380	88266	107190	125725	73000	95000	110000	110000							150000	14000
Chromium																				10 U	10 U
Copper		3066	3790	2852	1736	1504	1052	715	5.5 U	1900	770	660	410				2040	291		450	160
Iron										640	420	1200	850				591	1370		3500	1100
Lead		62.4 U	45 U	46 U	54 U	38 U	56 U	52 U	52 U	30U	20 U	10 U	10 U				31 U	20 U		50 U	50 U
Magnesium		8124	9010	9113	8948	8924	9458	10060	9440	9600	10000	10000	11000							12000	11000
Manganese																	299	358		390	330
Mercury																	0.0024				
Molybdenum																				20 U	20 U
Nickel																	4.1U			10 U	10 U
Potassium		3366	3169	3551	3632	3522	4092	5300	6615	3500	4400	5300	5300							6300	5600
Selenium																		40 U			
Silver																	0.1 U				
Sodium		6294	7072	8466	9736	10898	15038	19405	24590	10000	19000	21000	22000							26000	23000
Thallium																					
Uranium																					
Zinc		11148	10782	9498	7500	7870	7178	6265	2975	7700	6200	6300	5200				6840	3300		3800	3000
Dissolved Metals (µg/L)																					
Aluminum															940	2200			6300	34	23
Arsenic															2 U	1 U			4 U		
Barium															11	10			14	10	8.6
Beryllium															1 U	0.3 U			0.4 U	10 U	10 U
Cadmium															21	28			50	10 U	10 U
Calcium															73000	99000			36000	150000	11000
Chromium															1 U	0.9 U			0.5 U	10 U	10 U
Copper															580	940			3400	12	11
Iron															370	250			180	100 U	100 U
Lead															22 U	19			28	50 U	50 U
Magnesium															8000	9100			6.3	11000	7700
Manganese															350	330			290	380	270
Mercury																					
Molybdenum															0.5U	0.3			0.4 U	20 U	20 U
Nickel															4U	6.3			7.5	0.01 U	0.01 U
Potassium															2000 U				2300	6300	4400
Selenium																					
Silver															1 U	0.1 U			0.2 U		
Sodium															5000 U	> 10000			5500	27000	18000
Thallium															0.1 U	0.6 U			4 U		
Uranium															2.5	2.6			2.6		
Zinc															4900	6200			8000	2900	2200
Conventional Analyses:																					
Alkalinity (mg/L)																	10 U				
Chloride (mg/L)										2.7	5.5	6.4	8.2		6.2	3			1.3		
Cyanide (mg/L)																	0.01 U				
Dissolved Organic Carbon (mg/L)		8.64	3.43	2.41	1.36	1.12	1.85	0.69	0.57												
Fluoride (mg/L)										0.47	0.2	0.26	0.45		0.7				0.4		
Hardness (mg/L)																	191	350			
NO_2 & NO_3 (mg/L)										0.05	0.02	0.04	0.03		0.11	0.2 U	0.03		0.1		
Sulfate (mg/L)		207.98	237.42	263.03	269.49	287.02	280.7	342.14	398.34	270.8	361.4	373.7	407.1		406		242	394	240		
Total Phosphorous (mg/L)										0.01 U	0.01 U	0.01 U	0 01		1 U	330	0.01 U				
Total Suspended Solids (mg/L)																	13	131			
Field Measurements:																					
Conductivity (µS/cm)															800	820	498	778	385		
pH		4.4	4.4	4.41	5.2	5.4	5.8	5.7	7.9	5.1	5.3	5	6.6	6.8	5.01	5.01	5.1	6	4.72		
Stream Flow (cfs)		1.03	0.3	0.72	0.74	0.49	0.4	0.21	0.11						8						
Temperature (°C)										11	11	9.1	8	10	13.5	5	10.1	12 5	7		
Turbidity (NTU)																	8.5	9.4			

Data Notes:
J - Estimated value.
NR - Not Reported
TR- Trace amount of sample reported.
U - Parameter was analyzed for, but not detected above the reporting limit shown.
UJ - Parameter was analyzed for, but not detected. Detection limit is an estimated value.
▨ Grey shading ▨ indicates the concentration of analyte was not established, therefore not reported and analyzed.
1982-1983 Water Quality data was sampled for P-1 station only.

Data Source:
(a) Walters, et al. 1992. *Holden Mine Reclamation Project Final Report*. Pacific Northwest Laboratories,Richland, WA. (Data collected by Snyder 1982 - 1983)
(b) Walters, et al. 1992. *Holden Mine Reclamation Project Final Report*. Pacific Northwest Laboratories,Richland, WA. (Data collected in 1991)
(c) Kilburn, et al. 1994. *Geochemical data and sample locality maps for stream-sediment, heavy-mineral-concentrate, mill tailing, water, and precipitate samples collected in and around the Holden mine, Chelan County, Washington.* USGS Open File Report 94-680A Paper Version, 94-680B Diskette version (Data Collected in 1994).
(d) Kilburn, J.E. & S.J. Sutley. 1996. *Characterization of acid mine drainage at the Holden mine, Chelan, Washington*. USGS Open File Report 96-531. (Data collected in 1995)
(e) Kilburn, J.E. & S.J. Sutley. 1997: *Analytical results and comparative overview of geochemical studies conducted at the Holden Mine*, spring 1996 USGS Open File Report 97-128 (Data collected in Spring 1996).
(f) Kilburn, J.E. & S.J. Sutley. 1997. Preliminary data (no report attached, data collected in Fall 1996).
(g) Johnson, A., et al. 1997. *Effects of Holden Mine on the Water, Sediments and Benthic Invertebrates of Railroad Creek (Lake Chelan).* Environmental Investigations and Laboratory Services Program. Water Body No. WA-47-1020. Publication No. 97-330 (data collected in Spring and Fall 1996)

TABLE 5.3-32
SUMMARY OF RI WATER QUALITY DATA FOR COPPER CREEK DIVERSION
HOLDEN MINE RI/FS
DAMES & MOORE JOB NO. 17693-005-019

Parameters	CC-D	CC-D1	CC-D1	CC-D1	CC-D1X *	CC-D1
	4/17/97	5/21/97	7/12/97	9/16/97	9/16/97	5/2/98
Total Metals, (µg/L)						
Aluminum	20 U	▨	▨	▨	▨	▨
Arsenic	1 U	▨	▨	▨	▨	▨
Barium	5	▨	▨	▨	▨	▨
Beryllium	1 U	▨	▨	▨	▨	▨
Cadmium	0.2 U	▨	▨	▨	▨	▨
Calcium	4,960	▨	▨	▨	▨	▨
Chromium	5 U	▨	▨	▨	▨	▨
Copper	2 U	▨	▨	▨	▨	▨
Iron	20 U	▨	▨	▨	▨	▨
Lead	1 U	▨	▨	▨	▨	▨
Magnesium	720	▨	▨	▨	▨	▨
Manganese	1 U	▨	▨	▨	▨	▨
Mercury	0.1 U	▨	▨	▨	▨	▨
Molybdenum	NA	▨	▨	▨	▨	▨
Nickel	10 U	▨	▨	▨	▨	▨
Potassium	900	▨	▨	▨	▨	▨
Selenium	1 U	▨	▨	▨	▨	▨
Silver	0.2 U	▨	▨	▨	▨	▨
Sodium	800	▨	▨	▨	▨	▨
Thallium	1 U	▨	▨	▨	▨	▨
Uranium	NA	▨	▨	▨	▨	▨
Zinc	5	▨	▨	▨	▨	▨
Dissolved Metals, (µg/L)						
Aluminum	20U	20	20	20U	20U	60U
Arsenic	1 U	0.04U	1U	1U	1U	0.04U
Barium	5	6.67	14	5	4	6.78
Beryllium	1 U	0.04U	1U	1U	1U	0.04U
Cadmium	0.2 U	1.76	0.2U	0.2U	0.2U	2.57
Calcium	4920	4,690	3,050	3,620	3,640	5,770
Chromium	5 U	0.2U	5U	5U	5U	0.2U
Copper	2	45.8	2U	2U	2U	155
Iron	20 U	230	20U	20U	20U	20U
Lead	1 U	0.2J	1U	1U	1U	0.2U
Magnesium	720	660	390	460	460	660
Manganese	1 U	7.95	1U	1U	1U	15.5
Mercury	0.1 UJ	0.00022J	0.0005U	▨	▨	▨
Molybdenum	NA	0.44J	5U	5U	5U	0.38
Nickel	10 U	0.9	10U	10U	10U	2
Potassium	800	1,000	500U	790	760	610
Selenium	1 U	0.2UJ	1U	▨	▨	▨
Silver	0.2 U	0.04U	0.2U	0.2U	0.2U	0.04U
Sodium	830	820	590	590	600	690
Thallium	1 U	0.04UJ	1U	1U	1U	▨
Uranium	NA	0.04UJ	20U	20U	20U	▨
Zinc	5	172	7	4U	4U	372

Data Notes:
J - Estimated value.
U - Parameter was analyzed for but not detected for, but not detected above the reporting limit shown.
UJ - Parameter was analyzed for but not detected. Detection limit is an estimated value.
NA - Data Not Available
* 'X' after sample ID is an indication of field sample duplicate.
▨ **Grey shading** indicates the concentration of analyte was not established, therefore not reported nor analyzed.

TABLE 5.3-32
SUMMARY OF RI WATER QUALITY DATA FOR COPPER CREEK DIVERSION
HOLDEN MINE RI/FS
DAMES & MOORE JOB NO. 17693-005-019

Parameters	CC-D	CC-D1	CC-D1	CC-D1	CC-D1X *	CC-D1
	4/17/97	5/21/97	7/12/97	9/16/97	9/16/97	5/2/98
Conventional Analyses:						
Ortho-Phosphorous (mg/L)	▨	0.004	0.004UJ	▨	▨	▨
Post Chlorination Cyanide (mg/L)	NA	0.004U	0.004U	0.004U	0.004U	▨
Total Cyanide (mg/L)	NA	0.004U	0.004U	0.004U	0.004U	▨
Total Dissolved Solids (mg/L)	21	18	12	34J	28J	24
Total Phosphorous (mg/L)	▨	0.016U	0.016U	▨	▨	▨
Total Suspended Solids (mg/L)	1.0 U	2.1	1.1U	1.1UJ	1.1UJ	7
Chloride (mg/L)	1.0U	1.0U	1.0U	1.0U	1.1	▨
Nitrate + Nitrite (mg/L)	0.13	0.29	0.12	0.048	0.045	▨
Sulfate (mg/L)	6.2	11	2.5U	3.1	2.6	56
Alkalinity (mg/L CaCO3)	12	12	8.6	12	12	6.8
Amenable Cyanide (mg/L)	NA	0.004U	0.004U	0.004U	0.004U	▨
Color (Pt-CO)	▨	5U	5UJ	▨	▨	▨
Hardness, Dissolved (mg/L)	15	14	9	11	11	17
Field Measurements:						
pH	7.1 J	7.15	6.85	5.5	▨	7
Specific Conductivity (us)	75	39	36	25.5	▨	21
Temperature (C)	7.6	4.1	7.6	14.4	▨	7.3
Redox (mv)	▨	131	▨	▨	▨	▨

Data Notes:
J - Estimated value.
U - Parameter was analyzed for but not detected for, but not detected above the reporting limit shown.
UJ - Parameter was analyzed for but not detected. Detection limit is an estimated value.
NA - Data Not Available
* 'X' after sample ID is an indication of field sample duplicate.
▨ **Grey shading** ▨ indicates the concentration of analyte was not established, therefore not reported nor analyzed.

TABLE 5.3-33
SUMMARY OF HISTORICAL COPPER CREEK DIVERSION DATA (1994 & 1996)
HOLDEN MINE RI/FS
DAMES & MOORE JOB NO. 17693-005-019

Parameters	4chc346	659
	7/94[a]	5/96[b]
<u>Dissolved Metals, (µg/L)</u>		
Aluminum	6 U	20 U
Arsenic	2 U	4 U
Barium	5.8	5.7
Beryllium	1 U	0.4 U
Cadmium	1 U	0.7 U
Calcium	6000 U	3400
Chromium	1 U	0.5 U
Copper	0.59	5.6
Iron	100 U	57
Lead	0.2 U	0.3
Magnesium	320	1000 U
Manganese	0.9 U	3 U
Mercury	▨	▨
Molybdenum	0.4	0.5
Nickel	3 U	1 U
Potassium	300	620
Selenium	▨	▨
Silver	0.1 U	0.2 U
Sodium	300	1000 U
Thallium	0.1 U	4 U
Uranium	0.1 U	0.4 U
Zinc	2 U	38
<u>Conventional Analyses:</u>		
Bromide (mg/L)	0.1 U	▨
Fluoride (mg/L)	0.05 U	1.9
Chloride (mg/L)	0.1 U	0.4
NO_2 & NO_3 (mg/L)	0.1 U	0.2
PO_4 (mg/L)	1 U	▨
SO_4 (mg/L)	3.2	6
<u>Field Measurements:</u>		
pH	7.56	6.18
Temperature (°C)	4.5	10
Conductivity (^{L}S/cm)	2	3.3

<u>Data Notes:</u>
U - Parameter was analyzed for but not detected for, but not detected above the reporting limit shown.
Grey shading indicates the concentration of analyte indicates the concentration of analyte was not established, therefore not reported n

<u>Data Source:</u>
(a) Kilburn, et al. 1994. *Geochemical data and sample locality maps for stream-sediment, heavy-mineral-concentrate, mill tailing, water, and precipitate samples collected in and around the Holden mine, Chelan County, Washington.* USGS Open File Report 94-680A Paper Version, 94-680B Diskette version (Data Collected in 1994).
(b) Kilburn, J.E. & S.J. Sutley. 1997. *Analytical results and comparative overview of geochemical studies conducted at the Holden Mine*, USGS Open File Report 97-128 (Data collected in Spring 1996).

TABLE 5.3-34
SUMMARY OF RI WATER QUALITY DATA FOR COPPER CREEK
HOLDEN MINE RI/FS
DAMES & MOORE JOB NO. 17693-005-019

Parameters	CC-1				CC-2			
	5/23/97	7/11/97	9/15/97	5/2/98	5/23/97	7/11/97	9/15/97	5/2/98
Total Metals, (µg/L)								
Aluminum	20U	40	20	100J	20U	30	30	170J
Arsenic	NA	NA	NA	0.04U	NA	NA	NA	0.04U
Barium	6	4.99	4.61	5.64	6	4.89	4.89	6.31
Beryllium	0.04U	0.04U	0.04U	0.04U	0.04U	0.04U	0.04U	0.04U
Cadmium	0.04U	0.04U	0.04U	0.04U	0.04U	0.04U	0.04U	0.04U
Calcium	4,400	3,110	3,720	3980	4,420	3,170	3,680	4060
Chromium	5U	0.2U	0.2U	0.3	5U	0.2U	0.2U	0.4
Copper	2U	0.3	0.3	0.6U	2U	0.2	0.4	1
Iron	20U	30	20U	100	20U	30	20U	170
Lead	0.4U	0.3UJ	0.2UJ	0.06	0.2U	0.3UJ	0.2UJ	0.054
Magnesium	550	410	450	490	540	410	450	520
Manganese	1U	0.63	0.22	2.98	1U	0.82	0.30	4.91
Molybdenum	NA	NA	NA	0.49	NA	NA	NA	0.48
Nickel	10U	0.2	0.2	0.4	10U	0.2U	0.3	0.7
Potassium	530	710	500U	500U	580	650	500U	500U
Silver	0.04U	0.04U	0.04U	0.04U	0.06J	0.04U	0.04U	0.04U
Sodium	740	540	810	640	760	550	600	660
Zinc	4U	4U	4U	5	4	4U	5	4U
Dissolved Metals, (µg/L)								
Aluminum	20U	20U	20U	20U	20U	20U	20U	20U
Arsenic	NA	NA	NA	0.04U	NA	NA	NA	0.04
Barium	23	13.6	4.73	4.96	20	14.7	4.81	5.05
Beryllium	0.04U	0.04U	0.04U	0.04U	0.2U	0.04U	0.04U	0.04U
Cadmium	0.04U	0.08	0.04U	0.04U	0.04U	0.04U	0.04U	0.04U
Calcium	4,390	3,110	3,780	3790	4,300	3,080	3,780	3,850
Chromium	5U	0.2U	0.2U	0.2U	5U	0.2U	0.2U	0.2U
Copper	2U	0.3	0.2	0.5	2U	0.3	0.3	0.4
Iron	20U	20U	20U	20U	40	20U	20U	20U
Lead	0.4U	1.8J	0.2U	0.011U	7U	0.2UJ	0.3	0.011U
Magnesium	550	390	470	430	540	390	480	460
Manganese	1U	0.13	0.13U	0.82	1U	0.12	0.11U	0.72
Molybdenum	NA	NA	NA	0.48	NA	NA	NA	0.47
Nickel	10U	0.2U	0.2U	0.3	10U	0.2U	0.2U	0.3
Potassium	650	500U	630	500U	500	560	510	530
Silver	0.04U	0.04U	0.04U	0.04U	0.04U	0.04U	0.04U	0.04U
Sodium	800	570	620	600	800	570	600	620
Zinc	12	10	4U	4U	13	8	4U	4U
Conventional Analyses:								
Total Dissolved Solids (mg/L)	17	11J	32J	20	19	11J	23J	24
Total Suspended Solids (mg/L)	1.1U	1.0U	1.1U	4.9	1.1U	1.1U	1.1U	3.9
Sulfate (mg/L)	5.3	2.8	4.4	2.5U	4.8	2.5U	2.5U	2.7
Alkalinity (mg/L)	11	7.6	9.2	9.1	11	8.0	9.8	9.1
Hardness, Dissolved (mg/L)	13	9.3	11	11	13	9	11	12
Field Measurements:								
pH	7	6.0	6.0	8.0	7	7.3	6.1	8.1
Specific Conductivity (µs)	40	44	96	29	33	25	40	26
Temperature (°C)	4	5.9	7.9	6.3	4.2	6	7.6	5.7
Redox (mV)	NA	109	NA	NA	NA	NA	NA	NA
Iron (ion)	NA	NA	NA	NA	NA	NA	NA	NA
Turbidity (NTU)	NA	10	NA	NA	NA	10	NA	NA
Dissolved Oxygen (mg/L)	NA	15.7	NA	NA	NA	16	NA	NA

Data Notes:
J - Estimated Value.
U - Parameter was analyzed for, but not detected above the reporting limit shown.
UJ - Parameter was analyzed for but not detected. Detection limit is an estimated value.
NA - Not Analyzed

TABLE 5.3-35
SUMMARY OF HISTORICAL COPPER CREEK ANALYTICAL DATA (1982-1996)
HOLDEN MINE RI/FS
DAMES & MOORE JOB NO. 17693-005-019

Parameters — Sample Location	Copper Creek 1 (CC-1)															
Sample No.	USFS WATER QUALITY DATA [a]												348 [b]	514 [c]	620 [d]	730 [e]
Sample Date	5/12/82	6/9/82	6/22/82	7/14/82	8/25/82	9/28/82	6/1/83	6/22/83	7/19/83	8/10/83	8/31/83	9/27/83	7/94	7/95	5/96	9/96
Total Metals, (ug/L)																
Aluminum																110
Arsenic	29 U	29 U	29 U	29 U	29 U	29 U	29 U	29 U	29	11	29 U	29 U				
Barium																6.6
Beryllium																10 U
Cadmium																10 U
Calcium																6,800
Chromium													1 U	0.9 U	20 U	10 U
Copper	5 U	5 U	5 U	5 U	5 U	5 U	10 U	10 U	10 U	10 U	10 U	10 U				10 U
Iron	60	10 U	50 U	10	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U				2,500
Lead	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U				50 U
Magnesium																1,100
Manganese																16
Mercury																
Molybdenum																20 U
Nickel																10 U
Potassium																1000 U
Selenium																
Silver																
Sodium																1,100
Thallium																
Uranium																
Zinc	450	10 U	10 U	10 U	5 U	10 U	5 U	5 U	5 U	5 U	5 U	5 U				13
Dissolved Metals, (ug/L)																
Aluminum													6 U	10 U	20U	10
Arsenic													2 U	1 U	4 U	
Barium													4.5	4.7	5.6	6.5
Beryllium													1 U	0.3 U	0.4 U	10 U
Cadmium													1 U	1 U	0.7 U	10 U
Calcium													6000 U	5,300	4,200	6,000
Chromium													1 U	0.9 U	20 U	10 U
Copper													0.59	2 U	2 U	10 U
Iron													100 U	20 U	50U	140
Lead													0.2 U	0.3 U	0.2	50 U
Magnesium													390	460	1000U	1000 U
Manganese													0.9 U	0.4	3 U	10 U
Mercury																
Molybdenum													0.5	0.2	0.5	20 U
Nickel													3 U	0.3	1 U	0.01 U
Potassium													400		700	1000 U
Silver													0.1 U	0.1 U	0.2 U	
Sodium													400	780	1000U	1,100
Thallium													0.1 U	0.6 U	4 U	
Uranium													0.1 U	0.1 U	0.4 U	
Zinc													2	3 U	0.8 U	10 U
Conventional Analyses:																
Alkalinity (mg/L)	15.7	12	11	8.2	9.4	41.8	7	7.7	7.1	7.8	8.2	9.3				
Chloride (mg/L)													0.13	0.2	0.3	
Cyanide (mg/L)	0.01 U	0.00081	0.01 U	0.01 U	0.01 U	0.01 U	0.01 U	0.01 U	0.01 U	0.01 U	0.01 U	0.01 U				
Fluoride (mg/L)													0.05 U	0.2	0.1 U	
Hardness (mg/L)																
NO_2 & NO_3 (mg/L)													0.3	0.2 U	0.7	
Sulfate (mg/L)													3.3	3	5	
TSS (mg/L)	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U				
Field Measurements:																
Conductivity (^{L}S/cm)		31	21	23	26	31	25	29	24	25	26	34	20	80	35	
pH	7.25	7.21	6.99	7.15	7.39	7.27	6.95	6.94	6.95	6.85	7.09	6.93	7.42	7.46	5.93	
Stream Flow (cfs)																
Temperature (°C)	7	12	8	5	8	5							6	2	3	
Turbidity (NTU)	0.5	1.1	2.6	1.1	0.4	1.1	1.8	0.86	1.9	1.2	0.8	1.7				

Data Notes:

U - Parameter was analyzed for, but not detected above the reporting limit shown.

* According to the report, the samples were labeled as 'CC-1'.
However it was confirmed with Department of Ecology that the samples were actually more closely related to the Copper Creek 2 station.

▨ Grey Shading ▨ indicates the concentration of analyte was not established, therefore not reported nor analyzed.

Data Source:

(a) Anderson, Keith A. 1992. *Preliminary Assessment of the Holden Mine Site;* USFS Chelan Ranger District. (Data collected 1982-1983).

(b) Kilburn, et al. 1994. *Geochemical data and sample locality maps for stream-sediment, heavy-mineral-concentrate, mill tailing, water, and precipitate samples collected in and around the Holden mine, Chelan County, Washington.* USGS Open File Report 94-680A Paper Version, 94-680B Diskette version (Data Collected in 1994).

(c) Kilburn, J.E. & S.J. Sutley. 1996. *Characterization of acid mine drainage at the Holden mine, Chelan, Washington*. USGS Open File Report 96-531. (Data collected in 1995).

(d) Kilburn, J.E. & S.J. Sutley. 1997. *Analytical results and comparative overview of geochemical studies conducted at the Holden Mine*, spring 1996. USGS Open File Report 97-128 (Data collected in Spring 1996).

(e) Kilburn, J.E. & S.J. Sutley. 1997. Preliminary data (no report attached, data collected in Fall 1996).

(f) Johnson, A., et al. 1997. *Effects of Holden Mine on the Water, Sediments and Benthic Invertebrates of Railroad Creek (Lake Chelan).* Environmental Investigations and Laboratory Services Program. Water Body No. WA-47-1020. Publication No. 97-330 (data collected in Spring and Fall 1996).

TABLE 5.3-35
SUMMARY OF HISTORICAL COPPER CREEK ANALYTICAL DATA (1982-1996)
HOLDEN MINE RI/FS
DAMES & MOORE JOB NO. 17693-005-019

Parameters / Sample Location	Copper Creek 2 (CC-2)																	
Sample No.	USFS WATER QUALITY DATA [a]												349 [b]	512 [c]	619 [d]	CC Station [f]		729 [e]
Sample Date	5/12/82	6/9/82	6/22/82	7/14/82	8/25/82	9/28/82	6/1/83	6/22/83	7/19/83	8/10/83	8/31/83	9/27/83	7/94	7/95	5/96	6/12/96 *	9/10/96 *	9/96
Total Metals, (ug/L)																		
Aluminum																3.8	19	14
Arsenic	29 U	29 U	29 U	29 U	29 U	29 U	29 U	29 U	9	29	20					0.2 U	0.2 U	
Barium																		7.2
Beryllium																		10 U
Cadmium																0.02 U	0.1 U	10 U
Calcium																		10,000
Chromium																		10 U
Copper	5 U	5 U	5 U	5 U	5 U	5 U	10 U	10 U	10 U	10 U	10 U	10 U				0.24	0.23	10 U
Iron	150	40	40	60	10 U	50	20.	10 U	10 U	10 U	10 U	10 U				32	20 U	190
Lead	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U				0.04	0.1 U	50 U
Magnesium																		2,300
Manganese																1 U	1 U	10 U
Mercury																0.001 U		
Molybdenum																		20 U
Nickel																0.3		10 U
Potassium																		1,100
Selenium																	0.4 U	
Silver																0.01 U		
Sodium																		1,200
Thallium																		
Uranium																		
Zinc	5 U	10	10 U	10 U	5 U	10 U	5 U	5 U	5 U	5 U	5 U	5 U				1.1	1.1	10 U
Dissolved Metals, (ug/L)																		
Aluminum													6 U	10	20U		5.7	22
Arsenic													2 U	1 U	4 U			
Barium													4.6	4.6	5.7			6.7
Beryllium													1 U	0.3 U	0.4 U			10 U
Cadmium													1 U	1 U	0.7 U	0.02 U	0.01 U	10 U
Calcium													6000 U	3500	4400			6,000
Chromium													1 U	0.9 U	0.5 U			10 U
Copper													0.3	2 U	2 U	0.1	1.2	10 U
Iron													100 U	230	50U			100 U
Lead													0.2 U	0.3 U	0.3	0.02 U	0.04	50 U
Magnesium													400	340	1000U			1000 U
Manganese													0.9 U	2.6	3 U			10 U
Mercury																		
Molybdenum													0.4	0.2	0.6			20 U
Nickel													3 U	0.4	1 U	0.22		0.01 U
Potassium													400		700			1000 U
Silver													0.1 U	0.1 U	0.2 U	0.01 U		
Sodium													400	570	1000U			1,100
Thallium													0.1 U	0.6 U	4 U			
Uranium													0.1 U	0.1 U	0.4 U			
Zinc													2 U	3 U	2	0.4 U	1.5	10 U
Conventional analyses:																		
Alkalinity (mg/L)	22.5	13.2	11	8.4	9.6	11	7.3	7.6	7.8	7.8	8.2	10.8				10 U		
Chloride (mg/L)													0.13	0.2	0.2			
Cyanide (mg/L)	0.01 U	0.01 U	0.0013	0.01 U	0.01 U	0.0042	0.01 U	0.01 U	0.01 U	0.01 U	0.01 U	0.01 U				0.01 U		
Fluoride (mg/L)													0.05 U	0.2	0.1 U			
Hardness (mg/L)																12	13	
NO2 + NO3 (mg/L)																0.26		
Sulfate (mg/L)													3.3	3	5	3	4.3	
TSS (mg/L)	0.1 U	0.1 U	26.2	7.9	2		42.4			3.6	1.6	0.2				1	1 U	
Field Measurements:																		
Conductivity (LS/cm)	34	33	20	23	26	29	24	30	24	24	26	39	20	100	35	29	33	
pH	7.38	7.21	7.01	7.16	7.39	7.27	6.95	6.92	6.95	6.85	7.09	6.86	7.42	7.06	5.67	7.5	7.4	
Stream Flow (cfs)	1.31	18.89	136.73	40.73	8.78	7.68	117.17	17.87	18.67	23.08	7.96	0.17						
Temperature (°C)	3.5	5	4.5	4.5	8.5	5							6	3	3	4.4	8	
Turbidity (NTU)	0.5	1.1	2.6	1.1	0.4	2.9	4.2	1.8	1.2	1.3	0.9	1.6				0.5 U	1.3	

136.73
× 448.8
61,400 gpm

Data Notes:

U - Parameter was analyzed for, but not detected above the reporting limit shown.

* According to the report, the samples were labeled as 'CC-1'.
However it was confirmed with Department of Ecology that the samples were actually more closely related to the Copper Creek 2 station.

▨ Grey Shading ▨ indicates the concentration of analyte was not established, therefore not reported nor analyzed.

Data Source:

(a) Anderson, Keith A. 1992. *Preliminary Assessment of the Holden Mine Site;* USFS Chelan Ranger District. (Data collected 1982-1983).

(b) Kilburn, et al. 1994. *Geochemical data and sample locality maps for stream-sediment, heavy-mineral-concentrate, mill tailing, water, and precipitate samples collected in and around the Holden mine, Chelan County, Washington.* USGS Open File Report 94-680A Paper Version, 94-680B Diskette version (Data Collected in 1994).

(c) Kilburn, J.E. & S.J. Sutley. 1996. *Characterization of acid mine drainage at the Holden mine, Chelan, Washington*. USGS Open File Report 96-531. (Data collected in 1995).

(d) Kilburn, J.E. & S.J. Sutley. 1997. *Analytical results and comparative overview of geochemical studies conducted at the Holden Mine*, spring 1996. USGS Open File Report 97-128 (Data collected in Spring 1996).

(e) Kilburn, J.E. & S.J. Sutley. 1997. Preliminary data (no report attached, data collected in Fall 1996).

(f) Johnson, A., et al. 1997. *Effects of Holden Mine on the Water, Sediments and Benthic Invertebrates of Railroad Creek (Lake Chelan).* Environmental Investigations and Laboratory Services Program. Water Body No. WA-47-1020. Publication No. 97-330 (data collected in Spring and Fall 1996).

TABLE 5.3-36
SUMMARY OF WATER QUALITY DATA FOR HOLDEN CREEK
HOLDEN MINE RI/FS
DAMES & MOORE JOB NO. 17693-005-019

Parameters	Station No.	Holden Creek	HC-1	HC-2	HC-3	HC-4	355(a)
	Sampling Date	10/4/97	5/1/98	4/30/98	4/30/98	4/30/98	1994
Total Metals, (µg/L)							
Aluminum		40U	80U	240	70U	50U	▨
Arsenic		0.54	0.52	0.65	0.78	1.33	▨
Barium		4.27	5.04	6.17	5.76	6.82	▨
Beryllium		0.08U	0.04U	0.04U	0.04U	0.04U	▨
Cadmium		0.05	0.04U	0.07U	0.07U	0.06U	▨
Calcium		3,600	5180	5690	5010	4150	▨
Chromium		1U	0.2U	0.3	0.2U	0.2U	▨
Copper		0.7	1.2U	1.6J	1U	0.9U	▨
Iron		50	70	230	100	100	▨
Lead		0.3	0.054	0.129	0.067	0.069	▨
Magnesium		330	560	670	580	260	▨
Manganese		3.5	2.69	6.8	3.95	2.87	▨
Mercury		▨	▨	▨	▨	▨	▨
Molybdenum		0.43	0.5	0.53	0.45	0.69	▨
Nickel		0.2	0.2U	0.5	0.2U	0.2U	▨
Potassium		500U	500U	500U	600	500U	▨
Selenium		▨	▨	▨	▨	▨	▨
Silver		0.04U	0.04U	0.04U	0.04U	0.04U	▨
Sodium		630U	850	880	880	640	▨
Thallium		▨	▨	▨	▨	▨	▨
Uranium		▨	▨	▨	▨	▨	▨
Zinc		4U	5	5	4U	4	▨
Dissolved Metals, (µg/L)							
Aluminum		30U	50	30	20	20U	6U
Arsenic		0.5	0.39	0.45	0.61	1	2U
Barium		4.19	4.27	4.56	4.88	6.19	4.1
Beryllium		0.04U	0.04U	0.04U	0.04U	0.04U	1U
Cadmium		0.05	0.04U	0.05	0.04U	0.06	1U
Calcium		3,550	4980	5340	5030	3990	6000U
Chromium		0.2U	0.2U	0.2U	0.2U	0.2U	1U
Copper		0.9	0.6	0.7	0.6	0.5	1.4
Iron		20U	20U	20U	20	30	100U
Lead		0.3	0.018	0.011U	0.011U	0.011U	0.2U
Magnesium		330	520	580	570	230	210
Manganese		1.80	0.78	2.91	1.32	1.05	0.9U
Mercury		▨	▨	▨	▨	▨	▨
Molybdenum		0.5	0.46	0.49	0.43	0.64	0.2
Nickel		0.2U	0.2U	0.2	0.2U	0.2U	3U
Potassium		500U	500U	500U	500U	500U	200U
Selenium		▨	▨	▨	▨	▨	▨
Silver		0.04U	0.04U	0.04U	0.04U	0.04U	0.1U
Sodium		640U	850	820	880	610	950
Thallium		▨	▨	▨	▨	▨	▨
Uranium		▨	▨	▨	▨	▨	▨
Zinc		6	4U	4U	4U	4U	3

Data Notes:

J - Estimated value.
U - Parameter was analyzed for, but not detected above the reporting limit shown.
UJ - Parameter was analyzed for but not detected. Detection limit is an estimated value.
R - Data is rejected due to quality control concerns.
▨ **Grey shading** indicates the concentration of analyte was not established, therefore not reported nor analyzed.

Data Source:

(a) Kilbum, et al. 1994. *Geochemical data and sample locality maps for stream-sediment, heavy-mineral-concentrate, mill tailing, water, and precipitate samples collected in and around the Holden mine, Chelan County, Washington.* USGS Open File Report 94-680A Paper Version, 94-680B Diskette version (Data Collected in 1994).

TABLE 5.3-36
SUMMARY OF WATER QUALITY DATA FOR HOLDEN CREEK
HOLDEN MINE RI/FS
DAMES & MOORE JOB NO. 17693-005-019

Parameters	Station No.	Holden Creek	HC-1	HC-2	HC-3	HC-4	355[a]
	Sampling Date	10/4/97	5/1/98	4/30/98	4/30/98	4/30/98	1994
Total Petroleum Hydrocarbon (mg/L)							
Gasoline Range Hydrocarbons							
Diesel Range Hydrocarbons							
Motor Oil							
Polychlorinated Biphenyls (ug/L)							
Aroclor 1016							
Aroclor 1221							
Aroclor 1232							
Aroclor 1242							
Aroclor 1248							
Aroclor 1254							
Aroclor 1260							
Conventional Analyses							
Ortho-Phosphorous (mg/L)							
Post Chlorination Cyanide (mg/L)							
Total Cyanide (mg/L)							
Total Dissolved Solids (mg/L)		25J	28	24	14	11	
Total Phosphorous (mg/L)							
Total Suspended Solids (mg/L)		1.1U	1.8	5	1.9	2.2U	
Chloride (mg/L)							
NO_2 & NO_3 (mg/L)							
Sulfate (mg/L)		2.5U	2.6	2.7	2.7	2.5U	
Silicates (mg/L)							
Alkalinity (mg/L $CaCO_3$)		9.9	14	13	13	11	
Amenable Cyanide (mg/L)							
Color (Pt-CO)							
Hardness, Dissolved (mg/L)		10	15	16	15	11	
Field Measurements:							
pH		6.3	6.9	8.2	8.3	8.1	
Specific Conductivity (μS)		25	33	10	8	0	
Temperature (°C)		6.8	7.5	5	4	3	
Redox (mV)							
Iron (ion)							
Turbidity (NTU)			165	2	1	1	
Dissolved Oxygen (mg/L)			16.3	16.5	15.8	17.2	

Data Notes:
J - Estimated value.
U - Parameter was analyzed for, but not detected above the reporting limit shown.
UJ - Parameter was analyzed for but not detected. Detection limit is an estimated value.
R - Data is rejected due to quality control concerns.
Grey shading indicates the concentration of analyte was not established, therefore not reported nor analyzed.

Data Source:
(a) Kilburn, et al. 1994. *Geochemical data and sample locality maps for stream-sediment, heavy-mineral-concentrate, mill tailing, water, and precipitate samples collected in and around the Holden mine, Chelan County, Washington.* USGS Open File Report 94-680A Paper Version, 94-680B Diskette version (Data Collected in 1994).

TABLE 5.3-37
Summary of Water Quality Data for Big Creek
Holden Mine RIFS
Dames & Moore Job No. 17693-005-019

Parameters	Station No. / Sampling Date	BIG-1 / 5/2/98
Total Metals (ug/L)		
Aluminum		30U
Arsenic		0.33
Barium		7.09
Beryllium		0.04U
Cadmium		0.04U
Calcium		7,050
Chromium		0.2U
Copper		0.5U
Iron		20U
Lead		0.2U
Lead, low level		0.011U
Magnesium		360
Manganese		0.73
Molybdenum		0.35
Nickel		0.2U
Potassium		500U
Silver		0.04U
Sodium		660
Zinc		4U
Dissolved Metals (ug/L)		
Aluminum		30
Arsenic		0.29
Barium		6.51
Beryllium		0.04U
Cadmium		0.04U
Calcium		6,730
Chromium		0.2U
Copper		0.3
Iron		20U
Lead		0.2U
Lead, low level		0.011U
Magnesium		350
Manganese		0.29U
Molybdenum		0.33
Nickel		0.2U
Potassium		500U
Silver		0.04U
Sodium		640
Zinc		4U
Conventional Analyses		
Alkalinity (mg/L $CaCO_3$)		16
Hardness, Dissolved (mg/L)		18
Sulfate (mg/L)		2.6
Total Dissolved Solids (mg/L)		22
Total Suspended Solids (mg/L)		1U
Field Measurements		
Dissolved Oxygen (mg/L)		
pH		5.8
Specific Conductivity (uS)		55
Temperature (C)		5.3

Data Notes:
J - Estimated Value
U - Parameter was analyzed for, but not detected above the reporting limit shown.
UJ - Parameter was analyzed for, but not detected. Detection limit shown is an estimated value.
X - after the sample ID is an indication of field duplicate
Grey Shading indicates the concentration of analyte was not established, therefore not reported or analyzed.

TABLE 5.3-38
SUMMARY OF WATER QUALITY DATA FOR TENMILE CREEK
HOLDEN MINE RI/FS
DAMES & MOORE JOB NO. 17693-005-019

Parameter / Station No. / Sampling Date	Ten Mile Creek 9/19/97
Total Metals, (µg/L)	
Aluminum	30
Arsenic	0.14
Barium	6.17
Beryllium	0.04U
Cadmium	0.04U
Calcium	10,200
Chromium	0.2U
Copper	0.4
Iron	20U
Lead	0.2UJ
Magnesium	760
Manganese	0.31
Molybdenum	0.69
Nickel	0.3
Potassium	500U
Silver	0.04U
Sodium	740
Thallium	0.04U
Uranium	0.06
Zinc	4U
Dissolved Metals, (µg/L)	
Aluminum	20U
Arsenic	0.14
Barium	6.42
Beryllium	0.04U
Cadmium	0.04U
Calcium	10,600
Chromium	0.2U
Copper	0.3
Iron	20U
Lead	0.2U
Magnesium	790
Manganese	0.14U
Molybdenum	0.70
Nickel	0.4
Potassium	500U
Silver	0.04U
Sodium	790
Thallium	0.04U
Uranium	0.06
Zinc	4U
Conventional Analyses:	
Post Chlorination Cyanide (mg/L)	0.004UJ
Total Cyanide (mg/L)	0.004UJ
Total Dissolved Solids (mg/L)	44J
Total Suspended Solids (mg/L)	1.1U
Chloride (mg/L)	1.0U
NO_2 & NO_3 (mg/L)	0.011
Sulfate (mg/L)	9.4
Alkalinity (mg/L CaCO3)	25
Amenable Cyanide (mg/L)	0.004UJ
Hardness, Dissolved (mg/L)	30
Field Measurements:	
pH	7.2
Specific Conductivity (µS)	75
Temperature (°C)	7.6

Data Notes:
J - Estimated Value.
U - Parameter was analyzed for, but not detected above the reporting limit shown.
UJ - Parameter was analyzed for but not detected. Detection limit is an estimated value.
Sampling location was above the confluence with Railroad Creek and upstream of the road.

Parameters — Location	MTCA[1]	MTCA[2]	Federal MCLs[3]	Holden Village			Mine Influenced Area		Ball Field		Tailings Pile (TP-3)						Lucerne (US Forest Service Guard Station)	
Sample ID	Method A	Method B		HV-3 (H-3)		HV-3X (H-3)	HBKG-1		HBKG-2		DS-1		DS-1X	DS-2		DS-2X	LUCERNE	
Sampling Date				6/9/97	9/20/97	9/20/97	6/3/97	9/20/97	6/3/97	9/20/97	6/3/97	9/20/97	6/3/97	6/5/97	9/20/97	9/20/97	6/15/97	10/3/97
Dissolved Metals, (µg/L)																		
Aluminum	NE	NE	50 to 200[4]	20U	20U	20U	660	800	20U	20U	170	250	120	5,470	19,800	20,800	20U	20U
Arsenic	5	0.0583	50											0.8U	1U	2U		
Barium	NE	NE	2,000	14U	2J	2J	30	22J	39	2J	33	18J	29	14	22	22J	30	11
Beryllium	NE	0.0203	4	0.2U	1U	1U	0.8U	1U	0.8U	1U	0.8U	1U	0.8U	0.8	1U	1U	0.2U	1U
Cadmium	5	8	5	0.2U	0.2U	0.2U	43.1	39	3.18	0.4	3.1	1.4	4.1	1.2	2.5	2.4	0.2U	0.2U
Calcium	NE	NE	NE	13,200	12,800	12,900	37,000	53,500	9,830	10,100	96,200	44,200	86,600	51,400	123,000	127,000	14,200	14,500
Chromium	50	16,000 (Cr $^{+3}$)	100	5U	5U	5U	5U	5U	5U	5U	5U	5U	5U	5U	5U	5U	5U	5U
Copper	NE	592	1,300	3	2U	2U	3,030	2,370	10	2U	25	39	23	43	110	110	2U	2U
Iron	NE	NE	300[4]	20U	30	20	240	910	20U	20U	20U	20U	20U	30	72,300	76,800	310	200
Lead	5	NE	15	1U	1U	1U	5	2U	0.5U	1U	4U	5U	4U	4U	4U	1U	1U	1U
Magnesium	NE	NE	NE	1,890	1,800	1,810	4,860	7,710	1,050	980	11,000J	4,960	9,590J	6,950J	37,100	39,700	2,140	2,010
Manganese	NE	747	50[4]	2	1U	1U	129	175	3U	1U	524	116	376	338	1,860	1,950	8	5
Mercury	2	4.8	2											0.1U				
Molybdenum	NE	80	NE											0.8U	5U	5U		
Nickel	NE	320	100	10U	10U	10U	10	10	10U	10U	10	10U	10	10U	20	20	10U	10U
Potassium	NE	NE	NE	3,140	920	960	3,390	4,220	2,450	1,210	10,300	7,970	9,380	9,510	13,600	14,200	1,470	1,340
Selenium	NE	80	50											4U				
Silver	NE	80	100[4]	0.2U	0.2UJ	0.2UJ	0.8U	0.2UJ	0.8U	0.2UJ	0.8U	0.2UJ	0.8U	0.8U	0.2UJ	0.2UJ	0.2U	0.2U
Sodium	NE	NE	NE	4,750	1,500	1,530	3,330	4,900	2,150	1,380	3,910	2,180	3,820	2,770	6760	7,010	3,480	3,420
Thallium	NE	1.12	2											0.8U	2U	8U		
Uranium	NE	48	20											0.8	1.9	20U		
Zinc	NE	4,800	5000[4]	6	7	4U	4,900	5,170	30	11	222J	79	194J	174J	355	375	147	124
Total Petroleum Hydrocarbon, (mg/L)																		
Diesel Range Hydrocarbons	1.0	NE	NE				0.27X	0.25U						0.25U	0.25U	0.25U		
Gasoline Range Hydrocarbons	1.0	NE	NE				0.25U	0.25U						0.25U	0.25U	0.25U		
Motor Oil	1.0	NE	NE				0.50U	0.50U						0.5U	0.5U	0.5U		
Polychlorinated Biphenyls, (µg/L)																		
Aroclor 1016	0.1	0.0114	0.5				0.050U							0.050U				
Aroclor 1221	0.1	0.0114	0.5				0.10U							0.10U				
Aroclor 1232	0.1	0.0114	0.5				0.050U							0.050U				
Aroclor 1242	0.1	0.0114	0.5				0.050U							0.050U				
Aroclor 1248	0.1	0.0114	0.5				0.050U							0.050U				
Aroclor 1254	0.1	0.0114	0.5				0.050U							0.050U				
Aroclor 1260	0.1	0.0114	0.5				0.050U							0.050U				
Conventional Analyses:																		
Ortho-Phosphorous (mg/L)	-	-	-											0.004U				
Post Chlorination Cyanide (mg/L)	-	-	-											0.004U	0.004U	0.004U		
Total Cyanide (mg/L)	-	-	-											0.004U	0.004U	0.004U		
Total Dissolved Solids (mg/L)	-	-	-	74	65J	56J	190J	290J	47J	66J	490J	210J	420J	310	1,100J	1,100J	68	91J
Total Suspended Solids (mg/L)	-	-	-	160	2,400	2,800	18	11	53	1,000	15	6.9	7.4	7.9	11	16	1.0U	1.4
Chloride (mg/L)	-	-	-											1.0U	1.0U	1.0U		
NO_2 & NO_3 (mg/L)	-	-	-											0.29	0.053	0.057		
Sulfate (mg/L)	-	-	-	4.6	5.8	7.6	130	150	6.0	11	330	120	260	200	640	650	6.5	2.9
Alkalinity (mg/L $CaCO_3$)	-	-	-	52	38	42	4.4	7.9	30	32	9.6	1.3	7.9	1.0U	1.0U	1.0U	51	52
Amenable Cyanide (mg/L)	-	-	-											0.004U	0.004U	0.004U		
Color (Pt-CO)	-	-	-											5U				
Hardness, Dissolved (mg/L)	-	-	-	41	39	40	110	160	29	29	290	130	260	160	460	480	44	44
Total Phosphorous (mg/L)	-	-	-											0.035				
Field Measurements:																		
pH	-	-	-	6.64	6.54		5.13	5.11	6.01	6.3	5.44	5.24		4.01	4.07		5.49	5.25
Specific Conductivity (µS)	-	-	-	172	770		383	430	73	92	655	529		516	1050		140	105
Temperature (°C)	-	-	-	7.8	9.8		5	9.6	5.5	8	8.8	6.1		6.3	6.8		9	9.1
Redox (mV)	-	-	-	181			229		195		169			165				
Iron (ion)	-	-	-	Negative			Positive		Negative		Negative			Positive			Positive	
Turbidity (NTU)	-	-	-	48			3		610		9						5	
Dissolved Oxygen (mg/L)	-	-	-															

Data Notes:

J - Estimated value.

U - Parameter was analyzed for, but not detected above the reporting limit shown.

UJ - Parameter was analyzed for, but not detected. Detection limit is an estimated value.

R - Data is rejected due to quality control concerns.

X - Pattern profile does not match typical chromatographic profile.

Sample A-1 was collected from an additional portal located on site. The location of sample 'Lucerne' is Lucerne.

'X' after the sample ID is an indication of field duplicate.

* TP1-2L metals analysis from sample collected 9/20/97 are actually total metals.

** TP3-6L and TP3-6BL are collected at the same location.

1 - Model Toxics Control Act (MTCA) Method A, Toxics Cleanup Program, amended 1/96 (Chapter 173-340 WAC)

2 - Model Toxics Control Act Cleanup Levels and Risk Calculation (CLARCII), 2/96, Method B

3 - MCLs (Maximum Contaminant Levels), Drinking Water Regulations and Health Advisories, Office of Water, US EPA, 10/96

4 - Secondary MCLs (Maximum Contaminant Levels), Drinking Water Regulations and Health Advisories, Office of Water, US EPA, 10/96

▨ Grey shading indicates the concentration of analyte was not established, therefore not reported nor analyzed.

Parameters Location	MTCA[1]	MTCA[2]	Federal MCLs[3]	Tailings Pile 1 (TP-1)												Tailings Pile 2 (TP-2)													
Sample ID	Method A	Method B		TP1-1A		TP1-2A		TP1-3A		TP1-4A		TP1-5A		TP1-6A		PZ-1A	PZ-1B		PZ-1BX		PZ-3A		TP2-4A		TP2-5A	TP2-8A		TP2-11A	
Sampling Date				6/3/97	9/18/97	6/3/97	9/18/97	6/3/97	9/18/97	6/10/97	9/18/97	6/3/97	9/18/97	6/3/97	9/20/97	6/11/97	6/5/97	9/19/97	6/5/97	9/19/97	6/6/97	9/19/97	6/6/97	9/18/97	6/7/97	6/6/97	9/19/97	6/5/97	9/19/97
Dissolved Metals, (µg/L)																													
Aluminum	NE	NE	50 to 200[4]	2,290	1,210	7,110	6,640	2,080	4,400	30	20U	103,000	25,500	46,300	15,300	20U	20U	20U	20U	20U	20U	20U	20U	20U	20U	4,980	680	330	440
Arsenic	5	0.0583	50																		6	5							
Barium	NE	NE	2,000	37	22J	22	11J	18	15J	67	41J	30	8J	26	11J	28	19	7J	22	7J	47	25J	49	37J	26	29	20J	32	26J
Beryllium	NE	0.0203	4	20U	2U	0.4	5U	20U	5U	0.2U	1U	20U	1U	20U	1U	0.2U	4U	1U	4U	1U	4U	1U	4U	1U	0.8U	4U	1U	0.4U	1U
Cadmium	5	8	5	20U	0.2U	0.3	0.2U	1.7	1.6	0.2U	0.6	20U	1.8	100	28	0.2	0.2U	0.2U	0.2U	0.2U	4U	0.2U	4U	0.2U	0.9	7	4.9	1.6	2.9
Calcium	NE	NE	NE	62,300	79,700	87,100	303,000	257,000	282,000	63,900	97,200	144,000	104,000	66,400	35,000	83,300	295,000	271,000	298,000	269,000	212,000	198,000	232,000	187,000	83,700	243,000	308,000	57,100	127,000
Chromium	50	16,000 (Cr $^{+3}$)	100	5U	10U	5U	20U	5U	20U	5U	5U	5U	5U	5U	5U	5U	5U	5U	5U	5U	5U	5U	5U	5U	5U	5U	5U	5U	5U
Copper	NE	592	1,300	2U	4U	2U	10U	2U	10U	2U	2U	196	48	1,100	811	2U	2U	2U	2U	2U	2U	2U	3	2U	47	31	11	10	10
Iron	NE	NE	300[4]	218,000	519,000	321,000	1,690,000	344,000	1,520,000	30	20U	246,000	413,000	145,000	79,500	5,710	69,000	50,500	70,800	49,800	5,660	5,770	7,040	5,630	20U	20U	20U	20U	100
Lead	5	NE	15	100U	2U	1U	4U	1U	4U	1U	2U	100U	1U	100U	1U	1U	1U	2U	1U	2U	20U	1U	20U	1U	4U	20U	2U	1U	1U
Magnesium	NE	NE	NE	21,900J	37,400	33,200	132,000	56,100	139,000	6,330	13,200	78,400J	46,000	29,400J	12,000	5,080	18,700	16,400	19,200	16,200	24,100	22,200	27,400	29,600	8,150	37,700	39,100	4,870	12,800
Manganese	NE	747	50[4]	1,170	2,880	1,910	8,330	3,220	9,330	166	147	5,250	2,980	1,260	575	437	1,270	1,140	1,290	1,120	301	561	186	153	1	2,910	1,860	122	265
Mercury	2	4.8	2																		0.00128								
Molybdenum	NE	80	NE																		4U	5U							
Nickel	NE	320	100	10U	20U	20	50U	40	60	10U	10U	120	30	20	10U	10U	10U	10U	10U	10U	10U	10U	10U	10U	10U	30	10	10U	10
Potassium	NE	NE	NE	7,250	9,660	11,600	22,000	36,000	37,400	3,690	5,230	5,950	8,510	5,870	4,160	17,000	34,900	32,500	35,700	31,900	30,600	31,800	31,600	27,400	12,500	32,700	31,100	9,960	12,700
Selenium	NE	80	50																		20U								
Silver	NE	80	100[4]	20U	0.2UJ	20U	0.2UJ	20U	0.2UJ	0.2U	0.2UJ	20U	0.2UJ	20U	0.2UJ	0.2U	4U	0.2UJ	4U	0.2UJ	4U	0.2UJ	4U	0.2UJ	0.8U	4U	0.2UJ	0.4U	0.2UJ
Sodium	NE	NE	NE	6,670	7,950	7,960	28,100	12,800	17,000	7,660	7,780	9,030	6,820	4,640	3,630	3,630	8,920	7,680	9,130	7,530	7,440	7,240	7,190	6,580	3,100	9,120	9,160	2,820	4,310
Thallium	NE	1.12	2																		4U	1U							
Uranium	NE	48	20																		4U	20U							
Zinc	NE	4,800	5000[4]	466J	130	2,270	1,080	5,050	8,100	28	28	9,810J	2,730	11,400J	3,350	32	11U	10	8U	9	5U	7	11U	7	80	556	280	169	309
Total Petroleum Hydrocarbon, (mg/L)																													
Diesel Range Hydrocarbons	1.0	NE	NE																										
Gasoline Range Hydrocarbons	1.0	NE	NE																										
Motor Oil	1.0	NE	NE																										
Polychlorinated Biphenyls, (µg/L)																													
Aroclor 1016	0.1	0.0114	0.5																										
Aroclor 1221	0.1	0.0114	0.5																										
Aroclor 1232	0.1	0.0114	0.5																										
Aroclor 1242	0.1	0.0114	0.5																										
Aroclor 1248	0.1	0.0114	0.5																										
Aroclor 1254	0.1	0.0114	0.5																										
Aroclor 1260	0.1	0.0114	0.5																										
Conventional Analyses																													
Ortho-Phosphorous (mg/L)	-	-	-																		0.004UJ								
Post Chlorination Cyanide (mg/L)	-	-	-																		0.011	0.016							
Total Cyanide (mg/L)	-	-	-																		0.012	0.017							
Total Dissolved Solids (mg/L)	-	-	-	1,100J	2,000J	1,500J	6,700J	2,500J	6,100J	310	330J	2,600J	2,000J	1,500J	540J	370	1,400	1,200J	1,400	1,200J	970	860J	1,100	920J	370	1,200	1,400J	250	580J
Total Suspended Solids (mg/L)	-	-	-	170	64	37	93	35	280	480	390	320	380	26	13	4.2J	35	66	36	58	28	46	73	62	75	270	2,000	260	1,600
Chloride (mg/L)	-	-	-																		1.0	1.9							
NO$_2$ & NO$_3$ (mg/L)	-	-	-																		0.039	0.12							
Sulfate (mg/L)	-	-	-	620	1,200	1,000	3,700	1,500	3,800	160	300	1,700	1,000	850	330	190	850	750	840	720	670	510	720	570	280	820	970	150	390
Alkalinity (mg/L CaCO$_3$)	-	-	-	1.0U	1.0U	1.0U	1.0U	1.0U	1.0U	57	61	1.0U	1.0U	1.0U	1.0U	70	130	95	140	96	77	86	65	61	26	1.0U	7.3	3.2	4.2
Amenable Cyanide (mg/L)	-	-	-																		0.004U	0.004U							
Color (Pt-CO)	-	-	-																		60J								
Hardness, Dissolved (mg/L)	-	-	-	240	350	350	1,300	870	1,300	190	300	680	450	290	140	230	810	740	820	740	630	590	690	590	240	760	930	160	370
Total Phosphorous (mg/L)	-	-	-																		0.078								
Field Measurements																													
pH	-	-	-	5.54	5.51	5.16	4.91	5.3	5.25	6.74	6.9	4.31	4.14	4.26	4.51	6.43	6.85	6.48			6.57	6.61	7.21	6.94	6.02	5.12	5.32	5.06	5.36
Conductivity (Omho/cm or LS/cm)	-	-	-	1120	1690	1560	4710	2400	4470	537	804	250	1820	1750	659	743	1680	1420			1160	1150	1320	1120	740	1410	1440	432	914
Temperature (°C)	-	-	-	6.1	6.4	6.4	6.9	6.1	6.8	8.9	7.4	5.1	6.2	6.1	7.1	8.6	7.5	6.4			9.2	9.2	8	7.5	7.7	7.1	9.8	8.3	8
Redox (mV)	-	-	-	187		214		202		122		257		196			140				115		114		133	162		145	
Iron (ion)	-	-	-	Positive		Positive		Positive		Negative		Positive		Positive		Positive	Positive				Positive		Positive		Negative	Negative		Negative	
Turbidity (NTU)	-	-	-	137		26		200		126		395		9		122	72				148		78		210	173			
Dissolved Oxygen (mg/L)	-	-	-																										

Data Notes:
J - Estimated value.
U - Parameter was analyzed for, but not detected above the reporting limit shown.
UJ - Parameter was analyzed for, but not detected. Detection limit is an estimated value.
R - Data is rejected due to quality control concerns.
X - Pattern profile does not match typical chromatographic profile. 'X' after the sample ID is an indication of field duplicate.
Sample A-1 was collected from an additional portal located on site. The location of sample 'Lucerne' is Lucerne.

* TP1-2L metals analysis from sample collected 9/20/97 are actually total metals.
** TP3-6L and TP3-6BL are collected at the same location.

▨ Grey shading indicates the concentration of analyte was not established, therefore not reported nor analyzed.

TABLE 5.4-1
SUMMARY OF RI GROUNDWATER QUALITY DATA
HOLDEN MINE RI/FS
DAMES & MOORE JOB NO. 17693-005-019

Parameters	Location	MTCA[1]	MTCA[2]	Federal MCLs[3]	Tailings Pile 3 (TP-3)												Lysimeters														1100 Level Portal
	Sample ID	Method A	Method B		PZ-6A		TP3-4	TP3-6A		TP3-8		TP3-8X	TP3-9		TP3-10 (TP3-10A)		TP1-2L		TP1-3L		TP1-4L		TP1-6L		TP3-4L		TP3-6L**	TP3-6BL**	TP3-10L		A-1
	Sampling Date				6/10/97	9/20/97	6/4/97	6/4/97	9/19/97	6/4/97	9/19/97	6/4/97	6/4/97	9/19/97	6/4/97	9/19/97	6/3/97	9/20/97*	6/3/97	9/19/97	6/3/97	9/19/97	6/3/97	9/19/97	6/3/97	9/19/97	6/3/97	9/19/97	6/3/97	9/19/97	7/11/97
Dissolved Metals, (µg/L)																															
Aluminum		NE	NE	50 to 200[4]	20U	40U	9,870	540	60U	120	1,090	130	11,500	9,690	290	540	7,230	5,980	130U	100U	3,580	1,530	930	610	120	330	20U	20U	140	310	20U
Arsenic		5	0.0583	50																											
Barium		NE	NE	2,000	25	13J	25	47	17J	24	16J	24	18	17J	27	17J	14	8	15	5J	20	4J	20	5	35	7	17	6J	21	9	14.4
Beryllium		NE	0.0203	4	4U	2U	0.4U	0.4U	1U	0.8U	1U	0.8U	0.8	1U	0.4U	1U	4U	5U	4U	5U	20U	1U	0.8	5	0.8U	1U	20U	1U	20U	1U	0.04U
Cadmium		5	8	5	4U	0.2U	4.8	2.2	0.7	0.8U	0.8	0.8U	1.9	3.5	0.6	4.4	0.8U	10U	0.8U	0.2U	20U	0.2U	0.8	0.7	0.8U	2U	20U	0.2U	20U	2U	2.32
Calcium		NE	NE	NE	449,000	563,000	12,900	16,800	10,900	76,200	269,000	77,500	46,100	291,000	33,400	192,000	394,000	420,000	414,000	438,000	446,000	392,000	79,200	158,000	61,800	54,900	485,000	419,000	474,000	462,000	20,100
Chromium		50	16,000 (Cr $^{+3}$)	100	5U	10U	5U	5U	5U	5U	5U	5U	5U	5U	5U	5U	20U	20U	20U	20U	5U	5U	10	20	5U	5U	5U	5U	5U	5U	0.2U
Copper		NE	592	1,300	2U	4U	137	67	14	2U	10	2U	48	51	13	6	10U	10U	10U	10U	2U	2U	4	10	2U	2	2U	2U	2U	2U	120
Iron		NE	NE	300[4]	58,300	75,700	250	20U	20U	55,400	274,000	56,200	400	125,000	20	47,000	1,680,000	1,440,000	1,480,000	1,400,000	350,000	275,000	593,000	1,070,000	165,000	249,000	181,000	105,000	196,000	184,000	20U
Lead		5	NE	15	20U	2U	14	3U	1U	4U	4U	4U	2U	2U	2U	1U	4U	100U	4U	4U	100U	2U	4	2	4U	1U	100U	4U	100U	5U	0.4U J
Magnesium		NE	NE	NE	65,100	83,300	3,150J	2,040J	1,330	17,400J	68,300	17,700J	8,230J	41,400	3,590J	37,400	173,000	80,200	68,200	62,700	29,200J	27,100	42,700	103,000	32,700J	38,700	50,400J	57,400	24,200J	22,000	1,910
Manganese		NE	747	50[4]	1,500	1,490	183	57	3	656	2,560	667	1,370	3,490	62	1,400	10,800	8,540	4,530	4,460	4,250	2,490	3,740	6,210	1,580	1,790	2,430	1,680	2,320	2,190	27.8
Mercury		2	4.8	2																											
Molybdenum		NE	80	NE																											
Nickel		NE	320	100	10U	20U	10	10U	10U	10U	10U	10U	40	40	10U	20	50U	50U	50U	50U	10U	10U	20	50	10U	10U	10U	10U	10U	10U	1.0
Potassium		NE	NE	NE	62,100	75,700	1,570	3,390	1,500	19,800	37,600	19,900	6,740	18,900	7,410	22,200	69,200	55,000	39,900	51,200	18,400	13,800	27,300	33,800	26,500	26,700	50,600	47,400	38,200	38,400	1,770
Selenium		NE	80	50																											
Silver		NE	80	100[4]	4U	0.3J	0.4U	0.4U	0.2UJ	0.8U	0.2UJ	0.8U	0.4U	0.2UJ	0.4U	0.2UJ	4U	20U	4U	0.2UJ	20U	0.2UJ	0.8	0.2	0.8U	3U	20U	0.2J	30	3U	0.04U
Sodium		NE	NE	NE	15,000	17,200	2,080	1,500	1,160	4,620	11,200	4,710	3,110	10,700	2,000	7,990	52,500	46,700	103,000	24,800	13,700	13,000	11,400	10,700	10,400	10,500	36,400	87,500	34,300	112,000	1,220
Thallium		NE	1.12	2																											
Uranium		NE	48	20																											
Zinc		NE	4,800	5000[4]	15	25	590J	403J	102	58J	395	57J	194J	402	68J	534	690	580	260	120	280J	88	32	40	49J	36U	22J	52	32J	27U	257
Total Petroleum Hydrocarbon, (mg/L)																															
Diesel Range Hydrocarbons		1.0	NE	NE																											
Gasoline Range Hydrocarbons		1.0	NE	NE																											
Motor Oil		1.0	NE	NE																											
Polychlorinated Biphenyls, (µg/L)																															
Aroclor 1016		0.1	0.0114	0.5																											
Aroclor 1221		0.1	0.0114	0.5																											
Aroclor 1232		0.1	0.0114	0.5																											
Aroclor 1242		0.1	0.0114	0.5																											
Aroclor 1248		0.1	0.0114	0.5																											
Aroclor 1254		0.1	0.0114	0.5																											
Aroclor 1260		0.1	0.0114	0.5																											
Conventional Analyses																															
Ortho-Phosphorous (mg/L)		-	-	-																											
Post Chlorination Cyanide (mg/L)		-	-	-																											
Total Cyanide (mg/L)		-	-	-																											
Total Dissolved Solids (mg/L)		-	-	-	2,400	2,800J	170	86	59J	500	2,200J	570	350	1,800J	160	1,100J															86J
Total Suspended Solids (mg/L)		-	-	-	36	190	9.1	9.1	200	5.8	30	5.5	36	65	78	260															3.5
Chloride (mg/L)		-	-	-																											
NO_2 & NO_3 (mg/L)		-	-	-																											
Sulfate (mg/L)		-	-	-	1,500	1,700	83	49	25	340	1,400	340	200	1,100	100	660	4,500		3,800	3,800	2,000	2,000	1,200		600		1,800	1,900	1,800		40
Alkalinity (mg/L $CaCO_3$)		-	-	-	110	43	1.0U	2.3	7.2	8.8	1.0U	10	1.0U	1.0U	1.7	1.0U	1.0U		1.0U	1.0U	1.0U	1.0U	1.0		9.4		12	44	2.3		23
Amenable Cyanide (mg/L)		-	-	-																											
Color (Pt-CO)		-	-	-																											
Hardness, Dissolved (mg/L)		-	-	-	1,400	1,800	45	50	33	260	950	270	150	900	98	630	1,700		1,300	1,400	1,200	1,100	370	820	290		1,400	1,300	1,300		58
Total Phosphorous (mg/L)		-	-	-																											
Field Measurements																															
pH		-	-	-	5.95	6.45	3.97	5.2	6.14	5.65	5.53		3.81	4.37	4.99	5.43	6.28	5.75	5.43	6	4.2	4.81	5.06	4.3	6.16	5.72	6.23	6.77	6.69	6.36	8
Conductivity (µmho/cm or µS/cm)		-	-	-	2430	2800	340	154	103	844	2120		709	1820	2870	1210	5630	4840	4760	4520	2790	3570	1850	3180	1027	1350	2790	2940	2640	2710	141
Temperature (°C)		-	-	-	11.6	8	4.8	4.7	6.4	7	8.1		5.9	6.2	5.7	6.7	10.7	10.2	7.3	9.8	10.7	9.1	10	8.7	9.7	12	9.1	9.8	10.7	8.8	6.6
Redox (mV)		-	-	-	98		282	225		212			258		184		80		195		128		116		215		183		117		154
Iron (ion)		-	-	-	Positive		Positive	Negative		Positive			Positive		Negative		Positive		Positive		Positive		Positive		Positive		Positive		Positive		Negative
Turbidity (NTU)		-	-	-	213		52			12			6		88		8		81		1		0		145		0		21		
Dissolved Oxygen (mg/L)		-	-	-													13.6		13.42		13.74		14.3		8.35		13.16		13.88		

Data Notes:

J - Estimated value.
U - Parameter was analyzed for, but not detected above the reporting limit shown.
UJ - Parameter was analyzed for, but not detected. Detection limit is an estimated value.
R - Data is rejected due to quality control concerns.
X - Pattern profile does not match typical chromatographic profile. 'X' after the sample ID is an indication of field duplicate.
Sample A-1 was collected from an additional portal located on site. The location of sample 'Lucerne' is Lucerne.

* TP1-2L metals analysis from sample collected 9/20/97 are actually total metals.
** TP3-6L and TP3-6BL are collected at the same location.

▨ Grey shading indicates the concentration of analyte was not established, therefore not reported nor analyzed.

TABLE 5.4-2
SUMMARY OF RI SEEPAGE WATER QUALITY DATA
HOLDEN MINE RI/FS
DAMES & MOORE JOB NO. 17693-005-019

Parameters	Location	Tailings Pile 1 (TP-1)													Tailings Pile 2 (TP-2)						Tailings Pile 3 (TP-3)		Mine	Mill				Mine Influenced Area					TP-1
	Sampling Station	SP-1			SP-2								SP-2X		SP-3			SP-4			SP-5		SP-6	SP-7			SP-7X	SP-8	SP-9	SP-9X	SP-10W		SP-10E
	Sampling Date	5/23/97	7/12/97	5/2/98	5/18/97	6/2/97	6/9/97	6/16/97	7/12/97	9/16/97	10/5/97	5/2/98	7/12/97	5/2/98	5/20/97	7/12/97	9/16/97	5/20/97	7/12/97	5/2/98	5/20/97	7/12/97	5/21/97	5/21/97	7/12/97	9/19/97	5/21/97	5/21/97	5/23/97	5/23/97	5/21/97	7/12/97	5/21/97
Total Metals (µg/L)																																	
Aluminum																																	
Arsenic																																	
Barium																																	
Beryllium																																	
Cadmium																																	
Calcium																																	
Chromium																																	
Copper																																	
Iron																																	
Lead																																	
Magnesium																																	
Manganese																																	
Mercury																																	
Molybdenum																																	
Nickel																																	
Potassium																																	
Selenium																																	
Silver																																	
Sodium																																	
Thallium																																	
Uranium																																	
Zinc																																	
Dissolved Metals (µg/L)																																	
Aluminum		27,100	41,200	30700	94,600	71,800	70,000J	49,800	115,000	67,900	82,500	100000	121,000	99800	33,400	22,500	3,920	19,000	20,100	5570	25,600	10,400	14,600	190	20	1,790	200	9,620	30	20	4,740	3,530	9,850
Arsenic				1U	1.5				5U	5U		5U	5U	5U	1.6	1U	2U			1U				0.2U	1U	1U	0.2U						
Barium		15	13	11	15.2J	19	14J	9	12	5	5	2	10	3	14.7	21	23	36.7	30	61	18.6	22	12.0	12.9	27	21	12.5	22.2	30	29	15.4	27	18.4
Beryllium		0.7	5U	2U	1.7	20U	20U	20U	5U	2U	2U	2U	5U	2U	0.6	1U	1U	4U	1U	1U	0.4	1U	8U	0.2U	1U	1U	0.04	0.8U	0.8U	0.04U	0.8U	1U	0.2U
Cadmium		22.7	6	7	22.8	15	11J	20U	9	3.9	6	9	10	9	40.3	6	2.0	7.3	6	1.6	8.2	1.8	173	34.0	26	48	35.3	87.8	0.75	0.76	25.7	36	7.0
Calcium		102,000	200,000	140000	155,000	183,000	188,000J	189,000	241,000	180,000	173,000	232000	246,000	174000	137,000	184,000	278,000	114,000	117,000	37500	103,000	49,000	134,000	15,800	28,700	60,100	15,900	56,500	19,000	18,600	27,400	30,600	5,780
Chromium		10U	20U	10U	5	20U	20U	10U	20U	10U	10U	10U	20U	10U	1	5U	5U	2U	5U	5U	2	5U	4U	1U	5U	5U	1U	4U	5U	5U	4U	5U	1U
Copper		698	240	321	914	860	660J	224	790	101	181	475	870	474	1,280	583	90	670	344	133	1,100	402	12,700	2,810	1,930	7,560	2,800	7,880	3	2	2,210	2,110	760
Iron		542,000	1,260,000	705000	487,000	956,000J	925,000J	856,000	1,180,000	685,000	515,000	673000	1,200,000	675000	154,000	263,000	251,000	74,900	53,000	9730	19,500	8,670	30	120	220	710	120	30	20U	20U	30	30	14,100
Lead		1U	10U	5U	4U	20U	20U	100U	10U	10U	5U	5U	10U	5U	1J	5U	5U	2U	2U	1U	2J	2	15J	3J	3	13	4J	13J	0.4U	0.3U	4U	1U	20J
Magnesium		53,500	106,000	61200	96,800	107,000	106,000J	99,000	153,000	94,200	95,100	125000	155,000	125000	47,900	54,400	62,300	36,300	34,100	9840	23,800	10,700	15,000	4,810	5,680	11,500	4,860	5,380	2,090	2,070	3,870J	4,270	1,400
Manganese		3,380	6,310	3870	6,120	6,280	5,890J	5,220	8,570	5,250	4,980	6260	8,780	6280	3,000	3,410	3,850	1,750	1,710	522	1,100	453	1,160	116	185	451	144	419	1U	1U	160	191	58.9
Mercury					0.00244				0.00309				0.00308		0.00193J	0.00072								0.00068J	0.00023J		0.00051J						
Molybdenum				10U	0.8U				20U	10U		10U	20U	10U	0.2UJ	5U	5U			5U				0.2UJ	5U	5U	0.2UJ						
Nickel		20	50U	20U	119	60	60J	100	70	100	120	190	50U	200	17	10U	10U	13	10	10U	14	10U	86	6	10U	10	7	46	10U	10U	11	10	3
Potassium		9,870	16,300	11100	9,040	12,900	13,300J	14,700	9,640	9,840	7,380	9990	7,620	10100	14,100	17,400	29,300	9,530	13,700	3550	10,000	8,560	10,500	1,230	2,390	3,200UJ	1,260	3,980	1,010	1,020	2,500	3,490	3,650
Selenium					4				5U				5U		1J	2U								1UJ	1U		1UJ						
Silver		0.2U	0.2U	0.2U	0.8U	4U	4U	20U	0.2U	0.2U	0.2U	0.2U	0.2U	0.2U	0.2U	0.2U	0.2U	4U	0.2U	0.2U	0.2U	0.2U	8U	0.2U	0.2U	0.2U	0.13U	0.8U	0.8U	0.8U	0.8U	0.2U	0.2U
Sodium		12,800	20,100	14400	16,200	19,700	19,900J	21,300	23,300	13,600	13,100	19800	22,700	19600	8,610	11,300	11,500	7,310	7,760	2190	6,780	3,480	4,910	2,170	3,830	6,470J	2,170	2,440	3,470	3,440	2,760	2,920	1400
Thallium					0.8U				50U	10U			50U		0.2UJ	5U	5U							0.2UJ	1U	1U	0.2UJ						
Uranium					10.2				50U	50U			50U		2.9J	50U	50U							0.3J	20U	1U	0.33J						
Zinc		3,490	2,590	2050	5,600	4,570	4,430J	4,700	4,120	5,700	6,120	4630	3,890	4620	4,030	1,620	611	904	921	248	654	232	22,100	4,330	3,470	6,430	4,390	11,200	267	267	3,210	4,350	714

TABLE 5.4-2
SUMMARY OF RI SEEPAGE WATER QUALITY DATA
HOLDEN MINE RI/FS
DAMES & MOORE JOB NO. 17693-005-019

Parameters	Location	Tailings Pile 1 (TP-1)													Tailings Pile 2 (TP-2)						Tailings Pile 3 (TP-3)		Mine	Mill				Mine Influenced Area					TP-1
	Sampling Station	SP-1			SP-2								SP-2X		SP-3			SP-4			SP-5		SP-6	SP-7			SP-7X	SP-8	SP-9	SP-9X	SP-10W		SP-10E
	Sampling Date	5/23/97	7/12/97	5/2/98	5/18/97	6/2/97	6/9/97	6/16/97	7/12/97	9/16/97	10/5/97	5/2/98	7/12/97	5/2/98	5/20/97	7/12/97	9/16/97	5/20/97	7/12/97	5/2/98	5/20/97	7/12/97	5/21/97	5/21/97	7/12/97	9/19/97	5/21/97	5/21/97	5/23/97	5/23/97	5/21/97	7/12/97	5/21/97
Polychlorinated Biphenyls (ug/L)																																	
Aroclor 1016		0.050U	0.033U		0.017U				0.033U																								
Aroclor 1221		0.10U	0.067U		0.033U				0.067U																								
Aroclor 1232		0.050U	0.033U		0.017U				0.033U																								
Aroclor 1242		0.050U	0.033U		0.017U				0.033U																								
Aroclor 1248		0.050U	0.033U		0.017U				0.033U																								
Aroclor 1254		0.050U	0.033U		0.017U				0.033U																								
Aroclor 1260		0.050U	0.033U		0.017U				0.033U																								
Total Petroleum Hydrocarbons (mg/L)																																	
Diesel Range Hydrocarbons		0.25U	0.25U		0.25UJ		0.25U		0.25U	0.25U																							
Gasoline Range Hydrocarbons		0.25U	0.25U		0.25U				0.25U	0.25U																							
Motor Oil		0.50U	0.50U		0.50UJ		0.50U		0.50U	0.50U																							
Conventional Analyses																																	
Ortho-Phosphorous (mg/L)					0.017J				0.030J				0.029J		0.004UJ	0.006J								0.004U	0.009J		0.004U						
Post Chlorination Cyanide (mg/L)					0.004UJ				0.004U	0.004U			0.004U		0.004U	0.004U	0.005UJ							0.004U	0.004U		0.004U						
Total Cyanide (mg/L)					0.004UJ				0.004U	0.004U			0.004		0.004U	0.004U	0.005UJ							0.004	0.004U		0.004U						
Total Dissolved Solids (mg/L)		2,800	5,900	3200	3,700	4,700J	4,900	4,700	5,400	3,800J	3,300J	4400	5,800	4400	1,700	2,000	2,100J	1,100	980	280	840	370	880	130	180	390J	120	380	94	87	210	230	210
Total Phosphorous (mg/L)					0.040				0.040				0.034		0.016U	0.031								0.016U	0.018		0.016U						
Total Suspended Solids (mg/L)		13	8.9	2.2	4.5	5.6J	23	17	4.5	1.6J	6.4	9.1	2.7	6.1	3.4	10	36J	11	1.0U	1U	6.0	1.1U	1.0U	17	4.1	16	17	1.1U	2.0	1.0U	1.1U	2.4	1.1U
Chloride (mg/L)					1.0U				2.9	1.0U			2.4		1.0U	1.0U	1.1							1.0U	1.3	1.0U	1.0U						
NO_2 & NO_3 (mg/L)					0.14				0.032	0.010U			0.01U		0.15	0.044	0.010U							0.031	0.030		0.031						
Sulfate (mg/L)		1,700	3,200	2000	2,100	3,200	2,700	3,400	3,800	2,200	2,300	2700	4,000	2800	880	1,100	1,300	660	610	190	530	230	600	79	120	260	80	240	44	46	170	110	120
Silicates (mg/L)									45																								
Alkalinity (mg/L $CaCO_3$)		1.0U	1.0U	1U	1.0U	1.0U	1.0U	1.0U	1.0U	1.0U	1.0U	1U	1.0U	1U	1.0U	1.0U	1.0U	1.0U	1.0U	1U	1.0U	1.0U	15	4.3	1.4	1.0U	4	1.0U	15	15	1.0U	1.0U	1.0U
Amenable Cyanide (mg/L)					0.004UJ				0.004U	0.004U			0.004		0.004U	0.004U	0.004UJ							0.004	0.004U		0.004U						
Color (Pt-CO)					40J				20J				25J		15J	5J								10	5UJ		10						
Hardness, Dissolved (mg/L)		480	940	600	790	900	910	880	1200	840	820	1100	1200	950	540	680	950	440	430	130	360	170	400	59	99	200	60	160	56	55	84	94	20
Field Measurements																																	
pH		3.3	3.56	3.3	2.9 - 3.1	3.32	3	3.2	2.9	3.12	3.87	2.7			3.61	3.5	3.5	3.64	3.5	3.6	3.37	3.78	4.2	5.63	6.91	4.69		4.61	6.4		4.15	4.69	3.3
Specific Conductivity (µS)		2240 - 2570	4310	2830	2370 - 3910	3710	3580	3790	4495	3050	2810	3810			1790	2030	2040	1290	1260	338	1160	608	1040	240	264	505		623	198		370	301	594
Temperature (°C)		7.6	9.5	7.4	4.3 - 8.8	6.5	15.1	8.4	16	10	9.3	8.3			5.2	13.2	14	6	4.4	9.8	5	8.6	4.8	6.9	19.1			5.1	5.2		4.2	11.1	7
Redox (mV)		332	318			377	300	386	360						386	331		400	331		372	265	336	267	170			409			382	165	497
Iron (ion)		Positive	Positive					Positive	Positive						Positive	Positive		Positive	Positive		Positive		Negative	Negative	Positive			Negative			Negative	Negative	Positive

Data Notes:
J - Estimated value.
U - Parameter was analyzed for, but not detected above the reporting limit shown.
UJ - Parameter was analyzed for, but not detected. Detection limit is an estimated value.
An "X" following the sample identification indicates field duplicate.
X- Pattern is not indicative of a typical motor oil pattern.
Grey shading indicates the concentration of analyte was not established, therefore not reported nor analyzed.

TABLE 5.4-2
SUMMARY OF RI SEEPAGE WATER QUALITY DATA
HOLDEN MINE RI/FS
DAMES & MOORE JOB NO. 17693-005-019

Parameters / Location	Mine Influenced Area				Holden Village	Honeymoon Heights				Mine Influenced Area										
Sampling Station	SP-11	SP-11X	SP-12		SP-13	SP-14 Upper	SP-14		SP-14 Lower	SP-15E						SP-15W	SP-16			SP-16X
Sampling Date	5/22/97	5/22/97	5/23/97	7/12/97	6/2/97	10/3/97	5/23/97	9/18/97	10/3/97	5/22/97	6/2/97	6/9/97	6/16/97	7/12/97	10/5/97	5/22/97	5/22/97	7/12/97	9/16/97	7/12/97
Total Metals (µg/L)																				
Aluminum							440													
Arsenic																				
Barium							18													
Beryllium							4U													
Cadmium							3.46													
Calcium							1,830													
Chromium							5U													
Copper							830													
Iron							20													
Lead							6.0													
Magnesium							300													
Manganese							9													
Mercury																				
Molybdenum																				
Nickel							10U													
Potassium							500U													
Selenium																				
Silver							0.05J													
Sodium							700													
Thallium																				
Uranium																				
Zinc							446													
Dissolved Metals (µg/L)																				
Aluminum	150	150	1,380	1,590	20U	70	410	160U	900	1,940	2,240	3,350J	2,560	20U	680	30	2,040	3,490	2,630	3,350
Arsenic	0.3	0.2U															0.8U	1U	1U	1U
Barium	44.6	45.3	50	27	41	2	33	20	51	18	36.1	34.6J	43	43	36	23	21.6	37	24	37
Beryllium	0.04U	0.2U	0.8U	1U	0.8U	1U	4U	1U	1U	0.09	4U	0.3J	4U	1U	1U	0.04U	0.8U	1U	1U	1U
Cadmium	12.8	13.2	14.1	18	0.31	0.2U	3.46	1.2	12	54.6	55.8	66.9J	74	28	63	9.37	53.5	38	34	38
Calcium	25,300	24,100	9,610	16,200	10,400	700	1,800	1,730	5,020	47,900	38,300	46,800J	52,900	30,100	51,500	23,000	48,300	44,900	49,800	43,900
Chromium	1U	1U	5U	5U	5U	5U	5U	5U	5U	5U	1U	1U	5U	5U	5U	5U	4U	5U	5U	5U
Copper	460	472	2,000	1,910	2U	2U	788	52	1,410	3,560	3,950	4,930J	4,470	899	4,180	206	3,450	3,100	2,110	2,970
Iron	20U	20U	20U	20U	330	20U	20	480	30	80	80J	100J	110	20U	170	20U	60	500	80	450
Lead	1U	1U	0.2U	1U	0.8U	1U	4.8U	3	11	6.7U	8	14J	20U	1U	6	1.4U	5J	9	8	10
Magnesium	3,180	3,000	1,470	2,920	1,460	130	290	350	910	6,330	5,820	7,170J	8,260	5,930	9,040	2,590	6,530	6,500	4,560	6,270
Manganese	37.3	36.3	53	93	74	1U	8	4	43	247	198	250J	295	148	312	37	253	993	2,030	960
Mercury																	0.00056J	0.00093		0.00067
Molybdenum																	0.8UJ	5U	5U	5U
Nickel	6	5	10U	10U	10U	10U	10U	10U	10U	20	16	20J	20	10U	20	10U	28	30	20	30
Potassium	2,410	2,060	1,140	1,840	1,010	500U	500U	750UJ	560	3,460	3,910	5,270J	4,760	3,040	3,830	2,120	3,500	4,760	5,230	4,700
Selenium																	4UJ	1U		1U
Silver	0.05U	0.2U	0.04U	0.2U	1.1U	0.2U	0.04U	0.2U	0.2U	0.05U	0.2U	0.2U	4U	0.2U	0.2U	0.8U	0.04U	0.2U	0.2U	0.2U
Sodium	3,650	3,410	1,630	3,130	1,950	310U	730	590UJ	650	2,500	3,010	3,420J	3,940	3,450	3,710	3,380	2,980	4,820	3,350	4,600
Thallium																	0.8UJ	1U	1U	1U
Uranium																	0.8UJ	20U	20U	20U
Zinc	2,340	2,280	2,230	2,720	71	5	423	151	1,610	7,970	7,210	8,580J	9,810	3,590	8,960	2,260	7,690	4,920	4,050	4,810

TABLE 5.4-2
SUMMARY OF RI SEEPAGE WATER QUALITY DATA
HOLDEN MINE RI/FS
DAMES & MOORE JOB NO. 17693-005-019

Parameters / Location	Mine Influenced Area				Holden Village	Honeymoon Heights				Mine Influenced Area										
Sampling Station	**SP-11**	**SP-11X**	**SP-12**		**SP-13**	**SP-14 Upper**	**SP-14**		**SP-14 Lower**	**SP-15E**						**SP-15W**	**SP-16**			**SP-16X**
Sampling Date	**5/22/97**	**5/22/97**	**5/23/97**	**7/12/97**	**6/2/97**	**10/3/97**	**5/23/97**	**9/18/97**	**10/3/97**	**5/22/97**	**6/2/97**	**6/9/97**	**6/16/97**	**7/12/97**	**10/5/97**	**5/22/97**	**5/22/97**	**7/12/97**	**9/16/97**	**7/12/97**
Polychlorinated Biphenyls (ug/L)																				
Aroclor 1016																	0.050U	0.033U		
Aroclor 1221																	0.10U	0.067U		
Aroclor 1232																	0.050U	0.033U		
Aroclor 1242																	0.050U	0.033U		
Aroclor 1248																	0.050U	0.033U		
Aroclor 1254																	0.050U	0.033U		
Aroclor 1260																	0.050U	0.033U		
Total Petroleum Hydrocarbons (mg/L)																				
Diesel Range Hydrocarbons																	0.25U	0.25U	0.25U	
Gasoline Range Hydrocarbons																	0.25U	0.25U	0.25U	
Motor Oil																	0.50U	0.60X	0.50U	
Conventional Analyses																				
Ortho-Phosphorous (mg/L)																	0.004U	0.004UJ		0.004UJ
Post Chlorination Cyanide (mg/L)																	0.004U	0.004U	0.004U	0.004U
Total Cyanide (mg/L)																	0.004U	0.004U	0.004U	0.004U
Total Dissolved Solids (mg/L)	140	150	76	140	40J	5.0U	23	24J	32	280J	240J	270	320	180	280J	130J	280	270	270J	280
Total Phosphorous (mg/L)																	0.058	0.016U		0.018
Total Suspended Solids (mg/L)	7.8	5.2	1.1U	2.5	1.5	1.4	1.0U	5.8	1.1U	13J	6.6J	6.1	7.8	19	2.4	2.1J	7.9	1.1U	1.7J	1.1U
Chloride (mg/L)																	1.0U	1.0U	2.1	1.0U
NO_2 & NO_3 (mg/L)																	0.051	0.010U	0.010U	0.010U
Sulfate (mg/L)	82	84	45	62	4.4	2.5U	11	6.9	22	180	140	170	180	110	200	78	200	130	140	140
Silicates (mg/L)																				
Alkalinity (mg/L $CaCO_3$)	7.8	8.3	1.0U	1.0U	32	1.7	1.0U	1.0U	1.0U	1.0U	1.0U	1.0U	1.0U	2.5	1.0U	3.1	2.2	1.0U	1.0U	1.0U
Amenable Cyanide (mg/L)																	0.004U	0.004U	0.004U	0.004U
Color (Pt-CO)																	5U	5UJ		5UJ
Hardness, Dissolved (mg/L)	76	72	30	53	32	2	6	6	16	150	120	150	170	100	170	68	150	140	140	140
Field Measurements																				
pH	5.8		5.03	5.48	6	5.8	5.1	6.05	4.5	5.5	5.62	5.11	4.69	7	4.9	6.5	5.36	4.76	4.43	
Specific Conductivity (µS)	258		114 - 263	197	90	2(?)	36	17.5	71	460	423	544	569	252	471	226	467	403	423	
Temperature (°C)	4		3.5 - 5.9	5.1	8	5.5	2.3		7.7	8 2	13.5	16.6	13.2	17.6	8.2	5.6	8.1	23.9	12	
Redox (mV)				206			199			318	258	180	208	163		269	326	186		
Iron (ion)	Negative		Negative	Negative			Negative					Negative	Negative	Negative		Negative	Negative	Positive		

Data Notes:
J - Estimated value.
U - Parameter was analyzed for, but not detected above the reporting limit shown.
UJ - Parameter was analyzed for, but not detected. Detection limit is an estimated value.
An "X" following the sample identification indicates field duplicate.
X- Pattern is not indicative of a typical motor oil pattern.
Gray shading indicates the concentration of analyte was not established, therefore not reported nor analyzed.

**TABLE 5.4-2
SUMMARY OF RI SEEPAGE WATER QUALITY DATA
HOLDEN MINE RI/FS
DAMES & MOORE JOB NO. 17693-005-019**

Parameters / Location	Tailings Pile 3 (TP-3)				TP-1	Tailings Pile 3 (TP-3)				Mine Influenced Area													Upstream		
Sampling Station	SP-17		SP-18		SP-19	SP-21				SP-22	SP-23							SP-23 UP	SP-23 Vent Rd	SP-23B	SP-24	SP-25	SP-26		SP-27
Sampling Date	5/20/97	7/12/97	5/19/97	7/12/97	5/21/97	5/22/97	7/12/97	9/15/97	10/5/97	5/23/97	5/23/97	5/26/97	6/2/97	6/9/97	6/16/97	10/5/97	5/2/98	7/11/97	10/5/97	5/23/97	5/23/97	5/23/97	7/11/97	9/16/97	5/7/98
Total Metals (µg/L)																									
Aluminum						1,890																			
Arsenic						0.04U																			
Barium						13.9																			
Beryllium						0.06																			
Cadmium						1.11																			
Calcium						21,200																			
Chromium						0.2U																			
Copper						54.0																			
Iron						1,020																			
Lead						2.1J																			
Magnesium						3,490																			
Manganese						164																			
Mercury						0.1U																			
Molybdenum						0.34J																			
Nickel						4.5																			
Potassium						2,490																			
Selenium						0.2UJ																			
Silver						0.17J																			
Sodium						1,560																			
Thallium						0.04UJ																			
Uranium						0.13J																			
Zinc						113																			
Dissolved Metals (µg/L)																									
Aluminum	40	70	34,100	38,300	4,640	1,500	1,300	1,800	2,410	190	7,890	7,940	7,440	6,850J	5,390	4,670	5620	5,820	4,520	5,250	2,410	890	30	20U	20U
Arsenic																	1U								1U
Barium	18.7	23	33.1	21	21.3	14.0	22	21	26	33	33	40.0	26.5	28.5J	23	27	22	32	20	35	36	42	14	3	1U
Beryllium	0.04U	1U	0.84	1	0.8U	0.06	1U	1U	1U	20U	20U	0.2	4U	0.3J	4U	1U	1U	1U	1U	4U	20U	4U	1U	1U	1U
Cadmium	0.38	0.6	12.3	25	50.1	1.06	0.7	1.1	0.8	47.5	38.9	41.8	32.0	27.1J	22	23	34	26	22	28	47.7	34.1	0.3	0.3	0.2U
Calcium	5,290	4,570	103,000	77,000	33,600	22,800	18,000	44,800	42,100	58,000	17,000	15,900	11,100	10,300J	7,940	11,200	15500	10,900	10,500	14,100	45,300	37,400	3,760	4,640	4610
Chromium	0.2U	5U	0.6	5U	4U	0.2U	5U	5U	5U	5U	5U	1U	1U	1U	5U	5U	5U	5U	5U	5U	5U	5U	5U	5U	5U
Copper	11.0	8	950	1,220	4,180	51.8	34	34	34	2,140	6,850	6,470	6,100	5,940J	4,880	4,920	5340	5,560	4,520	4,900	3,660	1,880	28	22	2U
Iron	60	70	23,900	33,700	70	1,000	690	1,530	2,370	20U	20U	20U	20U	20U	20U	20U	20U	20U	20U	20U	220	20U	20U	20U	20U
Lead	0.2U	1U	1U	2U	6J	0.5J	1U	1U	1U	2.8U	20U	1U	1U	3J	20U	1U	0.22	1U.	1U	4U	4.3U	2.2U	1U	1U	1U
Magnesium	690	670	17,300	14,200	3,290	3,820	2,870	7,630	7,810	6,880	5,130	4,660	2,660	2,500J	1,630	2,290	3620	2,540	2,150	3,920	6,240	5,090	470	540	430
Manganese	8.94	8	1,810	1,290	247	174	108	304	348	264	248	223	130	115J	79	128	199	114	109	177	270	157	1U	1U	1
Mercury						0.1U																			
Molybdenum																	5U								5U
Nickel	0.7	10U	26.1	40	29	4.3	10U	10U	10	20	20	22	14	12J	10U	10	20	10	10	10	20	10	10U	10U	10U
Potassium	740	1,100	4,140	4,210	3,190	2,290	2,660	5,030	3,960	3,980	1,160	1,280	1,360	1,120J	840	1,340	1110	1,420	890	1,000	3,730	2,700	640	790	500U
Selenium																									
Silver	0.04U	0.2U	0.04U	0.2U	0.8U	0.2U	0.2U	0.2U	0.2U	0.04U	0.04U	0.2UJ	0.2U	0.2U	4U	0.2U	0.2U	0.2U	0.2U	0.04U	0.14	0.08	0.2U	0.2U	0.2U
Sodium	960	850	4,670	3,640	1,670	1,750	1,470	2,550	2,390	3,340	1,600	1,710	1,140	1,240J	1,000	1,360	1430	1,380	1,330	1,650	3,140	3,300	970	1,020	1110
Thallium																									
Uranium																									
Zinc	45	77	1,080	2,230	6,170	109	109	133	132	7,350	5,000	5,020	3,400	2,870J	2,250	2,460	4110	2,610	2,570	3,610	7,560	5,550	32	22	4U

TABLE 5.4-2
SUMMARY OF RI SEEPAGE WATER QUALITY DATA
HOLDEN MINE RI/FS
DAMES & MOORE JOB NO. 17693-005-019

Parameters	Location	Tailings Pile 3 (TP-3)				TP-1	Tailings Pile 3 (TP-3)				Mine Influenced Area													Upstream		
	Sampling Station	SP-17		SP-18		SP-19	SP-21				SP-22	SP-23							SP-23 UP	SP-23 Vent Rd	SP-23B	SP-24	SP-25	SP-26		SP-27
	Sampling Date	5/20/97	7/12/97	5/19/97	7/12/97	5/21/97	5/22/97	7/12/97	9/15/97	10/5/97	5/23/97	5/23/97	5/26/97	6/2/97	6/9/97	6/16/97	10/5/97	5/2/98	7/11/97	10/5/97	5/23/97	5/23/97	5/23/97	7/11/97	9/16/97	5/7/98
Polychlorinated Biphenyls (ug/L)																										
Aroclor 1016											0.050U															
Aroclor 1221											0.10U															
Aroclor 1232											0.050U															
Aroclor 1242											0.050U															
Aroclor 1248											0.050U															
Aroclor 1254											0.050U															
Aroclor 1260											0.050U															
Total Petroleum Hydrocarbons (mg/L)																										
Diesel Range Hydrocarbons											0.25U															
Gasoline Range Hydrocarbons																										
Motor Oil											0.50U															
Conventional Analyses																										
Ortho-Phosphorous (mg/L)																										
Post Chlorination Cyanide (mg/L)																										
Total Cyanide (mg/L)																										
Total Dissolved Solids (mg/L)		32	28	470	810	240	130	110	290J	220J	300	200	190	140J	140	95	110J	160	140	110J	160	280	230	39	30J	350
Total Phosphorous (mg/L)																										
Total Suspended Solids (mg/L)		1.0U	1.1U	1.2	11	1.4	2.9	1.2	1.4J	2.0	16	1.0U	1.1UJ	1.1UJ	1.5	1.0U	1.0U	1.5	1.1U	1.0U	1.1U	2.3	1.0U	1.1U	1.1UJ	2.2U
Chloride (mg/L)																										
NO_2 & NO_3 (mg/L)																										
Sulfate (mg/L)		5.2	11	560	380	130	84	61	140	140	200	130	110	81	72	59	66	88	70	68	100	180	170	6.2	2.5U	2.6
Silicates (mg/L)																										
Alkalinity (mg/L $CaCO_3$)		9.1	4.5	1.0U	1.0U	1.0U	2.4	1.0U	1.0U	1.0U	6.8	1.0U	1.0U	1.0U	1.0U	1.0U	1.0U	1U	1.0U	1.0U	1.0U	1.0U	1.0U	10	14	14
Amenable Cyanide (mg/L)																										
Color (Pt-CO)																										
Hardness, Dissolved (mg/L)		16	14	330	250	98	73	57	140	140	170	64	59	39	36	26	37	54	38	35	51	140	110	11	14	13
Field Measurements																										
pH		6.38	7.4	3.34	3.6	4.61	5.42	4.98	4.6	4.92	6	4.2	4.9	4.25	5	4	4.57	4.9		4.54	4.3	4.9	5.5	8.26	6	7.5
Specific Conductivity (µS)		43	47	1080	1040	418	285	220	448	374	433	360	276	277	260	203	196	179		182	285	382	323	25	31.8	6
Temperature (°C)		4.6	8.9	10.8	6.9	6.9	7.2	8.5	8.5	7.2	9.5	2.5	4.2	3.4	4.2	7	6.6	4.5		6.3	2.6	7.8	4.4	7.2	7.2	4.6
Redox (mV)		127	90	460	303	363	228	114			282	327	290	344	187	207					325	282	301			
Iron (ion)		Positive	Positive	Positive	Positive	Negative	Positive	Positive			Negative	Negative	Negative								Negative	Negative	Negative			

Data Notes:
J - Estimated value.
U - Parameter was analyzed for, but not detected above the reporting limit shown.
UJ - Parameter was analyzed for, but not detected. Detection limit is an estimated value.
An "X" following the sample identification indicates field duplicate.
X- Pattern is not indicative of a typical motor oil pattern.
▨ Grey shading Indicates the concentration of analyte was not established, therefore not reported nor analyzed.

TABLE 5.4-3
HISTORICAL SUMMARY OF GROUNDWATER WELL RESULTS (1991-1996)
HOLDEN MINE RI/FS
DAMES & MOORE JOB NO. 17693-005-019

Location	MTCA[1]	MTCA[2]		TP-2					TP-3					TP-2			TP-3		
Parameters Sample ID	Method A	Method B	Federal MCLs[3]	PZ-1A	PZ-1B	PZ-2A	PZ-2B	PZ-3A	PZ-4A	PZ-4B	PZ-4C	PZ-5A	PZ-6A	PZ-1B	PZ-2A	PZ-3A	PZ-4B	PZ-5A	PZ-6A
Sampling Date				6/4/91	6/4/91	6/4/91	6/4/91	6/4/91	6/4/91	6/4/91	6/4/91	6/4/91	6/4/91	8/5/91	8/5/91	8/5/91	8/5/91	8/5/91	8/5/91
Dissolved Metals (µg/L)																			
Aluminum	NE	16,000	50 to 200[4]																
Arsenic	5	0.0583	50																
Barium	NE	1,120	2,000																
Beryllium	NE	0.0203	4																
Cadmium	5	8	5																
Calcium	NE	NE	NE	194,054	219,036	114,500	536,228	155,925	14,142	116,592	82,278	253,209	493,724	184,365	117,465	158,810	142,865	217,250	475,680
Cobalt	NE	NE	NE																
Chromium	50	16,000 (Cr^{+3})	100																
Copper	NE	592	1,300	21	3	15	28	12	105	9	15	12	42	6	6	6	6	6	11
Iron	NE	NE	300[4]																
Lead	5	NE	15	105	33	110	175	69	31.2U	45	108	45	280	52	52	52	52	52	104
Magnesium	NE	NE	NE	23,905	19,278	14,520	57,099	21,486	1,851	9,162	27,498	20,355	87,430	15,730	14,490	22,940	11,290	16,435	77,820
Manganese	NE	747	50[4]																
Mercury	2	4.8	2																
Molybdenum	NE	80	NE																
Nickel	NE	320	100																
Potassium	NE	NE	NE	29,505	29,787	22,890	55,972	28,443	2,793	16,281	25,515	28,050	68,012	28,630	23,865	25,300	17,140	26,550	61,350
Selenium	NE	80	50																
Silver	NE	80	100[4]																
Silicate	NE	NE	NE	5,110	10,824	6,945	6,244	4,902	6,528	7,287	13,227	7,962	8,862	11,225	7,405	6,550	8,960	7,770	9,910
Sodium	NE	NE	NE	75,418	7,263	54,205	10,402	68,175	1,389	3,759	8,463	20,157	27,146	7,025	60,135	92,275	4,420	19,600	39,710
Thallium	NE	1.12	2																
Uranium	NE	48	20																
Zinc	NE	4,800	5000[4]	511	54	85	938	84	1,044	186	219	57	280	75	35	40	60	90	230
Conventional Analyses:																			
Chloride (mg/L)	NE	NE	NE	0.66	0.3	0.45	0.15	1.53	0.11	0.25	0.61	0.46	0.3	0.36	0.76	1.06	0.44	1.05	0.57
Fluoride (mg/L)	NE	NE	NE	1 U	1 U	1 U	1 U	1 U	0.05	1 U	1 U	1 U	1 U	3.06	0.84	1.14	2.72	1.49	2.56
Hardness (mg/L)	NE	NE	NE	583.1	626.6	345.8	1574.7	477.9	42.9	329	318.4	716.5	1592.8	525.4	353.1	491.1	403.5	610.5	1508.3
NO$_2$ & NO$_3$ (mg/L)	NE	NE	NE	1.4	0.17	0.15	0.25	0.23	0.52	0.25	0.49	1.03	0.06 U	0.22	0	0.11	1.02	0.3	0.24
Sulfate (mg/L)	NE	NE	NE	609.45	662.22	215.7	1585.89	544.05	75.11	316.48	1163.85	716.24	1699.7	490.71	173.62	575.6	401.49	562.42	1620.04

Data Notes:
J - Estimated value.
NE - Not Established
U - Parameter was analyzed for, but not detected above the reporting limit shown.
UJ - Parameter was analyzed for, but not detected. Detection limit is an estimated value.
1 - Model Toxics Control Act (MTCA) Method A, Toxics Cleanup Program, amended 1/96 (Chapter 173-340 WAC)
2 - Model Toxics Control Act Cleanup Levels and Risk Calculation (CLARCII), 2/96, Method B
3 - MCLs (Maximum Contaminant Levels), Drinking Water Regulations and Health Advisories, Office of Water, US EPA, 10/96
4 - Secondary MCLs (Maximum Contaminant Levels), Drinking Water Regulations and Health Advisories, Office of Water, US EPA, 10/96
Grey shading indicates the concentration of analyte was not established, therefore not reported nor analyzed.

Data Sources:
(a) Walters, et al. 1992. *Holden Mine Reclamation Project Final Report.* Pacific Northwest Laboratories,Richland, WA. (Data collected in 1991).
(b) Lambeth, R.H. 1995. Transmittal of laboratory data from samples collected at Holden Mine site by the US Bureau of Mines. (Data collected in 1994).

TABLE 5.4-3
HISTORICAL SUMMARY OF GROUNDWATER WELL RESULTS (1991-1996)
HOLDEN MINE RI/FS
DAMES & MOORE JOB NO. 17693-005-019

Location	MTCA[1]	MTCA[2]		TP-2							TP-2						MINE	BALL FIELD	TP-3		
Parameters Sample ID	Method A	Method B	Federal MCLs[3]	TP2-01L-01	TP2-04A-01	TP2-02L-01	TP2-08A-01	TP2-10L-01	TP2-11A-01	TP2-11L-01	TP2-01L-02	TP2-04A-02	TP2-07A-02	TP2-08A-02	TP2-10L-02	TP2-11A-02	HBKG-1-01	HBKG-1-02	D1-02	D2-02	D3-02
Sampling Date				7/95[b]	7/95[b]	7/95[b]	7/95[b]	7/95[b]	7/95[b]	7/95[b]	7/95[b]	7/95[b]	7/95[b]	7/95[b]	7/95[b]	7/95[b]	7/95[b]	7/95[b]	7/95[b]	7/95[b]	7/95[b]
Dissolved Metals (μg/L)																					
Aluminum	NE	16,000	50 to 200[4]	100U	100U	16,000	100U	100U	100U	100 U	100U	100U	100U	600	7,700	400	2,300	2,500	100 U	100 U	2,500
Arsenic	5	0.0583	50																		
Barium	NE	1,120	2,000																		
Beryllium	NE	0.0203	4																		
Cadmium	5	8	5	100U	100U	1,000	100U	100U	100U	100 U	100U	100U	100U	100U	100 U	100U	100 U	100 U	100 U	100 U	100 U
Calcium	NE	NE	NE	533,000	217,000	510,000	260,000	195,000	195,000	556,000	572,000	203,000	275,000	292,000	493,000	88,000	66,000	44,000	283,000	90,000	43,000
Cobalt	NE	NE	NE	100U	100U	500	100U	100U	100U	100 U	100U	100U	100U	100U	100 U	100U	100 U	100 U	100 U	100 U	100 U
Chromium	50	16,000 (Cr^{+3})	100																		
Copper	NE	592	1,300	100U	100U	2,000	100U	100U	100U	100 U	100U	100U	100U	100U	100 U	100U	7,300	6,700	100 U	100 U	6,100
Iron	NE	NE	300[4]	21,000	8,300	27,000	100U	177,000	49,000	4,000	46,900	4,000	8,200	100U	281,000	13,400	100 U	100 U	100 U	14,600	300
Lead	5	NE	15		100U	100U	100U	100U	100U	100 U	100U	100U		100U	100 U	100U	100 U	100 U	100 U	100 U	100 U
Magnesium	NE	NE	NE	56,000	30,000	134,000	31,000	66,000	23,000	32,000	46,000	28,000	42,000	42,000	89,000	10,300	10,600	5,800	42,000	8,500	5,900
Manganese	NE	747	50[4]	8,000	100U	41,000	100U	2,500	100U	2,000	5,600	100U	100U	1,600	3,200	500	100 U	200	1,600	100 U	200
Mercury	2	4.8	2																		
Molybdenum	NE	80	NE																		
Nickel	NE	320	100		100U	800	100U	100U	100U	100 U	100U	100U	100U	100U	100 U	100U	100 U	100 U	100 U	100 U	100 U
Potassium	NE	NE	NE								60,000	27,000	37,000	34,000	55,000	12,000		3,400	34,000	12,000	3,600
Selenium	NE	80	50																		
Silver	NE	80	100[4]																		
Silicate	NE	NE	NE	1,500	1,600	1,700	2,500	3,600	100U	100 U	1,400	600	800	1,200	2,200	1,400	3,200	1,800	1,100	900	1,900
Sodium	NE	NE	NE									7,600	8,900	11,000	22,000	4,700		3,700	8,900	4,200	3,500
Thallium	NE	1.12	2																		
Uranium	NE	48	20																		
Zinc	NE	4,800	5000[4]	2,200	100U	178,000	200	1,100	700	300	1,400	100U	100U	100U	5,500	200	12,000	9,300		200	10,300
Conventional Analyses:																					
Chloride (mg/L)	NE	NE	NE																		
Fluoride (mg/L)	NE	NE	NE																		
Hardness (mg/L)	NE	NE	NE																		
NO_2 & NO_3 (mg/L)	NE	NE	NE																		
Sulfate (mg/L)	NE	NE	NE																		

Data Notes:

J - Estimated value.
NE - Not Established
U - Parameter was analyzed for, but not detected above the reporting limit shown.
UJ - Parameter was analyzed for, but not detected. Detection limit is an estimated value.
1 - Model Toxics Control Act (MTCA) Method A, Toxics Cleanup Program, amended 1/96 (Chapter 173-340 WAC)
2 - Model Toxics Control Act Cleanup Levels and Risk Calculation (CLARCII), 2/96, Method B
3 - MCLs (Maximum Contaminant Levels), Drinking Water Regulations and Health Advisories, Office of Water, US EPA, 10/96
4 - Secondary MCLs (Maximum Contaminant Levels), Drinking Water Regulations and Health Advisories, Office of Water, US EPA, 10/96
▨ Grey shading indicates the concentration of analyte was not established, therefore not reported nor analyzed.

Data Sources:

(a) Walters, et al. 1992. *Holden Mine Reclamation Project Final Report.* Pacific Northwest Laboratories, Richland, WA. (Data collected in 1991).
(b) Lambeth, R.H. 1995. Transmittal of laboratory data from samples collected at Holden Mine site by the US Bureau of Mines. (Data collected in 1994).

TABLE 5.4-4
HISTORICAL SUMMARY OF SEEPAGE WATER RESULTS (1991-1996)
HOLDEN MINE RI/FS
DAMES & MOORE JOB NO. 17693-005-019

Parameters	Location	TAILINGS PILE (TP-1) AREA																								
	Sample ID	364	515	516	518	520	521	523	524	525	527	528	529	536	537	538	623	625	626	627	629	630	654	655	656	657
	Sampling Date	7/94^a	7/95^b	7/95^b	7/95^b	7/95^b	7/95^b	7/95^b	7/95^b	7/95^b	7/95^b	7/95^b	7/95^b	7/95^b	7/95^b	7/95^b	5/96^c	5/96^c	5/96^c	5/96^c	5/96^c	5/96^c	5/96^c	5/96^c	5/96^c	5/96^c
Total Metals (µg/L)																										
Aluminum		▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨
Arsenic		▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨
Barium		▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨
Beryllium		▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨
Cadmium		▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨
Calcium		▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨
Chromium		▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨
Copper		▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨
Iron		▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨
Lead		▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨
Magnesium		▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨
Manganese		▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨
Mercury		▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨
Molybdenum		▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨
Nickel		▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨
Potassium		▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨
Selenium		▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨
Silver		▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨
Sodium		▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨
Thallium		▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨
Uranium		▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨
Zinc		▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨
Dissolved Metals (µg/L)																										
Aluminum		> 6000	> 10,000	>10000	>10000	2600	>10000	4800	>10000	>10000	>10000	>10000	>10000	>10000	>10000	3800	550	95000	120000	57000	61000	12000	49000	53000	39000	15000
Arsenic		2 U	1 U	1 U	1 U	4.8	1 U	5.4	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	4 U	4 U	4 U	4 U	4 U	4 U	4 U	4 U	4 U	4 U
Barium		13	0.62	4	2.6	11	5.6	9.5	6.1	5.4	0.52	2.1	6	10	10	18	13	3.6	2	8.9	9.8	22	3.2	1	3.4	130
Beryllium		1 U	0.5	0.8	1.2	0.3 U	0.3 U	0.3 U	0.3 U	0.4	0.9	0.8	0.8	0.91	0.3 U	0.3	0.4 U	1.9	2.2	0.8	1	0.4 U	1	0.8	0.5	0.5
Cadmium		6.8	8.1	11	19	2	2	2	13	22	13	22	28	29	17	20	21	6.8	6.6	24	11	14	16	11	12	6.7
Calcium		39000	130000	99000	190000	110000	140000	130000	130000	130000	140000	130000	84000	80000	46000	21000	15000	140000	190000	110000	90000	14000	120000	95000	120000	15000
Chromium		1 U	2	2	6.1	0.9 U	1	0.9 U	2	1	2	2	2	1	0.9 U	0.9 U	0.5 U	7.7	8.4	5.7	3.8	0.5 U	8.6	10	5.4	2
Copper		53	270	410	780	4	59	36	200	140	170	330	300	410	160	1700	1500	490	480	1200	550	500	1100	1300	560	630
Iron		50000	> 500000	>500000	340000	>500000	>500000	>500000	>500000	480000	>500000	390000	110000	160000	110000	650	60	760000	990000	530000	390000	300	800000	950000	1100000	22000
Lead		2.7	0.3 U	0.3 U	0.3	0.5	4.6	0.6	0.9	0.3 U	0.3 U	0.3 U	0.3 U	1.7	0.4	0.3	2.1	0.6	0.5	1.5	0.4	0.5	0.82	1.9	0.5	0.84
Magnesium		17000	70000	47000	51000	39000	47000	51000	50000	47000	50000	44000	28000	30000	17000	2400	1700	120000	150000	64000	69000	5200	110000	97000	120000	10000
Manganese		1000	5100	3800	3900	3500	4100	4500	4400	2900	3300	2700	1500	1400	780	120	110	6300	7600	3600	3600	250	6600	6000	7200	730
Mercury		▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨
Molybdenum		0.1 U	0.1 U	0.1 U	0.1 U	0.1	0.1 U	0.2	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U
Nickel		18	100	75	43	12	15	13	15	26	25	28	23	18	13	6.8	20 U	150	170	14	87	12	18	11	14	5.8
Potassium		2000 U	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	1600	5500	8000	4100	3500	1100	3100	1600	7600	6900
Selenium		▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨
Silver		0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U
Sodium		4200	9900	8500	9200	6800	8100	7800	8900	>10000	>10000	>10000	9000	7300	4300	1500	1500	15000	19000	9400	12000	2000	17000	14000	17000	2700
Thallium		0.2	0.6 U	0.6 U	0.6 U	0.6 U	0.6 U	0.6 U	0.6 U	0.6 U	0.6 U	0.6 U	0.6 U	0.6 U	0.6 U	0.6 U	4 U	4 U	4 U	4 U	4 U	4 U	4 U	4 U	4 U	4 U
Uranium		1.2	23	14	31	1.1	8.8	1.3	6.7	2	1.8	2.9	2.2	5.8	3.5	1.1	0.7	16	18	7.4	7.2	0.8	4.2	5.7	3.1	2.6
Zinc		3800	7300	7200	4000	1200	1700	1400	2600	4900	5300	6000	4800	6200	3800	1800	2700	9500	11000	3100	7300	2700	2600	3300	4100	1100
Conventional Analyses:																										
Chloride (mg/L)		3.2	INT	INT	INT	INT	INT	INT	INT	1	INT	2	3	3	1.2	0.4	0.4	0.1 U	0.1 U	0.1 U	0.1 U	0.4	INT	INT	INT	0.5
Fluoride (mg/L)		0.57	6	3	3	3	2	3	4	1	2	2	1	1.2	0.4	0.3	0.2	0.1 U	0.1 U	0.1 U	1	0.4	2.7	2.9	3.1	1
NO_2 & NO_3 (mg/L)		0.1 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2	0.1	0.1 U	0.2	0.8	0.1 U	0.3	0.1 U	INT	0.1
Phosphate (mg/L)		1.0 U	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨
Sulfate (mg/L)		690	4400	3200	3200	2900	2600	3800	3900	1600	2300	1700	860	1000	240	120	60	4100	6300	3900	2700	240	3100	3700	2700	230
Field Measurements:																										
Conductivity (µS/cm)		1250	9160	8000	7360	7400	7360	8520	8980	5540	6060	5600	2680	3040	860	420	151	3300	4050	3240	2870	313	3520	3860	3560	593
pH		2.9	3.07	2.93	2.47	4.22	2.55	3.63	3.17	3.85	2.82	2.92	3.07	3.66	4.48	3.92	5.29	3.11	3.16	3.12	3.18	3.95	2.86	2.73	3.05	3.32
Temperature (°C)		11	10	15	11.5	10	9.5	11	5	6.5	6.5	8	5	11	10.5	6	13	11	8	8	8	3	7	7	7	7

Data Notes:

J - Estimated value.
U - Parameter was analyzed for, but not detected above the reporting limit shown.
UJ - Parameter was analyzed for, but not detected. Detection limit is an estimated value.
INT - Interference; result not available due to matrix interferences.
* *indicates that highest value from range of replicated samples were represented.*
▨ Grey shading indicates the concentration of analyte was not established, therefore not reported nor analyzed.

TABLE 5.4-4
HISTORICAL SUMMARY OF SEEPAGE WATER RESULTS (1991-1996)
HOLDEN MINE RI/FS
DAMES & MOORE JOB NO. 17693-005-019

Parameters	Location	TAILINGS PILE (TP-1) AREA							TAILINGS PILE (TP-2) AREA																		
	Sample ID	710	711	712	713	714	715	716	511	541	542	543	614	615	616	617	ECOLOGY TP#2	717	718	719	720	721	723	724	725	726	728
	Sampling Date	9/96^{d}	9/96^{d}	9/96^{d}	9/96^{d}	9/96^{d}	9/96^{d}	9/96^{d}	7/95^{b}	7/95^{b}	7/95^{b}	7/95^{b}	5/96^{c}	5/96^{c}	5/96^{c}	5/96^{c}	9/10/96^{e}	9/96^{d}	9/96^{d}	9/96^{d}	9/96^{d}	9/96^{d}	9/96^{d}	9/96^{d}	9/96^{d}	9/96^{d}	9/96^{d}
Total Metals (µg/L)																											
Aluminum		54000	36000	95000	23000	20000	64000	570	▨	▨	▨	▨	▨	▨	▨	▨	22600	59000	19000	14000	62000	19000	86000	18000	13000	10000	53000
Arsenic		▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨
Barium		5.1	9.7	5	9.5	5 U	36	6.7	▨	▨	▨	▨	▨	▨	▨	▨	▨	26	5.9	6.4	18	28	10	30	36	42	44
Beryllium		10 U	10 U	10 U	10 U	10 U	10 U	10 U	▨	▨	▨	▨	▨	▨	▨	▨	▨	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U
Cadmium		44	22	17	18	36	36	10 U	▨	▨	▨	▨	▨	▨	▨	▨	4	11	10 U	10 U	13	10 U	14	10 U	10 U	10 U	22
Calcium		300000	260000	250000	340000	330000	410000	15000	▨	▨	▨	▨	▨	▨	▨	▨	▨	360000	410000	340000	360000	320000	300000	300000	310000	370000	300000
Chromium		10 U	10 U	10 U	10 U	10 U	10 U	10 U	▨	▨	▨	▨	▨	▨	▨	▨	▨	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U
Copper		10 U	10 U	160	10 U	10 U	220	10 U	▨	▨	▨	▨	▨	▨	▨	▨	209	1300	120	58	640	95	140	280	190	160	180
Iron		1700000	1600000	1300000	1500000	1600000	1600000	44000	▨	▨	▨	▨	▨	▨	▨	▨	279000	320000	440000	230000	740000	310000	750000	210000	210000	260000	870000
Lead		57	76	50 U	50 U	68	50	50 U	▨	▨	▨	▨	▨	▨	▨	▨	20 U	50 U	50 U	50 U	50 U	50 U	50 U	50 U	50 U	50 U	50 U
Magnesium		200000	170000	150000	220000	220000	240000	4900	▨	▨	▨	▨	▨	▨	▨	▨	▨	110000	130000	110000	140000	100000	140000	78000	79000	94000	110000
Manganese		13000	11000	10000	15000	16000	16000	240	▨	▨	▨	▨	▨	▨	▨	▨	5030	4900	6700	5200	8000	4900	8800	5200	5200	5200	8000
Mercury		▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨
Molybdenum		20 U	20 U	20 U	20 U	20 U	20 U	20 U	▨	▨	▨	▨	▨	▨	▨	▨	▨	20 U	20 U	20 U	20 U	20 U	20 U	20 U	20 U	20 U	20 U
Nickel		10 U	10 U	10 U	10 U	10 U	45	10 U	▨	▨	▨	▨	▨	▨	▨	▨	▨	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U
Potassium		15000	16000	9500	20000	19000	30000	1200	▨	▨	▨	▨	▨	▨	▨	▨	▨	24000	28000	27000	32000	29000	31000	28000	29000	25000	32000
Selenium		▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	93	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨
Silver		▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨
Sodium		27000	23000	23000	21000	22000	31000	1300	▨	▨	▨	▨	▨	▨	▨	▨	▨	16000	16000	14000	20000	15000	19000	12000	12000	14000	18000
Thallium		▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨
Uranium		▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨
Zinc		7700	5000	8100	5700	6900	7900	300	▨	▨	▨	▨	▨	▨	▨	▨	1150	3400	1200	470	2100	730	7700	940	690	1200	3900
Dissolved Metals (µg/L)																											
Aluminum		54,000	36,000	96,000	23,000	20,000	110,000	53	8400	540	6500	2100	98	25000	18000	7700	▨	56000	19000	13000	59000	19000	88000	17000	12000	10000	51000
Arsenic		▨	▨	▨	▨	▨	▨	▨	1 U	1 U	1 U	1 U	4 U	4 U	4 U	4 U	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨
Barium		5.4	11	5 U	8.9	5 U	16	5.8	3.5	24	23	26	200	9.9	12	23	▨	19	5 U	5	7.1	20	11	28	32	48	41
Beryllium		10 U	10 U	10 U	10 U	10 U	10 U	10 U	0.3 U	0.3 U	0.3 U	0.3 U	0.4 U	0.6	0.4	0.4 U	▨	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U
Cadmium		50	26	21	23	34	43	10 U	5.9	2	7.4	4.1	0.8	8.9	16	10 U	▨	11	10 U	10 U	14	10 U	18	10 U	10 U	10 U	24
Calcium		300,000	260,000	250,000	340,000	340,000	470,000	16,000	130000	24000	120000	47000	2700	130000	120000	90000	▨	380000	410000	350000	380000	330000	300000	310000	320000	300000	300000
Chromium		10 U	10 U	10 U	10 U	10 U	10 U	10 U	0.9 U	0.9 U	0.9 U	0.9 U	0.5 U	2.6	0.8	0.5 U	▨	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U
Copper		10 U	10 U	180	10 U	10 U	450	10 U	200	46	310	130	34	1100	740	20	▨	1300	120	57	630	73	110	280	200	150	160
Iron		1600000	1500000	1300000	1400000	1600000	1500000	44000	270000	1900	10000	5400	49	170000	140000	59000	▨	290000	430000	230000	740000	290000	800000	210000	210000	210000	880000
Lead		73	50 U	50 U	50 U	50 U	56	50 U	0.3 U	0.3	2.7	1	0.2	0.65	1.2	0.5	▨	50 U	50 U	50 U	50 U	50 U	50 U	50 U	50 U	50 U	50 U
Magnesium		180000	150000	140000	200000	210000	270000	4700	27000	4200	24000	9600	1000 U	44000	28000	18000	▨	100000	130000	100000	140000	92000	130000	74000	74000	73000	100000
Manganese		13,000	11,000	9,800	15,000	16,000	19,000	200	2100	180	1000	410	80	2500	2000	940	▨	5000	6700	5200	8000	5000	9000	5200	5200	5200	7900
Mercury		▨	▨	▨	▨	▨	▨	▨	▨	▨	0.1 U	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨
Molybdenum		20 U	20 U	20 U	20 U	20 U	20 U	20 U	0.1 U	0.1 U	0.1 U	0.1 U	0.4 U	0.4 U	0.4 U	0.4 U	▨	20 U	20 U	20 U	20 U	20 U	20 U	20 U	20 U	20 U	20 U
Nickel		0.01 U	0.01 U	0.01 U	10	11	54	0.01 U	11	2.4	14	7.5	2	12	9.8	4.8	▨	10	0.01 U	0.01 U	0.01 U	0.01 U	0.01 U	0.01 U	0.01 U	0.01 U	0.01 U
Potassium		14000	15000	9200	19000	18000	26000	1200	▨	▨	▨	▨	1100	14000	12000	5000	▨	23000	28000	27000	28000	27000	32000	28000	27000	28000	32000
Selenium		▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨
Silver		▨	▨	▨	▨	▨	▨	▨	0.1 U	0.1 U	0.1 U	0.1 U	0.2 U	0.2 U	0.2 U	0.2 U	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨
Sodium		28000	24000	24000	22000	23000	37000	1700	6700	2000	6500	3000	1000 U	7700	6500	7900	▨	16000	18000	16000	19000	14000	21000	13000	12000	13000	18000
Thallium		▨	▨	▨	▨	▨	▨	▨	0.6 U	0.6 U	0.6 U	0.6 U	4 U	4 U	4 U	4 U	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨
Uranium		▨	▨	▨	▨	▨	▨	▨	3.2	0.2	1.9	0.5	0.4 U	2.6	3.6	0.5	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨
Zinc		7800	5000	8300	6000	7300	8700	330	1000	120	800	500	77	1300	3000	400	▨	3700	1300	510	2400	760	8000	950	780	960	4100
Conventional Analyses:																											
Chloride (mg/L)		▨	▨	▨	▨	▨	▨	▨	INT	0.5	1	0.6	0.3	0.9	0.4	0.5	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨
Fluoride (mg/L)		▨	▨	▨	▨	▨	▨	▨	1	INT	1	0.2	0.1 U	0.1 U	0.4	0.7	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨
NO_2 & NO_3 (mg/L)		▨	▨	▨	▨	▨	▨	▨	0.2 U	0.2 U	0.2 U	0.2 U	0.1	0.1 U	0.1 U	0.1	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨
Phosphate (mg/L)		▨	▨	▨	▨	▨	▨	▨					▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨
Sulfate (mg/L)		▨	▨	▨	▨	▨	▨	▨	1400	97	570	250	11	2000	1500	840	2250	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨
Field Measurements:																											
Conductivity (µS/cm)		▨	▨	▨	▨	▨	▨	▨	4420	300	1860	1020	36	2480	2070	1207	2905	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨
pH		▨	▨	▨	▨	▨	▨	▨	2.87	4.13	2.98	3.39	4.74	3.28	3.45	4.24	3.1	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨
Temperature (°C)		▨	▨	▨	▨	▨	▨	▨	15	18	22.5	22.5	16	5	8	7	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨

Data Notes:

J - Estimated value.

U - Parameter was analyzed for, but not detected above the reporting limit shown.

UJ - Parameter was analyzed for, but not detected. Detection limit is an estimated value.

INT - Interference; result not available due to matrix interferences.

* indicates that highest value from range of replicated samples were represented.

▨ Grey shading indicates the concentration of analyte was not established, therefore not reported nor analyzed.

TABLE 5.4-4
HISTORICAL SUMMARY OF SEEPAGE WATER RESULTS (1991-1996)
HOLDEN MINE RI/FS
DAMES & MOORE JOB NO. 17693-005-019

Parameters	Location	TAILINGS PILE (TP-3) AREA											MILL AREA								
	Sample ID	350	506	508	509	539	607	608	609	610	611	ECOLOGY TP#3	549 A	549 B	643	646	647	649	651	652	653
	Sampling Date	7/94^{a}	7/95^{b}	7/95^{b}	7/95^{b}	7/95^{b}	5/96^{c}	5/96^{c}	5/96^{c}	5/96^{c}	5/96^{c}	6/12/96^{e}	7/95^{b}	7/95^{b}	5/96^{c}	5/96^{c}	5/96^{c}	5/96^{c}	5/96^{c}	5/96^{c}	5/96^{c}
Total Metals (µg/L)																					
Aluminum		▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	25700	▨	▨	▨	▨	▨	▨	▨	▨	▨
Arsenic		▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	0.35	▨	▨	▨	▨	▨	▨	▨	▨	▨
Barium		▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨
Beryllium		▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨
Cadmium		▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	5.5	▨	▨	▨	▨	▨	▨	▨	▨	▨
Calcium		▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨
Chromium		▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨
Copper		▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	191	▨	▨	▨	▨	▨	▨	▨	▨	▨
Iron		▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	39900	▨	▨	▨	▨	▨	▨	▨	▨	▨
Lead		▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	2	▨	▨	▨	▨	▨	▨	▨	▨	▨
Magnesium		▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨
Manganese		▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	2140	▨	▨	▨	▨	▨	▨	▨	▨	▨
Mercury		▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	0.015	▨	▨	▨	▨	▨	▨	▨	▨	▨
Molybdenum		▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨
Nickel		▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	36	▨	▨	▨	▨	▨	▨	▨	▨	▨
Potassium		▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨
Selenium		▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨
Silver		▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	0.1 U	▨	▨	▨	▨	▨	▨	▨	▨	▨
Sodium		▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨
Thallium		▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨
Uranium		▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨
Zinc		▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	522	▨	▨	▨	▨	▨	▨	▨	▨	▨
Dissolved Metals (µg/L)																					
Aluminum		1500	> 10,000	9000	5300	40	27000	27000	15000	23000	18000	▨	> 10,000	> 10,000	280000	260000	760000	2800	32	620000	560000
Arsenic		2 U	1 U	1 U	1 U	1 U	4 U	4 U	4 U	4 U	4 U	▨	1	1	4 U	4 U	4 U	4 U	4 U	4 U	5
Barium		58	12	8.8	12	14	54	0.6 U	10	12	16	▨	6.4	2.8	4.8	5.6	6.9	12	10	14	10
Beryllium		1 U	0.4	0.3	0.3 U	0.3 U	0.4 U	0.4 U	0.9	0.6	0.8	▨	2.6	3.2	5.1	4.2	7.2	0.4 U	0.4 U	5.9	4.6
Cadmium		1 U	15	4.9	2	1 U	3.5	0.7 U	11	9.8	4.6	▨	1500	2300	2300	980	3000	79	22	1100	1000
Calcium		62000	110000	66000	40000	3600	79000	83000	49000	98000	95000	▨	160000	130000	270000	300000	400000	22000	6900	300000	320000
Chromium		1 U	0.9 U	0.9 U	0.9 U	0.9 U	0.5 U	0.5 U	0.6	0.5 U	0.6	▨	31	120	34	21	100	0.5 U	0.5 U	130	61
Copper		21	890	310	350	9.4	730	2 U	1100	730	300	▨	> 40,000	> 40,000	270000	240000	650000	9200	540	560000	540000
Iron		23000	100000	52000	6000	400	2800	3100	16000	42000	81000	▨	44000	> 500,000	25000	77000	290000	770	50 U	340000	260000
Lead		1.4	0.6	0.3	0.9	0.3 U	3	0.4	0.6	0.68	1.1	▨	26	23	5.3	5.1	7.4	6.5	1	54	19
Magnesium		8900	15000	13000	7000	390	23000	12000	11000	16000	19000	▨	> 100,000	> 100,000	140000	150000	510000	7900	2300	370000	340000
Manganese		140	1800	590	300	6.8	1200	3 U	1700	1900	2000	▨	> 6,000	> 6,000	8300	13000	33000	290	56	14000	13000
Mercury		▨	0.1	0.1 U	0.1 U	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨
Molybdenum		0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4	▨	0.1 U	0.1 U	0.4 U	0.4 U	0.4	0.4 U	0.4 U	0.4	0.6
Nickel		4	27	9.7	6.9	0.5	16	1 U	48	34	21	▨	150	180	260	220	720	11	2	190	190
Potassium		2000 U	▨	▨	▨	▨	6600	3500	4200	4700	7200	▨	▨	▨	490	700	500 U	1300	660	770	690
Selenium		▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨
Silver		0.1 U	0.1	0.1 U	0.1 U	0.1 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	▨	1.5	5.7	2.8	0.74	2.7	0.2 U	0.2 U	2.4	2.4
Sodium		2900	4300	3700	2700	600	7700	5600	4800	6200	6300	▨	6000	9200	12000	7800	16000	3000	1400	16000	15000
Thallium		0.3	0.6 U	0.6 U	0.6 U	0.6 U	4 U	4 U	4 U	4 U	4 U	▨	0.6	0.6	4 U	4 U	4 U	4 U	4 U	4 U	4 U
Uranium		0.4	1.3	1.1	0.7	0.1 U	1.6	0.4 U	2.8	1.6	1.4	▨	210	600	110	70	250	0.8	0.4 U	110	96
Zinc		130	1200	730	160	30	360	0.8 U	360	660	330	▨	81000	140000	160000	92000	610000	9200	3200	110000	86000
Conventional Analyses:																					
Chloride (mg/L)		0.65	1.0 U	1 U	0.4	0.9	0.6	0.6	0.5	0.5	0.3	▨	INT	INT	0.1 U	0.1 U	0.1 U	0.8	0.7	INT	INT
Fluoride (mg/L)		0.05 U	1	1	0.4	0.1	0.9	0.9	0.8	1.2	1	▨	7	60	6.6	6.6	0.1 U	2.6	2.2	INT	INT
NO_2 & NO_3 (mg/L)		0.1 U	0.2 U	0.2 U	0.2 U	1.5	0.1 U	0.4	0.1 U	0.1	0.1	0.01 U	0.2 U	0.2 U	0.1 U	0.1 U	0.1 U	0.3	0.2	INT	INT
Phosphate (mg/L)		1.0 U					▨	▨	▨	▨	▨	0.01 U			▨	▨	▨	▨	▨	▨	▨
Sulfate (mg/L)		456	730	520	260	6	710	620	470	1100	1200	548	12000	39700	4500	3800	8500	180	35	7700	6000
Field Measurements:																					
Conductivity (µS/cm)		1110	2100	2320	740	100	947	837	841	1298	1559	1080	16000	37500	4350	4040	6850	342	91	6380	5620
pH		2.82	3.29	3.63	3.74	5.67	3.01	3.3	2.9	3.23	2.92	3.7	3.12	2.79	3.25	3.42	4.06	4.71	5.8	3.41	4.24
Temperature (°C)		19	5	5	7	5.5	18	7	9.5	9.5	10	9.5	16	18	3	3	3	4	7	2	3

Data Notes:

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* indicates that highest value from range of replicated samples were represented.

▨ Grey shading indicates the concentration of analyte was not established, therefore not reported nor analyzed.

TABLE 5.4-4
HISTORICAL SUMMARY OF SEEPAGE WATER RESULTS (1991-1996)
HOLDEN MINE RI/FS
DAMES & MOORE JOB NO. 17693-005-019

Parameters	Location	MINE INFLUENCED AREA														NON-MINE INFLUENCED AREAS	
	Sample ID	547	548	622	624	631	632	633	634	637	638	639	640	650	658	515	507
	Sampling Date	7/95^b	7/95^b	5/96^c	5/96^c	5/96^c	5/96^c	5/96^c	5/96^c	5/96^c	5/96^c	5/96^c	5/96^c	5/96^c	5/96^c	7/95^b	7/95^b
Total Metals (µg/L)																	
Aluminum		▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨
Arsenic		▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨
Barium		▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨
Beryllium		▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨
Cadmium		▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨
Calcium		▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨
Chromium		▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨
Copper		▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨
Iron		▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨
Lead		▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨
Magnesium		▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨
Manganese		▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨
Mercury		▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨
Molybdenum		▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨
Nickel		▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨
Potassium		▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨
Selenium		▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨
Silver		▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨
Sodium		▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨
Thallium		▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨
Uranium		▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨
Zinc		▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨
Dissolved Metals (µg/L)																	
Aluminum		1200	2200	9800	620	24000	34000	65000	4000	160	3100	3400	2600	5000	10000	▨	1300
Arsenic		1 U	1	4 U	4 U	4 U	4 U	4 U	4 U	4 U	4 U	4 U	4 U	4 U	4 U	▨	1 U
Barium		22	11	15	12	4.8	4.9	2	15	25	17	16	16	14	20	▨	47
Beryllium		0.3 U	0.3 U	0.6	0.4 U	0.8	0.8	1.4	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	▨	0.3 U
Cadmium		24	62	110	22	5.6	12	5.5	33	9.2	66	68	71	78	22	▨	2
Calcium		41000	78000	67000	15000	110000	140000	130000	31000	23000	49000	52000	36000	77000	9500	▨	13000
Chromium		0.9 U	0.9 U	0.5 U	0.5 U	3.7	3.7	6.8	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	2.5	▨	0.9 U
Copper		2300	3000	8500	1700	320	310	570	1900	410	4600	4900	5000	6000	800	▨	48
Iron		190	20 U	51	50 U	800000	1200000	600000	160	50 U	110	110	180	50 U	15000	▨	100
Lead		7.9	0.6	12	2.1	0.79	0.4	0.6	0.3	0.2 U	5.8	7.2	7.8	0.6	36	▨	0.4
Magnesium		4400	9600	7200	1600	74000	130000	78000	4600	2800	7700	8200	7300	12000	2100	▨	1700
Manganese		50	320	570	110	5100	8800	5000	200	19	320	330	280	580	130	▨	370
Mercury		▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨
Molybdenum		0.1 U	0.1 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	▨	0.1 U
Nickel		10	78	48	11	8.4	15	16	12	3	41	44	17	140	5.6	▨	9.8
Potassium		▨	▨	4700	1500	10000	12000	1300	2100	1900	4000	4300	3300	6400	4300	▨	▨
Selenium		▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨
Silver		0.1 U	0.1 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	▨	0.1 U
Sodium		5500	5800	4800	1500	12000	16000	14000	3400	4600	5100	4300	3500	5900	1900	▨	1000
Thallium		0.6 U	0.6 U	4 U	4 U	4 U	4 U	4 U	4 U	4 U	4 U	4 U	4 U	4 U	4 U	▨	0.6 U
Uranium		0.4	0.7	5.1	0.6	3.2	2.6	4.3	0.4 U	0.4 U	0.4 U	0.4	0.4	0.9	4.8	▨	0.2
Zinc		2700	6500	14000	2800	1200	2400	2400	4300	1500	7500	7800	7800	8900	1400	▨	170
Conventional Analyses:																	
Chloride (mg/L)		1.7	1.7	0.3	0.5	0.1 U	0.1 U	0.1 U	0.5	1	0.5	0.5	0.9	0.5	0.8	INT	0.2
Fluoride (mg/L)		INT	0.7	0.9	0.2	0.1 U	0.1 U	0.1 U	0.3	0.2	0.4	0.5	0.6	1	0.7	6	INT
NO_2 & NO_3 (mg/L)		0.2 U	0.2 U	0.1	0.2	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.2	0.2	0.1	0.9	0.1 U	0.2 U	0.2 U
Phosphate (mg/L)				▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨
Sulfate (mg/L)		190	340	380	59	4000	5500	3900	200	83	250	250	200	INT	200	4400	60
Field Measurements:																	
Conductivity (µS/cm)		540	960	576	147	3350	3970	3520	343	203	430	441	390	662	740	9160	260
pH		4.45	4.55	4.41	5.2	3.49	3.44	2.84	4.24	5.73	5.05	5.08	5.15	4.75	2.89	3.07	4.65
Temperature (°C)		14	3	8	11	5	5	5	2	4	5	5	4	3	6	10	3.5

Data Notes:

J - Estimated value.

U - Parameter was analyzed for, but not detected above the reporting limit shown.

UJ - Parameter was analyzed for, but not detected. Detection limit is an estimated value.

INT - Interference; result not available due to matrix interferences.

* indicates that highest value from range of replicated samples were represented.

▨ Grey shading indicates the concentration of analyte was not established, therefore not reported nor analyzed.

Data Source:

(a) Kilburn, et al. 1994. *Geochemical data and sample locality maps for stream-sediment, heavy-mineral-concentrate, mill tailing, water, and precipitate samples collected in and around the Holden mine, Chelan County, Washington.* USGS Open File Report 94-680A Paper Version, 94-680B Diskette version (Data Collected in 1994)

(b) Kilburn, J.E. & S.J. Sutley. 1996. *Characterization of acid mine drainage at the Holden mine, Chelan, Washington.* USGS Open File Report 96-531. (Data collected in 1995).

(c) Kilburn, J.E. & S.J. Sutley. 1997. *Analytical results and comparative overview of geochemical studies conducted at the Holden Mine*, spring 1996 USGS Open File Report 97-128 (Data collected in Spring 1996).

(d) Kilburn, J.E. & S.J. Sutley. 1997. Preliminary data (no report attached, data collected in Fall 1996).

(e) Johnson, A., et al. 1997. *Effects of Holden Mine on the Water, Sediments and Benthic Invertebrates of Railroad Creek (Lake Chelan).*

TABLE 5.4-5
SUMMARY OF INTERSTITAL PORE WATER DATA
(FROM RAILROAD CREEK STREAMBED GRAVEL)
HOLDEN MINE RI/FS
DAMES & MOORE JOB NO. 17693-005-019

Parameters / Sample Location	RC-SITE W		RC-SITE E				
Sample ID	BKG	TP1-2	TP2-1	TP2-2	TP3-1	TP3-2	DG*
Sampling Date	4/1/94[a]	4/1/94[a]	4/1/94[a]	4/1/94[a]	4/1/94[a]	4/1/94[a]	4/1/94[a]
Dissolved Metals (µg/L)							
Aluminum	< DL	1500	17000	< DL	< DL	50	40
Barium	10	10	10	< DL	10	10	61000
Cadmium	< DL	10	< DL	< DL	< DL	< DL	< DL
Calcium	14000	20000	34000	7700	7800	7800	56000
Copper	< DL	10	250	< DL	10	< DL	< DL
Iron	20	95000	18000	1400	800	1200	22000
Lead	70	130	40	70	70	20	40
Magnesium	1600	11000	9700	980	900	880	5300
Manganese	< DL	630	650	20	40	20	< DL
Potassium	610	2500	1400	670	630	760	14000
Silicon	5300	5600	12000	4000	4200	4300	1400
Sodium	1200	1900	2000	920	960	1000	11000
Sulfur	3300	82000	78000	8200	3400	3500	120
Zinc	20	300	2300	60	50	40	6000
Conventional Analyses, (mg/L):							
Chloride	0.4	1	0.5 U	0.5 U	0.6	ND	ND
Sulfate (SO_4)^{*3}	8	240	240	24	9.3	ND	ND
Field Measurements							
pH (s.u.)	7.3	3.4	4	4.3	6.5	6.3	6.2
Specific Conductivity (µs)	28	1400	360	580	44	ND	ND
Redox (mV)	210	320	220	250	120	140	ND

Data Notes:

U - Parameter was analyzed for, but not detected above the reporting limit shown.
ND - Not Determined
< DL - Less Than Detection Limit (Variable Value)
* Questionable Analyses

Data Source:

(a) Lambeth, Robert H. 1994 Compilation of Data for Sampling Analysis of Interstital Pore Water at Railroad Creek Steambed Gravels.

TABLE 5.4-6
HISTORICAL SUMMARY OF MILL BUILDING DRIP SAMPLES (1995-1996)
HOLDEN MINE RI/FS
DAMES & MOORE JOB NO. 17693-005-019

Parameters / Location	MILL BUILDING AREA								
Sample ID	549A	549B	643	646	647	649	651	652	653
Sampling Date	7/95[a]	7/95[a]	5/96[b]	5/96[b]	5/96[b]	5/96[b]	5/96[b]	5/96[b]	5/96[b]
Total Metals (µg/L)									
Aluminum	▨	▨	▨	▨	▨	▨	▨	▨	▨
Arsenic	▨	▨	▨	▨	▨	▨	▨	▨	▨
Barium	▨	▨	▨	▨	▨	▨	▨	▨	▨
Beryllium	▨	▨	▨	▨	▨	▨	▨	▨	▨
Cadmium	▨	▨	▨	▨	▨	▨	▨	▨	▨
Calcium	▨	▨	▨	▨	▨	▨	▨	▨	▨
Chromium	▨	▨	▨	▨	▨	▨	▨	▨	▨
Copper	▨	▨	▨	▨	▨	▨	▨	▨	▨
Iron	▨	▨	▨	▨	▨	▨	▨	▨	▨
Lead	▨	▨	▨	▨	▨	▨	▨	▨	▨
Magnesium	▨	▨	▨	▨	▨	▨	▨	▨	▨
Manganese	▨	▨	▨	▨	▨	▨	▨	▨	▨
Mercury	▨	▨	▨	▨	▨	▨	▨	▨	▨
Molybdenum	▨	▨	▨	▨	▨	▨	▨	▨	▨
Nickel	▨	▨	▨	▨	▨	▨	▨	▨	▨
Potassium	▨	▨	▨	▨	▨	▨	▨	▨	▨
Selenium	▨	▨	▨	▨	▨	▨	▨	▨	▨
Silver	▨	▨	▨	▨	▨	▨	▨	▨	▨
Sodium	▨	▨	▨	▨	▨	▨	▨	▨	▨
Thallium	▨	▨	▨	▨	▨	▨	▨	▨	▨
Uranium	▨	▨	▨	▨	▨	▨	▨	▨	▨
Zinc	▨	▨	▨	▨	▨	▨	▨	▨	▨
Dissolved Metals (µg/L)									
Aluminum	>10,000	> 10,000	280,000	260,000	760,000	2,800	32	620,000	560,000
Arsenic	1	1	4 U	4 U	4 U	4 U	4 U	4 U	5
Barium	6.4	2.8	4.8	5.6	6.9	12	10	14	10
Beryllium	2.6	3.2	5.1	4.2	7.2	0.4 U	0.4 U	5.9	4.6
Cadmium	1,500	2,300	2,300	980	3,000	79	22	1,100	1,000
Calcium	160,000	130,000	270,000	300,000	400,000	22,000	6,900	300,000	320,000
Chromium	31	120	34	21	100	0.5 U	0.5 U	130	61
Copper	>40,000	>40,000	270,000	240,000	650,000	9,200	450	560,000	540,000
Iron	440,000	> 500,000	25,000	77,000	290,000	770	50 U	340,000	260,000
Lead	26	23	5.3	5.1	7.4	6.5	1	54	19
Magnesium	>100,000	>100,000	140,000	150,000	510,000	7,900	2,300	370,000	340,000
Manganese	>6,000	>6,000	8,300	13,000	33,000	290	56	14,000	13,000
Mercury	▨	▨	▨	▨	▨	▨	▨	▨	▨
Molybdenum	0.1 U	0.1 U	0.4 U	0.4 U	0.4	0.4 U	0.4 U	0.4	0.6
Nickel	150	180	260	220	720	11	2	190	190
Potassium	▨	▨	490	700	500 U	1300	660	770	690
Selenium	▨	▨	▨	▨	▨	▨	▨	▨	▨
Silver	1.5	5.7	2.8	0.74	2.7	0.2 U	0.2 U	2.4	2.4
Sodium	6,000	9,200	12,000	7,800	16,000	3,000	1,400	16,000	15,000
Thallium	0.6	0.6	4 U	4 U	4 U	4 U	4 U	4 U	4 U
Uranium	210	600	110	70	250	0.8	0.4 U	110	96
Zinc	81,000	140,000	350,000	190,000	610,000	9,200	3,200	290,000	230,000

Data Notes:
▨ Grey shading indicates the constituent was not analyzed.

Data Source:
(a) Kilburn, J.E. & S.J. Sutley. 1996. *Characterization of acid mine drainage at the Holden mine, Chelan, Washington*. USGS Open File Report 96-531. (Data collected in 1995).
(b) Kilburn, J.E. & S.J. Sutley. 1997. *Analytical results and comparative overview of geochemical studies conducted at the Holden Mine*, spring 1996. USGS Open File Report 97-128 (Data collected in Spring 1996).

TABLE 5.4-7
POTENTIAL COMPOUNDS OF CONCERN (PCOC) FOR GROUNDWATER
HOLDEN MINE RI/FS
DAMES & MOORE JOB NO. 17693-005-019

Area	Analytes Above MTCA-A/ MTCA-B or WAC 173-200	Analytes Above Federal MCLs	PCOC's	Samples Containing PCOC's
Honeymoon Heights	Cadmium, Copper, Iron, Zinc, pH	Not Applicable	Cadmium, Copper, Iron, Zinc, pH	SP-14 Upper (pH only), SP-14, SP-14 Lower, SP-23 UP, SP-23 Vent Rd, SP-23, SP-23B, SP-12, A-1
West Waste Rock Pile	Arsenic, Beryllium, Cadmium, Copper, Manganese, Zinc, TDS, pH, SO_4	Not Applicable	Arsenic, Beryllium, Cadmium, Copper, Manganese, Zinc, TDS, pH, SO_4	SP-6, SP-15E, SP-15W, SP-16, SP-9, SP11
East Waste Rock Pile	Cadmium, Copper, Iron, Zinc, pH	Not Applicable	Cadmium, Copper, Iron, Zinc, pH	SP-8, SP-19, SP-10W, SP-10E
Maintenance Yard	Cadmium, Copper, Zinc, pH	Not Applicable	Cadmium, Copper, Zinc, pH	HBKG-1
	Cadmium, Copper, Iron, Zinc, TDS, SO_4, pH	Not Applicable	Cadmium, Copper, Iron, Zinc, TDS, SO_4, pH	SP-7, SP-22, SP-24, SP-25
Tailings Pile 1	Beryllium, Cadmium, Copper, Iron, Manganese, Zinc, TDS, SO_4, pH	Not Applicable	Beryllium, Cadmium, Copper, Iron, Manganese, Zinc, TDS, SO_4, pH	TP1-1A, TP1-2A, TP1-3A, TP1-4A, TP1-5A, TP1-6A
	Arsenic, Beryllium, Cadmium, Copper, Iron, Manganese, Zinc, TDS, SO_4, pH, color	Not Applicable	Arsenic, Beryllium, Cadmium, Copper, Iron, Manganese, Zinc, TDS, SO_4, pH, color	SP-1, SP-2
Tailings Pile 2	Arsenic, Cadmium, Iron, Manganese, pH, TDS, SO_4, color	Not Applicable	Arsenic, Cadmium, Iron, Manganese, pH, TDS, SO_4, color	PZ-1A, PZ-1B, PZ-3A, TP2-4A,TP2-5A, TP2-8A, TP2-11A
	Arsenic, Beryllium, Cadmium, Copper, Iron, Manganese, TDS, SO_4, pH	Not Applicable	Arsenic, Beryllium, Cadmium, Copper, Iron, Manganese, TDS, SO_4, pH	SP-3, SP-4
Tailings Pile 3	Beryllium, Iron, Lead, Manganese, TDS, SO_4, pH	Not Applicable	Beryllium, Iron, Lead, Manganese, TDS, SO_4, pH	TP3-4, TP3-6A, TP3-8, TP3-9, TP3-10A, PZ-6A
East of Tailings Pile 3	Beryllium, Iron, Manganese, TDS, SO_4, pH	Not Applicable	Beryllium, Iron, Manganese, TDS, SO_4, pH	DS-1, DS-2
	Beryllium, Cadmium, Copper, Iron, Manganese, TDS, SO_4, pH	Not Applicable	Beryllium, Cadmium, Copper, Iron, Manganese, TDS, SO_4, pH	SP-5, SP-17, SP-18
	Cadmium, Copper, Zinc, pH	Not Applicable	Cadmium, Copper, Zinc, pH	SP-21
Lucerne	pH	Iron (secondary MCL)	Iron, pH	Lucerne

<u>Notes:</u>
Samples indicated as containing PCOCs may not contain all of the PCOCs listed or may contain PCOCs dependent upon the season.

TABLE 5.5-1
SUMMARY OF HISTORICAL DATA FOR SEDIMENTS FROM HOLDEN CREEK, AND RAILROAD CREEK
HOLDEN MINE RI/FS
DAMES & MOORE JOB NO. 17693-005-019

Parameters	Location	Holden Creek		Railroad Creek Upstream				
	Sample ID	355		356		367		RC-1
	Sample Date	7/94[a]		7/94[a]		7/94[a]		9/11/96[c]
	Sample Type	Sediment	Concentrate	Sediment	Concentrate	Sediment	Concentrate	Sediment
Total Metals, (mg/kg)								
Aluminum		86000		87000		78000		10400
Arsenic		3.1	500 U	1U	500 U	12	500 U	
Barium		470	300	480	300	340	300	
Beryllium		1	2 U	1	2 U	1	2 U	
Cadmium		0.552	50 U	0.085	50 U	2	50 U	0.3 U
Calcium		37000	70000	37000	150000	37000	70000	
Chromium		79	200	36	300	97	200	
Copper		74	70	12	10 U	37	70	29
Iron		63000	50000	47000	20000	99000	30000	15700
Lead		17	50	7	20	11	20 U	4.9
Magnesium		24000	20000	20000	50000	22000	15000	
Manganese		1300	1000	980	1000	1600	700	271
Mercury								
Molybdenum		0.076	10 U	0.58	10 U	1.3	10 U	
Nickel		31	50	20	50	28	30	
Potassium		8800		12000		7300		
Selenium								0.3 U
Silver		0.067	1 U	0.067U	1 U	0.067U	1 U	
Sodium		23000	5000	29000	5000 U	24000	5000	
Thallium								
Uranium		100 U		100 U		100 U		
Zinc		180	1500	110	500 U	130	1000	62

Parameters	Location	Railroad Creek Near Tailing Stockpiles												
	Sample ID	345		347		350		BKG 1/2	DG-1	TP1-2	TP2-1	TP2-2	TP3-1	RC-2
	Sample Date	7/94[a]		7/94[a]		7/94[a]		3/23/94[b]	3/23/94[b]	3/23/94[b]	3/23/94[b]	3/23/94[b]	3/23/94[b]	9/11/96[c]
	Sample Type	Sediment	Concentrate	Sediment	Concentrate	Sediment	Concentrate	Sediment	Sediment	Sediment	Sediment	Sediment	Sediment	Sediment
Total Metals, (mg/kg)														
Aluminum		78000		83000		34000		11300	9380	10800	10400	9330	11700	8540
Arsenic		10	500 U	13	500 U	1U	500 U	11.5	3.8	11.2	7.5	9.2	11.4	
Barium		540	3000	390	1500	220	10000 U	26.3	78.8	30.1	19.3	41.7	39.3	
Beryllium		1	2 U	1	2 U	1 U	2 U	0.08	0.07	0.1	0.11	0.14	0.13	
Cadmium		0.6	50 U	2	50 U	0.05U	50 U	0.93	1.1	1.8	1.2	1.8	1.3	0.3 U
Calcium		29000	70000	39000	70000	10000	15000	4600	2820	3800	3090	2950	3630	
Chromium		70	300	85	200	18	150	16.9	4.4	7.3	7.9	1.3	12.9	
Copper		140	500	240	300	200	2000	76.6	184	9.1	8.5	7.1	11.1	101
Iron		50000	30000	71000	15000	150000	50000	17000	20600	41300	30800	38400	27700	19000
Lead		24	30	14	20	66	50	7.1	4.2	6.5	4.4	5.6	6.3	5.6
Magnesium		20000	15000	24000	10000	8200	15000	6940	5590	6570	6980	5270	8940	
Manganese		860	700	1400	500	380	700	308	242	6.5	4.4	5.6	6.3	217
Mercury								0.02	0.02 U	0.02 U	0.02 U	0.02 U	0.02 U	
Molybdenum		2	70	0.93	10 U	12	700							
Nickel		30	50	29	10 U	2	10 U	15	21.6	16.2	12.5	10.7	25.7	
Potassium		10000		8200		7500		455	888	631	547	718	723	
Selenium								0.95	0.10 U	0.95	0.12	0.14	0.93	0.5
Silver		0.17	1 U	0.067U	1 U	1.2	1 U	0.64	0.73	5.6	0.6	0.72	0.76	
Sodium		24000	5000 U	25000	5000 U	9800	5000 U	345	318	336	312	294	368	
Thallium								0.15	0.14	0.14	0.1	0.13	0.12	
Uranium		100 U		100 U		100 U								
Zinc		280	1500	270	500 U	250	2000	110	126	106	75	118	152	113

Parameters	Location	Railroad Creek Downstream													
	Sample ID	4clc344		4clc346		4clc351		4clc352		4clc353		4cjc354		MP-7	RC-3
	Sample Date	7/94[a]		7/94[a]		7/94[a]		7/94[a]		7/94[a]		7/94[a]		9/11/96[c]	9/11/96[c]
	Sample Type	Sediment	oncentrat	Sediment	Concentrat	Sediment	Concentrate	Sediment	Concentrate	Sediment	Concentrate	Sediment	Concentrate	Sediment	Sediment
Total Metals, (mg/kg)															
Aluminum		83000		59000		89000		75000		88000		76000		13300	7890
Arsenic		1U	500 U	1U	500 U	1U	500 U	3.1	500 U	1U	500 U	3.5	500 U		
Barium		380	300	210	>10000	350	300	410	700	450	300	480	1500		
Beryllium		1	2 U	1U	2 U	1	2 U	1	2 U	1	2 U	1	2 U		
Cadmium		0.16	50 U	4.8	300	0.063	50 U	0.49	50 U	0.05U	50 U	0.63	50 U	0.9	0.5
Calcium		43000	100000	27000	30000	40000	100000	36000	100000	36000	150000	32000	70000		
Chromium		77	200	110	200	44	150	93	500	52	50	74	150		
Copper		23	50	750	5000	26	70	130	700	13	10 U	150	300	147	59
Iron		94000	30000	62000	300000	66000	20000	71000	30000	40000	30000	60000	20000	26300	14800
Lead		7	20 U	66	500	5	20 U	18	20	8	20 U	25	20 U	11	2.4
Magnesium		25000	20000	26000	10000	23000	15000	24000	20000	18000	7000	19000	10000		
Manganese		980	700	830	300	900	500	1200	700	790	700	980	300	289	285
Mercury															
Molybdenum		2U	10 U	14	10	0.43	10 U	1.8	10 U	0.35	10 U	4	20		
Nickel		29	30	51	50	20	10 U	32	30	22	10 U	25	10 U		
Potassium		7400		7400		7500		7600		12000		9200			
Selenium														0.6	0.3 U
Silver		<0.067	1 U	1.2	5	<0.067	1 U	0.11	1 U	0.45	1 U	0.098	1 U		
Sodium		22000	5000	17000	5000 U	24000	7000	22000	5000	28000	10000	23000	5000 U		
Thallium															
Uranium		100 U		100 U		100 U		100 U		100 U		100 U			
Zinc		120	500 U	1100	10000	110	500 U	230	1000	82	500 U	330	1500	216	144

Data Notes:

U - Parameter was analyzed for, but not detected above the reporting limit shown.

▨ Grey shading indicates the concentration of analyte was not established, therefore not reported and analyzed.

Data Source:

(a) Kilburn, et al. 1994. *Geochemical data and sample locality maps for stream-sediment, heavy-mineral-concentrate, mill tailing, water, and precipitate samples collected in and around the Holden mine, Chelan County, Washington.* USGS Open File Report 94-680A Paper Version, 94-680B Diskette version (Data Collected in 1994).
(b) Lambeth, R.H. 1995. Transmittal of laboratory data from samples collected at Holden Mine site by the US Bureau of Mines. (Data collected in 1994).
(c) Johnson, A., et al. 1997. *Effects of Holden Mine on the Water, Sediments and Benthic Invertebrates of Railroad Creek (Lake Chelan).*
Environmental Investigations and Laboratory Services Program. Water Body No. WA-47-1020. Publication No. 97-330 (data collected in Spring and Fall 1996).

TABLE 5.5-1
SUMMARY OF HISTORICAL DATA FOR SEDIMENTS FROM HOLDEN CREEK, AND RAILROAD CREEK
HOLDEN MINE RI/FS
DAMES & MOORE JOB NO. 17693-005-019

Parameters	Location	Holden Creek		Railroad Creek Upstream					Railroad Creek Near Tailing Stockpiles													Railroad Creek Downstream													
	Sample ID	355		356		367		RC-1	345		347		350		BKG 1/2	DG-1	TP1-2	TP2-1	TP2-2	TP3-1	RC-2	4cic344		4cic346		4cic351		4cic352		4cic353		4cjc354		MP-7	RC-3
	Sample Date	7/94[a]		7/94[a]		7/94[a]		9/11/96[c]	7/94[a]		7/94[a]		7/94[a]		3/23/94[b]	3/23/94[b]	3/23/94[b]	3/23/94[b]	3/23/94[b]	3/23/94[b]	9/11/96[c]	7/94[a]		7/94[a]		7/94[a]		7/94[a]		7/94[a]		7/94[a]		9/11/96[c]	9/11/96[c]
	Sample Type	Sediment	Concentrate	Sediment	Concentrate	Sediment	Concentrate	Sediment	Sediment	Concentrate	Sediment	Concentrate	Sediment	Concentrate	Sediment	Sediment	Sediment	Sediment	Sediment	Sediment	Sediment	Sediment	oncentrat	Sediment	Concentrat	Sediment	Concentrate	Sediment	Concentrate	Sediment	Concentrate	Sediment	Concentrate	Sediment	Sediment
Total Metals, (mg/kg)																																			
Aluminum		86000		87000		78000		10400	78000		83000		34000		11300	9380	10800	10400	9330	11700	8540	83000		59000		89000		75000		88000		76000		13300	7890
Arsenic		3.1	500 U	1U	500 U	12	500 U		10	500 U	13	500 U	1U	500 U	11.5	3.8	11.2	7.5	9.2	11.4		1U	500 U	1U	500 U	1U	500 U	3.1	500 U	1U	500 U	3.5	500 U		
Barium		470	300	480	300	340	300		540	3000	390	1500	220	10000 U	26.3	78.8	30.1	19.3	41.7	39.3		380	300	210	>10000	350	300	410	700	450	300	480	1500		
Beryllium		1	2 U	1	2 U	1	2 U		1	2 U	1	2 U	1 U	2 U	0.08	0.07	0.1	0.11	0.14	0.13		1	2 U	1U	2 U	1	2 U	1	2 U	1	2 U	1	2 U		
Cadmium		0.552	50 U	0.085	50 U	2	50 U	0.3 U	0.6	50 U	2	50 U	0.05U	50 U	0.93	1.1	1.8	1.2	1.8	1.3	0.3 U	0.16	50 U	4.8	300	0.063	50 U	0.49	50 U	0.05U	50 U	0.63	50 U	0.9	0.5
Calcium		37000	70000	37000	150000	37000	70000		29000	70000	39000	70000	10000	15000	4600	2820	3800	3090	2950	3630		43000	100000	27000	30000	40000	100000	36000	100000	36000	150000	32000	70000		
Chromium		79	200	36	300	97	200		70	300	85	200	18	150	16.9	4.4	7.3	7.9	1.3	12.9		77	200	110	200	44	150	93	500	52	50	74	150		
Copper		74	70	12	10 U	37	70	29	140	500	240	300	200	2000	76.6	184	9.1	8.5	7.1	11.1	101	23	50	750	5000	26	70	130	700	13	10 U	150	300	147	59
Iron		63000	50000	47000	20000	99000	30000	15700	50000	30000	71000	15000	150000	50000	17000	20600	41300	30800	38400	27700	19000	94000	30000	62000	300000	66000	20000	71000	30000	40000	30000	60000	20000	26300	14800
Lead		17	50	7	20	11	20 U	4.9	24	30	14	20	66	50	7.1	4.2	6.5	4.4	5.6	6.3	5.6	7	20 U	66	500	5	20 U	18	20	8	20 U	25	20 U	11	2.4
Magnesium		24000	20000	20000	50000	22000	15000		20000	15000	24000	10000	8200	15000	6940	5590	6570	6980	5270	8940		25000	20000	26000	10000	23000	15000	24000	20000	18000	7000	19000	10000		
Manganese		1300	1000	980	1000	1600	700	271	860	700	1400	500	380	700	308	242	6.5	4.4	5.6	6.3	217	980	700	830	300	900	500	1200	700	790	700	980	300	289	285
Mercury															0.02	0.02 U	0.02 U	0.02 U	0.02 U	0.02 U															
Molybdenum		0.076	10 U	0.58	10 U	1.3	10 U		2	70	0.93	10 U	12	700								2U	10 U	14	10	0.43	10 U	1.8	10 U	0.35	10 U	4	20		
Nickel		31	50	20	50	28	30		30	50	29	10 U	2	10 U	15	21.6	16.2	12.5	10.7	25.7		29	30	51	50	20	10 U	32	30	22	10 U	25	10 U		
Potassium		8800		12000		7300			10000		8200		7500		455	888	631	547	718	723		7400		7400		7500		7600		12000		9200			
Selenium								0.3 U							0.95	0.10 U	0.95	0.12	0.14	0.93	0.5													0.6	0.3 U
Silver		0.067	1 U	0.067U	1 U	0.067U	1 U		0.17	1 U	0.067U	1 U	1.2	1 U	0.64	0.73	5.6	0.6	0.72	0.76		<0.067	1 U	1.2	5	<0.067	1 U	0.11	1 U	0.45	1 U	0.098	1 U		
Sodium		23000	5000	29000	5000 U	24000	5000		24000	5000 U	25000	5000 U	9800	5000 U	345	318	336	312	294	368		22000	5000	17000	5000 U	24000	7000	22000	5000	28000	10000	23000	5000 U		
Thallium															0.15	0.14	0.14	0.1	0.13	0.12															
Uranium		100 U		100 U		100 U			100 U		100 U		100 U									100 U		100 U		100 U		100 U		100 U		100 U			
Zinc		180	1500	110	500 U	130	1000	62	280	1500	270	500 U	250	2000	110	126	106	75	118	152	113	120	500 U	1100	10000	110	500 U	230	1000	82	500 U	330	1500	216	144

Data Notes:

U - Parameter was analyzed for, but not detected above the reporting limit shown.

▨ Grey shading indicates the concentration of analyte was not established, therefore not reported and analyzed.

Data Source:

(a) Kilburn, et al. 1994. *Geochemical data and sample locality maps for stream-sediment, heavy-mineral-concentrate, mill tailing, water, and precipitate samples collected in and around the Holden mine, Chelan County, Washington.* USGS Open File Report 94-680A Paper Version, 94-680B Diskette version (Data Collected in 1994).
(b) Lambeth, R.H. 1995. Transmittal of laboratory data from samples collected at Holden Mine site by the US Bureau of Mines. (Data collected in 1994).
(c) Johnson, A., et al. 1997. *Effects of Holden Mine on the Water, Sediments and Benthic Invertebrates of Railroad Creek (Lake Chelan).* Environmental Investigations and Laboratory Services Program. Water Body No. WA-47-1020. Publication No. 97-330 (data collected in Spring and Fall 1996).

TABLE 5.5-2
SUMMARY OF FALL 1998 SEDIMENT DATA, STEHEKIN
HOLDEN MINE RI/FS
DAMES & MOORE JOB NO. 17693-005-019

Sample ID	STE-SED-101698-1	STE-SED-101698-2	STE-SED-101698-3A	STE-SED-101698-3B	STE-SED-101698-3C	STE-SED-101698-4	Statistical Calculations [1]						
							Minimum Concentration	Maximum Concentration	Approximate Distribution	Distribution Mean	Median	Standard Deviation	90th %
Date Collected	10/16/98	10/16/98	10/16/98	10/16/98	10/16/98	10/16/98							
<u>Metals, Total (mg/kg)</u>													
Aluminum	12,500	12,600	16,300	17,400	20,000	18,100	12,500	20,000	Lognormal	16,207	16,850	3,037	21,193
Arsenic	21.1	8.9	13.5	12.4	14.6	14.4	8.9	21.1	Lognormal	14.2	13.95	3.99	20.6
Cadmium	0.4	0.3U	0.5	0.5U	0.6U	0.4U	0.4	0.5	Neither[2]	0.45	0.45	0.071	*N/A*
Copper	24	21	40	39	48	40	21	48	Nonparametric	35.3	39.5	10.5	*N/A*
Iron	23,700	18,800	26,300	25,400	30,100	28,900	18,800	30,100	Lognormal	25,607	25,850	4,037	32,297
Lead	8	6	11	12	14	10	6	14	Lognormal	10.3	10.5	2.86	15.2
Manganese	255	212	339	342	404	353	212	404	Normal	318	341	70.5	420
Zinc	112	68.7	93	93.5	113	106	68.7	113	Nonparametric	97.7	99.8	16.7	*N/A*
<u>Conventional Analyses</u>													
pH (S.U.)	5.8 J	5.5 J	5.6 J	5.6 J	5.8 J	5.5 J	-	-	-	-	-	-	-
Total Solids (%)	60.3	62.5	40.8	36.5	40.2	47.4	-	-	-	-	-	-	-
Total Organic Carbon (%)	1.6	1.9	3.8	4.2	3.3	3.1	-	-	-	-	-	-	-
Total Volatile Solids (mg/kg)	38,000	54,000	140,000	190,000	150,000	100,000	-	-	-	-	-	-	-
Acid Volatile Sulfide (mg/kg)	2.9	4.0	1.3U	1.5U	1.4U	3.5	-	-	-	-	-	-	-

<u>Notes:</u>
U - Parameter was analyzed for, but not detected above the reporting limit shown.
J - Estimated Value
[1] Statistical analyses including approximating sample distributions, means, standard deviations, medians and background 90th percentile were calculated using an Excel version 5.0 macro designed by the Washington Department of Ecology and their guidance found in Statistical Guidance for Ecology Site Managers, Toxics Cleanup Program (August, 1992).
[2] The Excel macro could not approximate either distribution due to insufficient uncensored data points.
N/A - Not Available. Therefore, the 90th percentile was not determined.

TABLE 5.5-3
SUMMARY OF FALL 1998 SEDIMENT DATA, LUCERNE
HOLDEN MINE RI/FS
DAMES & MOORE JOB NO. 17693-005-019

Sample ID	LUC-SED-101598-1-1	LUC-SED-101598-2-1	LUC-SED-101598-3-1A	LUC-SED-101598-3-1B	LUC-SED-101598-3-1C	LUC-SED-101598-3-2	LUC-SED-101598-3.5-1	LUC-SED-101598-3.5-2	LUC-SED-101598-5-1	LUC-SED-101598-5-2	LUC-SED-101698-1-2	LUC-SED-101698-2-2	Statistical Calculations [1]						
													Minimum Concentration	Maximum Concentration	Approximate Distribution	Distribution Mean	Median	Standard Deviation	95th UCL
Date Collected	**10/15/98**	**10/15/98**	**10/15/98**	**10/15/98**	**10/15/98**	**10/15/98**	**10/15/98**	**10/15/98**	**10/15/98**	**10/15/98**	**10/16/98**	**10/16/98**							
Metals, Total (mg/kg)																			
Aluminum	11,400	9,390	14,600	13,800	14,600	18,400	12,100	16,200	16,100	15,000	16,500	13,500	9,390	18,400	Lognormal	14,330	14,600	2,476	15,868
Arsenic	4.6	3.1	6.6	9.8	7.6	7.7	6.6	9.4	18.8	9	11	6.3	3.1	18.8	Lognormal	8.44	7.65	3.96	11.2
Cadmium	0.6	0.4	0.9	2.3	1.1	1.4	1.3	2.0	1.3	1.2	1.9	0.9	0.4	2.3	Lognormal	1.30	1.25	0.566	1.8
Copper	67	46	106	165	121	171	140	219	170	153	191	109	46	219	Lognormal	141	147	50.5	188
Iron	20,800	15,400	28,400	26,100	27,000	33,200	20,700	28,300	52,800	27,800	29,300	24,200	15,400	52,800	Lognormal	27,877	27,400	9,178	33,120
Lead	5	4	7	9	7	9	8	14	16	11	12	7	4	16	Lognormal	9.17	8.5	3.58	11.8
Manganese	270	215	287	264	283	355	207	282	408	271	308	250	207	408	Lognormal	284	277	55.3	315
Zinc	173	131	285	352	297	334	297	365	426	288	318	226	131	426	Lognormal	294	297	81.9	358
Conventional Analyses																			
pH (s.u.)	6.0 J	6.2 J	5.8 J	4.7 J	5.3 J	5.4 J	5.5 J	5.7 J	5.8 J	5.7 J	5.3 J	5.0 J	-	-	-	-	-	-	-
Total Solids (%)	75.2	78.4	44.4	35.8	46.9	40.6	55.8	41	45.5	52.5	44.3	49.8	-	-	-	-	-	-	-
Total Organic Carbon (%)	0.3	0.38	7.9	15	11	14	6.2	5.2	2.5	1.9	5.9	10	-	-	-	-	-	-	-
Total Volatile Solids (mg/kg)	11,000	7,800	120,000	220,000	130,000	150,000	66,000	110,000	95,000	67,000	140,000	130,000	-	-	-	-	-	-	-
Acid Volatile Sulfide (mg/kg)	0.7U	0.7U	120	9.4	1.1U	48	24	96	91	3.3	14	10	-	-	-	-	-	-	-

Notes:
U - Parameter was analyzed for, but not detected above the reporting limit shown
J - Estimated Value
[1] Statistical analyses including approximating sample distributions, means, standard deviations, medians and 95th UCL were calculated using an Excel version 5.0 macro designed by the Washington Department of Ecology and their guidance found in Statistical Guidance for Ecology Site Managers, Toxics Cleanup Program (August, 1992).

TABLE 5.6-1
SUMMARY OF 1997 FERRICRETE, FLOCCULENT, AND PORTAL FILM DATA
HOLDEN MINE RI/FS
DAMES & MOORE JOB NO. 17693-005-019

	Ferricrete			Flocculent			Portal Film	
Parameters — **Sample ID**	**DMTP1E-1**	**DMTP1W-1A**	**DMTP1W-1B**	**Floc1-RC-2**	**Floc2-RC-5**	**Floc3-RC-9**	**Portal Film**	**Portal Film**
Sampling Date	**10/4/97**	**10/4/97**	**10/4/97**	**10/4/97**	**10/4/97**	**10/4/97**	**7/12/97**	**10/4/97**
Total Metals	mg/kg (dry)	mg/kg (dry)	mg/kg (dry)	mg/kg (wet)	mg/kg (wet)	mg/kg (dry)	mg/L	mg/L
Aluminum	10,100	15,100	10,900	3,240	5,410	16,600	12,900	6,120
Arsenic	7.8	14.6	1.1	20.1	47	126	2U	1U
Barium	38.8	42.8	1,100	14.5	24.1	31	1.42	0.81
Beryllium	0.5U	0.1U	0.1U	0.2U	0.5U	2U	0.13	0.12
Cadmium	1UJ	0.4J	3.3J	1.3J	4J	5J	0.16	0.26
Calcium	3,790	3,950	2,680	602	710	1,090	389	701
Chromium	16	25.3	9.7	2.9	5	10	0.53	0.3
Copper	101	90.8	2,340	164	492	982	222	346
Iron	111,000J	45,000J	37,500J	84,400J	125,000J	434,000J	1,430	1,650
Lead	10U	6	75	4U	10U	40U	13.8J	16
Magnesium	6,610	9,310	7,690	588	570	1,220	56.5	50
Manganese	230J	313J	232J	53.4J	182J	331J	9.06	4.41
Mercury	▨	▨	▨	▨	▨	▨	0.002U	▨
Molybdenum	3U	1.6	45.0	11.1	9	70	0.85	0.11
Nickel	11	12	4	2	5U	20U	0.4U	0.2U
Potassium	6,160	1,540	3,140	220	440	1,050U	21	20
Selenium	▨	▨	▨	▨	▨	▨	2U	▨
Silver	2	1.5	3.3	1.2	2	11	0.12U	0.07
Sodium	550	538	615	63U	70	210	17.9J	31
Thallium	2U	0.6U	0.9	0.10U	0.2U	0.4U	2U	1U
Uranium	2U	2U	3U	2U	4U	8U	1.13	1.8
Zinc	73J	91.2J	404J	145J	320J	481J	72	228
Conventional Analyses:								
Sulfide (mg/kg)	▨	▨	0.68UJ	▨	▨	▨	▨	▨

Data Notes:

J - Estimated value.

U - Parameter was analyzed for but not detected for, but not detected above the reporting limit shown.

UJ - Parameter was analyzed for but not detected. Detection limit is an estimated value.

▨ **Grey shading** indicates the concentration of analyte was not established, therefore not reported nor analyzed.

TABLE 5.7-1
HISTORICAL AIR MONITORING DATA
HOLDEN MINE RI/FS
DAMES & MOORE JOB NO. 17693-005-019

Parameters	#1 Ballpark	#1 Ballpark	#2 Upstream Tailings	#2 Upstream Tailings	#3 Upstream Tailings	#3 Upstream Tailings	#4 Streamside	#4 Streamside	#5 Volleyball Court	#5 Volleyball Court	#6 Downstream Tailings	#6 Downstream Tailings	#9 Chalet Hill	#9 Chalet Hill
	9/23/94	9/29/94	9/23/94	9/29/94	9/23/94	9/29/94	9/23/94	9/29/94	9/23/94	9/29/94	9/23/94	9/29/94	9/23/94	9/29/94
<u>**Metals, (ug/m^3)**</u>														
Aluminum	0.067	0.137	0.280	0.197	0.313	0.374	0.117	0.184	0.464	1.564	0.023	0.451	0.483	1.037
Arsenic	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨
Barium	0.001	0.001	0.004	0.006	0.003	0.007	0.001	0.005	0.006	0.061	0.002	0.062	0.008	0.012
Beryllium	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨
Cadmium	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨
Calcium	0.122	0.280	0.070	0.233	0.090	0.406	0.080	NR	0.226	0.167	NR	NR	0.155	0.167
Chromium	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨
Copper	0.020	0.022	0.020	0.017	0.036	0.053	0.00144 U	0.030	0.031	0.060	0.012	0.043	0.039	0.051
Iron	0.052	0.105	0.458	0.540	0.411	0.814	0.136	0.661	0.538	4.443	0.160	4.000	0.886	1.603
Lead	0.001	0.001	0.003	0.003	0.003	0.004	0.001	0.005	0.005	0.021	0.004	0.021	0.005	0.018
Magnesium	0.007	0.051	0.064	0.030	0.072	0.119	0.031	NR	0.122	0.484	NR	0.110	0.144	0.276
Manganese	0.002	0.003	0.005	0.004	0.005	0.007	0.002	0.004	0.008	0.028	0.002	0.010	0.014	0.028
Mercury	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨
Molybdenum	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨
Nickel	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨
Potassium	NR	NR	0.140	NR	NR	0.325	0.148	NR	NR	0.292	NR	0.139	0.138	NR
Selenium	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨
Silver	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨
Sodium	0.058	NR	NR	NR	NR	1.248	NR	NR	NR	NR	NR	NR	NR	NR
Thallium	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨
Uranium	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨
Zinc	0.004	0.002	0.011	0.011	0.012	0.017	0.006	0.021	0.023	0.073	0.023	0.067	0.021	0.495

<u>**Data Notes:**</u>

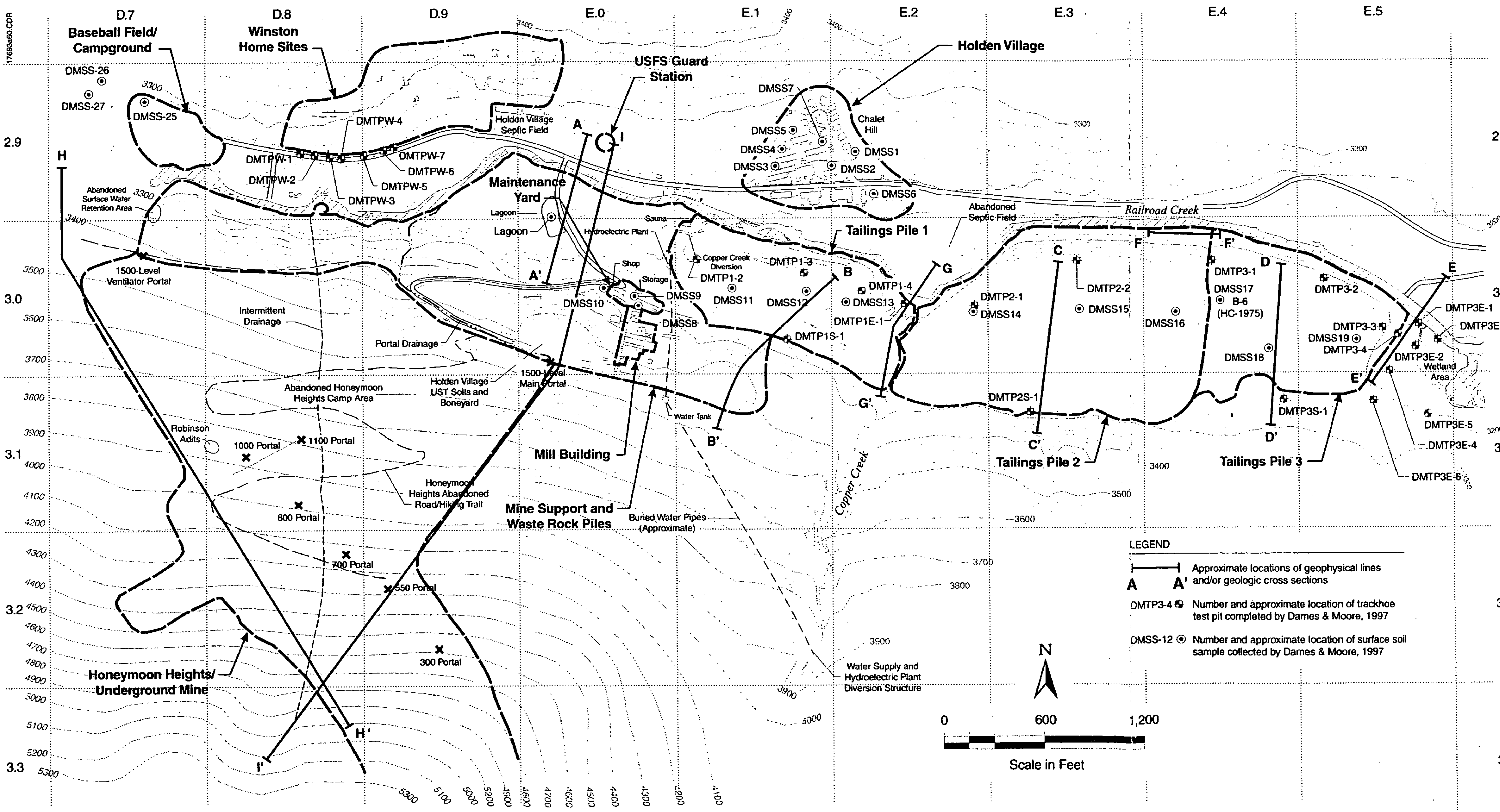
NR - Not Reported

U - Parameter was analyzed for but not detected for, but not detected above the reporting limit shown.

▨ Grey shading ▨ indicates the concentration of analyte was not established, therefore not reported nor analyzed.

<u>**Data Source:**</u>

Air Resource Specialist, Inc. (Data collected in 1994 and prepared for the U.S. Forest Service-Region 6-Wenatchee National Forest)



SOURCE: Base map information from USFS and Washington DNR, DEM CD ROM

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Figure 5.2-1

RI SOIL INVESTIGATION LOCATIONS

Holden Mine RI/FS
Draft Final RI Report

17693A59.CDR

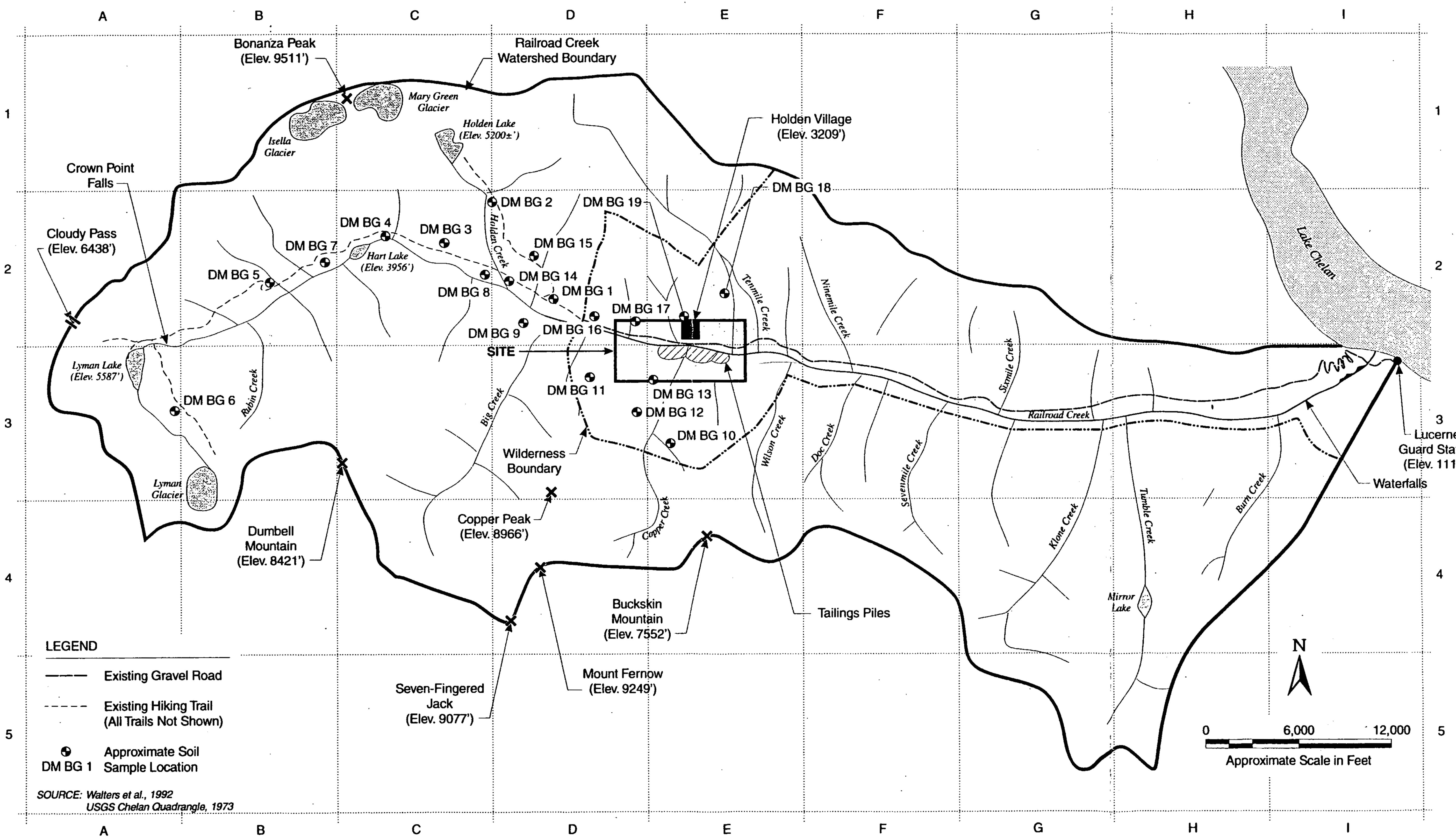

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Figure 5.2-2

AREA BACKGROUND SURFACE SOIL SAMPLE LOCATIONS

Holden Mine RI/FS
Draft Final RI Report

17693e62.CDR

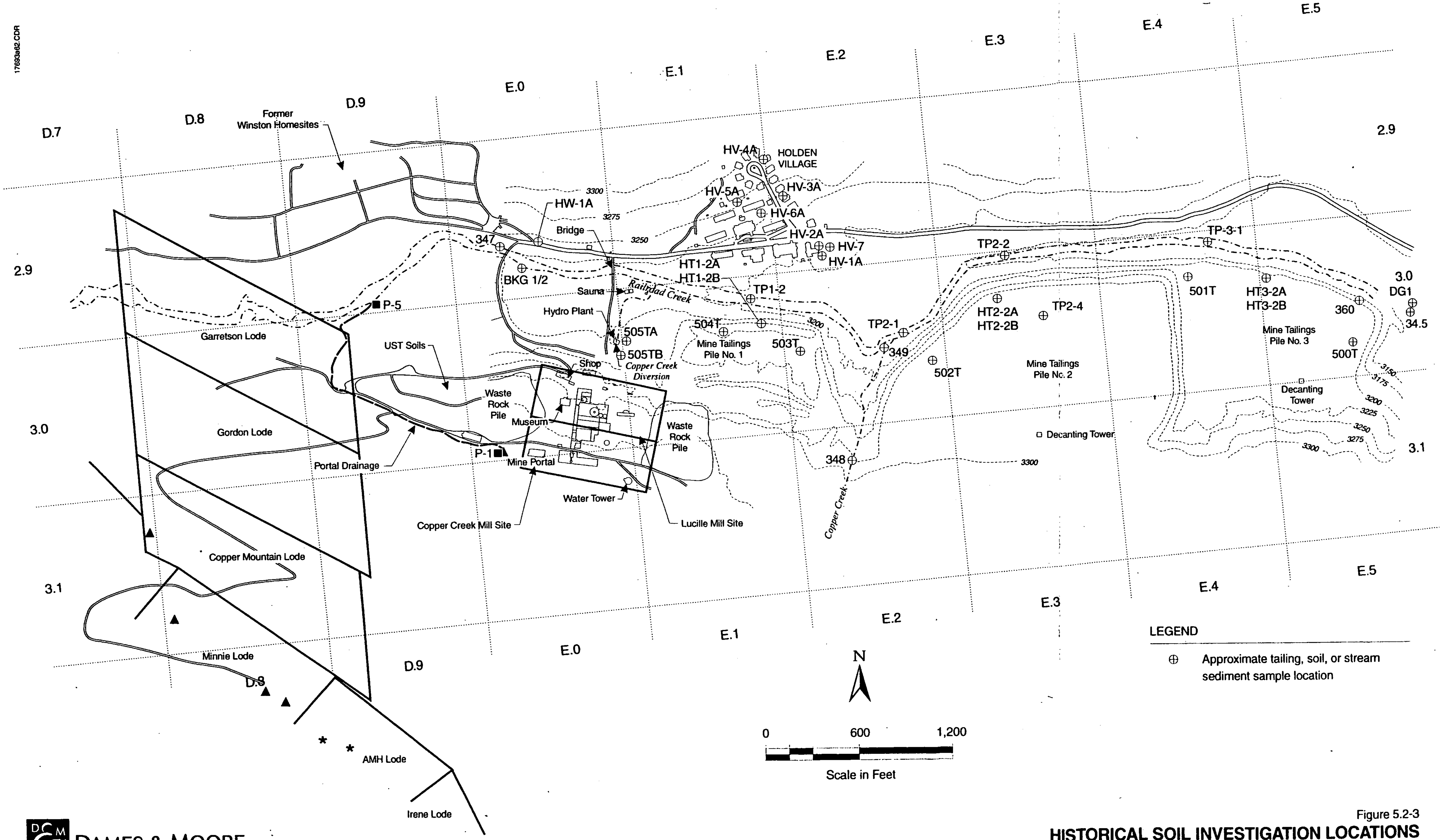

Figure 5.2-3

HISTORICAL SOIL INVESTIGATION LOCATIONS

Holden Mine RI/FS
Draft Final RI Report

DAMES & MOORE
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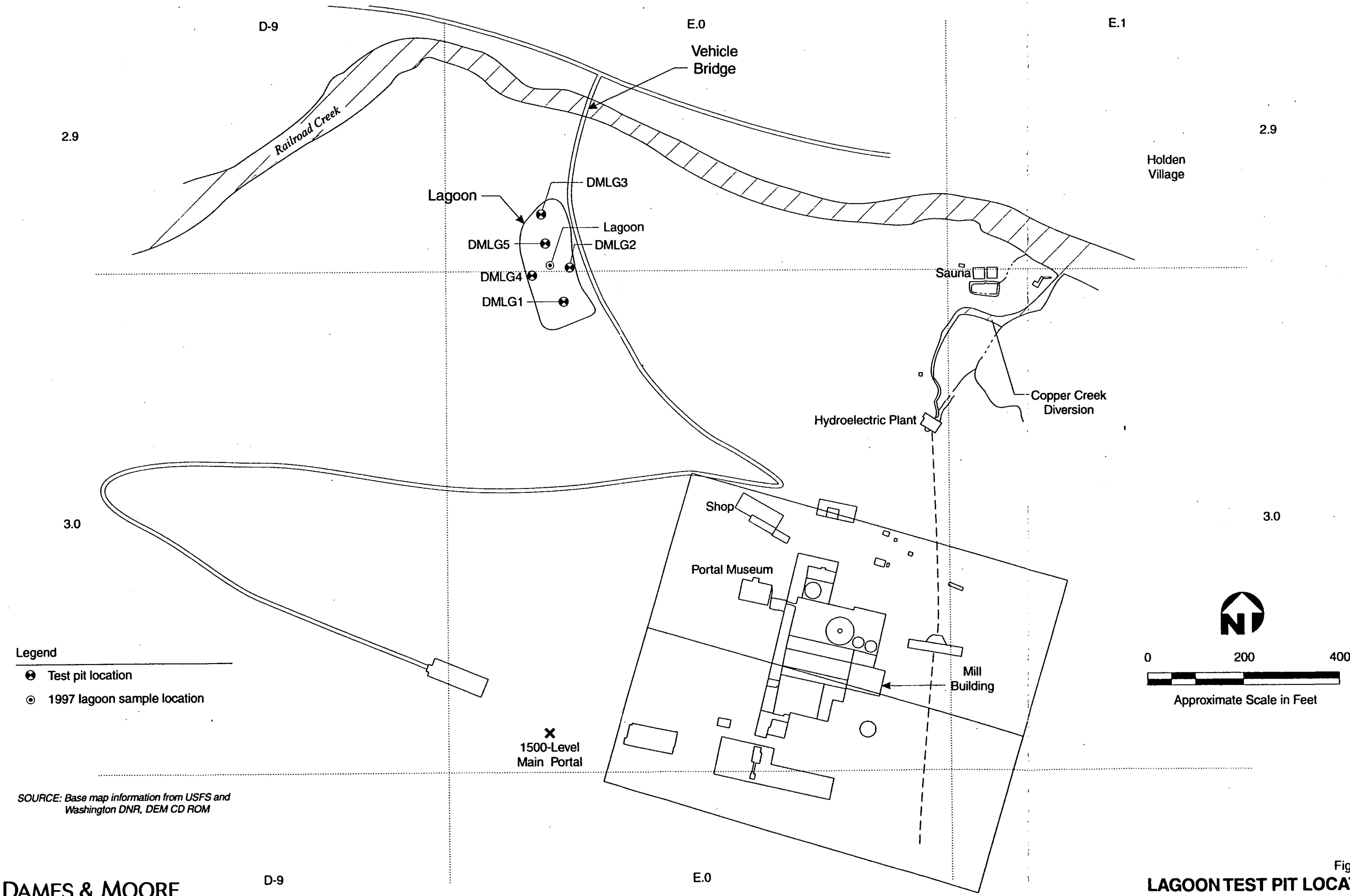
Job No. 17693-005-019

17693a61.CDR



SOURCE: Base map information from USFS and Washington DNR, DEM CD ROM

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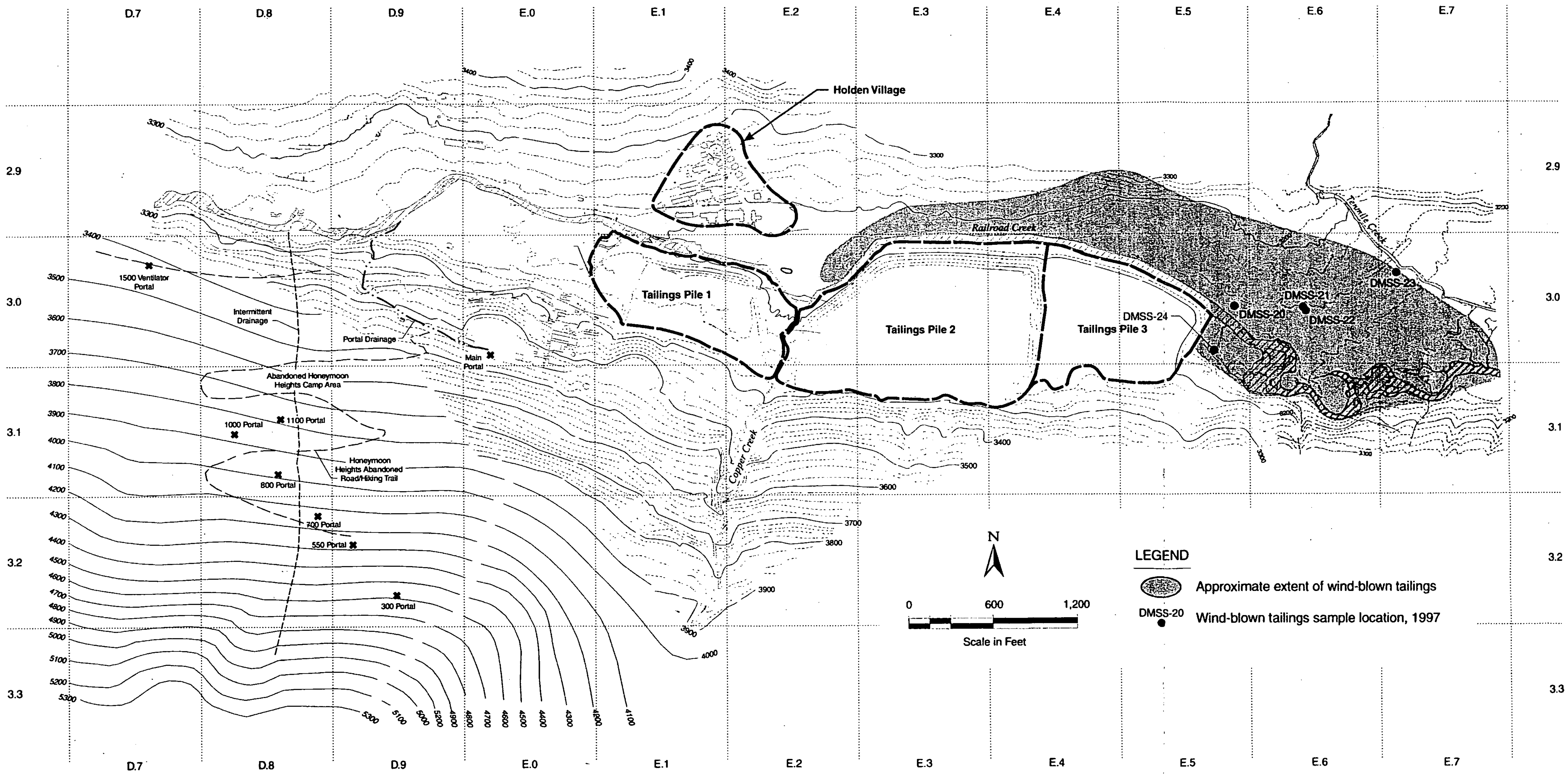
Job No. 17693-005-019

Figure 5.2-4
LAGOON TEST PIT LOCATIONS

Holden Mine RI/FS
Draft Final RI Report

17693a63.CDR



SOURCES: Base map information from USFS and Washington DNR, DEM CD ROM

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Figure 5.2-5

RI WIND-BLOWN TAILINGS SAMPLE LOCATIONS

Holden Mine RI/FS
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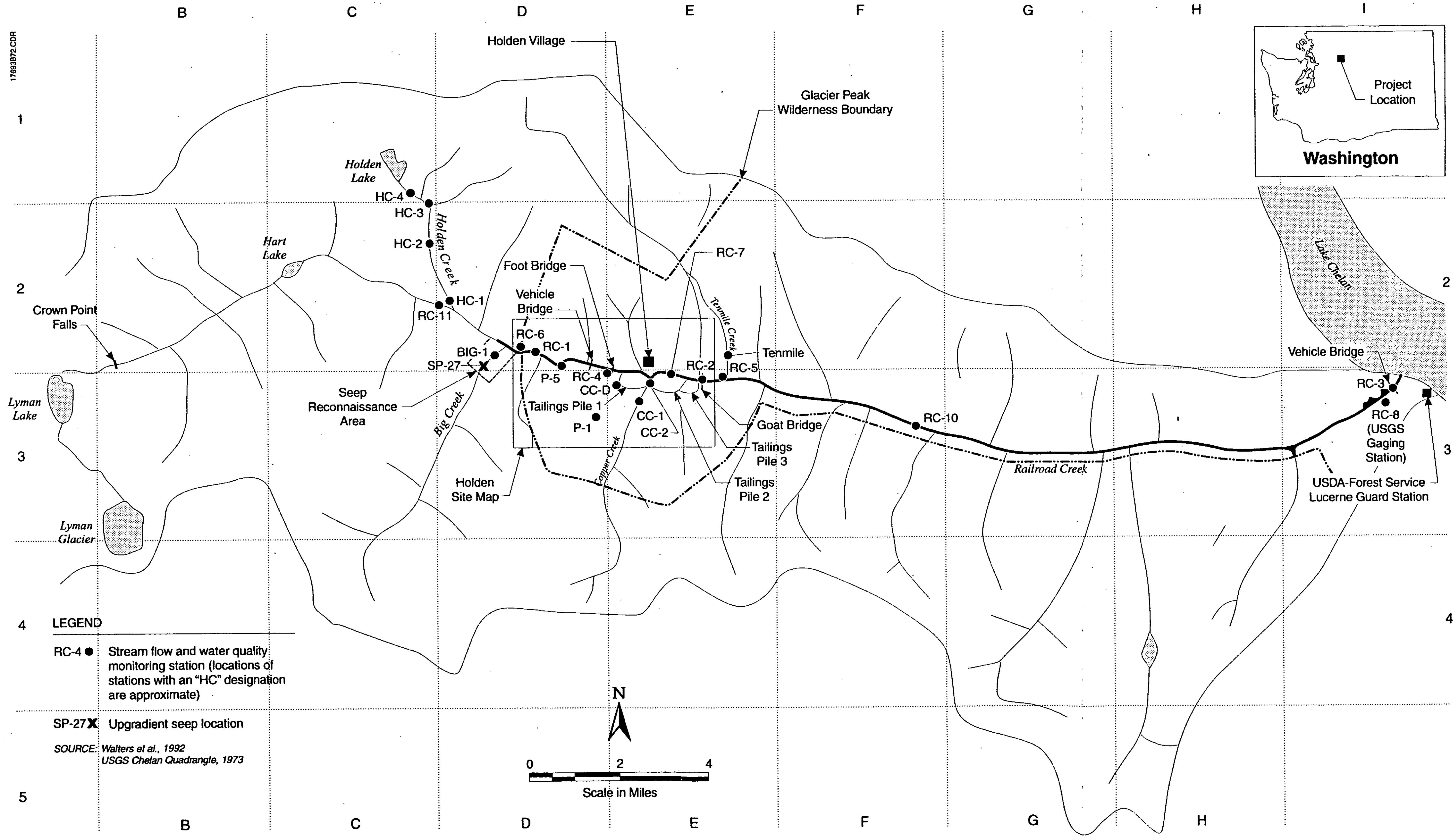

LEGEND

RC-4 ● Stream flow and water quality monitoring station (locations of stations with an "HC" designation are approximate)

SP-27 X Upgradient seep location

SOURCE: Walters et al., 1992
USGS Chelan Quadrangle, 1973

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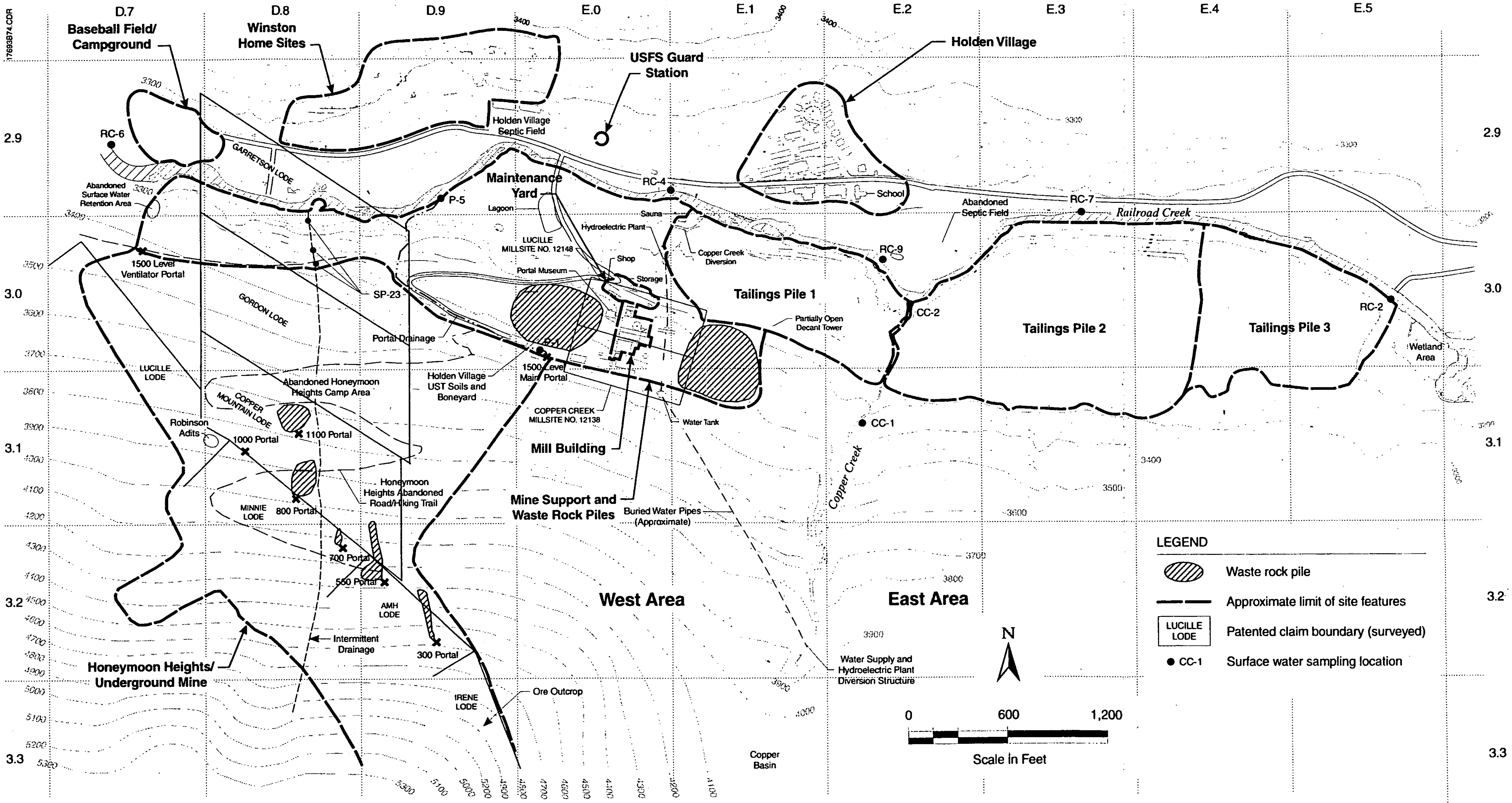
Figure 5.3-1

SURFACE WATER SAMPLE LOCATIONS—RAILROAD CREEK WATERSHED

Job No. 17693-005-019

Holden Mine RI/FS
Draft Final RI Report



SOURCE: Base map information from USFS and Washington DNR, DEM CD ROM

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Figure 5.3-2

RI WATER QUALITY SAMPLING LOCATIONS—SITE

Holden Mine RI/FS
Draft Final RI Report

17693b73.CDR

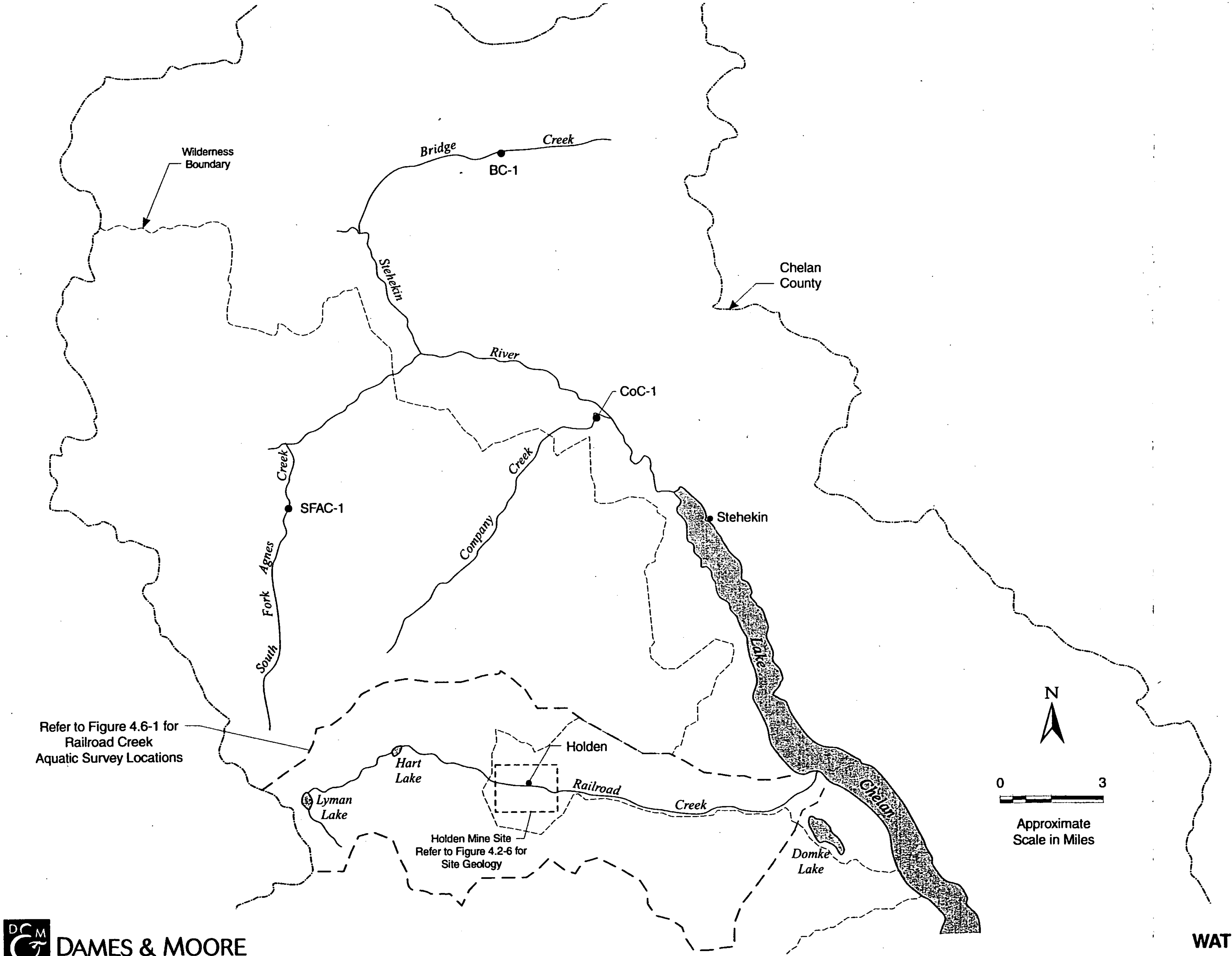

Figure 5.3-3

STEHEKIN RIVER WATERSHED—
WATER QUALITY SAMPLING LOCATIONS

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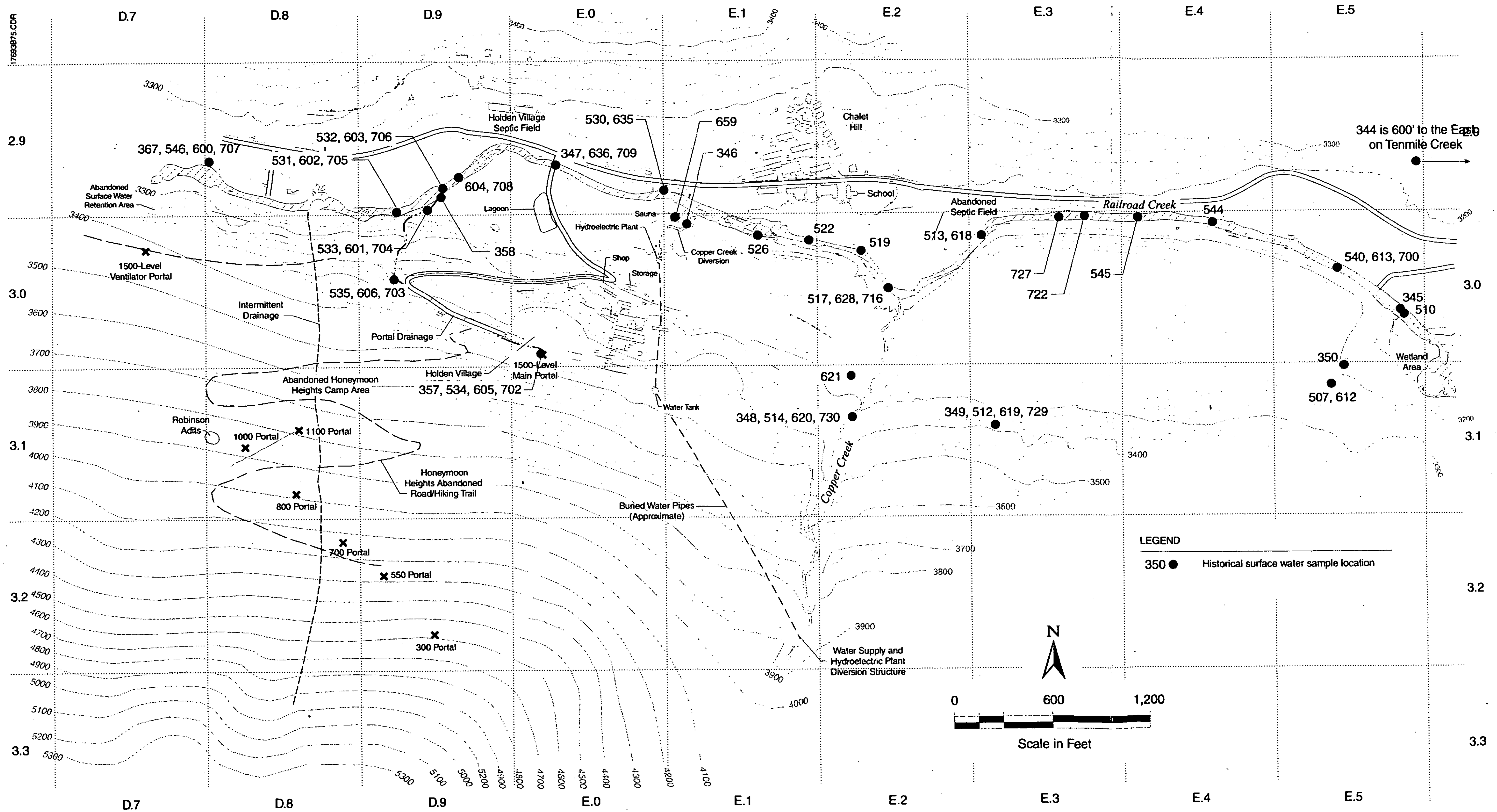
Holden Mine RI/FS
Draft Final RI Report



SOURCE: Base map information from USFS and Washington DNR, DEM CD ROM

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Figure 5.3-4

HISTORICAL SURFACE WATER SAMPLE LOCATIONS

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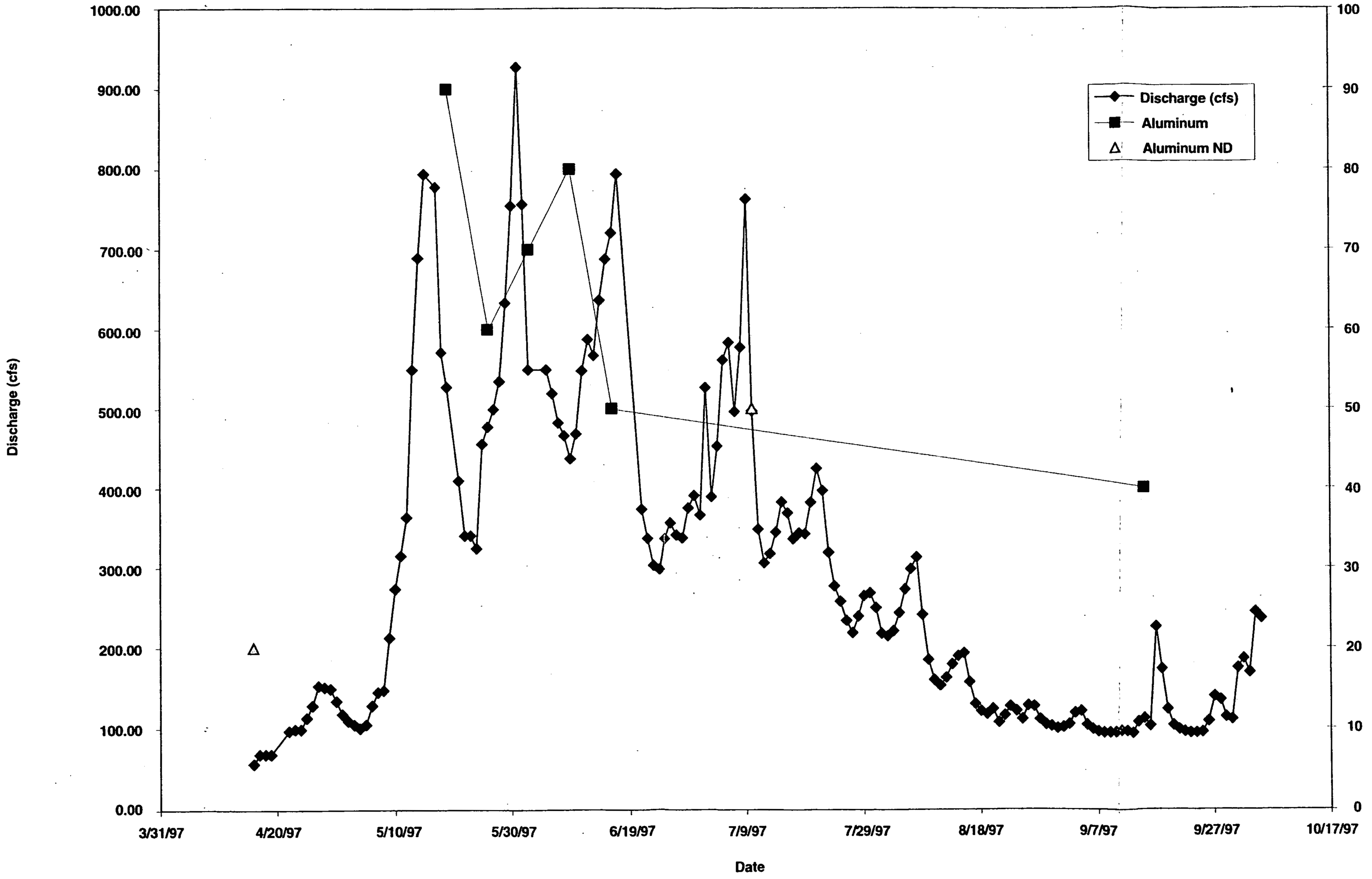

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Figure 5.3-5

1997 RC-4 FLOW VS. ALUMINUM CONCENTRATION (μg/L) AT RC-2

17693B82.CDR

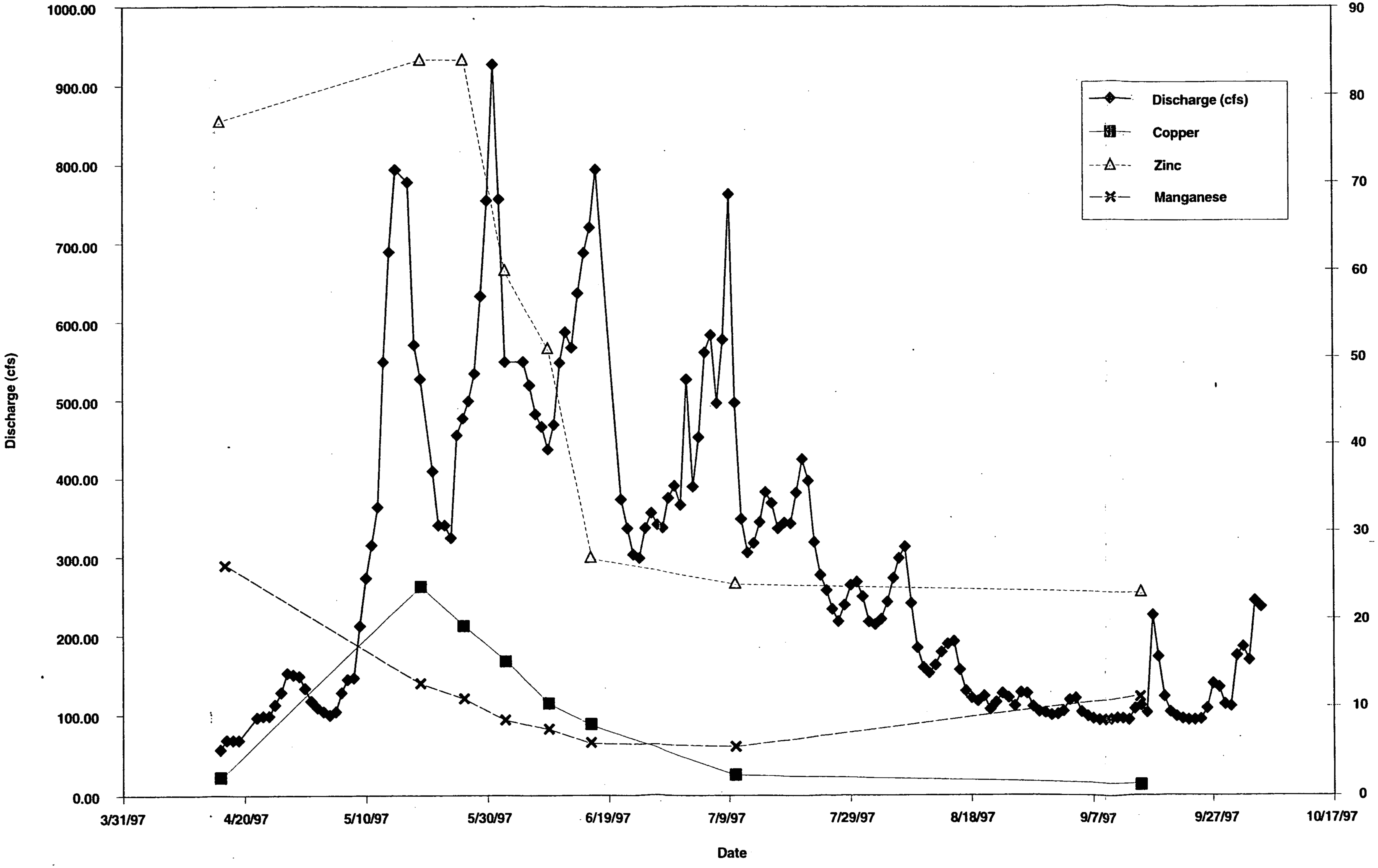

Figure 5.3-6

1997 RC-4 FLOW VS. COPPER, MANGANESE, AND ZINC CONCENTRATIONS (µg/L) AT RC-2

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Holden Mine RI/FS
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Job No. 17693-005-019

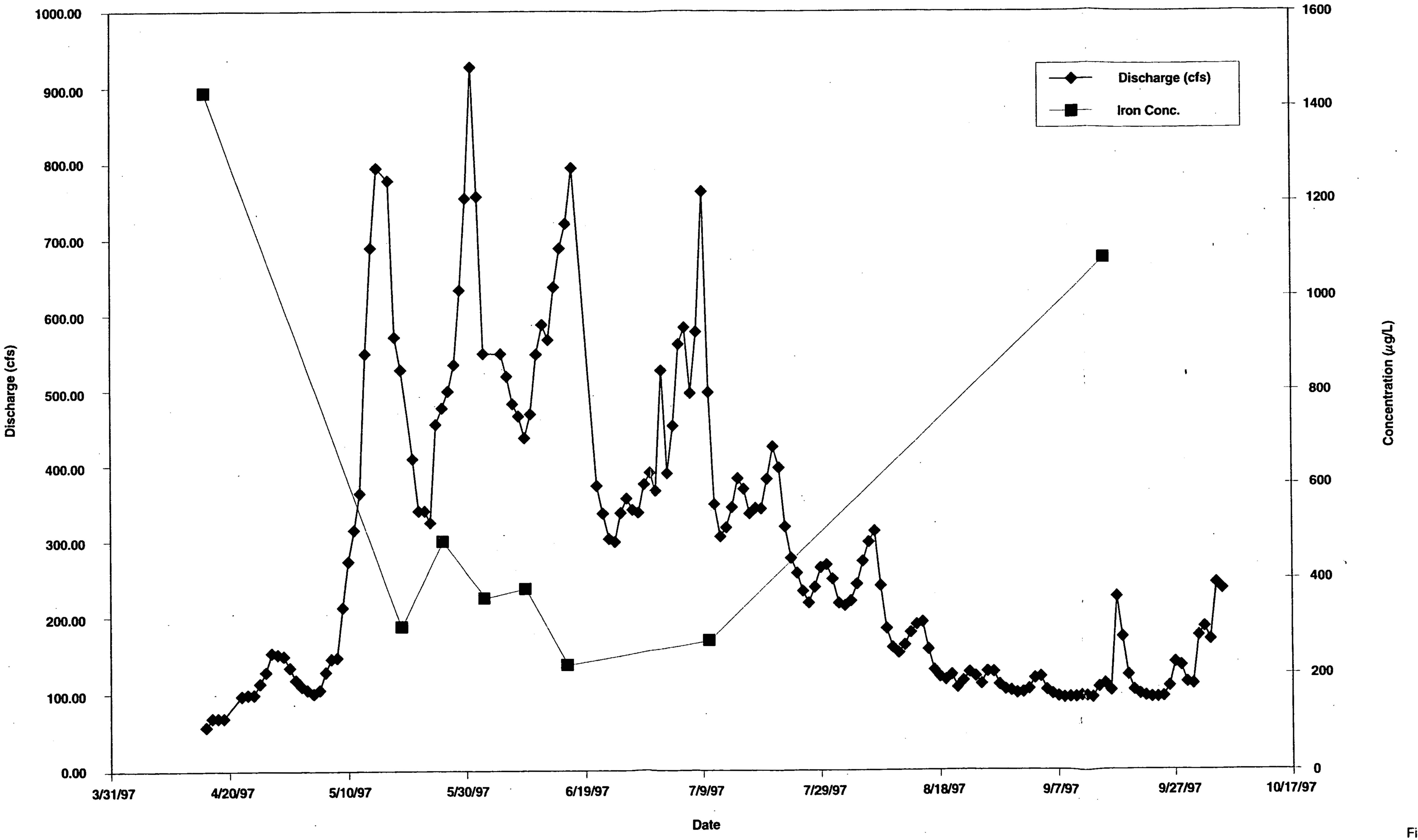

Figure 5.3-7

1997 RC-4 FLOW VS. IRON CONCENTRATION (µg/L) AT RC-2

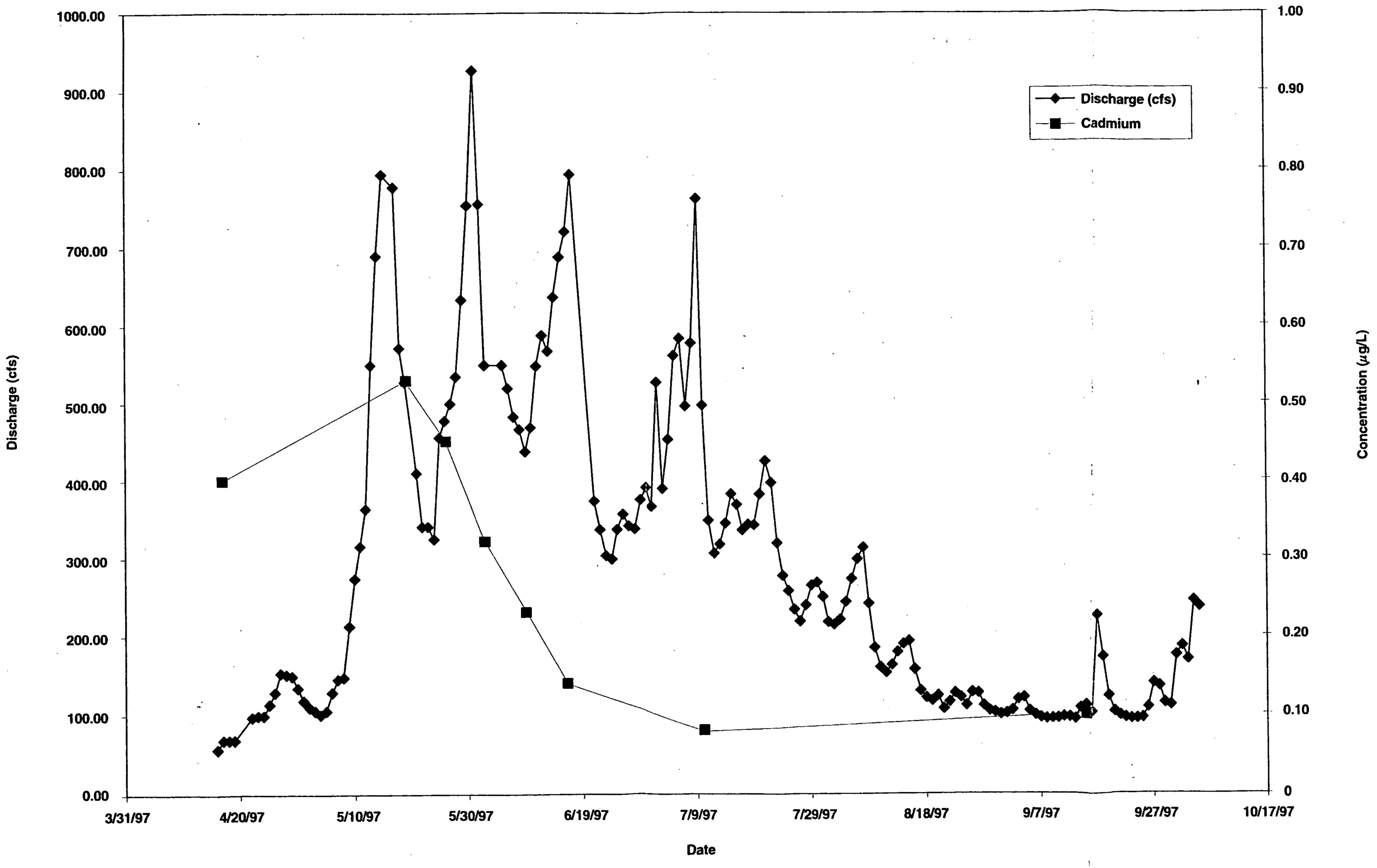

Figure 5.3-8

1997 RC-4 FLOW VS. CADMIUM CONCENTRATION (µg/L) AT RC-2

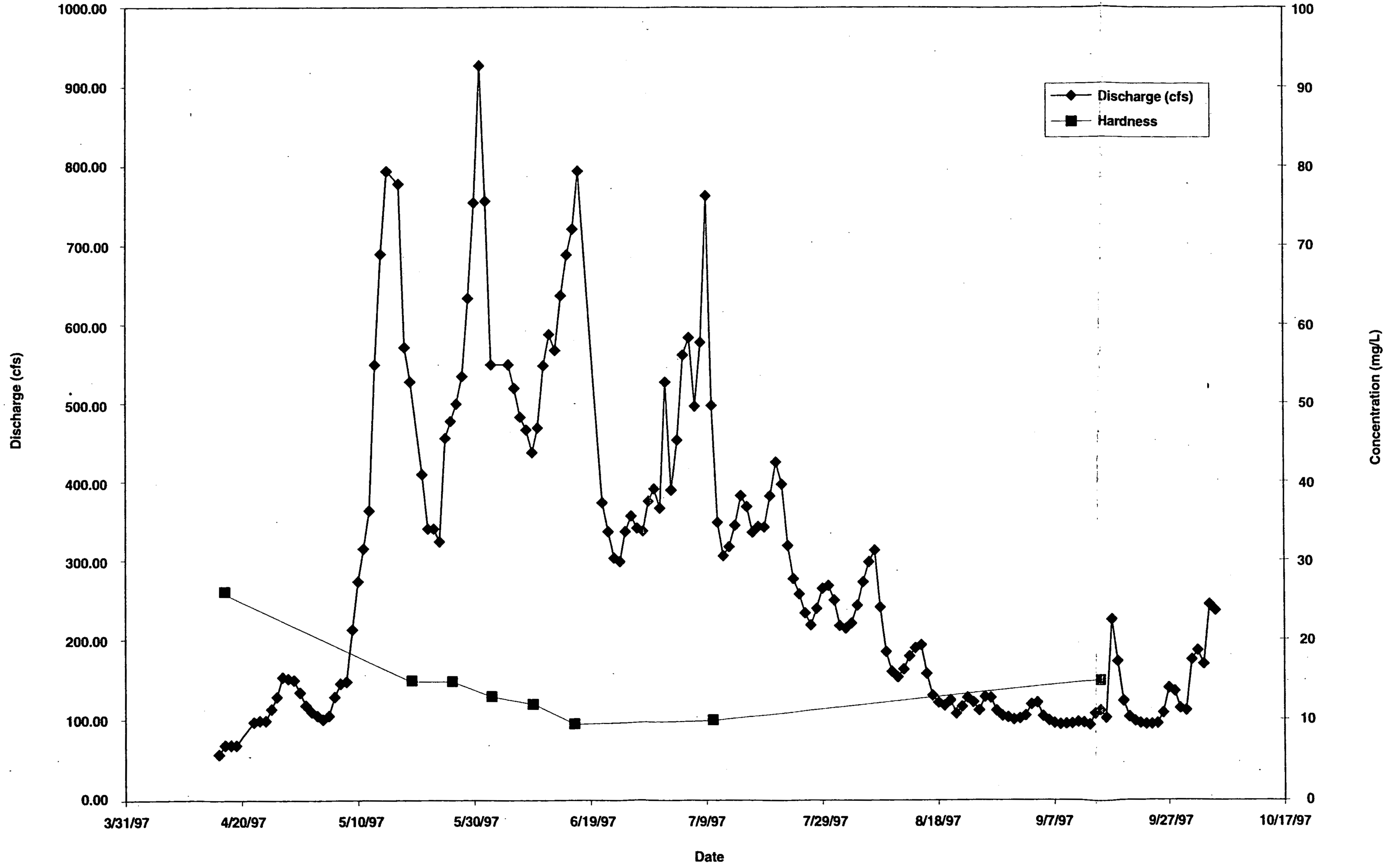

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Figure 5.3-9

1997 RC-4 FLOW VS. HARDNESS CONCENTRATION (mg/L) AT RC-2

17693B76.CDR

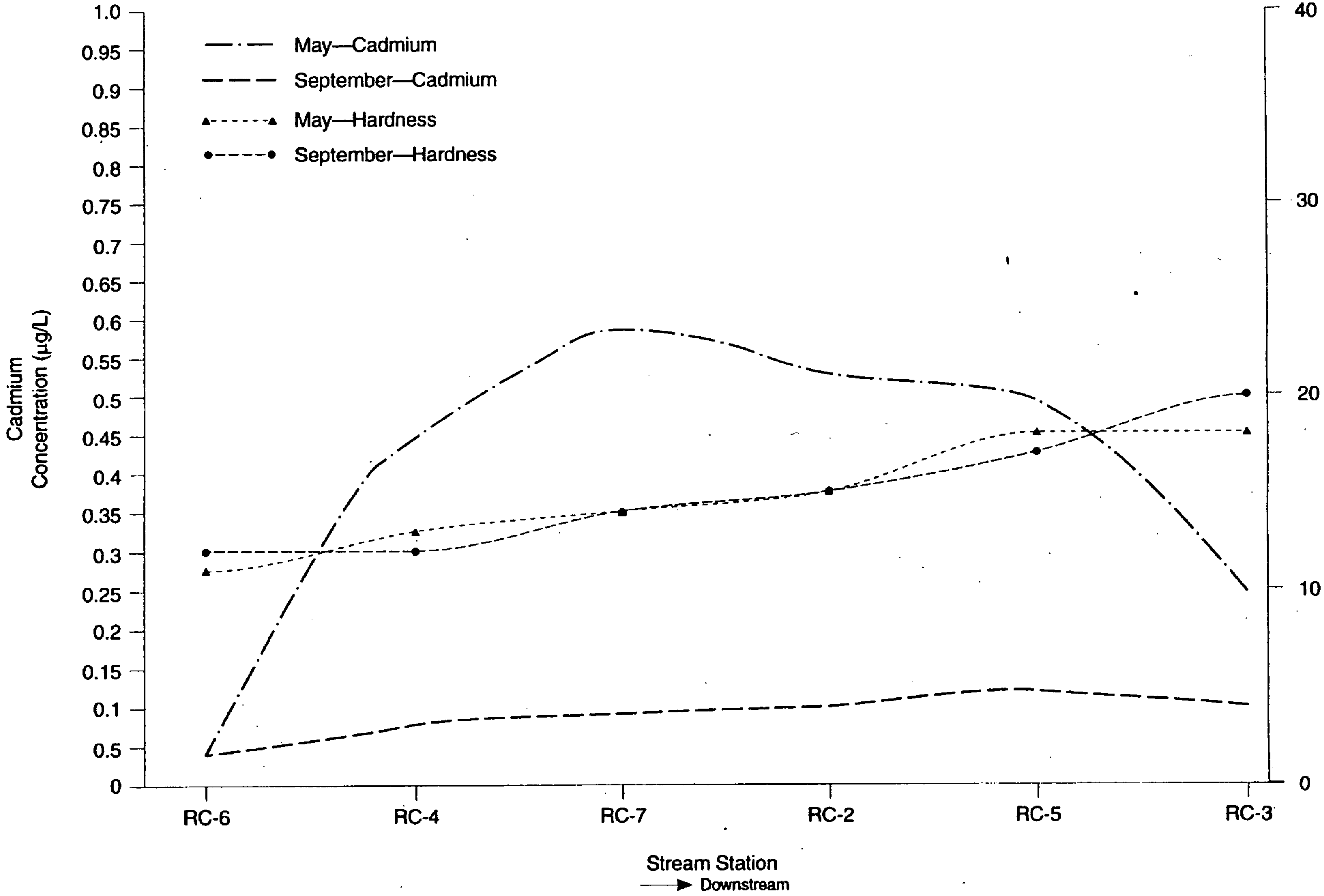

Figure 5.3-10

MAY AND SEPTEMBER 1997 CADMIUM AND HARDNESS CONCENTRATIONS

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17693B78.CDR

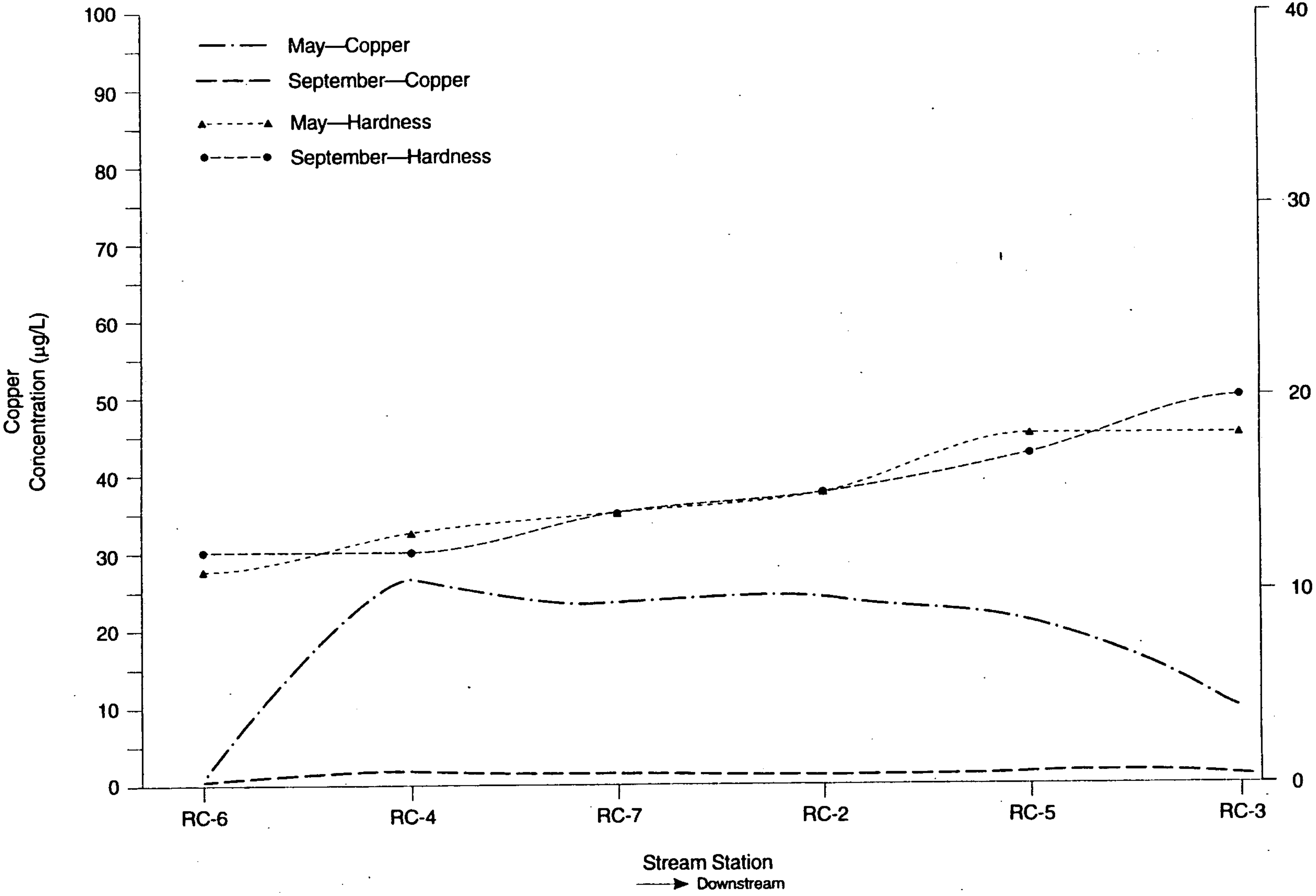

Figure 5.3-11

MAY AND SEPTEMBER 1997 COPPER AND HARDNESS CONCENTRATIONS

DAMES & MOORE
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Draft Final RI Report

Job No. 17693-005-019

17693B77.CDR

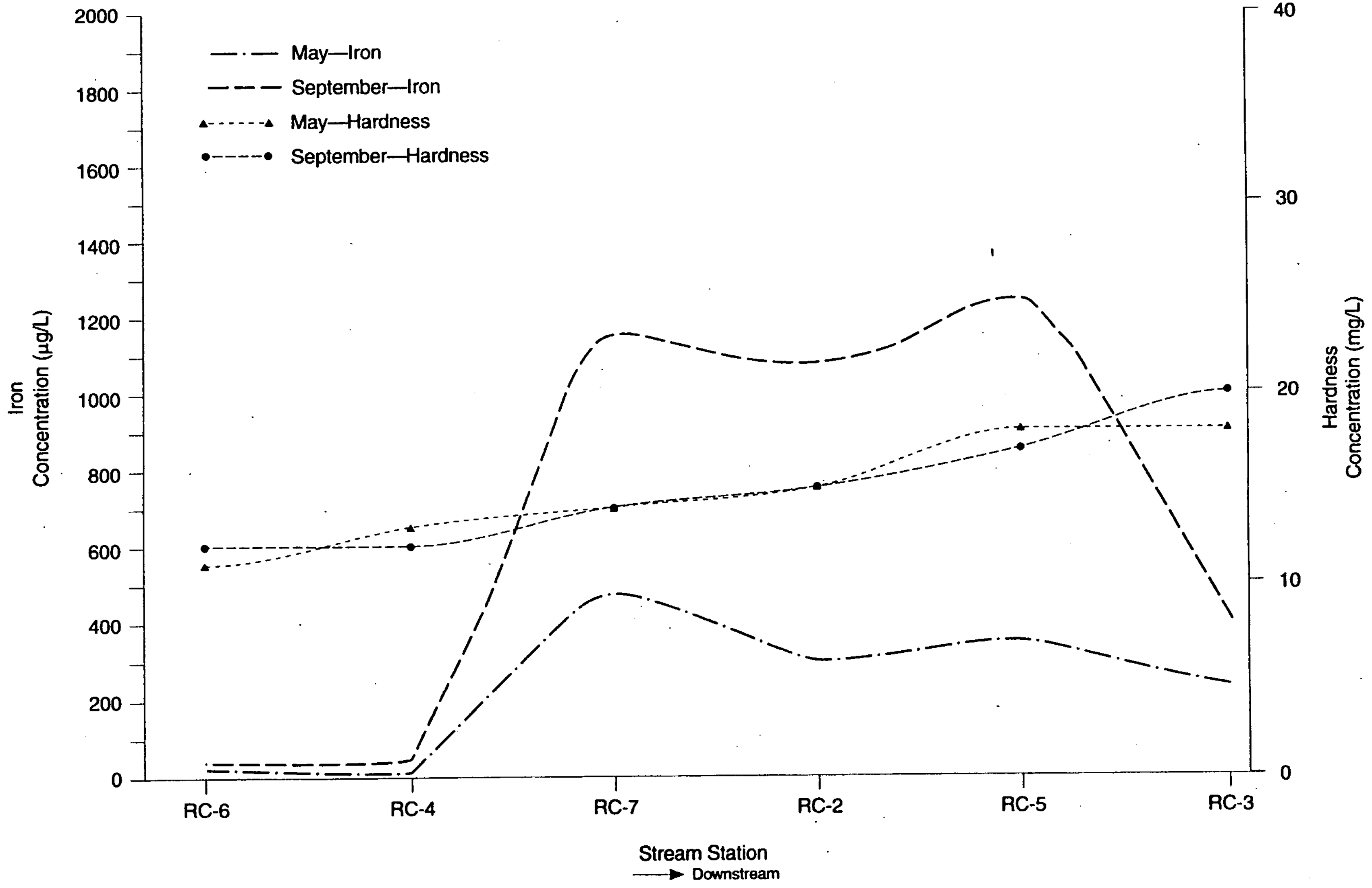

Figure 5.3-12

MAY AND SEPTEMBER 1997 IRON AND HARDNESS CONCENTRATIONS

DAMES & MOORE
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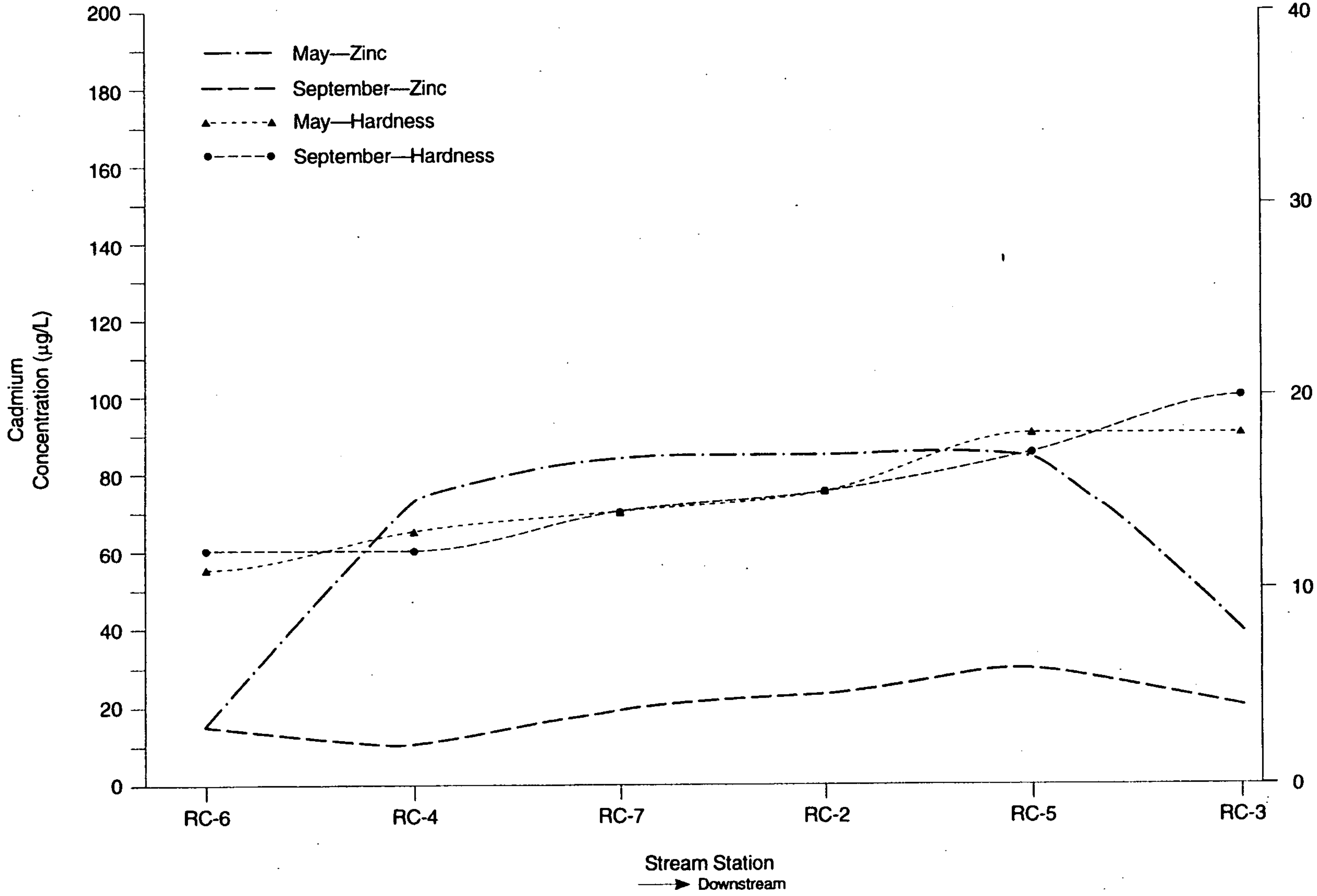

Figure 5.3-13

MAY AND SEPTEMBER 1997
ZINC AND HARDNESS CONCENTRATIONS

DAMES & MOORE
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Holden Mine RI/FS
Draft Final RI Report

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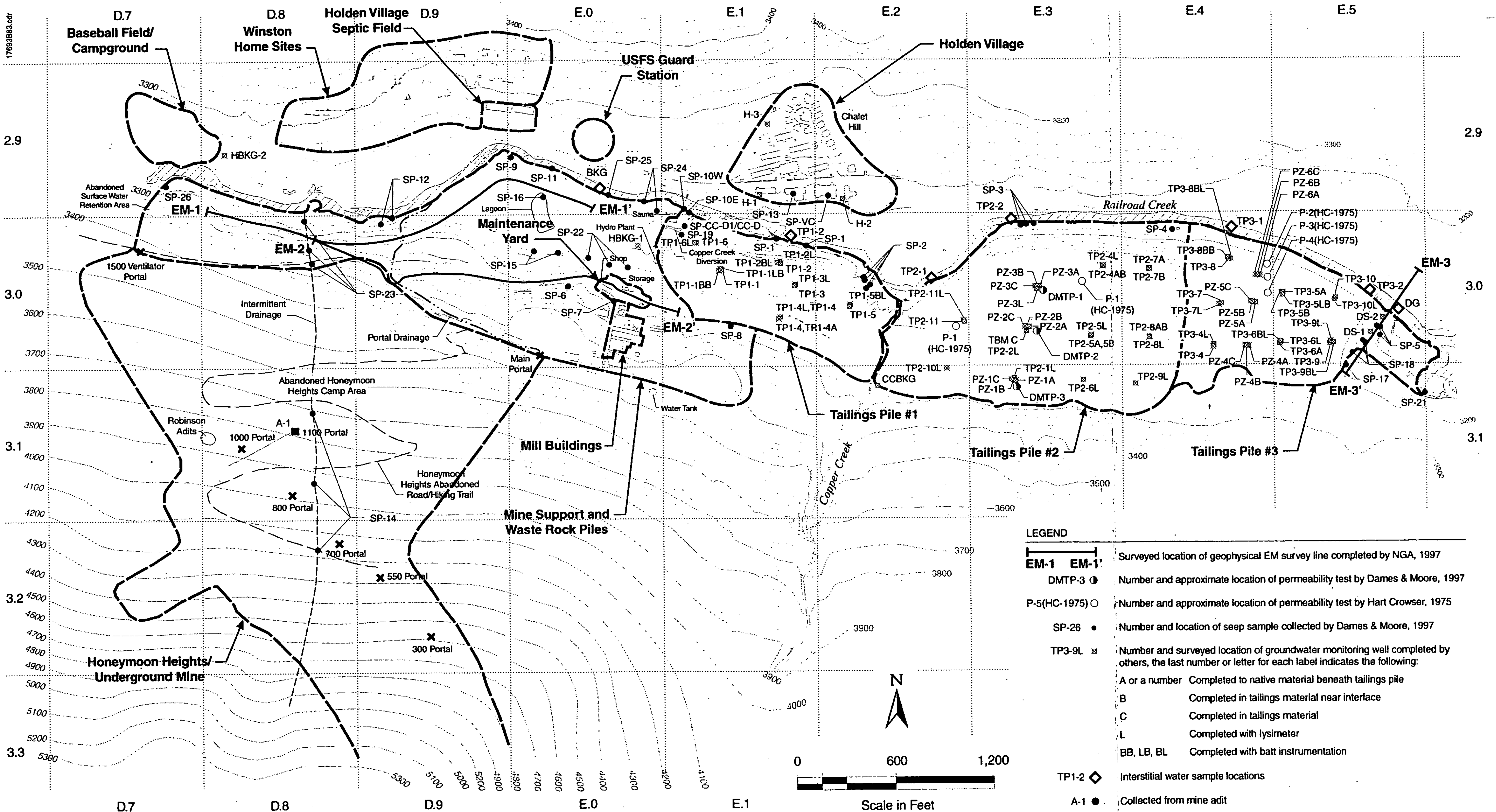

SOURCE: Base map information from USFS and Washington DNR, DEM CD ROM

Figure 5.4-1

RI HYDROGEOLOGIC INVESTIGATION LOCATIONS—SITE

DAMES & MOORE
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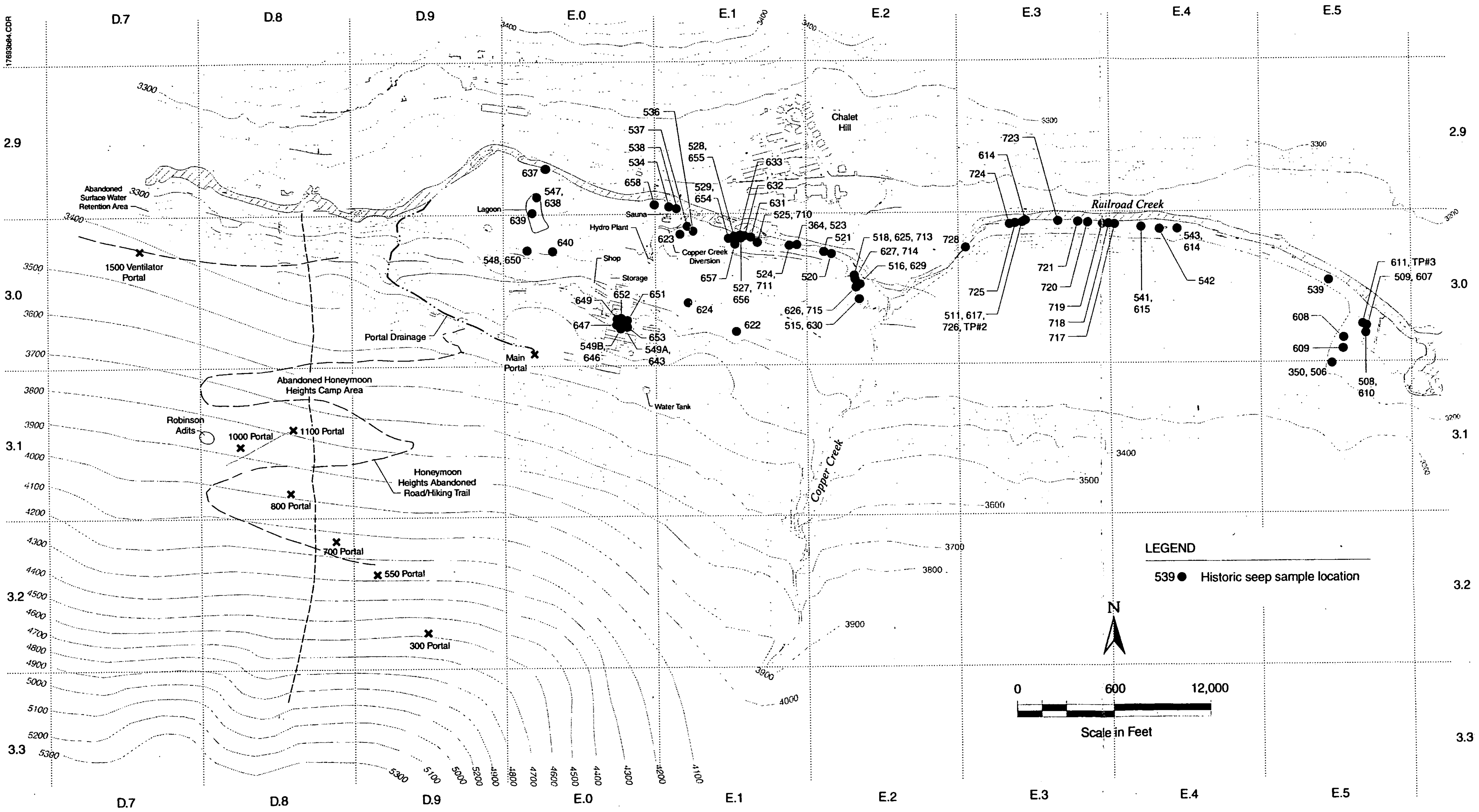
Job No. 17693-005-019



SOURCE: Base map information from USFS and Washington DNR, DEM CD ROM

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Figure 5.4-2

HISTORICAL SEEP SAMPLE LOCATIONS

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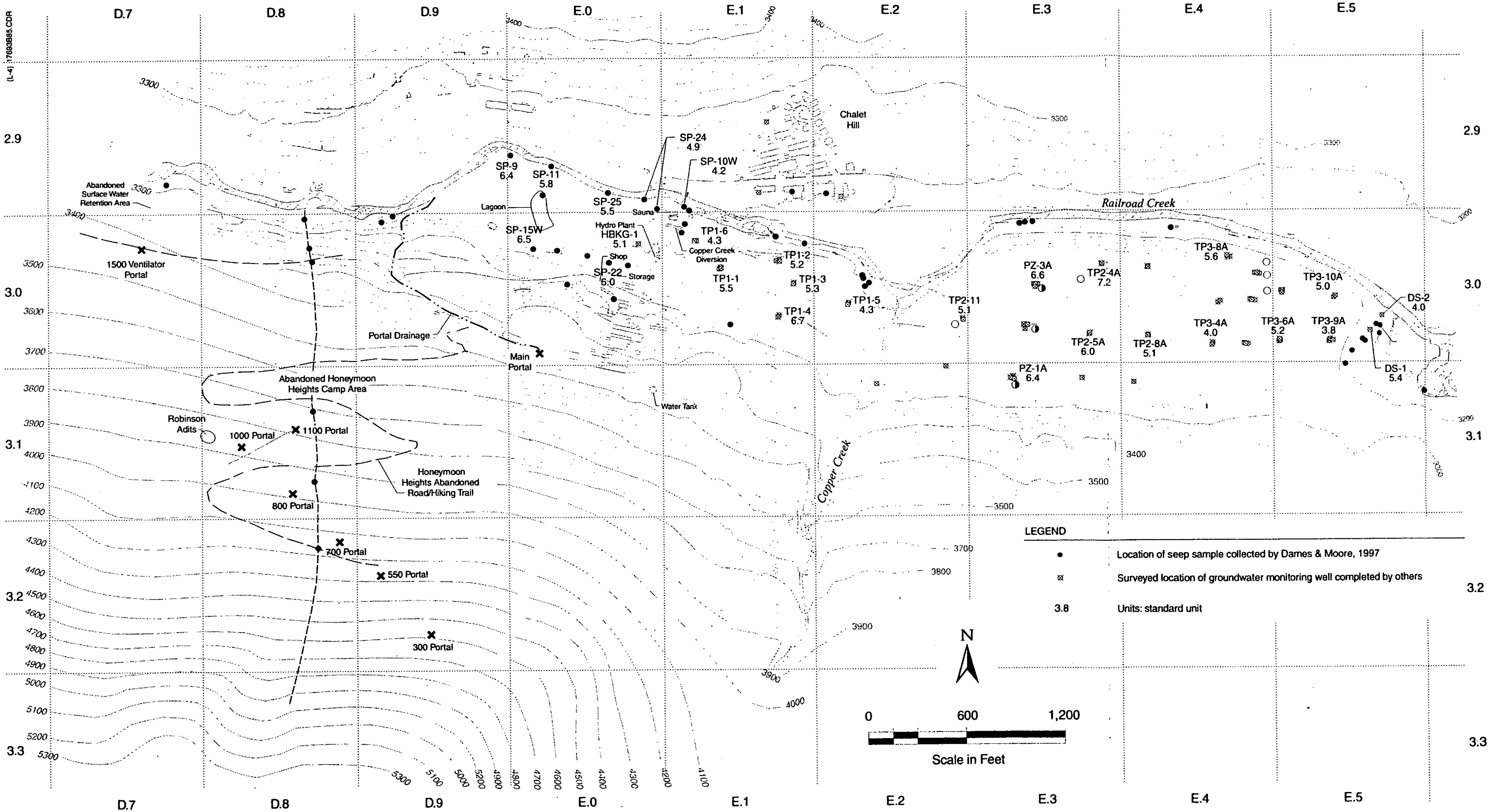

SOURCE: Base map information from USFS and Washington DNR, DEM CD ROM

Figure 5.4-3

pH, MAY 1997

WELLS COMPLETED IN NATIVE MATERIAL; ASSOCIATED SEEPS

DAMES & MOORE
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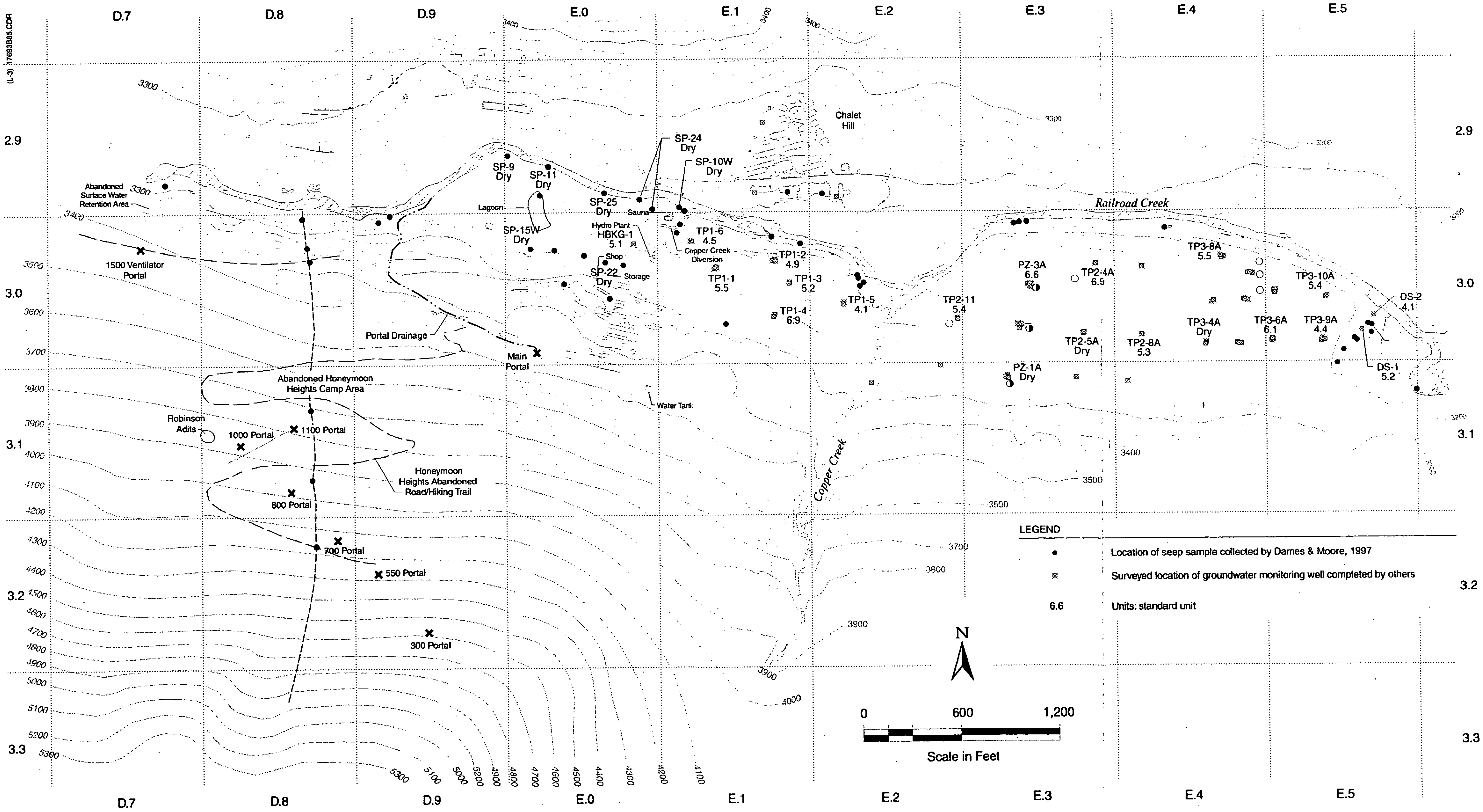

SOURCE: Base map information from USFS and Washington DNR, DEM CD ROM

Figure 5.4-4

pH, SEPTEMBER 1997
WELLS COMPLETED IN NATIVE MATERIAL; ASSOCIATED SEEPS

DAMES & MOORE
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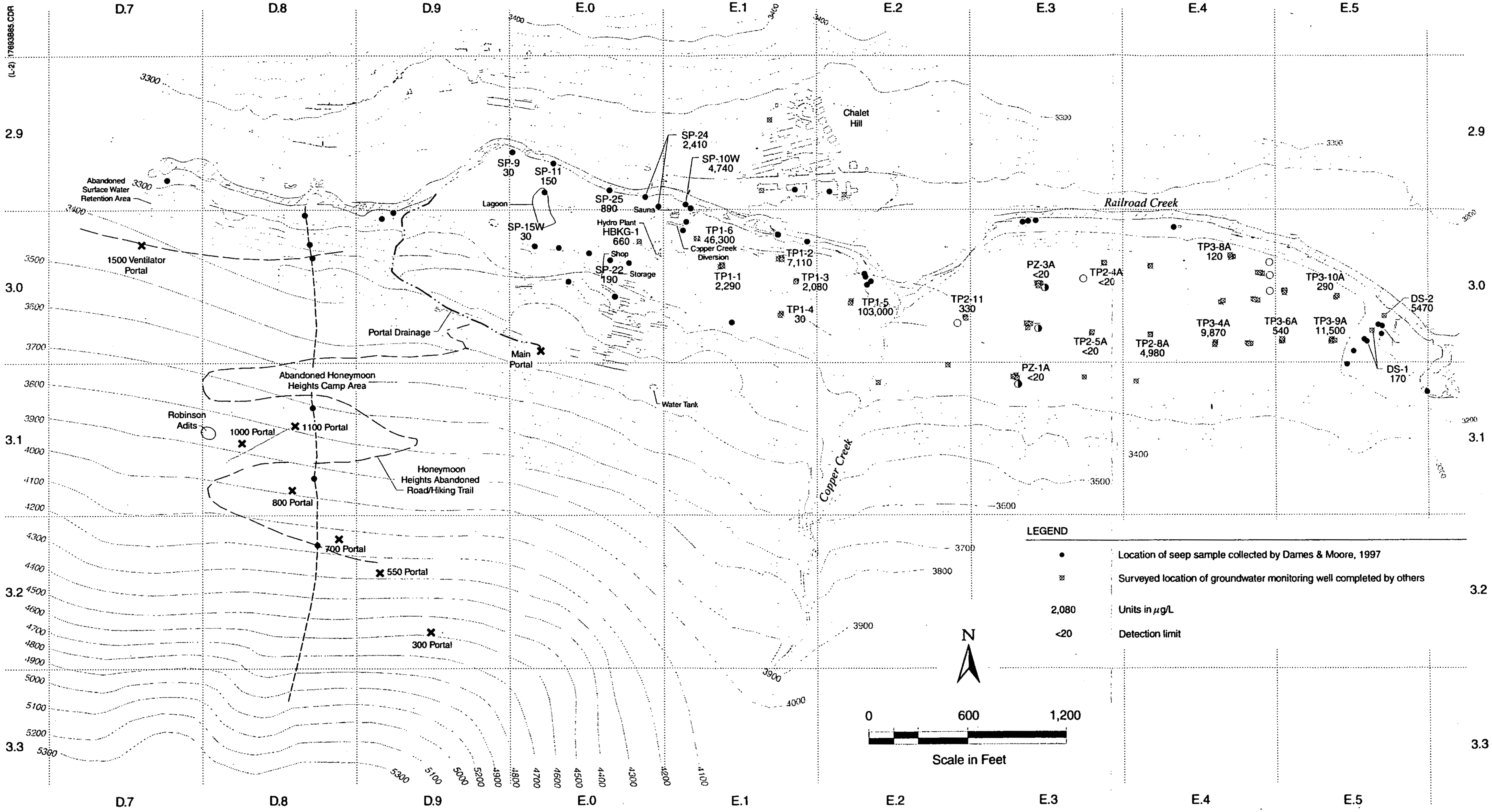
Job No. 17693-005-019



SOURCE: Base map information from USFS and Washington DNR, DEM CD ROM

Figure 5.4-5

DISSOLVED ALUMINUM CONCENTRATION, MAY 1997 WELLS COMPLETED IN NATIVE MATERIAL; ASSOCIATED SEEPS

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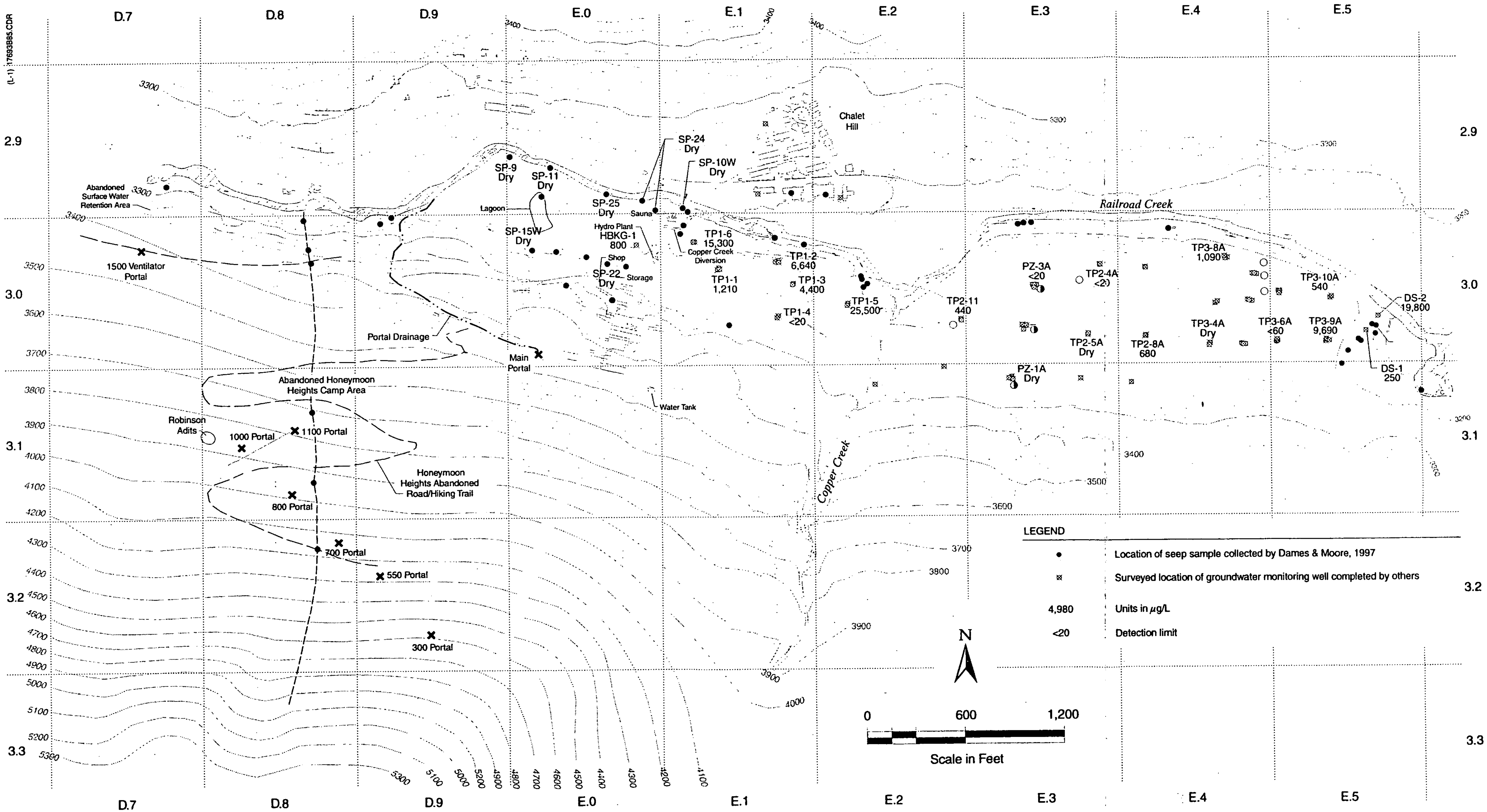

SOURCE: Base map information from USFS and Washington DNR, DEM CD ROM

Figure 5.4-6

DISSOLVED ALUMINUM CONCENTRATION, SEPTEMBER 1997
WELLS COMPLETED IN NATIVE MATERIAL; ASSOCIATED SEEPS

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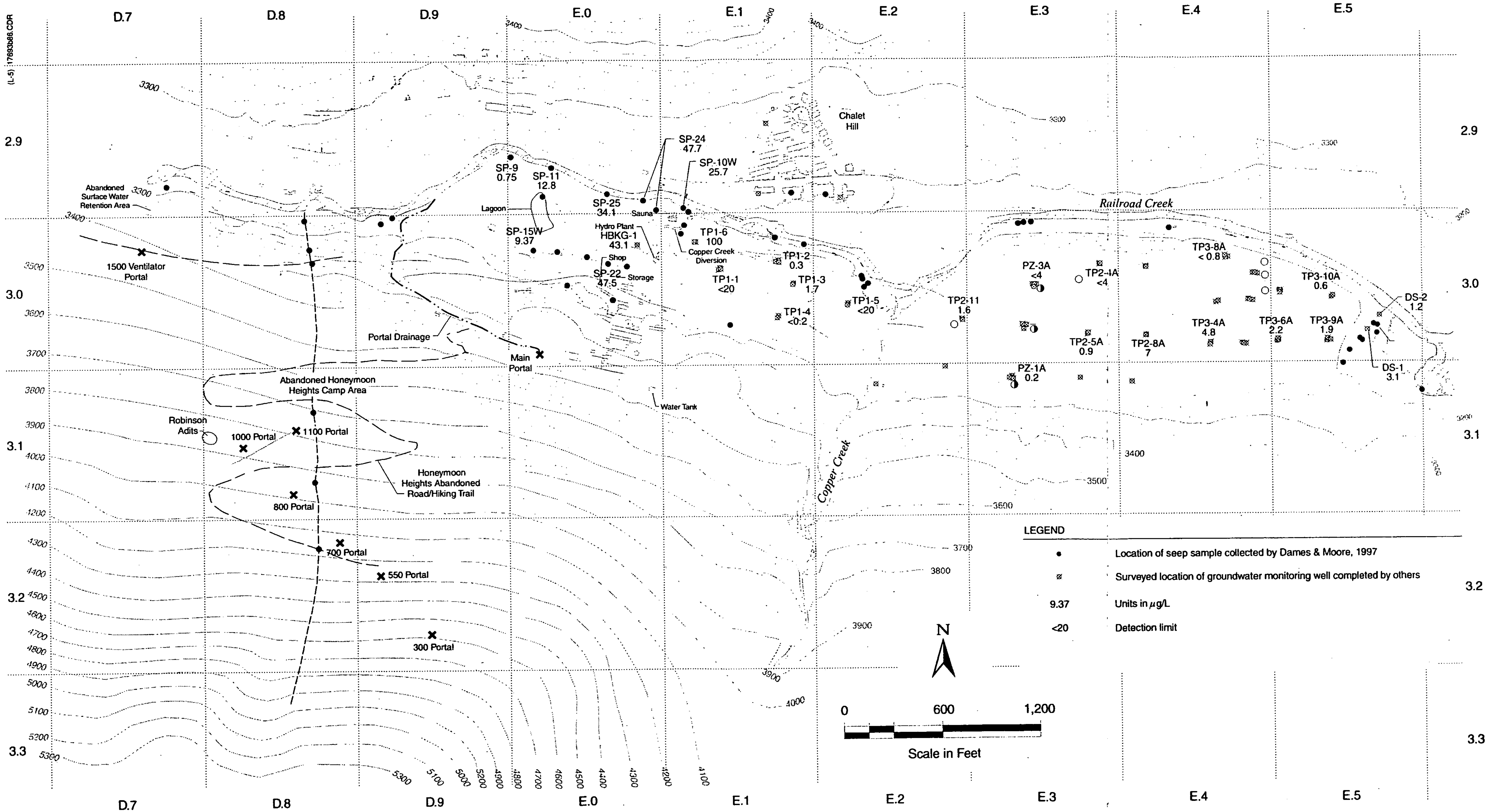

SOURCE: *Base map information from USFS and Washington DNR, DEM CD ROM*

Figure 5.4-7

DISSOLVED CADMIUM CONCENTRATION, MAY 1997
WELLS COMPLETED IN NATIVE MATERIAL; ASSOCIATED SEEPS

DAMES & MOORE
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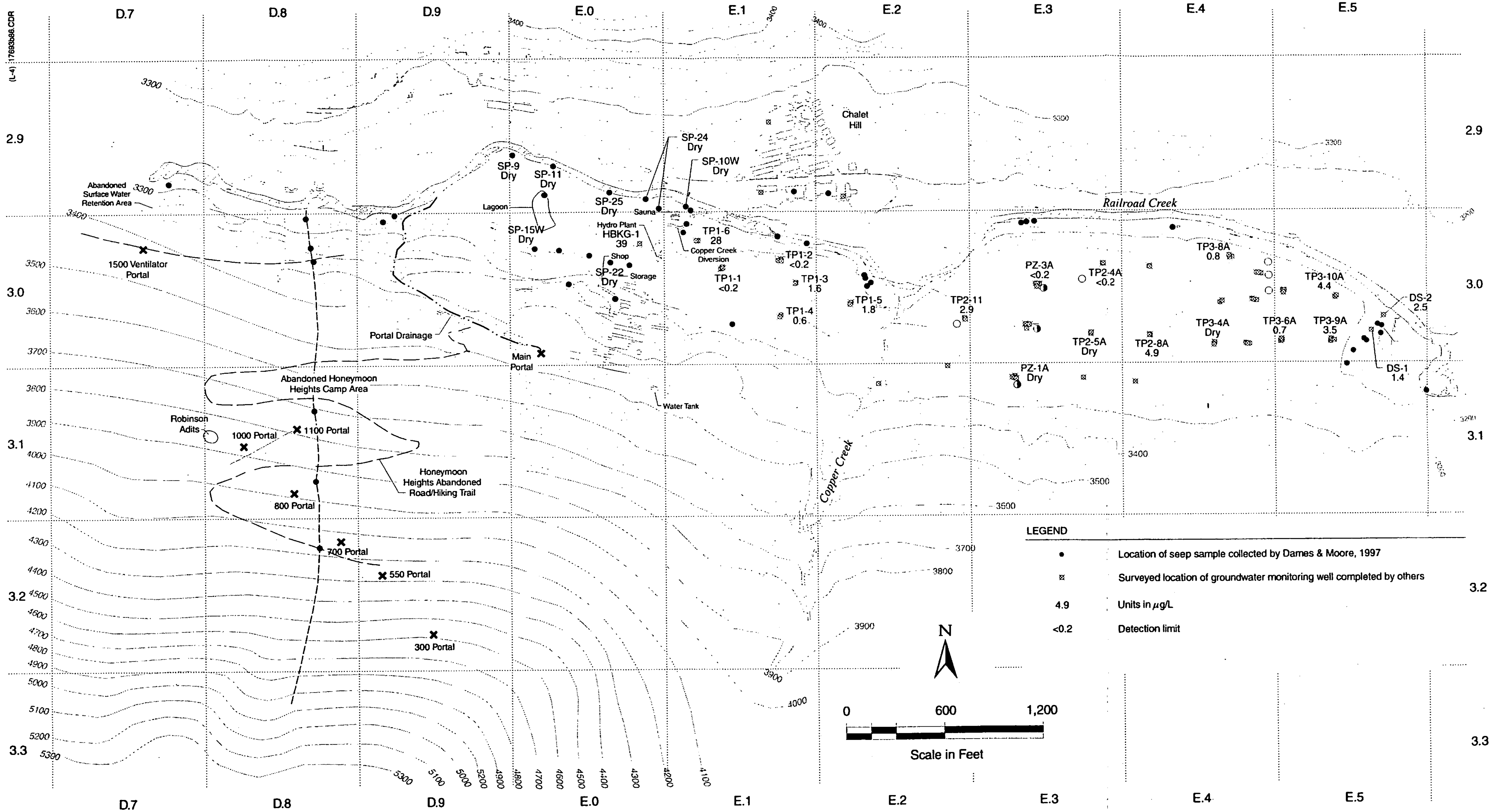
Job No. 17693-005-019



SOURCE: Base map information from USFS and Washington DNR, DEM CD ROM

Figure 5.4-8

DISSOLVED CADMIUM CONCENTRATION, SEPTEMBER 1997
WELLS COMPLETED IN NATIVE MATERIAL; ASSOCIATED SEEPS

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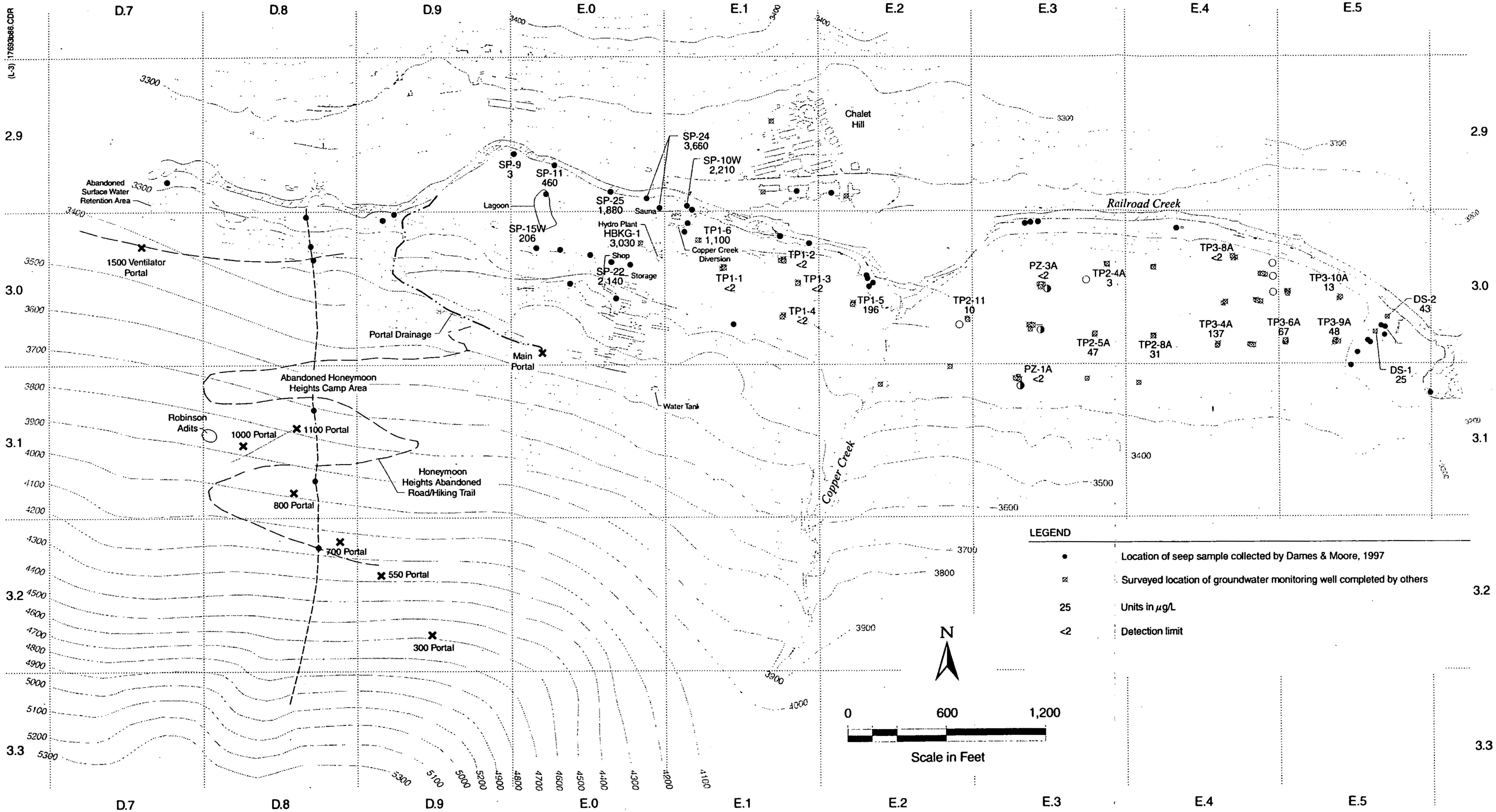

SOURCE: Base map information from USFS and Washington DNR, DEM CD ROM

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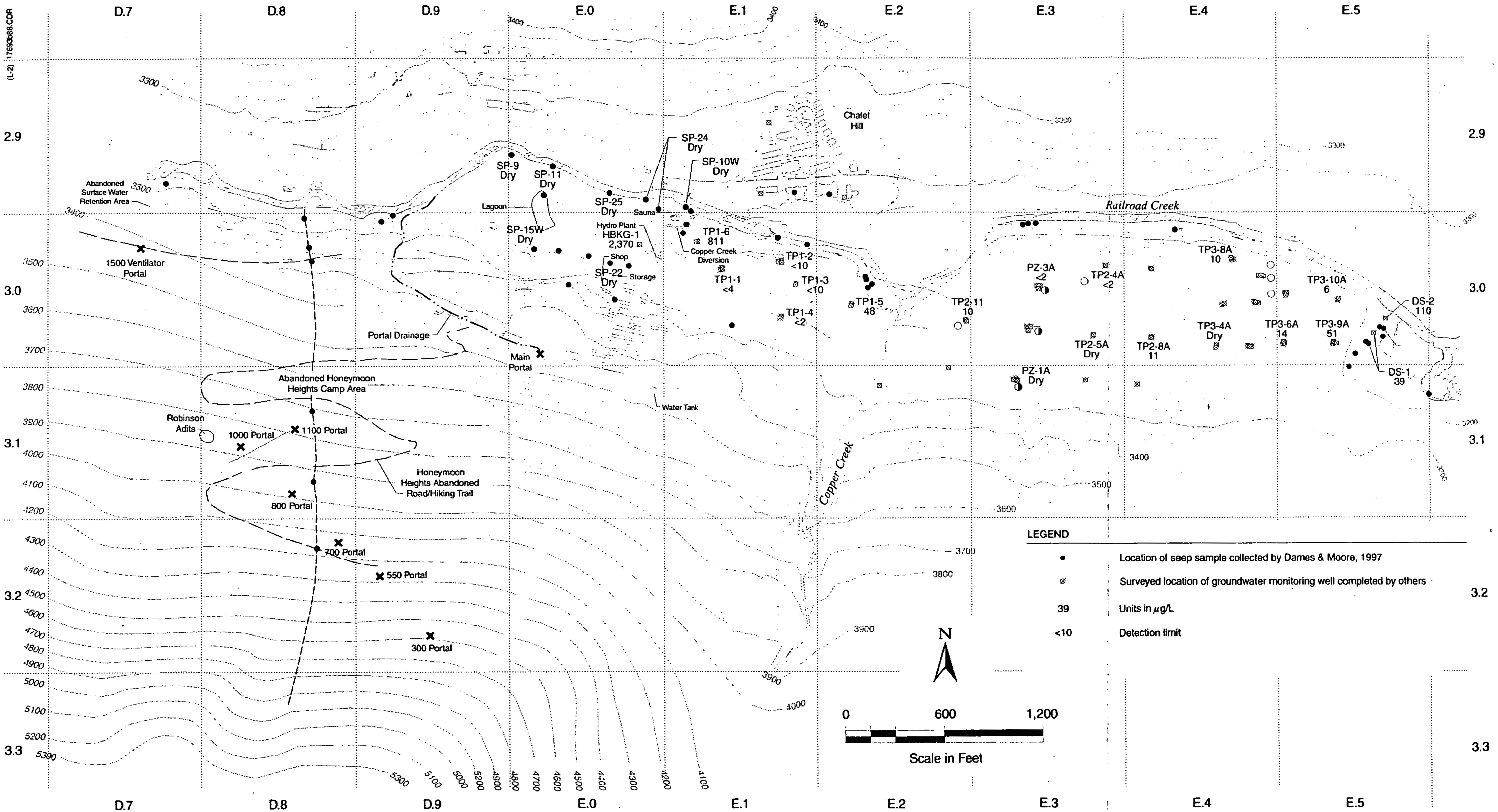
Figure 5.4-9

DISSOLVED COPPER CONCENTRATION, MAY 1997
WELLS COMPLETED IN NATIVE MATERIAL; ASSOCIATED SEEPS



SOURCE: Base map information from USFS and Washington DNR, DEM CD ROM

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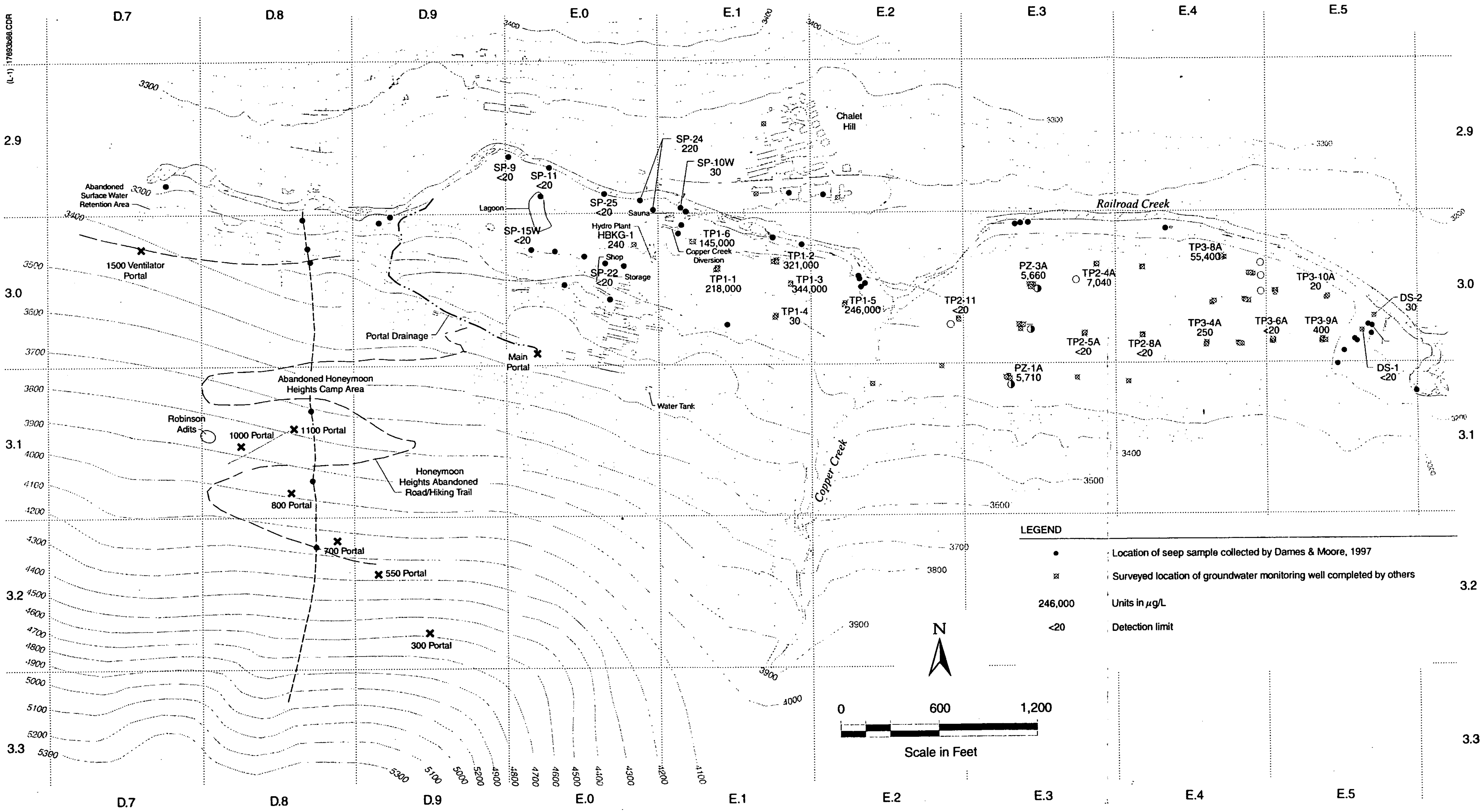
Figure 5.4-10

DISSOLVED COPPER CONCENTRATION, SEPTEMBER 1997
WELLS COMPLETED IN NATIVE MATERIAL; ASSOCIATED SEEPS



LEGEND

●	Location of seep sample collected by Dames & Moore, 1997
⊠	Surveyed location of groundwater monitoring well completed by others
246,000	Units in μg/L
<20	Detection limit

SOURCE: Base map information from USFS and Washington DNR, DEM CD ROM

Figure 5.4-11

DISSOLVED IRON CONCENTRATION, MAY 1997
WELLS COMPLETED IN NATIVE MATERIAL; ASSOCIATED SEEPS

DAMES & MOORE
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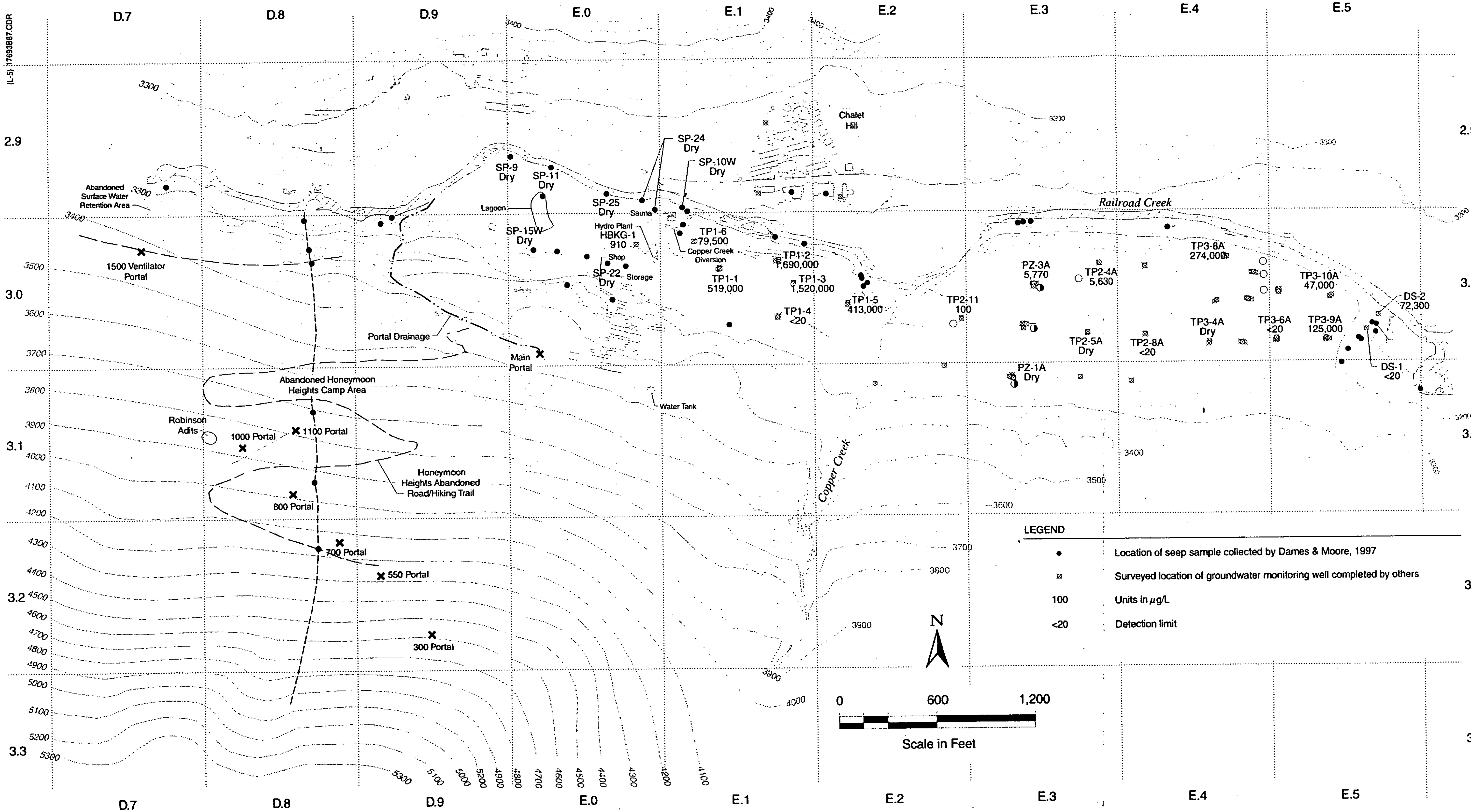

SOURCE: Base map information from USFS and Washington DNR, DEM CD ROM

Figure 5.4-12

DISSOLVED IRON CONCENTRATION, SEPTEMBER 1997 WELLS COMPLETED IN NATIVE MATERIAL; ASSOCIATED SEEPS

DAMES & MOORE
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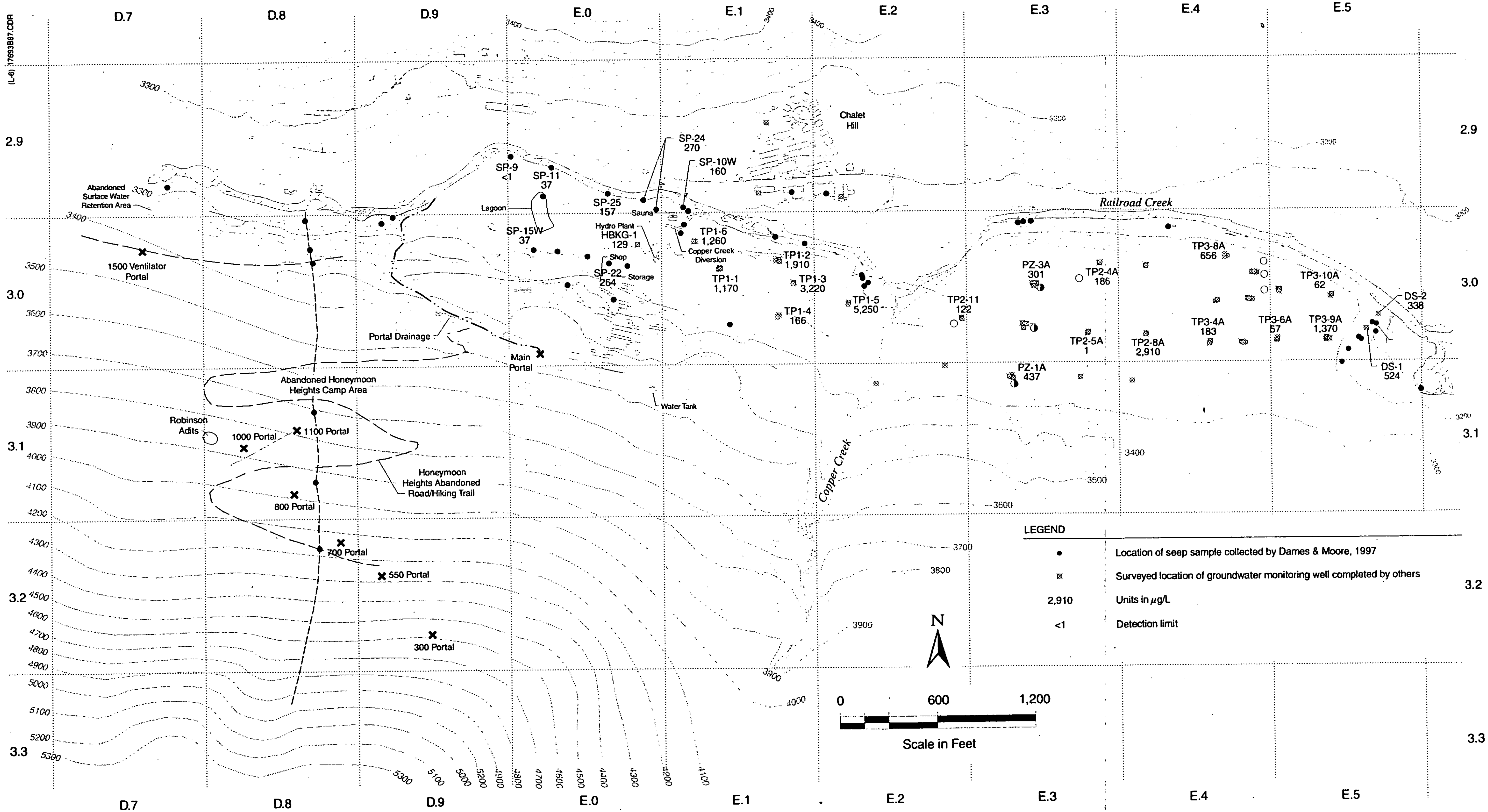

SOURCE: Base map information from USFS and Washington DNR, DEM CD ROM

Figure 5.4-13

DISSOLVED MANGANESE CONCENTRATION, MAY 1997
WELLS COMPLETED IN NATIVE MATERIAL; ASSOCIATED SEEPS

DAMES & MOORE
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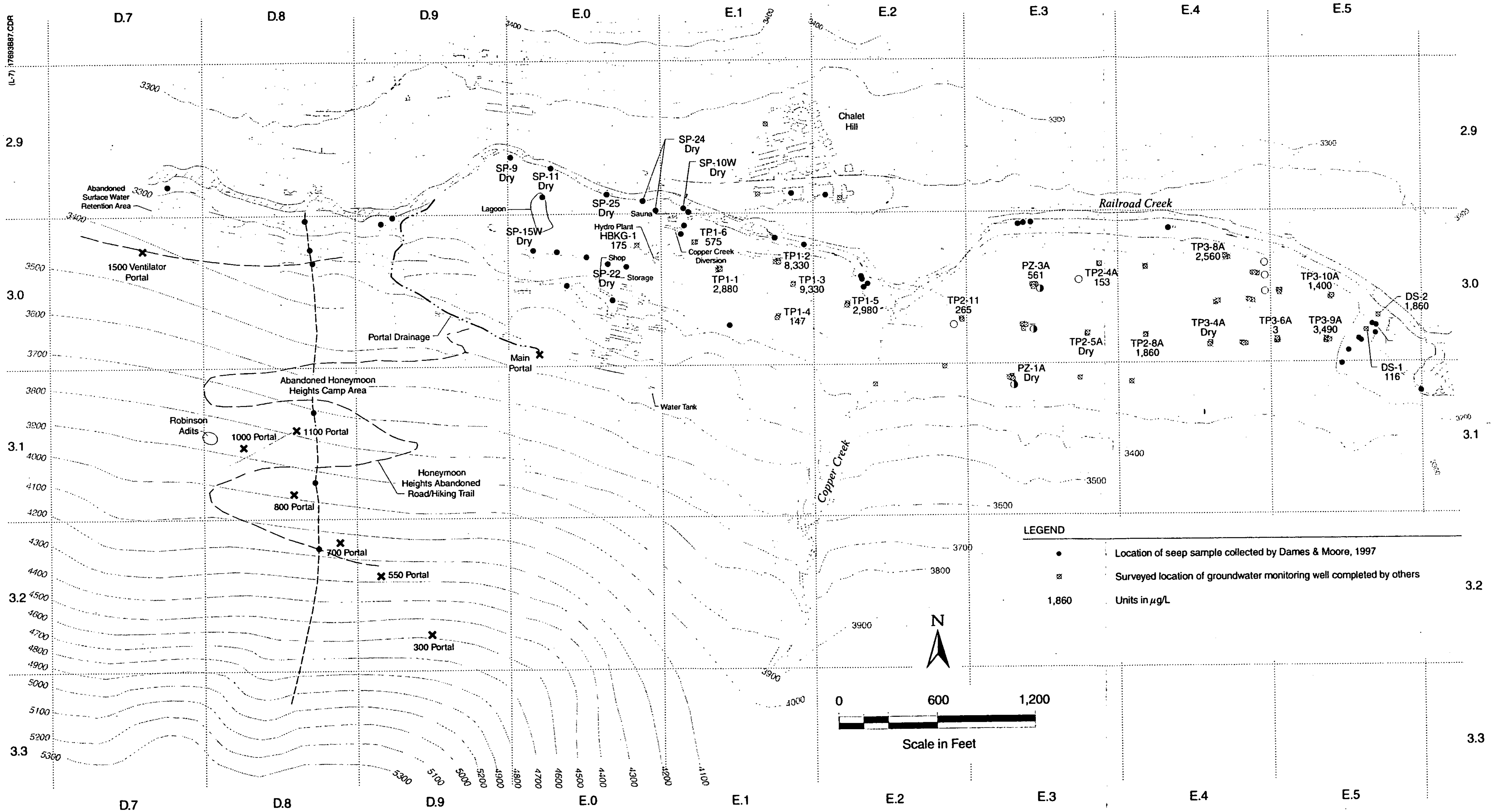
(L-7) 17693B87.CDR



SOURCE: Base map information from USFS and Washington DNR, DEM CD ROM

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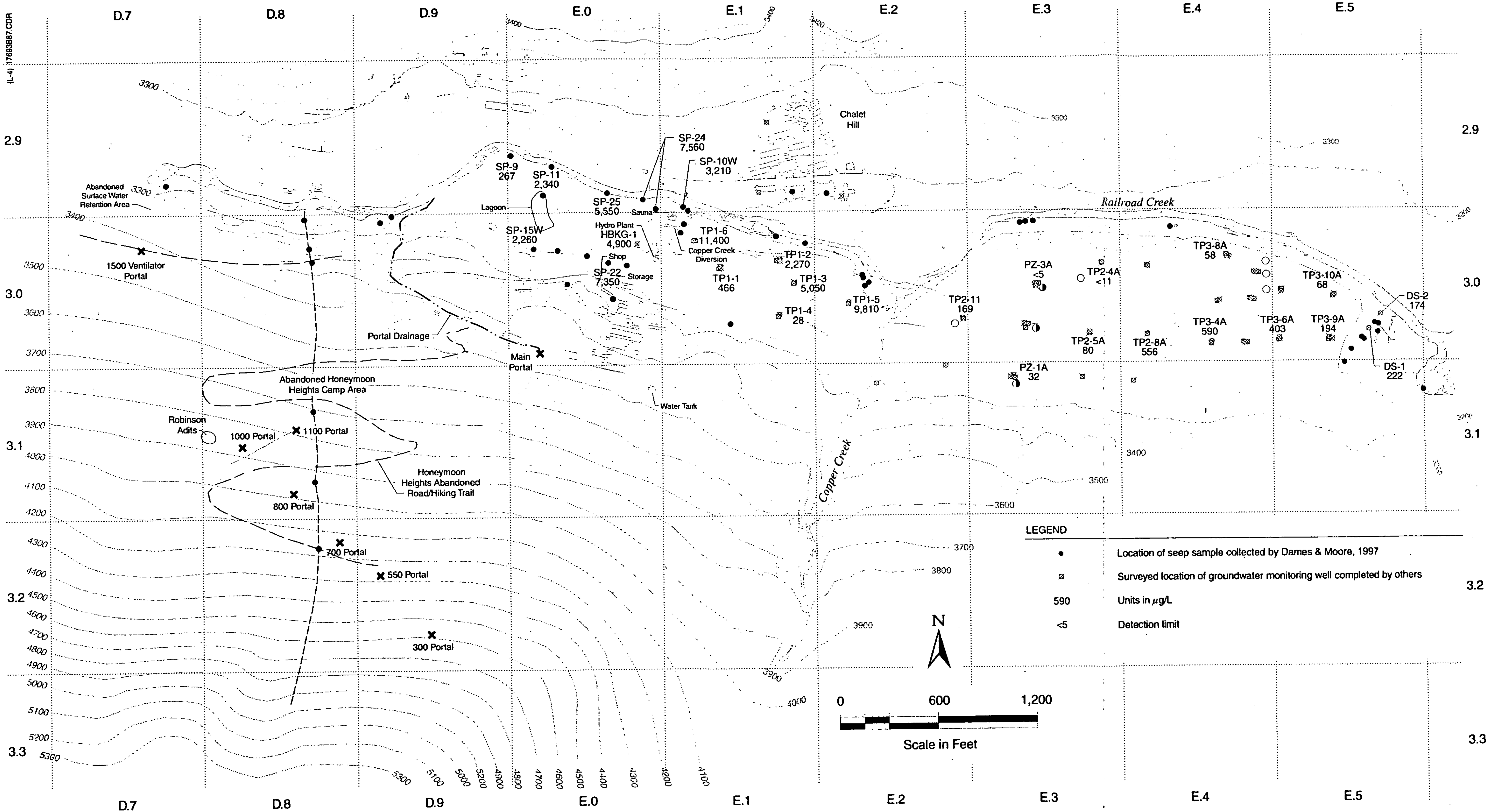
Job No. 17693-005-019

Figure 5.4-14

DISSOLVED MANGANESE CONCENTRATION, SEPTEMBER 1997 WELLS COMPLETED IN NATIVE MATERIAL; ASSOCIATED SEEPS



SOURCE: Base map information from USFS and Washington DNR, DEM CD ROM

Figure 5.4-15

DISSOLVED ZINC CONCENTRATION, MAY 1997
WELLS COMPLETED IN NATIVE MATERIAL; ASSOCIATED SEEPS

DAMES & MOORE
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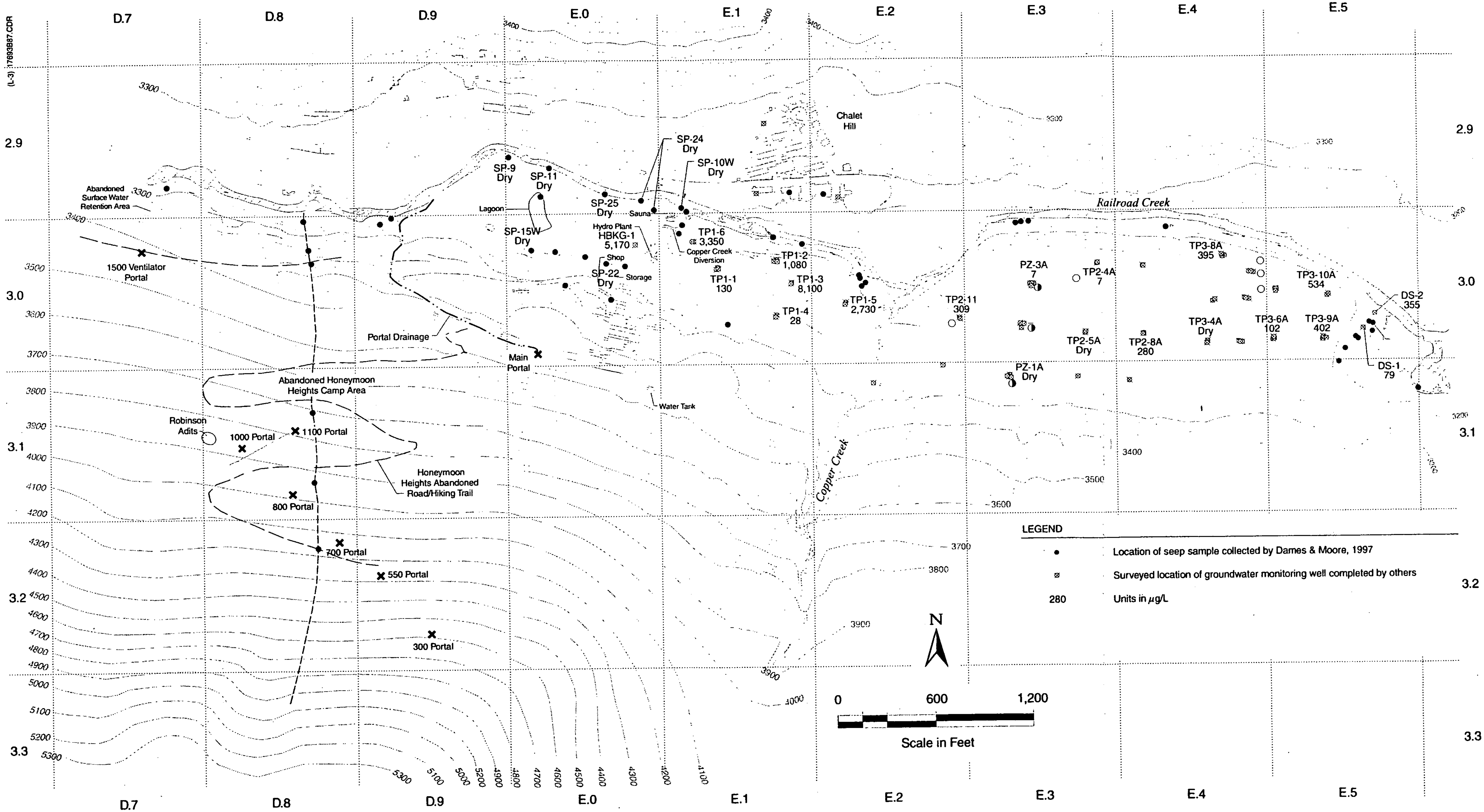

SOURCE: *Base map information from USFS and Washington DNR, DEM CD ROM*

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Figure 5.4-16

DISSOLVED ZINC CONCENTRATION, SEPTEMBER 1997 WELLS COMPLETED IN NATIVE MATERIAL; ASSOCIATED SEEPS

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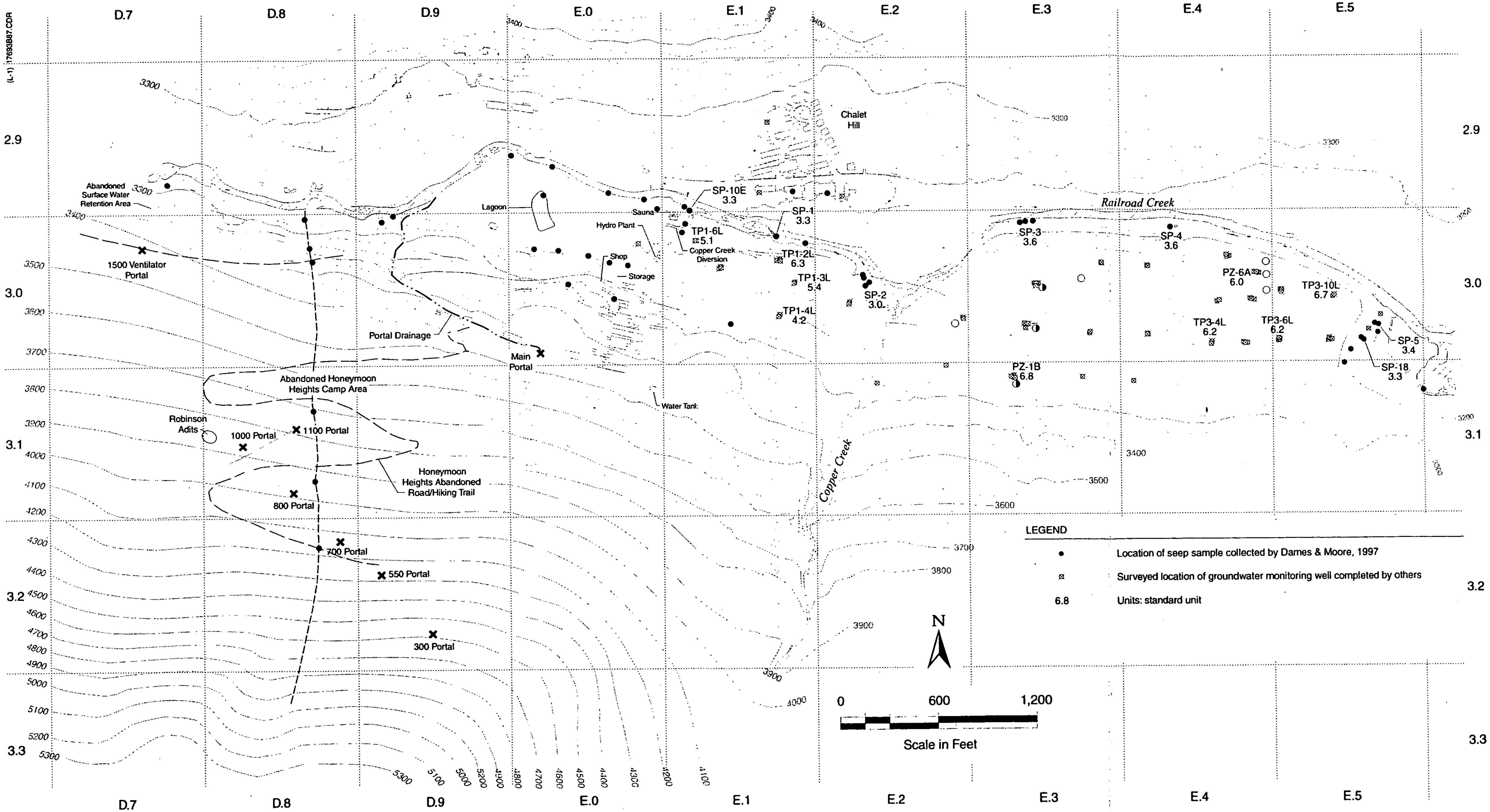

SOURCE: Base map information from USFS and Washington DNR, DEM CD ROM

Figure 5.4-17

pH, MAY 1997

WELLS/LYSIMETERS COMPLETED IN TAILINGS; ASSOCIATED SEEPS

DAMES & MOORE
GROUP
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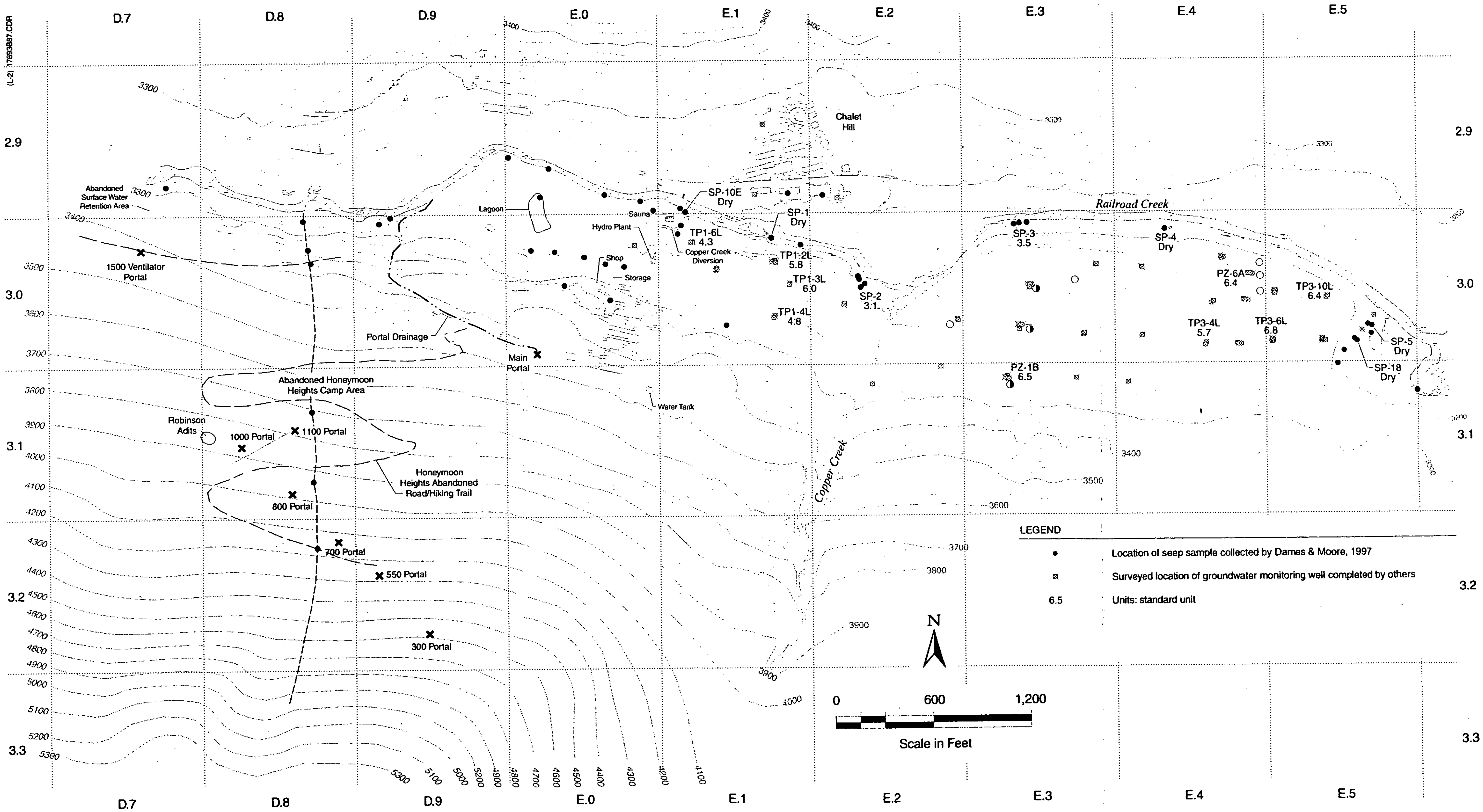


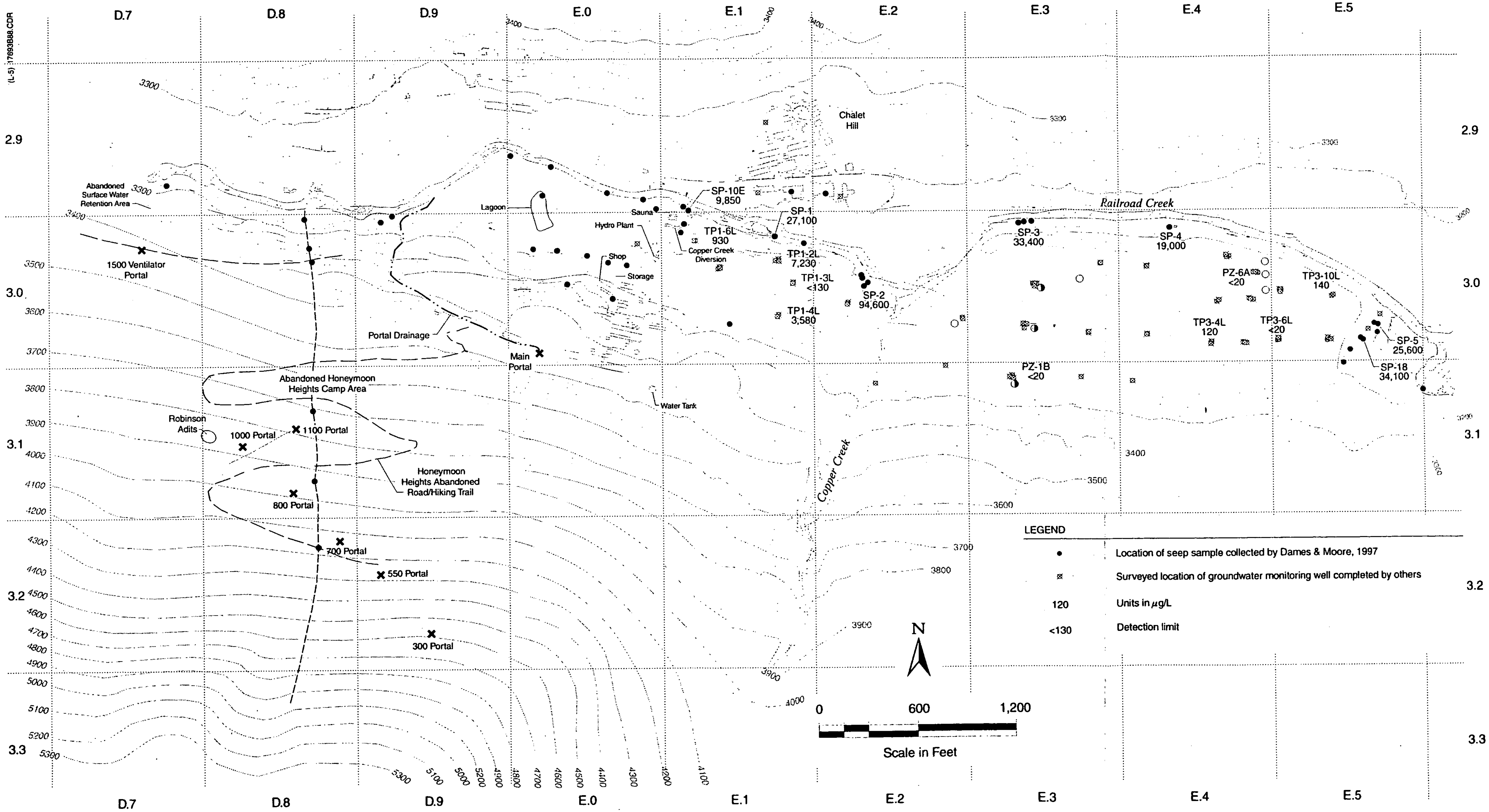
SOURCE: Base map information from USFS and Washington DNR, DEM CD ROM

Figure 5.4-18

pH, SEPTEMBER 1997
WELLS/LYSIMETERS COMPLETED IN TAILINGS; ASSOCIATED SEEPS

DAMES & MOORE
A DAMES & MOORE GROUP COMPANY

Job No. 17693-005-019



SOURCE: Base map information from USFS and Washington DNR, DEM CD ROM

Figure 5.4-19

DISSOLVED ALUMINUM CONCENTRATION, MAY 1997
WELLS/LYSIMETERS COMPLETED IN TAILINGS; ASSOCIATED SEEPS

DAMES & MOORE
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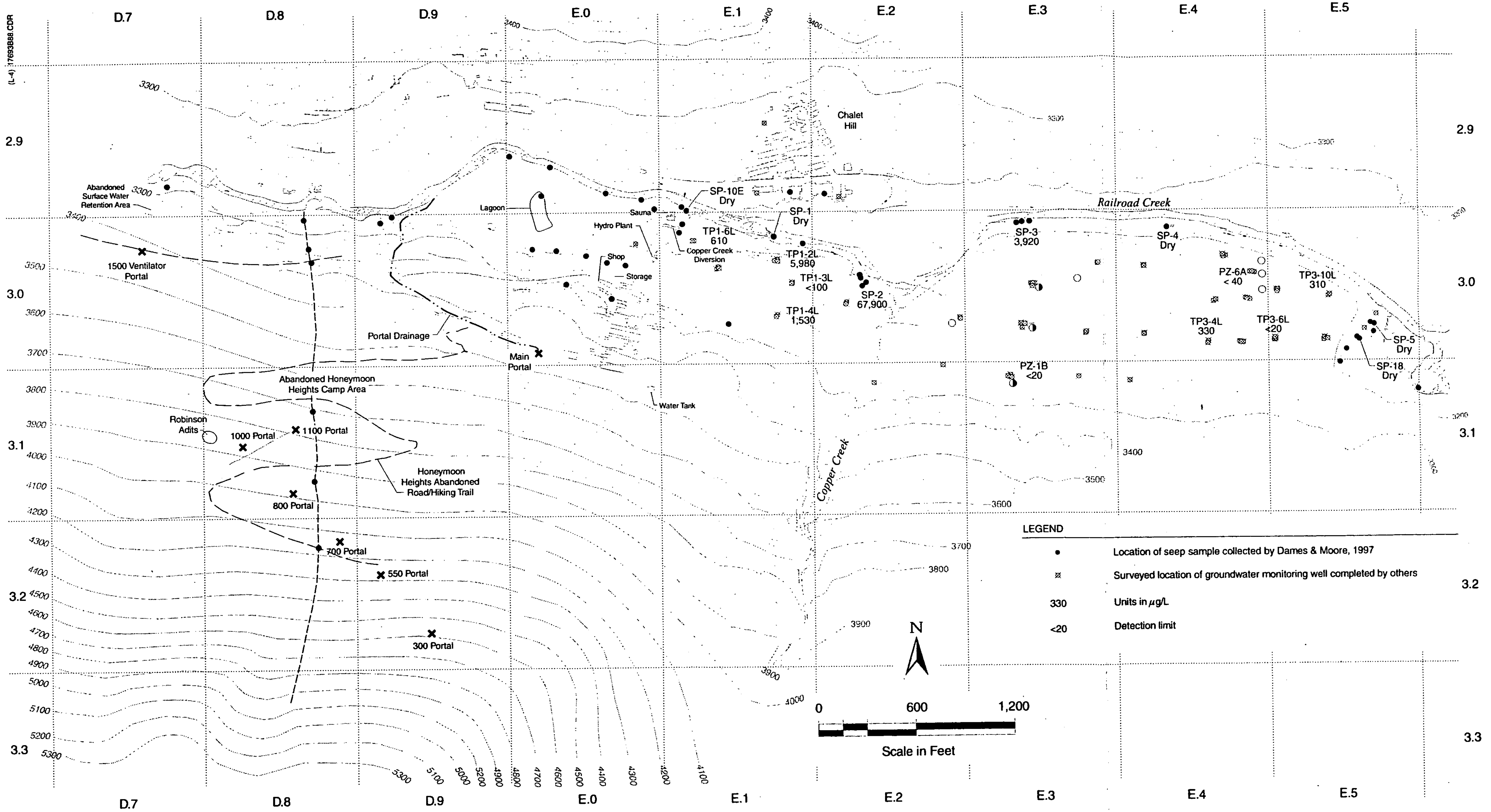
Job No. 17693-005-019



SOURCE: Base map information from USFS and Washington DNR, DEM CD ROM

Figure 5.4-20

DISSOLVED ALUMINUM CONCENTRATION, SEPTEMBER 1997
WELLS/LYSIMETERS COMPLETED IN TAILINGS; ASSOCIATED SEEPS

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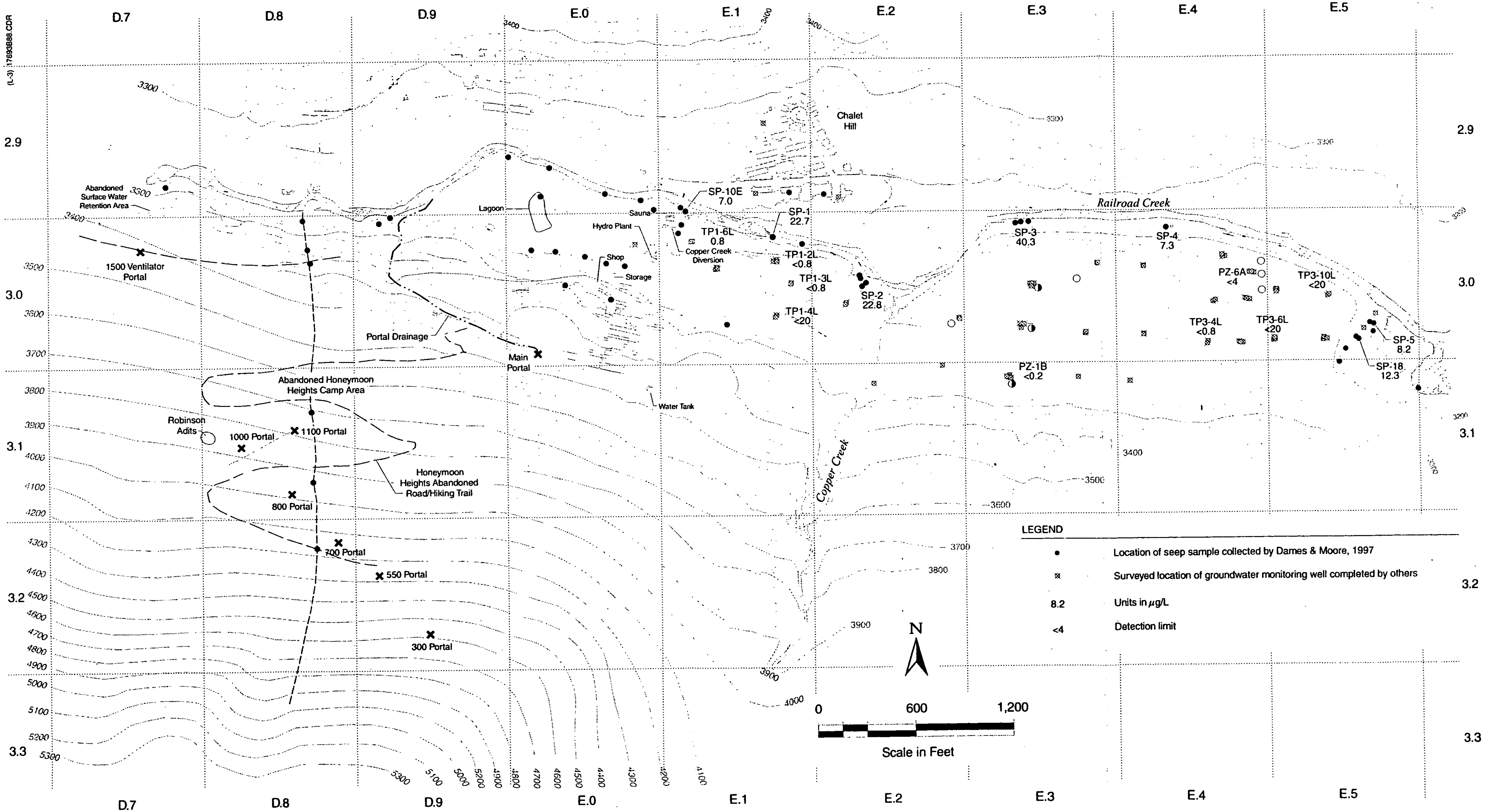

SOURCE: Base map information from USFS and Washington DNR, DEM CD ROM

Figure 5.4-21

DISSOLVED CADMIUM CONCENTRATION, MAY 1997
WELLS/LYSIMETERS COMPLETED IN TAILINGS; ASSOCIATED SEEPS

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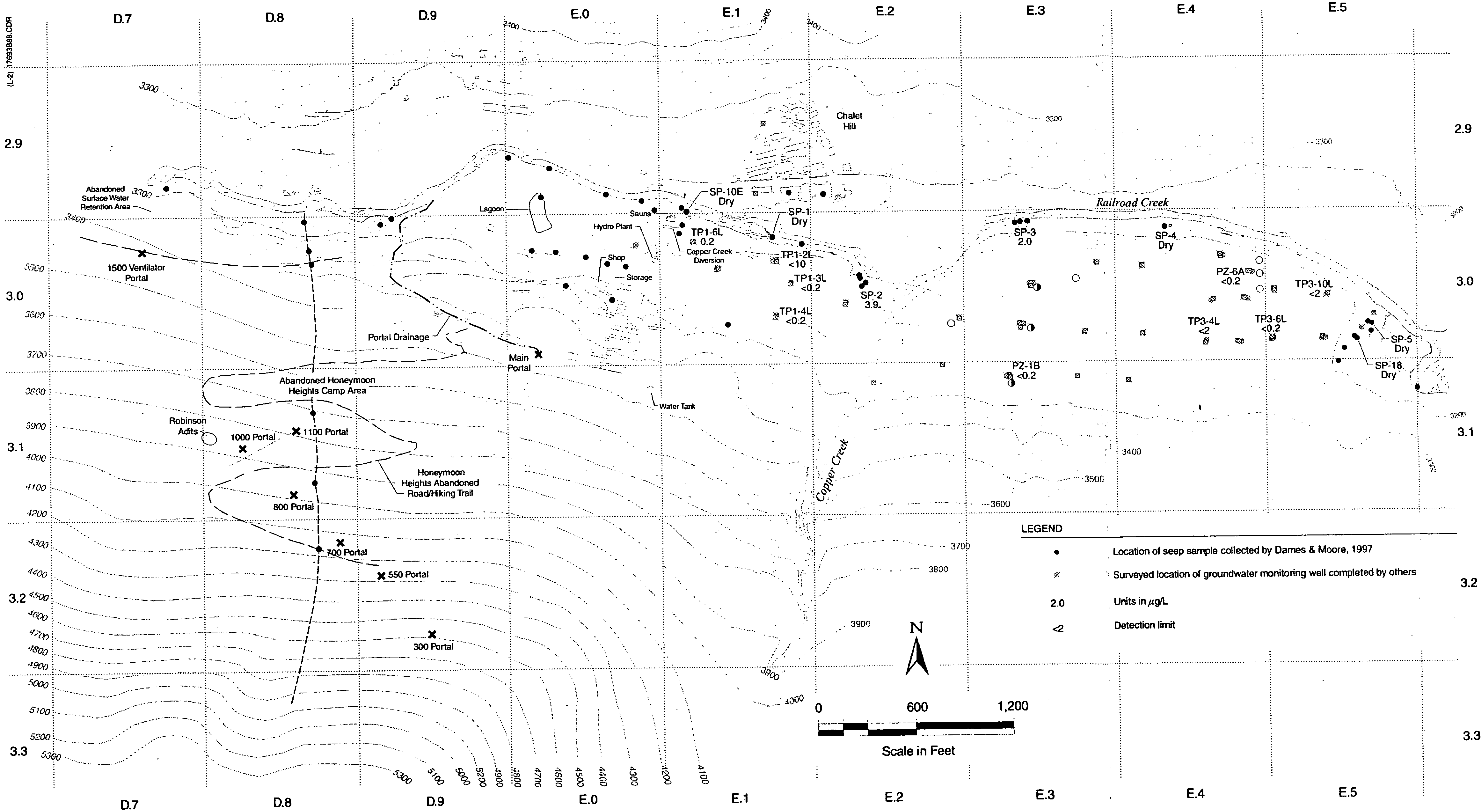
Job No. 17693-005-019



SOURCE: Base map information from USFS and Washington DNR, DEM CD ROM

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Figure 5.4-22

DISSOLVED CADMIUM CONCENTRATION, SEPTEMBER 1997 WELLS/LYSIMETERS COMPLETED IN TAILINGS; ASSOCIATED SEEPS

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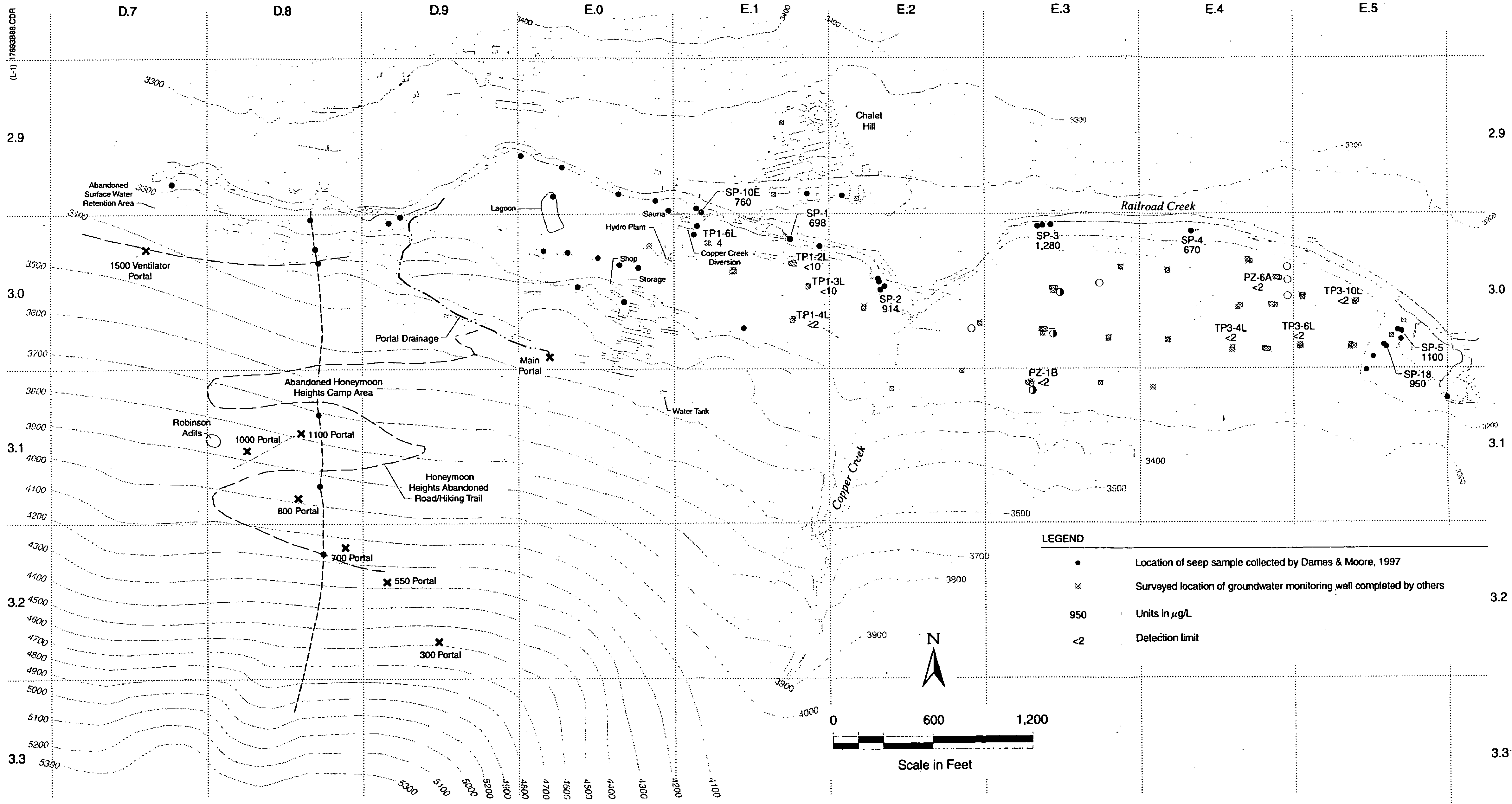
(L-1) 17693888.CDR



SOURCE: Base map information from USFS and Washington DNR, DEM CD ROM

DAMES & MOORE
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Job No. 17693-005-019

Figure 5.4-23

DISSOLVED COPPER CONCENTRATION, MAY 1997
WELLS/LYSIMETERS COMPLETED IN TAILINGS; ASSOCIATED SEEPS

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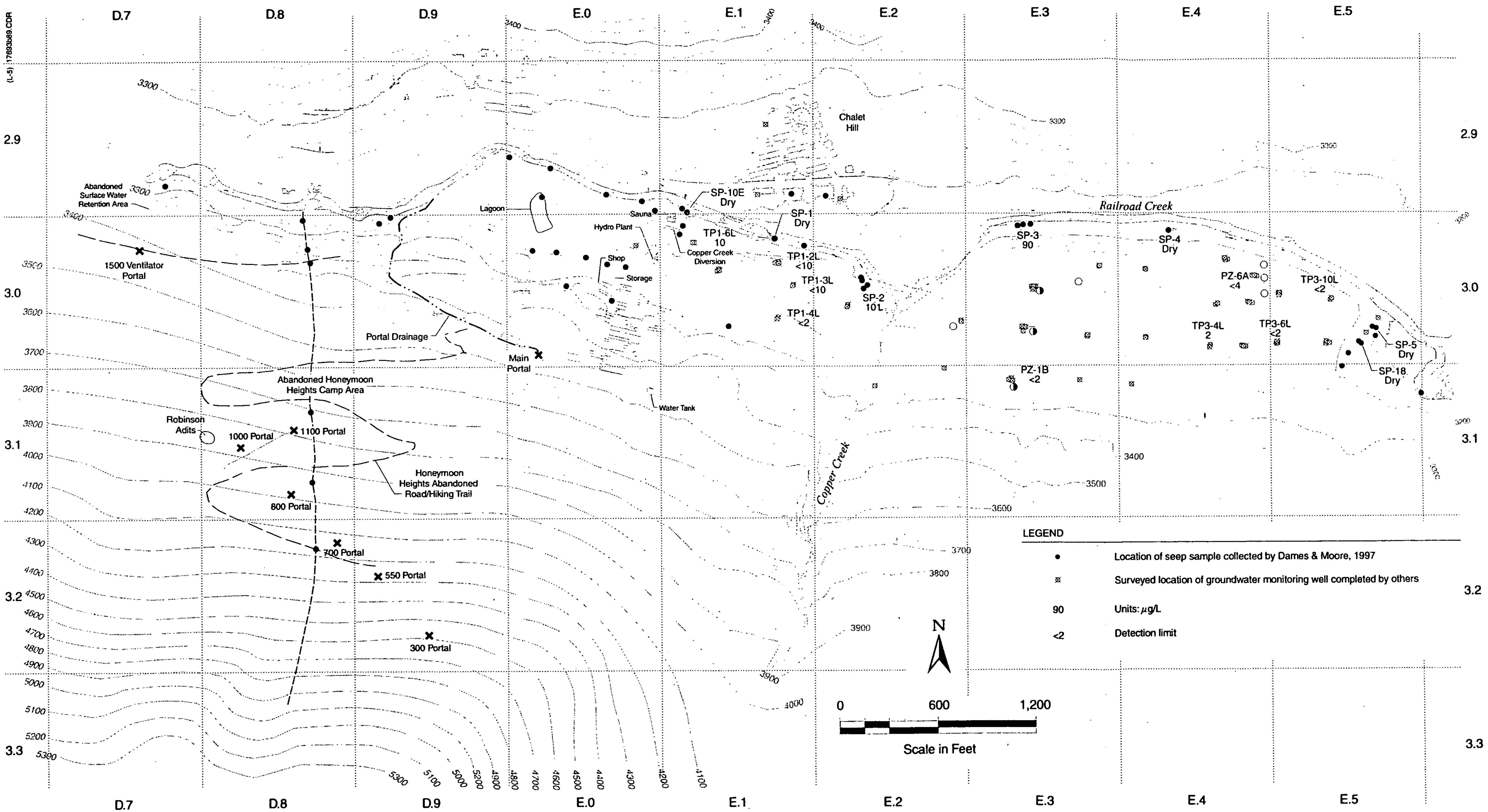
Draft Final RI Report



LEGEND

●	Location of seep sample collected by Dames & Moore, 1997
⊠	Surveyed location of groundwater monitoring well completed by others
90	Units: µg/L
<2	Detection limit

SOURCE: Base map information from USFS and Washington DNR, DEM CD ROM

Figure 5.4-24

DISSOLVED COPPER CONCENTRATION, SEPTEMBER 1997 WELLS/LYSIMETERS COMPLETED IN TAILINGS; ASSOCIATED SEEPS

DAMES & MOORE
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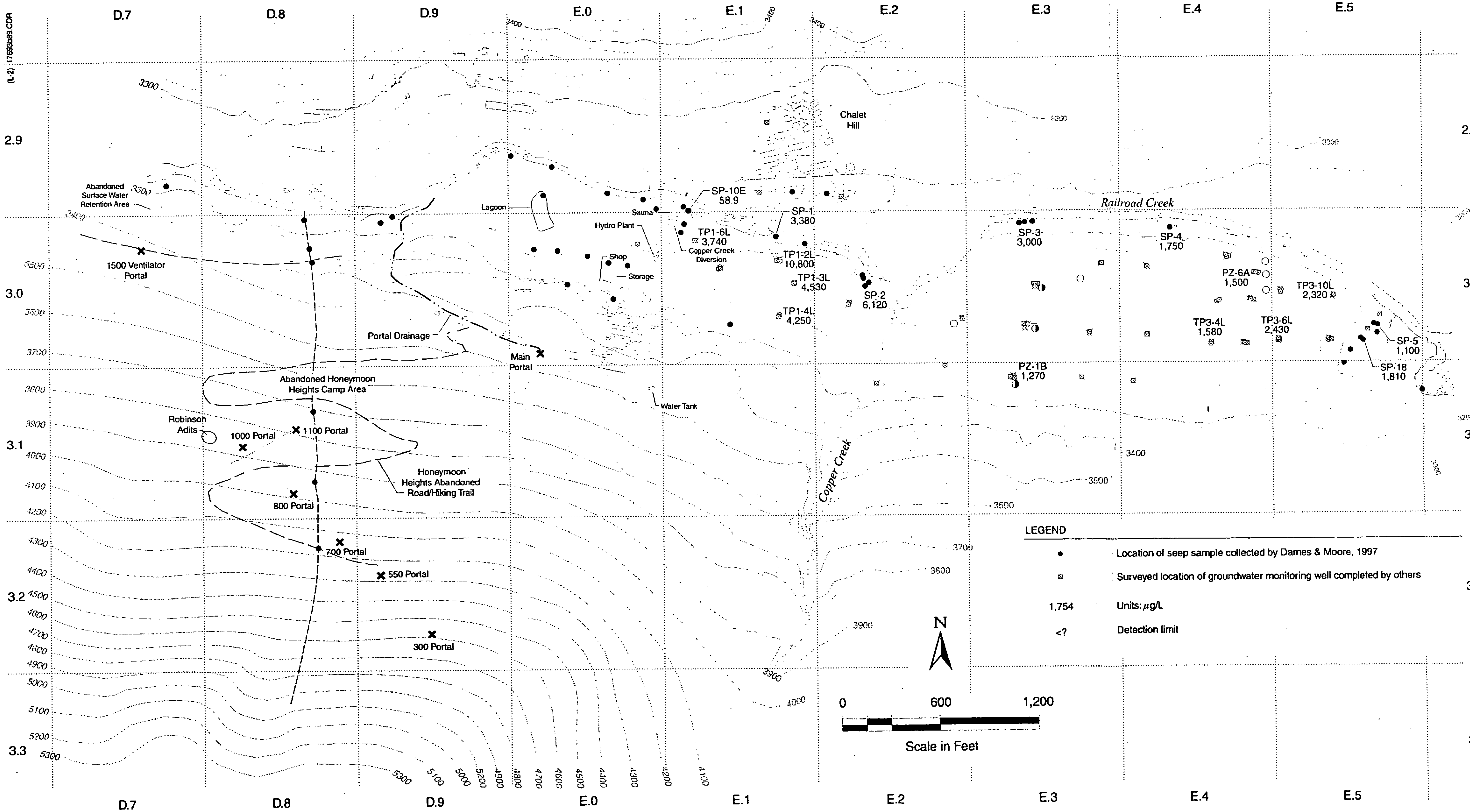

SOURCE: Base map information from USFS and Washington DNR, DEM CD ROM

Figure 5.4-25

DISSOLVED MANGANESE CONCENTRATION, MAY 1997
WELLS/LYSIMETERS COMPLETED IN TAILINGS; ASSOCIATED SEEPS

DAMES & MOORE
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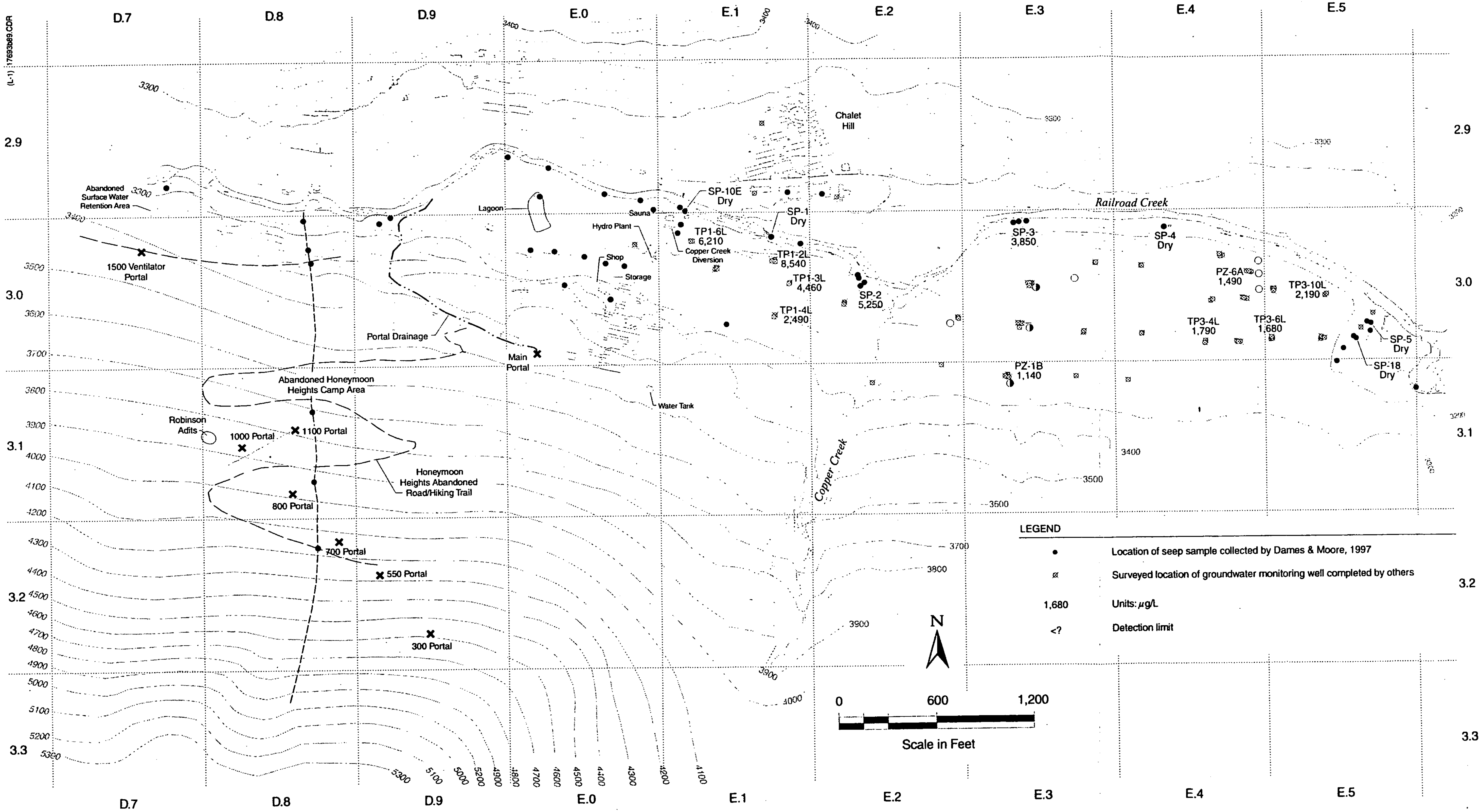

SOURCE: Base map information from USFS and Washington DNR, DEM CD ROM

Figure 5.4-26

DISSOLVED MANGANESE CONCENTRATION, SEPTEMBER 1997 WELLS/LYSIMETERS COMPLETED IN TAILINGS; ASSOCIATED SEEPS

DAMES & MOORE
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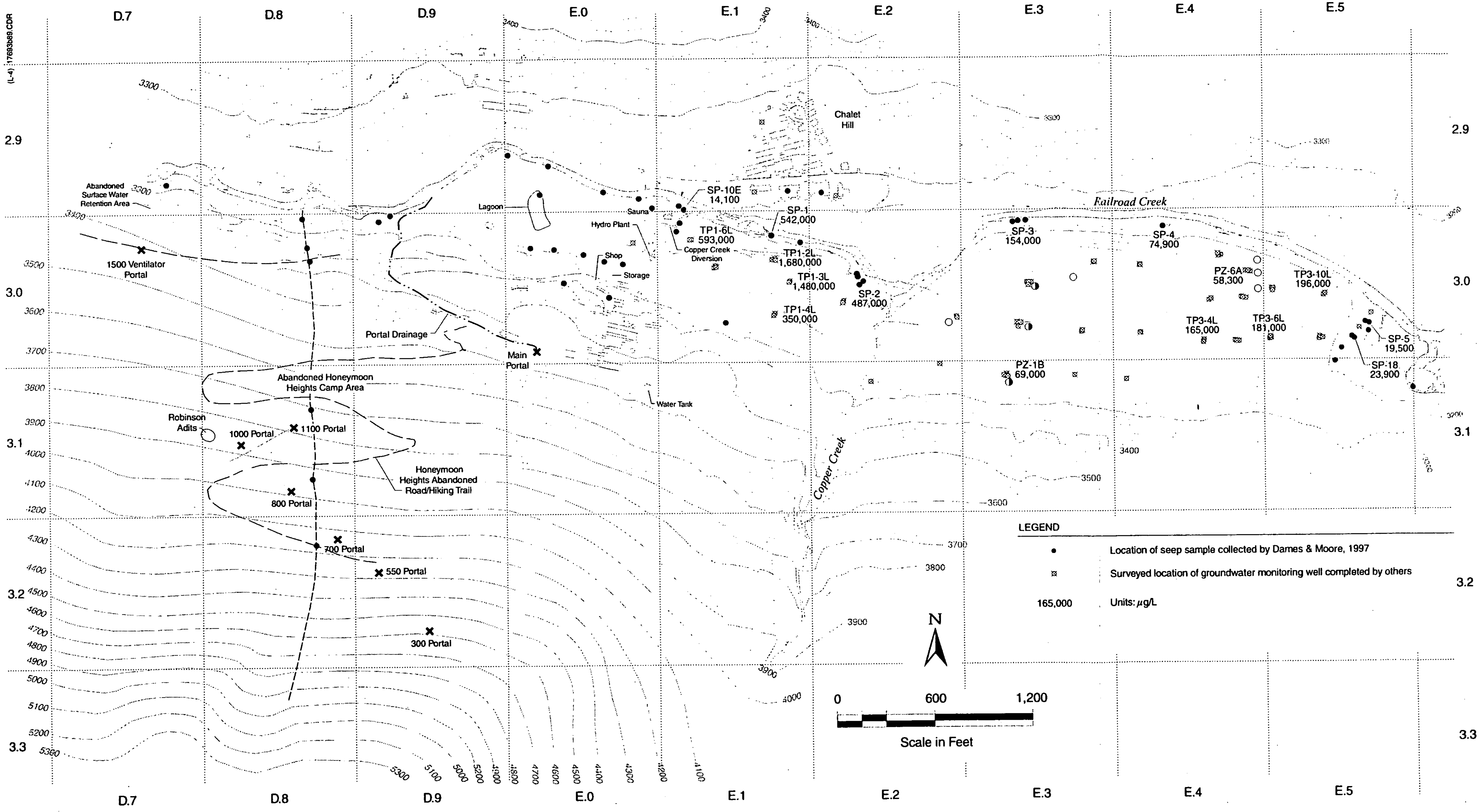
Job No. 17693-005-019

Holden Mine RI/FS
Draft Final RI Report
Internal Draft



SOURCE: Base map information from USFS and Washington DNR, DEM CD ROM

Figure 5.4-27

DISSOLVED IRON CONCENTRATION, MAY 1997 WELLS/LYSIMETERS COMPLETED IN TAILINGS; ASSOCIATED SEEPS

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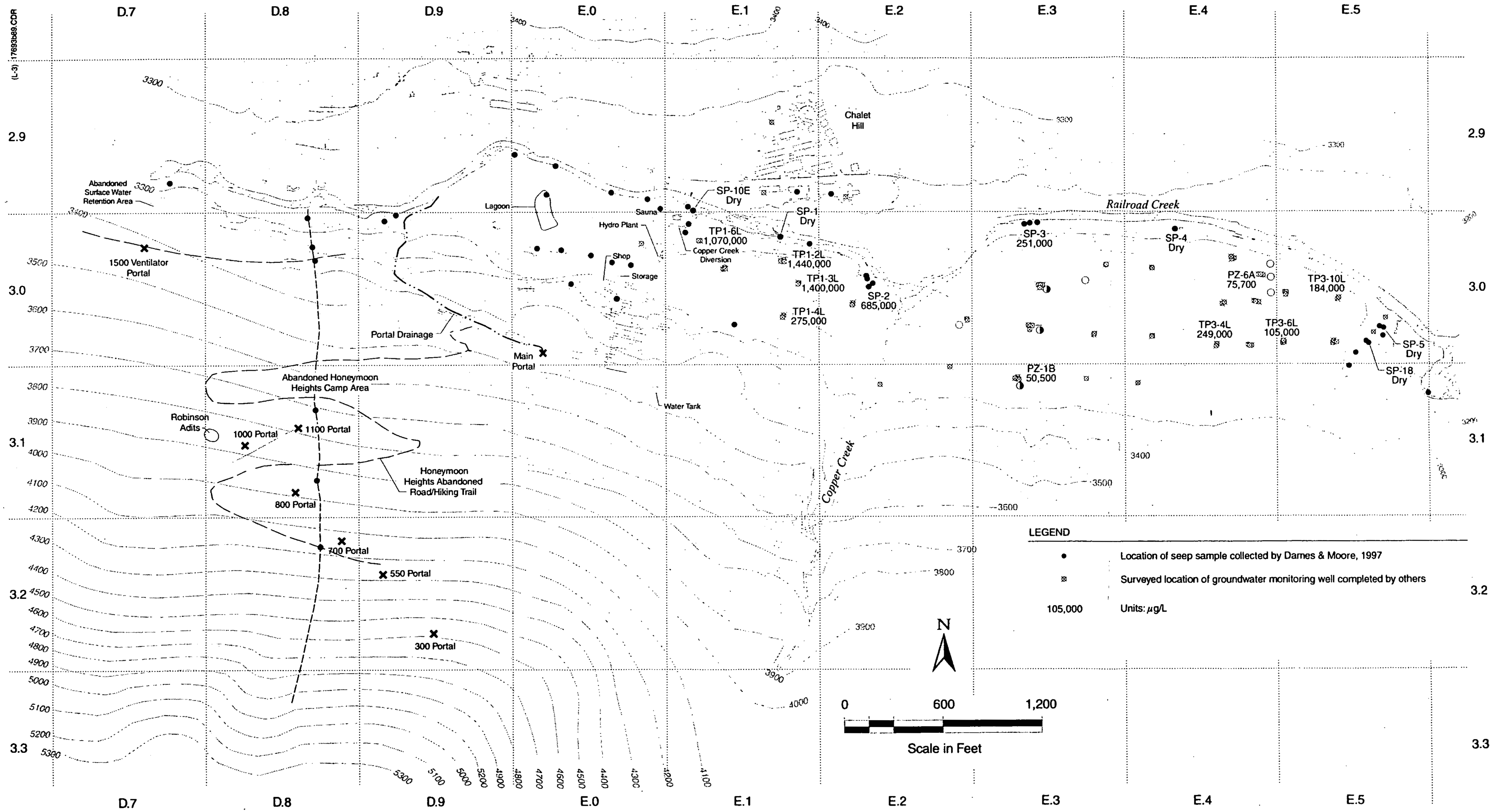

SOURCE: Base map information from USFS and Washington DNR, DEM CD ROM

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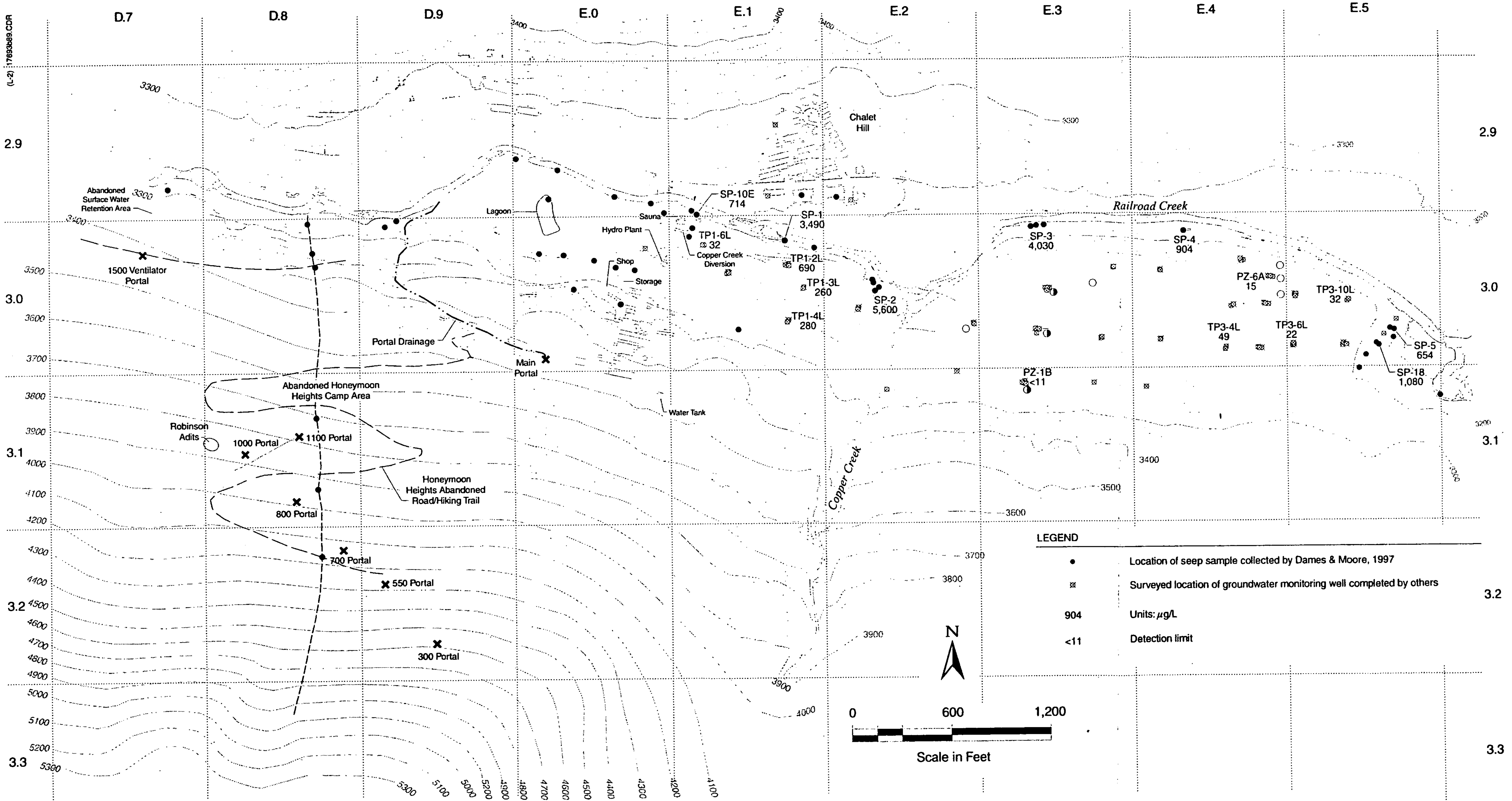
Figure 5.4-28

DISSOLVED IRON CONCENTRATION, SEPTEMBER 1997
WELLS/LYSIMETERS COMPLETED IN TAILINGS; ASSOCIATED SEEPS

Holden Mine RI/FS
Draft Final RI Report
Internal Draft



LEGEND

●	Location of seep sample collected by Dames & Moore, 1997
⊠	Surveyed location of groundwater monitoring well completed by others
904	Units: μg/L
<11	Detection limit

SOURCE: *Base map information from USFS and Washington DNR, DEM CD ROM*

Figure 5.4-29

DISSOLVED ZINC CONCENTRATION, MAY 1997
WELLS/LYSIMETERS COMPLETED IN TAILINGS; ASSOCIATED SEEPS

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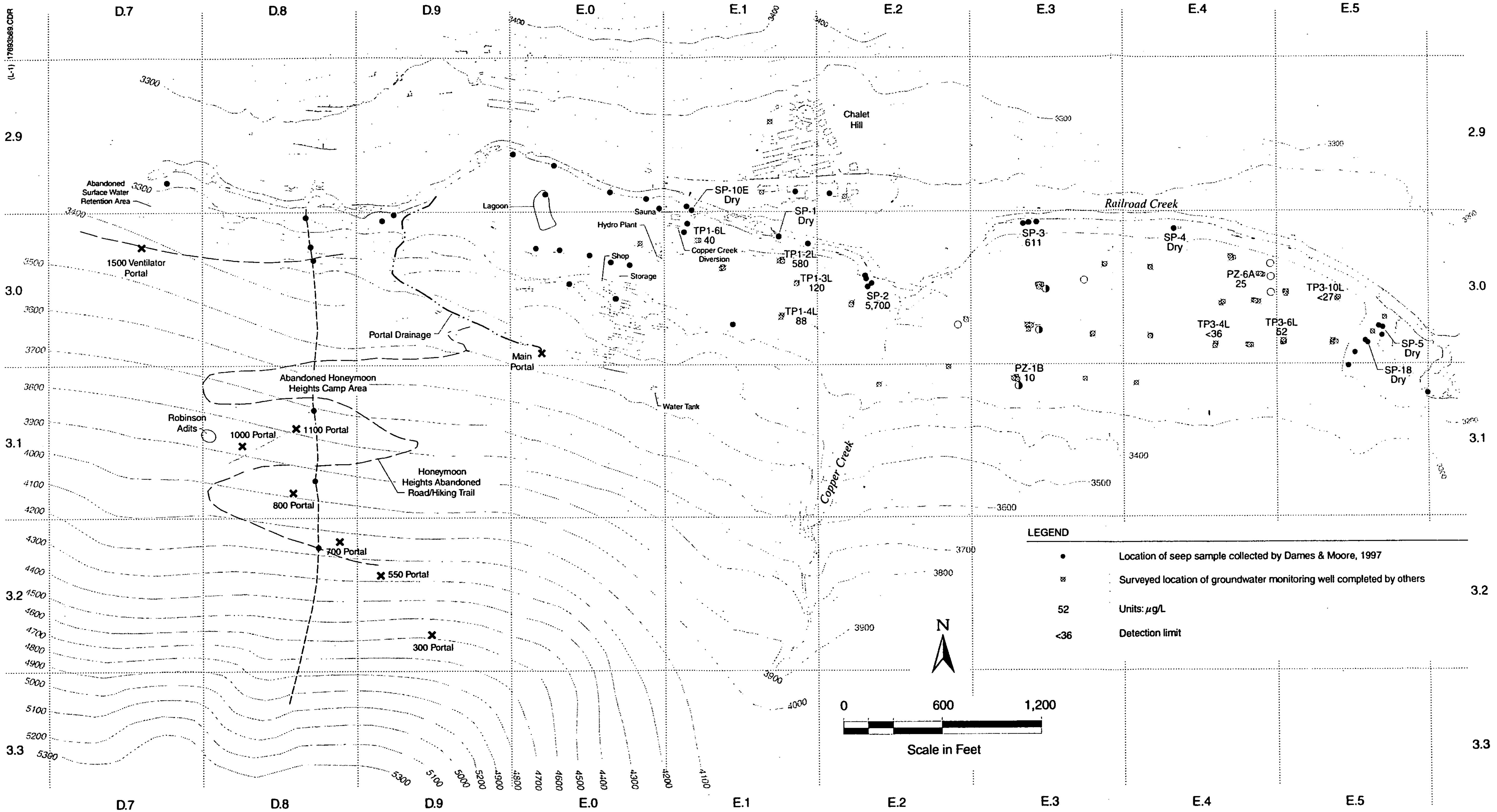
Job No. 17693-005-019



LEGEND

●	Location of seep sample collected by Dames & Moore, 1997
⊠	Surveyed location of groundwater monitoring well completed by others
52	Units: μg/L
<36	Detection limit

SOURCE: Base map information from USFS and Washington DNR, DEM CD ROM

Figure 5.4-30

DISSOLVED ZINC CONCENTRATION, SEPTEMBER 1997
WELLS/LYSIMETERS COMPLETED IN TAILINGS; ASSOCIATED SEEPS

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Job No. 17693-005-019

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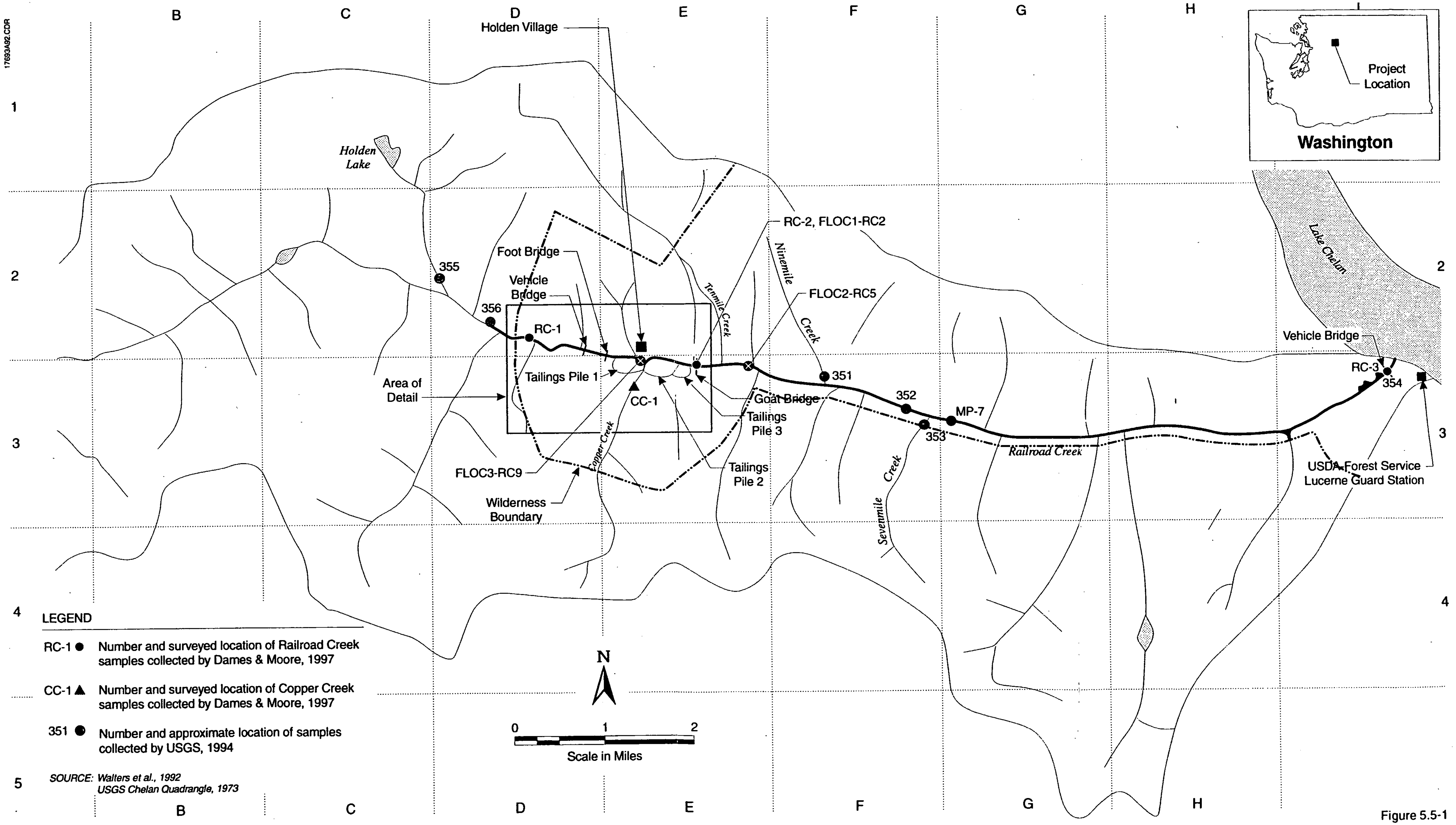

LEGEND

RC-1 ●	Number and surveyed location of Railroad Creek samples collected by Dames & Moore, 1997
CC-1 ▲	Number and surveyed location of Copper Creek samples collected by Dames & Moore, 1997
351 ●	Number and approximate location of samples collected by USGS, 1994

SOURCE: Walters et al., 1992
USGS Chelan Quadrangle, 1973

Figure 5.5-1

FLOCCULENT AND SEDIMENT SAMPLING LOCATIONS
RAILROAD CREEK

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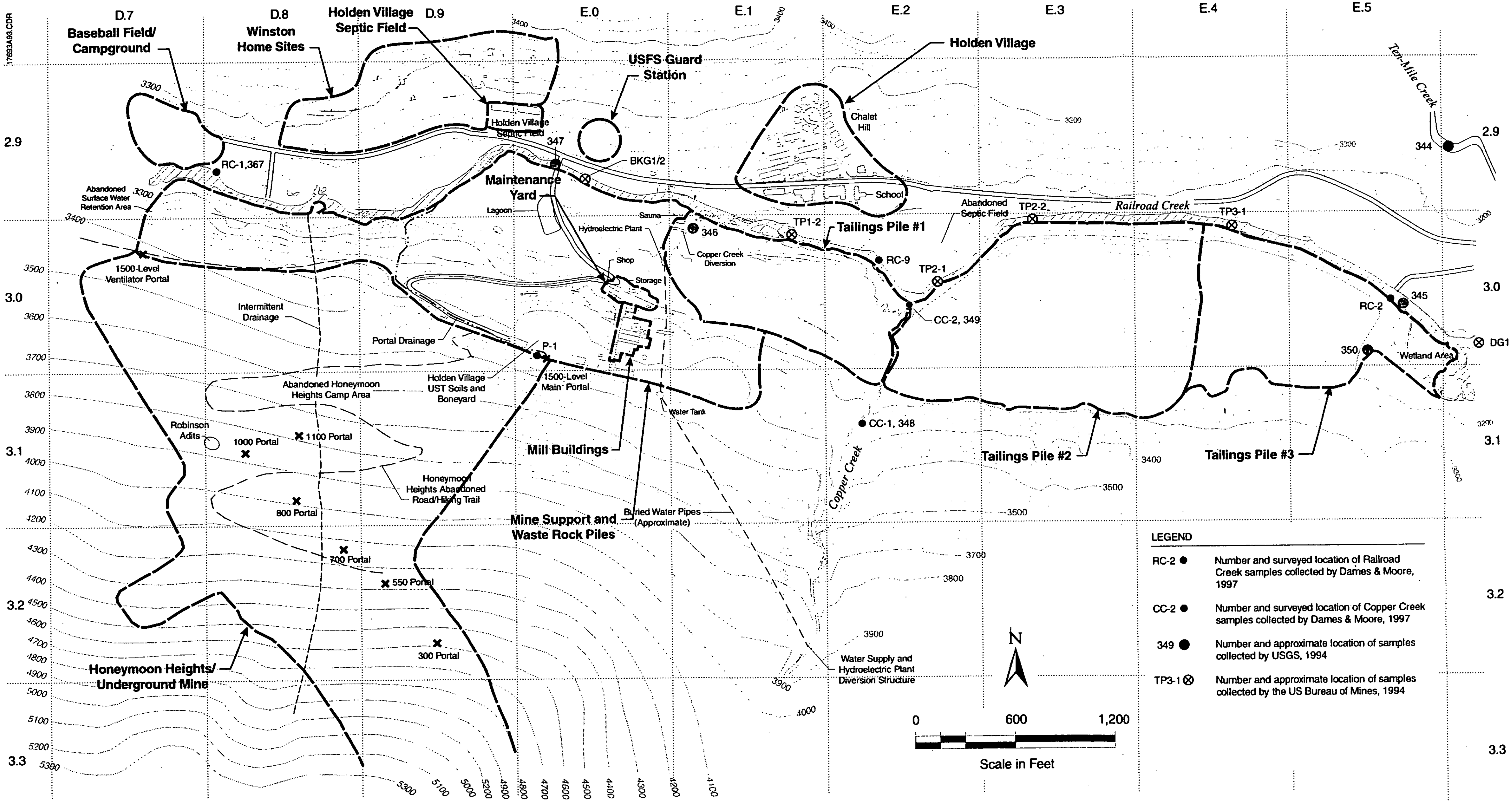

SOURCE: Base map information from USFS and Washington DNR, DEM CD ROM

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Figure 5.5-1a
FLOCCULENT AND SEDIMENT SAMPLING LOCATIONS—SITE

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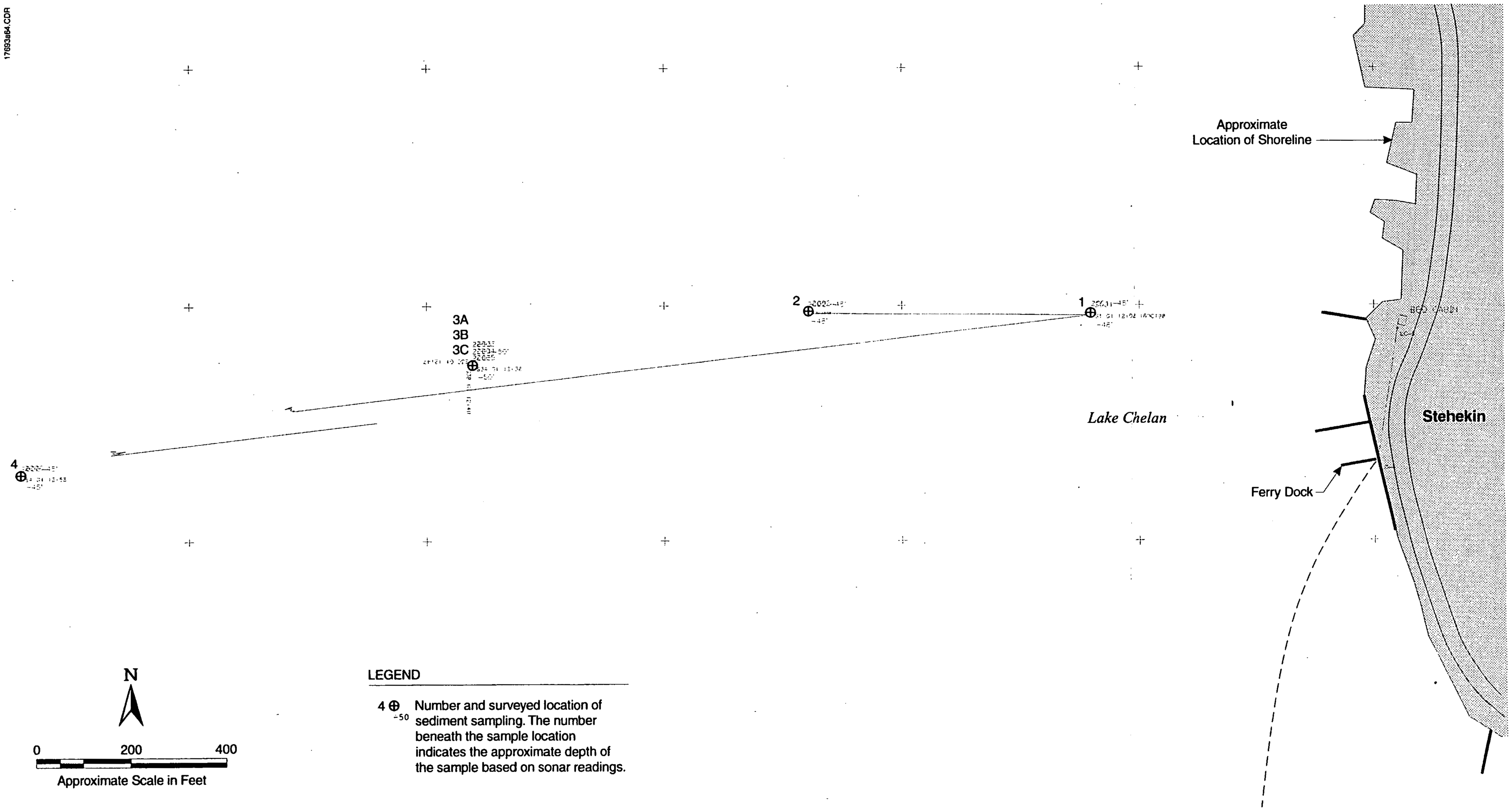

LEGEND

4 ⊕ -50 Number and surveyed location of sediment sampling. The number beneath the sample location indicates the approximate depth of the sample based on sonar readings.

Figure 5.5-2

STEHEKIN SEDIMENT SAMPLING

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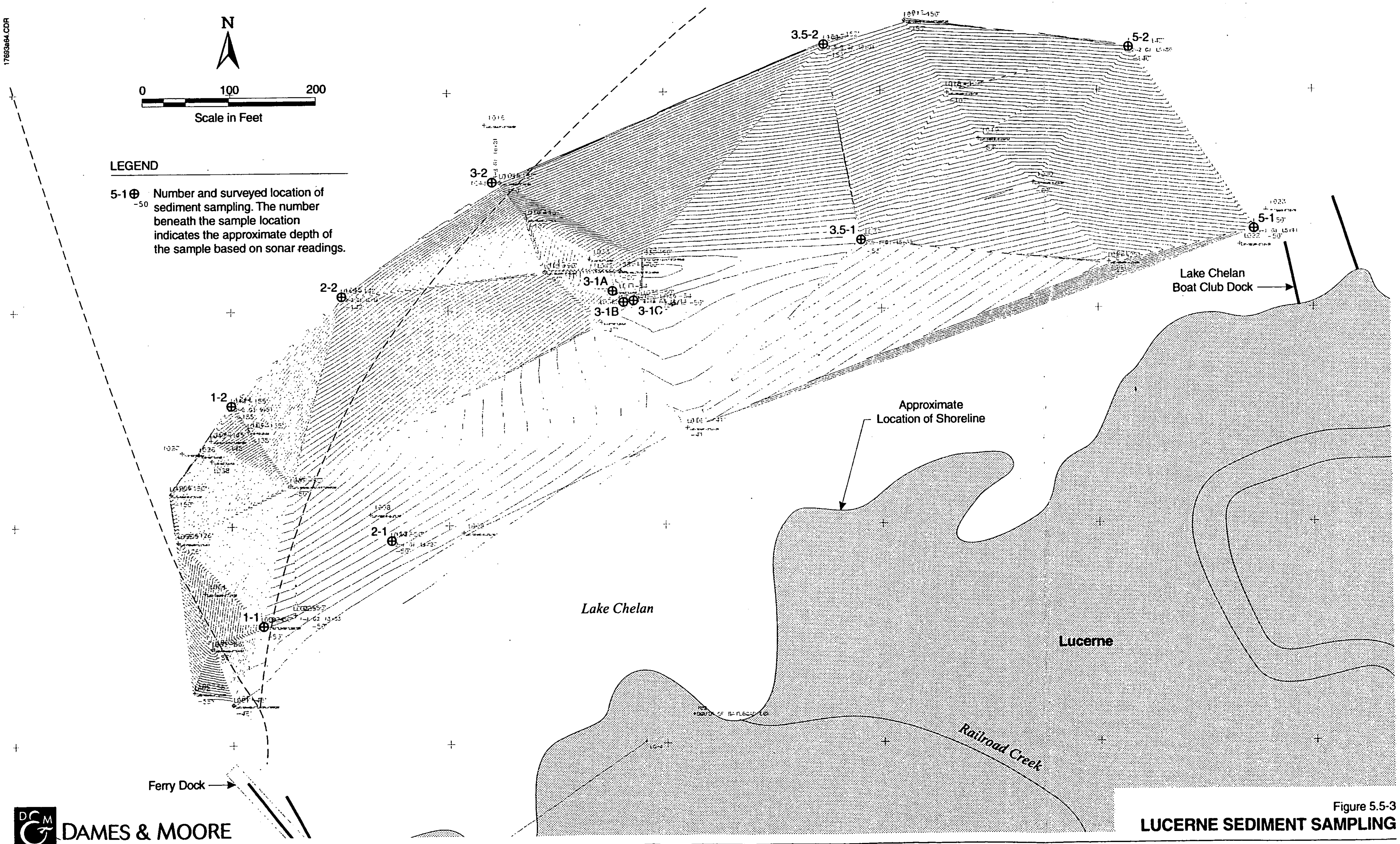

Figure 5.5-3
LUCERNE SEDIMENT SAMPLING

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Job No. 17693-005-019

17693B95.CDR

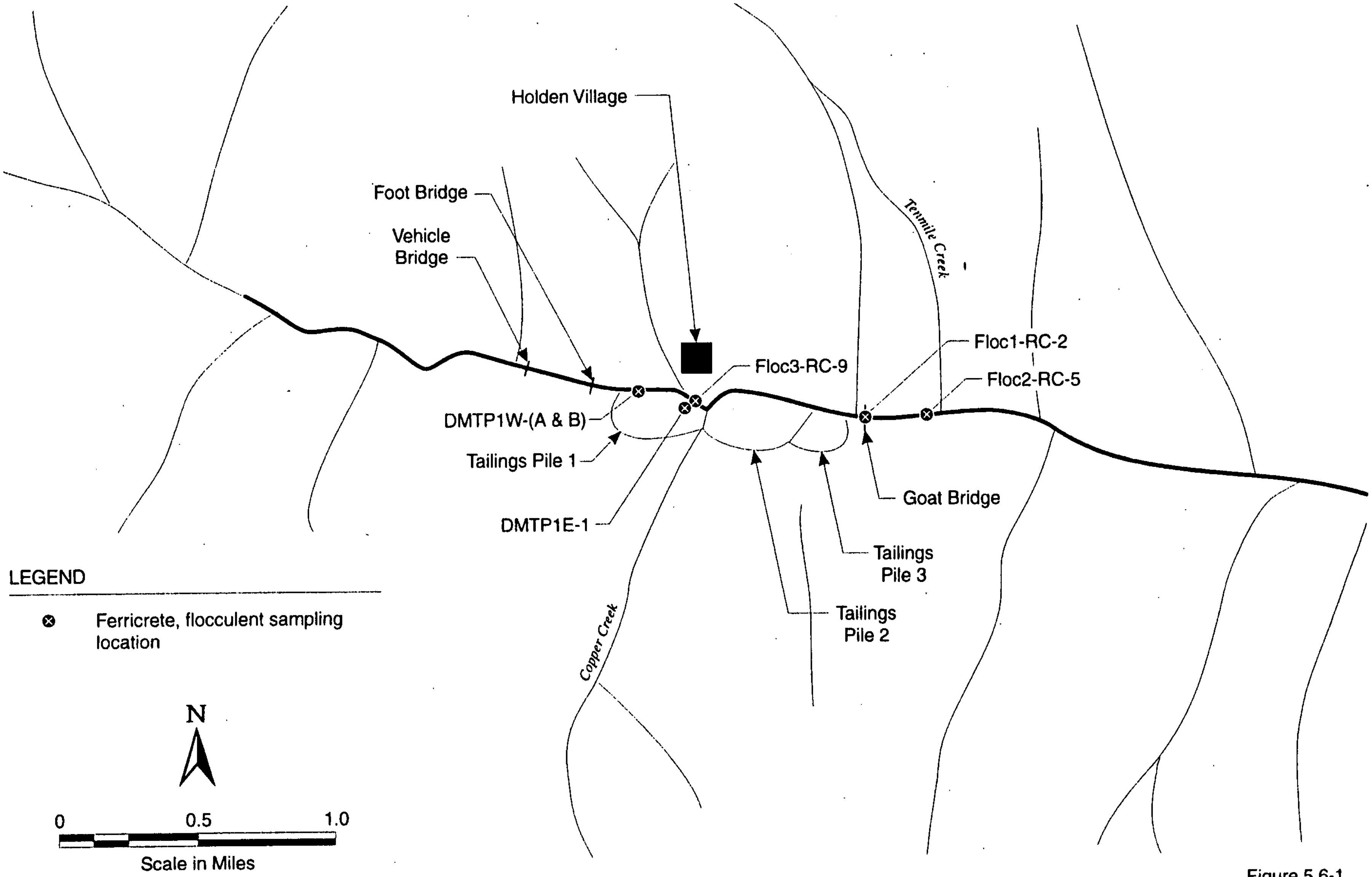

Figure 5.6-1

FERRICRETE AND FLOCCULENT RI SAMPLING LOCATIONS

DAMES & MOORE
A DAMES & MOORE GROUP COMPANY

Holden Mine RI/FS
Draft Final RI Report

Job No. 17693-005-019

6.0 TRANSPORT AND FATE OF COMPOUNDS OF POTENTIAL CONCERN

Most hard rock metal mines, like the Holden Mine, involve excavation and processing of ore rock to extract useful metals (e.g., copper and zinc) contained in minerals. The minerals may be smelted onsite to produce the metals, or, as in the case of the Holden Mine, the minerals are smelted off-site. As it is not practical to recover all the minerals (particularly those containing iron), non-recovered minerals remain onsite in: (1) the walls of the excavations (mine openings); (2) in rock removed to access the ore (waste rock); and (3) in residues remaining from the processing of ore (tailings).

The metal-containing minerals are formed under conditions in the earth's crust that are different than at the surface. Some differences include, pressure and temperature (both greater in the crust), and water and oxygen abundance (both greater at the surface due to exposure to the atmosphere). Because of these differences, the minerals remaining on a site after mining are usually unstable in the atmosphere and begin to breakdown almost immediately, releasing the metals they contain to flowing water, if present. An analogue for the process is the transformation of iron to rust, which happens because iron is unstable in the atmosphere; water flowing over the rust will contain iron.

Therefore, water flowing through mine sites very often contains metals reflecting the chemical instability of the rock. These waters are often dissimilar from natural waters because contact with the minerals as described above modifies the water chemistry. The mine waters may be acidic and contain relatively high concentrations of dissolved sulfur. As the waters flow away from a mine, waste rock, or tailings, the metals contained in the water can be removed by processes such as aeration, contact with acid neutralizing rock, and mixing with natural acid-neutralizing waters.

Understanding these processes as they apply specifically to the Holden Mine Site is critical to evaluating the sources of water quality impacts observed at the site and in Railroad Creek, and the options and benefits of remediation. The purpose of Section 6, therefore, is to: (1) describe the processes controlling release of metals from Site sources; (2) how metals are immobilized before they enter Railroad Creek; and (3) the processes occurring when waters from the Site mix with Railroad Creek (Figure 6.1-1).

This section has been structured to develop the current understanding of the processes occurring at the Holden Mine Site and how these processes impact the quality of surface water and groundwater at the site and in Railroad Creek.

Subsection 6.1 summarizes findings on Site conditions presented in previous sections of the report and provides some new information to give context to the subsequent discussion of processes.

Subsequent sections describe the chemical interpretation of processes at the Site.

Subsection 6.2 describes specific methods used to interpret chemical processes at the Site.

Subsection 6.3 is a general introduction to chemical processes occurring when reactive minerals are exposed to weathering by the atmosphere, and processes by which metals are removed.

Subsection 6.4 presents general Site wide evidence for the processes described in Subsection 6.3 and reduces the variations in water chemistry to mechanisms that are common to the whole Site.

Subsection 6.5 presents variations in the processes as they apply to the different components of the Site.

Subsection 6.6 discusses impacts to Railroad Creek and presents a mass balance for the chemical loads to determine if chemical loads can be accounted for by the known sources.

Subsection 6.7 compares Site with two other similar mine sites to determine if processes at the Holden Mine resemble processes elsewhere in similar environmental settings.

Subsection 6.8 discusses the formation of flocculent and ferricrete in Railroad Creek and the downstream transport of flocculent.

Subsection 6.9 discusses the metals data and transport mechanisms for sediment in Railroad Creek.

Subsection 6.10 provides conclusions for Section 6.

To assist in better understanding the Site conditions, Table 6.0-1 has been prepared which presents a key of Site features and media sampling/data collection locations as it relates to Figure 6.1-1a.

6.1 SITE CONDITIONS

6.1.1 Bedrock Geology and Mineralogy

Bedrock mineralogy is the underlying fundamental control on mine site water geochemistry. This section summarizes the mineralogy of the host rocks and ore deposit at the Site, as discussed in Section 4.2.3.

6.1.1.1 Host Rocks

The Holden Mine assemblage, which is the regional host for the Holden Mine deposit is dominated by hornblende bearing rocks that include amphibolite, hornblende gneiss, and hornblende-biotite schist. Calc-silicate rock, leucocratic gneiss, and plagioclase-biotite schist are less abundant constituents, and marble, pelitic schist, and metaconglomerate occur locally (Dragovich and Derkey, 1994). This latter assemblage includes the Martin Ridge and Buckskin schists, and the Fernow Gneiss of Youngberg and Wilson (1952).

The deposit itself is hosted by the Buckskin schist which is a quartz amphibole schist sequence, with at least two horizons of intermittent marble beds and calcareous schists (Youngberg and Wilson, 1952). Typical specimens have the following composition (Dubois, 1954):

- Layers of almost pure quartz
- Biotite-rich layers of 15 percent quartz (SiO_2), 45 percent plagioclase ($NaAlSi_3O_8$ to $CaAl_2Si_2O_8$), 30 percent biotite ($K(Mg,Fe)_3(AlSi_3O_{10})(OH)_2$), and 10 percent hornblende ($((Ca,Na)_{2-3}(Mg,Fe,Al)_5Si_6(Si,Al)_2O_{22}(OH)_2$ and diopside ($CaMgSi_2O_6$)

- Quartz-rich layers of 40 percent quartz, 30 percent plagioclase, 20 percent diopside, 4 percent hornblende, 2 percent sphene (CaTiO(SiO4)) and 2 percent biotite

In the vicinity of the mineralized zone, the amphibole is altered to a black biotite, with local chlorite ($(Mg,Fe)_3(Si,Al)_4O_{10}(OH)_2 \cdot (Mg,Fe)_3(OH)_6$) and sericite ($KAl_2(AlSi_3O_{10})(OH)_2$) alteration, and additional amounts of quartz and sulfides. The increase in the biotite is usually accompanied by a decrease in the lime-silicate (e.g., diopside) content.

6.1.1.2 Ore Deposit

Geologists at the Holden Mine originally classified the ore deposit as a vein-type deposit formed in a shear zone (Youngberg and Wilson, 1952). However, it has recently been re-classified as a metamorphosed Kuroko-type VMS deposit (Dragovich and Derkey, 1994). The ore zone is interpreted to be located within the limb of a large, northwest-trending, overturned, isoclinal fold.

Three distinct zones of mineralization, based on sulfide minerals can be distinguished (Dragovich and Derkey, 1994):

1. The "original footwall sulfide zone," contains pyrrhotite ($Fe_{1-x}S$), pyrite (FeS_2), biotite and sericite. Pyrite and pyrrhotite in this zone is largely disseminated, and the contact with the original footwall is diffuse or irregular.

2. The "original footwall ore zone" which contains pyrrhotite, chalcopyrite ($CuFeS_2$) and gold (Au) mineralization. This is partially interbedded with the footwall sulfide zone. Economically, it was the most important unit at the mine.

3. The "hanging wall ore zone," which contains pyrite and sphalerite (ZnS), with lesser amounts of pyrrhotite, chalcopyrite and galena (PbS). Over 50 percent of the mineralization in this zone is present as sulfides. The contact with the original hanging wall rocks is sharp.

Because this sequence is overturned, the "original footwall" is now the structural hanging wall.

Other minerals identified in the deposit include: magnetite (Fe_3O_4), quartz, molybdenite (MoS_2), calcite ($CaCO_3$), bournonite ($PbCuSbS_3$), silver (Ag), and possibly pitchblende (UO_2) (Youngberg and Wilson, 1952).

Post-ore intrusive "diabase" dykes cross the ore zone in several locations, varying from approximately twenty-four percent abundance at the 2125 level to almost fifty percent at the 2500 level (Ebbutt, 1956) (Figure 6.1-2). The dykes have a well-developed igneous texture, and are comprised of quartz-diorite. Typical specimens are light colored, with a porphyritic medium grained texture. They contain 10 percent quartz, 70 percent plagioclase, 10 percent hornblende, and 5 percent chlorite, with minor biotite, apatite ($Ca_5(PO_4)_3(OH,F,Cl)$), sphene, sericite and magnetite. They form sharp contacts with their host rocks (Dubois, 1954). The intrusives appear to be related to the late-Triassic Marblemount belt (Dragovich and Derkey, 1994). The dykes represent an important waste component of the ore and therefore the minerals are expected to be present in the tailings.

Other geologic units in the deposit area include:

- An anhydrite ($CaSO_4$) lens which was mapped for 120 feet along strike, immediately overlying the original hanging wall. The anhydride was described as a light gray, purple tinged mass, banded with the amphibolite host.
- Occasional bands of marble and lime-silicate granulites, with a composition of 5 percent quartz, 30 percent plagioclase, 30 percent diopside, 20 percent grossularite ($Ca3Al_2Si_3O_{12}$), and 10 percent calcite, with minor wollastonite ($CaSiO_3$).

6.1.1.3 Occurrence of Significant Sulfide Minerals

The primary sulfide minerals in the Holden Mine ore deposit occur in the following forms:

- Pyrite – abundant in mineralized zones, and as disseminations in the argillites. In the ore zone, it is highly brecciated, with corroded edges. Outside of the ore zone, cubes of pyrite are "not uncommon."
- Pyrrhotite – Abundant within ore zone, generally massive in form.
- Sphalerite – gradational phases between disseminations and massive replacements in the footwall of the ore zone. Sphalerite has a high iron content, and approaches marmatite (Zn-FeS) in composition. It is concentrated in the east-end of the mine.
- Chalcopyrite – Concentrated in the central part of the mineralized zone, varying from massive to disseminated. Replaces and/or heals fractures in pyrite and pyrrhotite.

6.1.1.4 Conclusion

The conclusions from the review of mineralogical information are:

- The dominant sulfide minerals present at the Holden Mine are iron-based (pyrite, pyrrhotite). Weathering of these minerals is a primary mechanism of the Holden Mine Site water chemistry.
- The dominant silicates are aluminum-based (plagioclase and biotite).
- Carbonate minerals are rare at the Holden Mine.
- Non-sulfide mineralogy of the tailings is expected to be dominated by minerals contained in the diabase dykes because the dykes intersect the ore zone, whereas the mine wall rocks and waste rock are more likely to be dominated by biotite schist.

6.1.2 Mineralogy of Secondary Minerals

Minerals (i.e., crystalline substances) and amorphous solids produced by weathering processes are visually apparent throughout the Holden Mine Site. These include ubiquitous orange-brown iron-stains on waste rock and tailings indicating iron oxides and white precipitates observed in the 1500-level main portal drainage (Figures 6.1-1 and 6.1-1a). The latter is believed to be amorphous aluminum hydroxide. Green (copper) stain is also present on marble waste rock in the two waste rock piles near the 1500-level main portal and in the abandoned mill building.

Crystalline crusts were observed in the mill building and where seepage emerges along the toes of the tailings piles. The USGS used X-Ray Diffraction (XRD) to determine the types of minerals present in 1994 (personal communication with Jim Kilburn, 1999) (Table 6.1-1). All minerals were identified to be sulfates in combination with aluminum, iron, copper, potassium, sodium, magnesium, zinc, and calcium. These minerals are not unique to the Holden Mine and have been documented at many other mine sites.

6.1.3 Hydrology/Hydrogeology

This section summarizes the hydrology/hydrogeology discussed in Sections 4.3 and 4.4, and describes a general conceptual site transport pathway model for the Site. The model serves as the basis for interpretation of surface water and groundwater PCOC discharge from Site features as they relate to water quality in Railroad Creek.

6.1.3.1 General Transport Pathway Model

The Site receives surface water and groundwater flow from upgradient sources that include snowmelt and rainfall runoff from adjacent valley sides and from direct precipitation as either rain or snow. Groundwater within the Railroad Creek valley and at the Site exists as shallow and deeper isolated occurrences. Shallow groundwater occurs near the base of the tailings piles and within a relatively thin near-surface alluvium/reworked glacial till (reworked sand and gravel) that is perched above less permeable glacial till. Site groundwater within these units discharges as seeps or as diffuse groundwater to Railroad Creek. The alluvium/reworked till unit is considered to be moderately permeable with estimated hydraulic conductivities ranging from 9×10^{-4} to 5.3×10^{-2} cm/sec. The underlying glacial till unit is a relatively low permeability material that is assumed to separate the groundwater that occurs in the bedrock fractures from the groundwater that occurs in the overlying alluvium/reworked till. The underlying glacial till unit may contain limited localized occurrences of water. The glacial till unit is estimated to have lower permeabilities than the alluvium/reworked till unit, with hydraulic conductivities ranging from 10^{-8} to 10^{-10} cm/sec.

The interrelationship between Site groundwater and surface water is the focus of the transport pathway discussion and includes the following mechanisms: (1) surface water overland flow and infiltration, (2) seepage as overland flow, (3) seepage as direct groundwater discharge to Railroad Creek, and (4) groundwater discharge as baseflow into the bed of Railroad Creek. Other transport pathways such as air transport of tailings or transport of tailings directly into Railroad Creek as a result of bank erosion are considered to be a minor influence on water quality in Railroad Creek.

In general, upslope surface water from direct precipitation and snow melt run-on infiltrates and recharges groundwater through fractures within the bedrock found along the valley sidewalls and through the pore spaces of the surficial deposits including the alluvium/reworked till unit, where present. Upslope surface water run-on results in overland flow and infiltration across and through Site features and eventually discharges to Railroad Creek as overland flow or as diffuse groundwater. Baseflow to Railroad Creek is provided by diffuse groundwater flow which likely flows in alluvium underlying the creek.

Seeps discharges from the surficial materials at the Site at points where local groundwater elevations are higher than ground elevations. Seepage may (1) discharge directly into Railroad Creek, (2) flow overland to Railroad Creek, and (3) flow overland and reinfiltrate. In the spring, most water enters the Site from snowmelt on the adjacent valley slopes, so that primary groundwater flow directions are perpendicular to the trend of Railroad Creek. Groundwater discharge to Railroad Creek decreases over the summer. Through the summer months as groundwater levels decrease, groundwater beneath the Site begins to flow downstream to the east rather than directly toward Railroad Creek. The flow loss occurs because water levels in Railroad Creek are above water levels in the alluvial aquifer near the eastern portion of the site. The area immediately east of tailings pile 3 replenishes groundwater storage and is assumed to discharge back to Railroad Creek along the reach in and near SP-21, immediately east of RC-2. This assumption is based on the observed exposure of bedrock on the south bank of Railroad Creek, immediately downstream of SP-21. The presence of bedrock, and absence of alluvial material, indicates that the groundwater likely becomes surface water (Railroad Creek) at this location. Seep discharge is largest in the spring and essentially stops by late summer, indicating snowmelt as the primary source of seep flow.

6.1.3.2 West Side of Site

The west side of the Site includes the Honeymoon Heights drainage area, mine area, underground mine workings, the east and west waste rock piles, mill building area, and the maintenance yard (Figures 6.1-1 and 6.1-1a). Some of the upslope run-on probably enters near-surface discontinuities in bedrock south and upslope of the Site and flows downward through bedrock fractures, through abandoned stopes and mineralized (unmined) portions of the underground mine and contacts residual mineralization on rock faces of the stopes and tunnels as shown on Figures 6.1-2 and 6.1-2a. The water emerges as either surface water overland flow (i.e., 1500-level main portal drainage) and can reinfiltrate as seeps that emerge as overland flow and/or as diffuse groundwater discharge to Railroad Creek.

Some of the overland flow from upslope run-on also moves across the Honeymoon Heights waste rock piles (800 and 1100 level) or the mill area, and the maintenance yard and then travels downslope to other drainage features such as the lagoon and other miscellaneous drainage channels (Figures 6.1-1a and 6.1-2b). Not all groundwater comes into contact with the underground mine workings. Some portion of groundwater flow from the west side of the site is assumed to be diverted into the abandoned Railroad Creek channel and also flows beneath the tailings piles.

6.1.3.3 East Side of Site

The east side of the Site includes tailings piles 1, 2, and 3 (Figure 6.1-1a). Upslope surface water overland flow from direct precipitation and snow melt is transported to Copper Creek and also infiltrates across and through tailings piles 1, 2, and 3. Surface water is further transported to other drainage features including ditches that divert water to Copper Creek, an abandoned decant tower near the southern margin of tailings pile 1, the Copper Creek diversion, and the sauna dipping pool. Groundwater recharge from upslope run-on and infiltration occurs through the fractures within the bedrock found along the valley sidewalls and in the alluvium/reworked till, where present (Figures 6.1-3 and 6.1-3a). Infiltration occurs through the tailings piles from a combination of sources including upslope run-on as well as snow-melt and direct precipitation on the tailings piles. Infiltration through these features contributes recharge to groundwater in the alluvium/reworked till beneath the tailings piles which eventually discharges as seeps and groundwater baseflow to Railroad Creek. The discharge rate decreases after the spring snow melt period. Some portion of groundwater flow from the west portion of the site is assumed to be diverted into the abandoned Railroad Creek channel and also flows beneath the tailings piles.

Evidence of significant surface and channel erosion in Site drainages was not observed and therefore, there does not appear to be a direct water borne pathway for significant quantities of metal-containing sediments to enter Railroad Creek from the Site. Under extreme flow events, bank erosion in Railroad Creek and channel shifting with subsequent erosion of tailings in Copper Creek can potentially transport tailings into Railroad Creek. Channel scour and re-suspension of flocculent and fine particulates originating as iron oxide (and other) metal precipitates, and which settle into the Railroad Creek streambed, is also a transport mechanism which can carry metals downstream. Although large channel scour events in Railroad Creek which transport bed material long distances downstream are not common (due to the size of the dominant bed material and bed armoring), transport of iron-oxides as fine suspended material was observed several times during high flow events in 1997.

6.2 GEOCHEMISTRY INTERPRETATION TOOLS

Interaction of minerals with the atmosphere and the formation of new minerals control the chemistry of waters originating from the Site. A critical component of the geochemical interpretation is therefore the determination of which minerals in the rocks are controlling the original source of the water, and which new minerals are forming and removing metals from solution. These two groups of minerals are referred to as primary, indicating that they are present in the rocks, and secondary, indicating that they are formed when metals released from the primary minerals react with other dissolved or solid constituents. The first group does not include all minerals in the rocks because some minerals are inherently unreactive.

The following subsections describe the interpretative tools that were used to evaluate chemical processes occurring at the Site.

6.2.1 Contribution of Primary Minerals

Subsection 6.1.1 described the types of primary minerals reported to be present in the rocks within the Holden Mine. The processes that contribute the components of primary minerals to mine water chemistry are introduced below and described in more detail in Subsection 6.3.

The controlling process on water chemistry at the Site is the oxidation of iron sulfide (pyrite), summarized as:

$$FeS_2 + 15/4O_2 + 7/2H2O \rightarrow Fe(OH)_3 + 2SO_4^{2-} + 4H+ \tag{6-1}$$

The acid (H^+) produced by this reaction, can then dissolve other minerals, for example, calcite:

$$2CaCO_3 + 4H^+ \rightarrow 2Ca^{2+} + 2H_2CO_3^{\circ} \tag{6-2}$$

or, other more abundant minerals (for example, potassium feldspar):

$$4KAlSi_3O_8 + 4H+ + 28H_2O \rightarrow 4K+ + 4Al(OH)_3 + 12H_4SiO_4 \tag{6-3}$$

It can be seen from reaction (6-1) that each mole of pyrite produces two moles of sulfate ion and four moles of hydrogen ions (representing acidity). Reactions (6-2) and (6-3) indicate that these four hydrogen ions then react with calcite and produce two ions of calcium or four ions of potassium. Therefore, if calcite were being dissolved, one ion of calcium or two ions of potassium would match one ion of sulfate. Comparison of the ratios of sulfate to other elements is used as a tool to understand which minerals may be contributing to mine water chemistry. Two different waters may have dissimilar concentrations of sulfate and other elements, but if the ratios are similar, a common source process is implied. In the above example, comparison of ratios of calcium to potassium would indicate the relative contributions of calcite and potassium feldspars to water chemistry.

6.2.2 Formation of Secondary Minerals

Subsection 6.1.2 also described the types of secondary minerals that have been observed within the Holden Mine (Table 6.1-1). These minerals are formed, in part, when the water can no longer contain the components that form the mineral. The simplest example is the formation of sodium chloride crystals when a solution of common salt is heated, causing water to be evaporated. The evaporation causes the concentrations of sodium and chloride to increase in the water. Eventually, the laws of thermodynamics dictate that salt crystals will form as the concentrations increase. As the crystals form, sodium and chloride are removed from the water and the concentrations of sodium and chloride in the water remain steady.

At hard rock metal mine sites, the formation of secondary minerals from water can be predicted or confirmed using the same principals. It is useful to predict the precipitation of secondary minerals because it indicates where metals are being removed from solution, and how these minerals may be preventing pH from increasing. Increase in pH allows heavy metals to precipitate. Further discussion of secondary mineral formation is provided in Subsection 6.3.3.

Several models are available to evaluate water chemistry for evidence of formation of secondary minerals. These models include MINTEQA2, WATEQF, PHREEQC and EQ3. The differences between the models include the database of elements and minerals, the ability to model mixing of waters (PHREEQC), and the ability to model saline solutions (EQ3). For this project, the MINTEQA2 (Allison et al. 1991) model was selected but with the database developed by Nordstrom et al. (1990). The reasons for this selection are as follows:

- The model was developed by the US Environmental Protection Agency and is probably the most widely used of its type.
- The Nordstrom et al. (1990) database is larger than the original MINTEQA2 database.
- Individual waters rather than mixed waters are evaluated.
- The waters at the Holden Mine are relatively dilute and do not require the use of EQ3.

The inputs to MINTEQA2 (and all comparable models) are the dissolved concentrations of all analyzed parameters, and other conditions such as temperature, pH, Eh and gas concentrations. The outputs from the model are:

- Ion (charge) balances (expressed as Cations-Anions/Total Ions, in meq/L)
- Mass distribution of dissolved ions and ion complexes

- Predicted saturation indices (SI) for any mineral possibly in equilibrium with the solution. If log(SI) is greater than 0, the solution is defined as saturated with respect to that mineral, meaning that the mineral may be in contact with the solution or precipitating. If log(SI)<0, the solution is said to be undersaturated meaning that the mineral is not in contact with the solution and would dissolve if present.

Optionally, minerals can be specified as "infinite solids" to determine the ion concentrations that would be present in solution. The model causes infinite solids to be saturated log(SI)=0 and therefore forces other constituents in solution to be in equilibrium with the solid. This is useful to assess the effect of the water coming into contact with the solid.

The model does not take into account kinetic constraints, hence over-saturation may be indicated, but the activation energy required to form the solid is greater than the energy available. The model often reports over-saturation with respect to highly crystalline silicates. The model is most useful in predicting the formation of amorphous solids, and soluble secondary minerals such as sulfates and carbonates.

Specifics of the approach used for the Holden Mine data included:

- The pH of the solutions was specified using measured values.
- Measured Eh (if available) was specified and used to define redox couples for Fe^{2+}/Fe^{3+} and Cu^{+}/Cu^{2+}. Eh sensitive modeling results were interpreted cautiously due to inherent uncertainty in field Eh measurement.
- Typical waters representing spring and fall conditions as measured during the RI were input into the model.
- Adsorption and co-precipitation were not modeled.

The modeling was used for the Site specifically to confirm formation of amorphous and crystalline solids from surface waters downstream of sources and how this process controls pH to specific levels in different parts of the Site. In some cases, the modeling also confirmed the formation of some of the efflorescent salts indicated in Table 6.1-1.

6.3 GENERAL CHEMICAL PROCESSES OPERATING AT THE HOLDEN MINE SITE

6.3.1 Chemical Rock Weathering Processes and Leaching of Metals

"Weathering" refers to the breakdown of rocks by atmospheric processes. It includes both physical and chemical breakdown. Chemical breakdown results in the release of metals to water and the formation of new minerals. At hard rock metal mine sites, important processes are:

- Sulfide mineral oxidation that produces acid and releases heavy metals
- Dissolution of other sulfide minerals by the strongly acidic solutions produced
- Consumption of acid by reaction with alkaline minerals such as carbonates and silicates

These processes are described further in the following subsections.

6.3.1.1 Sulfide Mineral Oxidation

The dominant source process controlling release of inorganic constituents at the Holden Mine is expected to be the oxidation of iron sulfide minerals, which releases oxidized iron and acidity (Figure 6.3-1). Oxygen is the typical oxidizing agent due to its abundance in the atmosphere. However, it is also a very significant control on the rate of weathering of sulfide minerals. It can limit the rate of weathering if it cannot be re-supplied at a greater rate than the maximum rate of oxidation. The role of oxygen supply is discussed further in Subsection 6.5.1 under the description of the chemical processes in the individual sources.

The overall process is summarized by Equation (6-1) above, but it is usually described as occurring in three steps:

- *Oxidation of sulfide to sulfate.* The first step results in the formation of soluble iron(II) sulfate weathering products on the surfaces of the iron sulfide mineral (Figure 6.3-1). The types of mineral formed depend on composition of groundwaters in contact with the mineral and the overall humidity. The reaction is catalyzed by sulfur-oxidizing bacteria (for example, *thiobacilli*). Acidity formed may be entrained in the initial oxidation product or dissolved in groundwaters in contact with the sulfide minerals. In some cases, oxidation of sulfur to sulfate may be incomplete resulting in formation of elemental sulfur. The overall reaction can be summarized as:

$$FeS_2 + 7/2O_2 + H_2O \rightarrow Fe^{2+} + 2SO_4^{2-} + 2H^+ \qquad (6\text{-}4)$$

- *Oxidation of iron(II) to iron(III).* The second stage is catalyzed by iron-oxidizing bacteria (e.g., *Thiobacillus ferrooxidans*), and is the rate-determining step for the complete oxidation of iron sulfide. The oxidation may occur in minerals containing iron(II) or by oxidation of groundwaters containing iron(II). The process consumes acidity:

$$Fe^{2+} + \tfrac{1}{4}O_2 + H^+ \rightarrow Fe^{3+} + \tfrac{1}{2}H_2O \qquad (6\text{-}5)$$

- *Hydrolysis of iron(III).* The final stage involves formation of ferric hydroxide. The reaction is rapid and produces further acidity:

$$Fe^{3+} + 3H_2O \rightarrow Fe(OH)_3 + 3H^+ \qquad (6\text{-}6)$$

The final step only occurs at pH>3. Under stronger acidic conditions (pH<3), ferric hydroxide does not precipitate and iron(III) remains in solution. The resulting strongly acidic oxidized solution is capable of oxidizing pyrite directly without oxygen:

$$FeS_2 + 14Fe^{3+} + 8H_2O \rightarrow 15Fe^{2+} + 2SO_4^{2-} + 16H^+ \qquad (6\text{-}7)$$

This reaction is capable of sustaining very low pHs (much less than 3) and does not require bacteria as a catalyst. However, the pH must be less than 3 to allow Fe^{3+} to be available as an oxidant.

Another iron sulfide mineral at the Holden Mine is pyrrhotite ($Fe_{1-x}S$). This mineral is commonly more reactive than pyrite (MEND 1991) but the reaction products are similar. Sulfur may be incompletely oxidized to elemental sulfur rather than sulfate.

The dominant copper mineral at the Holden Mine is chalcopyrite. It oxidizes by similar processes, releasing acid, sulfate and copper to solution:

$$CuFeS_2 + 17/4O_2 + 5/2H_2O \dashrightarrow Fe(OH)_3 + Cu^{2+} + 2H^+ + 2SO_4^{2-} \quad (6\text{-}8)$$

Chalcopyrite is less readily oxidized than pyrrhotite or pyrite (MEND 1991).

Like iron, copper will precipitate due to hydrolysis:

$$Cu^{2+} + 2H_2O \leftrightarrow Cu(OH)_2 + 2H^+ \quad (6\text{-}9)$$

This reaction occurs most at a higher pH (~4.0) than iron and produces a precipitate.

6.3.1.2 Oxidative Dissolution

Oxidative dissolution refers to the breakdown of other minerals by oxidizing their individual components (Figure 6.3-2). It is an important mechanism for release of heavy metals from other types of sulfide minerals (at the Holden Mine, primarily sphalerite and chalcopyrite). These minerals may not oxidize rapidly when exposed to atmospheric oxygen alone but when exposed to the strongly acidic solutions generated by oxidation of pyrite can be oxidized by dissolved iron(III):

$$ZnS + 8Fe^{3+} + 4H_2O \rightarrow 8Fe^{2+} + Zn^{2+} + SO_4^{2-} + 8H^+ \quad (6\text{-}10)$$

Sphalerite can also be oxidized directly by air:

$$ZnS + 2O_2 \rightarrow Zn^{2+} + SO_4^{2-} \quad (6\text{-}11)$$

A third mechanism of oxidative dissolution occurs when two different minerals with different rest potentials are in contact and form an electrical cell with one mineral acting as the cathode and the other as the anode (Kwong, 1995). If sphalerite (Rest Potential –240 mV) is on contact with pyrite (630 mV), oxidation of sphalerite occurs preferentially, and pyrite is protected from oxidation. Sphalerite acts as the anode undergoing oxidation:

$$ZnS \rightarrow Zn^{2+} + S^{\circ} + 2e- \quad (6\text{-}12)$$

This process only occurs in sulfide deposits where there is a strong electrical connection between sulfide grains.

6.3.1.3 Acid-Consuming Minerals

The water produced by weathering of sulfide minerals is typically acidic (pH<4), and contains elevated concentrations of sulfate and heavy metals (iron, copper and zinc).

The acid in the water can be removed by interaction of the solutions with other types of minerals, or by mixing of acidic solutions with waters containing dissolved alkalinity produced by contact with these minerals. An example is the buffering of acidity by contact with calcium carbonate minerals. These control pH at between 6 and 8:

$$CaCO_3 + H^+ \leftrightarrow Ca^{2+} + HCO_3^- \tag{6-13}$$

At the Holden Mine, carbonate minerals generally appear to be rare, but alumino-silicate minerals can potentially buffer acidity, primarily resulting in the release of aluminum, for example, reaction of the calcium end-member of plagioclase feldspar (anorthite):

$$CaAl_2Si_2O_8 + 8H^+ \rightarrow Ca^{2+} + 2Al^{3+} + 2H_4SiO_4^{\circ} \tag{6-14}$$

The crystallinity of the silicates limits their reactivity. Framework silicates such as feldspars, have limited reactivity. Layer silicates (for example, chlorite, biotite and sericite) can be very effective buffers due to their weak crystalline structure. Bioite is a relatively abundant mineral at the Holden Mine. It consumes acidity, releasing magnesium, iron, aluminum and silica. Diopside, a relatively abundant mineral at the Holden Mine, also reacts with acid releasing calcium and magnesium.

The aluminum released when alumino-silicates dissolve in acid can be hydrolyzed to aluminum hydroxide, releasing acidity:

$$Al^{3+} + 3H_2O \leftrightarrow Al(OH)_3 + 3H^+ \tag{6-15}$$

This buffer controls pH at between pH 4 and 5 and commonly results in the formation of pale precipitates in mine drainage (for example, the 1500-level main portal, P-1 discharge station). These precipitates are typically amorphous (non-crystalline) and incorporate other elements.

Ferric hydroxide also buffers acidity, though at a level considered undesirable because the pH of 3 to 3.5 is below the pH at which hydroxides of heavy metals such as copper will precipitate. The ferric hydroxide buffer reaction is:

$$Fe^{3+} + 3H_2O \leftrightarrow Fe(OH)_3 + 3H^+ \tag{6-16}$$

6.3.2 Seasonal Leaching Effects

The above processes describe how acidity and metals are possibly released and neutralized by reaction with nearby minerals. An important component in these interactions is the rate and flow of water. If water flow is completely absent, the processes largely proceed in isolation. For example, sulfide minerals will oxidize producing soluble weathering products but the resulting acidity and metal load will remain stored on the mineral surface. Neutralizing minerals will also slowly weather but the alkalinity produced will not be available. This is often the case for mine workings and waste rock associated with hard rock metal mine sites since preferential flow paths (for example, along fractures in the bedrock within the underground mine) develop. The weathering products remain stored and do not influence leachate quality unless contacted by water from a storm event or flooding.

If water flow is available to dissolve weathering products on a mineral surface, then the rate of flow and flow variability become important considerations. At the Holden Mine, flow of water is highly variable and results in significant seasonal variations in water quality associated with the source areas. These variations are illustrated conceptually in Figure 6.3-3. The sequence is shown as beginning in summer because this typically represents the time when accumulation of weathering products on mineral surfaces begins after extensive leaching by melt-waters in the spring. Summer is typically a dry season when little water infiltrates onto the surfaces of sources except during rain-storms. Under these conditions, weathering products accumulate on the surfaces of sulfide minerals but are not leached. Seepage water quality under these conditions typically represents groundwater baseflow, with little or no contribution from surface water drainage.

In the fall, rainfall leads to infiltration of water on and into rock piles. The downward moving flow front dissolves weathering products that accumulated in the summer. The flow front contacts buffering minerals and pH increases. Since the water flow rate is relatively low and slow, conditions are optimal for raising pH by contact with weaker buffering minerals (such as silicates).

In the winter, the formation of snow-pack ties up the moisture and causes flow to decrease again, and weathering products again begin to accumulate on mineral surfaces.

Melting of the snowpack in spring leads to the release of relatively large volumes of water and thorough flushing (though never complete) of weathering products from mineral surfaces. The resulting solutions are acidic and contain high solute concentrations. Buffering minerals may be less effective in the spring than in the fall due to the inability to fully react with solute because the water is relatively fast moving. As the melt event proceeds, solute loads and concentrations both increase. However, as weathering products are leached, it is possible for concentrations and loads to gradually decrease. This may occur in thin relatively coarse deposits such as waste rock where leaching can be nearly complete and not constrained by solubility of secondary minerals.

6.3.3 Natural Metal Removal Processes

Weathering and leaching of mine workings, waste rock or tailings results in water with variable pH (depending on the degree of acid consumption) and elevated sulfate and metal concentrations. These leachates are produced in oxidizing to reducing environments by relatively slow moving groundwaters. Upon exiting the areas, the leachates are exposed to contact with an unlimited supply of oxygen, atmospheric carbon dioxide concentrations, and mixing with dilute and frequently alkaline waters. Since these conditions differ from those in which the leachates formed, the solution chemistry adjusts (equilibrates) to the new condition. The following sections discuss these re-equilibration processes and the effect they have on concentrations of heavy metals in solution.

The processes described include:

- Dilution.
- pH Control.
- Eh control.
- Efflorescence.

- Co-precipitation.
- Sorption.

6.3.3.1 Description of Processes

Dilution

During the mixing of waters of different origins, the mass of some chemical parameters in solution may be conserved due to the lack of processes resulting in loss from solution. The concentration in the mixed solution reflects that the total mass is constant but contained in a different volume of water. The resulting concentration, C, produced can be calculated from:

$$C = (C_A Q_A + C_B Q_B)/(Q_A + Q_B) \qquad (6\text{-}17)$$

The concentrations and water quantities for the two mixed solutions are C_A, C_B, and Q_A, Q_B, respectively. Conservation of mass allows the origin of mixed waters to be evaluated. It can also be used to evaluate the reliability of the water balance by performing a mass balance.

Chemical parameters for which the above calculation is reliable are referred to as "conservative." No parameters are conservative under all conditions since mixing may produce a change in pH or Eh (oxidation/reduction potential) that could conceivably cause precipitation. However, in the context of mining environments, some elements can be regarded as conservative. Under oxidizing, relatively dilute conditions, sulfate is conserved. Sulfate is non-conservative when an acid water containing high concentrations of sulfate mixes with a solution containing high concentrations of calcium. Hydrated calcium sulfate (or gypsum) is precipitated when both calcium and sulfate are removed from solution. Similarly, calcium is removed from solution, and is non-conservative. Calcium is even less conservative than sulfate because it is readily dissolved from a variety of common rock types containing carbonate. Magnesium also suffers from similar limitations to calcium except that its sulfate (epsomite) is more soluble than calcium sulfate and is less likely to be precipitated from solution containing high sulfate concentrations. It is also less common than calcium as a readily soluble constituent in common rock types though it also occurs in carbonate rocks as dolomite and magnesite.

Anions of the halogen elements (fluoride, chloride, bromide, iodide) can also be conservative due to the relatively high solubility of their compounds. The main limitation is that their concentrations are usually not high enough in mine waters to be detected.

Most heavy elements are not conservative because other fate processes described below affect them. Zinc often shows quasi-conservative behavior because its hydroxide is relatively soluble under typical natural water conditions. However, it is co-precipitated when hydroxides of iron and aluminum precipitate.

For the Holden Mine, magnesium has been identified as a useful conservative element downstream of potential mine-influenced sources.

pH Control on Precipitation/Dissolution

Change in pH is probably the most important mechanism controlling the initial fate of metals in mine drainage. As described in Section 6.2.1, mine drainage often has a pH of less than 4 due to oxidation of sulfide minerals. As the acidic leachates contact buffering sources (minerals) and mix with alkaline waters, the pH increases. The stability of minerals is defined in part by pH. For example, the stability of aluminum hydroxide in terms of pH can be defined based on the reaction:

$$Al^{3+} + 3H_2O \leftrightarrow Al(OH)_3 + 3H^+ \qquad (6\text{-}18)$$

The equilibrium constant for the reaction is:

$$k = a_{H+}/a_{Al3+} \qquad (6\text{-}19)$$

This defines the relationship between pH (-log a_{H+}) and aluminum activity (a_{Al3+}) which in turn can be used to calculate part of the pH-activity diagram shown in Figure 6-3.4. Note that activities (a) are determined from concentrations adjusted using activity coefficients (γ), for example:

$$a_n = \gamma c_n \qquad (6\text{-}20)$$

Other reactions define other parts of the curve:

$$Al(OH)_2^+ + H_2O \leftrightarrow Al(OH)_3 + H^+ \qquad (6\text{-}21)$$

$$Al(OH)^{2+} + 2H_2O \leftrightarrow Al(OH)_3 + 2H^+ \qquad (6\text{-}22)$$

The outcome of this diagram is that as an acidic solution evolves in pH by contact with aluminum-containing minerals, pH increases and aluminum also increases (see hypothetical trajectory). Eventually, the stability line for aluminum hydroxide is reached and aluminum hydroxide precipitates. As long as aluminum hydroxide is in contact with the solution, the trajectory then follows the curve down as pH increases further (for example, if the water mixes with another alkaline water). Aluminum concentrations decrease as aluminum hydroxide precipitates. This is a very common effect at mine sites as demonstrated by the occurrence of white precipitates within the 1500-level main portal drainage (Figure 6.1-1a). Figure 6.3-4(a) shows aluminum concentrations on a log scale to illustrate the curve. Figure 6.3-4(b) shows the same diagram on an arithmetic scale to illustrate that once the curve is intersected, and pH continues to increase, aluminum concentrations decrease very rapidly, becoming "undetectable" by pH 5.

Similar curves can be drawn for other common precipitates such as red ferric hydroxide (Figure 6.3-5) and green basic copper carbonate. When carbonates form, the partial pressure of carbon dioxide also affects the pH and the type of mineral that form. For example, under atmospheric conditions, the stable basic copper carbonate is malachite, but at higher carbon dioxide pore pressures, azurite will form.

The pH changes therefore control the fate of dissolved potential contaminants by causing them to precipitate. Reversals in pH also cause dissolution by the same processes.

Eh Control on Precipitation/Dissolution

Eh describes the oxidation state of a constituent. Unlike pH which refers to the actual activity of hydrogen ions in a water, Eh does not refer to concentration of any particular ion. The oxidation state is defined by the balance between oxidation/reduction couples (in mine waters most commonly Fe^{2+}/Fe^{3+}):

$$Fe^{2+} = Fe^{3+} + e^- \qquad (6\text{-}23)$$

where:

e^- is an electron.

The equilibrium constant is:

$$k = a_{Fe3+}a_e/a_{Fe2+} \qquad (6\text{-}24)$$

Since k is constant, the ratio of activities of the iron ions defines a_e which is proportional to Eh.

Like pH, the stability of minerals can be defined in terms of Eh. Eh-pH diagrams are often constructed to show the stability of minerals and ions. If a mineral and dissolved ion are in contact and in equilibrium, the pH and Eh is constrained to the line shown on the pH-Eh diagram. In Figure 6.3-6, the line between Fe^{2+} and FeOOH is defined by the half reaction:

$$Fe^{2+} + 2H_2O \rightarrow FeOOH + 3H^+ + e^- \qquad (6\text{-}25)$$

The e^- indicates that an electron has been lost due to oxidation of Fe(II) to Fe(III). The reaction shows that the slope on the Eh-pH diagram is negative as shown in Figure 6.3-6 (assuming a fixed total iron concentration).

The electron can be taken up by any oxidizing species, for example oxygen (O_2):

$$\tfrac{1}{4}O_2 + e- + 2H^+ \rightarrow \tfrac{1}{2}H_2O. \qquad (6\text{-}26)$$

These diagrams can be used to explain the evolution of tailings groundwater. At the surface of the tailings, the sulfide minerals oxidize to produce acidic groundwater containing dissolved iron. At the surface, the presence of oxygen could allow Fe(II) and Fe(III) to be in equilibrium. As the water infiltrates into the tailings mass, only Fe^{2+} is stable. If neutralizing minerals are present, the pH will increase while Eh is decreasing. Alumino-silicate buffering constrains pH to between 4 and 5. If the porewater mixes with oxygenated groundwater (e.g., water in contact with a fast-flowing surface stream), the Eh increases, and eventually the solution reaches the line defining the stability between Fe^{2+} and iron oxyhydroxide. This causes iron oxyhydroxide to precipitate, removing iron from solution. As Eh further increases, pH will decrease due to the release of H^+ during precipitation. Eventually, the solution could be expected to enter the field in which only iron oxyhydroxide is stable.

Efflorescence

Efflorescence refers to the precipitation of minerals due to the evaporation of water. The process is very commonly observed along the edge of seeps, and mine drainage collection pools and streams during the summer. Efflorescence occurs when water becomes saturated with respect to minerals and nucleation of crystals can occur. Chemical saturation is defined by the solubility product (k_{sp}), which is the equilibrium constant for reactions such as:

$$CaSO_4 = Ca^{2+} + SO_4^{2-} \tag{6-27}$$

Whether a mineral can be expected to form by efflorescence is determined by the saturation index (SI):

$$SI = IAP/ksp \tag{6-28}$$

where:

IAP is the ion activity product. If SI is greater than 1, the mineral is expected to precipitate from the solution. As indicated above, there are kinetic considerations which prevent precipitation, so solutions can appear over-saturated. SIs are usually expressed as logs so that the critical value is 0, rather than 1.

Co-precipitation

Co-precipitation describes the mechanism by which trace metal ions are incorporated into the structure of precipitating solids (Figure 6.3-7). It is a very important process during pH and/or Eh changes, which cause precipitation of aluminum, manganese and iron oxyhydroxides. The trace metals may be present at concentrations well below those required to precipitate their own hydroxides but the rapid precipitation processes allow the elements to be incorporated into the structure due to their similar physico-chemical properties. Evidence of the process is commonly observed in the analysis of iron precipitates. Examples of elements affected by co-precipitation include copper, zinc, cadmium, cobalt, manganese and arsenic.

Sorption

Sorption describes surface charge effects that allow trace elements to be precipitated at lower concentrations than predicted based purely on the solubility of their oxides and hydroxides. The results are often indistinguishable from co-precipitation. However, sorption involves the trace elements attaching to the surface of iron and manganese oxyhydroxides after the oxyhydroxides have formed rather than during their formation. The process is common in stream beds where iron and manganese oxyhydroxides coat sediments. It is commonly observed that iron and manganese concentrations in fine stream sediments are very strongly correlated with concentrations of trace metals due to sorption.

Sorption refers to numerous complex surface processes, which are specific to each substrate. However, the main control is pH because the sorptive surfaces undergo charge reversal at a certain pH referred to as the zero-point-of-charge (zpc). The surfaces are positively charged as $pH<pH_{zpc}$ and negatively charged for $pH>pH_{zpc}$. Above pH_{zpc}, cations are therefore attracted to the surfaces. Figure 6.3-8 illustrates some typical curves showing amount adsorbed on goethite versus pH for several elements. The upper part of the curve represents near 100 percent adsorption. As shown, the transition from negligible to near complete adsorption occurs over a pH range of about 2 units. Sorption occurs onto organic materials and organisms (plants and animals). Intake of trace elements by plants and bacteria may occur.

6.3.4 Conclusions

Weathering of iron-bearing sulfide minerals (including pyrite, pyrrhotite and chalcopyrite) produces water containing acid, sulfate and iron. This water is strongly acidic and oxidizing, and can oxidize and dissolve other sulfide minerals (such as sphalerite). The acidic water also reacts with other minerals, particularly carbonate and silicates. These minerals consume acid, releasing their elements to solution. Reaction with silicates commonly releases aluminum, sodium, potassium, calcium and magnesium. The water produced by reaction with rocks commonly contains a mixture of elements reflecting these processes.

As mine-influenced water mixes with other more dilute waters, concentrations can be diluted. Metals can also be removed from solution by a variety of processes including pH and Eh increases (resulting in precipitation), efflorescence (removal by evapo-concentration), co-precipitation (removal of metals by precipitation), and sorption (removal by precipitation on secondary minerals). These processes can significantly remove metals before the water enters Railroad Creek.

6.4 EVIDENCE AND IMPLICATIONS OF GENERAL CHEMICAL PROCESSES AT THE HOLDEN MINE SITE

As a first step in understanding weathering processes at individual hard rock metal mine sites, it is useful to examine water chemistry for evidence of overall chemical controls. The exposed walls, waste rock and tailings all originate from a narrow geological sequence containing specific minerals as described in Section 6.1.2. It is expected that the chemistry of waters at the Site have some common characteristics that reflect:

- The presence of certain abundant reactive sulfide minerals (pyrite, pyrrhotite, chalcopyrite, sphalerite) and silicate minerals (principally chlorite, biotite and sericite) in the ore and host rocks
- The chemical changes resulting from oxygenation and mixing of these waters with the dilute runoff, groundwater, or surface water

The following subsections describe overall site-specific evidence for these reactions. The interpretative tool used is described in Section 6.2.1. Bivariate scatter plots showing concentrations of metals versus sulfate and each other were examined. If the data points fall on a straight line with a constant slope and intercept near 0 (arithmetic axes) or a slope of 1 (logarithmic axes), a constant ratio of the two parameters is implied. This indicates a common mineralogical source. For example, dissolution of sphalerite (ZnS) would produce a water with zinc/sulfate (Zn/SO_4)=1 (molar concentrations), regardless of the quantity of water contacting the mineral. A constant ratio can be preserved for several different waters all influenced by the same process. If the data lie on a straight line with a non-zero intercept (arithmetic axes) or a curvilinear trend (logarithmic axes), mixing of two different waters is indicated.

The data used in these interpretations are shown in Section 5 and include all surface water and seep samples collected in 1997 and 1998.

6.4.1 Evidence of Iron Sulfide Mineral Oxidation

Sulfate is the best indicator of oxidation processes because oxidation of iron sulfides (pyrite and pyrrhotite) (Figure 6.3-1) and oxidative dissolution of heavy metal sulfides (Figure 6.3-2) produce secondary iron sulfate salts. Iron is also released when pyrite and pyrrhotite are oxidized; it is only useful as an indicator of iron sulfide oxidation in low pH (<3.5) waters because at higher concentrations it is removed from solution as iron hydroxide.

Comparison of dissolved iron and sulfate data from seeps and surfaces waters (Figure 6.4-1) indicates a linear trend for the strongly acidic (pH<4) tailings pile seepage (seeps SP1, SP2, SP3, SP4 and SP5, which are depicted on the figure as tailings piles 1 through 3) and Railroad Creek upstream of the tailings seepages (RC-1 and RC-4). Two other separate clusters are apparent for Railroad Creek downstream of the tailings piles (stations RC-7, RC-2 and RC-5), and the mill building, rock piles and portal drainage (P1 and P5). The upper end of the linear trend indicates nearly exactly molar quantities of sulfate and iron, with sulfate exceeding iron. This is consistent with iron and sulfate released from oxidation of pyrite (FeS_2) and pyrrhotite ($Fe_{1-x}S$) although some iron may have originated from leaching of iron-bearing silicates (mainly hornblende in the tailings).

The linear trend reflects the mixing of tailings seepage waters of the type represented by tailings pile 1 with Railroad Creek waters originating upstream. This implies that the seep waters from tailings piles 2 and 3 are comparable to tailings pile 1 but more dilute due to mixing with dilution waters. The linear trend in Figure 6.4-1 reflects the mixing of tailings seepage waters of the type ($Fe>SO_4$) represented by tailings pile 1 with Railroad Creek waters originating upstream (RC-1, $SO_4>Fe$). This implies that the seep waters from tailings piles 2 and 3 are comparable to tailings pile 1, but more dilute due to mixing with Railroad Creek. It would be expected that the downstream waters in Railroad Creek (for example, RC-2 would lie exactly on this trend (i.e., Fe increasing with respect to SO_4 while $Fe/SO_4<1$). However, there appears to be more iron (i.e., $Fe=SO_4$) than would be expected. As the plot was constructed using "dissolved" iron, it is suspected that the iron is perhaps overestimated due to the presence of colloidal iron flocculent in the water; this would tend to overestimate the dissolved iron concentrations, while not affecting sulfate.

In summary, the relationship of iron and sulfate indicates that oxidation of pyrite and pyrrhotite are controlling processes on tailings seepage chemistry, as expected. Oxidation of these iron sulfide minerals releases iron, sulfate and acid.

The iron versus sulfate cluster for the mill building, portal discharge and rock piles suggest a different controlling process as discussed further below.

6.4.2 Evidence of Oxidation of Sphalerite

Sphalerite is dominantly zinc sulfide (ZnS), but iron sulfide may substitute for up to 40 percent, and up to 4 to 5 percent cadmium and manganese have been reported in sphalerites (Deer et al. 1966). Sphalerite at the Holden Mine is relatively iron-rich.

Zinc concentrations in drainage, particularly from the west part of the Site (mill building, 1500-level main portal drainage, waste rock piles) are consistent with oxidation of sphalerite and production of secondary zinc sulfate salts. Zinc and sulfate concentrations are correlated and the ratio is constant (Figure 6.4-2); however, zinc is less than sulfate. This can be explained as follows:

- Oxidation of iron sulfides releases iron, sulfate and acidity (Equations 6-4 to 6-6). The acidity released is proportional to the sulfate released.
- The acidity released enhances oxidation of sphalerite. The greater the acidity, the greater the release of zinc. Hence, the zinc concentration is proportional to acidity.
- As a result, sulfate, produced by oxidation of iron sulfide, is correlated with zinc produced by oxidation of sphalerite. In this process, sulfate exceeds zinc release.

The difference between tailings and other locations is consistent with negligible sphalerite concentrations in the tailings (due to ore processing) but residual sphalerite in the mine workings, waste rock piles, and the abandoned mill building.

Zinc to cadmium ratios (Figure 6.4-3) are nearly constant throughout the Site. The generally constant values indicate that cadmium is associated with sphalerite, and that sphalerite tends to have a constant zinc to cadmium value. Cadmium and zinc also show very similar chemical behavior in the range of natural conditions. This is a very common observation for hard rock metal mine sites, as at the Holden Mine where the type of sphalerite appears to be relatively uniform.

A very strong correlation exists between manganese and sulfate (Figure 6.4-4), and a constant ratio applies to the whole Site ($Mn/SO_4 = 0.005$). Manganese can be associated with both sulfides (e.g., pyrite, sphalerite), iron oxides and as a minor phase substituting in iron silicates. Manganese is relatively resistant to pH and Eh changes under surface conditions, hence it may remain in solution. The relationship suggests a constant Site-wide control on manganese chemistry (i.e., leaching of pyrite and sphalerite).

Sphalerite oxidation therefore occurs in the presence of acidic waters produced by the oxidation of iron sulfides. This releases zinc, cadmium and probably manganese.

6.4.3 Evidence of Oxidation of Chalcopyrite

Copper concentrations are consistent with oxidation of chalcopyrite and production of secondary copper sulfate salts. Several common copper sulfates have also been documented at the Site (see Table 6.1-1).

Relationships between copper and sulfate (Figure 6.4-5) are similar to zinc and sulfate (Figure 6.4-2), although the data are more scattered. Copper to sulfate ratios are greatest for the abandoned mill building, the east and west waste rock pile area seeps, and 1500-level main portal drainage (pH<5). The ratio is relatively consistent for these sources (~0.03). Lower ratios are apparent for the less acidic 1500-level main portal drainage. This reflects the strong pH control on copper concentrations at pH>5. As the pH increases, copper concentrations decrease but sulfate is unaffected.

The tailings pile seeps (noted on the Figure 6.4-5 as "tailings piles 1, 2 and 3") indicated a much lower ratio (10^{-4}) in acidic waters (pH<4). This is consistent with removal of the main source of copper (chalcopyrite) from the ore during processing. The tailings therefore contain little chalcopyrite compared to the underground mine workings, residual concentrates in the abandoned mill building and waste rock piles.

Based on this information, chalcopyrite is considered the primary mineral source of copper in Site waters. The abundance of available chalcopyrite is an important limitation on copper concentrations in seeps, as discussed later in this section.

6.4.4 Evidence of Acid-Buffering by Minerals

Assuming that acid production is represented by sulfate, the effect of acid-buffering can be evaluated by comparing sulfate concentrations with alkali and alkali earth elements commonly associated with acid-buffering minerals. At the Holden Mine, these minerals include carbonates containing calcium and magnesium (in marbles), calc-silicate rocks, and alumino-silicates containing magnesium (chlorite, micas, hornblende), calcium (hornblende, plagioclase feldspars), potassium (biotite, sericite) and sodium (hornblende, plagioclase, clays). Comparison of sulfate with potassium, magnesium, calcium, and sodium, as well as inter-comparisons for the elements can indicate the types of buffering reactions occurring.

Calcium is probably the most ubiquitous element (after silicon) as it occurs in plagioclase, diopside and hornblende. Plagioclase is a major component of all rock types.

Calcium shows a strong correlation with sulfate (Figure 6.4-6), though tailings pile 1 shows a different relationship than the other water sources. The calcium to sulfate ratio is approximately 0.5, except for tailings pile 1 (0.2). The constant ratios are consistent with leaching reactions of the type for calcic plagioclase:

$$CaAl_2Si_2O_8 + 8H^+ \rightarrow Ca^{2+} + 2Al^{3+} + 2H_4SiO_4^{\circ} \qquad (6\text{-}29)$$

The difference for tailings pile 1 suggests that leachate chemistry is controlled by different mineralogy or that the lower pH is allowing different minerals to react with the acidity.

Magnesium is also a ubiquitous element occurring in several minerals (hornblende, biotite and chlorite).

The ratio between sulfate and magnesium is nearly constant for the whole Site ($Mg/SO_4 \sim 0.2$, Figure 6.4-7). Railroad Creek waters show a decreasing ratio of magnesium to sulfate, consistent with mixing of the higher magnesium background surface waters with higher sulfate mine waters. The very strong relationship between magnesium and sulfate indicates a ubiquitous buffering reaction by magnesium and aluminum containing minerals (e.g., biotite), for example:

$$K(Mg_x,Fe_{1-x})_3(AlSi_3O_{10})(OH)_2 + 10H^+ \rightarrow K^+ + 3(1-x)Fe^{2+} + 3xMg^{2+} + Al^{3+} + 3H_4SiO_4 + H_2O \quad (6\text{-}30)$$

The value of x is less than 1. The same reaction could be written for chlorite or hornblende, both of which are also common minerals at the Holden Mine Site. Evidence that biotite is an important buffering control is shown by the relationship between potassium and magnesium (Figure 6.4-8). For the 1500-level portal drainage, the ratio of potassium to magnesium averages 0.33 which is consistent with buffering by biotite with x near 1 (i.e., 3 moles of magnesium for each mole of potassium) or additional buffering by other magnesium-based minerals lacking potassium such as chlorite. The lower potassium to magnesium ratio for tailings piles 1 and 2 indicates that bioite is less significant. This is consistent with the presence of diabase, which has little biotite or sericite.

Comparison of sulfate and aluminum also supports the general conclusion of buffering by alumino-silicates (Figure 6.4-9); however, aluminum concentrations are lowered by aluminum hydroxides precipitation, hence the relationship is only stable at higher sulfate and lower pH.

In summary, abundant alumino-silicates (calcic plagioclase, biotite and possible chlorite) are involved in buffering acid produced by oxidation of iron sulfide minerals.

6.4.5 Evidence of Metal Attenuation

Secondary mineral precipitation controls can be examined principally by comparing metal concentrations with pH. Further discussion of mineral solubility controls using MINTEQA2 (Allison et al. 1991) is provided in Section 6.5 for each of the water quality monitoring locations.

The relationship between iron and pH indicates a strong negative correlation (Figure 6.4-10). Lower pHs (<3.5) are associated with high iron concentrations in the tailings pile seeps. Scatter at higher pHs can be caused by colloidal flocculent indicating high "dissolved" iron concentrations (for example, in surface waters and emergent groundwater) and ferrous iron (ground waters), which remains in solution at neutral pH. Scatter can also be the result of concentrations near laboratory detection limits. The general relationship between iron and pH indicates pH control by precipitation/dissolution of iron oxyhydroxides. Difference in iron concentrations at various locations at the Site are therefore strongly controlled by solubility of secondary iron minerals produced when ferrous iron oxidizes to ferric iron which then precipitates as ferric hydroxide:

$$Fe^{2+} + \tfrac{1}{4}O_2 + H^+ \rightarrow Fe^{3+} + \tfrac{1}{2}H_2O \qquad (6\text{-}31)$$

$$Fe^{3+} + 3H_2O \leftrightarrow Fe(OH)_3 + 3H^+ \qquad (6\text{-}32)$$

The pH to aluminum relationship (Figure 6.4-11) is similar to iron except that the transition to low aluminum concentrations occurs between pH of 4 and 5. Above pH 5, aluminum concentrations are very low or are not detected above detection limits. The strong correlation implies aluminum solubility control by precipitation of aluminum hydroxide in mine waters.

$$Al^{3+} + 3H_2O \leftrightarrow Al(OH)_3 + 3H^+ \qquad (6\text{-}33)$$

Surface water in Railroad Creek has fairly constant aluminum concentrations (0.001 mmol/L) which are probably not high enough to be controlled by aluminum hydroxide ($Al(OH)_3$) solubility.

The strong relationships between pH to iron and pH to aluminum, and the abundance of both iron and aluminum in the rocks and tailings indicate that precipitates form when these minerals are released and serve as important pH buffers for the Holden Mine Site. It is therefore likely that the solubility of other minerals will also be limited due to the buffering capacity of these minerals.

The pH to copper relationship (Figure 6.4-12) shows some indication of pH controls. Copper is higher in concentration in the west area of the site than the east area. The abandoned mill building, portal drainage and waste rock piles indicate a negative correlation between copper and pH implying a constraint on copper concentrations for these data. In comparison, much lower copper concentrations are seen in the tailings pile seeps. The data do not have sufficient pH range to demonstrate a relationship between copper and pH, though tailings pile 1 has lower copper concentrations at higher pH. The tailings pile data probably indicate a limit to the availability of copper in the tailings but also possibly indicate the effects of co-precipitation of ferric hydroxides. In the case of limited copper availability in tailings, the correlation of pH and copper reflects only the increased leaching of copper by stronger acidic solutions. Copper concentrations in surface waters of Railroad Creek are very low and do not appear to be controlled by the solubility of copper secondary minerals. Coprecipitation and adsorption on iron coatings and other materials on stream sediments is expected to attenuate copper concentrations in stream waters.

The plot of pH and zinc (Figure 6.4-13) is similar to copper except that the mill building, portal drainage and waste rock piles appear to have relatively stable zinc concentrations (between 0.1 and 1 mg/L). This may imply a mineral solubility constraint, although zinc minerals are far more soluble than indicated by these data. The tailings pile data appear to indicate a limit to the availability of zinc, as zinc would be expected to occur at much higher concentrations in low pH water (by extrapolation of the pH to zinc trend for the mill building, portal drainage, and waste rock piles). The correlation of zinc and pH may, like copper, be caused by co-precipitation of zinc with ferric hydroxides, with the effect decreasing as pH decreases. Comparison of sulfate and aluminum also supports the general conclusion of buffering by alumino-silicates (Figure 6.4-9) shown by examination of magnesium and potassium concentrations. Sulfate is correlated with aluminum at high aluminum and sulfate concentrations indicating that generation of acid, represented by sulfate results in attack on alumino-silicates releasing aluminum in proportion to acidity. However, aluminum concentrations are lowered by aluminum hydroxides precipitation, hence the relationship is only stable at higher sulfate and lower pH. Aluminum is removed rather than sulfate as pH increases introducing scatter in the relationship between the parameters in Figure 6.4-9.

The cadmium to pH relationship is similar to Zn-pH indicating that zinc and cadmium show similar geochemical behavior (Figure 6.4-14).

Water chemistry indicates that pH is controlled by the formation of amorphous hydroxide precipitates of iron and aluminum. The formation of these precipitates constrains pH, which allows copper to remain in solution, but precipitation also allows attenuation by co-precipitation and provides a substrate for adsorption.

6.4.6 Conclusions

Evaluation of water chemistry indicates that geochemical behavior consistent with the well-known processes discussed in Section 6.3 is occurring throughout the Holden Mine Site. Conclusions from this section are as follows:

- Consistent geochemical processes are occurring throughout the Site, specifically iron sulfide oxidation, sphalerite and chalcopyrite oxidation, buffering and metal attenuation.

- The geochemistry of Site waters is generally consistent with oxidation of pyrite and pyrrhotite to release sulfate, iron and acid. The molar ratio of sulfate to iron in acidic solutions is consistent with the ratios in the minerals. Oxidation of iron sulfides is the main source of sulfate in the waters. Iron solubility is controlled by pH.
- Oxidation of sphalerite results in the release of zinc, cadmium and probably manganese. The low concentration of sphalerite in all of the tailings piles due to ore processing results in relatively low zinc concentrations in seepage water.
- Oxidation of chalcopyrite results in the release of copper. The abundance of chalcopyrite is an important limitation. The tailings piles contain very little chalcopyrite (due to ore processing) and therefore seeps from the tailings piles contain relatively low copper concentrations. Copper concentrations in surface water of Railroad Creek are low and are not controlled by the solubility of copper secondary minerals, but rather by sorption processes.
- Buffering of acidity produced by sulfide oxidation is occurring by the reaction of waters with alumino-silicates. The main silicates involved in the reaction appear to be calcic plagioclase, biotite and possibly chlorite. The contribution of these minerals is indicated by the correlation of calcium, magnesium, potassium and aluminum concentrations with sulfate and each other.
- Since alumino-silicates are ubiquitous and abundant, buffering occurs close to the source of acid generation.
- The release of aluminum by an acid reaction with alumino-silicates results in an important control on pH. Precipitation of aluminum hydroxide controls pH at 4.5. This limits the solubility of some metals (e.g., iron) but also allows pH to be low enough to allow copper, zinc and other metals to remain in solution. This in turn allows metals to reach Railroad Creek with little attenuation.
- The comparison of sulfate and aluminum supports the general conclusion of buffering by alumino-silicates; however, aluminum concentrations are lowered by aluminum hydroxide precipitation, hence the relationship is only stable at higher sulfate and lower pH.

6.5 GEOGRAPHICAL DESCRIPTION OF CHEMICAL PROCESSES

This section presents difference of the processes that are occurring in different parts of the Site and that reflect unique characteristics associated with specific sources. The differences in processes at these source areas are generally related to the movement of air and the movement of water. Air movement is a fundamental process control/factor because it is regulates the degree to which oxidation occurs. If oxygen is readily available, oxidation is not limited by oxygen supply but can occur at a rate dictated by the properties of the minerals. Water movement is also an important controlling factor because it controls the dissolution and transport of weathering products. Seasonal variations in water flow also control variations in load release of drainage waters that discharge to Railroad Creek.

6.5.1 Air and Water Movement Associated with the Honeymoon Heights and Mine Support Areas

The Honeymoon Heights and Mine Support areas include the underground mine, waste rock piles, abandoned mill building and maintenance yard. Each source area is described below.

6.5.1.1 Underground Mine Processes

Air Movement

The underground mine contains specific physical features which control the weathering and leaching of surfaces within the mine (Figure 6.5-1):

- Several portals are partially open to open (300-, 1100-, 1500-level main, and 1500-level ventilator); however, only the lowest portal (1500 level main) is discharging water on a year round basis.
- No major vertically-oriented surface openings such as "glory holes" (openings to the ground surface) or shafts exist.
- The mine is flooded below the 1500 level, and the majority of the stopes below the 1500-level have been backfilled.
- All of the stopes above the 1500 level are not backfilled.

An important feature of the underground mine is that it was reported to have a consistent internal temperature of 50°F (McWilliams, 1958), likely due to the geothermal gradient. This is an important factor to the availability and supply of oxygen for oxidation in the underground mine.

In the summer, it has been observed that air both enters and exits the mine at the 300-, 1100-, and 1500-level portals. This is likely due to the sinking of cool, dense air in the mine when the outside temperature is above 50°F, an effect resulting in air being drawn into the mine at other locations (i.e., 300-level), and rising of less dense air when the outside temperature is below 50°F. Air flow through the mine is also assumed to be caused by changes in barometric pressure. The air movement probably leads to oxygenation of relatively near surface workings as shown in Figure 6.5-1.

Winter is the likely time of relatively high air movement in the underground mine due to the significant temperature difference between the external environment and the mine (Figure 6.5-2). The average difference is estimated to be 30°F. As a result, warm air in the mine rises drawing air in through the lower portals and causing venting from the upper part of the mine. These conditions allow oxygen to penetrate into the workings resulting in oxidation of sulfide minerals and accumulation of weathering products through the winter. Stopes farther back within the mine probably experience relatively stagnant air conditions with relatively low oxygen concentrations and thus limited oxidation of sulfide minerals. Flooded stopes below the water table remain permanently inaccessible to oxygen.

In the spring, airflow reduces as external temperature increases and the external temperatures and mine temperatures are within 10°F (Figure 6.5-3).

Water Flow

The mine drainage area encompasses the underground mine, 1500-level main portal, 1100-level mine, and the 1500-level ventilator portal. The anticipated transport pathways for these areas are shown on Figure 6.5-4. Conceptual flowpaths for spring conditions (snowmelt period, roughly May to June) from the mine workings has been observed primarily from the 1500-level main portal, with relatively minor discharges from the 1100-level portal and the 1500-level ventilator portal. Mine water discharge occurring from any of the surface exposures of faults or shear zones which intersect the orebody have not been observed.

In the spring, snowmelt enters near-surface discontinuities in the bedrock south of the Site and flows downward through the open stopes above the 1500-level of the underground mine. Infiltrating groundwater flows through mineralized but unmined portions of the mine and contacts residual mineralization on rock faces of the stopes and tunnels. The water emerges at the 1500-level main portal (portal drainage), flows overland, and discharges to Railroad Creek. Infiltration to groundwater in the alluvium/reworked till may occur during overland flow transport which eventually reaches Railroad Creek as baseflow. The 1500-level main portal drainage and potential loading contribution is further discussed below under Portal Drainage.

Infiltration from upslope run-on also seasonally perches in the 1100-level tunnel which then emerges as Seep A-1. This water infiltrates the surfaces of the 800- and 1100-level waste rock piles. An intermittent seep was observed near the base of the 800-level waste rock pile; the seep was sampled as it entered the intermittent drainage (SP-14 lower). The intermittent drainage then eventually infiltrates colluvium and glacial till and is assumed to discharge into the Railroad Creek as baseflow; however, it is not known for certain whether seep SP-23 is the discharge point for the infiltrated water from the intermittent drainage; see Section 6.5.1.4 for further discussion.

The 1500-level ventilator portal is located approximately one-half mile west of the 1500-level main portal (Figures 6.1-1a). As mentioned in Section 4.1.3.2, a civil survey of the 1500-level ventilator portal indicated that the opening is approximately 20 feet higher in elevation than the 1500-level main portal. In addition, continuous flow measurements collected by a data logger installed at the 1500-level main portal (as discussed in Section 4.3.3.6) indicate relatively rapid and significant responses (within approximately one day) to precipitation events, which suggests that the pool behind the dammed portal is relatively low. Also, as discussed in Section 6.5.1.4, the chemistry of the water sampled at the 1500-level ventilator portal indicated very dilute concentrations of metals when compared with the 1500-level main portal drainage (P-1). Consequently, it is likely that the water observed flowing from the 1500-level ventilator portal is meteoric groundwater seeping out of the glacial soil through which the portal was noted to have been timbered for the first 300 feet.

In the event that the water was actually backed up behind the failed portion of the 1500-level main portal to a level that would allow water to flow from the 1500-level ventilator portal, the water would not likely flow out of the opening but more likely would drain down through the "300 feet of gravels" noted on the mine map. In such an event, water would most likely flow through the subsurface into Railroad Creek downstream of the ventilator portal. A seep was observed below the 1500-level ventilator portal (SP-26). However, as discussed in Section 6.5.1.4, the chemistry of the SP-26 water indicated very dilute concentrations of metals when compared with the 1500-level main portal drainage (P-1), and SP-26 likely reflects meteoric water affected by an abandoned surface water retention area with tailings materials, and not originating from the underground mine. As noted later in this section, no other unaccounted sources of metals loading are noted in Railroad Creek between RC-6 (upstream of Seep SP-26) and RC-4 (downstream sampling station).

In July and August, influx of water into the mine is assumed to be, on average, significantly less than during the snowmelt period. By fall, the influx of water into the mine from upslope is assumed to be entirely from rainfall. As these months experience lower precipitation, overland flow through the 800- and 1100-level waste rock piles is significantly reduced. Seeps downslope from Honeymoon Heights were noted to flow only in response to rainfall events during the fall 1997 field program.

Underground Mine Water Chemistry

Comparison of seepage chemistry from the Honeymoon Heights drainage area suggests that the upslope waters, represented by seep SP-14 (which includes SP-14, SP-14 Lower, and SP-14 Upper), have been only moderately influenced by the mine or natural occurrences of mineralization. Metals and sulfate concentrations for seep SP-14 appear to be chemically comparable to other waters at the Site, but with significant dilution (pH: 4.5 to 6.1, Cu: <2 to 1410 µg/L, Zn:5 to 1610 µg/L, SO_4:<2.5 to 22 mg/L). Seep A-1, collected from the 1100-level portal, appears to have little or no influence from the mineralized bedrock (Cu: 120 µg/L, Zn: 257 µg/L, Cd: 2.3 µg/L, SO_4:40 mg/L) and does not reflect water quality of the mine pool as noted at the 1500-level main portal drainage (P-1). Water from this seep appears to be derived from rainwater and snowmelt that infiltrates through the overlying surficial materials to the adit.

The only direct indicator of underground water chemistry and processes is provided by the 1500-level main portal drainage (P-1). However, comparisons of portal drainage water quality with water quality data collected from other sources indicated that the portal drainage water chemistry most closely resembles the water draining from the mill building. The USGS (personal communication with Jim Kilburn, 1999) indicated that numerous typical secondary sulfate minerals were identified in the mill building in 1995 and 1996 (Table 6.1-1). These minerals contain iron, copper, zinc, manganese, aluminum and sulfate and vary from highly soluble to sparingly soluble (Alpers et al. 1994). The minerals are formed when concentrated groundwaters derived from contact with oxidizing mineral concentrates and residual ore become chemically over-saturated with minerals. This can occur by mixing of different solutions and evapo-concentration.

By comparison, the same minerals are probably present in the underground mine. This is a reasonable assumption since the mine probably contains exposures of ore-type material which could not be extracted due to requirements for ground support, or because the volume was not justified by mining economics. Sulfates are formed on the walls of the underground mine by oxidation and are then rinsed during flushing events. Evaporation of water during drier periods (primarily winter) allows the salts to accumulate.

Experience at other underground mines within similar geologic conditions indicates that these salts may be present throughout the mine wherever water emerges and can evaporate such as where fractures and drill holes intersect mine walls and where water is locally ponded and then drains. Since water flow likely occurs unpredictably on some fractures and not others, these locations of stored oxidation products are randomly distributed. Significant deposits of salts are generally identified opportunistically rather than by prediction. Therefore, inspection of the underground workings to identify specific types of salts and accumulations of salts is unlikely to be successful in characterizing the salts because not all parts of the workings are accessible due to physical barriers (backfill and collapsed workings) and safety concerns (ground stability, air quality, hidden hazards).

The pathway from the sources to the soluble salts involves contact with the host rocks and mixing with other waters. The host rocks are primarily composed of alumino-silicates and isolated occurrences of marble. This results in addition of aluminum, magnesium, calcium, potassium and sodium to the water as has been observed throughout the Site. The addition of these elements largely occurs in proportion to sulfate, which is a surrogate for the release of acid. These are expected to be extremely complex pathways.

Significant seasonal effects are apparent in the 1500-level main portal drainage at station P-1. This is reflected in pH changes. Lowest pHs are observed in the spring, and pH increases through the summer. This is accompanied by decreasing aluminum, copper and zinc concentrations, but sulfate does not change significantly. The lower pH in the spring is probably caused by flushing of acidic salts from rock surfaces and fractures in the spring, and by local recharge of pools within the underground mine that have evaporated through the previous summer and winter. This acid load is less effectively neutralized by contact with neutralizing minerals and reflects the decreases in pH at the portal. During the summer, pH increases due to much lower acid load, longer contact times with neutralizing minerals in the underground mine and mixing with alkaline groundwater, resulting in more complete neutralization.

The minor variations in sulfate concentrations suggest that the source of the water does not change significantly (that is, the pool within the underground mine continues to supply the water observed at P-1). The variation in metal concentrations in P-1 drainage is related to the differences in pH, and precipitation of oxyhydroxides rather than changes in source release. Source release may increase in the spring due to flushing, as described above, but the pH variations produce the same effect.

A metals-loading analysis of surface water discharging from the portal drainage was performed using the data collected during the RI. The flow data and chemical data collected from the 1500 level main portal drainage (station P-1) during the May, July and September 1997 rounds were used in the analysis. A summary of the chemical data is provided in Section 5 of this report. Historical flow and chemical data from 1982, 1983, and 1991 were also evaluated for use in the loading analysis; however, the data were not used in the loading analysis due to the uncertainties associated with the accuracy of the flow measurements recorded for these periods.

The results of the loading analysis are shown in Figure 6.5-5. Zinc and copper exhibited similar loading trends, with the highest loads occurring in May and a decline in concentration through September. Copper loads are generally lower than zinc and decrease more significantly in the late summer and fall. Data indicate that the dissolved iron loads discharged at the portal are approximately one order of magnitude less than corresponding zinc loads and continue to decrease to September.

Sulfate loads were approximately one order of magnitude greater than corresponding metal (zinc, copper, iron) loads. The patterns of sulfate discharge are very similar to those observed for the metals. The mass of sulfate discharged from the portal greatly exceeds the mass of copper, zinc, iron and cadmium discharged at any given time.

6.5.1.2 Waste Rock Piles

Air Movement

Like mine workings, differences in temperature are important considerations in determining weathering processes (Figure 6.5-6). In summer, the interior of the pile is anticipated to be cooler than the ambient temperature and there is no process to drive oxygen deep into the pile. Oxygen enters the pile from the surface driven by diffusion leading to oxidation in the immediate pile surface only.

The decrease in temperatures in the winter potentially creates optimal conditions for convective air flow (Figure 6.5-6). Warmer temperatures in the pile are created by heat generated by the oxidation processes. The temperature difference allows air to be drawn into the base of the pile providing further oxygen for oxidation. The process is self-perpetuating and indicates that winter can result in significant increases in internal temperatures. This also allows oxidation rates to accelerate and encourages weathering products to accumulate.

In the spring, melting of snow results in flushing of accumulated salts by cold water (Figure 6.5-6). This can cool internal temperatures, and coupled with rising ambient temperatures, serves to reduce oxidation rates.

Water Flow

The locations of the waste rock piles are shown on Figure 6.1-1a. Four waste rock piles are discussed and include the west and east waste rock piles, and the 800- and 1100-level portal waste rock piles. Waste rock piles associated with the 300, 500 and 700 portals are located on bedrock and are relatively small. There was no field evidence of seep discharge or surface water overland flow observed at these piles; therefore, they are not further discussed.

In the spring, upslope snowmelt run-on flows as overland flow and infiltrates on the slopes south of the waste rock piles and within each rock pile. Weathering products accumulated during the winter are leached. In general, groundwater moves downslope in the alluvial/reworked till unit and in the soil/fill material, and discharges either as seep overland flow or as groundwater baseflow into Railroad Creek (Figure 6.5-4).

The spring conceptual groundwater flow path is to the north and northeast from the waste rock piles toward the intermittent drainage for the 800- and 1100-level waste rock piles, and toward Railroad Creek for the east and west waste rock piles, as shown on Figure 6.5-7. Some portion of groundwater flow is presumably diverted into the abandoned Railroad Creek channel. Groundwater in the alluvium/till that flows from the west waste rock pile appears to emerge as intermittent seeps, SP-6 and SP-15E, and continues as overland flow to the lagoon (Figures 6.1-3a).

Groundwater from the east waste rock pile appears to emerge as an intermittent seep (SP-8). Surface water flow from SP-8 flows overland across tailings pile 1 and is expressed as seep SP-19 before flowing into the Copper Creek diversion (Figure 6.1-3a).

In the fall, groundwater flow is reduced and flows in a more northeasterly direction, indicating less input from valley side slopes and more influence from the downvalley groundwater flow component (Figure 6.5-8). Seep discharge was not observed, but the movement of groundwater through the abandoned Railroad Creek channel presumably continues.

Waste Rock Leachate Chemistry

The chemistry of waters seeping from the vicinity of the waste rock piles is very similar to the P-1 discharge and the mill building when considering ratios of key elements. The main feature of the waters, as measured at SP-8, SP-15, and SP-14 (lower) are that they contain relatively high copper and zinc to sulfate ratios (0.1 mol/mol) and low iron to sulfate ratios ($<10^{-3}$ mol/mol) when compared to the tailings pile seepage (e.g., SP-2, SP-3, SP-4 and SP-5) (Cu/SO4 Zn/SO4$<10^{-3}$ and Fe/SO_4>0.1) and are only weakly acidic (pH>4). This indicates either that the water is derived from one source and the observed chemistry is a result of mixing and dilution, or that common geochemical mechanisms are operating to control water quality as described in subsection 6.4.

Seep SP-8 is geographically well removed from P-1 (1500-level main portal drainage) and seep SP-7 (mill building); therefore, a geochemically similar source seems more likely. The detailed composition of the waste rock piles is unknown although visual inspection indicates that they contain some mineralized material, including pyrite, chalcopyrite and sphalerite mixed with host alumino-silicate rocks and some marble, similar to those minerals reported by others to be present in the mine (see Section 4.2.3).

Since the piles were placed on hillsides and, therefore, relatively thin, they are probably well-oxygenated. Much of the mineralized material is likely to have been oxidized, resulting in the build-up of similar weathering products to those observed in the mill building. Leaching of these weathering products and contact with the host rocks would likely result in pH greater than 4. Iron precipitates, but zinc and, to a lessor degree, copper would remain in solution. The higher pH (near neutral) and lower zinc and much lower copper concentrations at SP15W shows that marble is present; marble was also observed on the surface of the west waste rock pile. Malachite staining was observed on blocks of marble on the surface of the west waste rock pile, indicating the control of copper concentrations by precipitation of copper carbonate (malachite).

6.5.1.3 Mill Building and Maintenance Yard

Remnants of ore bins in the uppermost portion of the mill building contain residual sulfide minerals. These materials are exposed to atmospheric weathering conditions on a continuous basis. Leaching of weathering products occurs in the spring when snow melts in the remnant ore bins, and at other times of the year during rainfall.

Upslope surface water run-on flows overland and infiltrates across and through the abandoned mill buildings, some of which contacts unprocessed ore and mineral salts (Figure 6.5-4). The water exits the abandoned mill building (SP-7) and flows eventually into the lagoon.

Unprocessed ore material within the mill building is undergoing oxidation. Precipitation and surface water run-on aid in this process and remove accumulated oxidation products (Table 6.1-1). Metal cations (e.g., Cu^{2+}, Fe^{3+}, Zn^{2+}, Cd^{2+}) and sulfate (SO_4^{2-}) are dissolved into the surface water. The pH of these waters decreases also, aiding in the dissolution of any sulfide material present. Metal salts found on the ground surface and walls of the mill building are the result of the evaporation of metal-bearing water or its interaction with native materials causing precipitation. Some of the metals become redissolved and transported from the mill building.

The transport pathways associated with the maintenance yard are shown on Figure 6.5-4. Similar transport pathways occur as compared to other Site features. Overland flow from the area drains eventually into the lagoon (Figure 6.1-3a). Infiltration associated with the maintenance yard area emerges as seep SP-22.

TPH was detected in the maintenance yard soil in a localized area up to two feet below ground surface (bgs). The area is relatively flat and the primary transport mechanism is assumed to be infiltration from surface run-on and snowmelt. The adsorption capacity of TPH in soil is assumed to be relatively high due to the nature of the materials observed (clayey silt), therefore, TPH in soil most likely attenuates with depth and lateral distance.

6.5.1.4 Downgradient Attenuation of Metals

This subsection qualitatively describes evidence of metal attenuation downgradient of the source areas. The processes occurring at each location are also indicated by symbol coding (Figure 6.5-9).

Seeps SP-26, SP-23, SP-23B, SP-12 and 1500-Level Ventilator Portal Discharge

Seep SP-26 flows during the spring from the south bank of Railroad Creek downslope of the 1500-level ventilator portal and a remnant detention pond feature. The analyses of the SP-26 sample detected (Figure 6.1-3a) pH-neutral water with some alkalinity (10 to 14 mg/L). The chemistry of the water is not comparable to mine discharge waters. Copper concentrations are 22 to 28 µg/L compared to >1000 µg/L (in May) in mine discharge. These concentrations are too low to be controlled by the formation of a copper carbonate. The copper concentrations possibly originate from the small detention pond that is speculated to have collected water from the 1500 ventilator portal during backfilling of the underground mine or from natural mineralization. The detention pond was observed to contain a small quantity, but SP-26 water is very dilute and most likely represents meltwater.

Seeps SP-23, SP-23B and SP-12 flow during the spring from the south bank of Railroad Creek between RC-1 and P-5 stations (Figure 6.1-3a). The results of laboratory analyses show many similar chemical characteristics to waters originating from the mill buildings, mine and waste rock piles. Seeps SP-23 and 23B have pH<5, and MINTEQA2 indicates that the pH is controlled by the presence of various aluminum hydroxides, sulfate and alunite ($KaI_3 (SO_4)_2 (OH)_6$). Iron was undetectable in the seeps suggesting that the water is well-oxidized. Eh measurements of about 300 mV confirmed that the water has been oxidized, removing iron from solution. Copper concentrations were not indicated to be controlled by a secondary mineral. SP-12 is less acidic (pH~5) and sulfate and metal concentrations are slightly less than SP-23 and SP-23B, but ratios of elements are comparable. Some discrimination of waters can be seen on a scatter plot of potassium versus sodium (Figure 6.5-10). This plot indicates that mine waters (P-1 and P-5) have higher Na/K ratios than waste rock pile or tailings.

One sample (VP-1, May 2, 1998) of the water discharging from the 1500 Level ventilation portal was very dilute (pH 6.4, sulfate 3.5 mg/L, Cu 0.7 µg/L, Zn <4 µg/L), which is consistent with a local meteoric source for the water.

Portal Drainage

Mine drainage from the 1500-level main portal (P-1) enters Railroad Creek at P-5 via a ditch. White precipitates are observed coating the ditch. The chemistry of the water changes little between the two points. In the spring, metal concentrations tend to be higher at P-1 than at P-5, but in the summer concentrations are comparable between the two points. The decrease in concentrations in the spring is interpreted to be due to dilute meltwater water entering the ditch from the valley sides and diluting the flow.

MINTEQA2 calculations indicate that the drainage is significantly over-saturated with respect to aluminum hydroxides and sulfates, alunite, barite and various iron hydroxides and cupricferrite. Saturation with respect to zinc minerals is not indicated. The precipitates observed indicate that precipitation is occurring, although some of the precipitate may not have formed in the ditch but formed in the mine and settled in the drainage. The active formation of flocculent as very fine particles, probably results in the over-estimation of dissolved metal concentrations in the water, hence the degree of over-saturation is probably less than predicted by MINTEQA2. It is likely that as the portal drainage emerges at P-1, it is in disequilibrium with the atmosphere due to the slow conversion oxidation of Fe(II) to Fe(III). This causes precipitation of iron minerals in the ditch and co-precipitation of other heavy metals (mainly copper). However, most of the iron precipitates due to oxidation, dilution, and neutralization. Analysis of the precipitate indicate that it contains mainly aluminum and iron with some copper and zinc.

The principal attenuating mechanisms in the ditch are assumed to be:

- Dilution by surface runoff
- Oxidation and precipitation of iron resulting in removal of iron and co-precipitation of copper oxide
- Precipitation of aluminum hydroxide resulting in removal of aluminum

As the 1500-level main portal drainage water enters Railroad Creek, the weakly acidic water mixes with the weakly alkaline stream water. The rapid pH shift causes any residual aluminum and iron to precipitate as amorphous hydroxides in the stream bed. Copper is also expected to form a fine flocculent as basic copper carbonate. This effect was simulated using MINTEQA2 by changing the pH and alkalinity to that of Railroad Creek. This indicated that the malachite might precipitate. Zinc would not be expected to precipitate. The rate at which copper carbonate might form determines whether copper would be removed from solution, or whether copper concentrations would be diluted below the solubility limits imposed by copper carbonates before the precipitates actually formed. The loading analysis presented subsequently in this section confirms that copper carbonates might form.

West Waste Rock Pile, Mill Building, and Seeps SP-9 and SP-11

This pathway includes seepage from the west waste rock pile and runoff from the abandoned mill building that collects in the lagoon (SP-16) before entering Railroad Creek at seeps SP-9 and SP-11 (Figure 6.1-3a). As noted in Section 6.3.2, the chemistry of these waters are all similar indicating weakly acidic conditions with pH control by precipitation of aluminum hydroxides and sulfates. Chemistry is also controlled locally by the formation of ferric oxyhydroxides, barite, copper carbonates and sulfates (antlerite, brochantite, malachite - SP-15E, July 12, 1997), and cupricferrite. The copper minerals were previously identified by the USGS (personal communication with Jim Kilburn, 1999) (Table 6.1-1) and during the RI. The weakly acidic seeps at SP-9 and SP-11 contain lower sulfate (44 and 82 mg/L), copper (3 and 460 µg/L) and zinc (267 and 2340 µg/L) concentrations and had higher pH (>5.8) than the upslope seeps. For SP-11, the difference appears to be a dilution effect possibly by mixing with weakly alkaline runoff water. The increase in pH probably resulted in copper precipitation but did not affect zinc. SP-9 is further diluted in zinc and copper concentrations.

It appears that this pathway involves both permanent and seasonal removal of metals from solution. These include:

- Permanent removal of iron and aluminum from solution due to formation of oxyhydroxide precipitates (oxidation and precipitation). This is implied by MINTEQA2 calculations and confirmed by field observations.
- Probable co-precipitation of other metals with iron and aluminum (copper). Analysis of precipitates elsewhere on the Site have confirmed that co-precipitation occurs.
- Seasonal evaporation at SP-15E resulting in removal of copper from solution by formation of copper sulfates (efflorescence); these salts were observed. Spring seepage waters are undersaturated with respect to these minerals, therefore, they will redissolve.
- Mixing of alkaline waters with weakly acidic waters resulting in the formation of basic copper carbonates (malachite). The shift in pH dictates that this will occur.
- Contact of weakly acidic waters with carbonate-containing rocks, resulting in the formation of basic copper carbonates (malachite). Green coatings have been observed on marble blocks exposed on the surface of the west waste rock pile.

Seeps SP-22 to SP-25 and SP-24

Seep SP-22 flows from the slope below the maintenance yard, mill building, and west waste rock pile (Figure 6.1-3a). The chemistry of the seep resembles other seeps in the vicinity, although when monitored in May 1997, it had a pH of 6 and weak alkalinity (7 mg/L). MINTEQA2 indicates that the water is in equilibrium with amorphous aluminum hydroxide. This implies that this water has been influenced by the same processes occurring in the waste rock piles, but that it has been significantly diluted rather than mixed with alkaline water or contacted alkaline materials.

Seeps SP-24 and 25 flow from the south bank of Railroad Creek north of seep SP-22. The seeps are chemically very similar to SP-22 except that the pH is lower. Aluminum concentrations are higher due to the lower pH. Overall, the chemistry of seeps SP-22, SP-24 and SP-25 are comparable to other seeps in the vicinity with differences probably caused by dilution. Attenuation of metal concentrations appears to be caused principally by precipitation of aluminum hydroxides. Attenuation by adsorption in soils is not apparent. Seeps SP-24 and SP-25 may be influenced by the lagoon area.

Seeps SP-8 to SP-19

Seep SP-8 flows from the east waste rock pile and then flows partly overland and subsurface, re-emerging at SP-19 (Figure 6.1-3a). The differences for magnesium (which acts as a conservative ion) concentrations between these two points are consistent with dilution by a non-buffering water source (e.g., snow melt). The water is probably well-oxidized at SP-8 as shown by low iron concentrations. MINTEQA2 predicts that aluminum minerals would be expected to precipitate. As pH was not observed to change between the two points (4.6 S.U.), and aluminum concentrations decreased in proportion to conservative ions, no additional precipitation appears to occur between these points..

Significant metal attenuation between SP-8 and SP-19 does not appear to occur.

Seeps SP-19 to SP-10E and SP-10W

Seep SP-19 flows from the western portion of tailings pile 1 into the Copper Creek diversion near the river sauna (Figure 6.1-3a). Seeps SP-10E and SP-10W flow from the south bank of Railroad Creek north of the river sauna. SP-10W closely resembles SP-19 and MINTEQA2 predicted similar controlling conditions. The pH of the water appears to be controlled by aluminum minerals. Conservative ions indicate that SP-19 and SP-10W are nearly identical. Zinc and copper concentrations were, however, lower than other seeps nearby. This implies either that the water mixed with a source containing comparable sulfate, etc. and very low zinc and copper, or that zinc and copper were adsorbed by contact with soil.

Seep SP-10E indicated 20 percent less sulfate, 80 percent less zinc and 64 percent less copper than SP-10W in May 1997. However, pH was 3.3 for SP-10E compared to 4.5 for SP-10W. MINTEQA2 indicate that SP-10E water is in equilibrium with iron hydroxide as a result of 14 mg Fe/L. Field measured Eh for both SP-10W and SP-10E were comparable and indicated that the waters are well-oxidized.

The difference between the SP-10W and SP-10E waters could be explained by the mixing of a water containing high iron concentrations with water of the SP-10W. If the water contained reduced iron, it would oxidize and hydrolyze upon emergence (equations 6-5 and 6-6 presented earlier in this section), buffering pH near 3 and causing ferric hydroxide to precipitate. Copper and zinc would co-precipitate. The iron-rich water would have to contain less sulfate than SP-10W to produce the lower sulfate in SP-10E.

Attenuating mechanisms between seeps SP-19, SP-10E and SP-10W include:

- Precipitation of aluminum hydroxides (implied by MINTEQA2 and field observations)
- Precipitation of ferric hydroxides (implied by MINTEQA2 and field observations)
- Co-precipitation of copper and zinc with ferric hydroxides (implied by observations from elsewhere that indicate ferric hydroxide precipitates also contain these metals)

Mixing of Seeps with Railroad Creek Water

The seeps flowing into Railroad Creek between station RC-1 and the Copper Creek diversion confluence (SP23, SP12, SP9, SP11, SP25, SP24, SP10W, SP10E) are all acidic to some degree. Therefore, neutralization will occur upon mixing with the Railroad Creek water. The increase in pH will cause any remaining aluminum in solution to be precipitated as aluminum hydroxide flocculent. Copper in solution may precipitate as basic copper carbonate.

6.5.2 Tailings Piles

6.5.2.1 Processes in the Tailings Piles

Air Movement

Unlike the underground mine and waste rock piles, oxygen access to the tailings occurs principally by diffusion. Consequently, seasonal variations in ambient air temperature do not result in transitions between diffusion and convective air movement (Figure 6.5-11). In tailings deposits, only the immediately exposed surface of the deposit is usually oxidized because the fine texture limits movement of air into the mass. However, the fine-grained nature of the tailings results in higher surface areas than for coarser deposits such as waste rock. During relatively dry periods, oxidation occurs resulting in the buildup of oxidation products. During wetter periods (typically during snowmelt), saturation of the near surface pores reduces oxygen diffusion but leaches accumulated weathering products.

Water Flow

This section describes the surface water and groundwater transport pathways associated with tailings piles 1, 2, and 3. The conceptual transport pathways are summarized on flow charts presented as Figures 6.5-12 through 6.5-14. Figure 6.1-3a shows the surface water flow paths over and around the tailings piles. Figures 6.5-15 and 6.5-16 present conceptual hydrogeologic cross-sections showing anticipated water flow through and beneath the tailings piles in May and September, respectively.

Surface water infiltrates through the tailings piles as a result of direct precipitation and surface water run-on from the slopes south of the tailings piles. The potential for infiltration is greatest in the spring when the snow on the piles and the slopes south of the piles melt, and immediately following significant precipitation events. The fine-grained nature of the tailings results in relatively low permeability (documented by Hart Crowser in 1975 and RI data; see Section 4.4-3), which limits the infiltration of water into the piles. The low permeability of the tailings results in isolated ponding of water on the surfaces of the piles, especially on tailings piles 2 and 3.

Tailings piles 2 and 3 surface water run-on is collected in ditches on the piles and diverted around tailings piles 2 and 3 (Figure 6.1-3a). A ditch located adjacent to the upslope access road of tailings pile 3 also collects and diverts surface water run-on around tailings pile 3. Surface water run-on for tailings pile 1 is directed into ditches on the pile which convey the run-on to the edges of the piles. The ditches are not lined and some surface water likely infiltrates into the tailings piles. On tailings pile 1, some of this surface water is also directed to a decant tower that was observed during the RI to not be completely sealed and provides a pathway for water to infiltrate into the pile (Figure 6.1-3a). Surface water from the Copper Creek diversion also flows across the westernmost portion of tailings pile 1.

The water that infiltrates tailings migrates downward and accumulates (based on groundwater monitoring) in the lower portions of the piles as a thin water-bearing zone (Figures 6.5-15 and 6.5-16). The water within this zone appears to be perched on a lower permeability layer at the base of the tailings. Evidence of this layer was observed in test pits completed during the RI. Groundwater elevations in monitoring wells screened in the tailings indicate that groundwater generally moves to the north toward Railroad Creek (Figures 6.5-7 and 6.5-8). This water discharges from the base of the tailings piles as a series of intermittent seeps which flow into Railroad Creek.

The differences in water levels in clustered monitoring wells installed in tailings piles 2 and 3 indicate that the groundwater within the tailings is not in direct hydraulic connection with the groundwater in the underlying alluvium/reworked till (Figure 6.5-15). The water levels in the monitoring wells screened in the tailings remain relatively constant throughout the year, only fluctuating approximately 3 feet during the 1997 field season. Water levels in the monitoring wells screened in the alluvium/reworked till underlying the tailings were observed in several cases to fluctuate more than 20 feet.

In the spring, when the recharge is greatest to the alluvium/reworked till, water levels in this unit increase relatively rapidly and the groundwater appears to be confined by the overlying low permeability tailings. This results in an upward vertical hydraulic gradient in the southern portions of the tailings piles which causes water from the alluvium/reworked till to move into the overlying tailings (Figure 6.5-15). In the northern portions of the piles, the water levels are higher in the tailings than in the alluvium/reworked till and water moves downward from the tailings into the underlying deposits. As water levels decline in the summer, the vertical hydraulic gradient reverses beneath the southern portions of the tailings piles and water within the tailings moves downward into the alluvium/reworked till (Figure 6.5-16).

Groundwater within the alluvium/reworked till generally moves in a northerly direction beneath the tailings piles (Figures 6.5-7 and 6.5-8). In May, the groundwater discharges into a series of seeps that flow into Railroad Creek. The groundwater also discharges as diffuse baseflow into Railroad Creek, as indicated by the apparent gaining conditions measured in this reach of the stream and the relationship between the water levels in the alluvium/reworked till which are higher than those observed in the creek. Some of the discharge to Railroad Creek is believed to occur through the abandoned Railroad Creek channel which is approximately parallel to the northern edges of the tailings piles. Flow within the abandoned channel is assumed to move in an easterly direction rather than to the north.

In September, the occurrence of seeps decreases significantly with only a few seeps observed (SP-1, SP-2 and SP-3) and seep flow rates decreasing significantly. In September, the groundwater flow within the abandoned Railroad Creek channel is evident based on the water levels in the wells near the former channel. Diffuse groundwater continues to discharge along the base of tailings piles 1 and 2, but portions of the reach of Railroad Creek near tailings pile 3 appear to be in a losing condition.

Groundwater Chemistry

The geochemistry of tailings groundwater, based on samples collected and analyzed from groundwater monitoring wells and seeps, is primarily influenced by oxidation of the surface tailings by oxygen entering through diffusion. This is indicated by the presence of a thin oxidized zone in the near surface and unoxidized tailings at depth. Water moving down through the tailings piles carries sulfate, acidity and reduced iron. Some of the iron is precipitated in the immediate subsurface as cementation but most of the iron moves downward in a reduced state. This water moves through the tailings, probably being neutralized by contact with alumino-silicates as is apparent for the whole Site. This process probably adds additional iron due to dissolution of hornblende. The extent of this neutralization is controlled by the length of the flow path. Waters entering the piles along the slopes adjacent to Railroad Creek, Copper Creek, and the Copper Creek diversion will have relatively short flow path lengths with little opportunity for neutralization. For this reason, the chemistry of seeps (SP1, SP2, SP3, SP4, SP5) observed along the toes of the tailings piles represents mixing of groundwater impacted by water moving downward through the pile over different flow path lengths.

The observed chemistry of the seeps generally reflects this hypothesis. The seep chemistry of all three piles is very similar. The differences are in pH and changes in ratios of elements, which imply drift toward Railroad Creek water chemistry. Seepage water probably mixes with unimpacted groundwater to varying degrees resulting in dilution of tailings groundwater. The pH changes also cause changes in iron concentrations, and co-precipitation of heavy metals such as copper, zinc and cadmium. The low pHs indicate precipitation of ferric hydroxide (see equation 6-6 presented earlier in this section). Internal groundwater pHs are generally greater than 4 and indicate silicate buffering as observed elsewhere at the Site.

Specific comments for individual piles are provided below.

Tailings Pile 1

Referring to Section 5 of this report, water chemistry data for monitoring wells (screened in the underlying surficial materials and within the tailings) and seeps in tailings pile 1 suggest that both affected and natural groundwaters flow under the tailings and discharge to Railroad Creek. Well TP1-6A reported the highest concentrations of copper (1100 µg/L), cadmium (100 µg/L) and zinc (11,400 µg/L); exceeding the levels recorded for seeps SP-1 and SP-2. Water from well TP1-4A represents groundwater that has not been impacted by tailings, as it contained low levels of metals and sulfate (Cu: <2 µg/L; Zn: 28 µg/L; Cd: <0.2 µg/L; Fe: 30 µg/L; SO_4: 300 mg/L) and a near-neutral pH (6.7). Zinc concentrations showed a degree of zonality within the groundwaters. Low zinc concentrations were detected near the upslope edge of the tailings (TP1-1 and TP1-4; 466 and 28 µg/L, respectively) whereas concentrations one to two orders of magnitude higher were observed in wells further downslope near Railroad Creek (TP1-2, 3, 5 and 6; 2,270 to 11,400 µg/L). These wells were comparable in zinc concentrations to discharge from seeps SP-1 and SP-2 (3490 and 4570 µg/L). The increase in zinc concentrations occurs approximately along the axis of the former Railroad Creek channel under the tailings.

Compared to the monitoring wells that are screened in the underlying surficial materials, wells screened in the tailings groundwater contained low concentrations of zinc. Iron concentrations were approximately three to five times higher. This suggests that tailings are contributing dissolved reduced iron and sulfate to the underlying groundwaters.

The chemistry of these monitoring wells is compatible with a groundwater flow pattern that includes natural groundwater from upslope and affected groundwater originating from the east waste rock pile and/or the mill buildings area. Further, these groundwater concentrations may be influenced by groundwater flowing within the former creek channel which underlies the tailings. This relatively permeable unit may control and channel the flow of affected groundwater from the weathered source areas, including the portal drainage, lagoon, waste rock piles, and mill area towards the SP-2 seep.

Tailings Pile 2 and 3

Groundwaters sampled from the underlying surficial material in the central areas of tailings piles 2 and 3 (e.g., wells PZ-1A, TP2-5A, TP3-6A) generally had low metal concentrations (e.g., Cu: <2 to 67 μg/L; Zn: 32 to 400 μg/L; Cd: 0.2 to 2.2 μg/L), although an occasional elevated iron level (5,710 μg/L iron) was observed in PZ-1A. This elevated level is probably the result of groundwaters leaching natural materials or minor incursions of tailings waters infiltrating the substrate.

The metals load discharged by the seeps (SP-3, SP-4, SP-5 and SP-18) appears to be the result of oxidation of tailings, possibly due to the interaction with groundwaters derived from Railroad Creek. Groundwater wells in the substrate near the tailings pile edges (e.g., TP2-4A, PZ-6A, TP3-8) had higher concentrations of iron (7,040 to 58,300 μ/L), sulfate (340 to 1,500 mg/L) and total dissolved solids (500 to 2,400 mg/L). Limited data on groundwaters in saturated tailings (e.g., PZ-1B) report elevated iron (69,000μg/L) and elevated sulfate concentrations (850 mg/L). These values are similar in magnitude to the concentrations recorded for the seeps (Fe: 23,900 to 154,000 μg/L; SO_4: 530 to 880 mg/L).

6.5.2.2 Metal Removal

Metal removal mechanisms are described below and are summarized in Figures 6.5-17 to 6.5-19.

Tailings Pile 1 Area

Seepage emerges from the base of tailings pile 1 at SP-1 and SP-2 and enters Railroad Creek. The seeps are strongly acidic (pH<4) and contain elevated concentrations of sulfate (>2000 mg/L) and iron (~1000 mg/L). As the acidic seepage mixes with Railroad Creek water, it goes through several rapid chemical changes including:

- Conversion of unoxidized ferrous iron to ferric iron by atmospheric and dissolved oxygen
- Increasing pH due to dilution and stream water alkalinity allowing additional ferric iron to precipitate as flocculent (in surface water) or goethite (in groundwater)
- Co-precipitation/sorption of copper with flocculent or ferricrete
- Further pH increase due to dilution and stream water alkalinity resulting in precipitation of aluminum as flocculent or aluminum hydroxide precipitate
- Formation of copper carbonate flocculent

Attenuation occurs by precipitation of ferricrete, aluminum hydroxide, copper carbonate and co-precipitation of copper with ferricrete.

MINTEQA2 indicates that the seep waters are saturated with respect to basic aluminum sulfate, alunite, barite, and goethite. Copper concentrations are low in both cases, hence, copper concentrations do not appear to be in equilibrium with any copper minerals. Analyses of ferricrete (formed by the precipitation of iron oxyhydroxides such as goethite) have indicated copper concentrations up to 2,340 mg/kg. Copper is expected to co-precipitate with goethite. The seeps tend to contain more zinc than copper but ferricrete proportionately contains much less zinc than copper. Copper tends to attenuate as groundwater containing ferrous iron is oxidized and goethite precipitates. Zinc attenuates to a lesser degree.

Tailings Piles 2 and 3

Mechanisms in the tailings pile 2 and 3 are identical to tailings pile 1. The seeps are geochemically identical except that seeps SP-3, SP-4 and SP-5 are more dilute than SP-1 and SP-2. This is attributed to partial mixing of Railroad Creek groundwater with seepage from the tailings pile and longer contact paths with neutralizing materials. The fate of the seeps is the same as seeps SP-1 and SP-2 from tailings pile 1.

6.6 RAILROAD CREEK

6.6.1 Surface Water Loading Analysis

6.6.1.1 Introduction

Dissolved metals enter Railroad Creek as seep flow, drainage flow and groundwater baseflow.

A chemical and flow mass balance analysis was performed for reaches of Railroad Creek that receive mine drainage and reaches located upstream and downstream of mine influences. The purpose of the mass balance was to:

(1) assess metal contribution in drainage water from point sources measured during the RI in relation to metal concentrations in Railroad Creek upstream of mine influences

(2) determine the point source discharges that contribute the highest metal concentrations to Railroad Creek

(3) assess if specific reaches within Railroad Creek contain non-point-source or "unaccounted" (assumed to be baseflow) metal load, and

(4) evaluate the chemical loading analyses in relation to the water balance of select reaches of Railroad Creek

Flow and metal concentrations of seeps and drainages were measured during the RI to assess contribution of these inputs to Railroad Creek during the May and September 1997 sampling rounds. Flow and water quality measurements in Railroad Creek were repeated at selected stations in late April/May 1998.

The effects of seep, drainage and groundwater inputs to the surface water quality of Railroad Creek are observed by the changes in seasonal water quality conditions in a downstream direction. Dissolved metals entering Railroad Creek in groundwater, seepage flow and flow from the 1500-level main portal drainage and other drainages attenuate within Railroad Creek by dilution, acid buffering and adsorption reactions in the surface waters. Some of the dissolved metals precipitate out of the water column and settle on the bottom of Railroad Creek.

Seasonal metals concentrations indicate that copper, zinc, and cadmium are at their highest levels during spring snowmelt (May/June) when seeps and discharge from the portal drainage are at their highest, as discussed previously in Section 5. Iron concentrations are at their highest during periods of lower flow. In addition, copper, zinc and cadmium increase the most dramatically between stations RC-1 and RC-4, and iron (and to a lesser extent zinc) concentrations increase most dramatically between stations RC-4 and RC-7. These observations indicate that copper, cadmium and zinc enter Railroad Creek from the portal drainage and associated seeps and drainages north of the tailings piles, and that iron is introduced primarily from seepage and groundwater flow from the tailings.

6.6.1.2 Mass Balance Calculation Method

The metal loading to Railroad Creek was computed using flow measurement data and analytical results for water samples collected over a two-day period in 1997. Specifically, loading was calculated as the measured concentration for each metal for each source times the flow rate of each source at the time the sample was collected. The individual source loading was compared to the computed loading for the same constituent at the same time within Railroad Creek. Loading is reported as mass per unit time. For the purposes of this study, the loading is reported as milligrams per second (mg/s), which are common units for reporting loading results.

Flow data used to compute the loading from the seeps and seep-related drainages were estimated and/or measured directly in the field at the time that the water quality sample was collected. Field flow measurement methods used were previously described in Sections 3 and 4. Flow measurement accuracy is directly related to the flow volume measured at each station and the measurement tools utilized. The accuracy of the flow measurements for the surface water in Railroad Creek ranges between 5 and 7 percent using a flow meter (Swoffer or Price AA), and 10 to 12 percent utilizing a bridgeboard, as used at RC-2 and RC-4 during high flow conditions.

The accuracy of seep flow measurements at SP-6 through SP-9, SP-14 through SP-19, SP-21, SP-23A and SP-23B was estimated to be ±25 percent.

Seep flow estimates for SP-1 through SP-5; SP-10E/W through SP-13; and SP-24 through SP-26 are assumed to be accurate within ±50 percent of the actual value because of limited amount of flow and the difficulty in capturing and measuring flow emerging as diffuse seepage. Although the accuracy of these measurements is marginal, the loading analysis will demonstrate that the load of select metals at these seep locations were an insignificant proportion to the overall load of select reaches of Railroad Creek.

It should be noted that the flow in Railroad Creek was dynamic and was changing during the period that seeps were sampled, and also during the time that Railroad Creek was sampled (particularly during the May and July sampling rounds). Consequently, the flow measurements recorded at the time of seep sampling did not always reflect comparative flow conditions relative to RC-2.

In order to provide comparative flow conditions between stations in Railroad Creek, the following assumptions and estimates were made for the loading analysis:

- Measured flow was used if flow conditions were not changing during the sampling round.
- Flow was estimated during dynamic flow conditions such that flow was consistent with downstream flow relationships between stations.
- Creek drainage and seep concentrations were assumed to be representative for the flow conditions encountered or estimated during the loading period.

The results of the loading analysis for May and September 1997 are presented in Tables 6.6-1 and 6.6-2, respectively. The analysis was performed by dividing Railroad Creek into two reaches. Reach 1 included the creek from RC-1 to RC-4. Reach 2 included the creek from RC-4 to RC-2. The tables show loading calculations for magnesium, zinc, cadmium, copper and iron. For each parameter, the flow was multiplied by the concentration for each source to yield the load. The loads were then added to give the cumulative load at each station. At RC-4 and RC-2, the cumulative load from each source was compared to the total load measured in Railroad Creek. Total load in Railroad Creek is the load calculated using the water quality data for samples collected at RC-4 or RC-2. The commutative load for each reach was subtracted from the total load of each reach. The results are referred to in the tables as "Reach 1 Balance" and "Reach 2 Balance." The tables also show the total balance. In general, these balances account for non-point-source discharges (groundwater) or (if negative) can indicate load loss due to flow loss or chemical effects. The balances also incorporate the uncertainties in the measurements of flows. The results for the April/May 1998 loading analysis are shown in Table 6.6-3. Percent loading for 1997 is provided by location on Figure 6.5-20.

6.6.1.3 Loading Analysis and Mass Balance Results - 1997

Conservative Parameter - Magnesium

As a first step to confirming the validity of the mass balance approach, a chemically conservative parameter, rather than a heavy metal, can be used to calibrate or verify the site-specific water balance discussed in Section 4.4. The term "conservative parameter" is described in Section 6.3.3.1. The purpose is to confirm the water mass balance using a parameter for which the total load can be accounted for. The parameter selected in this case was magnesium. The main reason for selecting this parameter is that magnesium is released by weathering processes at the Site and is always detectable. Other conservative parameters such as chloride are not released by weathering and are frequently non-detectable, and therefore are not appropriate for this purpose.

In Table 6.6-1 (May 1997 calculation), the incoming magnesium load at RC-1 was 5098 mg/s. In Reach 1 (defined as receiving mine and support area drainage – RC-1 to RC-4), the source load additions totaled 986 mg/s, for a cumulative load of 6084 mg/s. The greatest proportion of the load originates from P-5, followed by SP-23. The measured load in Railroad Creek at RC-4 was 6656 mg/s. The deficit between the two (cumulative at RC-4 and measured at RC-4) was +572 mg/s. If this load is applied to the inputs from groundwater calculated using the water balance (0.9 cfs, 25.49 L/s), the required concentration was 22.5 mg/L, as shown in Table 6.6-1. Magnesium concentrations were generally less than 10 mg/L in the portal drainage, lagoon and seeps. The calculated concentration was, therefore, greater than the expected concentrations, but statistically the two concentrations were equivalent because of the above-mentioned uncertainties associated with the flow estimates.

Relative to measured incoming load in Reach 2 (tailings influenced stream segment from RC-4 to RC-7), the additions of magnesium were less than the additions in Reach 1. The deficit was +1550 mg/s. The calculated concentration using this deficit was 26.1 mg/L (Table 6.6-1) which was close to the range of magnesium concentrations of 30 mg/L to greater than 100 mg/L in seeps.

The deficit between RC-7 and RC-2 was 684 mg/s, which was close to the contribution from SP-4 (515 mg/s).

The May 1997 analysis for magnesium implies that there are no significant missing magnesium load contributions in the spring. The deficits between surface water additions and measured loads in Railroad Creek can be accounted for by reasonable groundwater flows and magnesium concentrations.

The September 1997 magnesium load calculation for Reach 1 (Table 6.6-2) indicates little change between RC-1 and RC-4 (-19 mg/L). The load provided by the only measurable source (P-5) was not significant relative to the load entering the Site at RC-1, and represented only 1.1 percent of the load previously measured in May 1997. The Reach 1 balance was shown as a negative load (-75 mg/s). This small negative load was consistent with the apparent flow loss in the reach (Section 4.3.7). In Reach 2, the load balance was 711 mg/s, which can be accounted for by a groundwater contribution similar to that observed in May 1997.

In summary, the magnesium balance is in agreement with the site-specific water balance. The magnesium balance indicated that all major sources were identified and that the required flow balances were consistent with magnesium concentrations observed in both surface water and groundwater.

Quasi-Conservative Parameters – Zinc and Cadmium

Zinc and cadmium are often observed to show almost conservative behavior because their solubility is not influenced by pH within the pH range normally encountered on site. They can be adsorbed onto soil and sediment particles; however, this may not be a strong effect in coarse gravelly soils and stream beds.

The loading calculation of zinc followed the same approach as for magnesium. In May, the difference between RC-1 and RC-4 was 850 mg/s. The majority of this difference can be accounted for by P-5 (849 mg/s). SP-23 provided 71 mg/s, hence the cumulative load at RC-4 from measured sources was 1123 mg/s. This load at RC-2 was greater than the load at RC-4 (1034 mg/s). The balance of –90 mg/s is small relative to the inflow from P-5 and therefore is not significant. The data imply that all significant loads in Reach 1 have been identified.

In Reach 2, very little zinc was added compared to Reach 1. The Copper Creek diversion was the largest source. The required balance was 146 mg/s, which was larger than the point sources along Reach 2. The concentration required to produce this balance was 2.5 mg/L. This implies that groundwater originating in Reach 1 (i.e., from the mine support areas) enters Railroad Creek in Reach 2. The total of the balances for Reach 1 and Reach 2 is 56 mg/s. This is less than 5 percent of the total load in Railroad Creek and implies overall that non-point sources contribute insignificantly to the load in Railroad Creek during May. P-5 is the main source of zinc load (82 percent of load added downstream of RC-1, not including Copper Creek). Other sources account for less than 6 percent individually.

A similar approach was used for the September 1997 calculation. A contribution from groundwater was added in Reach 1 to account for the difference between load observed at RC-1 and RC-2 (63 mg/s) that could not be accounted for by load contributed by P-5 (16.9 mg/s). In September, non-point sources appear to represent the majority (77 percent) of the zinc load added to Railroad Creek between RC-1 and RC-2. The total balance (non-point source discharge, i.e., groundwater) for zinc between RC-1 and RC-2 in September 1997 (63 mg/s) is comparable to the total balance in May 1997 (56 mg/s).

The cadmium balance for May 1997 indicates that P-5 is the main source (5.1 mg/s, 70 percent of load added by the Site) and that the total balance is the next largest source (17 percent). In September, 1997, the contribution from non-point sources was 80 percent compared to 17 percent from P-5, though the load from non-point sources remained comparable (1.23 mg/s in May compared to 0.24 mg/s in September). The findings are comparable to zinc and indicate that portal drainage accounts for the majority of load entering Railroad Creek in May. In September, most load enters Railroad Creek through groundwater. The groundwater contribution appears to be relatively stable.

Non-Conservative Heavy Metals – Copper and Iron

Mass balances for copper and iron provide limited information because they are readily removed from solution by precipitation changes (as seeps mix with Railroad Creek) and adsorption.

The copper load observed at RC-4 in May 1997 (374 mg/s) can primarily be accounted for by P-5 (225 mg/s) with lessor contributions by SP-23 (97 mg/s) and RC-1 (16 mg/s). The balancing (groundwater) load (20 mg/s) was negligible compared to the other loads. Copper load appeared to decrease between R-4 and RC-2. The load required to balance was –48 mg/s. Overall, a small negative load balance of –28 mg/s was indicated for RC-1 to RC-2 after accounting for known sources. This is consistent with removal of copper solution by pH adjustment and adsorption, which occurs continually along Railroad Creek as low pH waters mix with surface water but is particularly likely in Reach 2 when iron is added by the tailings pile seeps. The negative balance does not preclude the addition of copper through groundwater sources. The balance indicates that the net effect of addition through groundwater and removal by attenuation mechanisms is net removal.

The September 1997 calculation indicated a positive load balance requirement in Reach 1 and negative load balance for Reach 2, although overall, a positive balancing load of 2.6 mg/s was obtained and is the largest source of load to Railroad Creek. Qualitatively, the calculations for May and September 1997 are similar. Differences between May and September reflect changes in P-5 water quality and quantity and removal of copper prior to mixing with Railroad Creek.

The calculation for iron indicated a load loss between RC-1 and RC-4 in May. Iron concentrations were very low and the decrease was probably due to near detection limit (0.02 mg/L) concentrations in Railroad Creek. Significant load increases were observed between RC-4 and RC-7, followed by a decrease between RC-7 and RC-2. The load added by surface seeps was not sufficient to account for the load increase observed, hence a balancing load of 1412 mg/s was added. The calculated iron concentration for the load is 24 mg/L. This concentration of iron is lower than observed in seeps which indicates that a portion of the iron added is precipitated and is, therefore, not accounted for under the dissolved load. The decrease in load between RC-7 and RC-2 may reflect oxidation of ferrous to ferric iron. As oxidation occurs, ferric iron is precipitated. The September calculation indicated a similar conclusion.

Dissolved iron is contributed primarily from groundwater baseflow along the tailings piles. Iron loads are highest during the spring when flows are the highest. Iron loads decline through summer and fall after seeps have begun to dry up and groundwater recharge is no longer occurring. Iron discharge is delayed relative to zinc, cadmium and copper because iron loads are from groundwater baseflow, not seeps or drainages. The delay in iron loading reflects an extended period of infiltration through the tailings piles with subsequent discharge through the base of the piles into the streambed of Railroad Creek. This also suggests that seep flow is sustained by bank storage and groundwater flow associated with the alluvial materials beneath the tailings piles, and is not necessarily directly related to recharge through the piles.

6.6.1.4 Loading Analysis and Mass Balance Results – Spring 1998

The loading of copper, zinc, cadmium and iron in Railroad Creek was estimated from the flow measurements and water quality results obtained during the 1998 May sampling round. The loading estimates were developed for all of the sampling locations with concurrent flows that were either measured or could be reasonably estimated from flow relationships between stations (see Section 4.3). The load values were developed for comparison with the May 1997 values and are assumed to be approximate given that flow timing was not considered in the calculation. Table 6.6-3 shows the May 1998 load estimates and is compared herein to Table 6.6-1.

In general, the May 1998 total load in Railroad Creek was larger for copper, zinc, and cadmium relative to 1997, and the iron load was lower. However, the pattern of loading was similar to 1997 with the majority of the load for copper, zinc and cadmium accounted for by the portal drainage, and the majority of the iron loads occurring between RC-4 and RC-2 from groundwater. Additionally, copper, zinc and iron loads decreased downstream of their sources, similar to 1997. Very little of the metals load observed at RC-2 appeared to be generated upstream of the Site, as indicated by low relative loads observed at upstream stations in Holden Creek, Big Creek and at RC-11.

The larger load values for copper, zinc and cadmium may be a result of the earlier sampling time relative to the first flush from the 1500-level main portal drainage as compared to the 1997 May sampling event. The 1997 May samples were collected during the initial part of snowmelt; however, based on the Railroad Creek hydrograph at RC-4, a melt event had already occurred by the time the samples were collected; sampling had been completed in April 1997 before, but not during, the event. In 1998, however, the samples were collected earlier in the melt period, during the first snowmelt event (see Section 4.3). The lower iron loading may reflect lower groundwater yields because of a delay in groundwater discharge to Railroad Creek, given that the sampling in 1998 occurred earlier in the melt period.

6.6.1.5 Loading Analysis and Mass Balance Results – Additional Source Areas

Waste Rock Piles and Mill Area

Additional source areas that contribute metals load to the site include the East and West Waste Rock piles and the mill area (Figure 6.5-20). The loading of dissolved cadmium, copper, iron, and zinc from these source areas was estimated from flow measurements and water quality results for seeps associated with these areas collected in the spring and fall of 1997. The loading analysis included the data from seeps SP-6 and SP-15E, associated with the west waste rock pile, SP-7 and SP-22 associated with the mill area, and SP-8 associated with the east waste rock pile. These seeps do not enter Railroad Creek as surface flow and are considered to contribute to downslope seeps and ultimately to the alluvial aquifer. The loading analysis was conducted to quantify the maximum load available from these areas that could contribute to dissolved metals loading into Railroad Creek. The loading data are provided in Table 6.6-4 and shown on Figure 6.5-20.

The data indicate that maximum loading from these source areas accounts for a small percentage of the total load at RC-2 ranging from 0.2 to 2.9% for cadmium, 0.1 to 4.3% for copper, less than 0.01% for iron, and 0.4 to 2.7% for zinc. The highest loads result from the mill area at SP-7 and the west waste rock pile at SP-15E in the spring. The seeps used for the loading analysis were not flowing in the fall except in response to significant precipitation.

SP-21

A loading analysis was also performed for data collected from SP-21 located east of tailings pile 3 and downstream of RC-2. Chemical data, direction of groundwater flow (especially in the fall), and the documented loss of flow in Reach 2 (RC-4 to RC-2) indicate that affected groundwater from the tailings and loss from Railroad Creek (unaccounted load) may be measurable at SP-21. Loading for dissolved cadmium, copper, iron, and zinc were calculated using flow measurements and analytical data collected in the spring and fall of 1997. The percentage load is based on RC-2 as an appropriate location downstream of SP-21 on Railroad Creek was not established.

The analysis indicates that loading for these metals ranges from 0.8 to 1.2% in the spring and 0.1% or less in the fall.

6.6.1.6 Conclusions

The following is concluded from the loading calculations:

- All significant observed loads have been identified and accounted for in Railroad Creek.
- Groundwater loads can be used to balance Site area chemical loading. Back-calculated concentrations using flow estimates compare well with expected groundwater sources such as mine discharge water and tailings seepage.
- Copper and zinc loads to Railroad Creek from measured point sources and other groundwater (baseflow) sources are highest during the spring snowmelt and groundwater discharge period when groundwater levels are highest in the deep wells beneath the tailings, and high flow occurs at the 1500-level portal drainage. During the May round when flows are the highest, the portal drainage is the primary source of loading of cadmium, copper and zinc to Railroad Creek.
- Seeps SP-23 and SP-23B are the two next highest point sources that are estimated to contribute cadmium, copper and zinc during May; however, this load drops to zero later in the year as seep SP-23 dries up.

- Infiltration of water from the portal drainage to the underlying alluvial aquifer may account for metals concentrations in seeps located downgradient from the portal drainage that flow into Railroad Creek or to groundwater baseflow.
- Iron enters Railroad Creek primarily by groundwater and iron loads are greater in September than May. Iron loads enter Railroad Creek downstream of the load sources (i.e., portal drainage) for cadmium, zinc and copper, which enter the creek as surface flows or seeps.
- Similar results were obtained in spring 1997 and 1998. Differences in absolute loadings were observed and can be attributed to differences in timing of monitoring. The 1998 monitoring was conducted during the initial part of snowmelt, likely resulting in the measurement of greater loads of copper, zinc and cadmium entering Railroad Creek.
- Additional source areas located at the west and east waste rock piles and the mill area are not significant loading sources to Railroad Creek. Metals loading at SP-21 may account for a component of unaccounted loads noted in September.

6.7 COMPARISON OF THE HOLDEN MINE WITH OTHER MINE SITES

This section provides case example comparisons of two other mines with characteristics similar to the Holden Mine. The examples are relatively typical of hard rock metal mines in northwestern North America and were selected on the basis of similar mine configuration, comparable waste types and leaching of similar elements. These cases illustrate that the chemical processes operating at the Holden Mine Site have been documented elsewhere, are not unique to the Holden Mine, and demonstrate that the Site does not represent extreme mine drainage conditions.

6.7.1 Baker Mine

The Baker Mine is a small underground gold mine located in a sub-alpine area in north central British Columbia. Similar to the Holden Mine Site, the Baker Mine experiences winter conditions during which a snow pack forms. In June, the snow pack melts releasing large quantities of water in a few weeks. Summers are relatively warm and dry with occasional thunderstorms. The fall is wetter before snow starts to accumulate in October. The summer is shorter than at the Holden Mine Site, but the overall climatic conditions are comparable.

Although the Baker Mine is much smaller than the Holden Mine, the configuration of the workings is comparable (Figure 6.7-1). Mine drainage exits from a single portal. A second portal is located 100 feet above this portal, and a small open pit is located on the slopes immediately above the mine; mine drainage does not flow from these two workings. The mine exploited an epithermal gold vein for a few years in the early 1980s and is now being reclaimed. The immediate mine sequence contains little carbonate. Two bulkheads were installed in the portals in 1993 with the intention of flooding the mine. However, as a result of leakage around the bulkheads, holes were drilled in the bulkheads to allow water to drain freely.

Monitoring of seeps from drill holes, fractures and backfill inside the workings prior to installing the plugs indicated that most seeps had pH between 3 and 3.5. As a result, acid generation within the Baker Mine has reached the most reactive stage and mine drainage is not expected to worsen.

Figures 6.7-2 to 6.7-4 compare drainage chemistry for the Baker Mine with the Holden Mine. P-5 was used rather than P-1 because it has a larger dataset. For comparative purposes, data for different years of monitoring are superimposed on one graph depicting one year. The Baker Mine dataset begins in May prior to the snow melt. The drainage pH is near 7. As the melt event begins, pH drops to 4.4, then as the portal discharge decreases pH increases until pH is near 7 in October. Almost exactly the same pH trend is seen at the Holden Mine 1500-level main portal drainage (P-5). During maximum flows, the pH of the Baker Mine discharge is low, but then steadily increases through the summer, reaching neutral conditions by September.

The mechanism involved is identical at both the Baker Mine and Holden Mine. The melting of the snow pack results in flushing of weathering products accumulated during the previous winter. As the melt event moderates, pH increases due to reduced leaching of acidic weathering products. The Baker Mine drainage contains a buff precipitate similar to the precipitate observed in the Holden Mine portal drainage. The lowermost extreme of pH values is controlled at both the Baker Mine and Holden Mine by the precipitation of aluminum hydroxides. The host rocks at the Baker Mine were altered to clay alumino-silicates during mineralization. The acid solutions formed by pyrite oxidation attack these minerals, resulting in the release of aluminum.

The comparison of copper concentrations indicates very similar concentrations and trends for the Baker Mine and Holden Mine. Copper concentrations are relatively low for the majority of the year for the Baker Mine, but increase as pH decreases during spring snowmelt (Figure 6.7-3). The almost identical copper concentrations indicate a common chemical control, which could be copper carbonates, or co-precipitation with aluminum hydroxide. Comparison of zinc concentrations indicates order-of-magnitude higher concentrations at the Holden Mine (Figure 6.7-4). Unlike the Holden Mine, the Baker Mine does not have zinc mineralization, and zinc concentrations are not constrained by secondary mineral formation at these pHs. The differences between the Baker Mine and the Holden Mine in terms of source zinc availability, therefore, become apparent.

6.7.2 Sullivan Mine

The Sullivan Mine is a relatively large underground massive sulfide lead-zinc deposit located in the Canadian Rocky Mountains. The area also experiences cold winters during which snow pack accumulates. The snow pack melts in April and May and summers are hot and dry. The Sullivan Mine has been operating since 1910 and consists of an active underground mine, an abandoned open pit, several waste rock piles and a relatively large tailings disposal area resulting from conventional flotation (the method utilized at the Holden Mine Site) of lead and zinc sulfides from a sulfide ore composed of pyrrhotite and pyrite.

6.7.2.1 Underground Mine

The underground development of the Sullivan Mine is accessed by a single portal. Drainage chemistry is summarized in Figures 6.7-2 to 6.7-4. The pH of the drainage is continuously low, approximately around

3, indicating buffering by iron hydroxide. The host rocks have little buffering capacity from carbonates or alumino-silicates. Seasonal variations are not apparent for pH. Copper is not abundant in the deposit; therefore, concentrations are lower than at the Holden Mine, but as pH remains low year round, the high solubility of secondary copper minerals results in relatively constant copper concentrations. Variations in copper concentrations are not readily correlated with season. In comparison, zinc concentrations are elevated throughout the year due to the abundance of zinc in the ore. Zinc concentrations also appear to peak in April during snow-melt.

6.7.2.2 Waste Rock

Waste rock has been disposed in two primary areas. Seepage is severely acidic and comparable to the underground drainage. Seepage from a second waste rock disposal area emerges at a pH between 4 and 5, contains elevated zinc concentrations, and has deposited a white precipitate in a nearby small stream. The precipitate has been found to be amorphous aluminum hydroxide.

6.7.2.3 Tailings

The tailings disposal area contains various types of ore processing residues including raw, high-sulfide tailings produced by preferential flotation of iron sulfides, and low-sulfide siliceous tailings. The tailings are classified as potentially acid generating due to the lack of acid buffering capacity. In one location downgradient of the high-sulfide tailings, acidic seepage has been noted. Seepage pH varies from 2.8 to 5.5, and is accompanied by about 20 g/L sulfate, and 10 g/L iron. Zinc, lead and copper concentrations are very low (<0.3, <0.001, <0.2 mg/L, respectively) despite the aggressive leaching conditions.

6.7.3 Conclusions

The Baker Mine showed comparable chemical behavior to the Holden Mine. Similarities included seasonal variation in pH due to flushing of acidic weathering products during snow melt, buffering of acidity by alumino-silicates, and formation of buff aluminum hydroxide precipitates at the mine portal. By analogy to the Baker Mine, it would be expected that the Holden Mine drainage would maintain at comparable pHs through the winter to those observed in the fall, rather than the lower pH observed in the spring.

The Sullivan Mine generally indicates much more severe acid rock drainage than observed at the Holden Mine probably due to the lack of abundant alumino-silicates to buffer acidity. The drainage from the Sullivan underground mine would probably be described as typical ARD. The Holden Mine drainage is, therefore, relatively weakly acidic when compared to most other acid producing mine sites. Some similarities to the Holden Mine include the presence of white aluminous precipitates downgradient from some waste rock piles, and low base metal concentrations in tailings seepage despite strong acid generating conditions, reflecting removal of base metal sulfides during processing.

The comparison of the Holden Mine with other mines indicates that geochemical processes occurring at the Holden Mine occur at other mine sites. The Baker Mine in particular shows many similarities to the Holden Mine. These include similar seasonal trends in pH (low in spring increasing through summer), minimum pH of 4.5 in mine drainage, comparable copper concentrations due to similar mineralogical (i.e., portal drainage) for cadmium, zinc and copper, which enter the creek as surface flows or seeps.

- Additional source areas (waste rock piles and mill area) are not significant load sources in the spring and generally contribute no load in the fall unless a precipitation event occurs.
- The sediments sampled both in Railroad Creek (above, adjacent, and downstream of the Site) as well as Lake Chelan (at Lucerne bar and the mouth of the Stehekin River) indicate similar concentrations of metals, except for copper and zinc which are slightly elevated (approximately two-fold) when compared to the upstream and reference sites. However, the copper and zinc are anticipated to be present in the relatively inert stable iron oxyhydroxide precipitates due to the neutral pH in both Railroad Creek and Lake Chelan.

control and buffering by alumino-silicates. The Baker Mine is believed to have a regional stable geochemical conditions. Likewise, the Holden Mine is also believed to be stable.

The similarities with other mines indicates that the experience gained at other sites will be applicable to planning remediation at the Holden Mine.

6.8 FLOCCULENT AND FERRICRETE

6.8.1 Flocculent

Iron flocculent is a colloidal material that is generated from baseflow groundwater contributed to Railroad Creek from the tailings piles. As the pH of the groundwater increases upon contact and mixing with surface water, iron oxyhydroxides become stable and precipitate. Some of the copper that is in solution and lesser amounts of cadmium, zinc and other metals coprecipitate with the iron as the iron flocculent is formed. During the fall and winter months when groundwater flow is low and the flow in Railroad Creek is low, the majority of the flocculent that is generated settles in the base of the creek bed with some limited transport downstream.

In the spring, when both groundwater and surface water flows are high, flocculent continues to be generated. Due to the high flow, spring flocculent and flocculent that has accumulated in the Creek bed from fall/winter are mobilized and are both transported downstream. Flocculent is transported during spring runoff and precipitation events.

6.8.2 Ferricrete Formation

Ferricrete is typically defined as a conglomerate consisting of sand and gravel cemented into a hard mass by ferric oxides and sulfates derived from the oxidation of percolating iron-bearing solutions. The vertical and lateral variation in thickness and character of ferricrete in Railroad Creek suggests that percolating solutions infiltrate whatever material is present. Ferricrete formation is dependent on the supply of salts and degree of oxygenation of the solution. Increased infiltration of waters to the tailings dissolves the accumulated iron and metal salts in the tailings, putting iron and metal cations, sulfate and acidity into solution. Ferrous iron (Fe^{2+}) in groundwater, discharges as baseflow to Railroad Creek where oxidation and an increase in pH occurs. Ferrous iron converts to ferric iron (Fe^{3+}), complexes with hydroxides forming iron oxyhydroxides and then precipitates. Other metals may also coprecipitate with the iron. Because of these factors, the rate of formation of ferricrete is not constant and is dependent on the local conditions.

The formation of ferricrete is probably an important factor limiting the development of a hyporheic zone in Railroad Creek. The hyporheic zone is defined as a zone of mixed groundwater and surface water that may occur in the interstices of the bed sediment in direct contact with the water (for example, Benner et al. 1995). If groundwater contains elevated concentrations of contaminants, it is conceivable that elevated concentrations could be present in the hyporheic zone. The substantial ferricrete deposits may limit direct mixing between groundwater originating from the tailings piles and Railroad Creek water by armoring the stream bed. It is expected that iron-bearing groundwater will be oxidized and neutralized within the ferricrete, preventing the development of the hyporheic zone and encouraging precipitation of metals within and beneath the ferricrete.

Upstream of the tailings piles, significant ferricrete deposits have not been observed. However, it generally appears that most contribution in the spring is by surface flow and in the fall the load contributed by groundwater is small. A hyporheic zone, if present, would be significant only in the fall.

6.9 SEDIMENT

As noted in Section 5, a number of stream sediment samples were collected historically from Railroad Creek by others (reported in Kilburn, et al., 1994; U.S. Bureau of Mines or Lambeth, R.E., 1995; and Ecology, or Johnson A., et al., 1997) and in Lake Chelan by Dames & Moore as part of the RI in 1998. Sediments were collected historically upstream, within and downstream of the Site from 11 sampling stations; no duplicate samples to measure variation within a particular sampling station were collected. Analyses for total metals were performed on the medium to fine sand, silt and clay fraction of the sediment. Metal (aluminum, arsenic, cadmium, copper, iron, manganese, lead, and zinc) concentrations for samples collected during 1994 show a slight increase in concentration in the vicinity of the Site in relation to the upstream concentrations. Data from tributary streams along Railroad Creek had similar but slightly lower concentrations of metals in sediments. Lake sediments were collected offshore of the mouth of Railroad Creek in 1998. Compared to the Railroad Creek sediment data, metals in lake sediments from the Lucerne bar have a similar but slightly higher concentration range. In general, the concentrations remain relatively constant from the Site to Lake Chelan.

Assuming that the sediment samples are representative, the uniformity of the metal concentrations downstream of the Site suggests that the stream sediment is not significantly diluted during downstream transport between the Site and Lake Chelan, and/or the tributaries contribute sediment with metals. Railroad Creek is characterized by a coarse (70 to 90 percent cobble-boulder matrix) grain size that is related to channel morphology and gradient. Fine sediment sources include limited areas of Railroad Creek, tributaries and the streambanks upstream and downstream of the Site. Sediment derived from the watershed area are transported downstream and deposited eventually into Lake Chelan.

Although downstream sediment transport in Railroad Creek is a potential compound of concern migration pathway, several physical mechanisms reduce the potential for this pathway to be significant. The majority of metals that have been deposited in the streambank sediments become progressively attenuated in a downstream direction as they migrate. Downstream sediment becomes interspersed with sediments from tributary and Railroad Creek streambed sources. Copper and zinc remain slightly elevated (approximately two-fold higher than upstream of the Site) from the Site to Lake Chelan. However, the metals are presumed to be present in the sediment as iron oxides and/or manganese oxides which are relatively inert and not readily available due to the neutral pH of both Railroad Creek and Lake Chelan.

6.10 CONCLUSIONS

Based on the results of the fate and transport analysis in conjunction with the current conceptual site model, conclusions are listed below; specific conclusions have also been presented in each main subsection of Section 6:

- The primary sulfide minerals in the Holden Mine ore deposit include pyrite, pyrrhotite, sphalerite and chalcopyrite.
- The Holden Mine deposit is hosted by the Buckskin Schist, which is a quartz amphibole schist sequence with at least two horizons of intermittent marble beds and calcareous schists. The dominant silicates are plagioclase and biotite (aluminum-based).
- Host rock mineralogy is the primary factor affecting water chemistry at the Site. Weathering of these minerals, especially sulfide minerals, dominates Site water chemistry. Non-sulfide mineralogy of the tailings is expected to be dominated by minerals contained in the ore and in diabase dikes whereas the mine wall rocks are dominated by biotite schist.
- Secondary mineralization and precipitates produced by weathering processes are visibly evident throughout the Site, including orange brown iron stains (iron oxyhydroxides) on waste rock and tailings, white precipitates (amorphous aluminum hydroxide) in the 1500-level main portal drainage, green stain (copper carbonate) on marble waste rock in the waste rock piles, and efflorescent crusts (metal sulfates) in the mill building and where seepage emerges along the toes of the tailings piles.
- Consistent geochemical processes are occurring across the Site including iron sulfide mineral oxidation, oxidation of sphalerite and chalcopyrite, and metal attenuation. Specific controls include the release of heavy metals (iron, copper, zinc, cadmium), the release of metals exerting pH control (iron, aluminum), and seep chemistry for different facilities reflecting different rock types (mine vs. tailings). This dictates the difference between water chemistry in the east and west parts of the Site. The underground mine, waste rock piles and mill building area are dominated by the effect of residual zinc and copper mineralization, whereas the tailings piles are dominated by concentrated iron sulfides and associated iron alumino-silicates.
- The oxidation of sulfide minerals is releasing iron and acid to surface water drainages. Buffering of acidity is occurring by the reaction of waters with alumino-silicates. This limits the solubility of some metals (e.g., iron) but also allows pH to be low enough to solubilize copper. However, since alumino-silicates are abundant, buffering occurs close to the source of acid generation.
- Within Railroad Creek, complete neutralization of acid drainage occurs causing precipitation of iron, aluminum and copper as flocculent. Zinc and cadmium are likely not precipitated appreciably within Railroad Creek.
- Comparison of sulfate and aluminum supports the general conclusion of buffering by alumino-silicates. Aluminum concentrations are lowered by aluminum hydroxide precipitation.

- Source controls reflect the differences in oxygen availability and water flow.
    - Portions of the underground mine are likely well-oxygenated through the winter months due to temperature differences between the underground mine and the ambient air, and may therefore be actively oxidizing in open stopes above the 1500-level of the mine. Random water flow in fractures dissolves weathering products, some of which are discharged in the 1500-level main portal drainage, and some of which are stored as salts formed by evapo-concentration. Discharge water reflects precipitation of iron in the workings and precipitation of aluminum within the mine and in the portal drainage and Railroad Creek.
    - The tailings piles are only oxygenated near the surface. Chemical processes leading to the release of heavy metals occur primarily in this zone and not at depth. Acid neutralization occurs at depth. Groundwaters contain reduced iron which rapidly oxidizes upon emergence in seeps, forming ferricrete and flocculent.
- The metal attenuation processes that occur downgradient of sources prior to entering Railroad Creek include precipitation due to pH increase and aeration, efflorescence (causing seasonal formation of salts), co-precipitation of heavy metals (primarily with iron), and adsorption. Precipitation of aluminum, iron and copper flocculent probably occurs when seeps mix with slightly alkaline Railroad Creek water and groundwater adjacent to Railroad Creek.
- The magnesium (conservative parameter) balance indicated that all major sources were identified and that the required flow balances were consistent with measured magnesium concentrations. Therefore, the magnesium balance corroborates the site-specific water balance in Section 4.4.
- Mass balance calculations for Railroad Creek at the Site indicate that the mass of zinc, cadmium, copper and iron originating from the underground mine, waste rock piles, and tailings piles has been accounted for. Seasonal and yearly variations are apparent reflecting changing variations in flow characteristics and timing of sampling with respect to the spring snowmelt.
- Copper and zinc loads to Railroad Creek from measured point sources and other groundwater (baseflow) sources are highest during the spring snowmelt and groundwater discharge period when groundwater levels are highest in the deep wells beneath the tailings, and high flow occurs at the 1500-level portal drainage. During the May round when flows are the highest, the portal drainage is the primary source of loading of cadmium, copper and zinc to Railroad Creek.
- Seeps SP-23 and SP-23B are the two next highest point sources that are estimated to contribute copper, cadmium and zinc during May; however, this load drops to zero later in the year as seep SP-23 dries up.
- Iron enters Railroad Creek primarily by groundwater and iron loads are greater in September than May. Iron loads enter Railroad Creek downstream of the load sources

TABLE 6.0-1
KEY OF SITE FEATURES & MEDIA SAMPLING/DATA COLLECTION LOCATIONS
HOLDEN MINE RI/FS
DAMES & MOORE JOB NO. 17693-005-019

Feature/Area or Media	Station No.	Location by Area	Coordinate	Comments
Feature/Area				
1500-Level Main Portal	N/A	Mine Support & Waste Rock	E.0-3.0	Near southern boundary
1500-Level Ventilator Portal	N/A	Mine Support & Waste Rock	D.7-3.0	Near western boundary
1100-Level Portal	N/A	Honeymoon Heights	D.8-3.1	
1000-Level Portal	N/A	Honeymoon Heights	D.8-3.1	
800-Level Portal	N/A	Honeymoon Heights	D.8-3.1	
700-Level Portal	N/A	Honeymoon Heights	D.8-3.2	
550-Level Portal	N/A	Honeymoon Heights	D.9-3.2	
300-Level Portal	N/A	Honeymoon Heights	D.9-3.2	
Abandoned Septic Field	N/A	SE of Holden Village	E.2-3.0	
Abandoned Surface Water Ret.	N/A	Mine Support & Waste Rock	D.7-2.9	
Baseball Field/Campground	N/A	Baseball Field/Campground	D.7-2.9, D.8-2.9	
Copper Creek	N/A	S. of Tailings Piles 1 & 2	E.1-3.1, E.1-3.2, E.2-3.0, E.3-3.1	
Copper Creek Diversion	N/A	W. of Tailings Pile 1	E.0-3.0, E.1-3.0	
East Waste Rock Pile	N/A	Mine Support & Waste Rock	E.1-3.0, E.1-3.1	
Holden Village	N/A	Holden Village	E.1-2.9, E.2-2.9	
Holden Village Septic Field	N/A	SE of Winston Home Sites	D.9-2.9, E.0-2.9	
Honeymoon Heights	N/A	Honeymoon Heights	D.7-3.0, 3.1, 3.2; D.8-3.0, 3.1, 3.2, 3.3; D.9-3.0, 3.1, 3.2, 3.3	
Hydroelectric Plant	N/A	W. of Tailings Pile 1	E.0-3.0	
Intermittent Drainage	N/A	Honeymoon Heights	D.8-3.0, D.8-3.1, D.8-3.2, D.8-3.3	
Lagoon	N/A	Mine Support & Waste Rock	E.0-2.9, E.0-3.0	
Lucerne Bar	N/A	Lucerne		
Lucerne Guard Station	N/A	Lucerne	I-3	
Maintenance Yard	N/A	Maintenance Yard	E.0-3.0	
Mill Building	N/A	Mill Building	E.0-3.0	
Mine Support and Waste Rock	N/A	Mine Support & Waste Rock	D.7-2.9, 3.0; D.8-2.9, 3.0; D.9-2.9, 3.0; E.0-2.9, 3.0, 3.1; E.1-3.0, 3.1, 2.9	
Portal Museum	N/A	Mine Support & Waste Rock	E.0-3.0	
Sauna	N/A	NW of Tailings Pile 1	E.1-3.0	
Shop	N/A	Maintenance Yard	E.0-3.0	
Storage	N/A	Maintenance Yard	E.0-3.0	
Tailings Pile 1	N/A	Tailings Pile 1	E.1-3.0, E.2-3.0, E.2-3.1	
Tailings Pile 2	N/A	Tailings Pile 2	E.2-3.0, E.2-3.1, E.3-3.0, E.3-3.1, E.4-3.0, E.4-3.1	
Tailings Pile 3	N/A	Tailings Pile 3	E.4-3.0, E.4-3.1, E.5-3.0, E.5-3.1	
USFS Guard Station	N/A	USFS Guard Station	E.0-2.9	
West Waste Rock Pile	N/A	Mine Support & Waste Rock	E.0-3.0	
Winston Home Sites	N/A	Winston Home Sites	D.8-2.9; D.9-2.8, 2.9; E.0-2.8, 2.9	
Geophysical Survey Lines				
A-A'	N/A	North of West Waste Rock Pile	E.0-2.9, E.0-3.0	
B1-B1'	N/A	Tailings Pile 1	E.1-3.0	
B2-B2'	N/A	East Waste Rock Pile	E.1-3.1	
C-C'	N/A	Tailings Pile 2	E.3-3.0, E.3-3.1	
D-D'	N/A	Tailings Pile 3	E.4-3.0, E.4-3.1	
E-E'	N/A	East of Tailings Pile 3	E.5-3.0, E.5-3.1	

TABLE 6.0-1
KEY OF SITE FEATURES & MEDIA SAMPLING/DATA COLLECTION LOCATIONS
HOLDEN MINE RI/FS
DAMES & MOORE JOB NO. 17693-005-019

Feature/Area or Media	Station No.	Location by Area	Coordinate	Comments
EM1-EM1'	N/A	Western Mine Support Area	D.8-2.9, D.8-3.0. D.9-2.9, D.9-3.0, E.0-2.9	
EM2-EM2'	N/A	Western Mine Support Area	D.8-3.0, D.9-3.0, E.0-3.0, E.1-3.0	
EM3-EM3'	N/A	East of Tailings Pile 3	E.5-3.0, E.5-3.1	
F-F'	N/A	North of Tailings Piles 2 & 3	E.4-3.0	
G-G'	N/A	Between Tailings Piles 1 & 2	E.2-3.0, E.2-3.1	
Sample Locations				
Groundwater Monitoring Wells				
	HBKG-1	W. of Tailings Pile 1	E.0-3.0	Potential background
	HBKG-2	E. of Baseball Field/Campgr.	D.8-2.9	Potential background
	CC-BKG	SW Tailings Pile 2	E.2-3.1	Background
	H-1	Holden Village	E.1-2.9	
	H-2	Holden Village	E.2-2.9	
	HV-3/H-3	Holden Village	E.1-2.9	Background
	DS-1	East of Tailings Pile 3	E.5-3.0	Downstream Wells:
	DS-2	East of Tailings Pile 3	E.5-3.0	Downstream Wells:
	TP1-1A	Tailings Pile 1	E.1-3.0	
	TP1-2A	Tailings Pile 1	E.1-3.0	
	TP1-2L	Tailings Pile 1	E.1-3.0	
	TP1-3A	Tailings Pile 1	E.1-3.0	
	TP1-3L	Tailings Pile 1	E.1-3.0	
	TP1-4A	Tailings Pile 1	E.1-3.0	
	TP1-4L	Tailings Pile 1	E.1-3.0	
	TP1-5A	Tailings Pile 1	E.2-3.0	
	TP1-6A	Tailings Pile 1	E.1-3.0	
	TP1-6L	Tailings Pile 1	E.1-3.0	
	PZ-1A	Tailings Pile 2	E.3-3.1	
	PZ-1B	Tailings Pile 2	E.3-3.1	
	PZ-1C	Tailings Pile 2	E.3-3.1	
	PZ-2A	Tailings Pile 2	E.3-3.0	
	PZ-2B	Tailings Pile 2	E.3-3.0	
	PZ-2C	Tailings Pile 2	E.3-3.0	
	PZ-3A	Tailings Pile 2	E.3-3.0	
	PZ-3B	Tailings Pile 2	E.3-3.0	
	PZ-3C	Tailings Pile 2	E.3-3.0	
	TP2-1L	Tailings Pile 2	E.3-3.1	
	TP2-2L	Tailings Pile 2	E.3-3.0	
	TP2-4A	Tailings Pile 2	E.3-3.0	
	TP2-4B	Tailings Pile 2	E.3-3.0	
	TP2-5A	Tailings Pile 2	E.3-3.0	
	TP2-5B	Tailings Pile 2	E.3-3.0	
	TP2-6L	Tailings Pile 2	E.3-3.1	
	TP2-7N&S	Tailings Pile 2	E.4-3.0	
	TP2-8A	Tailings Pile 2	E.4-3.0	
	TP2-8B	Tailings Pile 2	E.4-3.0	
	TP2-9L	Tailings Pile 2	E.4-3.1	
	TP2-10L	Tailings Pile 2	E.2-3.1	
	TP2-11	Tailings Pile 2	E.2-3.0	
	TP2-11L	Tailings Pile 2	E.2-3.0	
	TP3-4	Tailings Pile 3	E.4-3.0	

TABLE 6.0-1
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HOLDEN MINE RI/FS
DAMES & MOORE JOB NO. 17693-005-019

Feature/Area or Media	Station No.	Location by Area	Coordinate	Comments
	TP3-4L	Tailings Pile 3	E.4-3.0	
	TP3-5A	Tailings Pile 3	E.5-3.0	
	TP3-6A	Tailings Pile 3	E.5-3.0	
	TP3-6BL	Tailings Pile 3	E.5-3.0	
	TP3-7	Tailings Pile 3	E.4-3.0	
	TP3-8	Tailings Pile 3	E.4-3.0	
	TP3-9	Tailings Pile 3	E.5-3.0	
	TP3-10	Tailings Pile 3	E.5-3.0	
	TP3-10L	Tailings Pile 3	E.5-3.0	
	PZ-4A	Tailings Pile 3	E.4-3.0	
	PZ-4B	Tailings Pile 3	E.4-3.0	
	PZ-4C	Tailings Pile 3	E.4-3.0	
	PZ-5A	Tailings Pile 3	E.4-3.0	
	PZ-5B	Tailings Pile 3	E.4-3.0	
	PZ-5C	Tailings Pile 3	E.4-3.0	
	PZ-6A	Tailings Pile 3	E.4-3.0	
	PZ-6B	Tailings Pile 3	E.4-3.0	
	PZ-6C	Tailings Pile 3	E.4-3.0	
	Lucerne Well	Lucerne	I-3	Lucerne Guard Station
Subsurface/Surface Soil				
	DMSS-1	Holden Village	E.2-2.9	Surface soil
	DMSS-2	Holden Village	E.2-2.9	Surface soil
	DMSS-3	Holden Village	E.1-2.9	Surface soil
	DMSS-4	Holden Village	E.1-2.9	Surface soil
	DMSS-5	Holden Village	E.1-2.9	Surface soil
	DMSS-6	Holden Village	E.2-2.9	Surface soil
	DMSS-7	Holden Village	E.1-2.9	Surface soil
	DMSS-8	Maintenance Yard	E.0-3.0	Surface soil
	DMSS-9	Maintenance Yard	E.0-3.0	Surface soil
	DMSS-10	Maintenance Yard	E.0-3.0	Surface soil
	DMSS-11	Tailings Pile 1	E.1-3.0	Surface soil
	DMSS-12	Tailings Pile 1	E.1-3.0	Surface soil
	DMSS-13	Tailings Pile 1	E.2-3.0	Surface soil
	DMSS-14	Tailings Pile 2	E.2-3.0	Surface soil
	DMSS-15	Tailings Pile 2	E.3-3.0	Surface soil
	DMSS-16	Tailings Pile 2	E.4-3.0	Surface soil
	DMSS-17	Tailings Pile 3	E.4-3.0	Surface soil
	DMSS-18	Tailings Pile 3	E.4-3.0	Surface soil
	DMSS-19	Tailings Pile 3	E.5-3.0	Surface soil
	DMSS-20	East of Tailings Pile 3	E.5-3.0	Windblown tailings
	DMSS-21	East of Tailings Pile 3	E.6-3.0	Windblown tailings
	DMSS-22	East of Tailings Pile 3	E.6-3.0	Windblown tailings
	DMSS-23	East of Tailings Pile 3	E.7-3.0	Windblown tailings
	DMSS-24	East of Tailings Pile 3	E.5-3.0	Windblown tailings
	DMSS-25	Baseball Field	D.7-2.9	Surface soil
	DMSS-26	Wilderness Area	D.7-2.9	Surface soil
	DMSS-27	Wilderness Area	D.7-2.9	Surface soil
	Lagoon 6"	Lagoon	E.0-2.9	Surface soil
	Lagoon 2'	Lagoon	E.0-2.9	Subsurface soil sample
	DMLG1	Lagoon	E.0-3.0	Subsurface soil sample
	DMLG2	Lagoon	E.0-2.9	Subsurface soil sample
	DMLG3	Lagoon	E.0-2.9	Subsurface soil sample

TABLE 6.0-1
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HOLDEN MINE RI/FS
DAMES & MOORE JOB NO. 17693-005-019

Feature/Area or Media	Station No.	Location by Area	Coordinate	Comments
	DMLG4	Lagoon	E.0-3.0	Subsurface soil sample
	DMLG5	Lagoon	E.0-2.9	Subsurface soil sample
	DMBG1	Approximately 1-mile West of Site	D-2	Background surface soil
	DMBG2	Holden Creek Drainage	D-2	Background surface soil
	DMBG3	Between Holden Creek & Hart Lake	C-2	Background surface soil
	DMBG4	East of Hart Lake	C-2	Background surface soil
	DMBG5	Between Hart Lake & Crown Point	B-2	Background surface soil
	DMBG6	Lyman Lakes	A-3	Background surface soil
	DMBG7	West of Hart Lake	B-2	Background surface soil
	DMBG8	West of Holden Creek	C-2	Background surface soil
	DMBG9	West of Big Creek	D-2	Background surface soil
	DMBG10	Copper Basin	E-3	Background surface soil
	DMBG11	Southwest of Site	D-3	Background surface soil
	DMBG12	South of Site	D-3	Background surface soil
	DMBG13	Near South Site Boundary	E-3	Background surface soil
	DMBG14	Near Holden Creek	D-2	Background surface soil
	DMBG15	Near Holden Creek	D-2	Background surface soil
	DMBG16	West of Site Boundary	D-2	Background surface soil
	DMBG17	Near Winston Home Sites	D-2	Background surface soil
	DMBG18	Northeast of Site	E-2	Background surface soil
	DMBG19	North of Holden Village	E-2	Background surface soil
	DMTP1-2	Tailings Pile 1	E.1-3.0	Test pit excavation
	DMTP1-3	Tailings Pile 1	E.1-3.0	Test pit excavation
	DMTP1-4	Tailings Pile 1	E.1-3.0	Test pit excavation
	DMTP1S-1	Tailings Pile 1	E.1-3.0	Test pit excavation
	DMTP2-1	Tailings Pile 2	E.2-3.0	Test pit excavation
	DMTP2-2	Tailings Pile 2	E.3-3.0	Test pit excavation
	DMTP2S-1	Tailings Pile 2	E.3-3.1	Test pit excavation
	DMTP3-1	Tailings Pile 3	E.4-3.0	Test pit excavation
	DMTP3-2	Tailings Pile 3	E.5-3.0	Test pit excavation
	DMTP3-3	Tailings Pile 3	E.5-3.0	Test pit excavation
	DMTP3-4	Tailings Pile 3	E.5-3.0	Test pit excavation
	DMTP3S-1	Tailings Pile 3	E.4-3.1	Test pit excavation
	DMTP3E-1	Immed. east of Tailings Pile 3	E.5-3.0	Test pit excavation
	DMTP3E-2	Immed. east of Tailings Pile 3	E.5-3.0	Test pit excavation
	DMTP3E-3	Immed. east of Tailings Pile 3	E.5-3.0	Test pit excavation
	DMTP3E-4	Immed. east of Tailings Pile 3	E.5-3.0	Test pit excavation
	DMTP3E-5	Immed. east of Tailings Pile 3	E.5-3.1	Test pit excavation
	DMTP3E-6	Immed. east of Tailings Pile 3	E.5-3.1	Test pit excavation
	DMTPW-1	Winston home sites	D.8-2.9	Test pit excavation
	DMTPW-2	Winston home sites	D.8-2.9	Test pit excavation
	DMTPW-3	Winston home sites	D.8-2.9	Test pit excavation
	DMTPW-4	Winston home sites	D.8-2.9	Test pit excavation
	DMTPW-5	Winston home sites	D.9-2.9	Test pit excavation
	DMTPW-6	Winston home sites	D.9-2.9	Test pit excavation
	DMTPW-7	Winston home sites	D.9-2.9	Test pit excavation
Surface Water				
	RC-1	Railroad Creek	D.7-2.9	
	RC-1 North Bank	Railroad Creek	D.7-2.9	
	RC-1 South Bank	Railroad Creek	D.7-2.9	
	RC-2	Railroad Creek	E.5-3.0	
	RC-2 South Bank	Railroad Creek	E.5-3.0	

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KEY OF SITE FEATURES & MEDIA SAMPLING/DATA COLLECTION LOCATIONS
HOLDEN MINE RI/FS
DAMES & MOORE JOB NO. 17693-005-019

Feature/Area or Media	Station No.	Location by Area	Coordinate	Comments
	RC-3	Railroad Creek	I-3	
	RC-4	Railroad Creek	E.0-2.9	
	RC-4 South Bank	Railroad Creek	E.0-2.9	
	RC-5	Railroad Creek	E-3	
	RC-5A	Railroad Creek	E-3	
	RC-6	Railroad Creek	D.7-2.9	
	RC-6 North Bank	Railroad Creek	D.7-2.9	
	RC-7	Railroad Creek	E.4-3.0	
	RC-8	Railroad Creek	I-3	
	RC-8 North Bank	Railroad Creek	I-3	
	RC-10	Near Seven Mile Creek	F-3	
	RC-11	Upstream of Holden Creek	D-2	
	CC-1	Copper Creek	E.2-3.1	
	CC-2	Copper Creek	E.2-3.0	
	CC-D	Copper Creek Diversion	E.1-3.0	
	CC-D1	Copper Creek Diversion	E.1-3.0	
	P-1	Mine Support & Waste Rock	E.0-3.0	Portal Drainage/1500 Main
	P-5	Mine Support & Waste Rock	D.9-2.9	Portal Drainage/RR Creek
	HC-1	Holden Creek	D-2	
	HC-2	Holden Creek	C-2	
	HC-3	Holden Creek	C-2	
	HC-4	Holden Creek	C-1	
	Big-1	Big Creek	D-2	
	Tenmile Creek	Tenmile Creek	E-2	
Seeps				
	A1	Honeymoon Heights	D.8-3.1	1100 Level Portal
	SP1	Tailings Pile 1	E.1-3.0	
	SP2	Tailings Pile 1	E.2-3.0	
	SP3	Tailings Pile 2	E.3-3.0	
	SP4	Tailings Pile 3	E.4-3.0	
	SP5	East of Tailings Pile 3	E.5-3.0	
	SP6	West Waste Rock Pile	E.0-3.0	
	SP7	West Waste Rock Pile	E.0-3.0	
	SP8	East Waste Rock Pile	E.1-3.0	
	SP9	Between P-5 & RC-4	D.9-2.9	
	SP10W	River Sauna	E.1-2.9	
	SP10E	River Sauna	E.1-2.9	
	SP11	West of Vehicle Bridge	E.0-2.9	
	SP12	West of P-5	D.9-3.0	
	SP13	South of Holden Village	E.1-2.9, 3.0; E.2-2.9, 3.0	"Black Seep"
	SP14	Honeymoon Heights	D.8-3.1	
	SP15W	North of West Waste Rock Pile	E.0-3.0	
	SP15E	North of West Waste Rock Pile	E.0-3.0	
	SP16	Lagoon	E.0-2.9	
	SP17	East of Tailings Pile 3	E.5-3.1	
	SP18	East of Tailings Pile 3	E.5-3.0	Bank sample
	SP19	Tailings Pile 1	E.1-3.0	
	SP20	Tailings Pile 1 (Near Copper Creek)		
	SP21	East of Tailings Pile 3	2.6-3.1	
	SP22	North of Maintenance Yard	E.0-3.0	
	SP23	Between RC-1 and P-5	D.8-3.0	
	SP23B	Between RC-1 and P-5	D.8-3.0	

TABLE 6.0-1
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HOLDEN MINE RI/FS
DAMES & MOORE JOB NO. 17693-005-019

Feature/Area or Media	Station No.	Location by Area	Coordinate	Comments
	SP24	West of RC-4	E.0-2.9	
	SP25	Between Vehicle Bridge & RC-4	E.0-2.9	
	SP26	Between RC-1 and RC-6	D.7-2.9	
	SP-27	Near Big Creek	D-2	
	CC-D1	Copper Creek Diversion	E.1-2.9	
Sediment - Lake Chelan				
	1-1	Lucerne	N/A	
	1-2	Lucerne	N/A	
	2-1	Lucerne	N/A	
	2-2	Lucerne	N/A	
	3-1	Lucerne	N/A	
	3-1A	Lucerne	N/A	
	3-1B	Lucerne	N/A	
	3-1C	Lucerne	N/A	
	3-2	Lucerne	N/A	
	3.5-1	Lucerne	N/A	
	3.5-2	Lucerne	N/A	
	5-1	Lucerne	N/A	
	5-2	Lucerne	N/A	
	1	Stehekin	N/A	
	2	Stehekin	N/A	
	3A	Stehekin	N/A	
	3B	Stehekin	N/A	
	3C	Stehekin	N/A	
	4	Stehekin	N/A	
USGS Select Samples				
	344	Ten Mile Creek	E.6-2.9	
	345	Railroad Creek near RC-2	E.5-3.0	
	346	Copper Creek Diversion	E.1-3.0	
	347	Railroad Creek at Vehicle Bridge	E.0-2.9	
	350	East of Tailings Pile 3	E.5-3.0	
	351	Nine Mile Creek	F-3	
	352	Railroad Creek near Seven Mile Creek	F-3	
	353	Seven Mile Creek	F-3	
	354	Railroad Creek at Lucerene	N/A	
	355	Holden Creek	D-2	
	356	Railroad Creek West of Site	D-2	
	MP-7	Railroad Creek at Mile Post 7	G-3	
USBM Select Samples				
	BKG 1/2	Downstream of Vehicle Bridge	E.0-2.9	
	DG-1	Downstream of Tailings Pile 3	E.6-3.0	
	TP1-2	Adjacent to Tailings Pile1	E.1-3.0	
	TP2-1	Downstream of Copper Creek	E.2-3.0	
	TP2-2	Adjacent to Tailings Pile 2	E.3-3.0	
	TP3-1	Adjacent to Tailings Pile 3	E.4-3.0	
	RC-2	At Railroad Creek RC-2 Station	E.5-3.0	

TABLE 6.1-1
SECONDARY SULFATE MINERALS IDENTIFIED IN THE ABANDONED HOLDEN MILL AND TAILINGS

Mineral Name	Formula	Identified In:			Solubility (Alpers et al., 1994)
		Tailings (1994)	Mill 95	Mill 96	
Alunogen	$Al_2(SO_4)_3\ 17H_2O$	Present	Present		High
Ammoniojarosite	$(NH_4)Fe_3^{III}(SO_4)_2(OH)_6$		Present		Low
Anterlerite	$Cu_3(SO_4)(OH)_4$	Present	Present	Present	Low
Bianchite	$(Zn, Fe^{II})SO_4 \bullet 6H_2O$			Present	High
Bilinite	$Fe^{II}Fe^{III}(SO_4)_4 \bullet 22H_2O$		Present		High
Bonattite	$CuSO_4 \bullet 3H_2O$	Present	Present		High
Butlerite	$Fe^{III}(SO_4)(OH) \bullet 2H_2O$		Present		?
Chalcanthite	$CuSO_4 \bullet 5H_2O$	Present	Present	Present	High
Dietrichite	$(Zn, Fe^{III}, MII)Al_2(SO_4)_4 \bullet 22H_2O$	Present			?
Epsomite	$MgSO_4 \bullet 7H_2O$			Present	High
Goslarite	$ZnSO_4 \bullet 7H_2O$			Present	High
Gunnigite	$(Zn, Mn)SO_4 \bullet H_2O$	Present	Present		High
Gypsum	$CaSO_4 \bullet 2H_2O$	Present		Present	High
Halotrichite	$Fe^{II}Al_2(SO_4)_4 \bullet 22H_2O$	Present		Present	?
Hexahydrite	$MgSO_4\ 6H_2O$	Present		Present	High
Hexahydrite	$MgSO_4 \bullet 6H_2O$				High
Hydronium Jarosite	$(H_3O)Fe_3^{III}(SO_4)_2(OH)_6$		Present		Low
Jarosite	$KFe_3^{III}(SO_4)_2(OH)_6$	Present			Low
Melanterite	$Fe^{II}SO^4 \bullet 7H_2O$	Present		Present	High
Natrojarosite	$NaFe^{III}(SO_4)_2(OH)_6$		Present		Low
Pickeringite	$MgAl_2(SO_4)_4$	Present		Present	?
Romerite	$Fe^{III}Fe^{III}(SO^4)^4 \bullet 14H_2O$	Present		Present	High
Rozenite	$Fe^{II}SO^4 \bullet 4H_2O$	Present	Present	Present	High
Siderotil	$Fe^{II}SO^4 \bullet 5H_2O$	Present	Present	Present	High
Starkeyite	$MgSO_4 \bullet 4H_2O$		Present		High
Xitieshanite	$Fe^{III}(SO_4)(OH) \bullet 7H_2O$		Present		?

Table 6.6-1
Loading Calculations - Railroad Creek, May 1997
Holden Mine RI/FS
Dames & Moore Job No. 17693-005-019

		Magnesium				Zinc				Cadmium				Copper				Iron			
Station	Flows L/s	Conc. mg/L	Load mg/s	% Load of RC-2	Cumulative Load	Conc. mg/L	Load mg/s	% Load of RC-2	Cumulative Load	Conc. mg/L	Load mg/s	% Load of RC-2	Cumulative Load	Conc. mg/L	Load mg/s	% Load of RC-2	Cumulative Load	Conc. mg/L	Load mg/s	% Load of RC-2	Cumulative Load
RC-6	**14159***	**0.360**	**5097**			**0.016**	**226**	**17.9**		**0.00002**	**0.28**	**3.6**		**0.0007**	**9.91**	**2.8**		**0.03**	**425**	**9.4**	
RC-1	**14161.1**	**0.36**	**5098**	**53.9**	**5098**	**0.01**	**184**	**14.6**	**184**	**0.00002**	**0.28**	**3.5**	**0.28**	**0.0011**	**16**	**4.5**	**16**	**0.03**	**425**	**9.4**	**425**
SP-23	14.2	5.13	73	0.8	5171	5.00	71	5.6	255	0.0389	0.55	6.9	0.84	6.85	97	27.4	113	0.01	0	0	425
SP-23B	1.9	3.92	7	0.1	5178	3.61	7	0.6	262	0.0280	0.05	0.6	0.89	4.90	9	2.5	122	0.01	0	0	425
SP-12	1.9	1.47	3	0.03	5181	2.00	4	0.3	266	0.0141	0.03	0.4	0.92	2.0	4	1.1	126	0.01	0	0	425
P-5	96.3	9.29	894	9.5	6075	8.82	849	67.3	1115	0.0525	5.05	63.4	5.97	2.34	225	63.6	351	0.19	18	0.4	443
SP-9	0.5	2.09	1	0.01	6076	0.27	0	0	1115	0.0008	0.00	0	5.97	0.003	0	0	351	0.01	0	0	443
SP-11	0.5	3.18	2	0.02	6078	2.34	1	0.1	1116	0.0128	0.01	0.1	5.98	0.46	0	0	351	0.01	0	0	443
SP-24	0.9	6.24	6	0.1	6084	7.56	7	0.6	1123	0.0477	0.05	0.6	6.02	3.66	3	0.8	355	0.22	0	0	444
Reach 1 Balance	*25.5*	*22.45*	*572*	*6.0*	*6656*	*#N/A*	*-90*	*-7.1*	*1034*	*0.0080*	*0.20*	*2.5*	*6.23*	*0.77*	*20*	*5.6*	*374*	*#N/A*	*-160*	*-3.5*	*283*
RC-4	**14161.1**	**0.47**	**6656**	**70.4**		**0.07**	**1034**	**82.0**		**0.0004**	**6.23**	**78.3**		**0.0264**	**374**	**105.6**		**0.02**	**283**	**6.2**	
SP-10W	0.3	3.87	1	0.01	6657	3.21	1	0.1	1035	0.0257	0.01	0.1	6.23	2.21	1	0.3	375	0.03	0	0	283
SP-10E	0.3	1.4	0	0	6658	0.71	0	0	1035	0.0070	0.00	0	6.24	0.76	0	0	375	14.10	4	0.1	288
CCD	198.2	0.66	131	1.4	6789	0.17	34	2.7	1069	0.0018	0.35	4.4	6.58	0.046	9	2.5	385	0.23	46	1.0	334
SP-1	0.9	53.5	51	0.5	6839	3.49	3	0.2	1072	0.0227	0.02	0.3	6.61	0.698	1	0.3	385	542.00	513	11.3	847
SP-2	0.9	96.8	92	1.0	6931	5.60	5	0.4	1077	0.0228	0.02	0.3	6.63	0.914	1	0.3	386	487.00	461	10.2	1308
Copper Creek	424.8	0.55	234	2.5	7164	0.01	6	0.5	1083	0.000020	0.01	0.1	6.64	0.0010	0	0	386	0.04	17	0.4	1325
SP-3	4.7	47.9	227	2.4	7391	4.03	19	1.5	1102	0.0403	0.19	2.4	6.83	1.28	6	1.7	393	154.00	723	16.0	2048
Reach 2 Balance	*59.5*	*26.1*	*1550*	*16.4*	*8941*	*2.5*	*146*	*11.6*	*1248*	*0.0173*	*1.03*	*12.9*	*7.86*	*#N/A*	*-48*	*-13.6*	*345*	*23.74*	*1412*	*31.2*	*3460*
RC-7	**14867.8**	**0.59**	**8772**	**92.8**		**0.09**	**1264**	**100.2**		**0.00058**	**8.62**	**108.3**		**0.023**	**342**	**96.6**		**0.48**	**7132**	**157.4**	
SP-4	14.2	36.3	515	5.4	9456	0.90	12.8	1.0	1261	0.0073	0.10	1.3	7.96	0.670	10	2.8	354	74.90	1065	23.5	4524
RC-2	**15009.5**	**0.63**	**9456**	**100**		**0.08**	**1261**	**100**		**0.00053**	**7.96**	**100**		**0.024**	**354**	**100**		**0.30**	**4530**	**100**	
Total Balance	*85.0*	*24.97*	*2122*	*22.4*		*0.66*	*56*	*4.4*		*0.015*	*1.23*	*15.5*		*-0.32913*	*-28*	*-7.9*		*14.728*	*1252*	*27.6*	

Notes
1. Rows shown in **bold** are data for Railroad Creek monitoring stations.
2. Rows shown in *italics* are loads required balance the total load . The concentration and flow are set so that the load added (or subtracted) equals the load measured in Railroad Creek.
3. #N/A indicates a negative concentration required to produce a negative load.
4. "*Total balance*" is the sum of loads required to balance loads in both reaches.
5. The RC-6 station is required to balance upstream of RC-1 and not considered part of Reach 1. It is shown for comparison only to RC-1.
* Estimated Flow 500cfs

Table 6.6-2
Loading Calculations - Railroad Creek, September 1997
Holden Mine RI/FS
Dames & Moore Job No. 17693-005-019

Station	Flows L/s	Magnesium				Zinc				Cadmium				Copper				Iron			
		Conc. mg/L	Load mg/s	% Load of RC-2	Cumulative Load	Conc. mg/L	Load mg/s	% Load of RC-2	Cumulative Load	Conc. mg/L	Load mg/s	% Load of RC-2	Cumulative Load	Conc. mg/L	Load mg/s	% Load of RC-2	Cumulative Load	Conc. mg/L	Load mg/s	% Load of RC-2	Cumulative Load
RC - 6	**3710****	**0.35**	**1299**	**59.2**		**0.004**	**15**	**16.9**		**0.00002**	**0.074**	**19.1**		**0.0004**	**1.5**	**32.6**		**0.040**	**148**	**3.6**	
SP-26	0.3**	0.54	0.14	0.006		0.022	0.006	0.007		0.0003	0.00008	0.020		0.022	0.006	0.1		0.010	0.003	0.00007	
RC-1	**3737.1**	**0.35**	**1308**	**59.6**	**1308**	**0.0020**	**7**	**7.9**	**7**	**0.000020**	**0.07**	**17.9**	**0.07**	**0.00040**	**1.5**	**32.6**	**1.5**	**0.04**	**149**	**3.6**	**149**
SP-23	0.0		0	0	1308		0	0	7		0.00	0	0.07		0.0	0	1.5		0	0	149
SP-23B	0.0		0	0	1308		0	0	7		0.00	0	0.07		0.0	0	1.5		0	0	149
SP-12	0.0		0	0	1308		0	0	7		0.00	0	0.07		0.0	0	1.5		0	0	149
P-5	5.7	9.85	56	2.8	1364	2.98	17	19.1	24	0.008000	0.05	12.8	0.12	0.02800	0.2	4.3	1.7	0.01	0	0	150
SP-9	0.0		0	0	1364		0	0	24		0.00	0	0.12		0.0	0	1.7		0	0	150
SP-11	0.0		0	0	1364		0	0	24		0.00	0	0.12		0.0	0	1.7		0	0	150
SP-24	0.0		0	0	1364		0	0	24		0.00	0	0.12		0.0	0	1.7		0	0	150
Reach 1 Balance	*8.5*	*#N/A*	*-74.8*	*-3.4*	*1289*	*1.60*	*14*	*15.7*	*38*	*0.010000*	*0.08*	*20.5*	*0.21*	*0.70000*	*4.6*	*100*	*6.3*	*#N/A*	*-10*	*0.2*	*139*
RC-4	**3483.8**	**0.37**	**1289**	**58.7**		**0.011**	**36**	**42.7**		**0.000060**	**0.21**	**53.8**		**0.00180**	**6.3**	**137.0**		**0.04**	**139**	**3.3**	
SP-10W	0.0		0	0	1289		0	0	38		0.00	0	0.21		0.0	0	6.3		0	0	139
SP-10E	0.0		0	0	1289		0	0	38		0.00	0	0.21		0.0	0	6.3		0	0	139
CCD	198.2	0.46	91	4.1	1380	0.002	0	0	38	0.000100	0.02	5.1	0.22	0.00100	0.2	4.3	6.5	0.01	2	0.05	141
SP-1	0.0		0	0	1380		0	0	38		0.00	0	0.22		0.0	0	6.5		0	0	141
SP-2	0.1	94.20	12	0.5	1392	5.70	1	1.1	39	0.003900	0.00	0	0.23	0.10100	0.0	0	6.5	685.00	86	2.1	228
Copper Creek	141.6	0.47	67	3.1	1459	0.002	0	0	39	0.000020	0.00	0	0.23	0.00030	0.0	0	6.5	0.01	1	0.02	229
SP-3	0.4	62.30	26	1.2	1484	0.611	0	0	40	0.002000	0.00	0	0.23	0.09000	0.0	0	6.5	251.00	103	2.5	332
Reach 2 Balance	*34.0*	*20.92*	*711*	*32.4*	*2195*	*1.45*	*49*	*55.1*	*89*	*0.004600*	*0.16*	*41.0*	*0.39*	*#N/A*	*-2.0*	*-43.5*	*4.6*	*112.63*	*3827*	*92.0*	*4159*
RC-7	**4134.0**	**0.53**	**2191**	**99.8**		**0.02**	**79**	**88.9**		**0.000090**	**0.37**	**94.9**		**0.00130**	**5.4**	**117.4**		**1.15**	**4754**	**114.3**	
SP-4	0.0		0	0	2195		0	0	89		0.00	0	0.39		0.0	0	4.6		0	0	4159
RC-2	**3850.9**	**0.57**	**2195**	**100**		**0.02**	**89**	**100**		**0.000100**	**0.39**	**100**		**0.00120**	**4.6**	**100**		**1.08**	**4159**	**100**	
Total Balance	*42.5*	*14.98*	*636*	*29*		*1.48*	*63*	*70.8*		*0.0057*	*0.24*	*61.5*		*0.06*	*2.6*	*56.5*		*89.86*	*3817*	*91.8*	

Notes
1. Rows shown in **bold** are data for Railroad Creek monitoring stations.
2. Rows shown in *italics* are loads required to balance the total load . The concentration and flow are set so that the load added (or subtracted) aquals the load measured in Railroad Creek.
3. #N/A indicates a negative concentration required to produce a negative load.
4. A zero flow indicates no flow measured.
5. Concentrations are not shown if no flow was noted.
6. *"Total balance"* is the sum of loads required to balance loads in both reaches.
7. The RC-6 station is upstream of RC-1. SP-26 is located between RC-6 and RC-1. RC-6 and SP-26 are not considered part of Reach 1 in the loading calculations. They are provided for comparison only to RC-1.
** Average Flow

TABLE 6.6-3
LOADING CALCULATIONS – RAILROAD CREEK, MAY 1998

Station	Flow	Copper		Zinc		Cadmium		Iron	
Sample Date	(cfs)	Load (mg/s)	Conc. (ug/l)	Load (mg/s)	Conc. (ug/l)	Load (mg/s)	Conc. (ug/l)	Load (mg/s)	Conc. (ug/l)
HC-4 4/30/98	3	0.04	0.5	<.34	4U	<0.01	0.06	2.5	30
HC-3 4/30/98	7	0.12	0.6	<.78	4U	<0.01	0.04U	3.9	20
HC-2 4/30/98	13	0.25	0.7	<1.5	4U	0.02	0.05	<7.3	20U
HC-1 5/1/98	18	0.30	0.6	<2.0	4U	<0.02	0.04U	<10.1	20U
Big-1 5/2/98	86[1]	0.72	0.3	<9.6	4U	<0.1	0.04U	<48	20U
RC-11 5/1/98	150[2]	2.9	0.7	<17	4U	<0.17	0.04U	126	30
RC-6 5/3/98	500e	8.4	0.6	<56	4U	1.12	0.08	420	30
RC-1 5/3/98	500e	11.2	0.8	<56	4U	<0.56	0.04U	280	20
P-1 5/1/98	2.6	750	10300	2002	27500	11.6	160	31	430
P-5 5/1/98	3.8	510	4790	1351	12700	7.4	70	16	150
RC-4 5/3/98	508	593	41.7	1621	114	9.4	0.66	<285	20U
CC-D1 5/2/98	6.1	27	155	64	372	0.44	2.6	<3.4	20U
CC-2 5/2/98	42	0.59	0.5	<4.7	4U	<0.05	0.04U	<24	20U
RC-7 5/3/98	640e	672	37.5	2061	115	12	0.67	6810	380
RC-2 5/3/98	643	643	35.7	2034	113	12.2	0.68	6301	350
RC-3 5/5/98	1105	390	12.6	1392	45	8.0	0.26	5260	170

1 = Includes both Big Creek Channels
2 = Estimated from field observations
e = Estimated from 1997 flow relationships
U = Undetected above indicated level

Table 6.6-4
Loading Calculations - Additional Source Areas, Spring and Fall 1997
Holden Mine RI/FS
Dames & Moore Job No. 17693-005-019

Seep	Site Location	Date Collected	Flows L/s	Zinc Conc. mg/L	Zinc Load mg/s	Zinc % Load of RC-2	Cadmium Conc. mg/L	Cadmium Load mg/s	Cadmium % Load of RC-2	Copper Conc. mg/L	Copper Load mg/s	Copper % Load of RC-2	Iron Conc. mg/L	Iron Load mg/s	Iron % Load of RC-2
SP-6	West Waste Rock Pile	5/21/97	0.439	22.1	9.70	0.8	0.173	0.076	1.0	12.7	5.58	1.6	0.030	0.013	0.0002
SP-7	Mill Building	5/21/97	4.267	4.33	18.5	1.5	0.034	0.15	1.8	2.81	12	3.4	0.12	0.51	0.01
SP-7	Mill Building	9/19/97	--	3.47	N/A	N/A	0.026	N/A	N/A	1.93	N/A	N/A	0.22	N/A	N/A
SP-8	East Waste Rock Pile	5/21/97	0.568	11.2	6.36	0.5	0.088	0.050	0.6	7.88	4.48	1.3	0.030	0.017	0.0004
SP-15 W	Below SP6 at south end of lagoon	5/22/97	2.112	2.26	4.77	0.4	0.094	0.0198	0.2	0.21	0.435	0.1	0.010	0	0
SP-15 E	Below SP6 at south end of lagoon	5/22/97	4.267	7.97	34.0	2.7	0.055	0.233	2.9	3.56	15.2	4.3	0.080	0.34	0.008
SP-22	Below SP7/Mill Mtc yard	5/23/97	0.943	7.35	6.9	0.5	0.048	0.045	0.6	2.14	2.02	0.6	0.010	0	0
SP-21	East of Tailing Pile 3	5/22/97	55.5	0.11	6.05	0.5	0.001	0.06	0.8	0.052	2.87	0.8	1.00	55.5	1.2
SP-21	East of Tailing Pile 3	9/15/97	0.109	0.13	0.015	0.02	0.0011	0.00012	0.031	0.034	0.004	0.1	1.53	0.167	0.004

Notes
* Flow measurement not available.
Flow data for seeps taken from Table 4.4-8a. RC-2 Loading values for % loading calculation taken from Tables 6.6-1 and 6.6-2.
N/A = Not Applicable.

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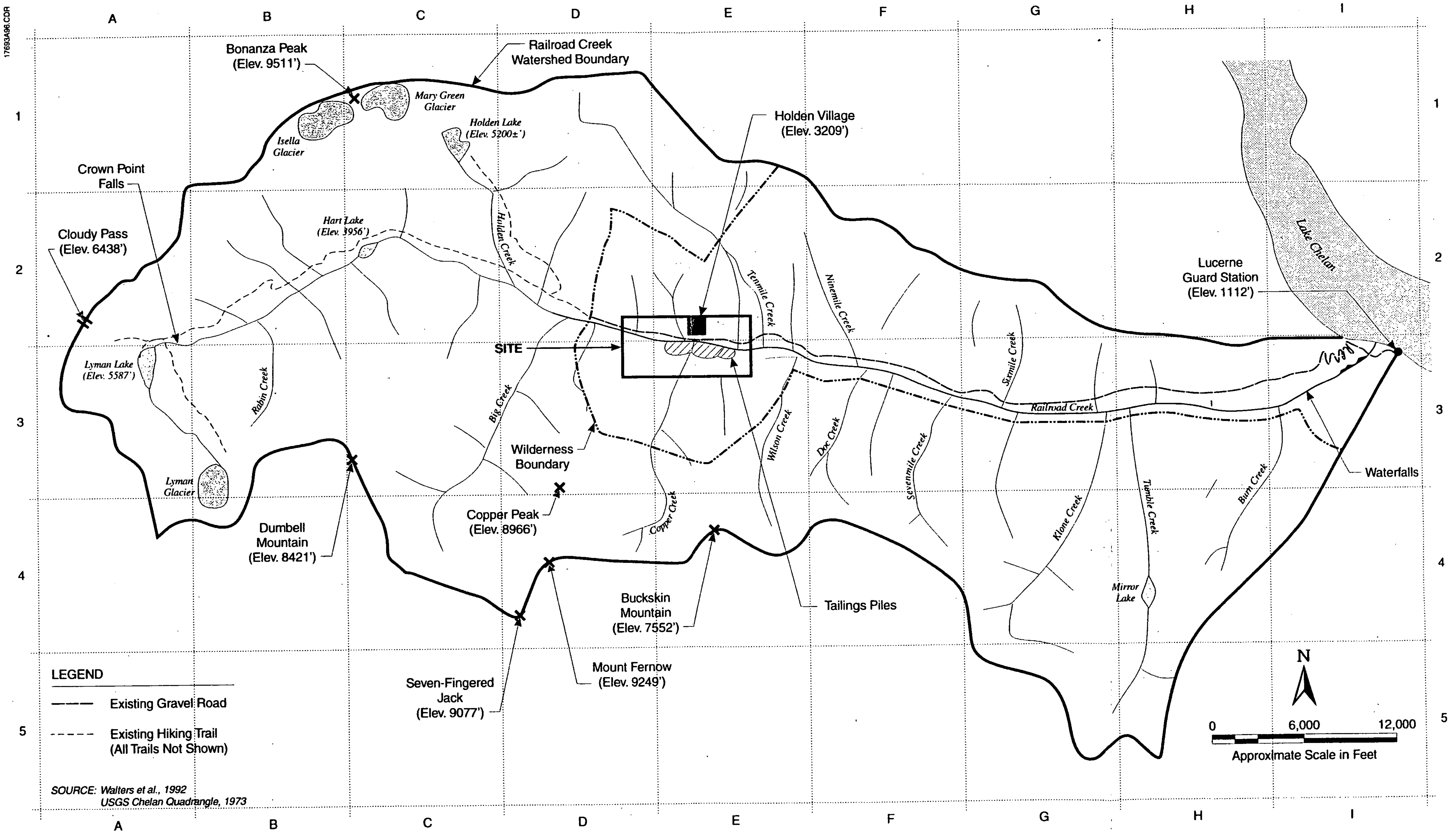

SOURCE: Walters et al., 1992
USGS Chelan Quadrangle, 1973

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Figure 6.1-1
RAILROAD CREEK WATERSHED MAP

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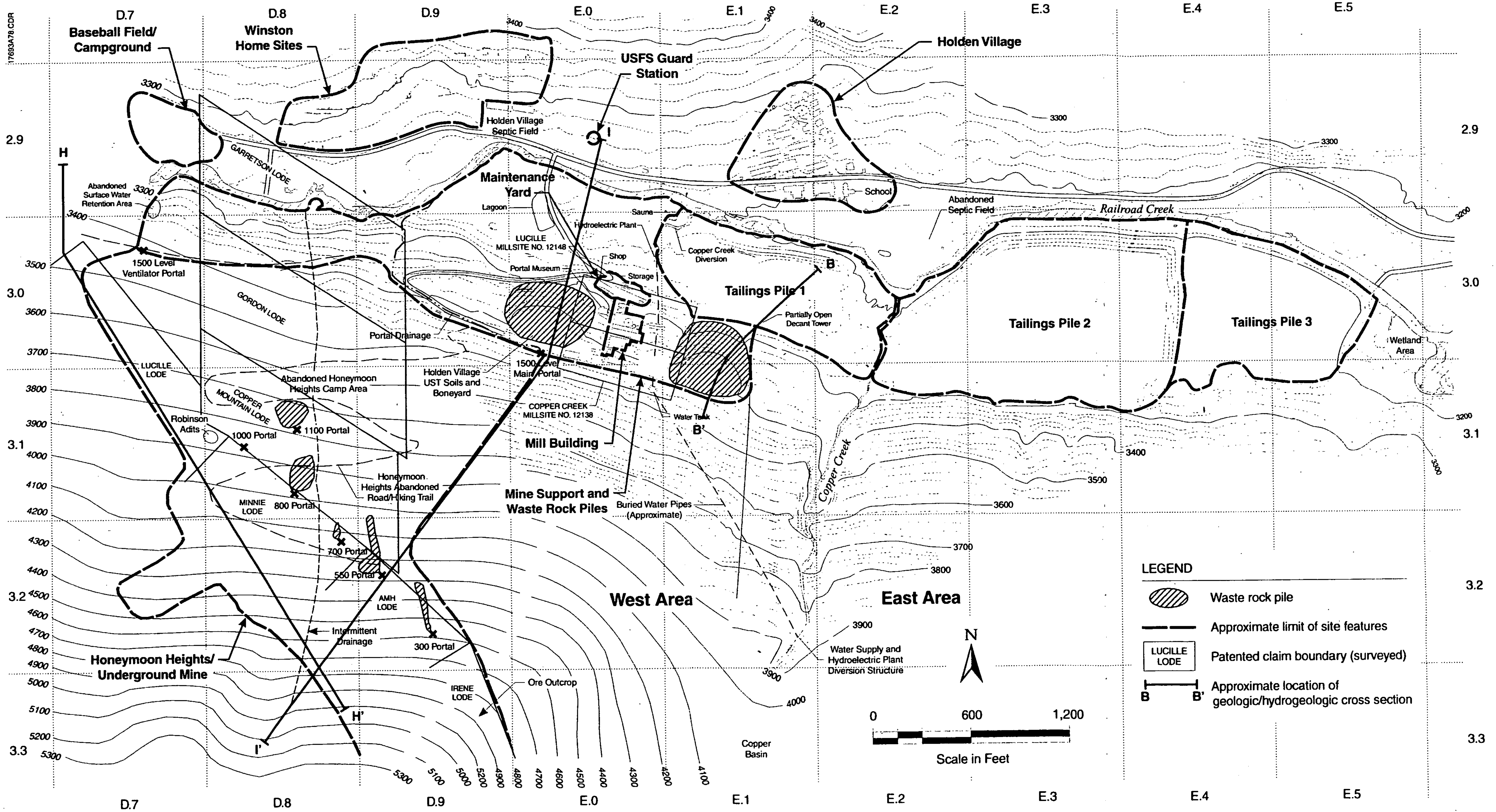

SOURCE: Base map information from USFS and Washington DNR, DEM CD ROM

Figure 6.1-1a

HOLDEN MINE SITE MAP

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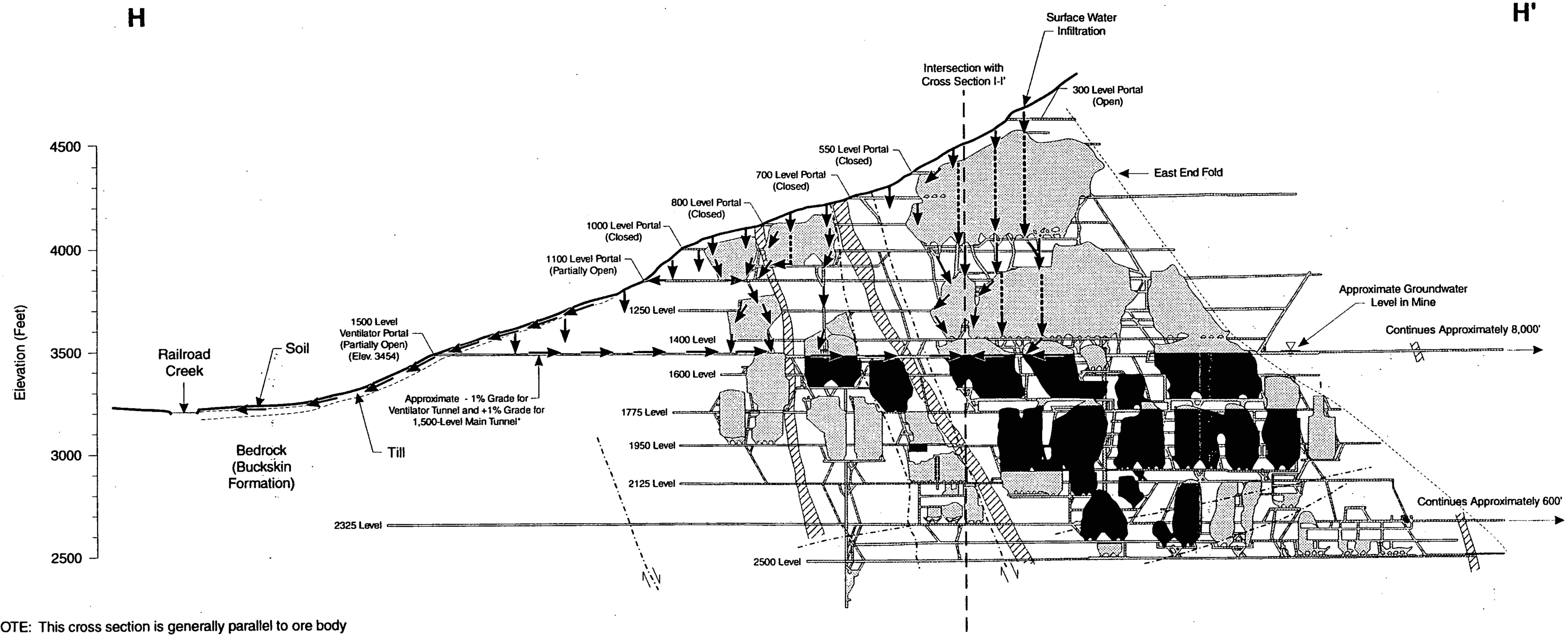

* NOTE: This cross section is generally parallel to ore body and 1500-level ventilator tunnel. Due to 1500-level main tunnel having +1% grade, water flow is toward main portal opening but not shown on this figure. (See Figures 6.1-2a and 6.1-2b)

SOURCES: *Northwest Geophysical Associates, 1997, Seismic Line A-A', B-B', Holden Mine Geophysical Investigation.*

Youngberg, E. A., Wilson, T. L., 1952, The Geology of the Holden Mine, Economic Geology, V. 47, No. 1, 1952, pp. 1-12.

W.A.B., 1942, Detailed Surface Geology Map, Howe Sound Co., Chelan Division

F.E., H.B.S., 1938, Geology of 1500 Level, Howe Sound Company Chelan Division

LEGEND

▒	Open stope
■	Backfilled stope
▨	Dike
-·-·-·-	Transform fault
→	Direction of inferred water movement

0 500 1,000

Approximate Horizontal and Vertical Scale in Feet

Figure 6.1-2

HOLDEN MINE SITE
CONCEPTUAL TRANSPORT PATHWAY OF MINE CROSS SECTION H-H'

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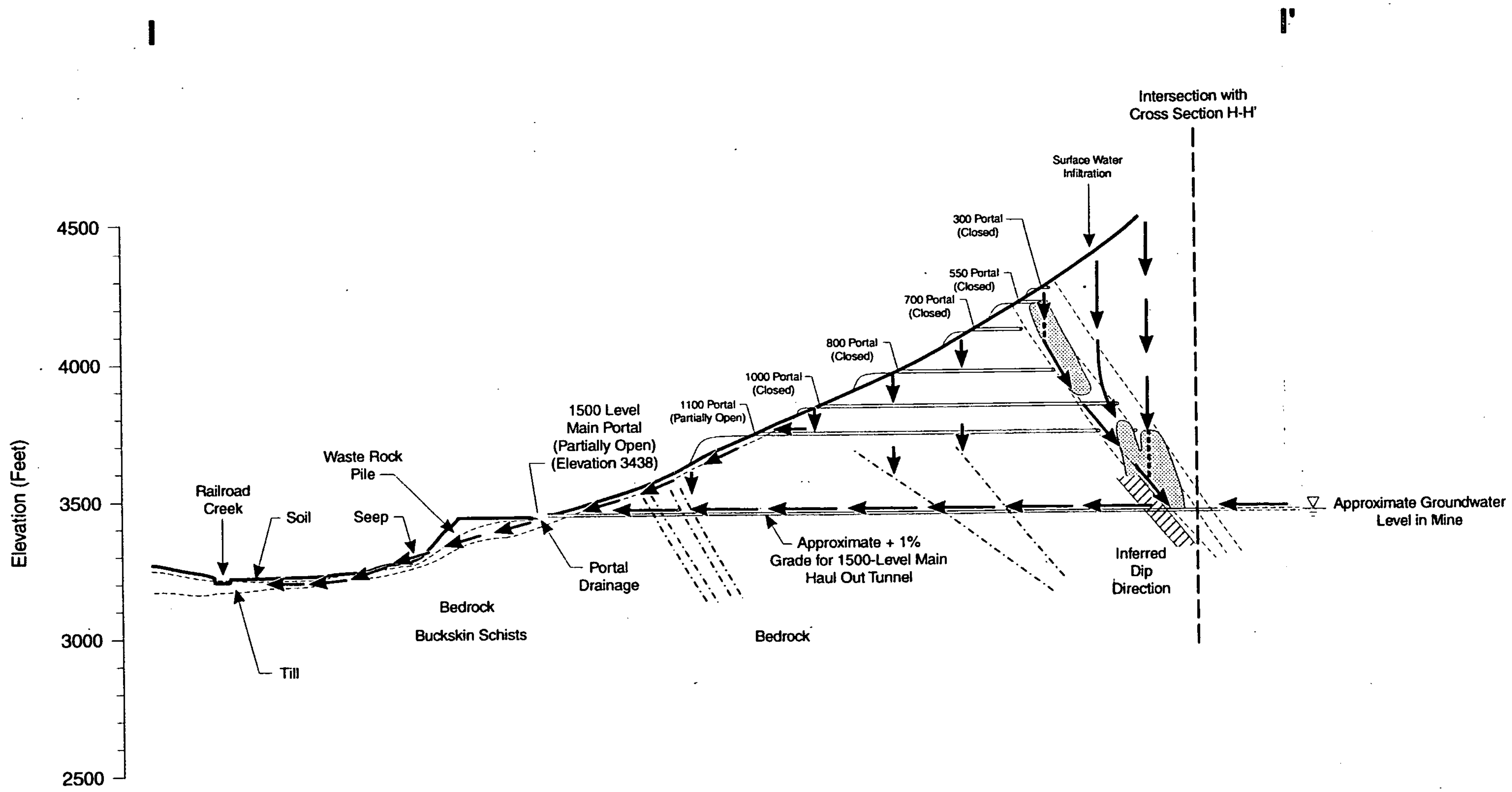

SOURCES: *Northwest Geophysical Associates, 1997, Seismic Line A-A', B-B', Holden Mine Geophysical Investigation.*

Youngberg, E. A., Wilson, T. L., 1952, The Geology of the Holden Mine, Economic Geology, V. 47, No. 1, 1952, pp. 1-12.

W.A.B., 1942, Detailed Surface Geology Map, Howe Sound Co., Chelan Division

F.E., H.B.S., 1938, Geology of 1500 Level, Howe Sound Company Chelan Division

LEGEND

░ Open stope

▨ Dike

-·-·- Trasform fault

→ Direction of inferred water movement

0 500 1,000

Approximate Horizontal and Vertical Scale in Feet

Figure 6.1-2a

HOLDEN MINE SITE
CONCEPTUAL TRANSPORT PATHWAY OF MINE CROSS SECTION I-I'

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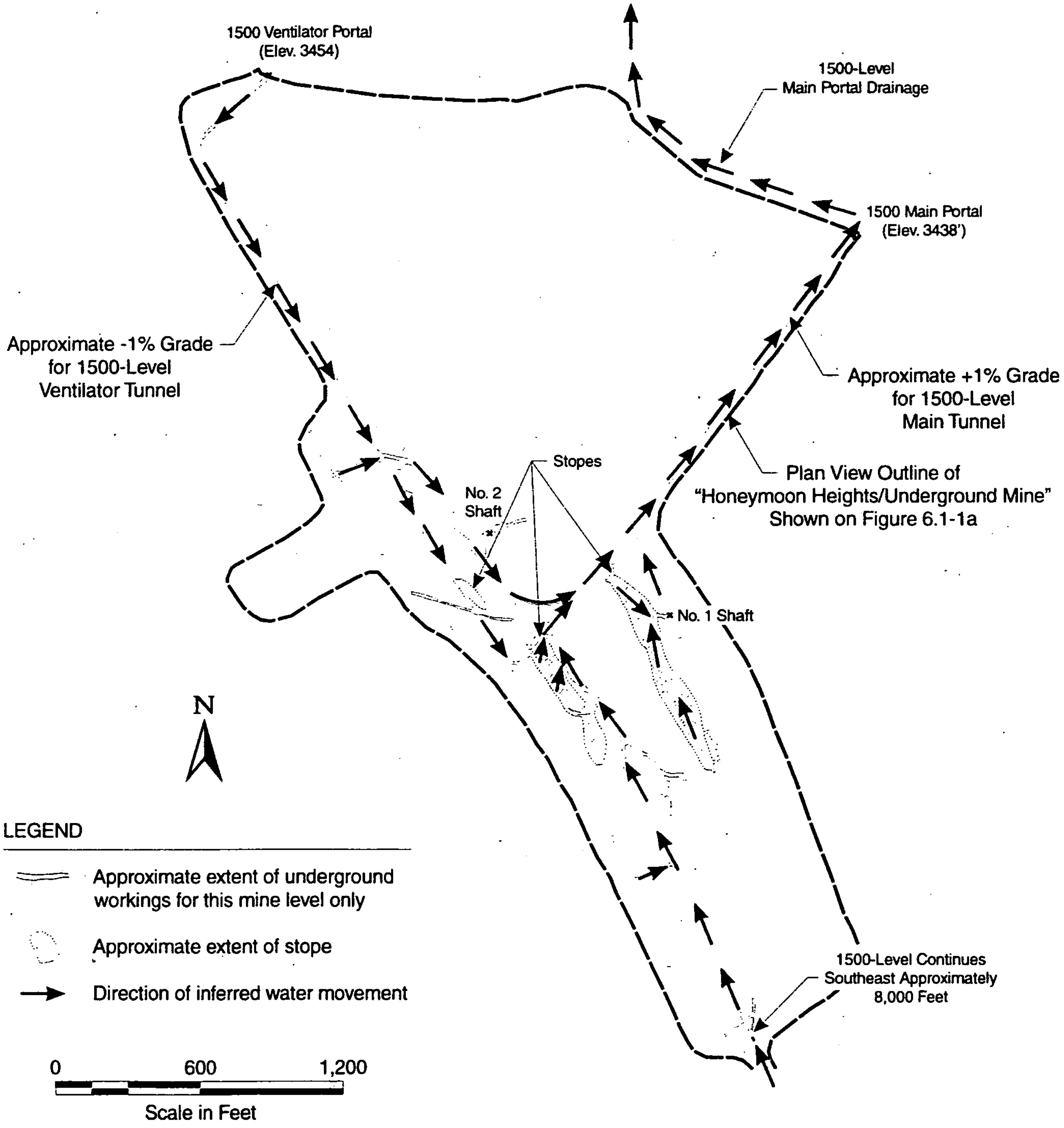

Figure 6.1-2b

HOLDEN MINE SITE
CONCEPTUAL TRANSPORT PATHWAY OF MINE PLAN VIEW OF 1500 LEVEL

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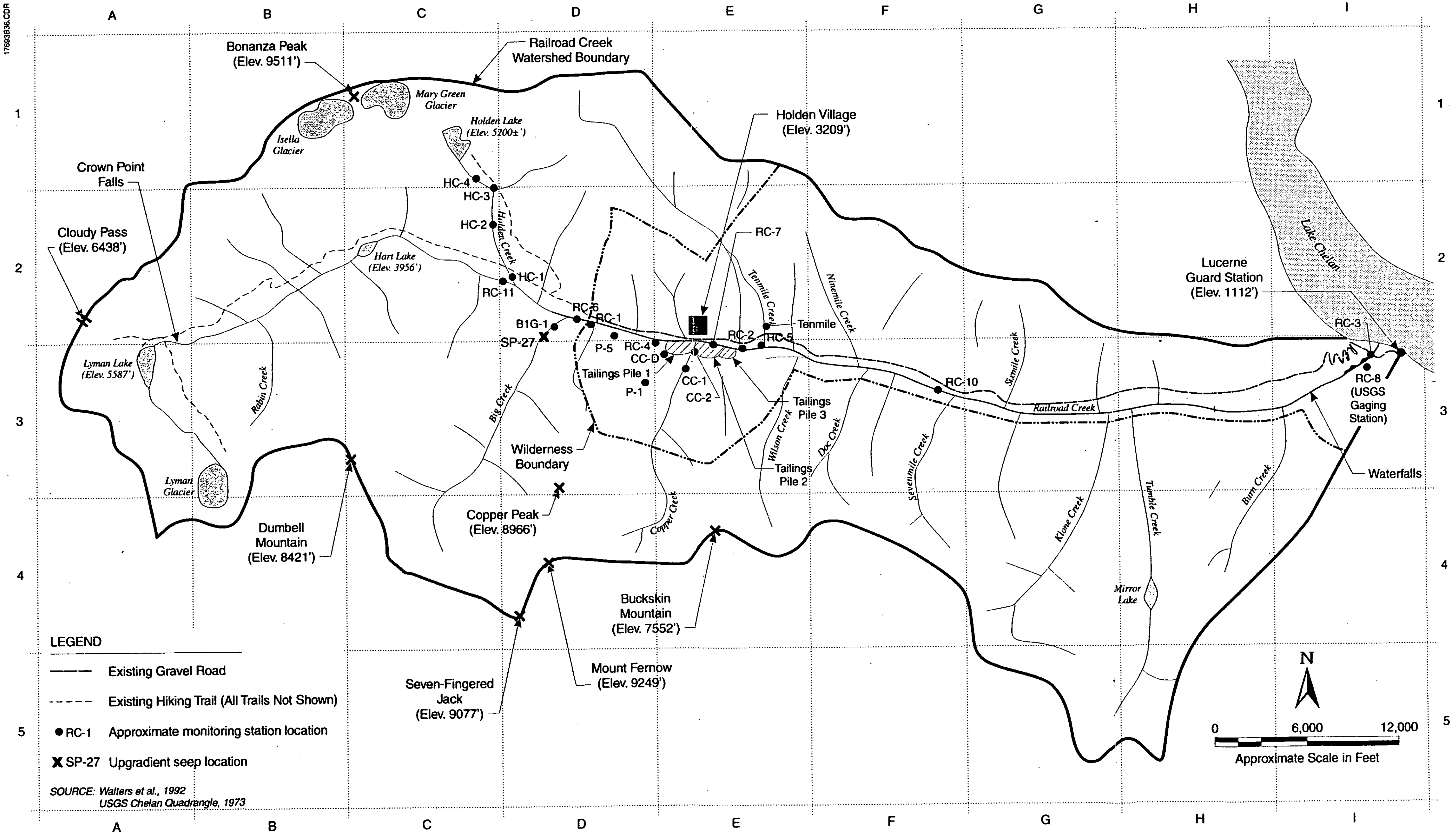

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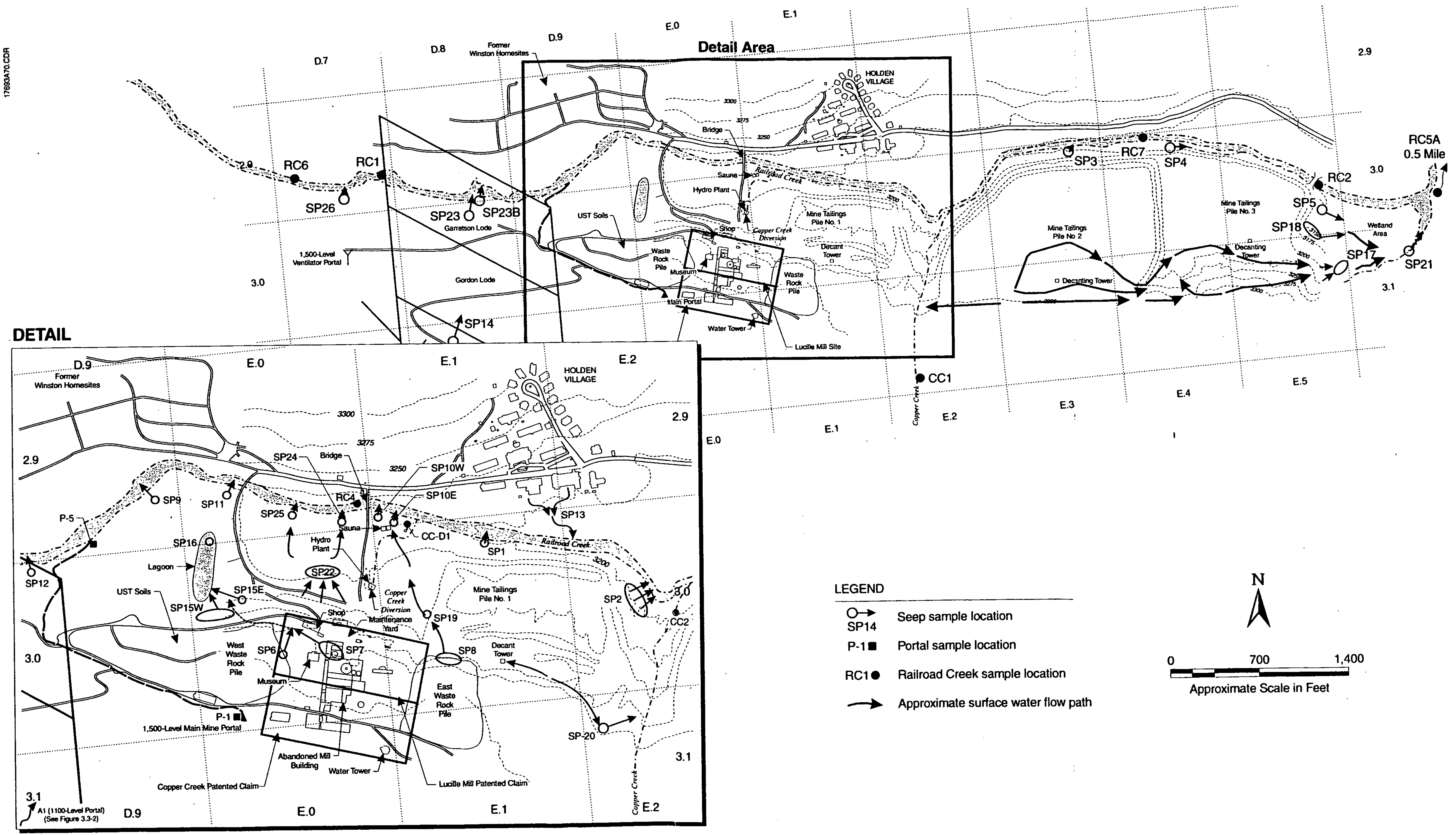
Figure 6.1-3

STREAMFLOW AND WATER QUALITY MONITORING STATIONS - RAILROAD CREEK

17693A70.CDR



SOURCE: ORB, 1975

Figure 6.1-3a

APPROXIMATE LOCATIONS OF SURFACE WATER RUNON AND RUNOFF

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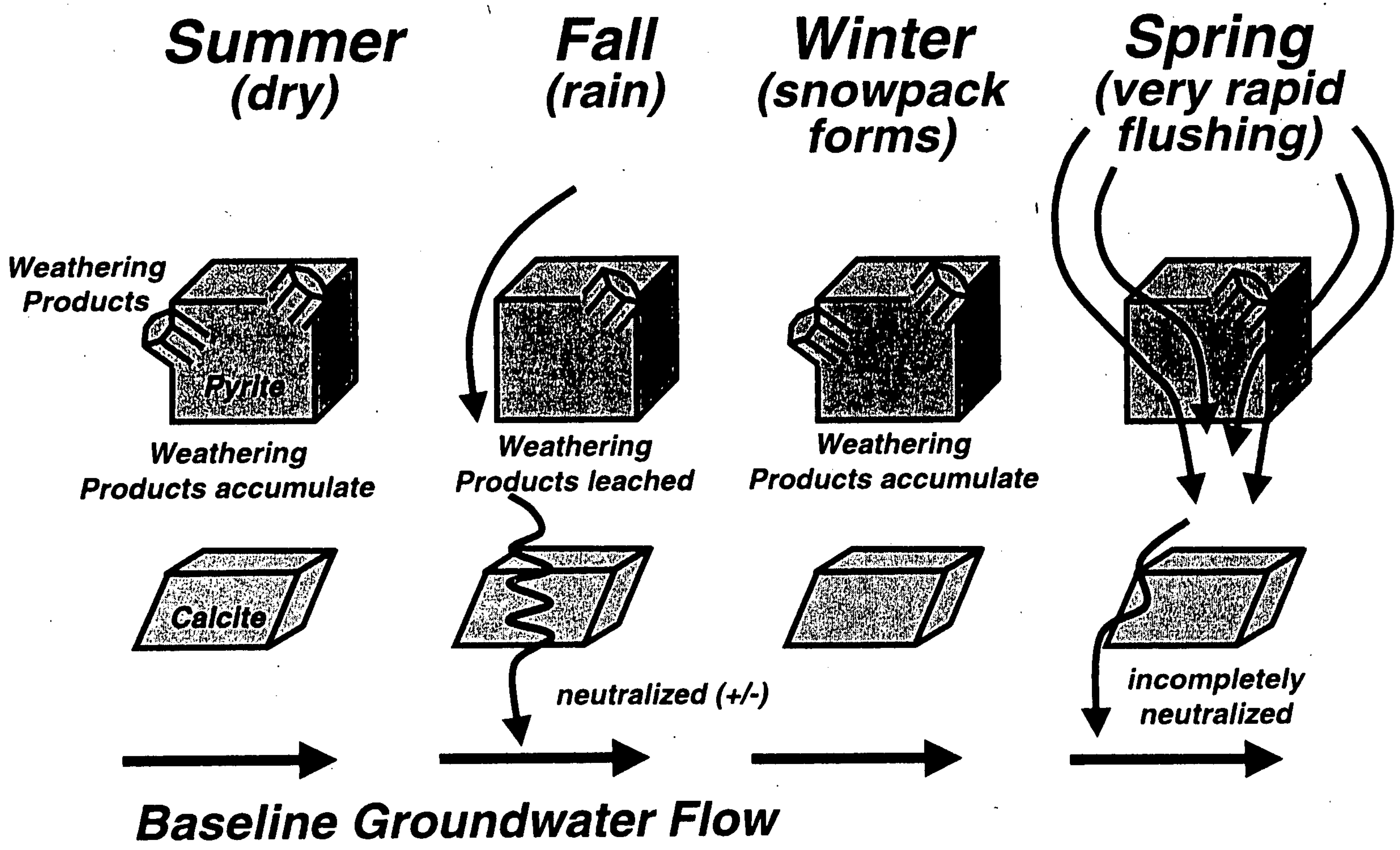

SOURCE: SRK

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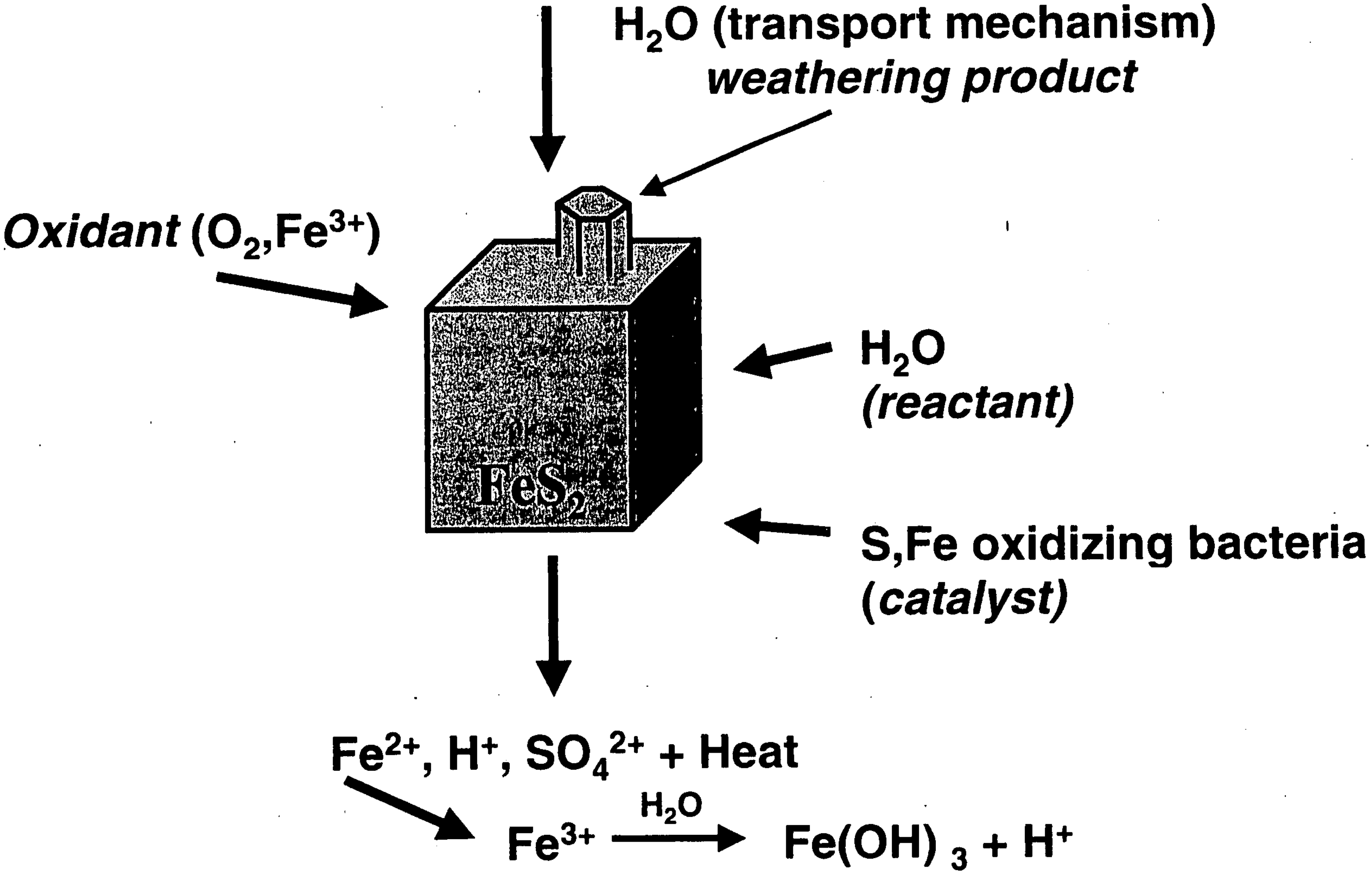
Figure 6.3-3

STORAGE AND TRANSPORT OF WEATHERING PRODUCTS



H_2O (transport mechanism)
weathering product

Oxidant (O_2,Fe^{3+})

FeS_2

H_2O
(reactant)

S,Fe oxidizing bacteria
(*catalyst)*

Fe^{2+}, H^+, $SO_4{}^{2+}$ + Heat

$Fe^{3+} \xrightarrow{H_2O} Fe(OH)_3 + H^+$

SOURCE: SRK

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Figure 6.3-1
SULFIDE OXIDATION

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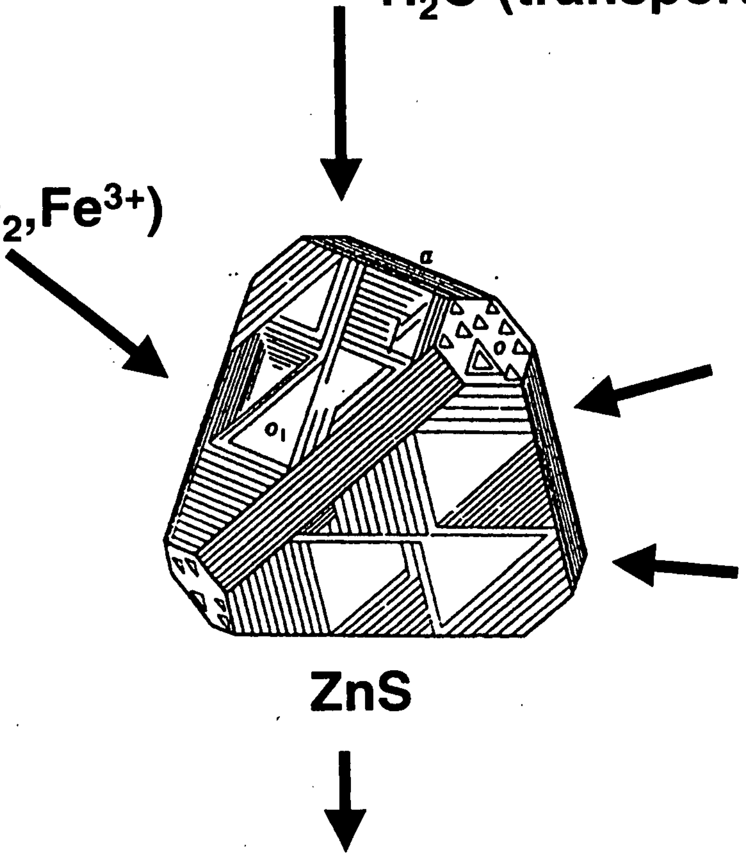

H_2O (transport mechanism)

Oxidant (O_2,Fe^{3+})

H_2O (reactant)

Bacteria-catalyst

ZnS

$Zn^{2+} + SO_4^{2-}$

SOURCE: SRK

Figure 6.3-2
OXIDATIVE DISSOLUTION

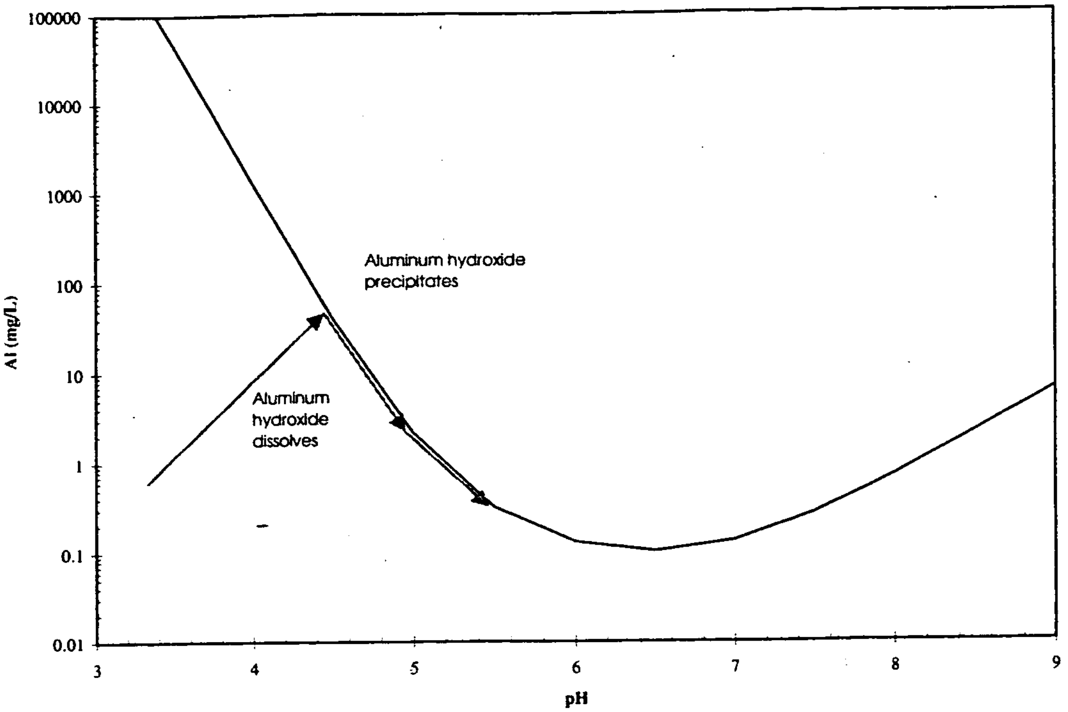

Figure 6.3-4a

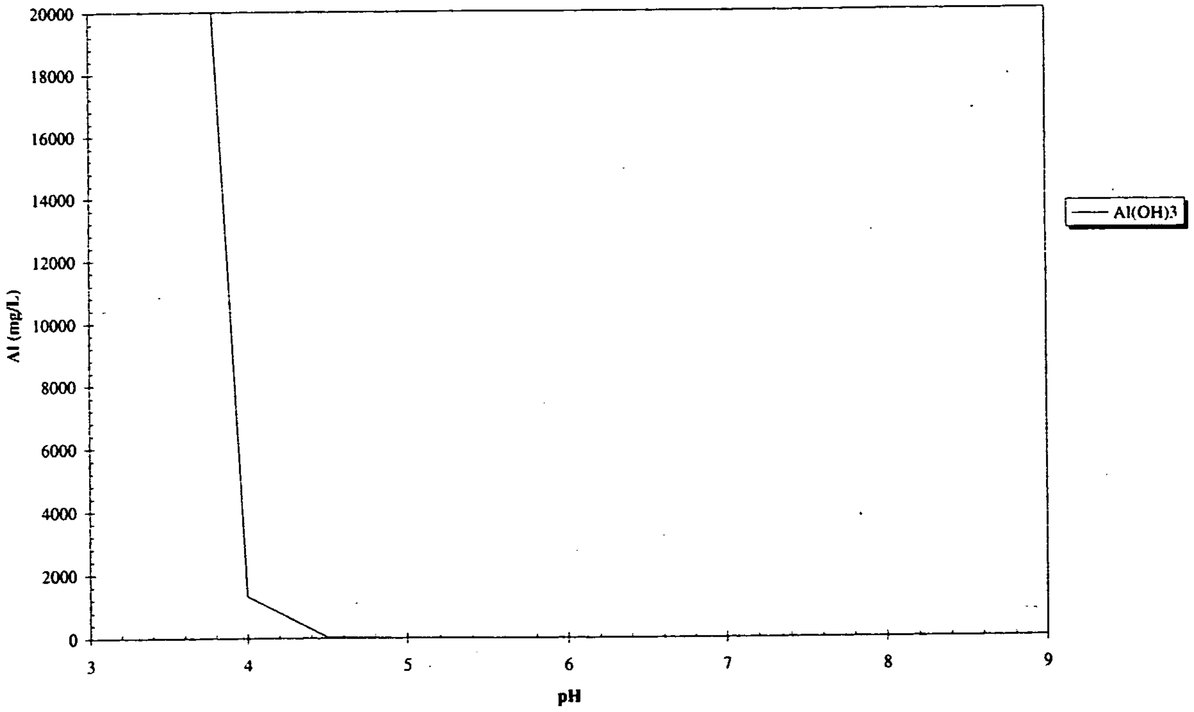

Figure 6.3-4b

SOURCE: SRK

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Figure 6.3-4

Al $(OH)_3$ STABILITY DIAGRAM

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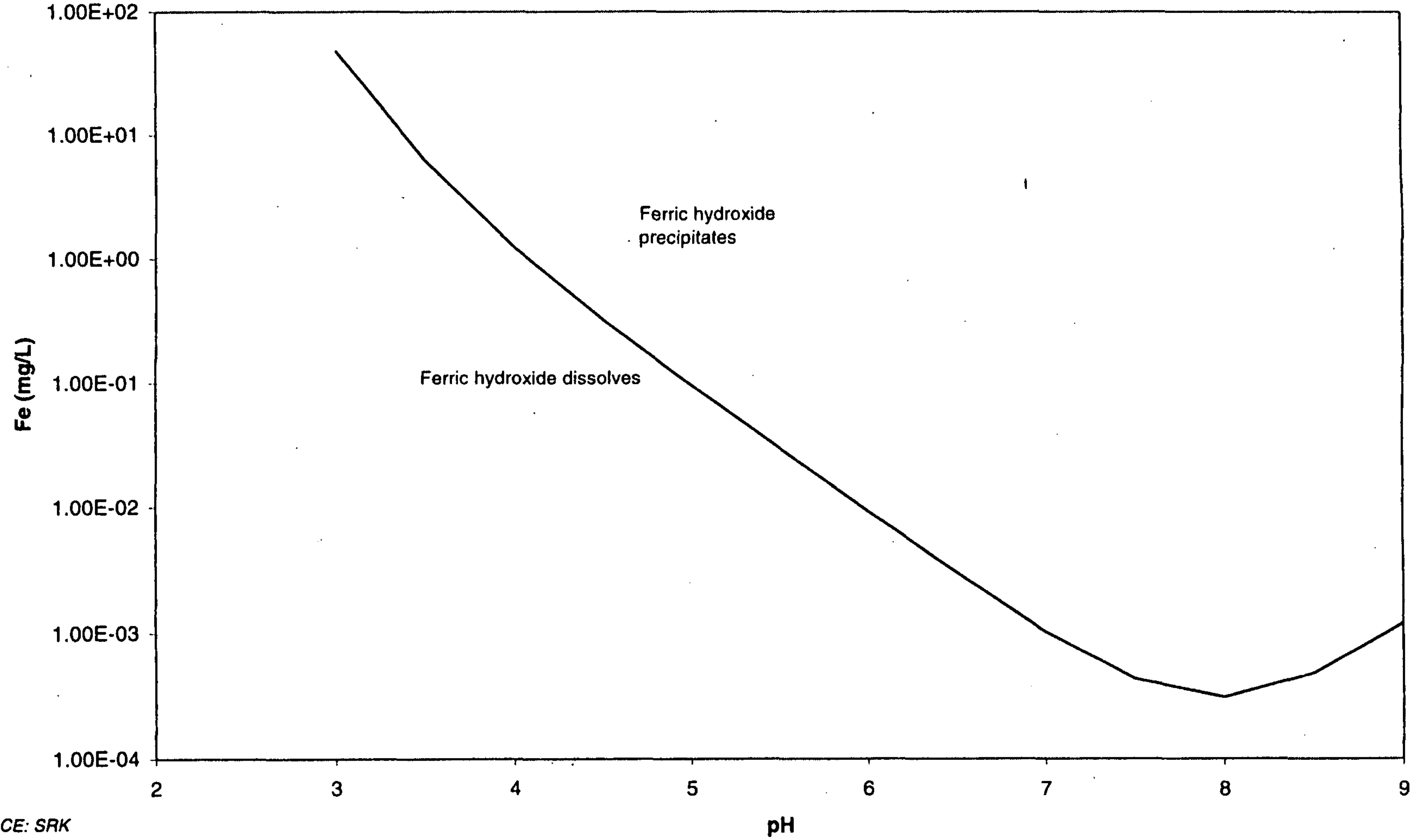

SOURCE: SRK

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Figure 6.3-5

Fe (OH)$_3$ STABILITY DIAGRAM

Holden Mine RI/FS
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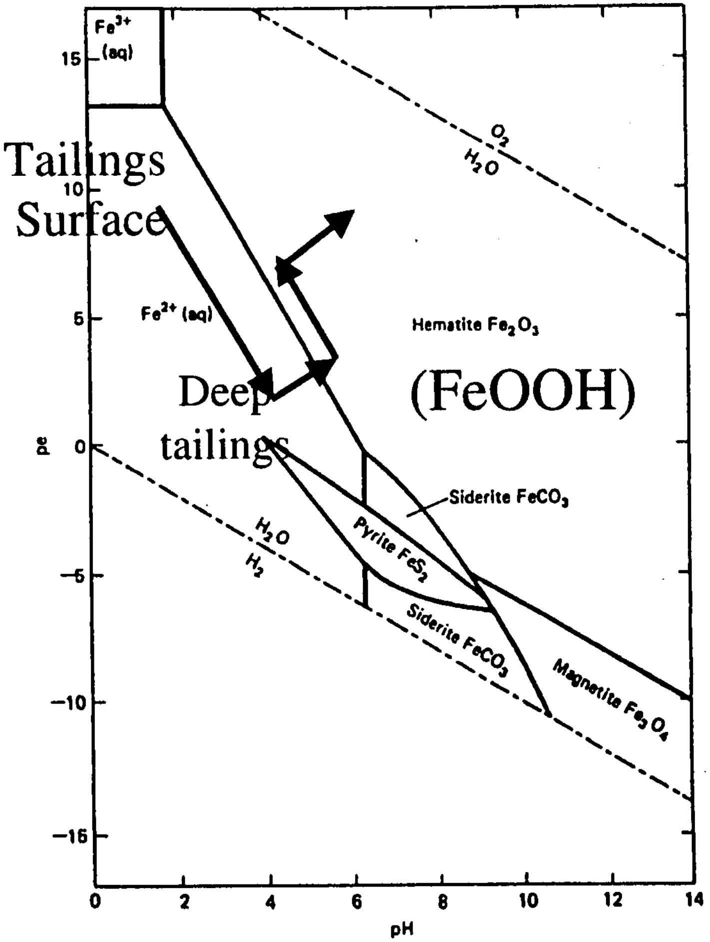
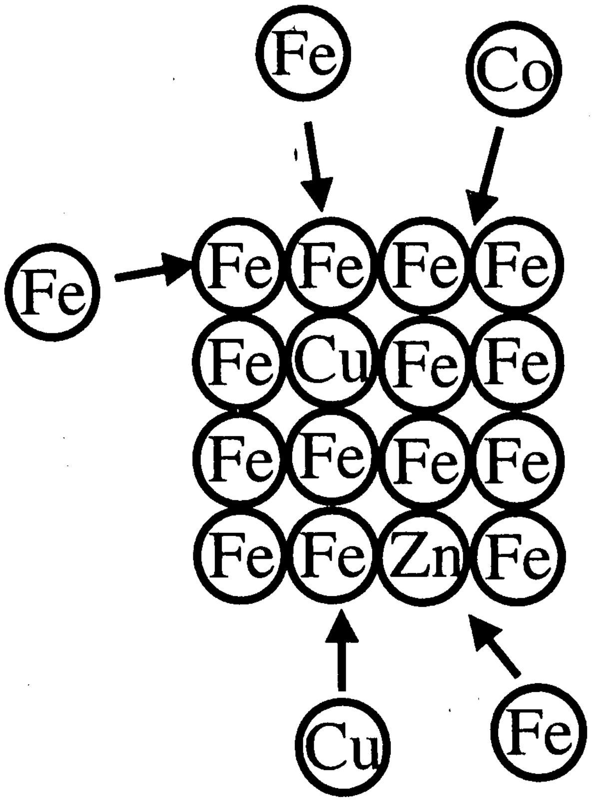


SOURCE: Garrels and Christ, 1965

Figure 6.3-6

pH-Eh CONTROL ON PRECIPITATION/DISSOLUTION OF IRON MINERALS AND IONS

Trace elements are co-precipitated with iron, manganese and aluminum oxyhydroxides



SOURCE: SRK

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Figure 6.3-7

CO-PRECIPITATION

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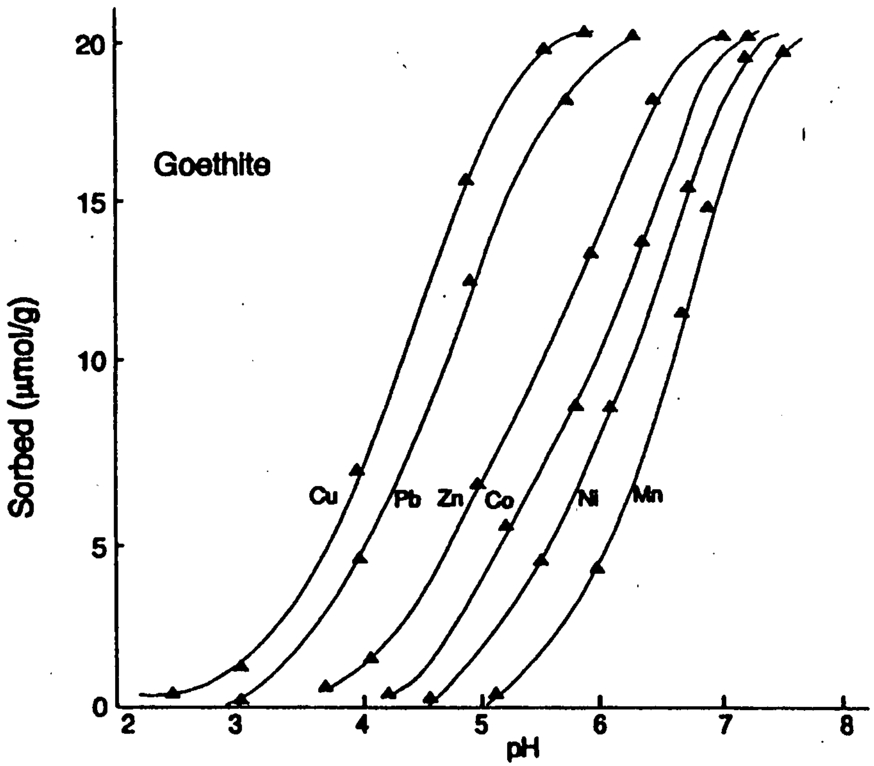

SOURCE: Schwertman and Taylor, 1989

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Figure 6.3-8

ADSORPTION OF GOETHITE

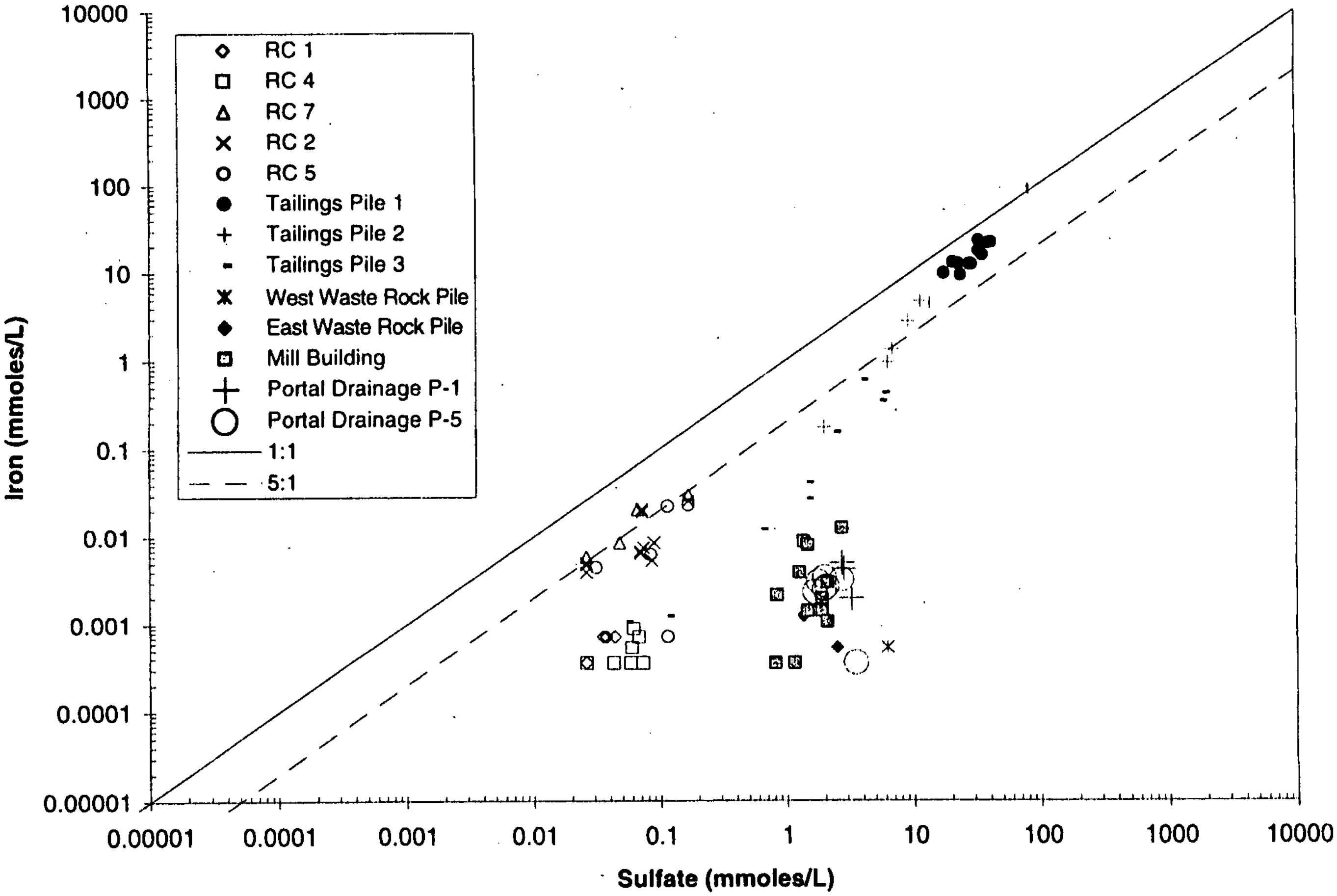

Figure 6.4-1

SURFACE AND SEEPAGE WATER SAMPLES IRON VS SULFATE SCATTER PLOT

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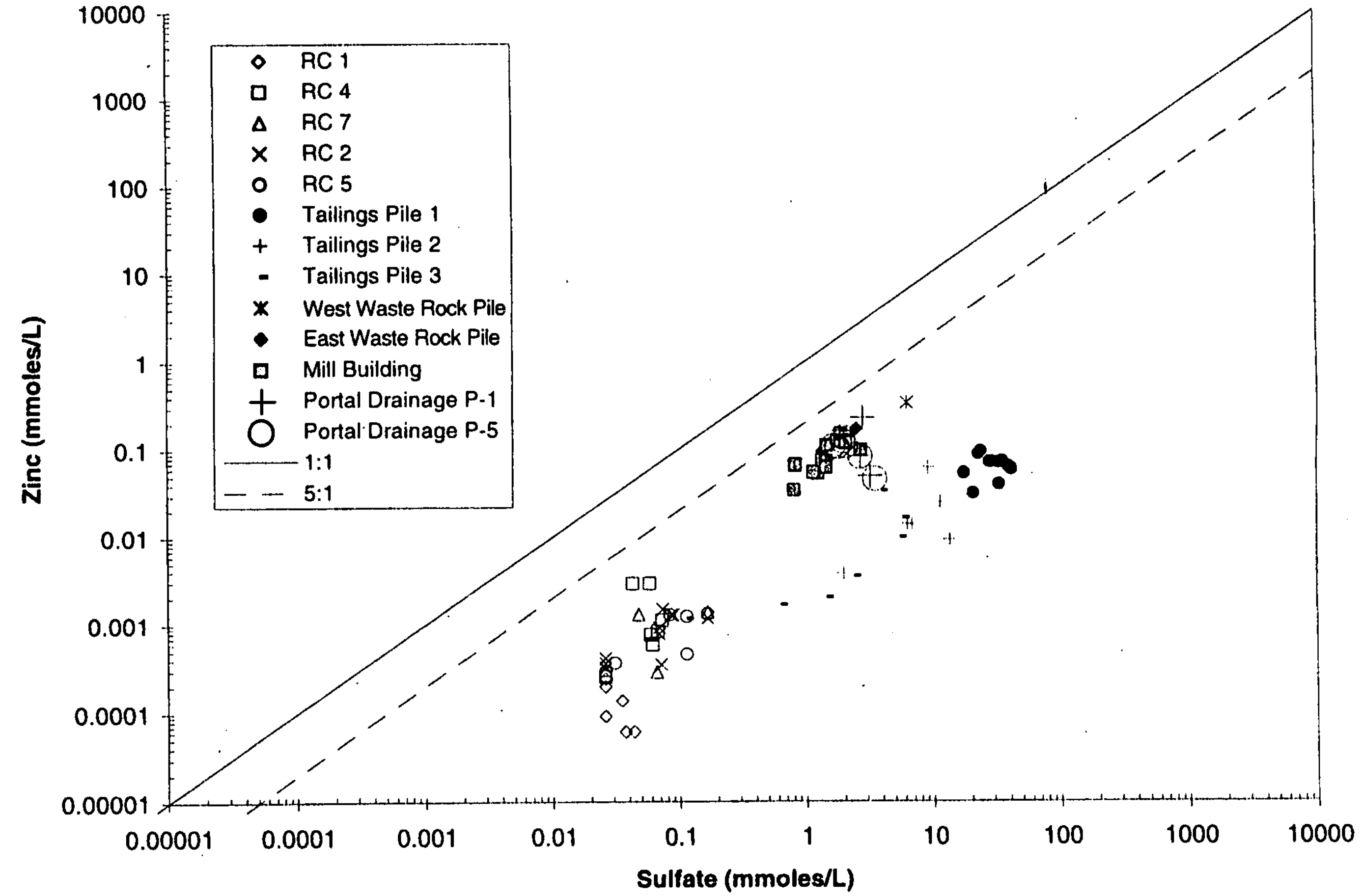

Figure 6.4-2

SURFACE AND SEEPAGE WATER SAMPLES ZINC VS SULFATE SCATTER PLOT

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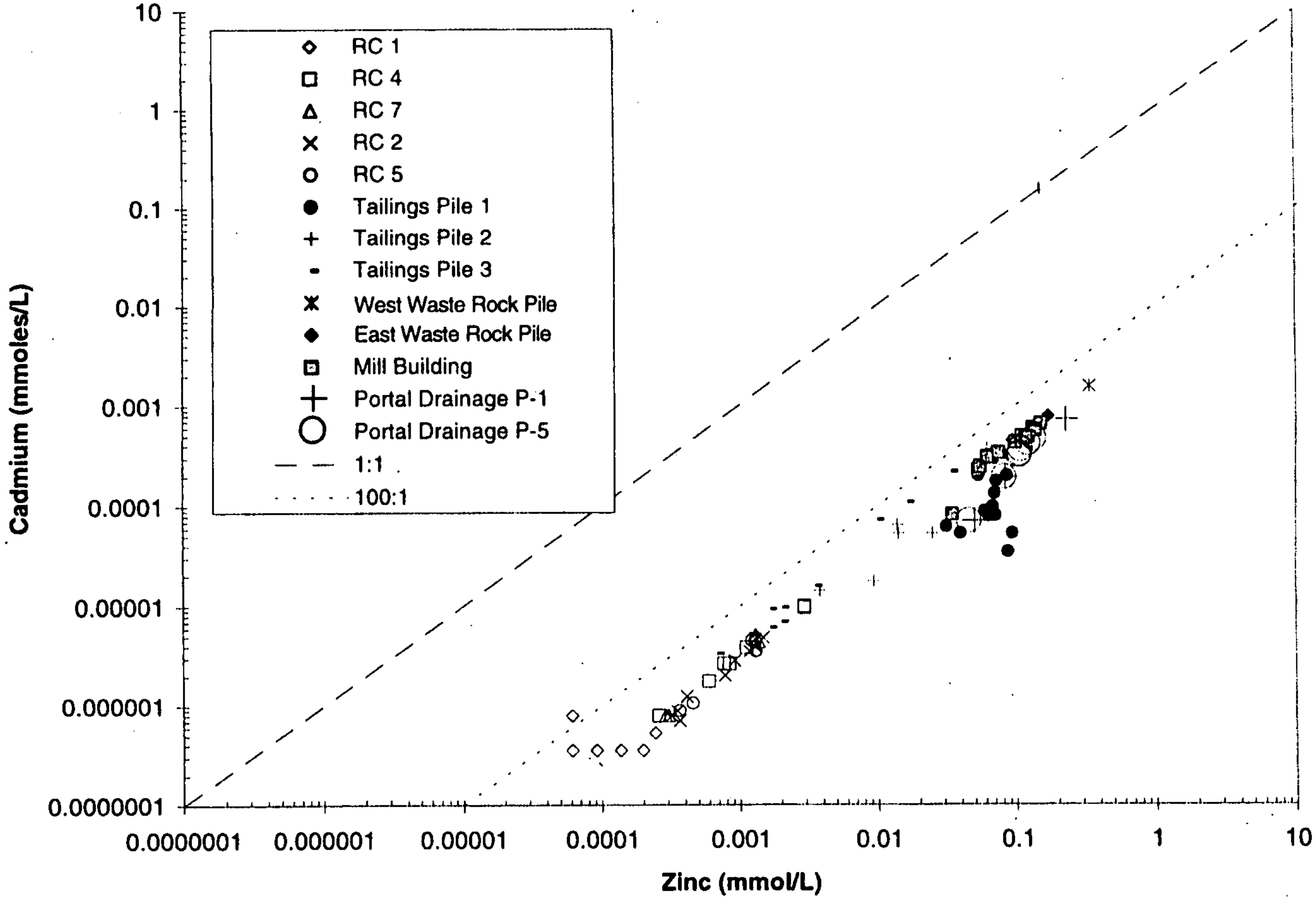

Figure 6.4-3

SURFACE AND SEEPAGE WATER SAMPLES ZINC VS CADMIUM SCATTER PLOT

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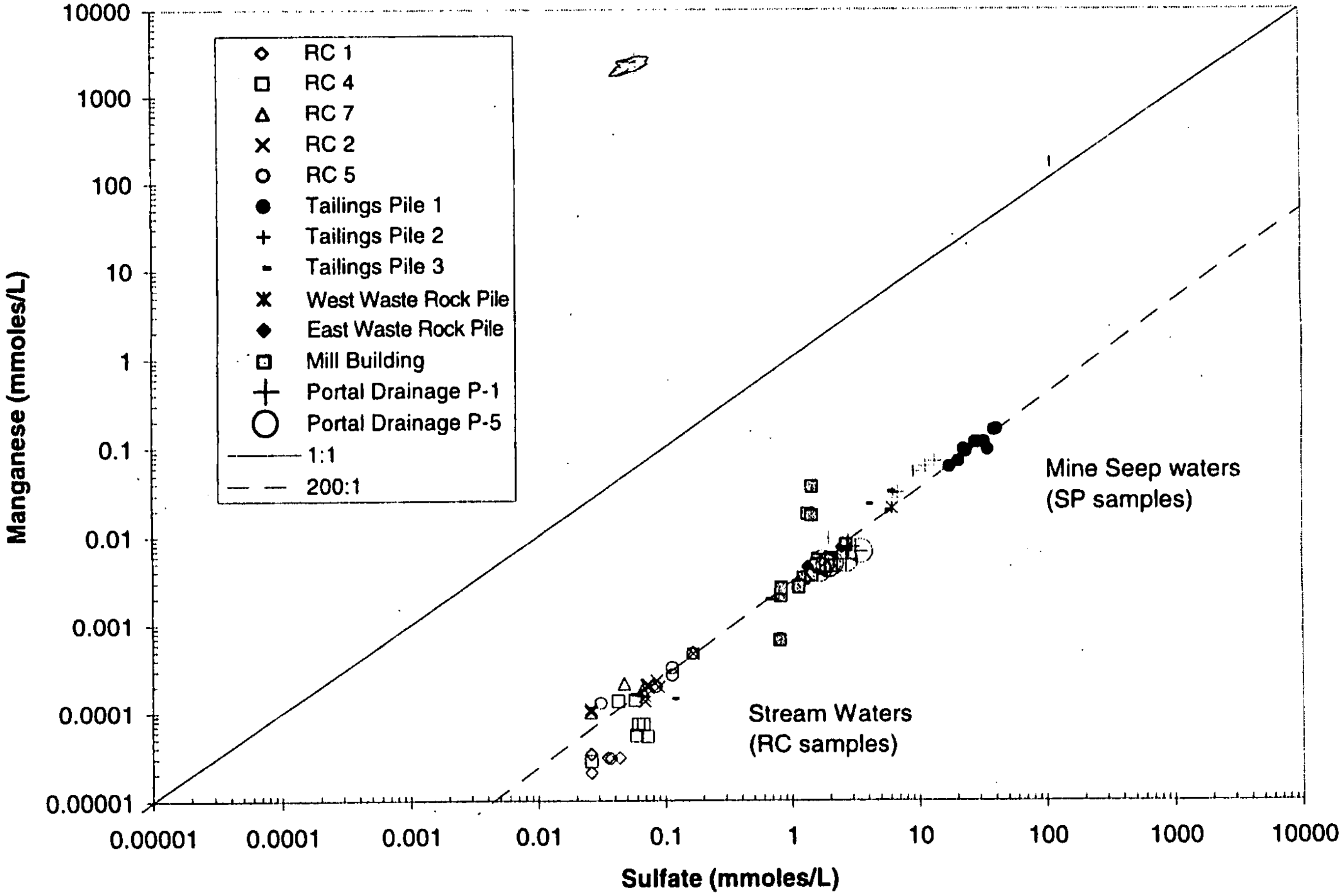

Figure 6.4-4

SURFACE AND SEEPAGE WATER SAMPLES
MANGANESE VS SULFATE SCATTER PLOT

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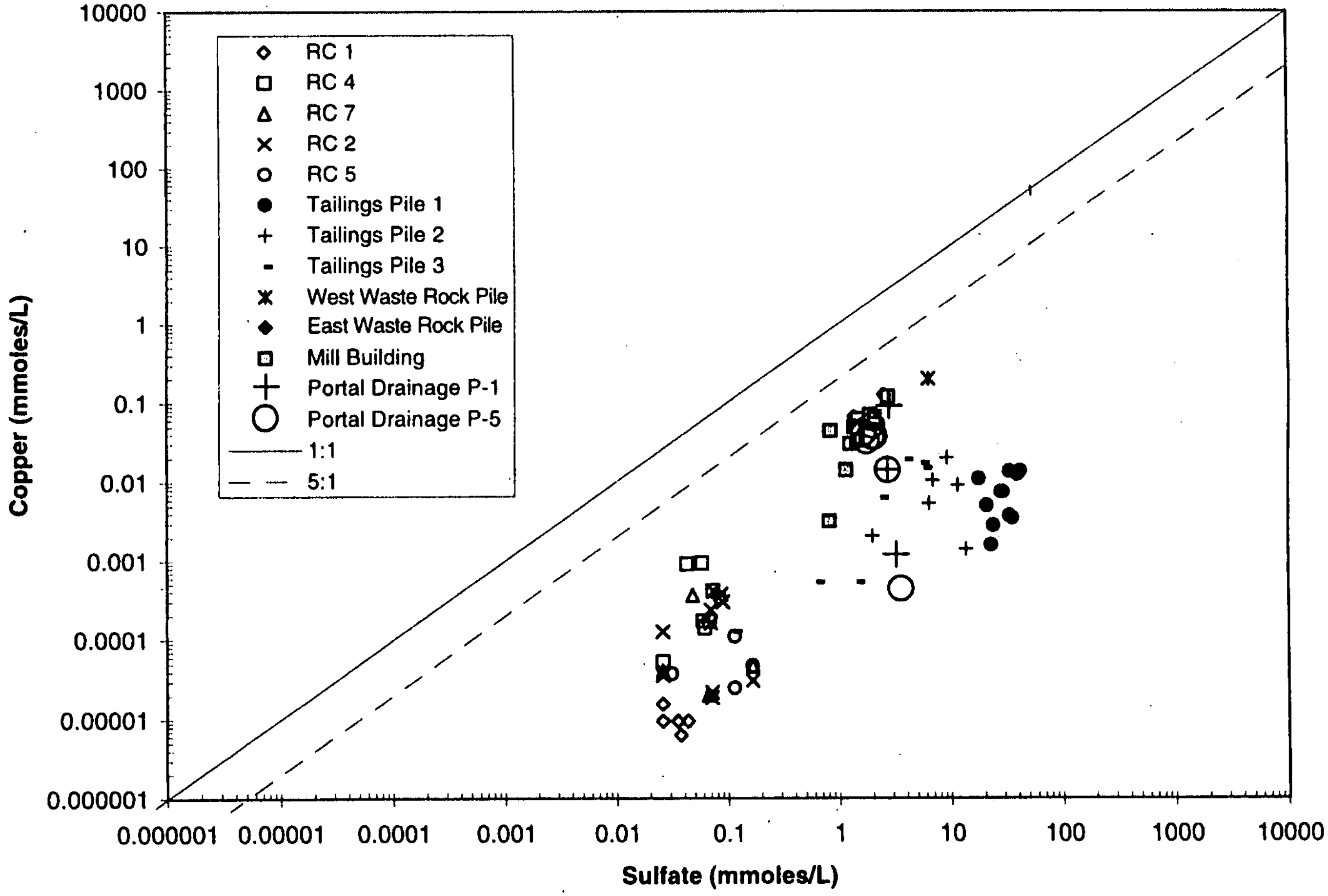

Figure 6.4-5

SURFACE AND SEEPAGE WATER SAMPLES COPPER VS SULFATE SCATTER PLOT

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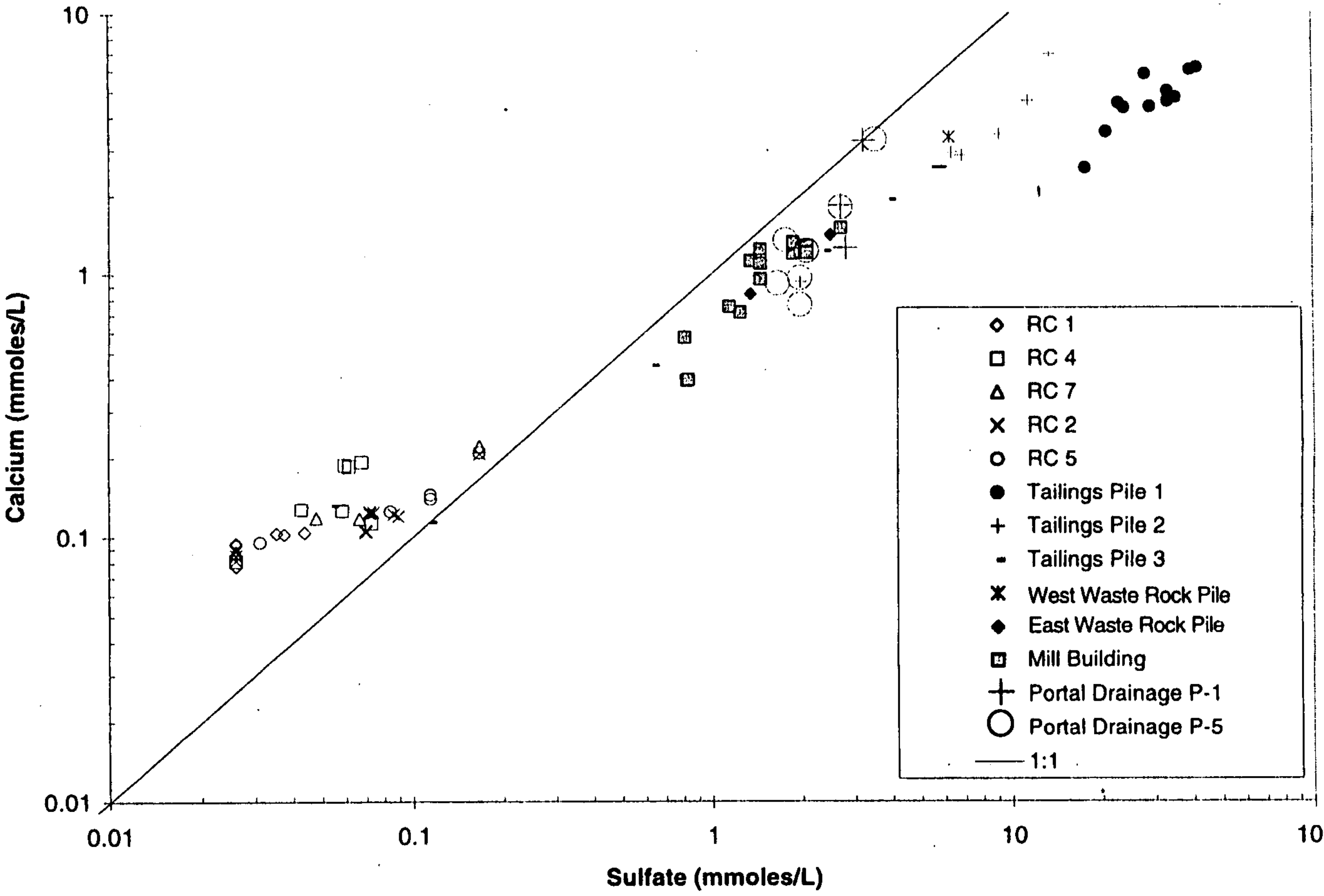

Figure 6.4-6

SURFACE AND SEEPAGE WATER SAMPLES CALCIUM VS SULFATE SCATTER PLOT

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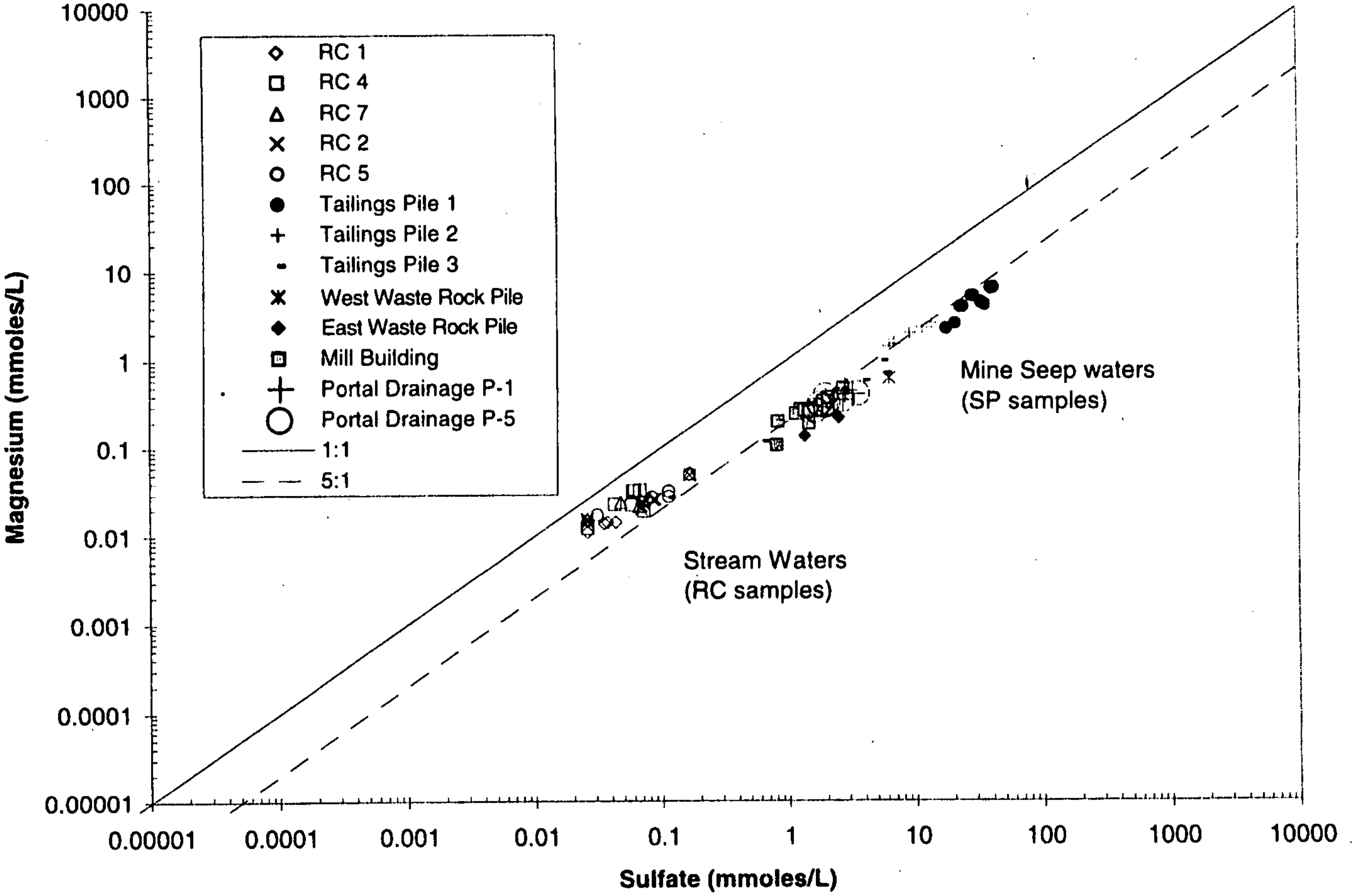

Figure 6.4-7

SURFACE AND SEEPAGE WATER SAMPLES
MAGNESIUM VS SULFATE SCATTER PLOT

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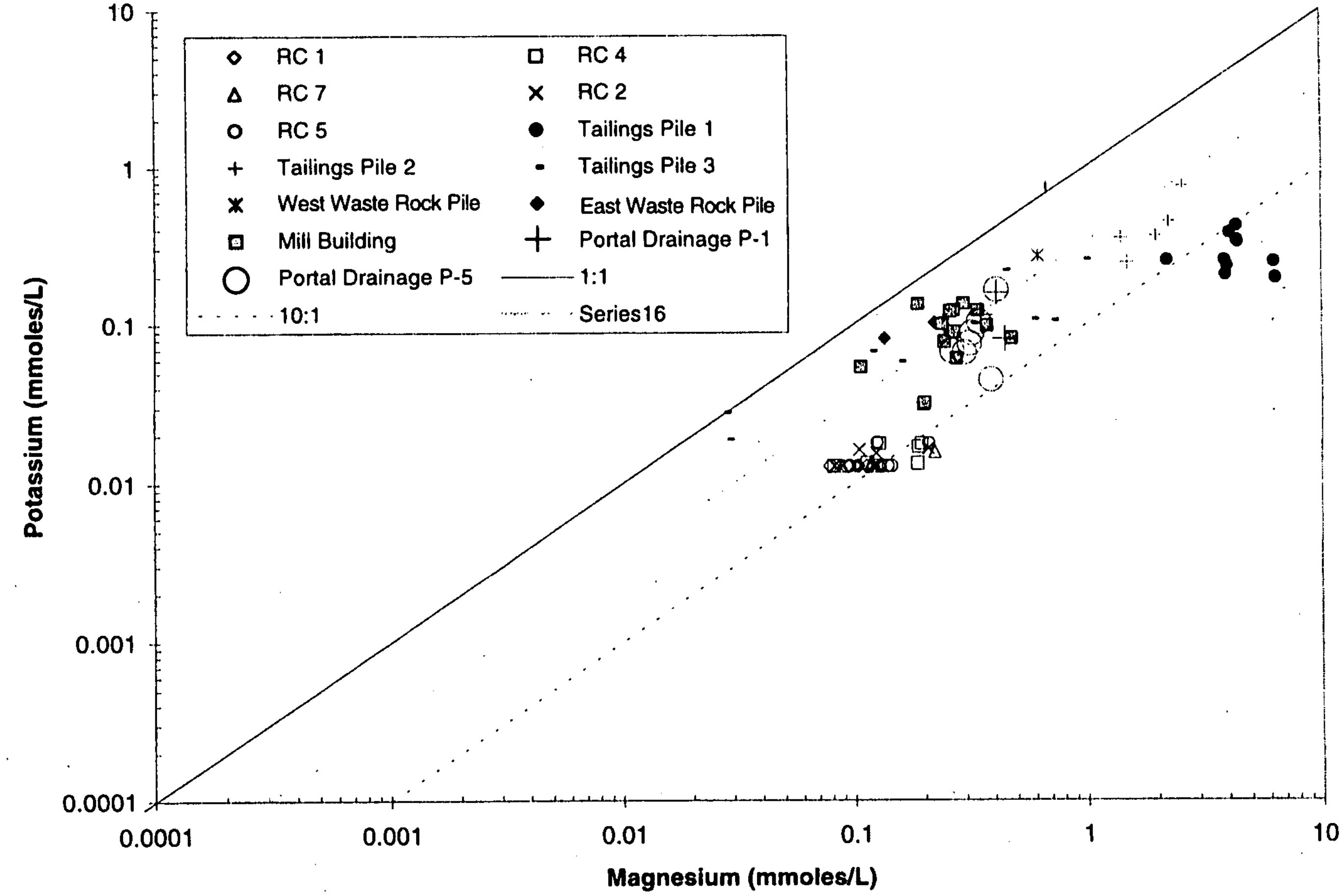

Figure 6.4-8

SURFACE AND SEEPAGE WATER SAMPLES POTASSIUM VS MAGNESIUM SCATTER PLOT

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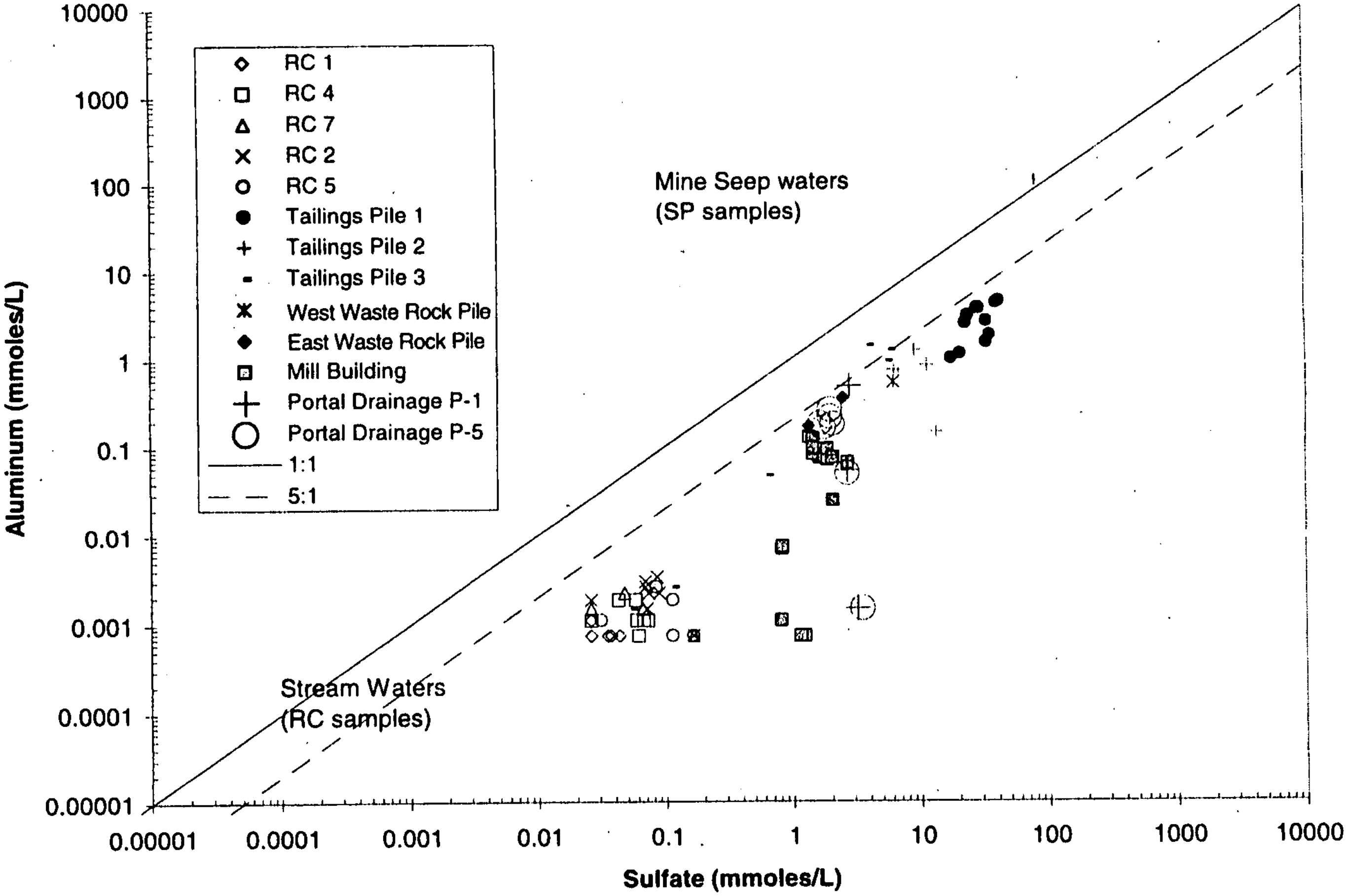

Figure 6.4-9

SURFACE AND SEEPAGE WATER SAMPLES ALUMINUM VS SULFATE SCATTER PLOT

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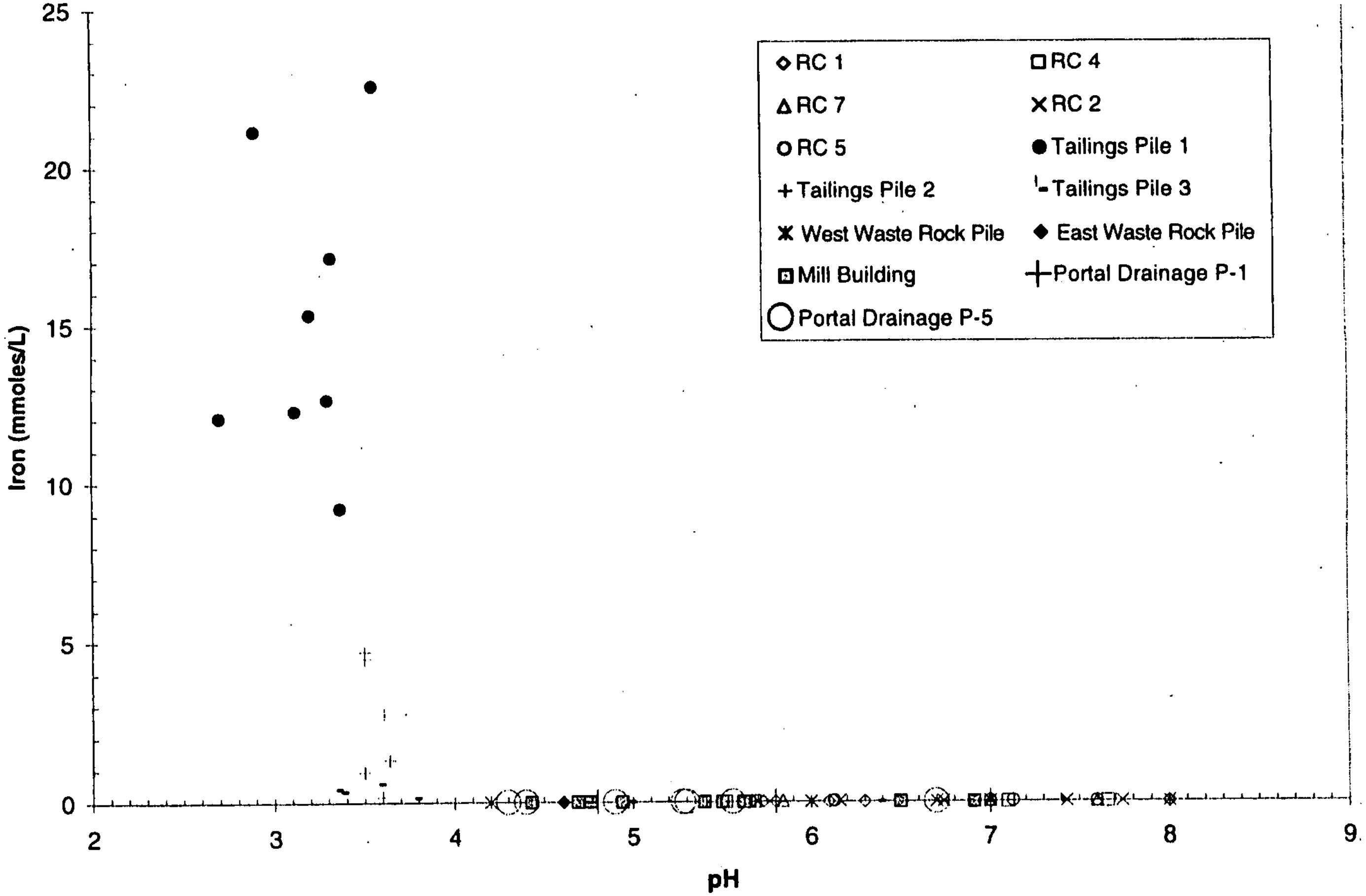

Figure 6.4-10

SURFACE AND SEEPAGE WATER SAMPLES IRON VS pH SCATTER PLOT

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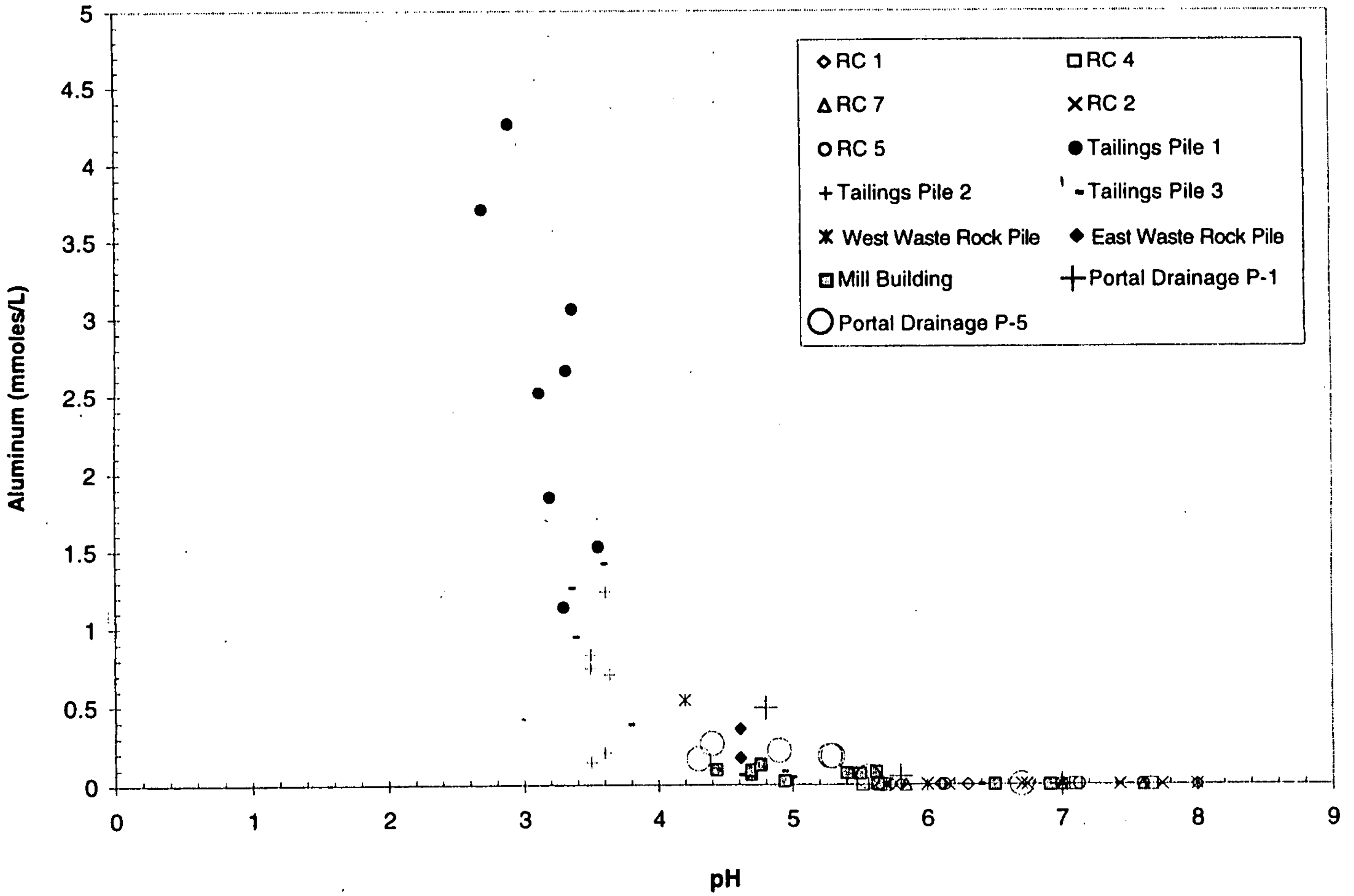

Figure 6.4-11

SURFACE AND SEEPAGE WATER SAMPLES ALUMINUM VS pH SCATTER PLOT

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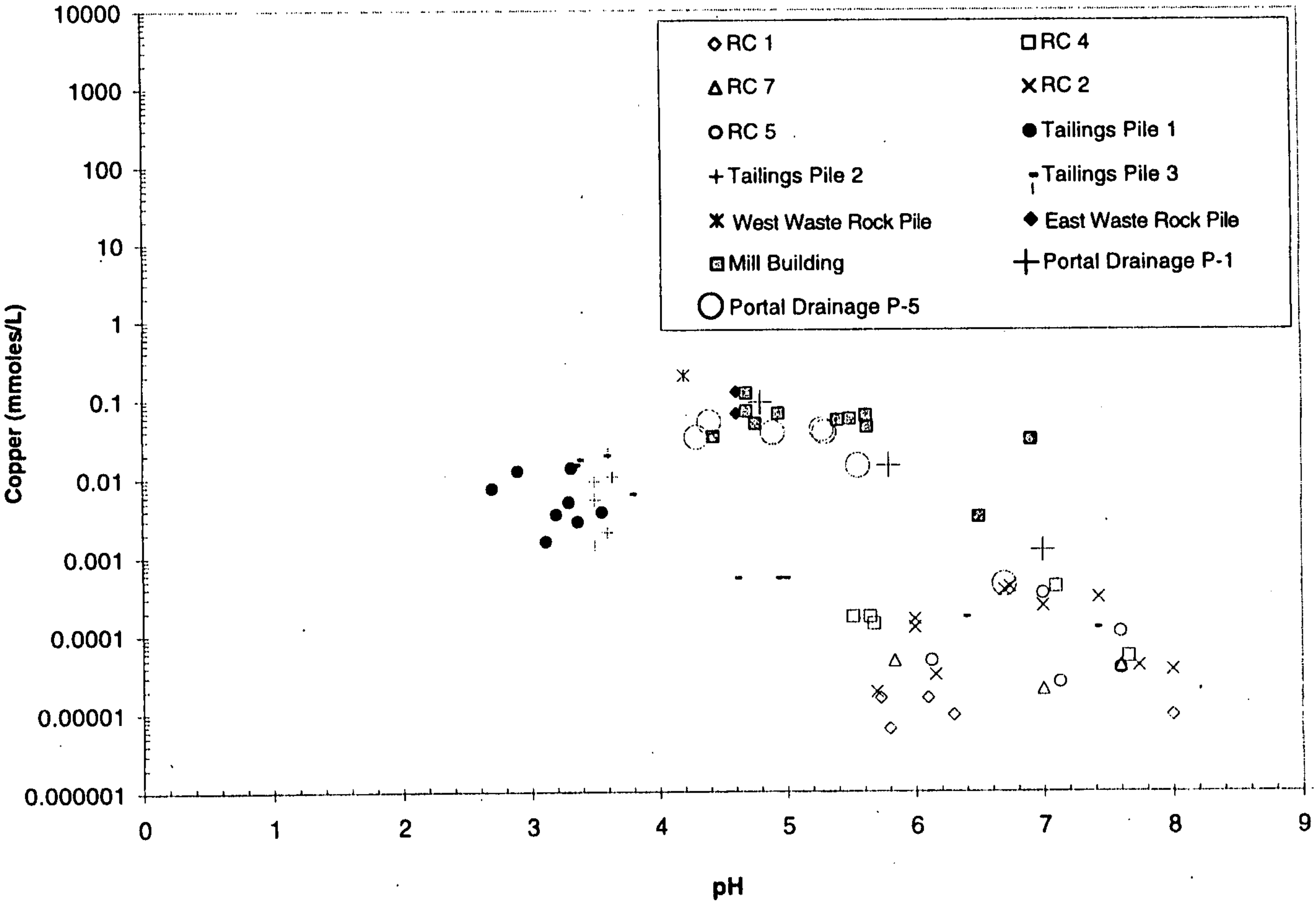

Figure 6.4-12

SURFACE AND SEEPAGE WATER SAMPLES
COPPER VS pH SCATTER PLOT

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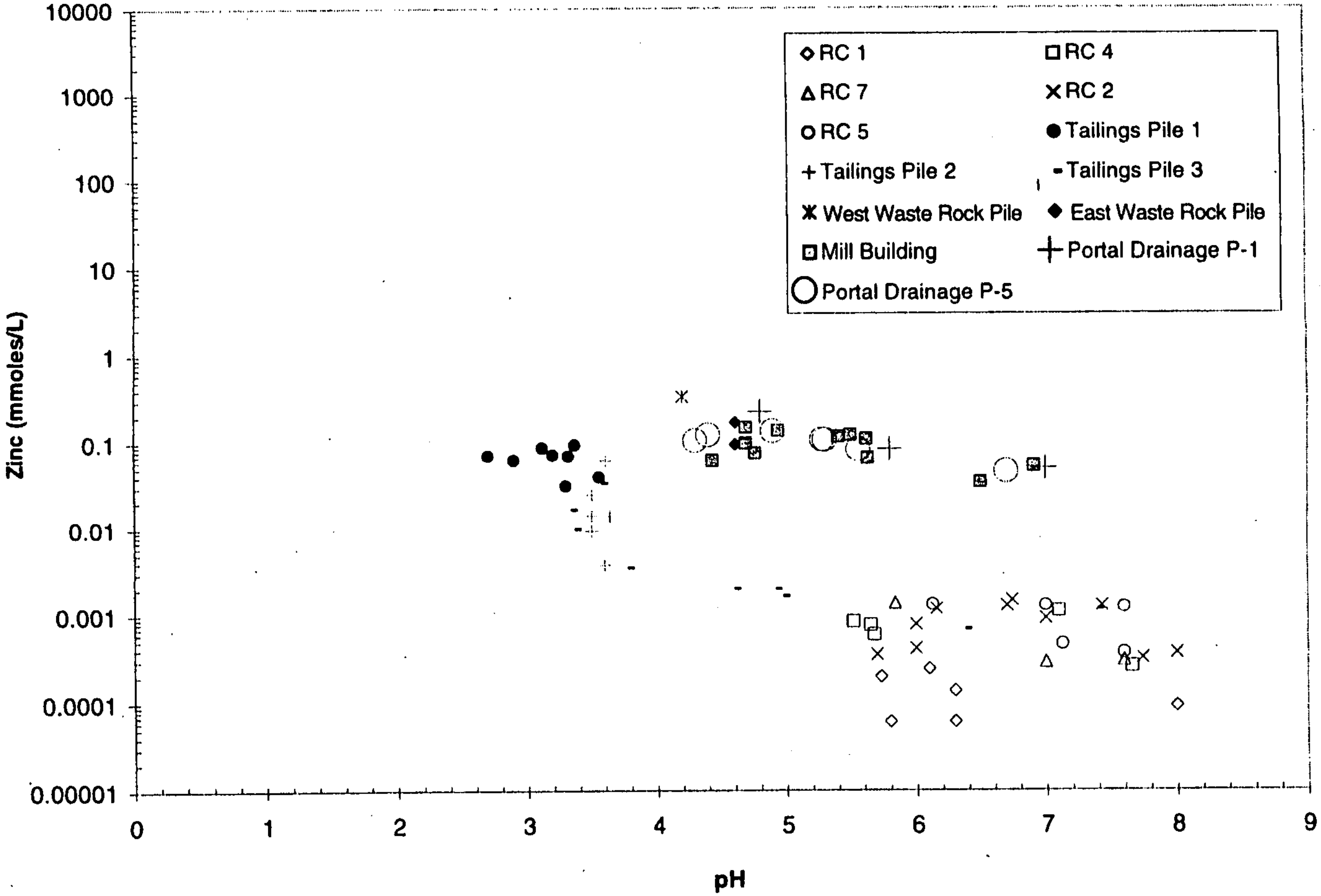

Figure 6.4-13

SURFACE AND SEEPAGE WATER SAMPLES
ZINC VS pH SCATTER PLOT

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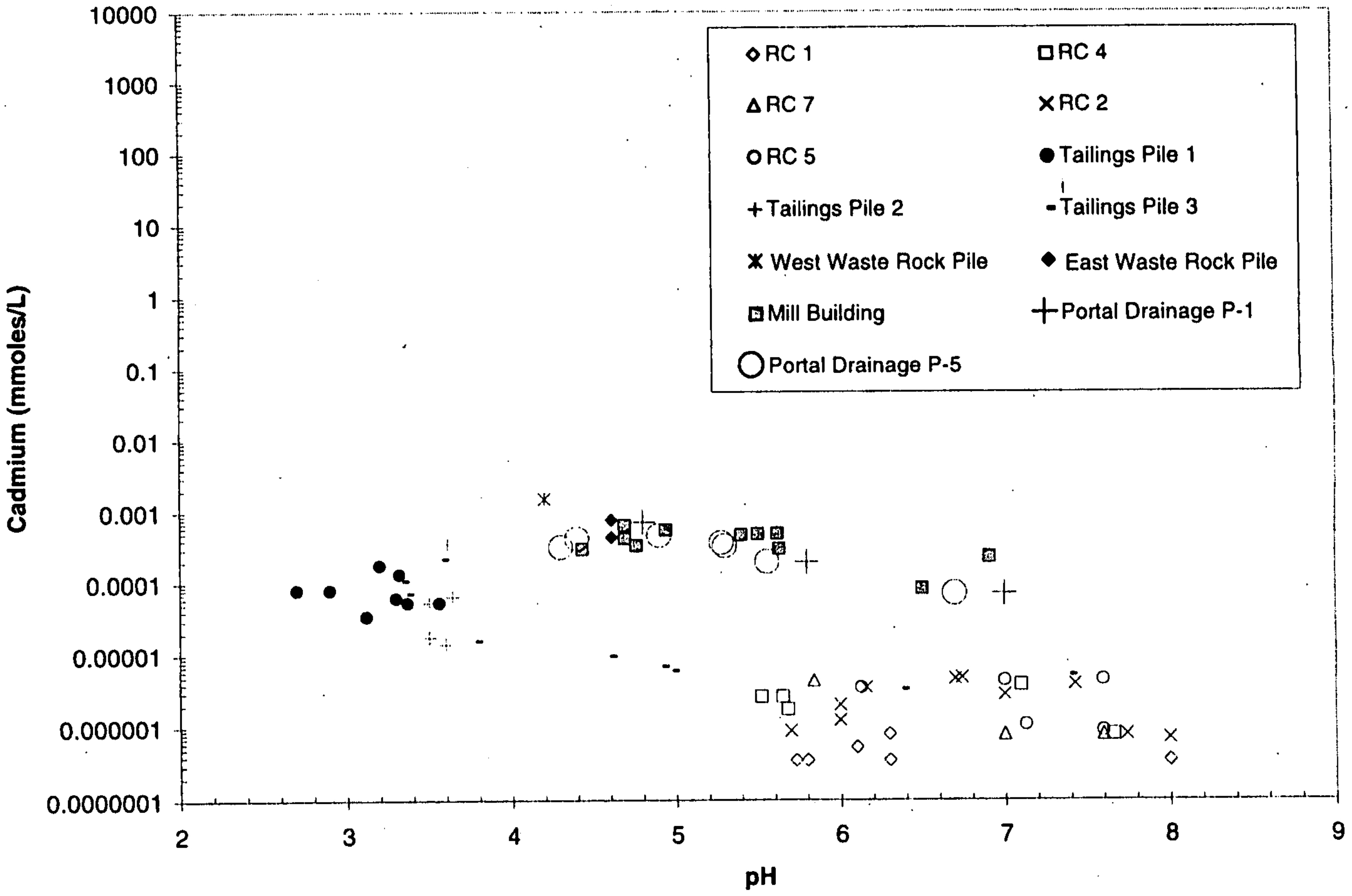

Figure 6.4-14

SURFACE AND SEEPAGE WATER SAMPLES CADMIUM VS pH SCATTER PLOT

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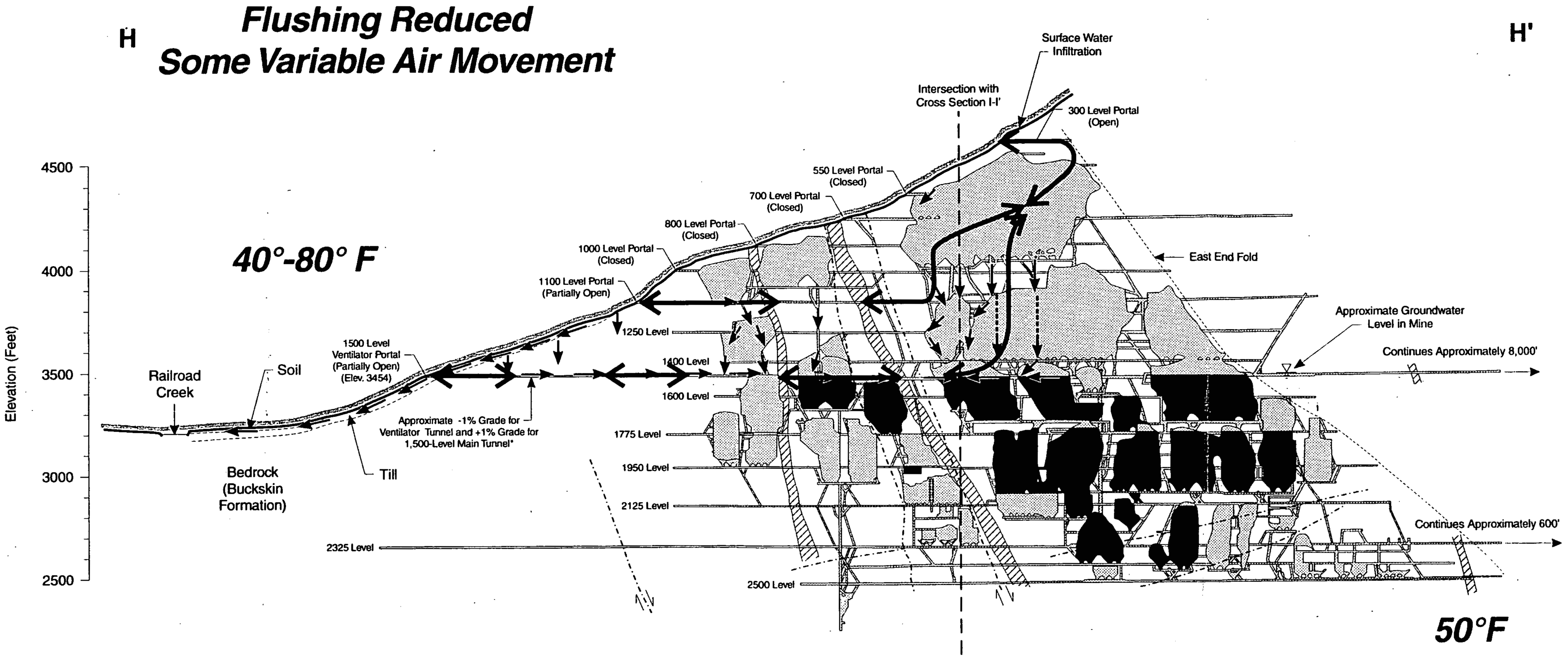

SOURCES: SRK

Northwest Geophysical Associates, 1997, Seismic Line A-A', B-B', Holden Mine Geophysical Investigation.

Youngberg, E. A., Wilson, T. L., 1952, The Geology of the Holden Mine, Economic Geology, V. 47, No. 1, 1952, pp. 1-12.

W.A.B., 1942, Detailed Surface Geology Map, Howe Sound Co., Chelan Division

F.E., H.B.S., 1938, Geology of 1500 Level, Howe Sound Company Chelan Division

LEGEND

▒	Open stope
■	Backfilled stope
▨	Dike
-·-·-·-	Transform fault
⟶	Direction of water movement
➔	Direction of air movement

* NOTE:
This cross section is generally parallel to ore body and 1500-level ventilator tunnel. Due to the 1500-level main tunnel having +1% grade, water flow is toward main portal opening but not shown on this figure. (See Figures 6.1-2a and 6.1-2b)

0 500 1,000
Approximate
Horizontal and Vertical
Scale in Feet

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Figure 6.5-1

GENERAL WATER AND AIR FLOW FEATURES IN THE UNDERGROUND MINE—SUMMER

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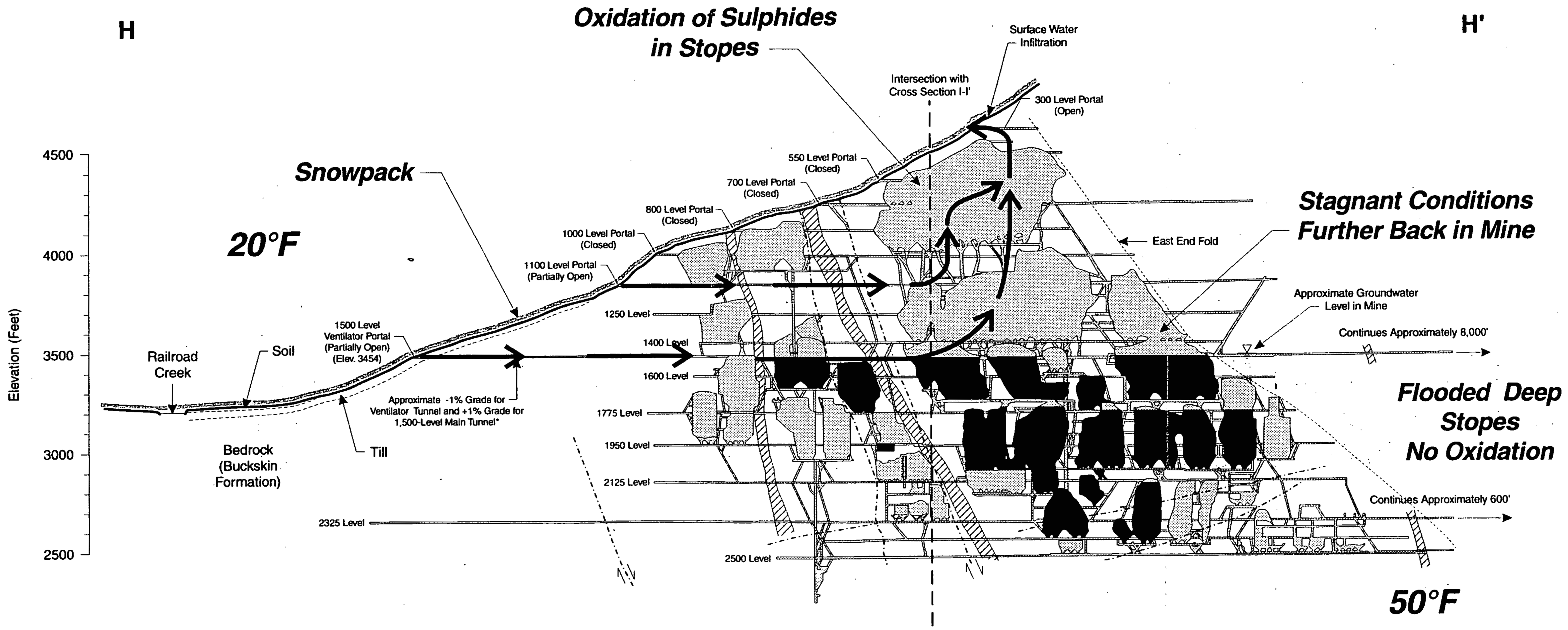

SOURCES: *SRK*

Northwest Geophysical Associates, 1997, Seismic Line A-A', B-B', Holden Mine Geophysical Investigation.

Youngberg, E. A., Wilson, T. L., 1952, The Geology of the Holden Mine, Economic Geology, V. 47, No. 1, 1952, pp. 1-12.

W.A.B., 1942, Detailed Surface Geology Map, Howe Sound Co., Chelan Division

F.E., H.B.S., 1938, Geology of 1500 Level, Howe Sound Company Chelan Division

LEGEND

- ▒ Open stope
- ■ Backfilled stope
- ▨ Dike
- –·–·–· Transform fault
- → Direction of water movement
- ➔ Direction of air movement

* NOTE:
This cross section is generally parallel to ore body and 1500-level ventilator tunnel. Due to the 1500-level main tunnel having +1% grade, water flow is toward main portal opening but not shown on this figure. (See Figures 6.1-2a and 6.1-2b)

0 500 1,000

Approximate
Horizontal and Vertical
Scale in Feet

Figure 6.5-2

GENERAL WATER AND AIR FLOW FEATURES IN THE UNDERGROUND MINE—WINTER

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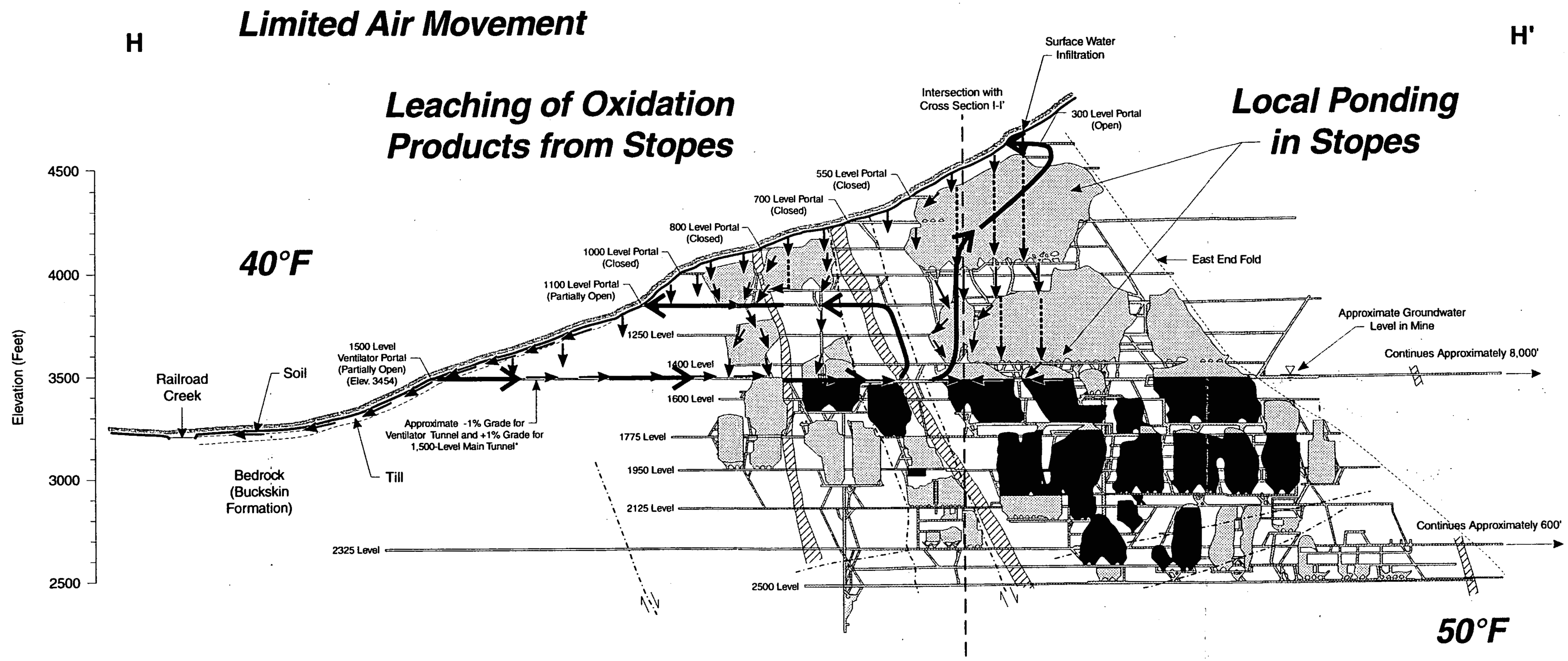

SOURCES: SRK

Northwest Geophysical Associates, 1997, Seismic Line A-A', B-B', Holden Mine Geophysical Investigation.

Youngberg, E. A., Wilson, T. L., 1952, The Geology of the Holden Mine, Economic Geology, V. 47, No. 1, 1952, pp. 1-12.

W.A.B., 1942, Detailed Surface Geology Map, Howe Sound Co., Chelan Division

F.E., H.B.S., 1938, Geology of 1500 Level, Howe Sound Company Chelan Division

LEGEND

░	Open stope
■	Backfilled stope
▨	Dike
-·-·-	Transform fault
→	Direction of water movement
➔	Direction of air movement

* NOTE:
This cross section is generally parallel to ore body and 1500-level ventilator tunnel. Due to the 1500-level main tunnel having +1% grade, water flow is toward main portal opening but not shown on this figure. (See Figures 6.1-2a and 6.1-2b)

0 500 1,000
Approximate Horizontal and Vertical Scale in Feet

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Figure 6.5-3

GENERAL WATER AND AIR FLOW FEATURES IN THE UNDERGROUND MINE—SPRING

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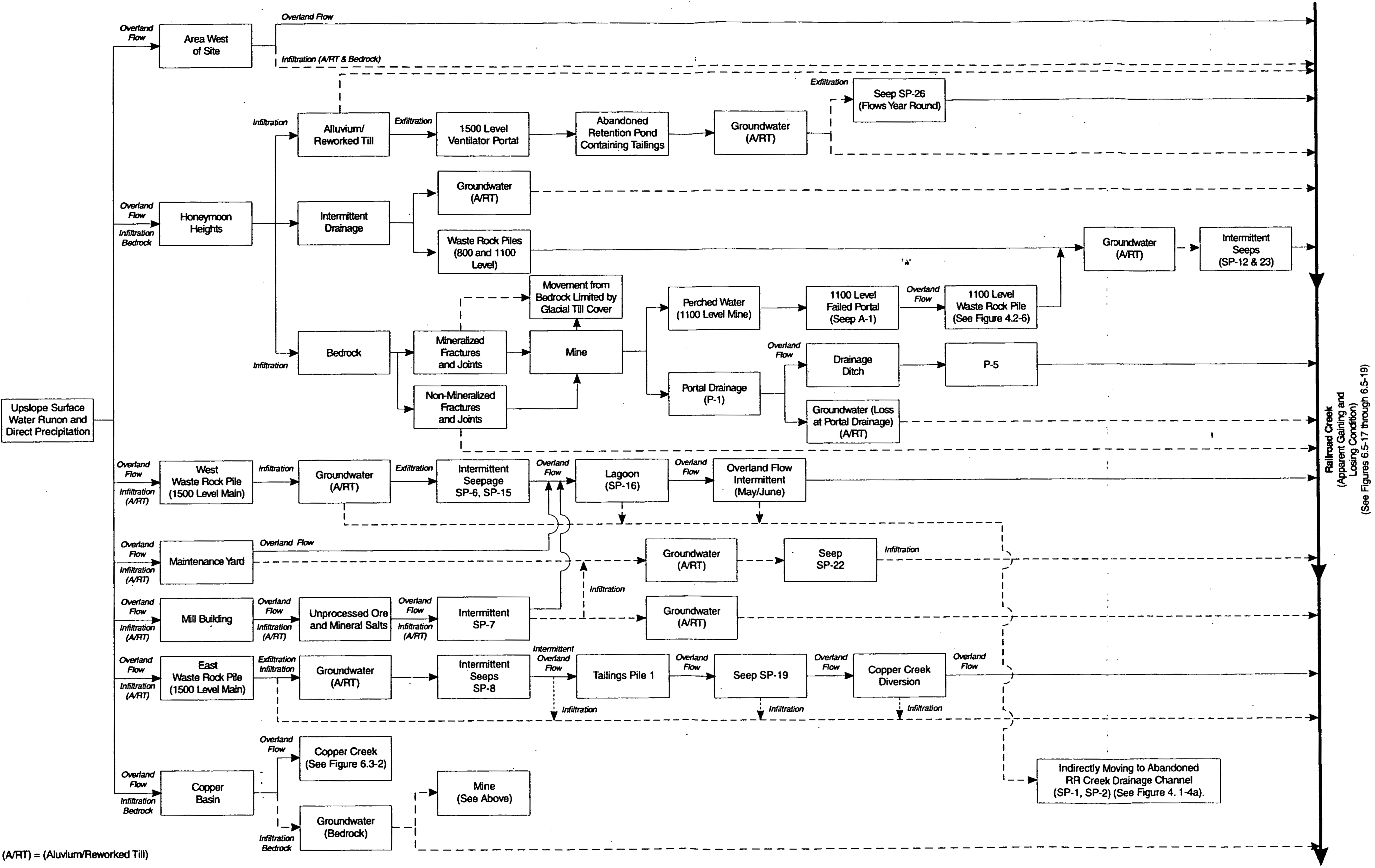

Figure 6.5-4

HONEYMOON HEIGHTS AND MINE SUPPORT AREAS CONCEPTUAL TRANSPORT PATHWAYS

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17693a73.CDR

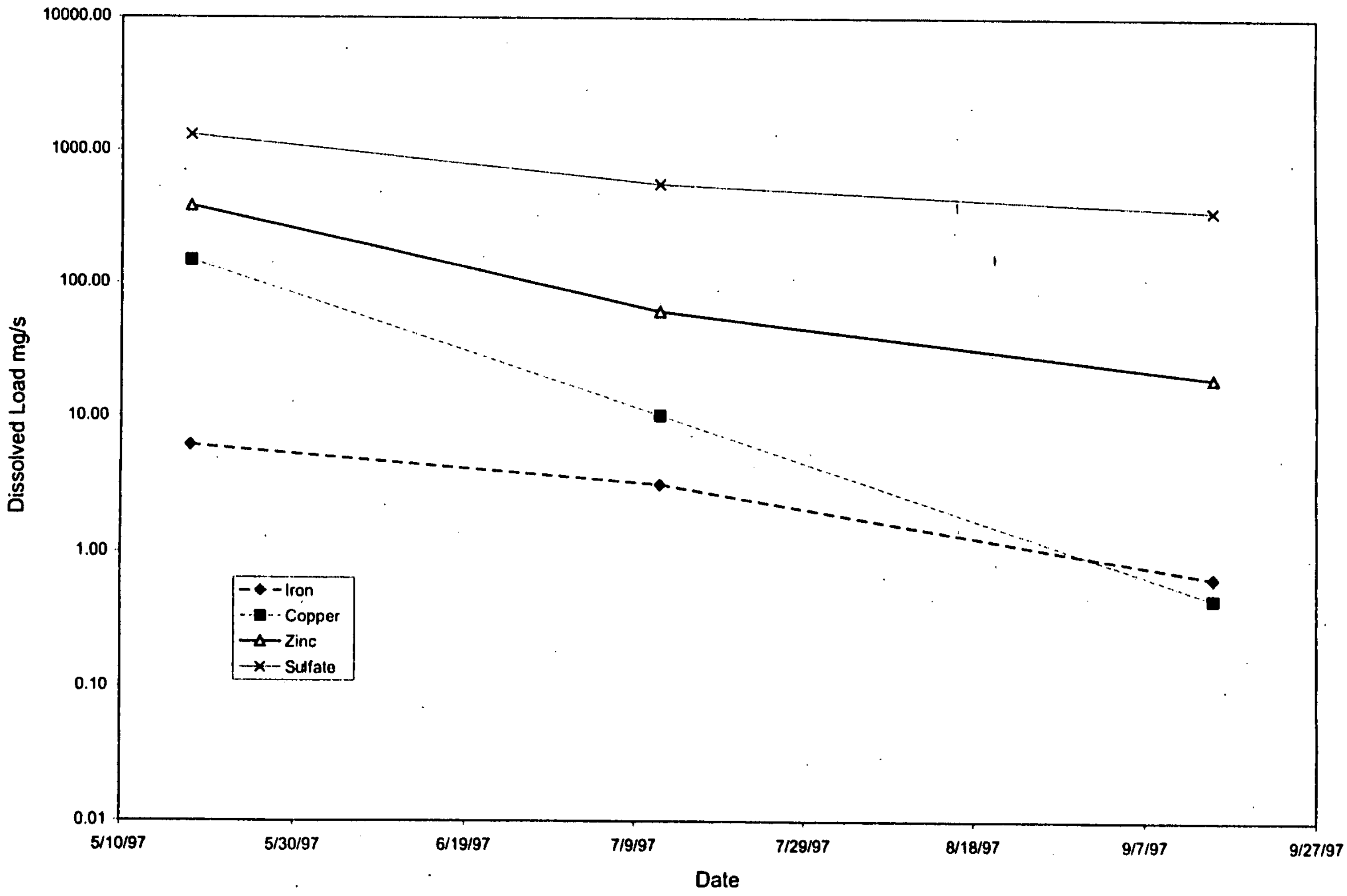

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Figure 6.5-5

1997 PORTAL DRAINAGE SULFATE AND METALS LOAD

Holden Mine RI/FS
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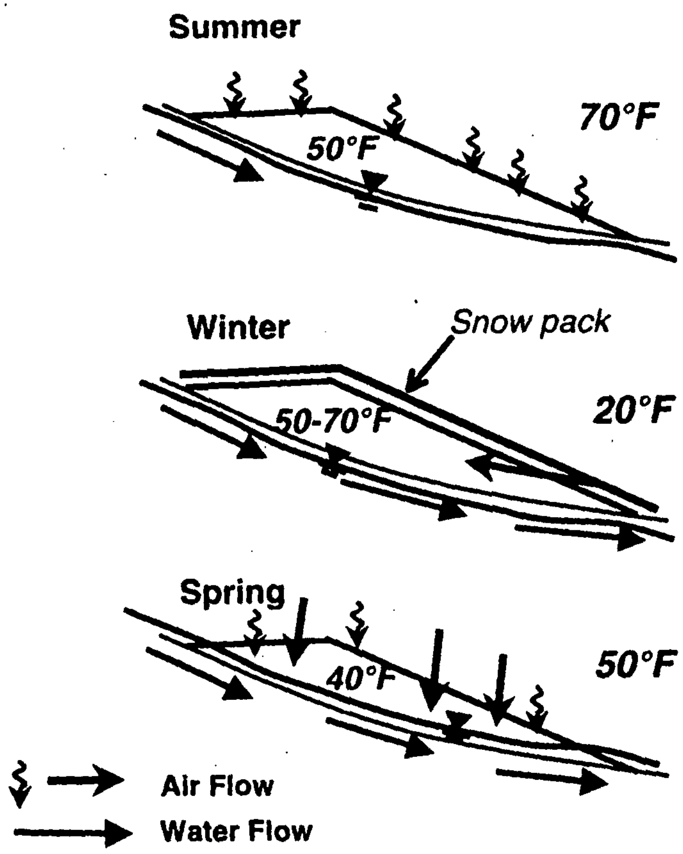
17693_01.PPT



Oxygen movement by diffusion
Oxidation in surface only
Water table low

Oxygen movement by convection
or diffusion
Limited leaching

Snow pack melts
Leaching of salts by
rising water table and infiltration

SOURCE: SRK

Figure 6.5-6

GENERAL WATER AND AIR FLOW FEATURES IN THE SIDE-HILL WASTE ROCK PILES

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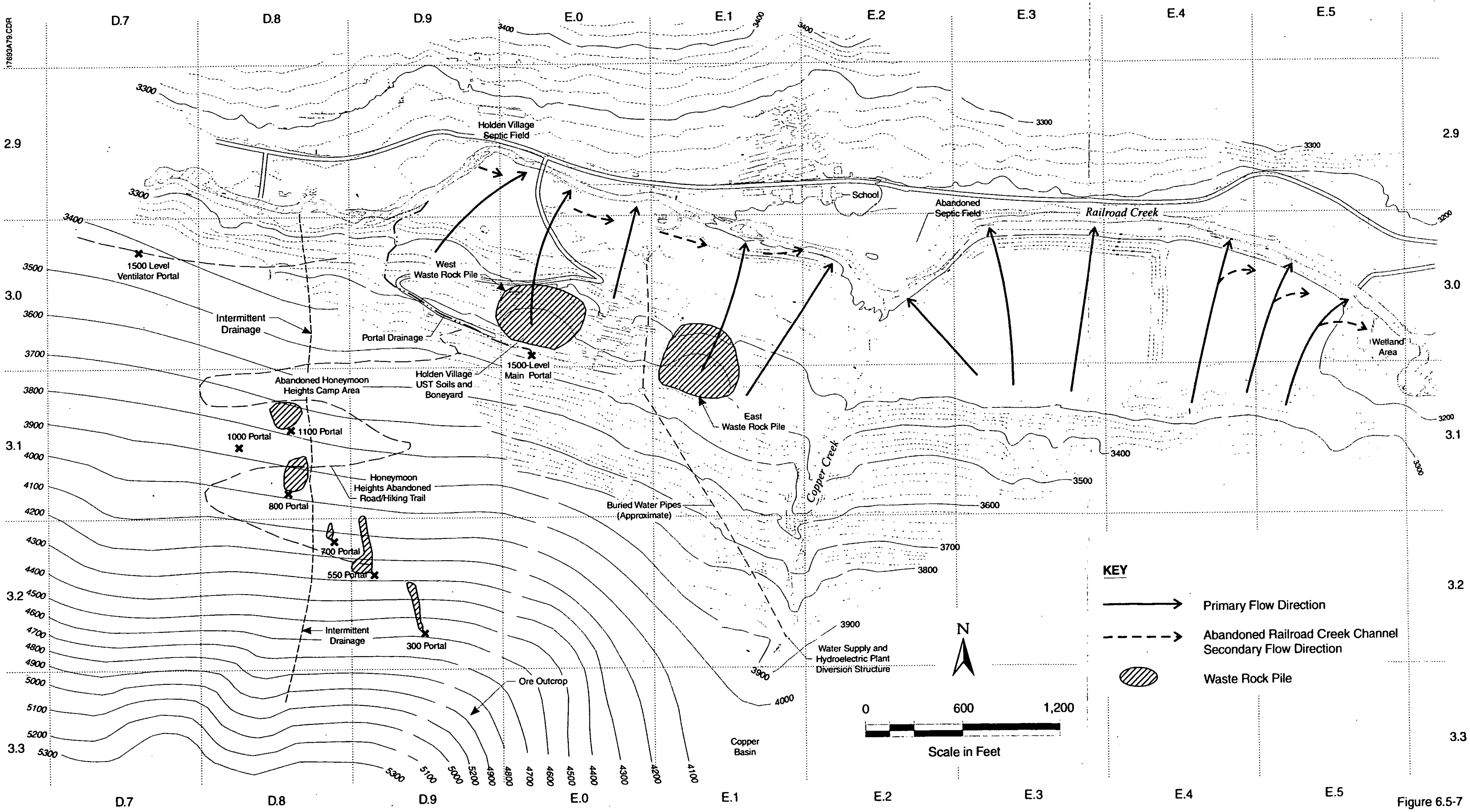

SOURCE: *Base map information from USFS and Washington DNR, DEM CD ROM*

Figure 6.5-7

CONCEPTUAL GROUNDWATER FLOWPATHS HOLDEN MINE SITE SPRING CONDITIONS

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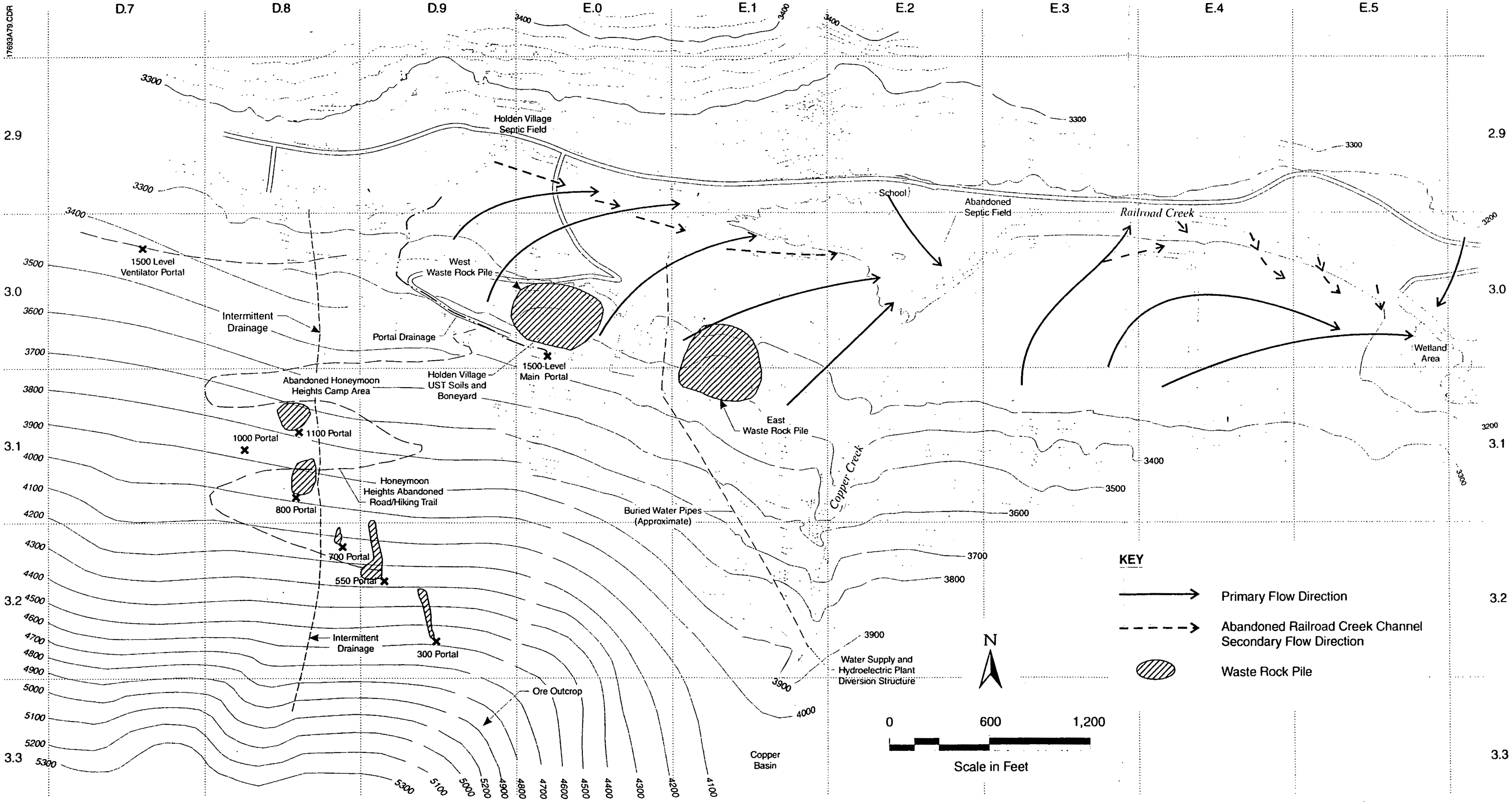

SOURCE: Base map information from USFS and Washington DNR, DEM CD ROM

Figure 6.5-8

CONCEPTUAL GROUNDWATER FLOWPATHS
HOLDEN MINE SITE
FALL CONDITIONS

DAMES & MOORE
GROUP
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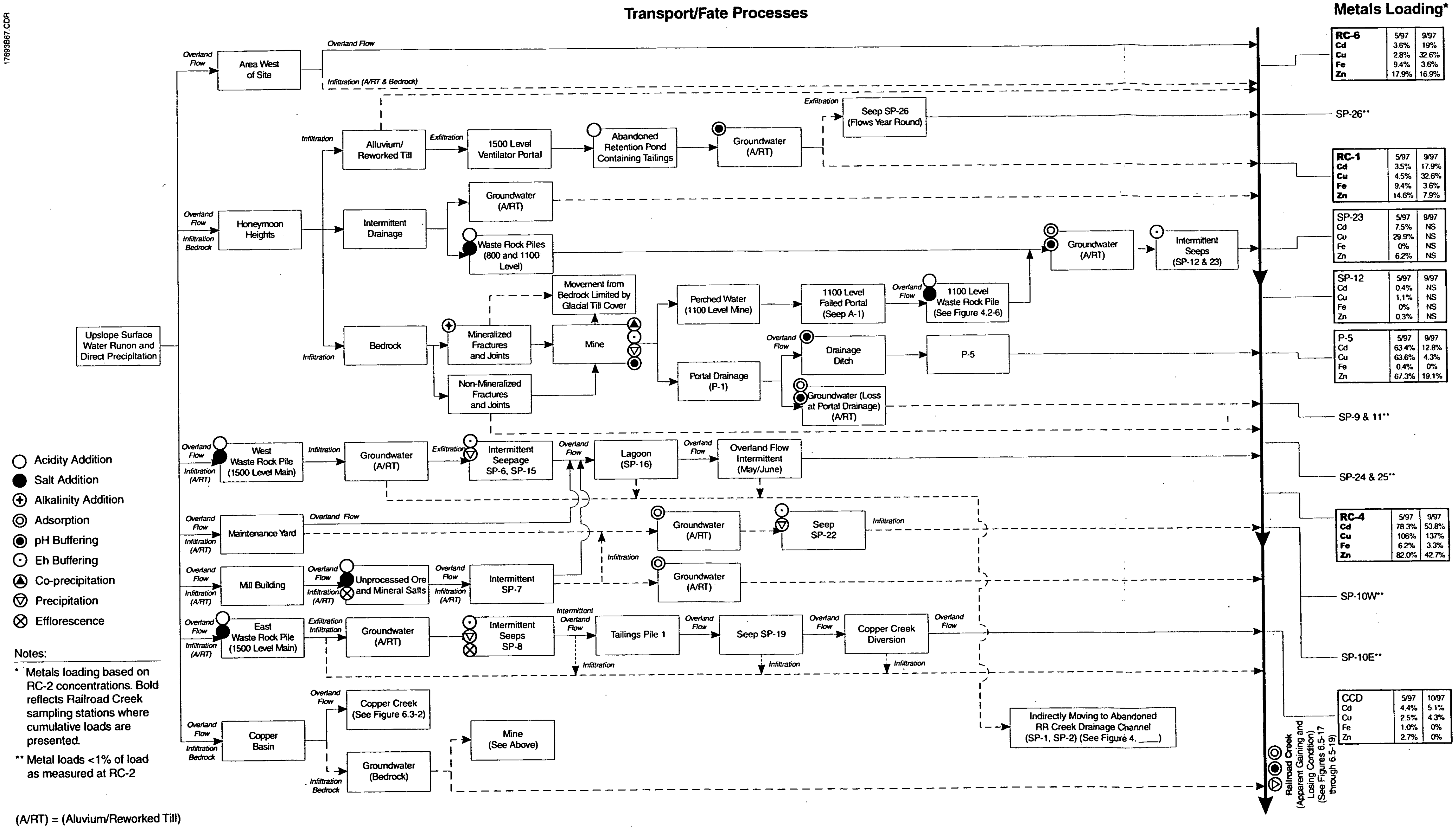


RC-6	5/97	9/97
Cd	3.6%	19%
Cu	2.8%	32.6%
Fe	9.4%	3.6%
Zn	17.9%	16.9%

RC-1	5/97	9/97
Cd	3.5%	17.9%
Cu	4.5%	32.6%
Fe	9.4%	3.6%
Zn	14.6%	7.9%

SP-23	5/97	9/97
Cd	7.5%	NS
Cu	29.9%	NS
Fe	0%	NS
Zn	6.2%	NS

SP-12	5/97	9/97
Cd	0.4%	NS
Cu	1.1%	NS
Fe	0%	NS
Zn	0.3%	NS

P-5	5/97	9/97
Cd	63.4%	12.8%
Cu	63.6%	4.3%
Fe	0.4%	0%
Zn	67.3%	19.1%

RC-4	5/97	9/97
Cd	78.3%	53.8%
Cu	106%	137%
Fe	6.2%	3.3%
Zn	82.0%	42.7%

CCD	5/97	10/97
Cd	4.4%	5.1%
Cu	2.5%	4.3%
Fe	1.0%	0%
Zn	2.7%	0%

Notes:

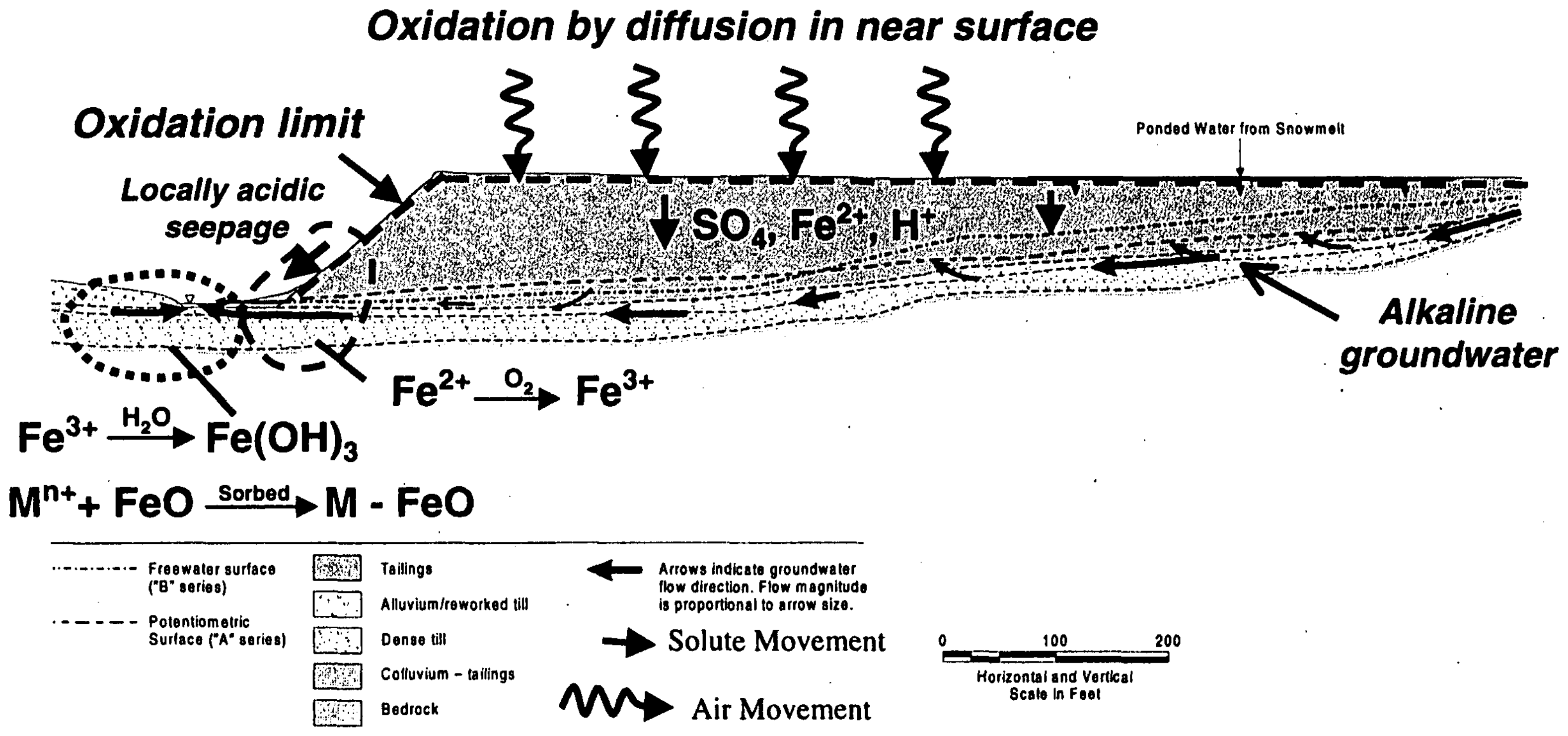
* Metals loading based on RC-2 concentrations. Bold reflects Railroad Creek sampling stations where cumulative loads are presented.

** Metal loads <1% of load as measured at RC-2

(A/RT) = (Aluvium/Reworked Till)

Figure 6.5-9

HONEYMOON HEIGHTS AND MINE SUPPORT AREAS CONCEPTUAL TRANSPORT/FATE PROCESSES AND RAILROAD CREEK METALS LOADING



SOURCE: SRK

Figure 6.5-11

GENERAL WATER AND AIR FLOW FEATURES IN TAILINGS

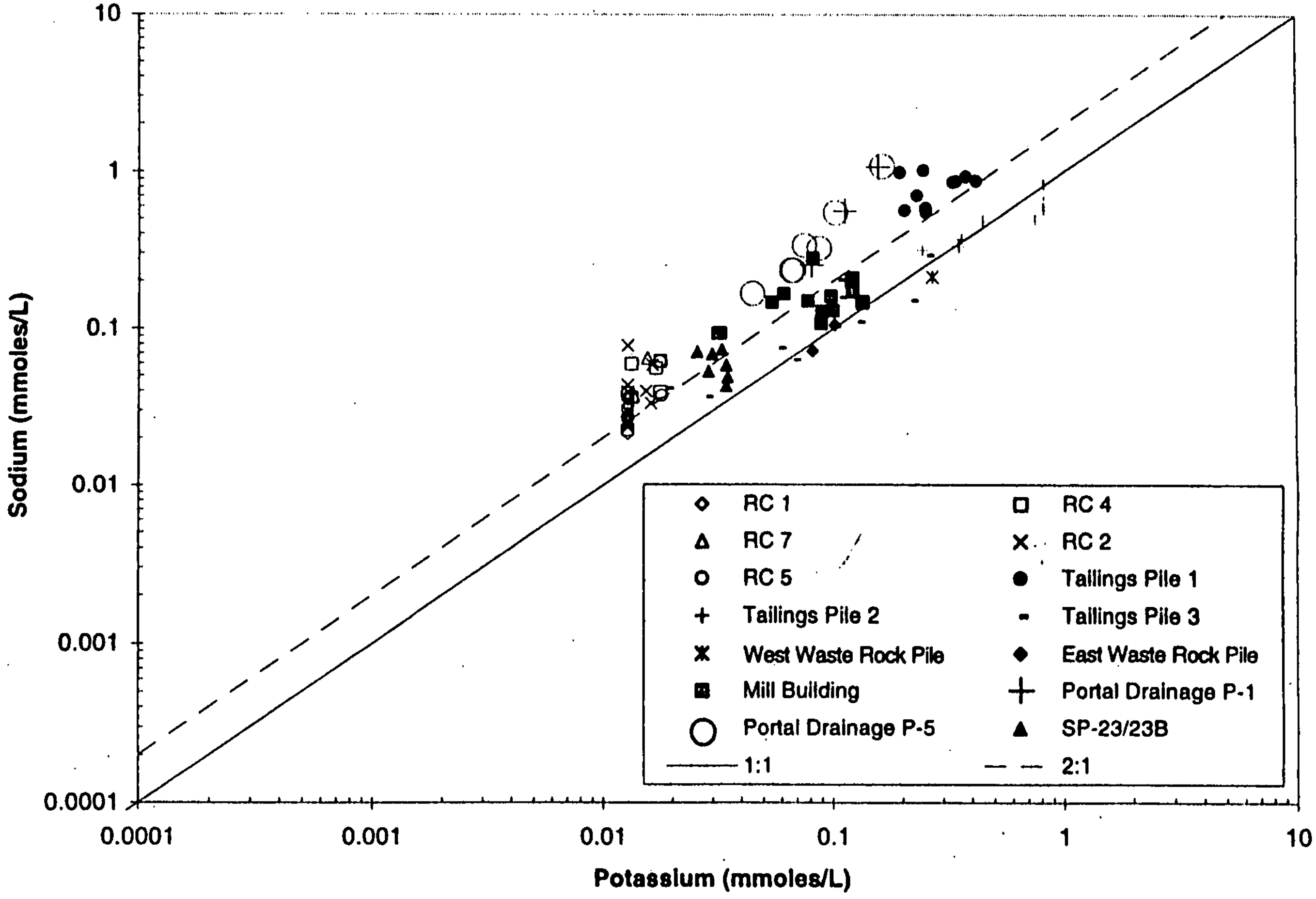


Figure 6.5-10

SURFACE AND SEEPAGE WATER SAMPLES
POTASSIUM VS SODIUM SCATTER PLOT

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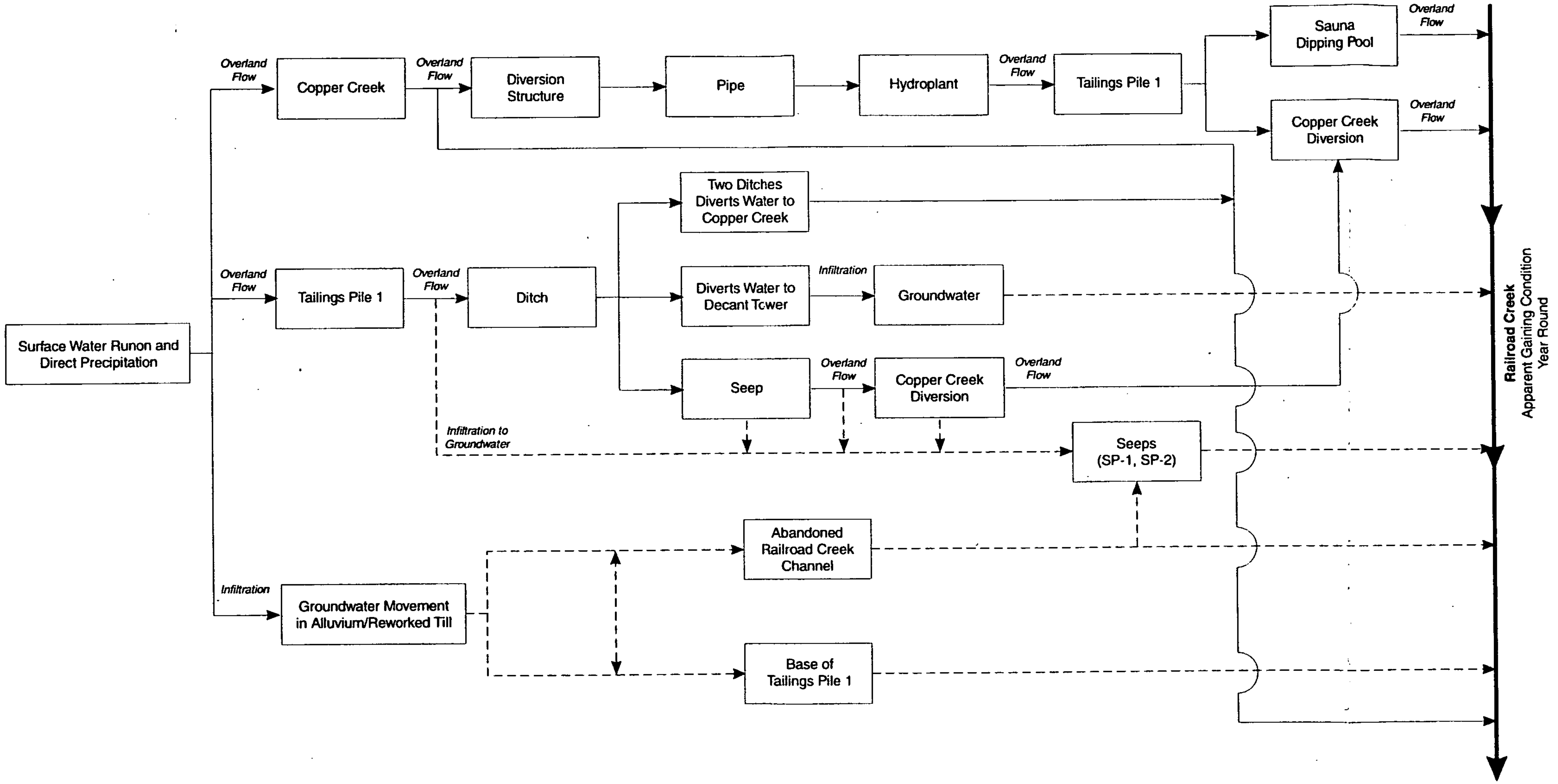

Figure 6.5-12

TAILINGS PILE 1
CONCEPTUAL TRANSPORT PATHWAYS

DAMES & MOORE
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Draft Final RI Report

Job No. 17693-005-019

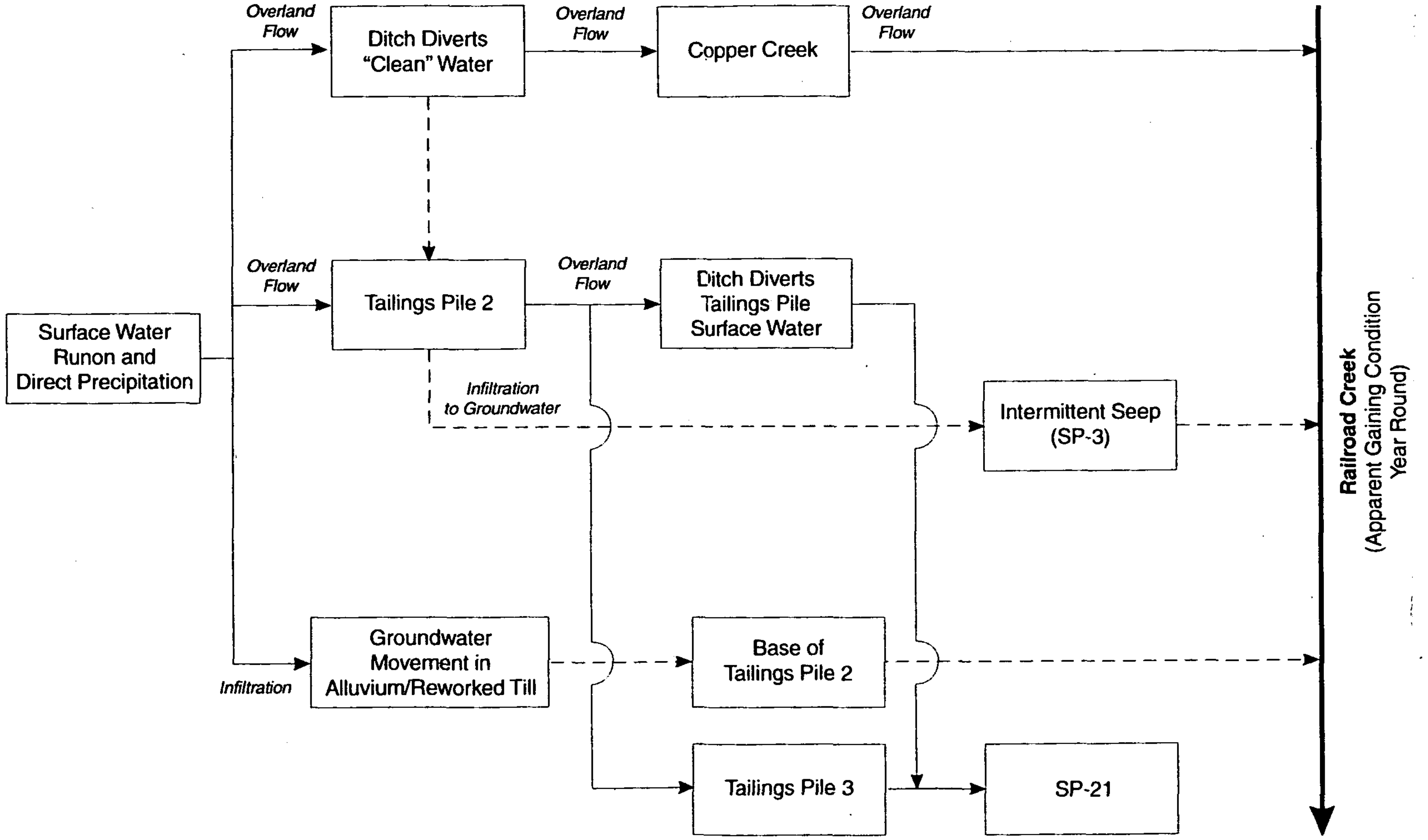

Figure 6.5-13

TAILINGS PILE 2
CONCEPTUAL TRANSPORT PATHWAYS

DAMES & MOORE
A DAMES & MOORE GROUP COMPANY

Holden Mine RI/FS
Draft Final RI Report

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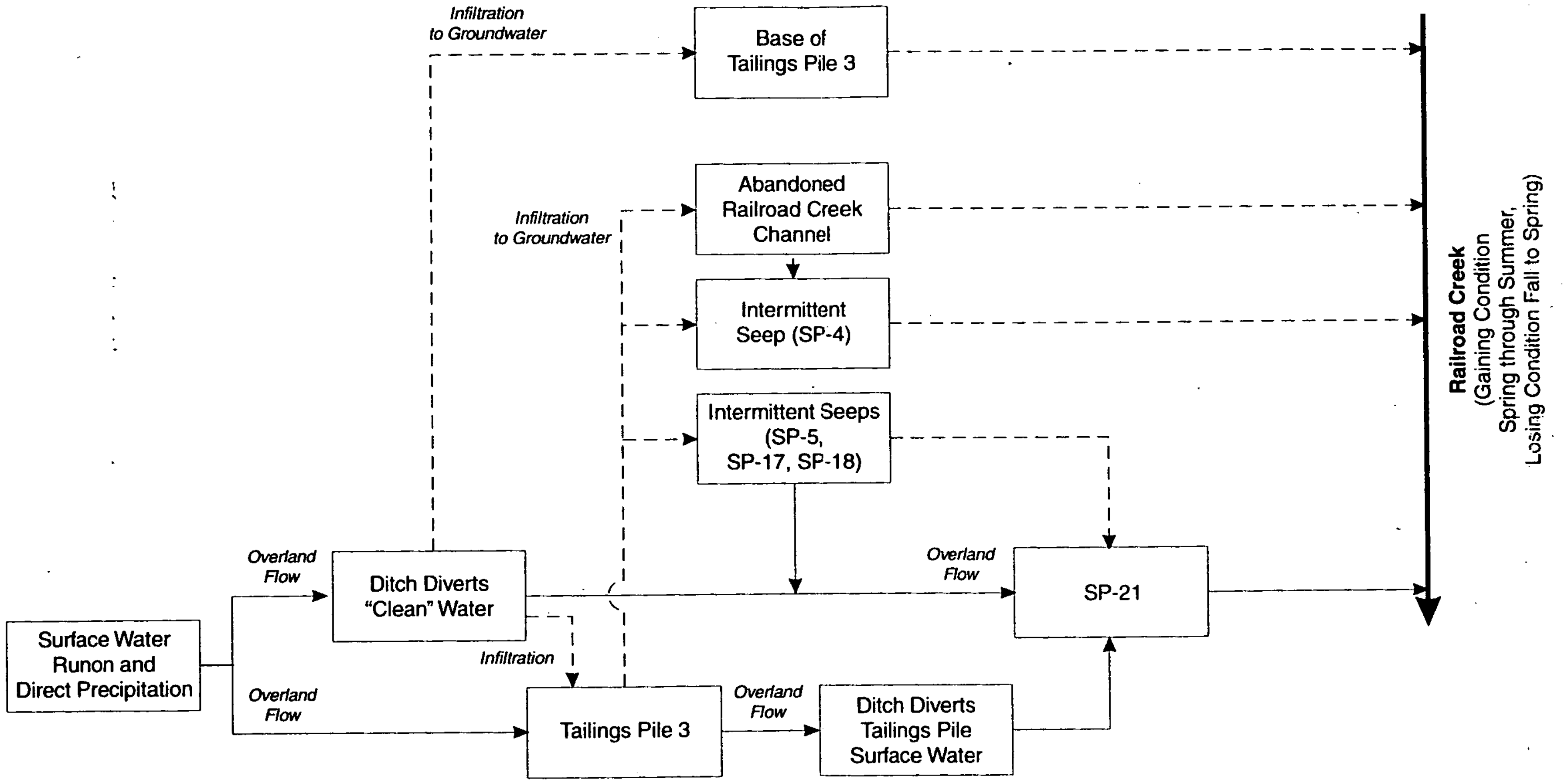

Figure 6.5-14

TAILINGS PILE 3

CONCEPTUAL TRANSPORT PATHWAYS

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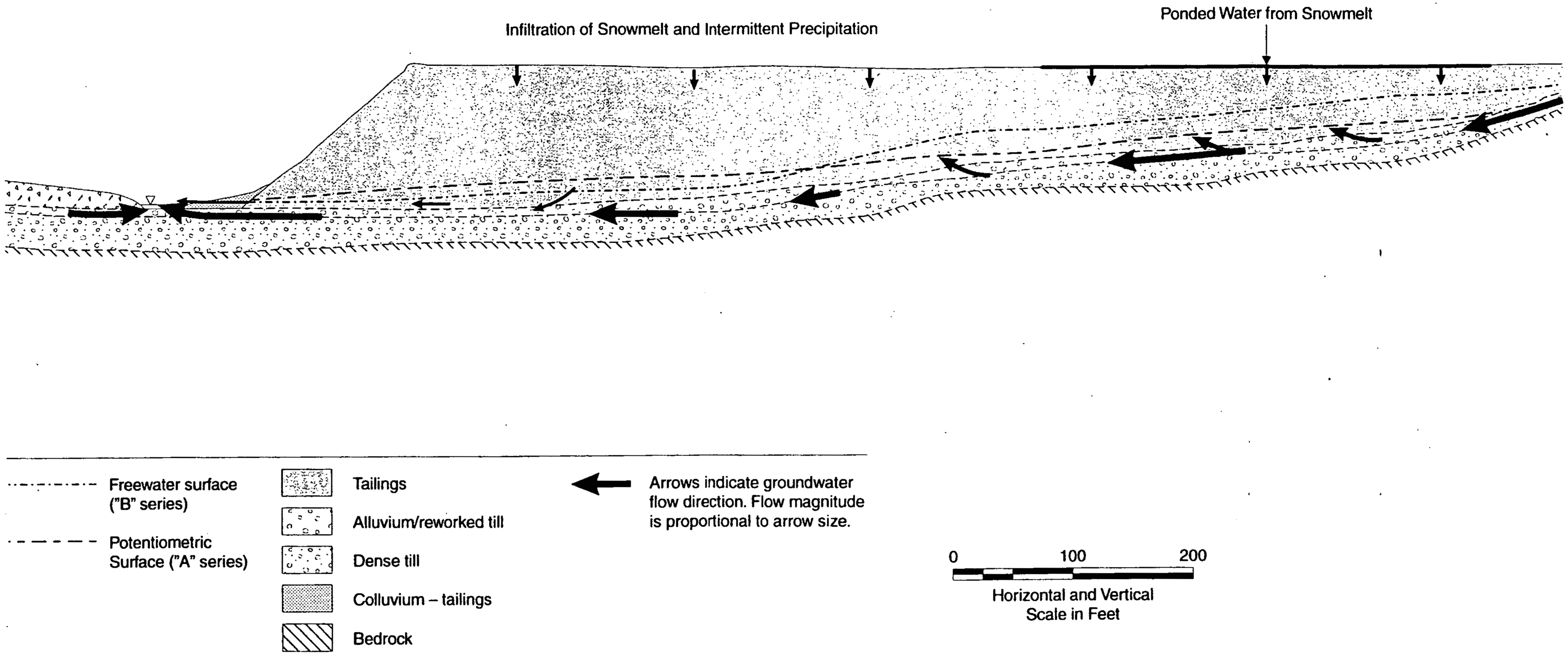


Figure 6.5-15

CONCEPTUAL HYDROGEOLOGIC CROSS SECTION
TAILINGS PILES #1, 2, AND 3—MAY

17693A77.CDR

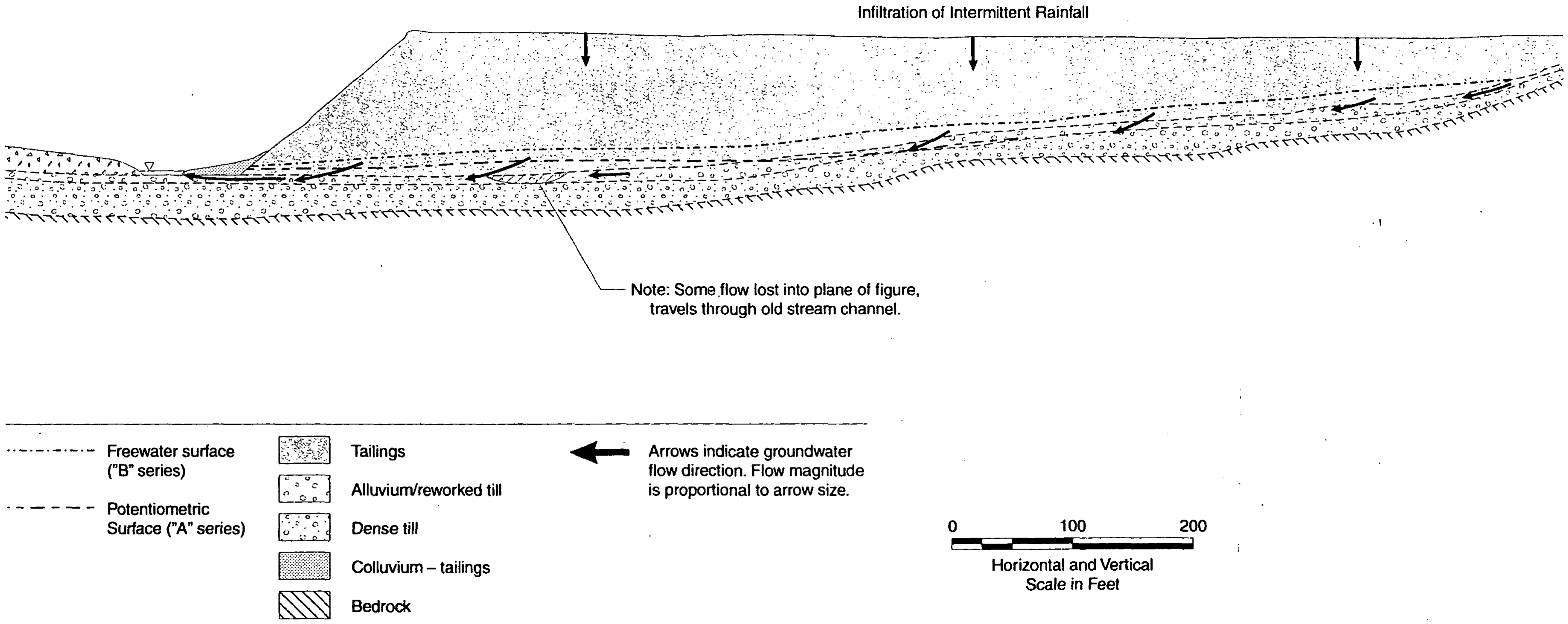


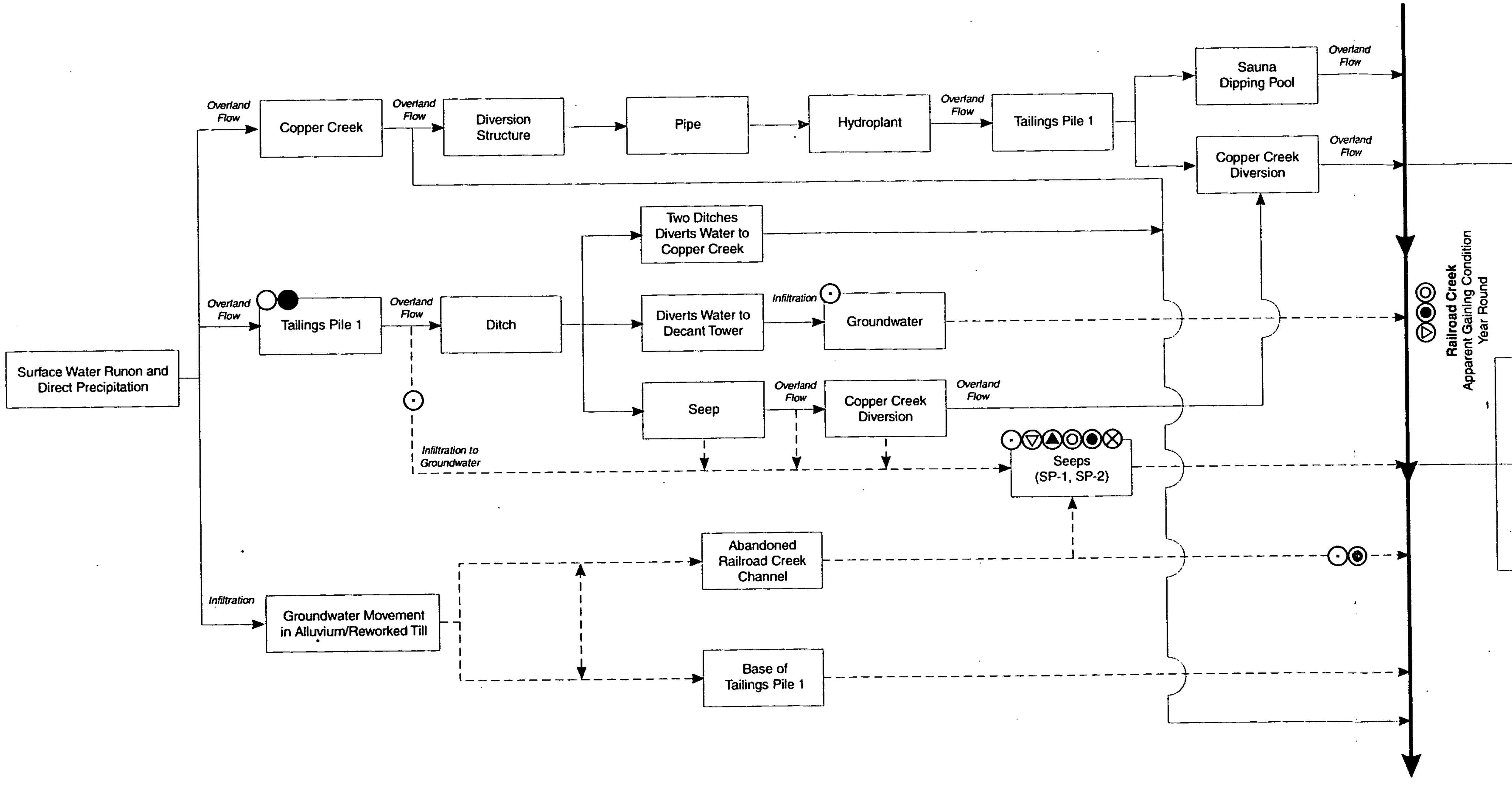
Figure 6.5-16

CONCEPTUAL HYDROGEOLOGIC CROSS SECTION TAILINGS PILES #1, 2, AND 3—SEPTEMBER

17693b68.CDR

Transport/Fate Processes

Metals Loading*



(See Figures 6.5-18 and 6.5-19)

CCD	5/97	10/97
Cd	4.4%	5.1%
Cu	2.5%	4.3%
Fe	1.0%	0.05%
Zn	2.7%	0%

SP-1	5/97	9/97
Cd	0.3%	NS
Cu	0.3%	NS
Fe	11.3%	NS
Zn	0.2%	NS

SP-13**

SP-2	5/97	9/97
Cd	0.3%	0%
Cu	0.3%	0%
Fe	10.2%	2.1%
Zn	0.4%	0.1%

Notes:

* Metals loading based on RC-2 concentrations. Bold reflects Railroad Creek sampling stations where cumulative loads are presented.

** Metal loads <1% of load as measured at RC-2.

- ○ Acidity Addition
- ● Salt Addition
- ⊕ Alkalinity Addition
- ◎ Adsorption
- ◉ pH Buffering
- ⊙ Eh Buffering
- ▲ Co-precipitation
- ▽ Precipitation
- ⊗ Efflorescence

Figure 6.5-17

TAILINGS PILE 1
CONCEPTUAL TRANSPORT/FATE PROCESSES

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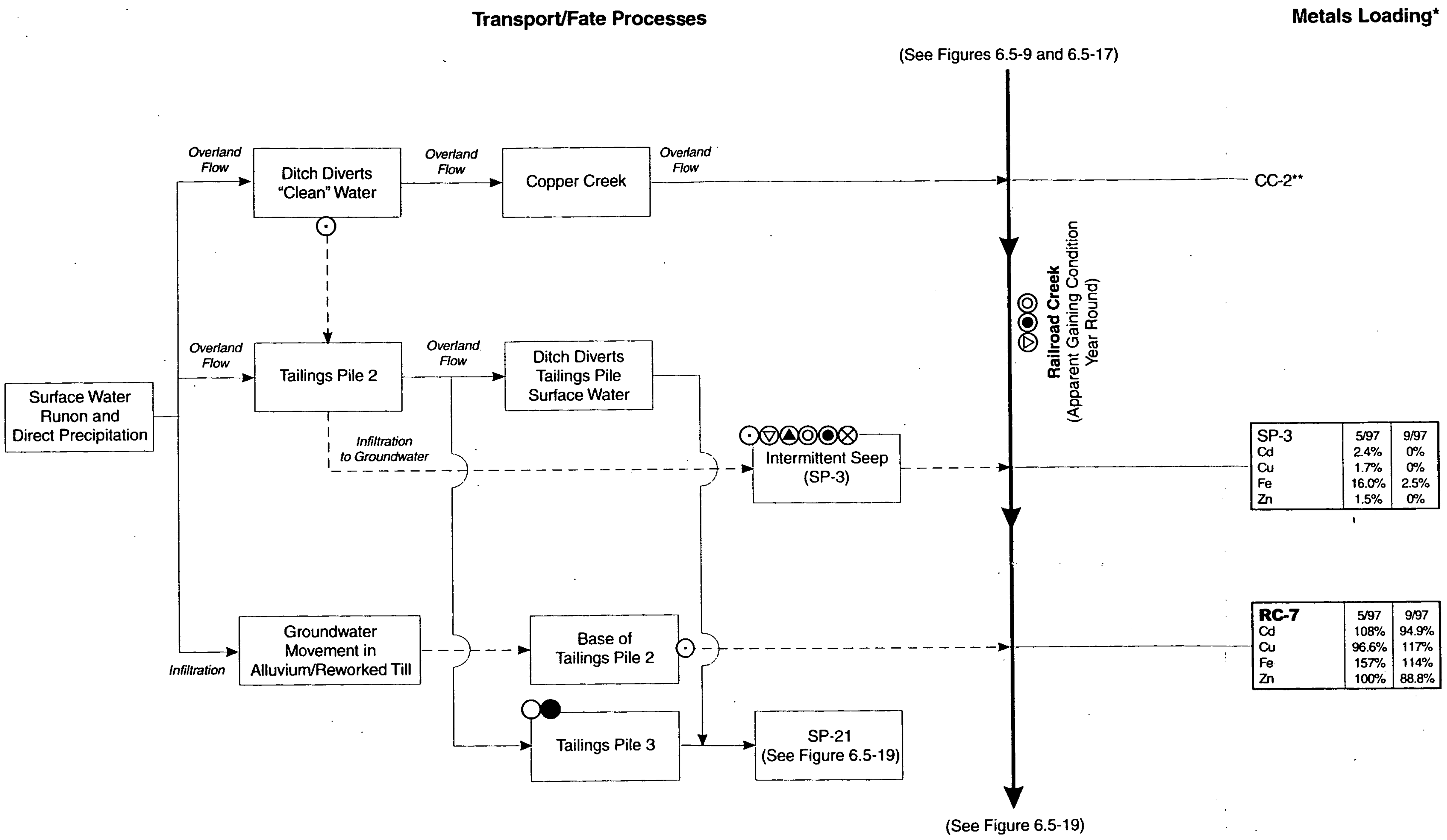

SP-3	5/97	9/97
Cd	2.4%	0%
Cu	1.7%	0%
Fe	16.0%	2.5%
Zn	1.5%	0%

RC-7	5/97	9/97
Cd	108%	94.9%
Cu	96.6%	117%
Fe	157%	114%
Zn	100%	88.8%

Notes:

- * Metals loading based on RC-2 concentrations. Bold reflects Railroad Creek sampling stations where cumulative loads are presented.
- ** Metal loads <1% of load as measured at RC-2.

○ Acidity Addition
● Salt Addition
⊕ Alkalinity Addition
◎ Adsorption
◉ pH Buffering
⊙ Eh Buffering
Ⓐ Co-precipitation
▽ Precipitation
⊗ Efflorescence

Figure 6.5-18

TAILINGS PILE 2
CONCEPTUAL TRANSPORT/FATE PROCESSES

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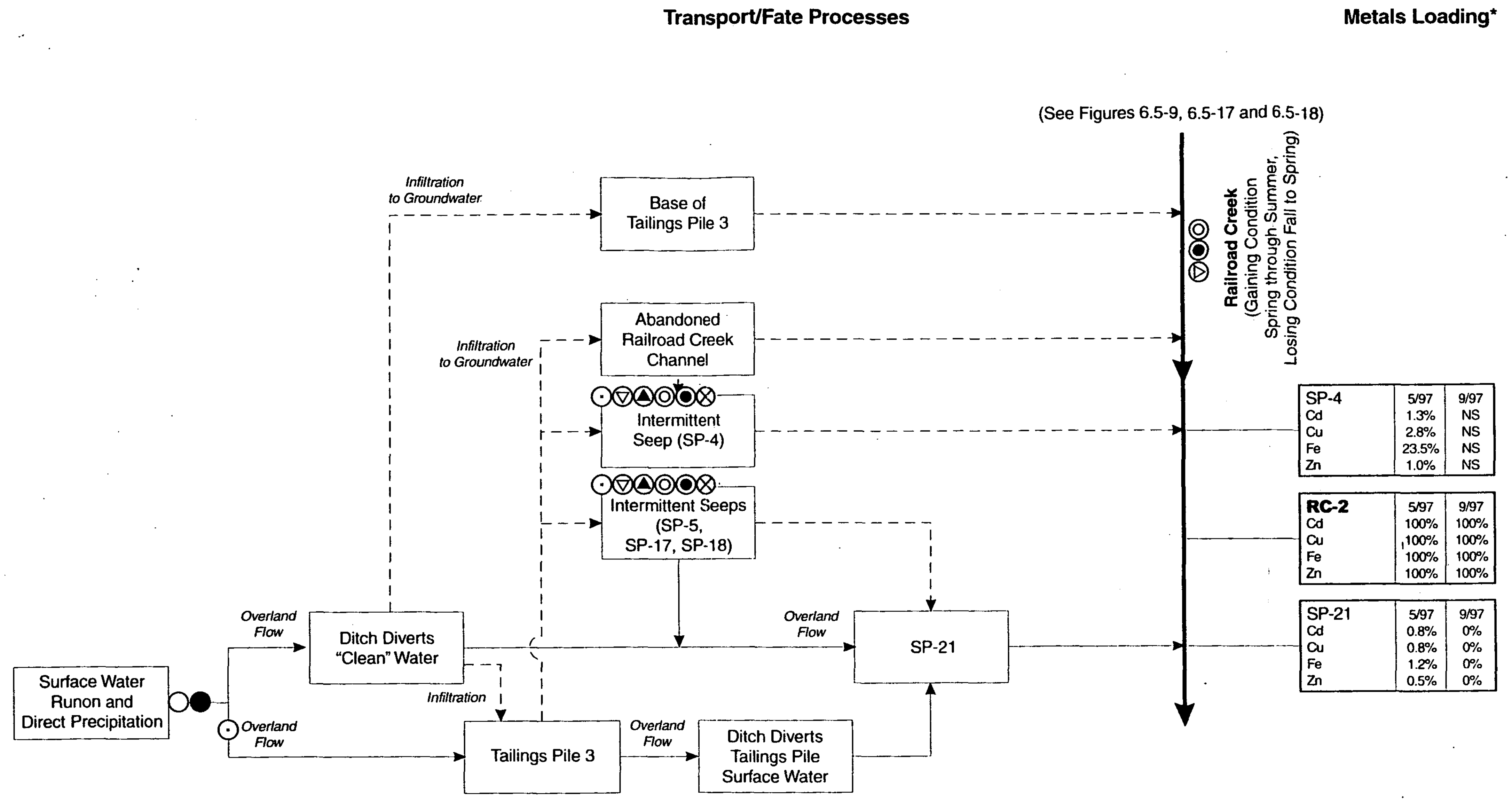
17693b70.CDR



SP-4	5/97	9/97
Cd	1.3%	NS
Cu	2.8%	NS
Fe	23.5%	NS
Zn	1.0%	NS

RC-2	5/97	9/97
Cd	100%	100%
Cu	100%	100%
Fe	100%	100%
Zn	100%	100%

SP-21	5/97	9/97
Cd	0.8%	0%
Cu	0.8%	0%
Fe	1.2%	0%
Zn	0.5%	0%

* Note:
Metals loading based on RC-2 concentrations. Bold reflects Railroad Creek sampling stations where cumulative loads are presented.

○ Acidity Addition
● Salt Addition
⊕ Alkalinity Addition
◎ Adsorption
◉ pH Buffering
⊙ Eh Buffering
▲ Co-precipitation
▽ Precipitation
⊗ Efflorescence

Figure 6.5-19

TAILINGS PILE 3
CONCEPTUAL TRANSPORT/FATE PROCESSES

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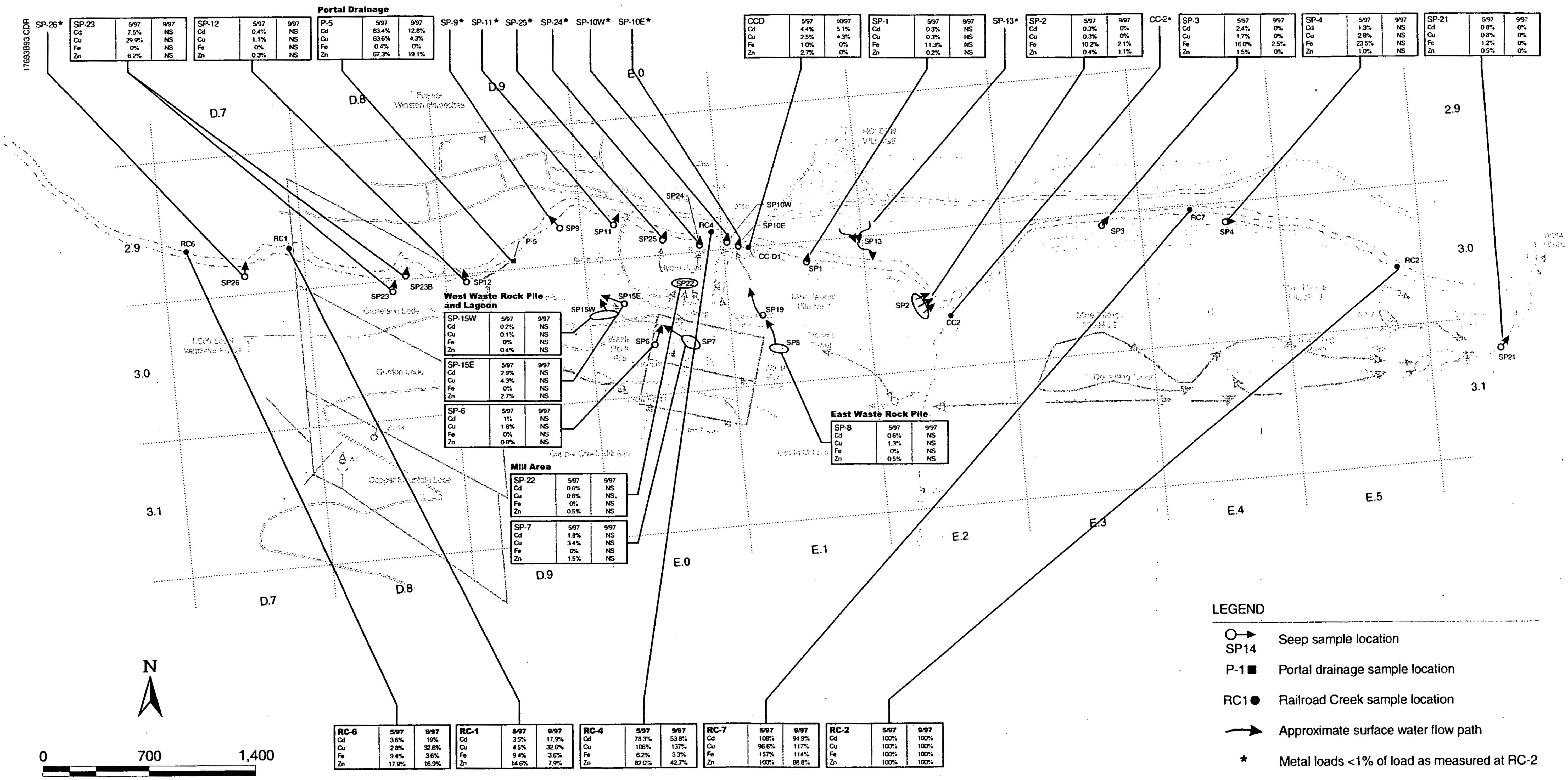

Portal Drainage

SP-23	5/97	9/97
Cd	7.5%	NS
Cu	29.9%	NS
Fe	0%	NS
Zn	6.2%	NS

SP-12	5/97	9/97
Cd	0.4%	NS
Cu	1.1%	NS
Fe	0%	NS
Zn	0.3%	NS

P-5	5/97	9/97
Cd	63.4%	12.8%
Cu	63.6%	4.3%
Fe	0.4%	0%
Zn	67.3%	19.1%

CCD	5/97	10/97
Cd	4.4%	5.1%
Cu	2.5%	4.3%
Fe	1.0%	0%
Zn	2.7%	0%

SP-1	5/97	9/97
Cd	0.3%	NS
Cu	0.3%	NS
Fe	11.3%	NS
Zn	0.2%	NS

SP-2	5/97	9/97
Cd	0.3%	0%
Cu	0.3%	0%
Fe	10.2%	2.1%
Zn	0.4%	1.1%

SP-3	5/97	9/97
Cd	2.4%	0%
Cu	1.7%	0%
Fe	16.0%	2.5%
Zn	1.5%	0%

SP-4	5/97	9/97
Cd	1.3%	NS
Cu	2.8%	NS
Fe	23.5%	NS
Zn	1.0%	NS

SP-21	5/97	9/97
Cd	0.8%	0%
Cu	0.8%	0%
Fe	1.2%	0%
Zn	0.5%	0%

West Waste Rock Pile and Lagoon

SP-15W	5/97	9/97
Cd	0.2%	NS
Cu	0.1%	NS
Fe	0%	NS
Zn	0.4%	NS

SP-15E	5/97	9/97
Cd	2.9%	NS
Cu	4.3%	NS
Fe	0%	NS
Zn	2.7%	NS

SP-6	5/97	9/97
Cd	1%	NS
Cu	1.6%	NS
Fe	0%	NS
Zn	0.8%	NS

Mill Area

SP-22	5/97	9/97
Cd	0.6%	NS
Cu	0.6%	NS.
Fe	0%	NS
Zn	0.5%	NS

SP-7	5/97	9/97
Cd	1.8%	NS
Cu	3.4%	NS
Fe	0%	NS
Zn	1.5%	NS

East Waste Rock Pile

SP-8	5/97	9/97
Cd	0.6%	NS
Cu	1.3%	NS
Fe	0%	NS
Zn	0.5%	NS

RC-6	**5/97**	**9/97**
Cd	3.6%	19%
Cu	2.8%	32.6%
Fe	9.4%	3.6%
Zn	17.9%	16.9%

RC-1	**5/97**	**9/97**
Cd	3.5%	17.9%
Cu	4.5%	32.6%
Fe	9.4%	3.6%
Zn	14.6%	7.9%

RC-4	**5/97**	**9/97**
Cd	78.3%	53.8%
Cu	106%	137%
Fe	6.2%	3.3%
Zn	82.0%	42.7%

RC-7	**5/97**	**9/97**
Cd	108%	94.9%
Cu	96.6%	117%
Fe	157%	114%
Zn	100%	88.8%

RC-2	**5/97**	**9/97**
Cd	100%	100%
Cu	100%	100%
Fe	100%	100%
Zn	100%	100%

LEGEND

○→ SP14	Seep sample location
P-1 ■	Portal drainage sample location
RC1 ●	Railroad Creek sample location
→	Approximate surface water flow path
*	Metal loads <1% of load as measured at RC-2
NS	Not sampled (no measurable flow)

NOTES:

Seep (SP) and portal loading is point source contribution to Railroad Creek as compared to RC-2.

Railroad Creek loading is representative of cumulative load.

Loading balance data are provided in Section 6.0 of the report.

SOURCE: ORB, 1975

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Figure 6.5-20

LOADING OF SELECT METALS IN RAILROAD CREEK - SITE

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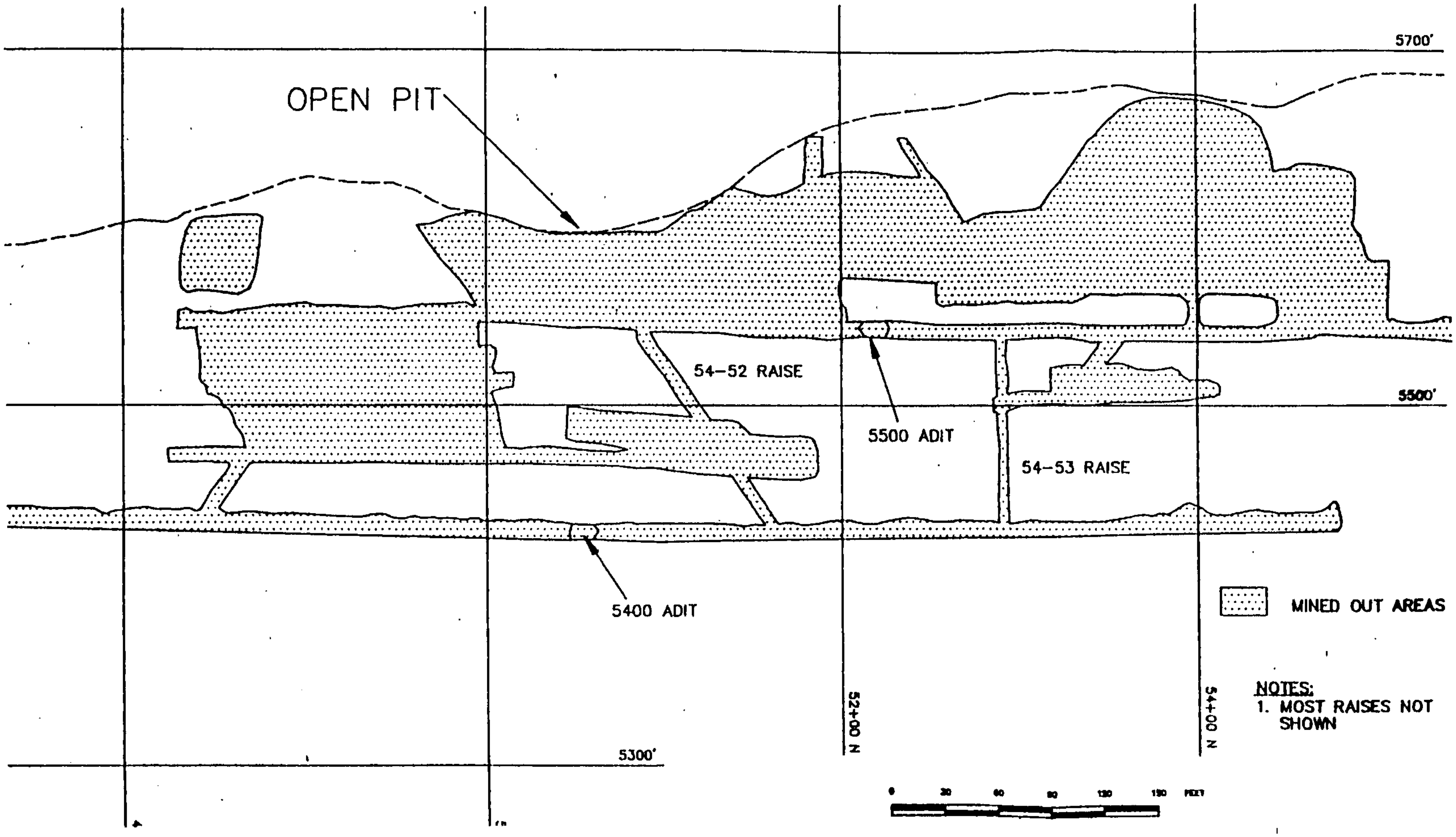

SOURCE: SRK

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Figure 6.7-1

CROSS SECTION OF BAKER MINE

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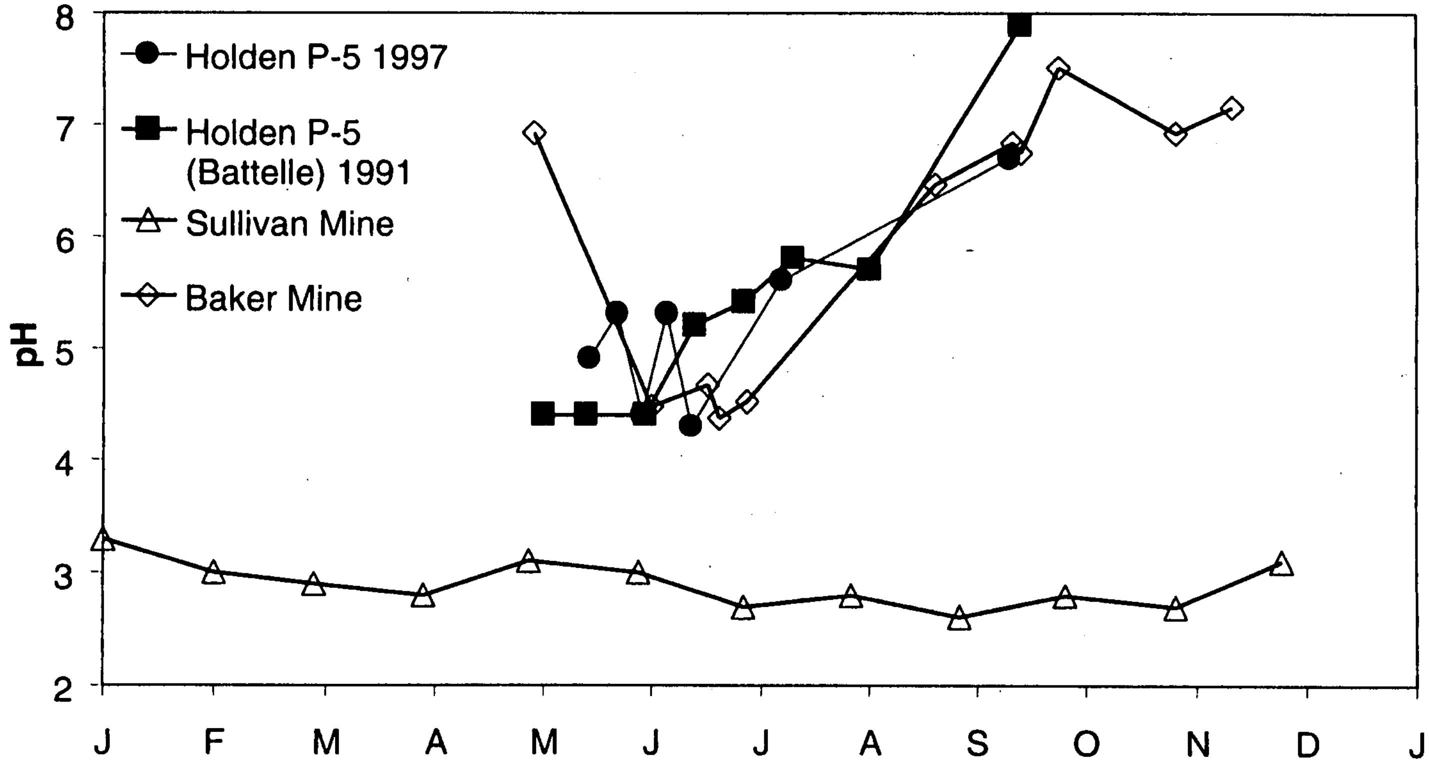

SOURCE: SRK

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Figure 6.7-2

PORTAL DISCHARGE pH FROM SELECTED MINES

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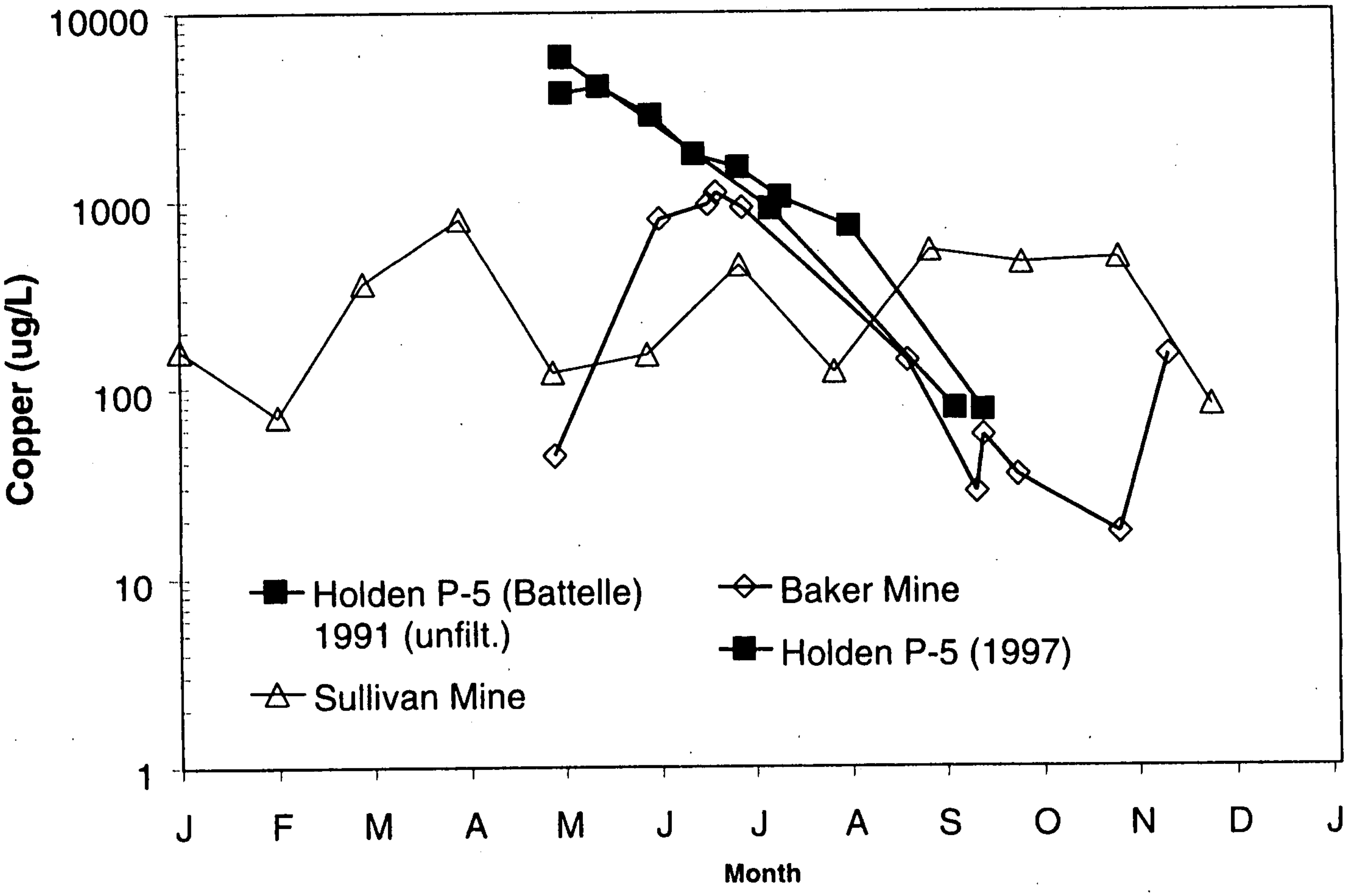

SOURCE: SRK

Figure 6.7-3

COPPER DISCHARGE CONCENTRATIONS FROM SELECTED MINES

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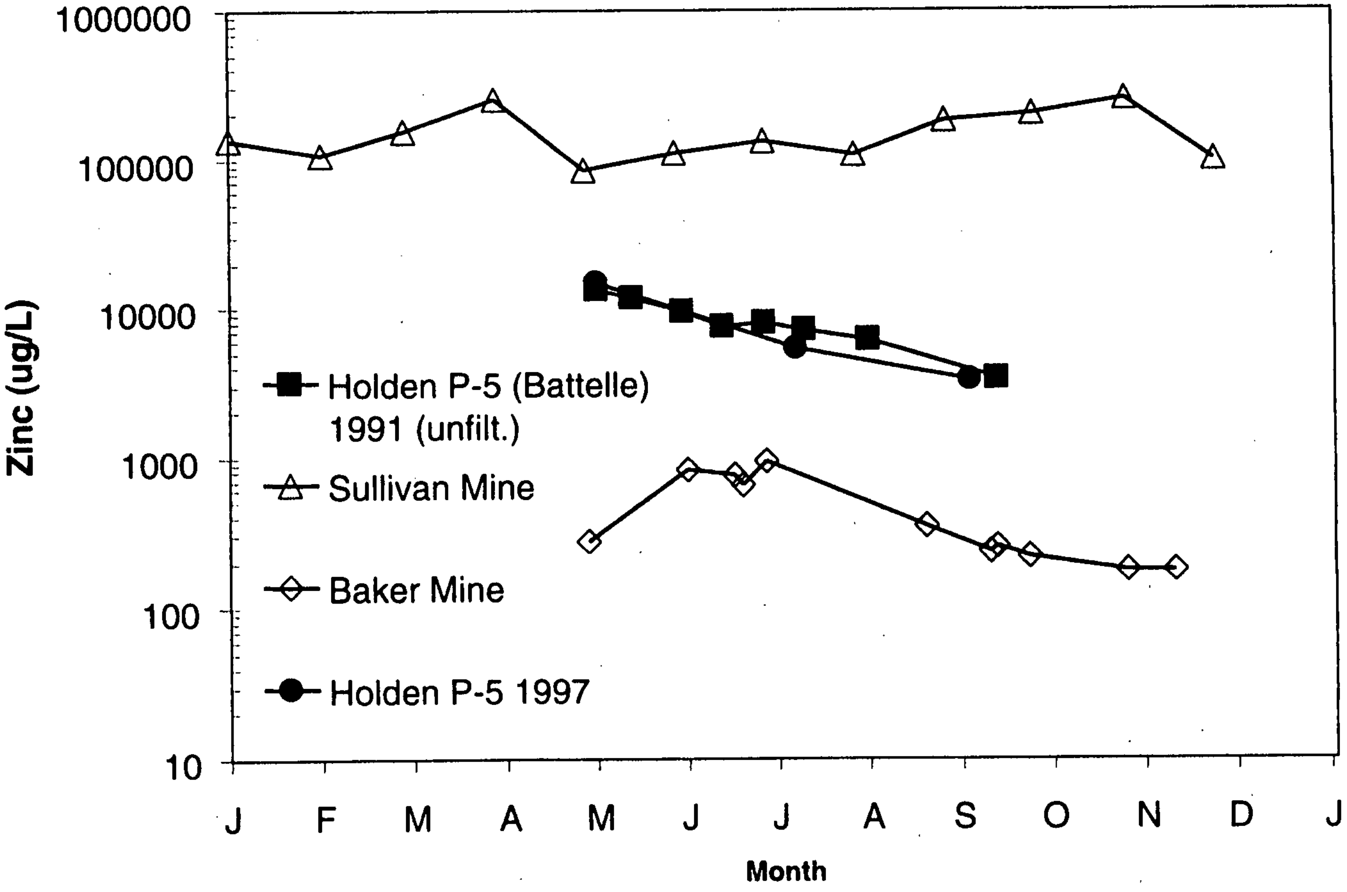

SOURCE: SRK

Figure 6.7-4

ZINC DISCHARGE CONCENTRATIONS FROM SELECTED MINES

6.0 TRANSPORT AND FATE OF COMPOUNDS OF POTENTIAL CONCERN

Most hard rock metal mines, like the Holden Mine, involve excavation and processing of ore rock to extract useful metals (e.g., copper and zinc) contained in minerals. The minerals may be smelted onsite to produce the metals, or, as in the case of the Holden Mine, the minerals are smelted off-site. As it is not practical to recover all the minerals (particularly those containing iron), non-recovered minerals remain onsite in: (1) the walls of the excavations (mine openings); (2) in rock removed to access the ore (waste rock); and (3) in residues remaining from the processing of ore (tailings).

The metal-containing minerals are formed under conditions in the earth's crust that are different than at the surface. Some differences include, pressure and temperature (both greater in the crust), and water and oxygen abundance (both greater at the surface due to exposure to the atmosphere). Because of these differences, the minerals remaining on a site after mining are usually unstable in the atmosphere and begin to breakdown almost immediately, releasing the metals they contain to flowing water, if present. An analogue for the process is the transformation of iron to rust, which happens because iron is unstable in the atmosphere; water flowing over the rust will contain iron.

Therefore, water flowing through mine sites very often contains metals reflecting the chemical instability of the rock. These waters are often dissimilar from natural waters because contact with the minerals as described above modifies the water chemistry. The mine waters may be acidic and contain relatively high concentrations of dissolved sulfur. As the waters flow away from a mine, waste rock, or tailings, the metals contained in the water can be removed by processes such as aeration, contact with acid neutralizing rock, and mixing with natural acid-neutralizing waters.

Understanding these processes as they apply specifically to the Holden Mine Site is critical to evaluating the sources of water quality impacts observed at the site and in Railroad Creek, and the options and benefits of remediation. The purpose of Section 6, therefore, is to: (1) describe the processes controlling release of metals from Site sources; (2) how metals are immobilized before they enter Railroad Creek; and (3) the processes occurring when waters from the Site mix with Railroad Creek (Figure 6.1-1).

This section has been structured to develop the current understanding of the processes occurring at the Holden Mine Site and how these processes impact the quality of surface water and groundwater at the site and in Railroad Creek.

Subsection 6.1 summarizes findings on Site conditions presented in previous sections of the report and provides some new information to give context to the subsequent discussion of processes.

Subsequent sections describe the chemical interpretation of processes at the Site.

Subsection 6.2 describes specific methods used to interpret chemical processes at the Site.

Subsection 6.3 is a general introduction to chemical processes occurring when reactive minerals are exposed to weathering by the atmosphere, and processes by which metals are removed.

Subsection 6.4 presents general Site wide evidence for the processes described in Subsection 6.3 and reduces the variations in water chemistry to mechanisms that are common to the whole Site.

Subsection 6.5 presents variations in the processes as they apply to the different components of the Site.

Subsection 6.6 discusses impacts to Railroad Creek and presents a mass balance for the chemical loads to determine if chemical loads can be accounted for by the known sources.

Subsection 6.7 compares Site with two other similar mine sites to determine if processes at the Holden Mine resemble processes elsewhere in similar environmental settings.

Subsection 6.8 discusses the formation of flocculent and ferricrete in Railroad Creek and the downstream transport of flocculent.

Subsection 6.9 discusses the metals data and transport mechanisms for sediment in Railroad Creek.

Subsection 6.10 provides conclusions for Section 6.

To assist in better understanding the Site conditions, Table 6.0-1 has been prepared which presents a key of Site features and media sampling/data collection locations as it relates to Figure 6.1-1a.

6.1 SITE CONDITIONS

6.1.1 Bedrock Geology and Mineralogy

Bedrock mineralogy is the underlying fundamental control on mine site water geochemistry. This section summarizes the mineralogy of the host rocks and ore deposit at the Site, as discussed in Section 4.2.3.

6.1.1.1 Host Rocks

The Holden Mine assemblage, which is the regional host for the Holden Mine deposit is dominated by hornblende bearing rocks that include amphibolite, hornblende gneiss, and hornblende-biotite schist. Calc-silicate rock, leucocratic gneiss, and plagioclase-biotite schist are less abundant constituents, and marble, pelitic schist, and metaconglomerate occur locally (Dragovich and Derkey, 1994). This latter assemblage includes the Martin Ridge and Buckskin schists, and the Fernow Gneiss of Youngberg and Wilson (1952).

The deposit itself is hosted by the Buckskin schist which is a quartz amphibole schist sequence, with at least two horizons of intermittent marble beds and calcareous schists (Youngberg and Wilson, 1952). Typical specimens have the following composition (Dubois, 1954):

- Layers of almost pure quartz
- Biotite-rich layers of 15 percent quartz ($SiO2$), 45 percent plagioclase ($NaAlSiO3O8$ to $CaAl2Si2O8$), 30 percent biotite ($K(Mg,Fe)3(AlSi3O10)(OH)2$), and 10 percent hornblende (($(Ca,Na)2\text{-}3(Mg,Fe,Al)5Si6(Si,Al)2O22(OH)2$ and diopside ($CaMgSi2O6$)

- Quartz-rich layers of 40 percent quartz, 30 percent plagioclase, 20 percent diopside, 4 percent hornblende, 2 percent sphene ($CaTiO(SiO4)$) and 2 percent biotite

In the vicinity of the mineralized zone, the amphibole is altered to a black biotite, with local chlorite ($(Mg,Fe)_3(Si,Al)_4O_{10}(OH)_2.(Mg,Fe)_3(OH)_6$) and sericite ($KAl_2(AlSi_3O_{10})(OH)_2$) alteration, and additional amounts of quartz and sulfides. The increase in the biotite is usually accompanied by a decrease in the lime-silicate (e.g., diopside) content.

6.1.1.2 Ore Deposit

Geologists at the Holden Mine originally classified the ore deposit as a vein-type deposit formed in a shear zone (Youngberg and Wilson, 1952). However, it has recently been re-classified as a metamorphosed Kuroko-type VMS deposit (Dragovich and Derkey, 1994). The ore zone is interpreted to be located within the limb of a large, northwest-trending, overturned, isoclinal fold.

Three distinct zones of mineralization, based on sulfide minerals can be distinguished (Dragovich and Derkey, 1994):

1. The "original footwall sulfide zone," contains pyrrhotite ($Fe_{1-x}S$), pyrite (FeS_2), biotite and sericite. Pyrite and pyrrhotite in this zone is largely disseminated, and the contact with the original footwall is diffuse or irregular.

2. The "original footwall ore zone" which contains pyrrhotite, chalcopyrite ($CuFeS_2$) and gold (Au) mineralization. This is partially interbedded with the footwall sulfide zone. Economically, it was the most important unit at the mine.

3. The "hanging wall ore zone," which contains pyrite and sphalerite (ZnS), with lesser amounts of pyrrhotite, chalcopyrite and galena (PbS). Over 50 percent of the mineralization in this zone is present as sulfides. The contact with the original hanging wall rocks is sharp.

Because this sequence is overturned, the "original footwall" is now the structural hanging wall.

Other minerals identified in the deposit include: magnetite (Fe_3O_4), quartz, molybdenite (MoS_2), calcite ($CaCO_3$), bournonite ($PbCuSbS_3$), silver (Ag), and possibly pitchblende (UO_2) (Youngberg and Wilson, 1952).

Post-ore intrusive "diabase" dykes cross the ore zone in several locations, varying from approximately twenty-four percent abundance at the 2125 level to almost fifty percent at the 2500 level (Ebbutt, 1956) (Figure 6.1-2). The dykes have a well-developed igneous texture, and are comprised of quartz-diorite. Typical specimens are light colored, with a porphyritic medium grained texture. They contain 10 percent quartz, 70 percent plagioclase, 10 percent hornblende, and 5 percent chlorite, with minor biotite, apatite ($Ca_5(PO_4)_3(OH,F,Cl)$), sphene, sericite and magnetite. They form sharp contacts with their host rocks (Dubois, 1954). The intrusives appear to be related to the late-Triassic Marblemount belt (Dragovich and Derkey, 1994). The dykes represent an important waste component of the ore and therefore the minerals are expected to be present in the tailings.

Other geologic units in the deposit area include:

- An anhydrite ($CaSO_4$) lens which was mapped for 120 feet along strike, immediately overlying the original hanging wall. The anhydride was described as a light gray, purple tinged mass, banded with the amphibolite host.
- Occasional bands of marble and lime-silicate granulites, with a composition of 5 percent quartz, 30 percent plagioclase, 30 percent diopside, 20 percent grossularite ($Ca3Al_2Si_3O_{12}$), and 10 percent calcite, with minor wollastonite ($CaSiO_3$).

6.1.1.3 Occurrence of Significant Sulfide Minerals

The primary sulfide minerals in the Holden Mine ore deposit occur in the following forms:

- Pyrite – abundant in mineralized zones, and as disseminations in the argillites. In the ore zone, it is highly brecciated, with corroded edges. Outside of the ore zone, cubes of pyrite are "not uncommon."
- Pyrrhotite – Abundant within ore zone, generally massive in form.
- Sphalerite – gradational phases between disseminations and massive replacements in the footwall of the ore zone. Sphalerite has a high iron content, and approaches marmatite (Zn-FeS) in composition. It is concentrated in the east-end of the mine.
- Chalcopyrite – Concentrated in the central part of the mineralized zone, varying from massive to disseminated. Replaces and/or heals fractures in pyrite and pyrrhotite.

6.1.1.4 Conclusion

The conclusions from the review of mineralogical information are:

- The dominant sulfide minerals present at the Holden Mine are iron-based (pyrite, pyrrhotite). Weathering of these minerals is a primary mechanism of the Holden Mine Site water chemistry.
- The dominant silicates are aluminum-based (plagioclase and biotite).
- Carbonate minerals are rare at the Holden Mine.
- Non-sulfide mineralogy of the tailings is expected to be dominated by minerals contained in the diabase dykes because the dykes intersect the ore zone, whereas the mine wall rocks and waste rock are more likely to be dominated by biotite schist.

6.1.2 Mineralogy of Secondary Minerals

Minerals (i.e., crystalline substances) and amorphous solids produced by weathering processes are visually apparent throughout the Holden Mine Site. These include ubiquitous orange-brown iron-stains on waste rock and tailings indicating iron oxides and white precipitates observed in the 1500-level main portal drainage (Figures 6.1-1 and 6.1-1a). The latter is believed to be amorphous aluminum hydroxide. Green (copper) stain is also present on marble waste rock in the two waste rock piles near the 1500-level main portal and in the abandoned mill building.

Crystalline crusts were observed in the mill building and where seepage emerges along the toes of the tailings piles. The USGS used X-Ray Diffraction (XRD) to determine the types of minerals present in 1994 (personal communication with Jim Kilburn, 1999) (Table 6.1-1). All minerals were identified to be sulfates in combination with aluminum, iron, copper, potassium, sodium, magnesium, zinc, and calcium. These minerals are not unique to the Holden Mine and have been documented at many other mine sites.

6.1.3 Hydrology/Hydrogeology

This section summarizes the hydrology/hydrogeology discussed in Sections 4.3 and 4.4, and describes a general conceptual site transport pathway model for the Site. The model serves as the basis for interpretation of surface water and groundwater PCOC discharge from Site features as they relate to water quality in Railroad Creek.

6.1.3.1 General Transport Pathway Model

The Site receives surface water and groundwater flow from upgradient sources that include snowmelt and rainfall runoff from adjacent valley sides and from direct precipitation as either rain or snow. Groundwater within the Railroad Creek valley and at the Site exists as shallow and deeper isolated occurrences. Shallow groundwater occurs near the base of the tailings piles and within a relatively thin near-surface alluvium/reworked glacial till (reworked sand and gravel) that is perched above less permeable glacial till. Site groundwater within these units discharges as seeps or as diffuse groundwater to Railroad Creek. The alluvium/reworked till unit is considered to be moderately permeable with estimated hydraulic conductivities ranging from 9×10^{-4} to 5.3×10^{-2} cm/sec. The underlying glacial till unit is a relatively low permeability material that is assumed to separate the groundwater that occurs in the bedrock fractures from the groundwater that occurs in the overlying alluvium/reworked till. The underlying glacial till unit may contain limited localized occurrences of water. The glacial till unit is estimated to have lower permeabilities than the alluvium/reworked till unit, with hydraulic conductivities ranging from 10^{-8} to 10^{-10} cm/sec.

The interrelationship between Site groundwater and surface water is the focus of the transport pathway discussion and includes the following mechanisms: (1) surface water overland flow and infiltration, (2) seepage as overland flow, (3) seepage as direct groundwater discharge to Railroad Creek, and (4) groundwater discharge as baseflow into the bed of Railroad Creek. Other transport pathways such as air transport of tailings or transport of tailings directly into Railroad Creek as a result of bank erosion are considered to be a minor influence on water quality in Railroad Creek.

In general, upslope surface water from direct precipitation and snow melt run-on infiltrates and recharges groundwater through fractures within the bedrock found along the valley sidewalls and through the pore spaces of the surficial deposits including the alluvium/reworked till unit, where present. Upslope surface water run-on results in overland flow and infiltration across and through Site features and eventually discharges to Railroad Creek as overland flow or as diffuse groundwater. Baseflow to Railroad Creek is provided by diffuse groundwater flow which likely flows in alluvium underlying the creek.

Seeps discharges from the surficial materials at the Site at points where local groundwater elevations are higher than ground elevations. Seepage may (1) discharge directly into Railroad Creek, (2) flow overland to Railroad Creek, and (3) flow overland and reinfiltrate. In the spring, most water enters the Site from snowmelt on the adjacent valley slopes, so that primary groundwater flow directions are perpendicular to the trend of Railroad Creek. Groundwater discharge to Railroad Creek decreases over the summer. Through the summer months as groundwater levels decrease, groundwater beneath the Site begins to flow downstream to the east rather than directly toward Railroad Creek. The flow loss occurs because water levels in Railroad Creek are above water levels in the alluvial aquifer near the eastern portion of the site. The area immediately east of tailings pile 3 replenishes groundwater storage and is assumed to discharge back to Railroad Creek along the reach in and near SP-21, immediately east of RC-2. This assumption is based on the observed exposure of bedrock on the south bank of Railroad Creek, immediately downstream of SP-21. The presence of bedrock, and absence of alluvial material, indicates that the groundwater likely becomes surface water (Railroad Creek) at this location. Seep discharge is largest in the spring and essentially stops by late summer, indicating snowmelt as the primary source of seep flow.

6.1.3.2 West Side of Site

The west side of the Site includes the Honeymoon Heights drainage area, mine area, underground mine workings, the east and west waste rock piles, mill building area, and the maintenance yard (Figures 6.1-1 and 6.1-1a). Some of the upslope run-on probably enters near-surface discontinuities in bedrock south and upslope of the Site and flows downward through bedrock fractures, through abandoned stopes and mineralized (unmined) portions of the underground mine and contacts residual mineralization on rock faces of the stopes and tunnels as shown on Figures 6.1-2 and 6.1-2a. The water emerges as either surface water overland flow (i.e., 1500-level main portal drainage) and can reinfiltrate as seeps that emerge as overland flow and/or as diffuse groundwater discharge to Railroad Creek.

Some of the overland flow from upslope run-on also moves across the Honeymoon Heights waste rock piles (800 and 1100 level) or the mill area, and the maintenance yard and then travels downslope to other drainage features such as the lagoon and other miscellaneous drainage channels (Figures 6.1-1a and 6.1-2b). Not all groundwater comes into contact with the underground mine workings. Some portion of groundwater flow from the west side of the site is assumed to be diverted into the abandoned Railroad Creek channel and also flows beneath the tailings piles.

6.1.3.3 East Side of Site

The east side of the Site includes tailings piles 1, 2, and 3 (Figure 6.1-1a). Upslope surface water overland flow from direct precipitation and snow melt is transported to Copper Creek and also infiltrates across and through tailings piles 1, 2, and 3. Surface water is further transported to other drainage features including ditches that divert water to Copper Creek, an abandoned decant tower near the southern margin of tailings pile 1, the Copper Creek diversion, and the sauna dipping pool. Groundwater recharge from upslope run-on and infiltration occurs through the fractures within the bedrock found along the valley sidewalls and in the alluvium/reworked till, where present (Figures 6.1-3 and 6.1-3a). Infiltration occurs through the tailings piles from a combination of sources including upslope run-on as well as snow-melt and direct precipitation on the tailings piles. Infiltration through these features contributes recharge to groundwater in the alluvium/reworked till beneath the tailings piles which eventually discharges as seeps and groundwater baseflow to Railroad Creek. The discharge rate decreases after the spring snow melt period. Some portion of groundwater flow from the west portion of the site is assumed to be diverted into the abandoned Railroad Creek channel and also flows beneath the tailings piles.

Evidence of significant surface and channel erosion in Site drainages was not observed and therefore, there does not appear to be a direct water borne pathway for significant quantities of metal-containing sediments to enter Railroad Creek from the Site. Under extreme flow events, bank erosion in Railroad Creek and channel shifting with subsequent erosion of tailings in Copper Creek can potentially transport tailings into Railroad Creek. Channel scour and re-suspension of flocculent and fine particulates originating as iron oxide (and other) metal precipitates, and which settle into the Railroad Creek streambed, is also a transport mechanism which can carry metals downstream. Although large channel scour events in Railroad Creek which transport bed material long distances downstream are not common (due to the size of the dominant bed material and bed armoring), transport of iron-oxides as fine suspended material was observed several times during high flow events in 1997.

6.2 GEOCHEMISTRY INTERPRETATION TOOLS

Interaction of minerals with the atmosphere and the formation of new minerals control the chemistry of waters originating from the Site. A critical component of the geochemical interpretation is therefore the determination of which minerals in the rocks are controlling the original source of the water, and which new minerals are forming and removing metals from solution. These two groups of minerals are referred to as primary, indicating that they are present in the rocks, and secondary, indicating that they are formed when metals released from the primary minerals react with other dissolved or solid constituents. The first group does not include all minerals in the rocks because some minerals are inherently unreactive.

The following subsections describe the interpretative tools that were used to evaluate chemical processes occurring at the Site.

6.2.1 Contribution of Primary Minerals

Subsection 6.1.1 described the types of primary minerals reported to be present in the rocks within the Holden Mine. The processes that contribute the components of primary minerals to mine water chemistry are introduced below and described in more detail in Subsection 6.3.

The controlling process on water chemistry at the Site is the oxidation of iron sulfide (pyrite), summarized as:

$$FeS_2 + 15/4O_2 + 7/2H2O \rightarrow Fe(OH)_3 + 2SO_4^{2-} + 4H+ \qquad (6\text{-}1)$$

The acid (H^+) produced by this reaction, can then dissolve other minerals, for example, calcite:

$$2CaCO_3 + 4H^+ \rightarrow 2Ca^{2+} + 2H_2CO_3^{\circ} \qquad (6\text{-}2)$$

or, other more abundant minerals (for example, potassium feldspar):

$$4KAlSi_3O_8 + 4H+ + 28H_2O \rightarrow 4K+ + 4Al(OH)_3 + 12H_4SiO_4 \qquad (6\text{-}3)$$

It can be seen from reaction (6-1) that each mole of pyrite produces two moles of sulfate ion and four moles of hydrogen ions (representing acidity). Reactions (6-2) and (6-3) indicate that these four hydrogen ions then react with calcite and produce two ions of calcium or four ions of potassium. Therefore, if calcite were being dissolved, one ion of calcium or two ions of potassium would match one ion of sulfate. Comparison of the ratios of sulfate to other elements is used as a tool to understand which minerals may be contributing to mine water chemistry. Two different waters may have dissimilar concentrations of sulfate and other elements, but if the ratios are similar, a common source process is implied. In the above example, comparison of ratios of calcium to potassium would indicate the relative contributions of calcite and potassium feldspars to water chemistry.

6.2.2 Formation of Secondary Minerals

Subsection 6.1.2 also described the types of secondary minerals that have been observed within the Holden Mine (Table 6.1-1). These minerals are formed, in part, when the water can no longer contain the components that form the mineral. The simplest example is the formation of sodium chloride crystals when a solution of common salt is heated, causing water to be evaporated. The evaporation causes the concentrations of sodium and chloride to increase in the water. Eventually, the laws of thermodynamics dictate that salt crystals will form as the concentrations increase. As the crystals form, sodium and chloride are removed from the water and the concentrations of sodium and chloride in the water remain steady.

At hard rock metal mine sites, the formation of secondary minerals from water can be predicted or confirmed using the same principals. It is useful to predict the precipitation of secondary minerals because it indicates where metals are being removed from solution, and how these minerals may be preventing pH from increasing. Increase in pH allows heavy metals to precipitate. Further discussion of secondary mineral formation is provided in Subsection 6.3.3.

Several models are available to evaluate water chemistry for evidence of formation of secondary minerals. These models include MINTEQA2, WATEQF, PHREEQC and EQ3. The differences between the models include the database of elements and minerals, the ability to model mixing of waters (PHREEQC), and the ability to model saline solutions (EQ3). For this project, the MINTEQA2 (Allison et al. 1991) model was selected but with the database developed by Nordstrom et al. (1990). The reasons for this selection are as follows:

- The model was developed by the US Environmental Protection Agency and is probably the most widely used of its type.
- The Nordstrom et al. (1990) database is larger than the original MINTEQA2 database.
- Individual waters rather than mixed waters are evaluated.
- The waters at the Holden Mine are relatively dilute and do not require the use of EQ3.

The inputs to MINTEQA2 (and all comparable models) are the dissolved concentrations of all analyzed parameters, and other conditions such as temperature, pH, Eh and gas concentrations. The outputs from the model are:

- Ion (charge) balances (expressed as Cations-Anions/Total Ions, in meq/L)
- Mass distribution of dissolved ions and ion complexes

- Predicted saturation indices (SI) for any mineral possibly in equilibrium with the solution. If log(SI) is greater than 0, the solution is defined as saturated with respect to that mineral, meaning that the mineral may be in contact with the solution or precipitating. If log(SI)<0, the solution is said to be undersaturated meaning that the mineral is not in contact with the solution and would dissolve if present.

Optionally, minerals can be specified as "infinite solids" to determine the ion concentrations that would be present in solution. The model causes infinite solids to be saturated log(SI)=0 and therefore forces other constituents in solution to be in equilibrium with the solid. This is useful to assess the effect of the water coming into contact with the solid.

The model does not take into account kinetic constraints, hence over-saturation may be indicated, but the activation energy required to form the solid is greater than the energy available. The model often reports over-saturation with respect to highly crystalline silicates. The model is most useful in predicting the formation of amorphous solids, and soluble secondary minerals such as sulfates and carbonates.

Specifics of the approach used for the Holden Mine data included:

- The pH of the solutions was specified using measured values.
- Measured Eh (if available) was specified and used to define redox couples for Fe^{2+}/Fe^{3+} and Cu^{+}/Cu^{2+}. Eh sensitive modeling results were interpreted cautiously due to inherent uncertainty in field Eh measurement.
- Typical waters representing spring and fall conditions as measured during the RI were input into the model.
- Adsorption and co-precipitation were not modeled.

The modeling was used for the Site specifically to confirm formation of amorphous and crystalline solids from surface waters downstream of sources and how this process controls pH to specific levels in different parts of the Site. In some cases, the modeling also confirmed the formation of some of the efflorescent salts indicated in Table 6.1-1.

6.3 GENERAL CHEMICAL PROCESSES OPERATING AT THE HOLDEN MINE SITE

6.3.1 Chemical Rock Weathering Processes and Leaching of Metals

"Weathering" refers to the breakdown of rocks by atmospheric processes. It includes both physical and chemical breakdown. Chemical breakdown results in the release of metals to water and the formation of new minerals. At hard rock metal mine sites, important processes are:

- Sulfide mineral oxidation that produces acid and releases heavy metals
- Dissolution of other sulfide minerals by the strongly acidic solutions produced
- Consumption of acid by reaction with alkaline minerals such as carbonates and silicates

These processes are described further in the following subsections.

6.3.1.1 Sulfide Mineral Oxidation

The dominant source process controlling release of inorganic constituents at the Holden Mine is expected to be the oxidation of iron sulfide minerals, which releases oxidized iron and acidity (Figure 6.3-1). Oxygen is the typical oxidizing agent due to its abundance in the atmosphere. However, it is also a very significant control on the rate of weathering of sulfide minerals. It can limit the rate of weathering if it cannot be re-supplied at a greater rate than the maximum rate of oxidation. The role of oxygen supply is discussed further in Subsection 6.5.1 under the description of the chemical processes in the individual sources.

The overall process is summarized by Equation (6-1) above, but it is usually described as occurring in three steps:

- *Oxidation of sulfide to sulfate.* The first step results in the formation of soluble iron(II) sulfate weathering products on the surfaces of the iron sulfide mineral (Figure 6.3-1). The types of mineral formed depend on composition of groundwaters in contact with the mineral and the overall humidity. The reaction is catalyzed by sulfur-oxidizing bacteria (for example, *thiobacilli*). Acidity formed may be entrained in the initial oxidation product or dissolved in groundwaters in contact with the sulfide minerals. In some cases, oxidation of sulfur to sulfate may be incomplete resulting in formation of elemental sulfur. The overall reaction can be summarized as:

$$FeS_2 + 7/2O_2 + H_2O \rightarrow Fe^{2+} + 2SO_4^{2-} + 2H^+ \qquad (6\text{-}4)$$

- *Oxidation of iron(II) to iron(III).* The second stage is catalyzed by iron-oxidizing bacteria (e.g., *Thiobacillus ferrooxidans*), and is the rate-determining step for the complete oxidation of iron sulfide. The oxidation may occur in minerals containing iron(II) or by oxidation of groundwaters containing iron(II). The process consumes acidity:

$$Fe^{2+} + \tfrac{1}{4}O_2 + H^+ \rightarrow Fe^{3+} + \tfrac{1}{2}H_2O \qquad (6\text{-}5)$$

- *Hydrolysis of iron(III).* The final stage involves formation of ferric hydroxide. The reaction is rapid and produces further acidity:

$$Fe^{3+} + 3H_2O \rightarrow Fe(OH)_3 + 3H^+ \qquad (6\text{-}6)$$

The final step only occurs at $pH>3$. Under stronger acidic conditions ($pH<3$), ferric hydroxide does not precipitate and iron(III) remains in solution. The resulting strongly acidic oxidized solution is capable of oxidizing pyrite directly without oxygen:

$$FeS_2 + 14Fe^{3+} + 8H_2O \rightarrow 15Fe^{2+} + 2SO_4^{2-} + 16H^+ \qquad (6\text{-}7)$$

This reaction is capable of sustaining very low pHs (much less than 3) and does not require bacteria as a catalyst. However, the pH must be less than 3 to allow Fe^{3+} to be available as an oxidant.

Another iron sulfide mineral at the Holden Mine is pyrrhotite ($Fe_{1-x}S$). This mineral is commonly more reactive than pyrite (MEND 1991) but the reaction products are similar. Sulfur may be incompletely oxidized to elemental sulfur rather than sulfate.

The dominant copper mineral at the Holden Mine is chalcopyrite. It oxidizes by similar processes, releasing acid, sulfate and copper to solution:

$$CuFeS_2 + 17/4O_2 + 5/2H_2O \dashrightarrow Fe(OH)_3 + Cu^{2+} + 2H^+ + 2SO_4^{2-} \qquad (6\text{-}8)$$

Chalcopyrite is less readily oxidized than pyrrhotite or pyrite (MEND 1991).

Like iron, copper will precipitate due to hydrolysis:

$$Cu^{2+} + 2H_2O \leftrightarrow Cu(OH)_2 + 2H^+ \qquad (6\text{-}9)$$

This reaction occurs most at a higher pH (~4.0) than iron and produces a precipitate.

6.3.1.2 Oxidative Dissolution

Oxidative dissolution refers to the breakdown of other minerals by oxidizing their individual components (Figure 6.3-2). It is an important mechanism for release of heavy metals from other types of sulfide minerals (at the Holden Mine, primarily sphalerite and chalcopyrite). These minerals may not oxidize rapidly when exposed to atmospheric oxygen alone but when exposed to the strongly acidic solutions generated by oxidation of pyrite can be oxidized by dissolved iron(III):

$$ZnS + 8Fe^{3+} + 4H_2O \rightarrow 8Fe^{2+} + Zn^{2+} + SO_4^{2-} + 8H^+ \qquad (6\text{-}10)$$

Sphalerite can also be oxidized directly by air:

$$ZnS + 2O_2 \rightarrow Zn^{2+} + SO_4^{2-} \qquad (6\text{-}11)$$

A third mechanism of oxidative dissolution occurs when two different minerals with different rest potentials are in contact and form an electrical cell with one mineral acting as the cathode and the other as the anode (Kwong, 1995). If sphalerite (Rest Potential –240 mV) is on contact with pyrite (630 mV), oxidation of sphalerite occurs preferentially, and pyrite is protected from oxidation. Sphalerite acts as the anode undergoing oxidation:

$$ZnS \rightarrow Zn^{2+} + S^o + 2e- \qquad (6\text{-}12)$$

This process only occurs in sulfide deposits where there is a strong electrical connection between sulfide grains.

6.3.1.3 Acid-Consuming Minerals

The water produced by weathering of sulfide minerals is typically acidic (pH<4), and contains elevated concentrations of sulfate and heavy metals (iron, copper and zinc).

The acid in the water can be removed by interaction of the solutions with other types of minerals, or by mixing of acidic solutions with waters containing dissolved alkalinity produced by contact with these minerals. An example is the buffering of acidity by contact with calcium carbonate minerals.. These control pH at between 6 and 8:

$$CaCO_3 + H^+ \leftrightarrow Ca^{2+} + HCO_3^- \qquad (6\text{-}13)$$

At the Holden Mine, carbonate minerals generally appear to be rare, but alumino-silicate minerals can potentially buffer acidity, primarily resulting in the release of aluminum, for example, reaction of the calcium end-member of plagioclase feldspar (anorthite):

$$CaAl_2Si_2O_8 + 8H^+ \rightarrow Ca^{2+} + 2Al^{3+} + 2H_4SiO_4^{\circ} \qquad (6\text{-}14)$$

The crystallinity of the silicates limits their reactivity. Framework silicates such as feldspars, have limited reactivity. Layer silicates (for example, chlorite, biotite and sericite) can be very effective buffers due to their weak crystalline structure. Bioite is a relatively abundant mineral at the Holden Mine. It consumes acidity, releasing magnesium, iron, aluminum and silica. Diopside, a relatively abundant mineral at the Holden Mine, also reacts with acid releasing calcium and magnesium.

The aluminum released when alumino-silicates dissolve in acid can be hydrolyzed to aluminum hydroxide, releasing acidity:

$$Al^{3+} + 3H_2O \leftrightarrow Al(OH)_3 + 3H^+ \qquad (6\text{-}15)$$

This buffer controls pH at between pH 4 and 5 and commonly results in the formation of pale precipitates in mine drainage (for example, the 1500-level main portal, P-1 discharge station). These precipitates are typically amorphous (non-crystalline) and incorporate other elements.

Ferric hydroxide also buffers acidity, though at a level considered undesirable because the pH of 3 to 3.5 is below the pH at which hydroxides of heavy metals such as copper will precipitate. The ferric hydroxide buffer reaction is:

$$Fe^{3+} + 3H_2O \leftrightarrow Fe(OH)_3 + 3H^+ \qquad (6\text{-}16)$$

6.3.2 Seasonal Leaching Effects

The above processes describe how acidity and metals are possibly released and neutralized by reaction with nearby minerals. An important component in these interactions is the rate and flow of water. If water flow is completely absent, the processes largely proceed in isolation. For example, sulfide minerals will oxidize producing soluble weathering products but the resulting acidity and metal load will remain stored on the mineral surface. Neutralizing minerals will also slowly weather but the alkalinity produced will not be available. This is often the case for mine workings and waste rock associated with hard rock metal mine sites since preferential flow paths (for example, along fractures in the bedrock within the underground mine) develop. The weathering products remain stored and do not influence leachate quality unless contacted by water from a storm event or flooding.

If water flow is available to dissolve weathering products on a mineral surface, then the rate of flow and flow variability become important considerations. At the Holden Mine, flow of water is highly variable and results in significant seasonal variations in water quality associated with the source areas. These variations are illustrated conceptually in Figure 6.3-3. The sequence is shown as beginning in summer because this typically represents the time when accumulation of weathering products on mineral surfaces begins after extensive leaching by melt-waters in the spring. Summer is typically a dry season when little water infiltrates onto the surfaces of sources except during rain-storms. Under these conditions, weathering products accumulate on the surfaces of sulfide minerals but are not leached. Seepage water quality under these conditions typically represents groundwater baseflow, with little or no contribution from surface water drainage.

In the fall, rainfall leads to infiltration of water on and into rock piles. The downward moving flow front dissolves weathering products that accumulated in the summer. The flow front contacts buffering minerals and pH increases. Since the water flow rate is relatively low and slow, conditions are optimal for raising pH by contact with weaker buffering minerals (such as silicates).

In the winter, the formation of snow-pack ties up the moisture and causes flow to decrease again, and weathering products again begin to accumulate on mineral surfaces.

Melting of the snowpack in spring leads to the release of relatively large volumes of water and thorough flushing (though never complete) of weathering products from mineral surfaces. The resulting solutions are acidic and contain high solute concentrations. Buffering minerals may be less effective in the spring than in the fall due to the inability to fully react with solute because the water is relatively fast moving. As the melt event proceeds, solute loads and concentrations both increase. However, as weathering products are leached, it is possible for concentrations and loads to gradually decrease. This may occur in thin relatively coarse deposits such as waste rock where leaching can be nearly complete and not constrained by solubility of secondary minerals.

6.3.3 Natural Metal Removal Processes

Weathering and leaching of mine workings, waste rock or tailings results in water with variable pH (depending on the degree of acid consumption) and elevated sulfate and metal concentrations. These leachates are produced in oxidizing to reducing environments by relatively slow moving groundwaters. Upon exiting the areas, the leachates are exposed to contact with an unlimited supply of oxygen, atmospheric carbon dioxide concentrations, and mixing with dilute and frequently alkaline waters. Since these conditions differ from those in which the leachates formed, the solution chemistry adjusts (equilibrates) to the new condition. The following sections discuss these re-equilibration processes and the effect they have on concentrations of heavy metals in solution.

The processes described include:

- Dilution.
- pH Control.
- Eh control.
- Efflorescence.

- Co-precipitation.
- Sorption.

6.3.3.1 Description of Processes

Dilution

During the mixing of waters of different origins, the mass of some chemical parameters in solution may be conserved due to the lack of processes resulting in loss from solution. The concentration in the mixed solution reflects that the total mass is constant but contained in a different volume of water. The resulting concentration, C, produced can be calculated from:

$$C = (C_A Q_A + C_B Q_B)/(Q_A + Q_B) \qquad (6\text{-}17)$$

The concentrations and water quantities for the two mixed solutions are C_A, C_B, and Q_A, Q_B, respectively. Conservation of mass allows the origin of mixed waters to be evaluated. It can also be used to evaluate the reliability of the water balance by performing a mass balance.

Chemical parameters for which the above calculation is reliable are referred to as "conservative." No parameters are conservative under all conditions since mixing may produce a change in pH or Eh (oxidation/reduction potential) that could conceivably cause precipitation. However, in the context of mining environments, some elements can be regarded as conservative. Under oxidizing, relatively dilute conditions, sulfate is conserved. Sulfate is non-conservative when an acid water containing high concentrations of sulfate mixes with a solution containing high concentrations of calcium. Hydrated calcium sulfate (or gypsum) is precipitated when both calcium and sulfate are removed from solution. Similarly, calcium is removed from solution, and is non-conservative. Calcium is even less conservative than sulfate because it is readily dissolved from a variety of common rock types containing carbonate. Magnesium also suffers from similar limitations to calcium except that its sulfate (epsomite) is more soluble than calcium sulfate and is less likely to be precipitated from solution containing high sulfate concentrations. It is also less common than calcium as a readily soluble constituent in common rock types though it also occurs in carbonate rocks as dolomite and magnesite.

Anions of the halogen elements (fluoride, chloride, bromide, iodide) can also be conservative due to the relatively high solubility of their compounds. The main limitation is that their concentrations are usually not high enough in mine waters to be detected.

Most heavy elements are not conservative because other fate processes described below affect them. Zinc often shows quasi-conservative behavior because its hydroxide is relatively soluble under typical natural water conditions. However, it is co-precipitated when hydroxides of iron and aluminum precipitate.

For the Holden Mine, magnesium has been identified as a useful conservative element downstream of potential mine-influenced sources.

pH Control on Precipitation/Dissolution

Change in pH is probably the most important mechanism controlling the initial fate of metals in mine drainage. As described in Section 6.2.1, mine drainage often has a pH of less than 4 due to oxidation of sulfide minerals. As the acidic leachates contact buffering sources (minerals) and mix with alkaline waters, the pH increases. The stability of minerals is defined in part by pH. For example, the stability of aluminum hydroxide in terms of pH can be defined based on the reaction:

$$Al^{3+} + 3H_2O \leftrightarrow Al(OH)_3 + 3H^+ \qquad (6\text{-}18)$$

The equilibrium constant for the reaction is:

$$k = a_{H+}/a_{Al3+} \qquad (6\text{-}19)$$

This defines the relationship between pH (-log a_{H+}) and aluminum activity (a_{Al3+}) which in turn can be used to calculate part of the pH-activity diagram shown in Figure 6-3.4. Note that activities (a) are determined from concentrations adjusted using activity coefficients (γ), for example:

$$a_n = \gamma c_n \qquad (6\text{-}20)$$

Other reactions define other parts of the curve:

$$Al(OH)_2^+ + H_2O \leftrightarrow Al(OH)_3 + H^+ \qquad (6\text{-}21)$$

$$Al(OH)^{2+} + 2H_2O \leftrightarrow Al(OH)_3 + 2H^+ \qquad (6\text{-}22)$$

The outcome of this diagram is that as an acidic solution evolves in pH by contact with aluminum-containing minerals, pH increases and aluminum also increases (see hypothetical trajectory). Eventually, the stability line for aluminum hydroxide is reached and aluminum hydroxide precipitates. As long as aluminum hydroxide is in contact with the solution, the trajectory then follows the curve down as pH increases further (for example, if the water mixes with another alkaline water). Aluminum concentrations decrease as aluminum hydroxide precipitates. This is a very common effect at mine sites as demonstrated by the occurrence of white precipitates within the 1500-level main portal drainage (Figure 6.1-1a). Figure 6.3-4(a) shows aluminum concentrations on a log scale to illustrate the curve. Figure 6.3-4(b) shows the same diagram on an arithmetic scale to illustrate that once the curve is intersected, and pH continues to increase, aluminum concentrations decrease very rapidly, becoming "undetectable" by pH 5.

Similar curves can be drawn for other common precipitates such as red ferric hydroxide (Figure 6.3-5) and green basic copper carbonate. When carbonates form, the partial pressure of carbon dioxide also affects the pH and the type of mineral that form. For example, under atmospheric conditions, the stable basic copper carbonate is malachite, but at higher carbon dioxide pore pressures, azurite will form.

The pH changes therefore control the fate of dissolved potential contaminants by causing them to precipitate. Reversals in pH also cause dissolution by the same processes.

Eh Control on Precipitation/Dissolution

Eh describes the oxidation state of a constituent. Unlike pH which refers to the actual activity of hydrogen ions in a water, Eh does not refer to concentration of any particular ion. The oxidation state is defined by the balance between oxidation/reduction couples (in mine waters most commonly Fe^{2+}/Fe^{3+}):

$$Fe^{2+} = Fe^{3+} + e^- \qquad (6\text{-}23)$$

where:

e^- is an electron.

The equilibrium constant is:

$$k = a_{Fe3+}a_e/a_{Fe2+} \qquad (6\text{-}24)$$

Since k is constant, the ratio of activities of the iron ions defines a_e which is proportional to Eh.

Like pH, the stability of minerals can be defined in terms of Eh. Eh-pH diagrams are often constructed to show the stability of minerals and ions. If a mineral and dissolved ion are in contact and in equilibrium, the pH and Eh is constrained to the line shown on the pH-Eh diagram. In Figure 6.3-6, the line between Fe^{2+} and FeOOH is defined by the half reaction:

$$Fe^{2+} + 2H_2O \rightarrow FeOOH + 3H^+ + e^- \qquad (6\text{-}25)$$

The e^- indicates that an electron has been lost due to oxidation of Fe(II) to Fe(III). The reaction shows that the slope on the Eh-pH diagram is negative as shown in Figure 6.3-6 (assuming a fixed total iron concentration).

The electron can be taken up by any oxidizing species, for example oxygen (O_2):

$$\tfrac{1}{4}O_2 + e- + 2H^+ \rightarrow \tfrac{1}{2}H_2O. \qquad (6\text{-}26)$$

These diagrams can be used to explain the evolution of tailings groundwater. At the surface of the tailings, the sulfide minerals oxidize to produce acidic groundwater containing dissolved iron. At the surface, the presence of oxygen could allow Fe(II) and Fe(III) to be in equilibrium. As the water infiltrates into the tailings mass, only Fe^{2+} is stable. If neutralizing minerals are present, the pH will increase while Eh is decreasing. Alumino-silicate buffering constrains pH to between 4 and 5. If the porewater mixes with oxygenated groundwater (e.g., water in contact with a fast-flowing surface stream), the Eh increases, and eventually the solution reaches the line defining the stability between Fe^{2+} and iron oxyhydroxide. This causes iron oxyhydroxide to precipitate, removing iron from solution. As Eh further increases, pH will decrease due to the release of H^+ during precipitation. Eventually, the solution could be expected to enter the field in which only iron oxyhydroxide is stable.

Efflorescence

Efflorescence refers to the precipitation of minerals due to the evaporation of water. The process is very commonly observed along the edge of seeps, and mine drainage collection pools and streams during the summer. Efflorescence occurs when water becomes saturated with respect to minerals and nucleation of crystals can occur. Chemical saturation is defined by the solubility product (k_{sp}), which is the equilibrium constant for reactions such as:

$$CaSO_4 = Ca^{2+} + SO_4^{2-} \tag{6-27}$$

Whether a mineral can be expected to form by efflorescence is determined by the saturation index (SI):

$$SI = IAP/ksp \tag{6-28}$$

where:

> IAP is the ion activity product. If SI is greater than 1, the mineral is expected to precipitate from the solution. As indicated above, there are kinetic considerations which prevent precipitation, so solutions can appear over-saturated. SIs are usually expressed as logs so that the critical value is 0, rather than 1.

Co-precipitation

Co-precipitation describes the mechanism by which trace metal ions are incorporated into the structure of precipitating solids (Figure 6.3-7). It is a very important process during pH and/or Eh changes, which cause precipitation of aluminum, manganese and iron oxyhydroxides. The trace metals may be present at concentrations well below those required to precipitate their own hydroxides but the rapid precipitation processes allow the elements to be incorporated into the structure due to their similar physico-chemical properties. Evidence of the process is commonly observed in the analysis of iron precipitates. Examples of elements affected by co-precipitation include copper, zinc, cadmium, cobalt, manganese and arsenic.

Sorption

Sorption describes surface charge effects that allow trace elements to be precipitated at lower concentrations than predicted based purely on the solubility of their oxides and hydroxides. The results are often indistinguishable from co-precipitation. However, sorption involves the trace elements attaching to the surface of iron and manganese oxyhydroxides after the oxyhydroxides have formed rather than during their formation. The process is common in stream beds where iron and manganese oxyhydroxides coat sediments. It is commonly observed that iron and manganese concentrations in fine stream sediments are very strongly correlated with concentrations of trace metals due to sorption.

Sorption refers to numerous complex surface processes, which are specific to each substrate. However, the main control is pH because the sorptive surfaces undergo charge reversal at a certain pH referred to as the zero-point-of-charge (zpc). The surfaces are positively charged as $pH<pH_{zpc}$ and negatively charged for $pH>pH_{zpc}$. Above pH_{zpc}, cations are therefore attracted to the surfaces. Figure 6.3-8 illustrates some typical curves showing amount adsorbed on goethite versus pH for several elements. The upper part of the curve represents near 100 percent adsorption. As shown, the transition from negligible to near complete adsorption occurs over a pH range of about 2 units. Sorption occurs onto organic materials and organisms (plants and animals). Intake of trace elements by plants and bacteria may occur.

6.3.4 Conclusions

Weathering of iron-bearing sulfide minerals (including pyrite, pyrrhotite and chalcopyrite) produces water containing acid, sulfate and iron. This water is strongly acidic and oxidizing, and can oxidize and dissolve other sulfide minerals (such as sphalerite). The acidic water also reacts with other minerals, particularly carbonate and silicates. These minerals consume acid, releasing their elements to solution. Reaction with silicates commonly releases aluminum, sodium, potassium, calcium and magnesium. The water produced by reaction with rocks commonly contains a mixture of elements reflecting these processes.

As mine-influenced water mixes with other more dilute waters, concentrations can be diluted. Metals can also be removed from solution by a variety of processes including pH and Eh increases (resulting in precipitation), efflorescence (removal by evapo-concentration), co-precipitation (removal of metals by precipitation), and sorption (removal by precipitation on secondary minerals). These processes can significantly remove metals before the water enters Railroad Creek.

6.4 EVIDENCE AND IMPLICATIONS OF GENERAL CHEMICAL PROCESSES AT THE HOLDEN MINE SITE

As a first step in understanding weathering processes at individual hard rock metal mine sites, it is useful to examine water chemistry for evidence of overall chemical controls. The exposed walls, waste rock and tailings all originate from a narrow geological sequence containing specific minerals as described in Section 6.1.2. It is expected that the chemistry of waters at the Site have some common characteristics that reflect:

- The presence of certain abundant reactive sulfide minerals (pyrite, pyrrhotite, chalcopyrite, sphalerite) and silicate minerals (principally chlorite, biotite and sericite) in the ore and host rocks
- The chemical changes resulting from oxygenation and mixing of these waters with the dilute runoff, groundwater, or surface water

The following subsections describe overall site-specific evidence for these reactions. The interpretative tool used is described in Section 6.2.1. Bivariate scatter plots showing concentrations of metals versus sulfate and each other were examined. If the data points fall on a straight line with a constant slope and intercept near 0 (arithmetic axes) or a slope of 1 (logarithmic axes), a constant ratio of the two parameters is implied. This indicates a common mineralogical source. For example, dissolution of sphalerite (ZnS) would produce a water with zinc/sulfate (Zn/SO_4)=1 (molar concentrations), regardless of the quantity of water contacting the mineral. A constant ratio can be preserved for several different waters all influenced by the same process. If the data lie on a straight line with a non-zero intercept (arithmetic axes) or a curvilinear trend (logarithmic axes), mixing of two different waters is indicated.

The data used in these interpretations are shown in Section 5 and include all surface water and seep samples collected in 1997 and 1998.

6.4.1 Evidence of Iron Sulfide Mineral Oxidation

Sulfate is the best indicator of oxidation processes because oxidation of iron sulfides (pyrite and pyrrhotite) (Figure 6.3-1) and oxidative dissolution of heavy metal sulfides (Figure 6.3-2) produce secondary iron sulfate salts. Iron is also released when pyrite and pyrrhotite are oxidized; it is only useful as an indicator of iron sulfide oxidation in low pH (<3.5) waters because at higher concentrations it is removed from solution as iron hydroxide.

Comparison of dissolved iron and sulfate data from seeps and surfaces waters (Figure 6.4-1) indicates a linear trend for the strongly acidic (pH<4) tailings pile seepage (seeps SP1, SP2, SP3, SP4 and SP5, which are depicted on the figure as tailings piles 1 through 3) and Railroad Creek upstream of the tailings seepages (RC-1 and RC-4). Two other separate clusters are apparent for Railroad Creek downstream of the tailings piles (stations RC-7, RC-2 and RC-5), and the mill building, rock piles and portal drainage (P1 and P5). The upper end of the linear trend indicates nearly exactly molar quantities of sulfate and iron, with sulfate exceeding iron. This is consistent with iron and sulfate released from oxidation of pyrite (FeS_2) and pyrrhotite ($Fe_{1-x}S$) although some iron may have originated from leaching of iron-bearing silicates (mainly hornblende in the tailings).

The linear trend reflects the mixing of tailings seepage waters of the type represented by tailings pile 1 with Railroad Creek waters originating upstream. This implies that the seep waters from tailings piles 2 and 3 are comparable to tailings pile 1 but more dilute due to mixing with dilution waters. The linear trend in Figure 6.4-1 reflects the mixing of tailings seepage waters of the type ($Fe>SO_4$) represented by tailings pile 1 with Railroad Creek waters originating upstream (RC-1, $SO_4>Fe$). This implies that the seep waters from tailings piles 2 and 3 are comparable to tailings pile 1, but more dilute due to mixing with Railroad Creek. It would be expected that the downstream waters in Railroad Creek (for example, RC-2 would lie exactly on this trend (i.e., Fe increasing with respect to SO_4 while $Fe/SO_4<1$). However, there appears to be more iron (i.e., $Fe=SO_4$) than would be expected. As the plot was constructed using "dissolved" iron, it is suspected that the iron is perhaps overestimated due to the presence of colloidal iron flocculent in the water; this would tend to overestimate the dissolved iron concentrations, while not affecting sulfate.

In summary, the relationship of iron and sulfate indicates that oxidation of pyrite and pyrrhotite are controlling processes on tailings seepage chemistry, as expected. Oxidation of these iron sulfide minerals releases iron, sulfate and acid.

The iron versus sulfate cluster for the mill building, portal discharge and rock piles suggest a different controlling process as discussed further below.

6.4.2 Evidence of Oxidation of Sphalerite

Sphalerite is dominantly zinc sulfide (ZnS), but iron sulfide may substitute for up to 40 percent, and up to 4 to 5 percent cadmium and manganese have been reported in sphalerites (Deer et al. 1966). Sphalerite at the Holden Mine is relatively iron-rich.

Zinc concentrations in drainage, particularly from the west part of the Site (mill building, 1500-level main portal drainage, waste rock piles) are consistent with oxidation of sphalerite and production of secondary zinc sulfate salts. Zinc and sulfate concentrations are correlated and the ratio is constant (Figure 6.4-2); however, zinc is less than sulfate. This can be explained as follows:

- Oxidation of iron sulfides releases iron, sulfate and acidity (Equations 6-4 to 6-6). The acidity released is proportional to the sulfate released.
- The acidity released enhances oxidation of sphalerite. The greater the acidity, the greater the release of zinc. Hence, the zinc concentration is proportional to acidity.
- As a result, sulfate, produced by oxidation of iron sulfide, is correlated with zinc produced by oxidation of sphalerite. In this process, sulfate exceeds zinc release.

The difference between tailings and other locations is consistent with negligible sphalerite concentrations in the tailings (due to ore processing) but residual sphalerite in the mine workings, waste rock piles, and the abandoned mill building.

Zinc to cadmium ratios (Figure 6.4-3) are nearly constant throughout the Site. The generally constant values indicate that cadmium is associated with sphalerite, and that sphalerite tends to have a constant zinc to cadmium value. Cadmium and zinc also show very similar chemical behavior in the range of natural conditions. This is a very common observation for hard rock metal mine sites, as at the Holden Mine where the type of sphalerite appears to be relatively uniform.

A very strong correlation exists between manganese and sulfate (Figure 6.4-4), and a constant ratio applies to the whole Site ($Mn/SO_4 = 0.005$). Manganese can be associated with both sulfides (e.g., pyrite, sphalerite), iron oxides and as a minor phase substituting in iron silicates. Manganese is relatively resistant to pH and Eh changes under surface conditions, hence it may remain in solution. The relationship suggests a constant Site-wide control on manganese chemistry (i.e., leaching of pyrite and sphalerite).

Sphalerite oxidation therefore occurs in the presence of acidic waters produced by the oxidation of iron sulfides. This releases zinc, cadmium and probably manganese.

6.4.3 Evidence of Oxidation of Chalcopyrite

Copper concentrations are consistent with oxidation of chalcopyrite and production of secondary copper sulfate salts. Several common copper sulfates have also been documented at the Site (see Table 6.1-1).

Relationships between copper and sulfate (Figure 6.4-5) are similar to zinc and sulfate (Figure 6.4-2), although the data are more scattered. Copper to sulfate ratios are greatest for the abandoned mill building, the east and west waste rock pile area seeps, and 1500-level main portal drainage ($pH<5$). The ratio is relatively consistent for these sources (~0.03). Lower ratios are apparent for the less acidic 1500-level main portal drainage. This reflects the strong pH control on copper concentrations at $pH>5$. As the pH increases, copper concentrations decrease but sulfate is unaffected.

The tailings pile seeps (noted on the Figure 6.4-5 as "tailings piles 1, 2 and 3") indicated a much lower ratio (10^{-4}) in acidic waters ($pH<4$). This is consistent with removal of the main source of copper (chalcopyrite) from the ore during processing. The tailings therefore contain little chalcopyrite compared to the underground mine workings, residual concentrates in the abandoned mill building and waste rock piles.

Based on this information, chalcopyrite is considered the primary mineral source of copper in Site waters. The abundance of available chalcopyrite is an important limitation on copper concentrations in seeps, as discussed later in this section.

6.4.4 Evidence of Acid-Buffering by Minerals

Assuming that acid production is represented by sulfate, the effect of acid-buffering can be evaluated by comparing sulfate concentrations with alkali and alkali earth elements commonly associated with acid-buffering minerals. At the Holden Mine, these minerals include carbonates containing calcium and magnesium (in marbles), calc-silicate rocks, and alumino-silicates containing magnesium (chlorite, micas, hornblende), calcium (hornblende, plagioclase feldspars), potassium (biotite, sericite) and sodium (hornblende, plagioclase, clays). Comparison of sulfate with potassium, magnesium, calcium, and sodium, as well as inter-comparisons for the elements can indicate the types of buffering reactions occurring.

Calcium is probably the most ubiquitous element (after silicon) as it occurs in plagioclase, diopside and hornblende. Plagioclase is a major component of all rock types.

Calcium shows a strong correlation with sulfate (Figure 6.4-6), though tailings pile 1 shows a different relationship than the other water sources. The calcium to sulfate ratio is approximately 0.5, except for tailings pile 1 (0.2). The constant ratios are consistent with leaching reactions of the type for calcic plagioclase:

$$CaAl_2Si_2O_8 + 8H^+ \rightarrow Ca^{2+} + 2Al^{3+} + 2H_4SiO_4^{\circ} \qquad (6\text{-}29)$$

The difference for tailings pile 1 suggests that leachate chemistry is controlled by different mineralogy or that the lower pH is allowing different minerals to react with the acidity.

Magnesium is also a ubiquitous element occurring in several minerals (hornblende, biotite and chlorite).

The ratio between sulfate and magnesium is nearly constant for the whole Site ($Mg/SO_4 \sim 0.2$, Figure 6.4-7). Railroad Creek waters show a decreasing ratio of magnesium to sulfate, consistent with mixing of the higher magnesium background surface waters with higher sulfate mine waters. The very strong relationship between magnesium and sulfate indicates a ubiquitous buffering reaction by magnesium and aluminum containing minerals (e.g., biotite), for example:

$$K(Mg_x,Fe_{1-x})_3(AlSi_3O_{10})(OH)_2 + 10H^+ \rightarrow K^+ + 3(1-x)Fe^{2+} + 3xMg^{2+} + Al^{3+} + 3H_4SiO_4 + H_2O \qquad (6\text{-}30)$$

The value of x is less than 1. The same reaction could be written for chlorite or hornblende, both of which are also common minerals at the Holden Mine Site. Evidence that biotite is an important buffering control is shown by the relationship between potassium and magnesium (Figure 6.4-8). For the 1500-level portal drainage, the ratio of potassium to magnesium averages 0.33 which is consistent with buffering by biotite with x near 1 (i.e., 3 moles of magnesium for each mole of potassium) or additional buffering by other magnesium-based minerals lacking potassium such as chlorite. The lower potassium to magnesium ratio for tailings piles 1 and 2 indicates that bioite is less significant. This is consistent with the presence of diabase, which has little biotite or sericite.

Comparison of sulfate and aluminum also supports the general conclusion of buffering by alumino-silicates (Figure 6.4-9); however, aluminum concentrations are lowered by aluminum hydroxides precipitation, hence the relationship is only stable at higher sulfate and lower pH.

In summary, abundant alumino-silicates (calcic plagioclase, biotite and possible chlorite) are involved in buffering acid produced by oxidation of iron sulfide minerals.

6.4.5 Evidence of Metal Attenuation

Secondary mineral precipitation controls can be examined principally by comparing metal concentrations with pH. Further discussion of mineral solubility controls using MINTEQA2 (Allison et al. 1991) is provided in Section 6.5 for each of the water quality monitoring locations.

The relationship between iron and pH indicates a strong negative correlation (Figure 6.4-10). Lower pHs (<3.5) are associated with high iron concentrations in the tailings pile seeps. Scatter at higher pHs can be caused by colloidal flocculent indicating high "dissolved" iron concentrations (for example, in surface waters and emergent groundwater) and ferrous iron (ground waters), which remains in solution at neutral pH. Scatter can also be the result of concentrations near laboratory detection limits. The general relationship between iron and pH indicates pH control by precipitation/dissolution of iron oxyhydroxides. Difference in iron concentrations at various locations at the Site are therefore strongly controlled by solubility of secondary iron minerals produced when ferrous iron oxidizes to ferric iron which then precipitates as ferric hydroxide:

$$Fe^{2+} + \frac{1}{4}O_2 + H^+ \rightarrow Fe^{3+} + \frac{1}{2}H_2O \qquad (6\text{-}31)$$

$$Fe^{3+} + 3H_2O \leftrightarrow Fe(OH)_3 + 3H^+ \qquad (6\text{-}32)$$

The pH to aluminum relationship (Figure 6.4-11) is similar to iron except that the transition to low aluminum concentrations occurs between pH of 4 and 5. Above pH 5, aluminum concentrations are very low or are not detected above detection limits. The strong correlation implies aluminum solubility control by precipitation of aluminum hydroxide in mine waters.

$$Al^{3+} + 3H_2O \leftrightarrow Al(OH)_3 + 3H^+ \qquad (6\text{-}33)$$

Surface water in Railroad Creek has fairly constant aluminum concentrations (0.001 mmol/L) which are probably not high enough to be controlled by aluminum hydroxide ($Al(OH)_3$) solubility.

The strong relationships between pH to iron and pH to aluminum, and the abundance of both iron and aluminum in the rocks and tailings indicate that precipitates form when these minerals are released and serve as important pH buffers for the Holden Mine Site. It is therefore likely that the solubility of other minerals will also be limited due to the buffering capacity of these minerals.

The pH to copper relationship (Figure 6.4-12) shows some indication of pH controls. Copper is higher in concentration in the west area of the site than the east area. The abandoned mill building, portal drainage and waste rock piles indicate a negative correlation between copper and pH implying a constraint on copper concentrations for these data. In comparison, much lower copper concentrations are seen in the tailings pile seeps. The data do not have sufficient pH range to demonstrate a relationship between copper and pH, though tailings pile 1 has lower copper concentrations at higher pH. The tailings pile data probably indicate a limit to the availability of copper in the tailings but also possibly indicate the effects of co-precipitation of ferric hydroxides. In the case of limited copper availability in tailings, the correlation of pH and copper reflects only the increased leaching of copper by stronger acidic solutions. Copper concentrations in surface waters of Railroad Creek are very low and do not appear to be controlled by the solubility of copper secondary minerals. Coprecipitation and adsorption on iron coatings and other materials on stream sediments is expected to attenuate copper concentrations in stream waters.

The plot of pH and zinc (Figure 6.4-13) is similar to copper except that the mill building, portal drainage and waste rock piles appear to have relatively stable zinc concentrations (between 0.1 and 1 mg/L). This may imply a mineral solubility constraint, although zinc minerals are far more soluble than indicated by these data. The tailings pile data appear to indicate a limit to the availability of zinc, as zinc would be expected to occur at much higher concentrations in low pH water (by extrapolation of the pH to zinc trend for the mill building, portal drainage, and waste rock piles). The correlation of zinc and pH may, like copper, be caused by co-precipitation of zinc with ferric hydroxides, with the effect decreasing as pH decreases. Comparison of sulfate and aluminum also supports the general conclusion of buffering by alumino-silicates (Figure 6.4-9) shown by examination of magnesium and potassium concentrations. Sulfate is correlated with aluminum at high aluminum and sulfate concentrations indicating that generation of acid, represented by sulfate results in attack on alumino-silicates releasing aluminum in proportion to acidity. However, aluminum concentrations are lowered by aluminum hydroxides precipitation, hence the relationship is only stable at higher sulfate and lower pH. Aluminum is removed rather than sulfate as pH increases introducing scatter in the relationship between the parameters in Figure 6.4-9.

The cadmium to pH relationship is similar to Zn-pH indicating that zinc and cadmium show similar geochemical behavior (Figure 6.4-14).

Water chemistry indicates that pH is controlled by the formation of amorphous hydroxide precipitates of iron and aluminum. The formation of these precipitates constrains pH, which allows copper to remain in solution, but precipitation also allows attenuation by co-precipitation and provides a substrate for adsorption.

6.4.6 Conclusions

Evaluation of water chemistry indicates that geochemical behavior consistent with the well-known processes discussed in Section 6.3 is occurring throughout the Holden Mine Site. Conclusions from this section are as follows:

- Consistent geochemical processes are occurring throughout the Site, specifically iron sulfide oxidation, sphalerite and chalcopyrite oxidation, buffering and metal attenuation.

- The geochemistry of Site waters is generally consistent with oxidation of pyrite and pyrrhotite to release sulfate, iron and acid. The molar ratio of sulfate to iron in acidic solutions is consistent with the ratios in the minerals. Oxidation of iron sulfides is the main source of sulfate in the waters. Iron solubility is controlled by pH.
- Oxidation of sphalerite results in the release of zinc, cadmium and probably manganese. The low concentration of sphalerite in all of the tailings piles due to ore processing results in relatively low zinc concentrations in seepage water.
- Oxidation of chalcopyrite results in the release of copper. The abundance of chalcopyrite is an important limitation. The tailings piles contain very little chalcopyrite (due to ore processing) and therefore seeps from the tailings piles contain relatively low copper concentrations. Copper concentrations in surface water of Railroad Creek are low and are not controlled by the solubility of copper secondary minerals, but rather by sorption processes.
- Buffering of acidity produced by sulfide oxidation is occurring by the reaction of waters with alumino-silicates. The main silicates involved in the reaction appear to be calcic plagioclase, biotite and possibly chlorite. The contribution of these minerals is indicated by the correlation of calcium, magnesium, potassium and aluminum concentrations with sulfate and each other.
- Since alumino-silicates are ubiquitous and abundant, buffering occurs close to the source of acid generation.
- The release of aluminum by an acid reaction with alumino-silicates results in an important control on pH. Precipitation of aluminum hydroxide controls pH at 4.5. This limits the solubility of some metals (e.g., iron) but also allows pH to be low enough to allow copper, zinc and other metals to remain in solution. This in turn allows metals to reach Railroad Creek with little attenuation.
- The comparison of sulfate and aluminum supports the general conclusion of buffering by alumino-silicates; however, aluminum concentrations are lowered by aluminum hydroxide precipitation, hence the relationship is only stable at higher sulfate and lower pH.

6.5 GEOGRAPHICAL DESCRIPTION OF CHEMICAL PROCESSES

This section presents difference of the processes that are occurring in different parts of the Site and that reflect unique characteristics associated with specific sources. The differences in processes at these source areas are generally related to the movement of air and the movement of water. Air movement is a fundamental process control/factor because it is regulates the degree to which oxidation occurs. If oxygen is readily available, oxidation is not limited by oxygen supply but can occur at a rate dictated by the properties of the minerals. Water movement is also an important controlling factor because it controls the dissolution and transport of weathering products. Seasonal variations in water flow also control variations in load release of drainage waters that discharge to Railroad Creek.

6.5.1 Air and Water Movement Associated with the Honeymoon Heights and Mine Support Areas

The Honeymoon Heights and Mine Support areas include the underground mine, waste rock piles, abandoned mill building and maintenance yard. Each source area is described below.

6.5.1.1 Underground Mine Processes

Air Movement

The underground mine contains specific physical features which control the weathering and leaching of surfaces within the mine (Figure 6.5-1):

- Several portals are partially open to open (300-, 1100-, 1500-level main, and 1500-level ventilator); however, only the lowest portal (1500 level main) is discharging water on a year round basis.
- No major vertically-oriented surface openings such as "glory holes" (openings to the ground surface) or shafts exist.
- The mine is flooded below the 1500 level, and the majority of the stopes below the 1500-level have been backfilled.
- All of the stopes above the 1500 level are not backfilled.

An important feature of the underground mine is that it was reported to have a consistent internal temperature of 50°F (McWilliams, 1958), likely due to the geothermal gradient. This is an important factor to the availability and supply of oxygen for oxidation in the underground mine.

In the summer, it has been observed that air both enters and exits the mine at the 300-, 1100-, and 1500-level portals. This is likely due to the sinking of cool, dense air in the mine when the outside temperature is above 50°F, an effect resulting in air being drawn into the mine at other locations (i.e., 300-level), and rising of less dense air when the outside temperature is below 50°F. Air flow through the mine is also assumed to be caused by changes in barometric pressure. The air movement probably leads to oxygenation of relatively near surface workings as shown in Figure 6.5-1.

Winter is the likely time of relatively high air movement in the underground mine due to the significant temperature difference between the external environment and the mine (Figure 6.5-2). The average difference is estimated to be 30°F. As a result, warm air in the mine rises drawing air in through the lower portals and causing venting from the upper part of the mine. These conditions allow oxygen to penetrate into the workings resulting in oxidation of sulfide minerals and accumulation of weathering products through the winter. Stopes farther back within the mine probably experience relatively stagnant air conditions with relatively low oxygen concentrations and thus limited oxidation of sulfide minerals. Flooded stopes below the water table remain permanently inaccessible to oxygen.

In the spring, airflow reduces as external temperature increases and the external temperatures and mine temperatures are within 10°F (Figure 6.5-3).

Water Flow

The mine drainage area encompasses the underground mine, 1500-level main portal, 1100-level mine, and the 1500-level ventilator portal. The anticipated transport pathways for these areas are shown on Figure 6.5-4. Conceptual flowpaths for spring conditions (snowmelt period, roughly May to June) from the mine workings has been observed primarily from the 1500-level main portal, with relatively minor discharges from the 1100-level portal and the 1500-level ventilator portal. Mine water discharge occurring from any of the surface exposures of faults or shear zones which intersect the orebody have not been observed.

In the spring, snowmelt enters near-surface discontinuities in the bedrock south of the Site and flows downward through the open stopes above the 1500-level of the underground mine. Infiltrating groundwater flows through mineralized but unmined portions of the mine and contacts residual mineralization on rock faces of the stopes and tunnels. The water emerges at the 1500-level main portal (portal drainage), flows overland, and discharges to Railroad Creek. Infiltration to groundwater in the alluvium/reworked till may occur during overland flow transport which eventually reaches Railroad Creek as baseflow. The 1500-level main portal drainage and potential loading contribution is further discussed below under Portal Drainage.

Infiltration from upslope run-on also seasonally perches in the 1100-level tunnel which then emerges as Seep A-1. This water infiltrates the surfaces of the 800- and 1100-level waste rock piles. An intermittent seep was observed near the base of the 800-level waste rock pile; the seep was sampled as it entered the intermittent drainage (SP-14 lower). The intermittent drainage then eventually infiltrates colluvium and glacial till and is assumed to discharge into the Railroad Creek as baseflow; however, it is not known for certain whether seep SP-23 is the discharge point for the infiltrated water from the intermittent drainage; see Section 6.5.1.4 for further discussion.

The 1500-level ventilator portal is located approximately one-half mile west of the 1500-level main portal (Figures 6.1-1a). As mentioned in Section 4.1.3.2, a civil survey of the 1500-level ventilator portal indicated that the opening is approximately 20 feet higher in elevation than the 1500-level main portal. In addition, continuous flow measurements collected by a data logger installed at the 1500-level main portal (as discussed in Section 4.3.3.6) indicate relatively rapid and significant responses (within approximately one day) to precipitation events, which suggests that the pool behind the dammed portal is relatively low. Also, as discussed in Section 6.5.1.4, the chemistry of the water sampled at the 1500-level ventilator portal indicated very dilute concentrations of metals when compared with the 1500-level main portal drainage (P-1). Consequently, it is likely that the water observed flowing from the 1500-level ventilator portal is meteoric groundwater seeping out of the glacial soil through which the portal was noted to have been timbered for the first 300 feet.

In the event that the water was actually backed up behind the failed portion of the 1500-level main portal to a level that would allow water to flow from the 1500-level ventilator portal, the water would not likely flow out of the opening but more likely would drain down through the "300 feet of gravels" noted on the mine map. In such an event, water would most likely flow through the subsurface into Railroad Creek downstream of the ventilator portal. A seep was observed below the 1500-level ventilator portal (SP-26). However, as discussed in Section 6.5.1.4, the chemistry of the SP-26 water indicated very dilute concentrations of metals when compared with the 1500-level main portal drainage (P-1), and SP-26 likely reflects meteoric water affected by an abandoned surface water retention area with tailings materials, and not originating from the underground mine. As noted later in this section, no other unaccounted sources of metals loading are noted in Railroad Creek between RC-6 (upstream of Seep SP-26) and RC-4 (downstream sampling station).

In July and August, influx of water into the mine is assumed to be, on average, significantly less than during the snowmelt period. By fall, the influx of water into the mine from upslope is assumed to be entirely from rainfall. As these months experience lower precipitation, overland flow through the 800- and 1100-level waste rock piles is significantly reduced. Seeps downslope from Honeymoon Heights were noted to flow only in response to rainfall events during the fall 1997 field program.

Underground Mine Water Chemistry

Comparison of seepage chemistry from the Honeymoon Heights drainage area suggests that the upslope waters, represented by seep SP-14 (which includes SP-14, SP-14 Lower, and SP-14 Upper), have been only moderately influenced by the mine or natural occurrences of mineralization. Metals and sulfate concentrations for seep SP-14 appear to be chemically comparable to other waters at the Site, but with significant dilution (pH: 4.5 to 6.1, Cu: <2 to 1410 µg/L, Zn:5 to 1610 µg/L, SO_4:<2.5 to 22 mg/L). Seep A-1, collected from the 1100-level portal, appears to have little or no influence from the mineralized bedrock (Cu: 120 µg/L, Zn: 257 µg/L, Cd: 2.3 µg/L, SO_4:40 mg/L) and does not reflect water quality of the mine pool as noted at the 1500-level main portal drainage (P-1). Water from this seep appears to be derived from rainwater and snowmelt that infiltrates through the overlying surficial materials to the adit.

The only direct indicator of underground water chemistry and processes is provided by the 1500-level main portal drainage (P-1). However, comparisons of portal drainage water quality with water quality data collected from other sources indicated that the portal drainage water chemistry most closely resembles the water draining from the mill building. The USGS (personal communication with Jim Kilburn, 1999) indicated that numerous typical secondary sulfate minerals were identified in the mill building in 1995 and 1996 (Table 6.1-1). These minerals contain iron, copper, zinc, manganese, aluminum and sulfate and vary from highly soluble to sparingly soluble (Alpers et al. 1994). The minerals are formed when concentrated groundwaters derived from contact with oxidizing mineral concentrates and residual ore become chemically over-saturated with minerals. This can occur by mixing of different solutions and evapo-concentration.

By comparison, the same minerals are probably present in the underground mine. This is a reasonable assumption since the mine probably contains exposures of ore-type material which could not be extracted due to requirements for ground support, or because the volume was not justified by mining economics. Sulfates are formed on the walls of the underground mine by oxidation and are then rinsed during flushing events. Evaporation of water during drier periods (primarily winter) allows the salts to accumulate.

Experience at other underground mines within similar geologic conditions indicates that these salts may be present throughout the mine wherever water emerges and can evaporate such as where fractures and drill holes intersect mine walls and where water is locally ponded and then drains. Since water flow likely occurs unpredictably on some fractures and not others, these locations of stored oxidation products are randomly distributed. Significant deposits of salts are generally identified opportunistically rather than by prediction. Therefore, inspection of the underground workings to identify specific types of salts and accumulations of salts is unlikely to be successful in characterizing the salts because not all parts of the workings are accessible due to physical barriers (backfill and collapsed workings) and safety concerns (ground stability, air quality, hidden hazards).

The pathway from the sources to the soluble salts involves contact with the host rocks and mixing with other waters. The host rocks are primarily composed of alumino-silicates and isolated occurrences of marble. This results in addition of aluminum, magnesium, calcium, potassium and sodium to the water as has been observed throughout the Site. The addition of these elements largely occurs in proportion to sulfate, which is a surrogate for the release of acid. These are expected to be extremely complex pathways.

Significant seasonal effects are apparent in the 1500-level main portal drainage at station P-1. This is reflected in pH changes. Lowest pHs are observed in the spring, and pH increases through the summer. This is accompanied by decreasing aluminum, copper and zinc concentrations, but sulfate does not change significantly. The lower pH in the spring is probably caused by flushing of acidic salts from rock surfaces and fractures in the spring, and by local recharge of pools within the underground mine that have evaporated through the previous summer and winter. This acid load is less effectively neutralized by contact with neutralizing minerals and reflects the decreases in pH at the portal. During the summer, pH increases due to much lower acid load, longer contact times with neutralizing minerals in the underground mine and mixing with alkaline groundwater, resulting in more complete neutralization.

The minor variations in sulfate concentrations suggest that the source of the water does not change significantly (that is, the pool within the underground mine continues to supply the water observed at P-1). The variation in metal concentrations in P-1 drainage is related to the differences in pH, and precipitation of oxyhydroxides rather than changes in source release. Source release may increase in the spring due to flushing, as described above, but the pH variations produce the same effect.

A metals-loading analysis of surface water discharging from the portal drainage was performed using the data collected during the RI. The flow data and chemical data collected from the 1500 level main portal drainage (station P-1) during the May, July and September 1997 rounds were used in the analysis. A summary of the chemical data is provided in Section 5 of this report. Historical flow and chemical data from 1982, 1983, and 1991 were also evaluated for use in the loading analysis; however, the data were not used in the loading analysis due to the uncertainties associated with the accuracy of the flow measurements recorded for these periods.

The results of the loading analysis are shown in Figure 6.5-5. Zinc and copper exhibited similar loading trends, with the highest loads occurring in May and a decline in concentration through September. Copper loads are generally lower than zinc and decrease more significantly in the late summer and fall. Data indicate that the dissolved iron loads discharged at the portal are approximately one order of magnitude less than corresponding zinc loads and continue to decrease to September.

Sulfate loads were approximately one order of magnitude greater than corresponding metal (zinc, copper, iron) loads. The patterns of sulfate discharge are very similar to those observed for the metals. The mass of sulfate discharged from the portal greatly exceeds the mass of copper, zinc, iron and cadmium discharged at any given time.

6.5.1.2 Waste Rock Piles

Air Movement

Like mine workings, differences in temperature are important considerations in determining weathering processes (Figure 6.5-6). In summer, the interior of the pile is anticipated to be cooler than the ambient temperature and there is no process to drive oxygen deep into the pile. Oxygen enters the pile from the surface driven by diffusion leading to oxidation in the immediate pile surface only.

The decrease in temperatures in the winter potentially creates optimal conditions for convective air flow (Figure 6.5-6). Warmer temperatures in the pile are created by heat generated by the oxidation processes. The temperature difference allows air to be drawn into the base of the pile providing further oxygen for oxidation. The process is self-perpetuating and indicates that winter can result in significant increases in internal temperatures. This also allows oxidation rates to accelerate and encourages weathering products to accumulate.

In the spring, melting of snow results in flushing of accumulated salts by cold water (Figure 6.5-6). This can cool internal temperatures, and coupled with rising ambient temperatures, serves to reduce oxidation rates.

Water Flow

The locations of the waste rock piles are shown on Figure 6.1-1a. Four waste rock piles are discussed and include the west and east waste rock piles, and the 800- and 1100-level portal waste rock piles. Waste rock piles associated with the 300, 500 and 700 portals are located on bedrock and are relatively small. There was no field evidence of seep discharge or surface water overland flow observed at these piles; therefore, they are not further discussed.

In the spring, upslope snowmelt run-on flows as overland flow and infiltrates on the slopes south of the waste rock piles and within each rock pile. Weathering products accumulated during the winter are leached. In general, groundwater moves downslope in the alluvial/reworked till unit and in the soil/fill material, and discharges either as seep overland flow or as groundwater baseflow into Railroad Creek (Figure 6.5-4).

The spring conceptual groundwater flow path is to the north and northeast from the waste rock piles toward the intermittent drainage for the 800- and 1100-level waste rock piles, and toward Railroad Creek for the east and west waste rock piles, as shown on Figure 6.5-7. Some portion of groundwater flow is presumably diverted into the abandoned Railroad Creek channel. Groundwater in the alluvium/till that flows from the west waste rock pile appears to emerge as intermittent seeps, SP-6 and SP-15E, and continues as overland flow to the lagoon (Figures 6.1-3a).

Groundwater from the east waste rock pile appears to emerge as an intermittent seep (SP-8). Surface water flow from SP-8 flows overland across tailings pile 1 and is expressed as seep SP-19 before flowing into the Copper Creek diversion (Figure 6.1-3a).

In the fall, groundwater flow is reduced and flows in a more northeasterly direction, indicating less input from valley side slopes and more influence from the downvalley groundwater flow component (Figure 6.5-8). Seep discharge was not observed, but the movement of groundwater through the abandoned Railroad Creek channel presumably continues.

Waste Rock Leachate Chemistry

The chemistry of waters seeping from the vicinity of the waste rock piles is very similar to the P-1 discharge and the mill building when considering ratios of key elements. The main feature of the waters, as measured at SP-8, SP-15, and SP-14 (lower) are that they contain relatively high copper and zinc to sulfate ratios (0.1 mol/mol) and low iron to sulfate ratios ($<10^{-3}$ mol/mol) when compared to the tailings pile seepage (e.g., SP-2, SP-3, SP-4 and SP-5) (Cu/SO4 Zn/SO4$<10^{-3}$ and $Fe/SO_4>0.1$) and are only weakly acidic (pH>4). This indicates either that the water is derived from one source and the observed chemistry is a result of mixing and dilution, or that common geochemical mechanisms are operating to control water quality as described in subsection 6.4.

Seep SP-8 is geographically well removed from P-1 (1500-level main portal drainage) and seep SP-7 (mill building); therefore, a geochemically similar source seems more likely. The detailed composition of the waste rock piles is unknown although visual inspection indicates that they contain some mineralized material, including pyrite, chalcopyrite and sphalerite mixed with host alumino-silicate rocks and some marble, similar to those minerals reported by others to be present in the mine (see Section 4.2.3).

Since the piles were placed on hillsides and, therefore, relatively thin, they are probably well-oxygenated. Much of the mineralized material is likely to have been oxidized, resulting in the build-up of similar weathering products to those observed in the mill building. Leaching of these weathering products and contact with the host rocks would likely result in pH greater than 4. Iron precipitates, but zinc and, to a lessor degree, copper would remain in solution. The higher pH (near neutral) and lower zinc and much lower copper concentrations at SP15W shows that marble is present; marble was also observed on the surface of the west waste rock pile. Malachite staining was observed on blocks of marble on the surface of the west waste rock pile, indicating the control of copper concentrations by precipitation of copper carbonate (malachite).

6.5.1.3 Mill Building and Maintenance Yard

Remnants of ore bins in the uppermost portion of the mill building contain residual sulfide minerals. These materials are exposed to atmospheric weathering conditions on a continuous basis. Leaching of weathering products occurs in the spring when snow melts in the remnant ore bins, and at other times of the year during rainfall.

Upslope surface water run-on flows overland and infiltrates across and through the abandoned mill buildings, some of which contacts unprocessed ore and mineral salts (Figure 6.5-4). The water exits the abandoned mill building (SP-7) and flows eventually into the lagoon.

Unprocessed ore material within the mill building is undergoing oxidation. Precipitation and surface water run-on aid in this process and remove accumulated oxidation products (Table 6.1-1). Metal cations (e.g., Cu^{2+}, Fe^{3+}, Zn^{2+}, Cd^{2+}) and sulfate (SO_4^{2-}) are dissolved into the surface water. The pH of these waters decreases also, aiding in the dissolution of any sulfide material present. Metal salts found on the ground surface and walls of the mill building are the result of the evaporation of metal-bearing water or its interaction with native materials causing precipitation. Some of the metals become redissolved and transported from the mill building.

The transport pathways associated with the maintenance yard are shown on Figure 6.5-4. Similar transport pathways occur as compared to other Site features. Overland flow from the area drains eventually into the lagoon (Figure 6.1-3a). Infiltration associated with the maintenance yard area emerges as seep SP-22.

TPH was detected in the maintenance yard soil in a localized area up to two feet below ground surface (bgs). The area is relatively flat and the primary transport mechanism is assumed to be infiltration from surface run-on and snowmelt. The adsorption capacity of TPH in soil is assumed to be relatively high due to the nature of the materials observed (clayey silt), therefore, TPH in soil most likely attenuates with depth and lateral distance.

6.5.1.4 Downgradient Attenuation of Metals

This subsection qualitatively describes evidence of metal attenuation downgradient of the source areas. The processes occurring at each location are also indicated by symbol coding (Figure 6.5-9).

Seeps SP-26, SP-23, SP-23B, SP-12 and 1500-Level Ventilator Portal Discharge

Seep SP-26 flows during the spring from the south bank of Railroad Creek downslope of the 1500-level ventilator portal and a remnant detention pond feature. The analyses of the SP-26 sample detected (Figure 6.1-3a) pH-neutral water with some alkalinity (10 to 14 mg/L). The chemistry of the water is not comparable to mine discharge waters. Copper concentrations are 22 to 28 µg/L compared to >1000 µg/L (in May) in mine discharge. These concentrations are too low to be controlled by the formation of a copper carbonate. The copper concentrations possibly originate from the small detention pond that is speculated to have collected water from the 1500 ventilator portal during backfilling of the underground mine or from natural mineralization. The detention pond was observed to contain a small quantity, but SP-26 water is very dilute and most likely represents meltwater.

Seeps SP-23, SP-23B and SP-12 flow during the spring from the south bank of Railroad Creek between RC-1 and P-5 stations (Figure 6.1-3a). The results of laboratory analyses show many similar chemical characteristics to waters originating from the mill buildings, mine and waste rock piles. Seeps SP-23 and 23B have pH<5, and MINTEQA2 indicates that the pH is controlled by the presence of various aluminum hydroxides, sulfate and alunite ($KaI_3 (SO_4)_2 (OH)_6$). Iron was undetectable in the seeps suggesting that the water is well-oxidized. Eh measurements of about 300 mV confirmed that the water has been oxidized, removing iron from solution. Copper concentrations were not indicated to be controlled by a secondary mineral. SP-12 is less acidic (pH~5) and sulfate and metal concentrations are slightly less than SP-23 and SP-23B, but ratios of elements are comparable. Some discrimination of waters can be seen on a scatter plot of potassium versus sodium (Figure 6.5-10). This plot indicates that mine waters (P-1 and P-5) have higher Na/K ratios than waste rock pile or tailings.

One sample (VP-1, May 2, 1998) of the water discharging from the 1500 Level ventilation portal was very dilute (pH 6.4, sulfate 3.5 mg/L, Cu 0.7 µg/L, Zn <4 µg/L), which is consistent with a local meteoric source for the water.

Portal Drainage

Mine drainage from the 1500-level main portal (P-1) enters Railroad Creek at P-5 via a ditch. White precipitates are observed coating the ditch. The chemistry of the water changes little between the two points. In the spring, metal concentrations tend to be higher at P-1 than at P-5, but in the summer concentrations are comparable between the two points. The decrease in concentrations in the spring is interpreted to be due to dilute meltwater water entering the ditch from the valley sides and diluting the flow.

MINTEQA2 calculations indicate that the drainage is significantly over-saturated with respect to aluminum hydroxides and sulfates, alunite, barite and various iron hydroxides and cupricferrite. Saturation with respect to zinc minerals is not indicated. The precipitates observed indicate that precipitation is occurring, although some of the precipitate may not have formed in the ditch but formed in the mine and settled in the drainage. The active formation of flocculent as very fine particles, probably results in the over-estimation of dissolved metal concentrations in the water, hence the degree of over-saturation is probably less than predicted by MINTEQA2. It is likely that as the portal drainage emerges at P-1, it is in disequilibrium with the atmosphere due to the slow conversion oxidation of Fe(II) to Fe(III). This causes precipitation of iron minerals in the ditch and co-precipitation of other heavy metals (mainly copper). However, most of the iron precipitates due to oxidation, dilution, and neutralization. Analysis of the precipitate indicate that it contains mainly aluminum and iron with some copper and zinc.

The principal attenuating mechanisms in the ditch are assumed to be:

- Dilution by surface runoff
- Oxidation and precipitation of iron resulting in removal of iron and co-precipitation of copper oxide
- Precipitation of aluminum hydroxide resulting in removal of aluminum

As the 1500-level main portal drainage water enters Railroad Creek, the weakly acidic water mixes with the weakly alkaline stream water. The rapid pH shift causes any residual aluminum and iron to precipitate as amorphous hydroxides in the stream bed. Copper is also expected to form a fine flocculent as basic copper carbonate. This effect was simulated using MINTEQA2 by changing the pH and alkalinity to that of Railroad Creek. This indicated that the malachite might precipitate. Zinc would not be expected to precipitate. The rate at which copper carbonate might form determines whether copper would be removed from solution, or whether copper concentrations would be diluted below the solubility limits imposed by copper carbonates before the precipitates actually formed. The loading analysis presented subsequently in this section confirms that copper carbonates might form.

West Waste Rock Pile, Mill Building, and Seeps SP-9 and SP-11

This pathway includes seepage from the west waste rock pile and runoff from the abandoned mill building that collects in the lagoon (SP-16) before entering Railroad Creek at seeps SP-9 and SP-11 (Figure 6.1-3a). As noted in Section 6.3.2, the chemistry of these waters are all similar indicating weakly acidic conditions with pH control by precipitation of aluminum hydroxides and sulfates. Chemistry is also controlled locally by the formation of ferric oxyhydroxides, barite, copper carbonates and sulfates (antlerite, brochantite, malachite - SP-15E, July 12, 1997), and cupricferrite. The copper minerals were previously identified by the USGS (personal communication with Jim Kilburn, 1999) (Table 6.1-1) and during the RI. The weakly acidic seeps at SP-9 and SP-11 contain lower sulfate (44 and 82 mg/L), copper (3 and 460 µg/L) and zinc (267 and 2340 µg/L) concentrations and had higher pH (>5.8) than the upslope seeps. For SP-11, the difference appears to be a dilution effect possibly by mixing with weakly alkaline runoff water. The increase in pH probably resulted in copper precipitation but did not affect zinc. SP-9 is further diluted in zinc and copper concentrations.

It appears that this pathway involves both permanent and seasonal removal of metals from solution. These include:

- Permanent removal of iron and aluminum from solution due to formation of oxyhydroxide precipitates (oxidation and precipitation). This is implied by MINTEQA2 calculations and confirmed by field observations.
- Probable co-precipitation of other metals with iron and aluminum (copper). Analysis of precipitates elsewhere on the Site have confirmed that co-precipitation occurs.
- Seasonal evaporation at SP-15E resulting in removal of copper from solution by formation of copper sulfates (efflorescence); these salts were observed. Spring seepage waters are undersaturated with respect to these minerals, therefore, they will redissolve.
- Mixing of alkaline waters with weakly acidic waters resulting in the formation of basic copper carbonates (malachite). The shift in pH dictates that this will occur.
- Contact of weakly acidic waters with carbonate-containing rocks, resulting in the formation of basic copper carbonates (malachite). Green coatings have been observed on marble blocks exposed on the surface of the west waste rock pile.

Seeps SP-22 to SP-25 and SP-24

Seep SP-22 flows from the slope below the maintenance yard, mill building, and west waste rock pile (Figure 6.1-3a). The chemistry of the seep resembles other seeps in the vicinity, although when monitored in May 1997, it had a pH of 6 and weak alkalinity (7 mg/L). MINTEQA2 indicates that the water is in equilibrium with amorphous aluminum hydroxide. This implies that this water has been influenced by the same processes occurring in the waste rock piles, but that it has been significantly diluted rather than mixed with alkaline water or contacted alkaline materials.

Seeps SP-24 and 25 flow from the south bank of Railroad Creek north of seep SP-22. The seeps are chemically very similar to SP-22 except that the pH is lower. Aluminum concentrations are higher due to the lower pH. Overall, the chemistry of seeps SP-22, SP-24 and SP-25 are comparable to other seeps in the vicinity with differences probably caused by dilution. Attenuation of metal concentrations appears to be caused principally by precipitation of aluminum hydroxides. Attenuation by adsorption in soils is not apparent. Seeps SP-24 and SP-25 may be influenced by the lagoon area.

Seeps SP-8 to SP-19

Seep SP-8 flows from the east waste rock pile and then flows partly overland and subsurface, re-emerging at SP-19 (Figure 6.1-3a). The differences for magnesium (which acts as a conservative ion) concentrations between these two points are consistent with dilution by a non-buffering water source (e.g., snow melt). The water is probably well-oxidized at SP-8 as shown by low iron concentrations. MINTEQA2 predicts that aluminum minerals would be expected to precipitate. As pH was not observed to change between the two points (4.6 S.U.), and aluminum concentrations decreased in proportion to conservative ions, no additional precipitation appears to occur between these points.

Significant metal attenuation between SP-8 and SP-19 does not appear to occur.

Seeps SP-19 to SP-10E and SP-10W

Seep SP-19 flows from the western portion of tailings pile 1 into the Copper Creek diversion near the river sauna (Figure 6.1-3a). Seeps SP-10E and SP-10W flow from the south bank of Railroad Creek north of the river sauna. SP-10W closely resembles SP-19 and MINTEQA2 predicted similar controlling conditions. The pH of the water appears to be controlled by aluminum minerals. Conservative ions indicate that SP-19 and SP-10W are nearly identical. Zinc and copper concentrations were, however, lower than other seeps nearby. This implies either that the water mixed with a source containing comparable sulfate, etc. and very low zinc and copper, or that zinc and copper were adsorbed by contact with soil.

Seep SP-10E indicated 20 percent less sulfate, 80 percent less zinc and 64 percent less copper than SP-10W in May 1997. However, pH was 3.3 for SP-10E compared to 4.5 for SP-10W. MINTEQA2 indicate that SP-10E water is in equilibrium with iron hydroxide as a result of 14 mg Fe/L. Field measured Eh for both SP-10W and SP-10E were comparable and indicated that the waters are well-oxidized.

The difference between the SP-10W and SP-10E waters could be explained by the mixing of a water containing high iron concentrations with water of the SP-10W. If the water contained reduced iron, it would oxidize and hydrolyze upon emergence (equations 6-5 and 6-6 presented earlier in this section), buffering pH near 3 and causing ferric hydroxide to precipitate. Copper and zinc would co-precipitate. The iron-rich water would have to contain less sulfate than SP-10W to produce the lower sulfate in SP-10E.

Attenuating mechanisms between seeps SP-19, SP-10E and SP-10W include:

- Precipitation of aluminum hydroxides (implied by MINTEQA2 and field observations)
- Precipitation of ferric hydroxides (implied by MINTEQA2 and field observations)
- Co-precipitation of copper and zinc with ferric hydroxides (implied by observations from elsewhere that indicate ferric hydroxide precipitates also contain these metals)

Mixing of Seeps with Railroad Creek Water

The seeps flowing into Railroad Creek between station RC-1 and the Copper Creek diversion confluence (SP23, SP12, SP9, SP11, SP25, SP24, SP10W, SP10E) are all acidic to some degree. Therefore, neutralization will occur upon mixing with the Railroad Creek water. The increase in pH will cause any remaining aluminum in solution to be precipitated as aluminum hydroxide flocculent. Copper in solution may precipitate as basic copper carbonate.

6.5.2 Tailings Piles

6.5.2.1 Processes in the Tailings Piles

Air Movement

Unlike the underground mine and waste rock piles, oxygen access to the tailings occurs principally by diffusion. Consequently, seasonal variations in ambient air temperature do not result in transitions between diffusion and convective air movement (Figure 6.5-11). In tailings deposits, only the immediately exposed surface of the deposit is usually oxidized because the fine texture limits movement of air into the mass. However, the fine-grained nature of the tailings results in higher surface areas than for coarser deposits such as waste rock. During relatively dry periods, oxidation occurs resulting in the buildup of oxidation products. During wetter periods (typically during snowmelt), saturation of the near surface pores reduces oxygen diffusion but leaches accumulated weathering products.

Water Flow

This section describes the surface water and groundwater transport pathways associated with tailings piles 1, 2, and 3. The conceptual transport pathways are summarized on flow charts presented as Figures 6.5-12 through 6.5-14. Figure 6.1-3a shows the surface water flow paths over and around the tailings piles. Figures 6.5-15 and 6.5-16 present conceptual hydrogeologic cross-sections showing anticipated water flow through and beneath the tailings piles in May and September, respectively.

Surface water infiltrates through the tailings piles as a result of direct precipitation and surface water run-on from the slopes south of the tailings piles. The potential for infiltration is greatest in the spring when the snow on the piles and the slopes south of the piles melt, and immediately following significant precipitation events. The fine-grained nature of the tailings results in relatively low permeability (documented by Hart Crowser in 1975 and RI data; see Section 4.4-3), which limits the infiltration of water into the piles. The low permeability of the tailings results in isolated ponding of water on the surfaces of the piles, especially on tailings piles 2 and 3.

Tailings piles 2 and 3 surface water run-on is collected in ditches on the piles and diverted around tailings piles 2 and 3 (Figure 6.1-3a). A ditch located adjacent to the upslope access road of tailings pile 3 also collects and diverts surface water run-on around tailings pile 3. Surface water run-on for tailings pile 1 is directed into ditches on the pile which convey the run-on to the edges of the piles. The ditches are not lined and some surface water likely infiltrates into the tailings piles. On tailings pile 1, some of this surface water is also directed to a decant tower that was observed during the RI to not be completely sealed and provides a pathway for water to infiltrate into the pile (Figure 6.1-3a). Surface water from the Copper Creek diversion also flows across the westernmost portion of tailings pile 1.

The water that infiltrates tailings migrates downward and accumulates (based on groundwater monitoring) in the lower portions of the piles as a thin water-bearing zone (Figures 6.5-15 and 6.5-16). The water within this zone appears to be perched on a lower permeability layer at the base of the tailings. Evidence of this layer was observed in test pits completed during the RI. Groundwater elevations in monitoring wells screened in the tailings indicate that groundwater generally moves to the north toward Railroad Creek (Figures 6.5-7 and 6.5-8). This water discharges from the base of the tailings piles as a series of intermittent seeps which flow into Railroad Creek.

The differences in water levels in clustered monitoring wells installed in tailings piles 2 and 3 indicate that the groundwater within the tailings is not in direct hydraulic connection with the groundwater in the underlying alluvium/reworked till (Figure 6.5-15). The water levels in the monitoring wells screened in the tailings remain relatively constant throughout the year, only fluctuating approximately 3 feet during the 1997 field season. Water levels in the monitoring wells screened in the alluvium/reworked till underlying the tailings were observed in several cases to fluctuate more than 20 feet.

In the spring, when the recharge is greatest to the alluvium/reworked till, water levels in this unit increase relatively rapidly and the groundwater appears to be confined by the overlying low permeability tailings. This results in an upward vertical hydraulic gradient in the southern portions of the tailings piles which causes water from the alluvium/reworked till to move into the overlying tailings (Figure 6.5-15). In the northern portions of the piles, the water levels are higher in the tailings than in the alluvium/reworked till and water moves downward from the tailings into the underlying deposits. As water levels decline in the summer, the vertical hydraulic gradient reverses beneath the southern portions of the tailings piles and water within the tailings moves downward into the alluvium/reworked till (Figure 6.5-16).

Groundwater within the alluvium/reworked till generally moves in a northerly direction beneath the tailings piles (Figures 6.5-7 and 6.5-8). In May, the groundwater discharges into a series of seeps that flow into Railroad Creek. The groundwater also discharges as diffuse baseflow into Railroad Creek, as indicated by the apparent gaining conditions measured in this reach of the stream and the relationship between the water levels in the alluvium/reworked till which are higher than those observed in the creek. Some of the discharge to Railroad Creek is believed to occur through the abandoned Railroad Creek channel which is approximately parallel to the northern edges of the tailings piles. Flow within the abandoned channel is assumed to move in an easterly direction rather than to the north.

In September, the occurrence of seeps decreases significantly with only a few seeps observed (SP-1, SP-2 and SP-3) and seep flow rates decreasing significantly. In September, the groundwater flow within the abandoned Railroad Creek channel is evident based on the water levels in the wells near the former channel. Diffuse groundwater continues to discharge along the base of tailings piles 1 and 2, but portions of the reach of Railroad Creek near tailings pile 3 appear to be in a losing condition.

Groundwater Chemistry

The geochemistry of tailings groundwater, based on samples collected and analyzed from groundwater monitoring wells and seeps, is primarily influenced by oxidation of the surface tailings by oxygen entering through diffusion. This is indicated by the presence of a thin oxidized zone in the near surface and unoxidized tailings at depth. Water moving down through the tailings piles carries sulfate, acidity and reduced iron. Some of the iron is precipitated in the immediate subsurface as cementation but most of the iron moves downward in a reduced state. This water moves through the tailings, probably being neutralized by contact with alumino-silicates as is apparent for the whole Site. This process probably adds additional iron due to dissolution of hornblende. The extent of this neutralization is controlled by the length of the flow path. Waters entering the piles along the slopes adjacent to Railroad Creek, Copper Creek, and the Copper Creek diversion will have relatively short flow path lengths with little opportunity for neutralization. For this reason, the chemistry of seeps (SP1, SP2, SP3, SP4, SP5) observed along the toes of the tailings piles represents mixing of groundwater impacted by water moving downward through the pile over different flow path lengths.

The observed chemistry of the seeps generally reflects this hypothesis. The seep chemistry of all three piles is very similar. The differences are in pH and changes in ratios of elements, which imply drift toward Railroad Creek water chemistry. Seepage water probably mixes with unimpacted groundwater to varying degrees resulting in dilution of tailings groundwater. The pH changes also cause changes in iron concentrations, and co-precipitation of heavy metals such as copper, zinc and cadmium. The low pHs indicate precipitation of ferric hydroxide (see equation 6-6 presented earlier in this section). Internal groundwater pHs are generally greater than 4 and indicate silicate buffering as observed elsewhere at the Site.

Specific comments for individual piles are provided below.

Tailings Pile 1

Referring to Section 5 of this report, water chemistry data for monitoring wells (screened in the underlying surficial materials and within the tailings) and seeps in tailings pile 1 suggest that both affected and natural groundwaters flow under the tailings and discharge to Railroad Creek. Well TP1-6A reported the highest concentrations of copper (1100 μg/L), cadmium (100 μg/L) and zinc (11,400 μg/L); exceeding the levels recorded for seeps SP-1 and SP-2. Water from well TP1-4A represents groundwater that has not been impacted by tailings, as it contained low levels of metals and sulfate (Cu: <2 μg/L; Zn: 28 μg/L; Cd: <0.2 μg/L; Fe: 30 μg/L; SO_4: 300 mg/L) and a near-neutral pH (6.7). Zinc concentrations showed a degree of zonality within the groundwaters. Low zinc concentrations were detected near the upslope edge of the tailings (TP1-1 and TP1-4; 466 and 28 μg/L, respectively) whereas concentrations one to two orders of magnitude higher were observed in wells further downslope near Railroad Creek (TP1-2, 3, 5 and 6; 2,270 to 11,400 μg/L). These wells were comparable in zinc concentrations to discharge from seeps SP-1 and SP-2 (3490 and 4570 μg/L). The increase in zinc concentrations occurs approximately along the axis of the former Railroad Creek channel under the tailings.

Compared to the monitoring wells that are screened in the underlying surficial materials, wells screened in the tailings groundwater contained low concentrations of zinc. Iron concentrations were approximately three to five times higher. This suggests that tailings are contributing dissolved reduced iron and sulfate to the underlying groundwaters.

The chemistry of these monitoring wells is compatible with a groundwater flow pattern that includes natural groundwater from upslope and affected groundwater originating from the east waste rock pile and/or the mill buildings area. Further, these groundwater concentrations may be influenced by groundwater flowing within the former creek channel which underlies the tailings. This relatively permeable unit may control and channel the flow of affected groundwater from the weathered source areas, including the portal drainage, lagoon, waste rock piles, and mill area towards the SP-2 seep.

Tailings Pile 2 and 3

Groundwaters sampled from the underlying surficial material in the central areas of tailings piles 2 and 3 (e.g., wells PZ-1A, TP2-5A, TP3-6A) generally had low metal concentrations (e.g., Cu: <2 to 67 µg/L; Zn: 32 to 400 µg/L; Cd: 0.2 to 2.2 µg/L), although an occasional elevated iron level (5,710 µg/L iron) was observed in PZ-1A. This elevated level is probably the result of groundwaters leaching natural materials or minor incursions of tailings waters infiltrating the substrate.

The metals load discharged by the seeps (SP-3, SP-4, SP-5 and SP-18) appears to be the result of oxidation of tailings, possibly due to the interaction with groundwaters derived from Railroad Creek. Groundwater wells in the substrate near the tailings pile edges (e.g., TP2-4A, PZ-6A, TP3-8) had higher concentrations of iron (7,040 to 58,300 µ/L), sulfate (340 to 1,500 mg/L) and total dissolved solids (500 to 2,400 mg/L). Limited data on groundwaters in saturated tailings (e.g., PZ-1B) report elevated iron (69,000µg/L) and elevated sulfate concentrations (850 mg/L). These values are similar in magnitude to the concentrations recorded for the seeps (Fe: 23,900 to 154,000 µg/L; SO_4: 530 to 880 mg/L).

6.5.2.2 Metal Removal

Metal removal mechanisms are described below and are summarized in Figures 6.5-17 to 6.5-19.

Tailings Pile 1 Area

Seepage emerges from the base of tailings pile 1 at SP-1 and SP-2 and enters Railroad Creek. The seeps are strongly acidic (pH<4) and contain elevated concentrations of sulfate (>2000 mg/L) and iron (~1000 mg/L). As the acidic seepage mixes with Railroad Creek water, it goes through several rapid chemical changes including:

- Conversion of unoxidized ferrous iron to ferric iron by atmospheric and dissolved oxygen
- Increasing pH due to dilution and stream water alkalinity allowing additional ferric iron to precipitate as flocculent (in surface water) or goethite (in groundwater)
- Co-precipitation/sorption of copper with flocculent or ferricrete
- Further pH increase due to dilution and stream water alkalinity resulting in precipitation of aluminum as flocculent or aluminum hydroxide precipitate
- Formation of copper carbonate flocculent

Attenuation occurs by precipitation of ferricrete, aluminum hydroxide, copper carbonate and co-precipitation of copper with ferricrete.

MINTEQA2 indicates that the seep waters are saturated with respect to basic aluminum sulfate, alunite, barite, and goethite. Copper concentrations are low in both cases, hence, copper concentrations do not appear to be in equilibrium with any copper minerals. Analyses of ferricrete (formed by the precipitation of iron oxyhydroxides such as goethite) have indicated copper concentrations up to 2,340 mg/kg. Copper is expected to co-precipitate with goethite. The seeps tend to contain more zinc than copper but ferricrete proportionately contains much less zinc than copper. Copper tends to attenuate as groundwater containing ferrous iron is oxidized and goethite precipitates. Zinc attenuates to a lesser degree.

Tailings Piles 2 and 3

Mechanisms in the tailings pile 2 and 3 are identical to tailings pile 1. The seeps are geochemically identical except that seeps SP-3, SP-4 and SP-5 are more dilute than SP-1 and SP-2. This is attributed to partial mixing of Railroad Creek groundwater with seepage from the tailings pile and longer contact paths with neutralizing materials. The fate of the seeps is the same as seeps SP-1 and SP-2 from tailings pile 1.

6.6 RAILROAD CREEK

6.6.1 Surface Water Loading Analysis

6.6.1.1 Introduction

Dissolved metals enter Railroad Creek as seep flow, drainage flow and groundwater baseflow.

A chemical and flow mass balance analysis was performed for reaches of Railroad Creek that receive mine drainage and reaches located upstream and downstream of mine influences. The purpose of the mass balance was to:

(1) assess metal contribution in drainage water from point sources measured during the RI in relation to metal concentrations in Railroad Creek upstream of mine influences

(2) determine the point source discharges that contribute the highest metal concentrations to Railroad Creek

(3) assess if specific reaches within Railroad Creek contain non-point-source or "unaccounted" (assumed to be baseflow) metal load, and

(4) evaluate the chemical loading analyses in relation to the water balance of select reaches of Railroad Creek

Flow and metal concentrations of seeps and drainages were measured during the RI to assess contribution of these inputs to Railroad Creek during the May and September 1997 sampling rounds. Flow and water quality measurements in Railroad Creek were repeated at selected stations in late April/May 1998.

The effects of seep, drainage and groundwater inputs to the surface water quality of Railroad Creek are observed by the changes in seasonal water quality conditions in a downstream direction. Dissolved metals entering Railroad Creek in groundwater, seepage flow and flow from the 1500-level main portal drainage and other drainages attenuate within Railroad Creek by dilution, acid buffering and adsorption reactions in the surface waters. Some of the dissolved metals precipitate out of the water column and settle on the bottom of Railroad Creek.

Seasonal metals concentrations indicate that copper, zinc, and cadmium are at their highest levels during spring snowmelt (May/June) when seeps and discharge from the portal drainage are at their highest, as discussed previously in Section 5. Iron concentrations are at their highest during periods of lower flow. In addition, copper, zinc and cadmium increase the most dramatically between stations RC-1 and RC-4, and iron (and to a lesser extent zinc) concentrations increase most dramatically between stations RC-4 and RC-7. These observations indicate that copper, cadmium and zinc enter Railroad Creek from the portal drainage and associated seeps and drainages north of the tailings piles, and that iron is introduced primarily from seepage and groundwater flow from the tailings.

6.6.1.2 Mass Balance Calculation Method

The metal loading to Railroad Creek was computed using flow measurement data and analytical results for water samples collected over a two-day period in 1997. Specifically, loading was calculated as the measured concentration for each metal for each source times the flow rate of each source at the time the sample was collected. The individual source loading was compared to the computed loading for the same constituent at the same time within Railroad Creek. Loading is reported as mass per unit time. For the purposes of this study, the loading is reported as milligrams per second (mg/s), which are common units for reporting loading results.

Flow data used to compute the loading from the seeps and seep-related drainages were estimated and/or measured directly in the field at the time that the water quality sample was collected. Field flow measurement methods used were previously described in Sections 3 and 4. Flow measurement accuracy is directly related to the flow volume measured at each station and the measurement tools utilized. The accuracy of the flow measurements for the surface water in Railroad Creek ranges between 5 and 7 percent using a flow meter (Swoffer or Price AA), and 10 to 12 percent utilizing a bridgeboard, as used at RC-2 and RC-4 during high flow conditions.

The accuracy of seep flow measurements at SP-6 through SP-9, SP-14 through SP-19, SP-21, SP-23A and SP-23B was estimated to be ±25 percent.

Seep flow estimates for SP-1 through SP-5; SP-10E/W through SP-13; and SP-24 through SP-26 are assumed to be accurate within ±50 percent of the actual value because of limited amount of flow and the difficulty in capturing and measuring flow emerging as diffuse seepage. Although the accuracy of these measurements is marginal, the loading analysis will demonstrate that the load of select metals at these seep locations were an insignificant proportion to the overall load of select reaches of Railroad Creek.

It should be noted that the flow in Railroad Creek was dynamic and was changing during the period that seeps were sampled, and also during the time that Railroad Creek was sampled (particularly during the May and July sampling rounds). Consequently, the flow measurements recorded at the time of seep sampling did not always reflect comparative flow conditions relative to RC-2.

In order to provide comparative flow conditions between stations in Railroad Creek, the following assumptions and estimates were made for the loading analysis:

- Measured flow was used if flow conditions were not changing during the sampling round.
- Flow was estimated during dynamic flow conditions such that flow was consistent with downstream flow relationships between stations.
- Creek drainage and seep concentrations were assumed to be representative for the flow conditions encountered or estimated during the loading period.

The results of the loading analysis for May and September 1997 are presented in Tables 6.6-1 and 6.6-2, respectively. The analysis was performed by dividing Railroad Creek into two reaches. Reach 1 included the creek from RC-1 to RC-4. Reach 2 included the creek from RC-4 to RC-2. The tables show loading calculations for magnesium, zinc, cadmium, copper and iron. For each parameter, the flow was multiplied by the concentration for each source to yield the load. The loads were then added to give the cumulative load at each station. At RC-4 and RC-2, the cumulative load from each source was compared to the total load measured in Railroad Creek. Total load in Railroad Creek is the load calculated using the water quality data for samples collected at RC-4 or RC-2. The commutative load for each reach was subtracted from the total load of each reach. The results are referred to in the tables as "Reach 1 Balance" and "Reach 2 Balance." The tables also show the total balance. In general, these balances account for non-point-source discharges (groundwater) or (if negative) can indicate load loss due to flow loss or chemical effects. The balances also incorporate the uncertainties in the measurements of flows. The results for the April/May 1998 loading analysis are shown in Table 6.6-3. Percent loading for 1997 is provided by location on Figure 6.5-20.

6.6.1.3 Loading Analysis and Mass Balance Results - 1997

Conservative Parameter - Magnesium

As a first step to confirming the validity of the mass balance approach, a chemically conservative parameter, rather than a heavy metal, can be used to calibrate or verify the site-specific water balance discussed in Section 4.4. The term "conservative parameter" is described in Section 6.3.3.1. The purpose is to confirm the water mass balance using a parameter for which the total load can be accounted for. The parameter selected in this case was magnesium. The main reason for selecting this parameter is that magnesium is released by weathering processes at the Site and is always detectable. Other conservative parameters such as chloride are not released by weathering and are frequently non-detectable, and therefore are not appropriate for this purpose.

In Table 6.6-1 (May 1997 calculation), the incoming magnesium load at RC-1 was 5098 mg/s. In Reach 1 (defined as receiving mine and support area drainage – RC-1 to RC-4), the source load additions totaled 986 mg/s, for a cumulative load of 6084 mg/s. The greatest proportion of the load originates from P-5, followed by SP-23. The measured load in Railroad Creek at RC-4 was 6656 mg/s. The deficit between the two (cumulative at RC-4 and measured at RC-4) was +572 mg/s. If this load is applied to the inputs from groundwater calculated using the water balance (0.9 cfs, 25.49 L/s), the required concentration was 22.5 mg/L, as shown in Table 6.6-1. Magnesium concentrations were generally less than 10 mg/L in the portal drainage, lagoon and seeps. The calculated concentration was, therefore, greater than the expected concentrations, but statistically the two concentrations were equivalent because of the above-mentioned uncertainties associated with the flow estimates.

Relative to measured incoming load in Reach 2 (tailings influenced stream segment from RC-4 to RC-7), the additions of magnesium were less than the additions in Reach 1. The deficit was +1550 mg/s. The calculated concentration using this deficit was 26.1 mg/L (Table 6.6-1) which was close to the range of magnesium concentrations of 30 mg/L to greater than 100 mg/L in seeps.

The deficit between RC-7 and RC-2 was 684 mg/s, which was close to the contribution from SP-4 (515 mg/s).

The May 1997 analysis for magnesium implies that there are no significant missing magnesium load contributions in the spring. The deficits between surface water additions and measured loads in Railroad Creek can be accounted for by reasonable groundwater flows and magnesium concentrations.

The September 1997 magnesium load calculation for Reach 1 (Table 6.6-2) indicates little change between RC-1 and RC-4 (-19 mg/L). The load provided by the only measurable source (P-5) was not significant relative to the load entering the Site at RC-1, and represented only 1.1 percent of the load previously measured in May 1997. The Reach 1 balance was shown as a negative load (-75 mg/s). This small negative load was consistent with the apparent flow loss in the reach (Section 4.3.7). In Reach 2, the load balance was 711 mg/s, which can be accounted for by a groundwater contribution similar to that observed in May 1997.

In summary, the magnesium balance is in agreement with the site-specific water balance. The magnesium balance indicated that all major sources were identified and that the required flow balances were consistent with magnesium concentrations observed in both surface water and groundwater.

Quasi-Conservative Parameters – Zinc and Cadmium

Zinc and cadmium are often observed to show almost conservative behavior because their solubility is not influenced by pH within the pH range normally encountered on site. They can be adsorbed onto soil and sediment particles; however, this may not be a strong effect in coarse gravelly soils and stream beds.

The loading calculation of zinc followed the same approach as for magnesium. In May, the difference between RC-1 and RC-4 was 850 mg/s. The majority of this difference can be accounted for by P-5 (849 mg/s). SP-23 provided 71 mg/s, hence the cumulative load at RC-4 from measured sources was 1123 mg/s. This load at RC-2 was greater than the load at RC-4 (1034 mg/s). The balance of –90 mg/s is small relative to the inflow from P-5 and therefore is not significant. The data imply that all significant loads in Reach 1 have been identified.

In Reach 2, very little zinc was added compared to Reach 1. The Copper Creek diversion was the largest source. The required balance was 146 mg/s, which was larger than the point sources along Reach 2. The concentration required to produce this balance was 2.5 mg/L. This implies that groundwater originating in Reach 1 (i.e., from the mine support areas) enters Railroad Creek in Reach 2. The total of the balances for Reach 1 and Reach 2 is 56 mg/s. This is less than 5 percent of the total load in Railroad Creek and implies overall that non-point sources contribute insignificantly to the load in Railroad Creek during May. P-5 is the main source of zinc load (82 percent of load added downstream of RC-1, not including Copper Creek). Other sources account for less than 6 percent individually.

A similar approach was used for the September 1997 calculation. A contribution from groundwater was added in Reach 1 to account for the difference between load observed at RC-1 and RC-2 (63 mg/s) that could not be accounted for by load contributed by P-5 (16.9 mg/s). In September, non-point sources appear to represent the majority (77 percent) of the zinc load added to Railroad Creek between RC-1 and RC-2. The total balance (non-point source discharge, i.e., groundwater) for zinc between RC-1 and RC-2 in September 1997 (63 mg/s) is comparable to the total balance in May 1997 (56 mg/s).

The cadmium balance for May 1997 indicates that P-5 is the main source (5.1 mg/s, 70 percent of load added by the Site) and that the total balance is the next largest source (17 percent). In September, 1997, the contribution from non-point sources was 80 percent compared to 17 percent from P-5, though the load from non-point sources remained comparable (1.23 mg/s in May compared to 0.24 mg/s in September). The findings are comparable to zinc and indicate that portal drainage accounts for the majority of load entering Railroad Creek in May. In September, most load enters Railroad Creek through groundwater. The groundwater contribution appears to be relatively stable.

Non-Conservative Heavy Metals – Copper and Iron

Mass balances for copper and iron provide limited information because they are readily removed from solution by precipitation changes (as seeps mix with Railroad Creek) and adsorption.

The copper load observed at RC-4 in May 1997 (374 mg/s) can primarily be accounted for by P-5 (225 mg/s) with lessor contributions by SP-23 (97 mg/s) and RC-1 (16 mg/s). The balancing (groundwater) load (20 mg/s) was negligible compared to the other loads. Copper load appeared to decrease between R-4 and RC-2. The load required to balance was –48 mg/s. Overall, a small negative load balance of –28 mg/s was indicated for RC-1 to RC-2 after accounting for known sources. This is consistent with removal of copper solution by pH adjustment and adsorption, which occurs continually along Railroad Creek as low pH waters mix with surface water but is particularly likely in Reach 2 when iron is added by the tailings pile seeps. The negative balance does not preclude the addition of copper through groundwater sources. The balance indicates that the net effect of addition through groundwater and removal by attenuation mechanisms is net removal.

The September 1997 calculation indicated a positive load balance requirement in Reach 1 and negative load balance for Reach 2, although overall, a positive balancing load of 2.6 mg/s was obtained and is the largest source of load to Railroad Creek. Qualitatively, the calculations for May and September 1997 are similar. Differences between May and September reflect changes in P-5 water quality and quantity and removal of copper prior to mixing with Railroad Creek.

The calculation for iron indicated a load loss between RC-1 and RC-4 in May. Iron concentrations were very low and the decrease was probably due to near detection limit (0.02 mg/L) concentrations in Railroad Creek. Significant load increases were observed between RC-4 and RC-7, followed by a decrease between RC-7 and RC-2. The load added by surface seeps was not sufficient to account for the load increase observed, hence a balancing load of 1412 mg/s was added. The calculated iron concentration for the load is 24 mg/L. This concentration of iron is lower than observed in seeps which indicates that a portion of the iron added is precipitated and is, therefore, not accounted for under the dissolved load. The decrease in load between RC-7 and RC-2 may reflect oxidation of ferrous to ferric iron. As oxidation occurs, ferric iron is precipitated. The September calculation indicated a similar conclusion.

Dissolved iron is contributed primarily from groundwater baseflow along the tailings piles. Iron loads are highest during the spring when flows are the highest. Iron loads decline through summer and fall after seeps have begun to dry up and groundwater recharge is no longer occurring. Iron discharge is delayed relative to zinc, cadmium and copper because iron loads are from groundwater baseflow, not seeps or drainages. The delay in iron loading reflects an extended period of infiltration through the tailings piles with subsequent discharge through the base of the piles into the streambed of Railroad Creek. This also suggests that seep flow is sustained by bank storage and groundwater flow associated with the alluvial materials beneath the tailings piles, and is not necessarily directly related to recharge through the piles.

6.6.1.4 Loading Analysis and Mass Balance Results – Spring 1998

The loading of copper, zinc, cadmium and iron in Railroad Creek was estimated from the flow measurements and water quality results obtained during the 1998 May sampling round. The loading estimates were developed for all of the sampling locations with concurrent flows that were either measured or could be reasonably estimated from flow relationships between stations (see Section 4.3). The load values were developed for comparison with the May 1997 values and are assumed to be approximate given that flow timing was not considered in the calculation. Table 6.6-3 shows the May 1998 load estimates and is compared herein to Table 6.6-1.

In general, the May 1998 total load in Railroad Creek was larger for copper, zinc, and cadmium relative to 1997, and the iron load was lower. However, the pattern of loading was similar to 1997 with the majority of the load for copper, zinc and cadmium accounted for by the portal drainage, and the majority of the iron loads occurring between RC-4 and RC-2 from groundwater. Additionally, copper, zinc and iron loads decreased downstream of their sources, similar to 1997. Very little of the metals load observed at RC-2 appeared to be generated upstream of the Site, as indicated by low relative loads observed at upstream stations in Holden Creek, Big Creek and at RC-11.

The larger load values for copper, zinc and cadmium may be a result of the earlier sampling time relative to the first flush from the 1500-level main portal drainage as compared to the 1997 May sampling event. The 1997 May samples were collected during the initial part of snowmelt; however, based on the Railroad Creek hydrograph at RC-4, a melt event had already occurred by the time the samples were collected; sampling had been completed in April 1997 before, but not during, the event. In 1998, however, the samples were collected earlier in the melt period, during the first snowmelt event (see Section 4.3). The lower iron loading may reflect lower groundwater yields because of a delay in groundwater discharge to Railroad Creek, given that the sampling in 1998 occurred earlier in the melt period.

6.6.1.5 Loading Analysis and Mass Balance Results – Additional Source Areas

Waste Rock Piles and Mill Area

Additional source areas that contribute metals load to the site include the East and West Waste Rock piles and the mill area (Figure 6.5-20). The loading of dissolved cadmium, copper, iron, and zinc from these source areas was estimated from flow measurements and water quality results for seeps associated with these areas collected in the spring and fall of 1997. The loading analysis included the data from seeps SP-6 and SP-15E, associated with the west waste rock pile, SP-7 and SP-22 associated with the mill area, and SP-8 associated with the east waste rock pile. These seeps do not enter Railroad Creek as surface flow and are considered to contribute to downslope seeps and ultimately to the alluvial aquifer. The loading analysis was conducted to quantify the maximum load available from these areas that could contribute to dissolved metals loading into Railroad Creek. The loading data are provided in Table 6.6-4 and shown on Figure 6.5-20.

The data indicate that maximum loading from these source areas accounts for a small percentage of the total load at RC-2 ranging from 0.2 to 2.9% for cadmium, 0.1 to 4.3% for copper, less than 0.01% for iron, and 0.4 to 2.7% for zinc. The highest loads result from the mill area at SP-7 and the west waste rock pile at SP-15E in the spring. The seeps used for the loading analysis were not flowing in the fall except in response to significant precipitation.

SP-21

A loading analysis was also performed for data collected from SP-21 located east of tailings pile 3 and downstream of RC-2. Chemical data, direction of groundwater flow (especially in the fall), and the documented loss of flow in Reach 2 (RC-4 to RC-2) indicate that affected groundwater from the tailings and loss from Railroad Creek (unaccounted load) may be measurable at SP-21. Loading for dissolved cadmium, copper, iron, and zinc were calculated using flow measurements and analytical data collected in the spring and fall of 1997. The percentage load is based on RC-2 as an appropriate location downstream of SP-21 on Railroad Creek was not established.

The analysis indicates that loading for these metals ranges from 0.8 to 1.2% in the spring and 0.1% or less in the fall.

6.6.1.6 Conclusions

The following is concluded from the loading calculations:

- All significant observed loads have been identified and accounted for in Railroad Creek.
- Groundwater loads can be used to balance Site area chemical loading. Back-calculated concentrations using flow estimates compare well with expected groundwater sources such as mine discharge water and tailings seepage.
- Copper and zinc loads to Railroad Creek from measured point sources and other groundwater (baseflow) sources are highest during the spring snowmelt and groundwater discharge period when groundwater levels are highest in the deep wells beneath the tailings, and high flow occurs at the 1500-level portal drainage. During the May round when flows are the highest, the portal drainage is the primary source of loading of cadmium, copper and zinc to Railroad Creek.
- Seeps SP-23 and SP-23B are the two next highest point sources that are estimated to contribute cadmium, copper and zinc during May; however, this load drops to zero later in the year as seep SP-23 dries up.

- Infiltration of water from the portal drainage to the underlying alluvial aquifer may account for metals concentrations in seeps located downgradient from the portal drainage that flow into Railroad Creek or to groundwater baseflow.
- Iron enters Railroad Creek primarily by groundwater and iron loads are greater in September than May. Iron loads enter Railroad Creek downstream of the load sources (i.e., portal drainage) for cadmium, zinc and copper, which enter the creek as surface flows or seeps.
- Similar results were obtained in spring 1997 and 1998. Differences in absolute loadings were observed and can be attributed to differences in timing of monitoring. The 1998 monitoring was conducted during the initial part of snowmelt, likely resulting in the measurement of greater loads of copper, zinc and cadmium entering Railroad Creek.
- Additional source areas located at the west and east waste rock piles and the mill area are not significant loading sources to Railroad Creek. Metals loading at SP-21 may account for a component of unaccounted loads noted in September.

6.7 COMPARISON OF THE HOLDEN MINE WITH OTHER MINE SITES

This section provides case example comparisons of two other mines with characteristics similar to the Holden Mine. The examples are relatively typical of hard rock metal mines in northwestern North America and were selected on the basis of similar mine configuration, comparable waste types and leaching of similar elements. These cases illustrate that the chemical processes operating at the Holden Mine Site have been documented elsewhere, are not unique to the Holden Mine, and demonstrate that the Site does not represent extreme mine drainage conditions.

6.7.1 Baker Mine

The Baker Mine is a small underground gold mine located in a sub-alpine area in north central British Columbia. Similar to the Holden Mine Site, the Baker Mine experiences winter conditions during which a snow pack forms. In June, the snow pack melts releasing large quantities of water in a few weeks. Summers are relatively warm and dry with occasional thunderstorms. The fall is wetter before snow starts to accumulate in October. The summer is shorter than at the Holden Mine Site, but the overall climatic conditions are comparable.

Although the Baker Mine is much smaller than the Holden Mine, the configuration of the workings is comparable (Figure 6.7-1). Mine drainage exits from a single portal. A second portal is located 100 feet above this portal, and a small open pit is located on the slopes immediately above the mine; mine drainage does not flow from these two workings. The mine exploited an epithermal gold vein for a few years in the early 1980s and is now being reclaimed. The immediate mine sequence contains little carbonate. Two bulkheads were installed in the portals in 1993 with the intention of flooding the mine. However, as a result of leakage around the bulkheads, holes were drilled in the bulkheads to allow water to drain freely.

Monitoring of seeps from drill holes, fractures and backfill inside the workings prior to installing the plugs indicated that most seeps had pH between 3 and 3.5. As a result, acid generation within the Baker Mine has reached the most reactive stage and mine drainage is not expected to worsen.

Figures 6.7-2 to 6.7-4 compare drainage chemistry for the Baker Mine with the Holden Mine. P-5 was used rather than P-1 because it has a larger dataset. For comparative purposes, data for different years of monitoring are superimposed on one graph depicting one year. The Baker Mine dataset begins in May prior to the snow melt. The drainage pH is near 7. As the melt event begins, pH drops to 4.4, then as the portal discharge decreases pH increases until pH is near 7 in October. Almost exactly the same pH trend is seen at the Holden Mine 1500-level main portal drainage (P-5). During maximum flows, the pH of the Baker Mine discharge is low, but then steadily increases through the summer, reaching neutral conditions by September.

The mechanism involved is identical at both the Baker Mine and Holden Mine. The melting of the snow pack results in flushing of weathering products accumulated during the previous winter. As the melt event moderates, pH increases due to reduced leaching of acidic weathering products. The Baker Mine drainage contains a buff precipitate similar to the precipitate observed in the Holden Mine portal drainage. The lowermost extreme of pH values is controlled at both the Baker Mine and Holden Mine by the precipitation of aluminum hydroxides. The host rocks at the Baker Mine were altered to clay alumino-silicates during mineralization. The acid solutions formed by pyrite oxidation attack these minerals, resulting in the release of aluminum.

The comparison of copper concentrations indicates very similar concentrations and trends for the Baker Mine and Holden Mine. Copper concentrations are relatively low for the majority of the year for the Baker Mine, but increase as pH decreases during spring snowmelt (Figure 6.7-3). The almost identical copper concentrations indicate a common chemical control, which could be copper carbonates, or co-precipitation with aluminum hydroxide. Comparison of zinc concentrations indicates order-of-magnitude higher concentrations at the Holden Mine (Figure 6.7-4). Unlike the Holden Mine, the Baker Mine does not have zinc mineralization, and zinc concentrations are not constrained by secondary mineral formation at these pHs. The differences between the Baker Mine and the Holden Mine in terms of source zinc availability, therefore, become apparent.

6.7.2 Sullivan Mine

The Sullivan Mine is a relatively large underground massive sulfide lead-zinc deposit located in the Canadian Rocky Mountains. The area also experiences cold winters during which snow pack accumulates. The snow pack melts in April and May and summers are hot and dry. The Sullivan Mine has been operating since 1910 and consists of an active underground mine, an abandoned open pit, several waste rock piles and a relatively large tailings disposal area resulting from conventional flotation (the method utilized at the Holden Mine Site) of lead and zinc sulfides from a sulfide ore composed of pyrrhotite and pyrite.

6.7.2.1 Underground Mine

The underground development of the Sullivan Mine is accessed by a single portal. Drainage chemistry is summarized in Figures 6.7-2 to 6.7-4. The pH of the drainage is continuously low, approximately around

3, indicating buffering by iron hydroxide. The host rocks have little buffering capacity from carbonates or alumino-silicates. Seasonal variations are not apparent for pH. Copper is not abundant in the deposit; therefore, concentrations are lower than at the Holden Mine, but as pH remains low year round, the high solubility of secondary copper minerals results in relatively constant copper concentrations. Variations in copper concentrations are not readily correlated with season. In comparison, zinc concentrations are elevated throughout the year due to the abundance of zinc in the ore. Zinc concentrations also appear to peak in April during snow-melt.

6.7.2.2 Waste Rock

Waste rock has been disposed in two primary areas. Seepage is severely acidic and comparable to the underground drainage. Seepage from a second waste rock disposal area emerges at a pH between 4 and 5, contains elevated zinc concentrations, and has deposited a white precipitate in a nearby small stream. The precipitate has been found to be amorphous aluminum hydroxide.

6.7.2.3 Tailings

The tailings disposal area contains various types of ore processing residues including raw, high-sulfide tailings produced by preferential flotation of iron sulfides, and low-sulfide siliceous tailings. The tailings are classified as potentially acid generating due to the lack of acid buffering capacity. In one location downgradient of the high-sulfide tailings, acidic seepage has been noted. Seepage pH varies from 2.8 to 5.5, and is accompanied by about 20 g/L sulfate, and 10 g/L iron. Zinc, lead and copper concentrations are very low (<0.3, <0.001, <0.2 mg/L, respectively) despite the aggressive leaching conditions.

6.7.3 Conclusions

The Baker Mine showed comparable chemical behavior to the Holden Mine. Similarities included seasonal variation in pH due to flushing of acidic weathering products during snow melt, buffering of acidity by alumino-silicates, and formation of buff aluminum hydroxide precipitates at the mine portal. By analogy to the Baker Mine, it would be expected that the Holden Mine drainage would maintain at comparable pHs through the winter to those observed in the fall, rather than the lower pH observed in the spring.

The Sullivan Mine generally indicates much more severe acid rock drainage than observed at the Holden Mine probably due to the lack of abundant alumino-silicates to buffer acidity. The drainage from the Sullivan underground mine would probably be described as typical ARD. The Holden Mine drainage is, therefore, relatively weakly acidic when compared to most other acid producing mine sites. Some similarities to the Holden Mine include the presence of white aluminous precipitates downgradient from some waste rock piles, and low base metal concentrations in tailings seepage despite strong acid generating conditions, reflecting removal of base metal sulfides during processing.

The comparison of the Holden Mine with other mines indicates that geochemical processes occurring at the Holden Mine occur at other mine sites. The Baker Mine in particular shows many similarities to the Holden Mine. These include similar seasonal trends in pH (low in spring increasing through summer), minimum pH of 4.5 in mine drainage, comparable copper concentrations due to similar mineralogical control and buffering by alumino-silicates. The Baker Mine is believed to have a regional stable geochemical conditions. Likewise, the Holden Mine is also believed to be stable.

The similarities with other mines indicates that the experience gained at other sites will be applicable to planning remediation at the Holden Mine.

6.8 FLOCCULENT AND FERRICRETE

6.8.1 Flocculent

Iron flocculent is a colloidal material that is generated from baseflow groundwater contributed to Railroad Creek from the tailings piles. As the pH of the groundwater increases upon contact and mixing with surface water, iron oxyhydroxides become stable and precipitate. Some of the copper that is in solution and lesser amounts of cadmium, zinc and other metals coprecipitate with the iron as the iron flocculent is formed. During the fall and winter months when groundwater flow is low and the flow in Railroad Creek is low, the majority of the flocculent that is generated settles in the base of the creek bed with some limited transport downstream.

In the spring, when both groundwater and surface water flows are high, flocculent continues to be generated. Due to the high flow, spring flocculent and flocculent that has accumulated in the Creek bed from fall/winter are mobilized and are both transported downstream. Flocculent is transported during spring runoff and precipitation events.

6.8.2 Ferricrete Formation

Ferricrete is typically defined as a conglomerate consisting of sand and gravel cemented into a hard mass by ferric oxides and sulfates derived from the oxidation of percolating iron-bearing solutions. The vertical and lateral variation in thickness and character of ferricrete in Railroad Creek suggests that percolating solutions infiltrate whatever material is present. Ferricrete formation is dependent on the supply of salts and degree of oxygenation of the solution. Increased infiltration of waters to the tailings dissolves the accumulated iron and metal salts in the tailings, putting iron and metal cations, sulfate and acidity into solution. Ferrous iron (Fe^{2+}) in groundwater, discharges as baseflow to Railroad Creek where oxidation and an increase in pH occurs. Ferrous iron converts to ferric iron (Fe^{3+}), complexes with hydroxides forming iron oxyhydroxides and then precipitates. Other metals may also coprecipitate with the iron. Because of these factors, the rate of formation of ferricrete is not constant and is dependent on the local conditions.

The formation of ferricrete is probably an important factor limiting the development of a hyporheic zone in Railroad Creek. The hyporheic zone is defined as a zone of mixed groundwater and surface water that may occur in the interstices of the bed sediment in direct contact with the water (for example, Benner et al. 1995). If groundwater contains elevated concentrations of contaminants, it is conceivable that elevated concentrations could be present in the hyporheic zone. The substantial ferricrete deposits may limit direct mixing between groundwater originating from the tailings piles and Railroad Creek water by armoring the stream bed. It is expected that iron-bearing groundwater will be oxidized and neutralized within the ferricrete, preventing the development of the hyporheic zone and encouraging precipitation of metals within and beneath the ferricrete.

Upstream of the tailings piles, significant ferricrete deposits have not been observed. However, it generally appears that most contribution in the spring is by surface flow and in the fall the load contributed by groundwater is small. A hyporheic zone, if present, would be significant only in the fall.

6.9 SEDIMENT

As noted in Section 5, a number of stream sediment samples were collected historically from Railroad Creek by others (reported in Kilburn, et al., 1994; U.S. Bureau of Mines or Lambeth, R.E., 1995; and Ecology, or Johnson A., et al., 1997) and in Lake Chelan by Dames & Moore as part of the RI in 1998. Sediments were collected historically upstream, within and downstream of the Site from 11 sampling stations; no duplicate samples to measure variation within a particular sampling station were collected. Analyses for total metals were performed on the medium to fine sand, silt and clay fraction of the sediment. Metal (aluminum, arsenic, cadmium, copper, iron, manganese, lead, and zinc) concentrations for samples collected during 1994 show a slight increase in concentration in the vicinity of the Site in relation to the upstream concentrations. Data from tributary streams along Railroad Creek had similar but slightly lower concentrations of metals in sediments. Lake sediments were collected offshore of the mouth of Railroad Creek in 1998. Compared to the Railroad Creek sediment data, metals in lake sediments from the Lucerne bar have a similar but slightly higher concentration range. In general, the concentrations remain relatively constant from the Site to Lake Chelan.

Assuming that the sediment samples are representative, the uniformity of the metal concentrations downstream of the Site suggests that the stream sediment is not significantly diluted during downstream transport between the Site and Lake Chelan, and/or the tributaries contribute sediment with metals. Railroad Creek is characterized by a coarse (70 to 90 percent cobble-boulder matrix) grain size that is related to channel morphology and gradient. Fine sediment sources include limited areas of Railroad Creek, tributaries and the streambanks upstream and downstream of the Site. Sediment derived from the watershed area are transported downstream and deposited eventually into Lake Chelan.

Although downstream sediment transport in Railroad Creek is a potential compound of concern migration pathway, several physical mechanisms reduce the potential for this pathway to be significant. The majority of metals that have been deposited in the streambank sediments become progressively attenuated in a downstream direction as they migrate. Downstream sediment becomes interspersed with sediments from tributary and Railroad Creek streambed sources. Copper and zinc remain slightly elevated (approximately two-fold higher than upstream of the Site) from the Site to Lake Chelan. However, the metals are presumed to be present in the sediment as iron oxides and/or manganese oxides which are relatively inert and not readily available due to the neutral pH of both Railroad Creek and Lake Chelan.

6.10 CONCLUSIONS

Based on the results of the fate and transport analysis in conjunction with the current conceptual site model, conclusions are listed below; specific conclusions have also been presented in each main subsection of Section 6:

- The primary sulfide minerals in the Holden Mine ore deposit include pyrite, pyrrhotite, sphalerite and chalcopyrite.
- The Holden Mine deposit is hosted by the Buckskin Schist, which is a quartz amphibole schist sequence with at least two horizons of intermittent marble beds and calcareous schists. The dominant silicates are plagioclase and biotite (aluminum-based).
- Host rock mineralogy is the primary factor affecting water chemistry at the Site. Weathering of these minerals, especially sulfide minerals, dominates Site water chemistry. Non-sulfide mineralogy of the tailings is expected to be dominated by minerals contained in the ore and in diabase dikes whereas the mine wall rocks are dominated by biotite schist.
- Secondary mineralization and precipitates produced by weathering processes are visibly evident throughout the Site, including orange brown iron stains (iron oxyhydroxides) on waste rock and tailings, white precipitates (amorphous aluminum hydroxide) in the 1500-level main portal drainage, green stain (copper carbonate) on marble waste rock in the waste rock piles, and efflorescent crusts (metal sulfates) in the mill building and where seepage emerges along the toes of the tailings piles.
- Consistent geochemical processes are occurring across the Site including iron sulfide mineral oxidation, oxidation of sphalerite and chalcopyrite, and metal attenuation. Specific controls include the release of heavy metals (iron, copper, zinc, cadmium), the release of metals exerting pH control (iron, aluminum), and seep chemistry for different facilities reflecting different rock types (mine vs. tailings). This dictates the difference between water chemistry in the east and west parts of the Site. The underground mine, waste rock piles and mill building area are dominated by the effect of residual zinc and copper mineralization, whereas the tailings piles are dominated by concentrated iron sulfides and associated iron alumino-silicates.
- The oxidation of sulfide minerals is releasing iron and acid to surface water drainages. Buffering of acidity is occurring by the reaction of waters with alumino-silicates. This limits the solubility of some metals (e.g., iron) but also allows pH to be low enough to solubilize copper. However, since alumino-silicates are abundant, buffering occurs close to the source of acid generation.
- Within Railroad Creek, complete neutralization of acid drainage occurs causing precipitation of iron, aluminum and copper as flocculent. Zinc and cadmium are likely not precipitated appreciably within Railroad Creek.
- Comparison of sulfate and aluminum supports the general conclusion of buffering by alumino-silicates. Aluminum concentrations are lowered by aluminum hydroxide precipitation.

- Source controls reflect the differences in oxygen availability and water flow.
  - Portions of the underground mine are likely well-oxygenated through the winter months due to temperature differences between the underground mine and the ambient air, and may therefore be actively oxidizing in open stopes above the 1500-level of the mine. Random water flow in fractures dissolves weathering products, some of which are discharged in the 1500-level main portal drainage, and some of which are stored as salts formed by evapo-concentration. Discharge water reflects precipitation of iron in the workings and precipitation of aluminum within the mine and in the portal drainage and Railroad Creek.
  - The tailings piles are only oxygenated near the surface. Chemical processes leading to the release of heavy metals occur primarily in this zone and not at depth. Acid neutralization occurs at depth. Groundwaters contain reduced iron which rapidly oxidizes upon emergence in seeps, forming ferricrete and flocculent.
- The metal attenuation processes that occur downgradient of sources prior to entering Railroad Creek include precipitation due to pH increase and aeration, efflorescence (causing seasonal formation of salts), co-precipitation of heavy metals (primarily with iron), and adsorption. Precipitation of aluminum, iron and copper flocculent probably occurs when seeps mix with slightly alkaline Railroad Creek water and groundwater adjacent to Railroad Creek.
- The magnesium (conservative parameter) balance indicated that all major sources were identified and that the required flow balances were consistent with measured magnesium concentrations. Therefore, the magnesium balance corroborates the site-specific water balance in Section 4.4.
- Mass balance calculations for Railroad Creek at the Site indicate that the mass of zinc, cadmium, copper and iron originating from the underground mine, waste rock piles, and tailings piles has been accounted for. Seasonal and yearly variations are apparent reflecting changing variations in flow characteristics and timing of sampling with respect to the spring snowmelt.
- Copper and zinc loads to Railroad Creek from measured point sources and other groundwater (baseflow) sources are highest during the spring snowmelt and groundwater discharge period when groundwater levels are highest in the deep wells beneath the tailings, and high flow occurs at the 1500-level portal drainage. During the May round when flows are the highest, the portal drainage is the primary source of loading of cadmium, copper and zinc to Railroad Creek.
- Seeps SP-23 and SP-23B are the two next highest point sources that are estimated to contribute copper, cadmium and zinc during May; however, this load drops to zero later in the year as seep SP-23 dries up.
- Iron enters Railroad Creek primarily by groundwater and iron loads are greater in September than May. Iron loads enter Railroad Creek downstream of the load sources

(i.e., portal drainage) for cadmium, zinc and copper, which enter the creek as surface flows or seeps.

- Additional source areas (waste rock piles and mill area) are not significant load sources in the spring and generally contribute no load in the fall unless a precipitation event occurs.
- The sediments sampled both in Railroad Creek (above, adjacent, and downstream of the Site) as well as Lake Chelan (at Lucerne bar and the mouth of the Stehekin River) indicate similar concentrations of metals, except for copper and zinc which are slightly elevated (approximately two-fold) when compared to the upstream and reference sites. However, the copper and zinc are anticipated to be present in the relatively inert stable iron oxyhydroxide precipitates due to the neutral pH in both Railroad Creek and Lake Chelan.

TABLE 6.0-1
KEY OF SITE FEATURES & MEDIA SAMPLING/DATA COLLECTION LOCATIONS
HOLDEN MINE RI/FS
DAMES & MOORE JOB NO. 17693-005-019

Feature/Area or Media	Station No.	Location by Area	Coordinate	Comments
Feature/Area				
1500-Level Main Portal	N/A	Mine Support & Waste Rock	E.0-3.0	Near southern boundary
1500-Level Ventilator Portal	N/A	Mine Support & Waste Rock	D.7-3.0	Near western boundary
1100-Level Portal	N/A	Honeymoon Heights	D.8-3.1	
1000-Level Portal	N/A	Honeymoon Heights	D.8-3.1	
800-Level Portal	N/A	Honeymoon Heights	D.8-3.1	
700-Level Portal	N/A	Honeymoon Heights	D.8-3.2	
550-Level Portal	N/A	Honeymoon Heights	D.9-3.2	
300-Level Portal	N/A	Honeymoon Heights	D.9-3.2	
Abandoned Septic Field	N/A	SE of Holden Village	E.2-3.0	
Abandoned Surface Water Ret.	N/A	Mine Support & Waste Rock	D.7-2.9	
Baseball Field/Campground	N/A	Baseball Field/Campground	D.7-2.9, D.8-2.9	
Copper Creek	N/A	S. of Tailings Piles 1 & 2	E.1-3.1, E.1-3.2, E.2-3.0, E.3-3.1	
Copper Creek Diversion	N/A	W. of Tailings Pile 1	E.0-3.0, E.1-3.0	
East Waste Rock Pile	N/A	Mine Support & Waste Rock	E.1-3.0, E.1-3.1	
Holden Village	N/A	Holden Village	E.1-2.9, E.2-2.9	
Holden Village Septic Field	N/A	SE of Winston Home Sites	D.9-2.9, E.0-2.9	
Honeymoon Heights	N/A	Honeymoon Heights	D.7-3.0, 3.1, 3.2; D.8-3.0, 3.1, 3.2, 3.3; D.9-3.0, 3.1, 3.2, 3.3	
Hydroelectric Plant	N/A	W. of Tailings Pile 1	E.0-3.0	
Intermittent Drainage	N/A	Honeymoon Heights	D.8-3.0, D.8-3.1, D.8-3.2, D.8-3.3	
Lagoon	N/A	Mine Support & Waste Rock	E.0-2.9, E.0-3.0	
Lucerne Bar	N/A	Lucerne		
Lucerne Guard Station	N/A	Lucerne	I-3	
Maintenance Yard	N/A	Maintenance Yard	E.0-3.0	
Mill Building	N/A	Mill Building	E.0-3.0	
Mine Support and Waste Rock	N/A	Mine Support & Waste Rock	D.7-2.9, 3.0; D.8-2.9, 3.0; D.9-2.9, 3.0; E.0-2.9, 3.0, 3.1; E.1-3.0, 3.1, 2.9	
Portal Museum	N/A	Mine Support & Waste Rock	E.0-3.0	
Sauna	N/A	NW of Tailings Pile 1	E.1-3.0	
Shop	N/A	Maintenance Yard	E.0-3.0	
Storage	N/A	Maintenance Yard	E.0-3.0	
Tailings Pile 1	N/A	Tailings Pile 1	E.1-3.0, E.2-3.0, E.2-3.1	
Tailings Pile 2	N/A	Tailings Pile 2	E.2-3.0, E.2-3.1, E.3-3.0, E.3-3.1, E.4-3.0, E.4-3.1	
Tailings Pile 3	N/A	Tailings Pile 3	E.4-3.0, E.4-3.1, E.5-3.0, E.5-3.1	
USFS Guard Station	N/A	USFS Guard Station	E.0-2.9	
West Waste Rock Pile	N/A	Mine Support & Waste Rock	E.0-3.0	
Winston Home Sites	N/A	Winston Home Sites	D.8-2.9; D.9-2.8, 2.9; E.0-2.8, 2.9	
Geophysical Survey Lines				
A-A'	N/A	North of West Waste Rock Pile	E.0-2.9, E.0-3.0	
B1-B1'	N/A	Tailings Pile 1	E.1-3.0	
B2-B2'	N/A	East Waste Rock Pile	E.1-3.1	
C-C'	N/A	Tailings Pile 2	E.3-3.0, E.3-3.1	
D-D'	N/A	Tailings Pile 3	E.4-3.0, E.4-3.1	
E-E'	N/A	East of Tailings Pile 3	E.5-3.0, E.5-3.1	

TABLE 6.0-1
KEY OF SITE FEATURES & MEDIA SAMPLING/DATA COLLECTION LOCATIONS
HOLDEN MINE RI/FS
DAMES & MOORE JOB NO. 17693-005-019

Feature/Area or Media	Station No.	Location by Area	Coordinate	Comments
EM1-EM1'	N/A	Western Mine Support Area	D.8-2.9, D.8-3.0. D.9-2.9, D.9-3.0, E.0-2.9	
EM2-EM2'	N/A	Western Mine Support Area	D.8-3.0, D.9-3.0, E.0-3.0, E.1-3.0	
EM3-EM3'	N/A	East of Tailings Pile 3	E.5-3.0, E.5-3.1	
F-F'	N/A	North of Tailings Piles 2 & 3	E.4-3.0	
G-G'	N/A	Between Tailings Piles 1 & 2	E.2-3.0, E.2-3.1	
Sample Locations				
Groundwater Monitoring Wells				
	HBKG-1	W. of Tailings Pile 1	E.0-3.0	Potential background
	HBKG-2	E. of Baseball Field/Campgr.	D.8-2.9	Potential background
	CC-BKG	SW Tailings Pile 2	E.2-3.1	Background
	H-1	Holden Village	E.1-2.9	
	H-2	Holden Village	E.2-2.9	
	HV-3/H-3	Holden Village	E.1-2.9	Background
	DS-1	East of Tailings Pile 3	E.5-3.0	Downstream Wells:
	DS-2	East of Tailings Pile 3	E.5-3.0	Downstream Wells:
	TP1-1A	Tailings Pile 1	E.1-3.0	
	TP1-2A	Tailings Pile 1	E.1-3.0	
	TP1-2L	Tailings Pile 1	E.1-3.0	
	TP1-3A	Tailings Pile 1	E.1-3.0	
	TP1-3L	Tailings Pile 1	E.1-3.0	
	TP1-4A	Tailings Pile 1	E.1-3.0	
	TP1-4L	Tailings Pile 1	E.1-3.0	
	TP1-5A	Tailings Pile 1	E.2-3.0	
	TP1-6A	Tailings Pile 1	E.1-3.0	
	TP1-6L	Tailings Pile 1	E.1-3.0	
	PZ-1A	Tailings Pile 2	E.3-3.1	
	PZ-1B	Tailings Pile 2	E.3-3.1	
	PZ-1C	Tailings Pile 2	E.3-3.1	
	PZ-2A	Tailings Pile 2	E.3-3.0	
	PZ-2B	Tailings Pile 2	E.3-3.0	
	PZ-2C	Tailings Pile 2	E.3-3.0	
	PZ-3A	Tailings Pile 2	E.3-3.0	
	PZ-3B	Tailings Pile 2	E.3-3.0	
	PZ-3C	Tailings Pile 2	E.3-3.0	
	TP2-1L	Tailings Pile 2	E.3-3.1	
	TP2-2L	Tailings Pile 2	E.3-3.0	
	TP2-4A	Tailings Pile 2	E.3-3.0	
	TP2-4B	Tailings Pile 2	E.3-3.0	
	TP2-5A	Tailings Pile 2	E.3-3.0	
	TP2-5B	Tailings Pile 2	E.3-3.0	
	TP2-6L	Tailings Pile 2	E.3-3.1	
	TP2-7N&S	Tailings Pile 2	E.4-3.0	
	TP2-8A	Tailings Pile 2	E.4-3.0	
	TP2-8B	Tailings Pile 2	E.4-3.0	
	TP2-9L	Tailings Pile 2	E.4-3.1	
	TP2-10L	Tailings Pile 2	E.2-3.1	
	TP2-11	Tailings Pile 2	E.2-3.0	
	TP2-11L	Tailings Pile 2	E.2-3.0	
	TP3-4	Tailings Pile 3	E.4-3.0	

TABLE 6.0-1
KEY OF SITE FEATURES & MEDIA SAMPLING/DATA COLLECTION LOCATIONS
HOLDEN MINE RI/FS
DAMES & MOORE JOB NO. 17693-005-019

Feature/Area or Media	Station No.	Location by Area	Coordinate	Comments
	TP3-4L	Tailings Pile 3	E.4-3.0	
	TP3-5A	Tailings Pile 3	E.5-3.0	
	TP3-6A	Tailings Pile 3	E.5-3.0	
	TP3-6BL	Tailings Pile 3	E.5-3.0	
	TP3-7	Tailings Pile 3	E.4-3.0	
	TP3-8	Tailings Pile 3	E.4-3.0	
	TP3-9	Tailings Pile 3	E.5-3.0	
	TP3-10	Tailings Pile 3	E.5-3.0	
	TP3-10L	Tailings Pile 3	E.5-3.0	
	PZ-4A	Tailings Pile 3	E.4-3.0	
	PZ-4B	Tailings Pile 3	E.4-3.0	
	PZ-4C	Tailings Pile 3	E.4-3.0	
	PZ-5A	Tailings Pile 3	E.4-3.0	
	PZ-5B	Tailings Pile 3	E.4-3.0	
	PZ-5C	Tailings Pile 3	E.4-3.0	
	PZ-6A	Tailings Pile 3	E.4-3.0	
	PZ-6B	Tailings Pile 3	E.4-3.0	
	PZ-6C	Tailings Pile 3	E.4-3.0	
	Lucerne Well	Lucerne	I-3	Lucerne Guard Station
Subsurface/Surface Soil				
	DMSS-1	Holden Village	E.2-2.9	Surface soil
	DMSS-2	Holden Village	E.2-2.9	Surface soil
	DMSS-3	Holden Village	E.1-2.9	Surface soil
	DMSS-4	Holden Village	E.1-2.9	Surface soil
	DMSS-5	Holden Village	E.1-2.9	Surface soil
	DMSS-6	Holden Village	E.2-2.9	Surface soil
	DMSS-7	Holden Village	E.1-2.9	Surface soil
	DMSS-8	Maintenance Yard	E.0-3.0	Surface soil
	DMSS-9	Maintenance Yard	E.0-3.0	Surface soil
	DMSS-10	Maintenance Yard	E.0-3.0	Surface soil
	DMSS-11	Tailings Pile 1	E.1-3.0	Surface soil
	DMSS-12	Tailings Pile 1	E.1-3.0	Surface soil
	DMSS-13	Tailings Pile 1	E.2-3.0	Surface soil
	DMSS-14	Tailings Pile 2	E.2-3.0	Surface soil
	DMSS-15	Tailings Pile 2	E.3-3.0	Surface soil
	DMSS-16	Tailings Pile 2	E.4-3.0	Surface soil
	DMSS-17	Tailings Pile 3	E.4-3.0	Surface soil
	DMSS-18	Tailings Pile 3	E.4-3.0	Surface soil
	DMSS-19	Tailings Pile 3	E.5-3.0	Surface soil
	DMSS-20	East of Tailings Pile 3	E.5-3.0	Windblown tailings
	DMSS-21	East of Tailings Pile 3	E.6-3.0	Windblown tailings
	DMSS-22	East of Tailings Pile 3	E.6-3.0	Windblown tailings
	DMSS-23	East of Tailings Pile 3	E.7-3.0	Windblown tailings
	DMSS-24	East of Tailings Pile 3	E.5-3.0	Windblown tailings
	DMSS-25	Baseball Field	D.7-2.9	Surface soil
	DMSS-26	Wilderness Area	D.7-2.9	Surface soil
	DMSS-27	Wilderness Area	D.7-2.9	Surface soil
	Lagoon 6"	Lagoon	E.0-2.9	Surface soil
	Lagoon 2'	Lagoon	E.0-2.9	Subsurface soil sample
	DMLG1	Lagoon	E.0-3.0	Subsurface soil sample
	DMLG2	Lagoon	E.0-2.9	Subsurface soil sample
	DMLG3	Lagoon	E.0-2.9	Subsurface soil sample

Feature/Area or Media	Station No.	Location by Area	Coordinate	Comments
	DMLG4	Lagoon	E.0-3.0	Subsurface soil sample
	DMLG5	Lagoon	E.0-2.9	Subsurface soil sample
	DMBG1	Approximately 1-mile West of Site	D-2	Background surface soil
	DMBG2	Holden Creek Drainage	D-2	Background surface soil
	DMBG3	Between Holden Creek & Hart Lake	C-2	Background surface soil
	DMBG4	East of Hart Lake	C-2	Background surface soil
	DMBG5	Between Hart Lake & Crown Point	B-2	Background surface soil
	DMBG6	Lyman Lakes	A-3	Background surface soil
	DMBG7	West of Hart Lake	B-2	Background surface soil
	DMBG8	West of Holden Creek	C-2	Background surface soil
	DMBG9	West of Big Creek	D-2	Background surface soil
	DMBG10	Copper Basin	E-3	Background surface soil
	DMBG11	Southwest of Site	D-3	Background surface soil
	DMBG12	South of Site	D-3	Background surface soil
	DMBG13	Near South Site Boundary	E-3	Background surface soil
	DMBG14	Near Holden Creek	D-2	Background surface soil
	DMBG15	Near Holden Creek	D-2	Background surface soil
	DMBG16	West of Site Boundary	D-2	Background surface soil
	DMBG17	Near Winston Home Sites	D-2	Background surface soil
	DMBG18	Northeast of Site	E-2	Background surface soil
	DMBG19	North of Holden Village	E-2	Background surface soil
	DMTP1-2	Tailings Pile 1	E.1-3.0	Test pit excavation
	DMTP1-3	Tailings Pile 1	E.1-3.0	Test pit excavation
	DMTP1-4	Tailings Pile 1	E.1-3.0	Test pit excavation
	DMTP1S-1	Tailings Pile 1	E.1-3.0	Test pit excavation
	DMTP2-1	Tailings Pile 2	E.2-3.0	Test pit excavation
	DMTP2-2	Tailings Pile 2	E.3-3.0	Test pit excavation
	DMTP2S-1	Tailings Pile 2	E.3-3.1	Test pit excavation
	DMTP3-1	Tailings Pile 3	E.4-3.0	Test pit excavation
	DMTP3-2	Tailings Pile 3	E.5-3.0	Test pit excavation
	DMTP3-3	Tailings Pile 3	E.5-3.0	Test pit excavation
	DMTP3-4	Tailings Pile 3	E.5-3.0	Test pit excavation
	DMTP3S-1	Tailings Pile 3	E.4-3.1	Test pit excavation
	DMTP3E-1	Immed. east of Tailings Pile 3	E.5-3.0	Test pit excavation
	DMTP3E-2	Immed. east of Tailings Pile 3	E.5-3.0	Test pit excavation
	DMTP3E-3	Immed. east of Tailings Pile 3	E.5-3.0	Test pit excavation
	DMTP3E-4	Immed. east of Tailings Pile 3	E.5-3.0	Test pit excavation
	DMTP3E-5	Immed. east of Tailings Pile 3	E.5-3.1	Test pit excavation
	DMTP3E-6	Immed. east of Tailings Pile 3	E.5-3.1	Test pit excavation
	DMTPW-1	Winston home sites	D.8-2.9	Test pit excavation
	DMTPW-2	Winston home sites	D.8-2.9	Test pit excavation
	DMTPW-3	Winston home sites	D.8-2.9	Test pit excavation
	DMTPW-4	Winston home sites	D.8-2.9	Test pit excavation
	DMTPW-5	Winston home sites	D.9-2.9	Test pit excavation
	DMTPW-6	Winston home sites	D.9-2.9	Test pit excavation
	DMTPW-7	Winston home sites	D.9-2.9	Test pit excavation
Surface Water				
	RC-1	Railroad Creek	D.7-2.9	
	RC-1 North Bank	Railroad Creek	D.7-2.9	
	RC-1 South Bank	Railroad Creek	D.7-2.9	
	RC-2	Railroad Creek	E.5-3.0	
	RC-2 South Bank	Railroad Creek	E.5-3.0	

TABLE 6.0-1
KEY OF SITE FEATURES & MEDIA SAMPLING/DATA COLLECTION LOCATIONS
HOLDEN MINE RI/FS
DAMES & MOORE JOB NO. 17693-005-019

Feature/Area or Media	Station No.	Location by Area	Coordinate	Comments
	RC-3	Railroad Creek	I-3	
	RC-4	Railroad Creek	E.0-2.9	
	RC-4 South Bank	Railroad Creek	E.0-2.9	
	RC-5	Railroad Creek	E-3	
	RC-5A	Railroad Creek	E-3	
	RC-6	Railroad Creek	D.7-2.9	
	RC-6 North Bank	Railroad Creek	D.7-2.9	
	RC-7	Railroad Creek	E.4-3.0	
	RC-8	Railroad Creek	I-3	
	RC-8 North Bank	Railroad Creek	I-3	
	RC-10	Near Seven Mile Creek	F-3	
	RC-11	Upstream of Holden Creek	D-2	
	CC-1	Copper Creek	E.2-3.1	
	CC-2	Copper Creek	E.2-3.0	
	CC-D	Copper Creek Diversion	E.1-3.0	
	CC-D1	Copper Creek Diversion	E.1-3.0	
	P-1	Mine Support & Waste Rock	E.0-3.0	Portal Drainage/1500 Main
	P-5	Mine Support & Waste Rock	D.9-2.9	Portal Drainage/RR Creek
	HC-1	Holden Creek	D-2	
	HC-2	Holden Creek	C-2	
	HC-3	Holden Creek	C-2	
	HC-4	Holden Creek	C-1	
	Big-1	Big Creek	D-2	
	Tenmile Creek	Tenmile Creek	E-2	
Seeps				
	A1	Honeymoon Heights	D.8-3.1	1100 Level Portal
	SP1	Tailings Pile 1	E.1-3.0	
	SP2	Tailings Pile 1	E.2-3.0	
	SP3	Tailings Pile 2	E.3-3.0	
	SP4	Tailings Pile 3	E.4-3.0	
	SP5	East of Tailings Pile 3	E.5-3.0	
	SP6	West Waste Rock Pile	E.0-3.0	
	SP7	West Waste Rock Pile	E.0-3.0	
	SP8	East Waste Rock Pile	E.1-3.0	
	SP9	Between P-5 & RC-4	D.9-2.9	
	SP10W	River Sauna	E.1-2.9	
	SP10E	River Sauna	E.1-2.9	
	SP11	West of Vehicle Bridge	E.0-2.9	
	SP12	West of P-5	D.9-3.0	
	SP13	South of Holden Village	E.1-2.9, 3.0; E.2-2.9, 3.0	"Black Seep"
	SP14	Honeymoon Heights	D.8-3.1	
	SP15W	North of West Waste Rock Pile	E.0-3.0	
	SP15E	North of West Waste Rock Pile	E.0-3.0	
	SP16	Lagoon	E.0-2.9	
	SP17	East of Tailings Pile 3	E.5-3.1	
	SP18	East of Tailings Pile 3	E.5-3.0	Bank sample
	SP19	Tailings Pile 1	E.1-3.0	
	SP20	Tailings Pile 1 (Near Copper Creek)		
	SP21	East of Tailings Pile 3	2.6-3.1	
	SP22	North of Maintenance Yard	E.0-3.0	
	SP23	Between RC-1 and P-5	D.8-3.0	
	SP23B	Between RC-1 and P-5	D.8-3.0	

TABLE 6.0-1
KEY OF SITE FEATURES & MEDIA SAMPLING/DATA COLLECTION LOCATIONS
HOLDEN MINE RI/FS
DAMES & MOORE JOB NO. 17693-005-019

Feature/Area or Media	Station No.	Location by Area	Coordinate	Comments
	SP24	West of RC-4	E.0-2.9	
	SP25	Between Vehicle Bridge & RC-4	E.0-2.9	
	SP26	Between RC-1 and RC-6	D.7-2.9	
	SP-27	Near Big Creek	D-2	
	CC-D1	Copper Creek Diversion	E.1-2.9	
Sediment - Lake Chelan				
	1-1	Lucerne	N/A	
	1-2	Lucerne	N/A	
	2-1	Lucerne	N/A	
	2-2	Lucerne	N/A	
	3-1	Lucerne	N/A	
	3-1A	Lucerne	N/A	
	3-1B	Lucerne	N/A	
	3-1C	Lucerne	N/A	
	3-2	Lucerne	N/A	
	3.5-1	Lucerne	N/A	
	3.5-2	Lucerne	N/A	
	5-1	Lucerne	N/A	
	5-2	Lucerne	N/A	
	1	Stehekin	N/A	
	2	Stehekin	N/A	
	3A	Stehekin	N/A	
	3B	Stehekin	N/A	
	3C	Stehekin	N/A	
	4	Stehekin	N/A	
USGS Select Samples				
	344	Ten Mile Creek	E.6-2.9	
	345	Railroad Creek near RC-2	E.5-3.0	
	346	Copper Creek Diversion	E.1-3.0	
	347	Railroad Creek at Vehicle Bridge	E.0-2.9	
	350	East of Tailings Pile 3	E.5-3.0	
	351	Nine Mile Creek	F-3	
	352	Railroad Creek near Seven Mile Creek	F-3	
	353	Seven Mile Creek	F-3	
	354	Railroad Creek at Lucerene	N/A	
	355	Holden Creek	D-2	
	356	Railroad Creek West of Site	D-2	
	MP-7	Railroad Creek at Mile Post 7	G-3	
USBM Select Samples				
	BKG 1/2	Downstream of Vehicle Bridge	E.0-2.9	
	DG-1	Downstream of Tailings Pile 3	E.6-3.0	
	TP1-2	Adjacent to Tailings Pile1	E.1-3.0	
	TP2-1	Downstream of Copper Creek	E.2-3.0	
	TP2-2	Adjacent to Tailings Pile 2	E.3-3.0	
	TP3-1	Adjacent to Tailings Pile 3	E.4-3.0	
	RC-2	At Railroad Creek RC-2 Station	E.5-3.0	

TABLE 6.1-1
SECONDARY SULFATE MINERALS IDENTIFIED IN THE ABANDONED HOLDEN MILL AND TAILINGS

Mineral Name	Formula	Identified In:			Solubility (Alpers et al., 1994)
		Tailings (1994)	Mill 95	Mill 96	
Alunogen	$Al_2(SO_4)_3\ 17H_2O$	Present	Present		High
Ammoniojarosite	$(NH_4)Fe_3^{III}(SO_4)_2(OH)_6$		Present		Low
Anterlerite	$Cu_3(SO_4)(OH)_4$	Present	Present	Present	Low
Bianchite	$(Zn, Fe^{II})SO_4 \bullet 6H_2O$			Present	High
Bilinite	$Fe^{II}Fe^{III}(SO_4)_4 \bullet 22H_2O$		Present		High
Bonattite	$CuSO_4 \bullet 3H_2O$	Present	Present		High
Butlerite	$Fe^{III}(SO_4)(OH) \bullet 2H_2O$		Present		?
Chalcanthite	$CuSO_4 \bullet 5H_2O$	Present	Present	Present	High
Dietrichite	$(Zn, Fe^{III}, MII)Al_2(SO_4)_4 \bullet 22H_2O$	Present			?
Epsomite	$MgSO_4 \bullet 7H_2O$			Present	High
Goslarite	$ZnSO_4 \bullet 7H_2O$			Present	High
Gunnigite	$(Zn, Mn)SO_4 \bullet H_2O$	Present	Present		High
Gypsum	$CaSO_4 \bullet 2H_2O$	Present		Present	High
Halotrichite	$Fe^{II}Al_2(SO_4)_4 \bullet 22H_2O$	Present		Present	?
Hexahydrite	$MgSO_4\ 6H_2O$	Present		Present	High
Hexahydrite	$MgSO_4 \bullet 6H_2O$				High
Hydronium Jarosite	$(H_3O)Fe_3^{III}(SO_4)_2(OH)_6$		Present		Low
Jarosite	$KFe_3^{III}(SO_4)_2(OH)_6$	Present			Low
Melanterite	$Fe^{II}SO^4 \bullet 7H_2O$	Present		Present	High
Natrojarosite	$NaFe^{III}(SO_4)_2(OH)_6$		Present		Low
Pickeringite	$MgAl_2(SO_4)_4$	Present		Present	?
Romerite	$Fe^{III}Fe^{III}(SO^4)^4 \bullet 14H_2O$	Present		Present	High
Rozenite	$Fe^{II}SO^4 \bullet 4H_2O$	Present	Present	Present	High
Siderotil	$Fe^{II}SO^4 \bullet 5H_2O$	Present	Present	Present	High
Starkeyite	$MgSO_4 \bullet 4H_2O$		Present		High
Xitieshanite	$Fe^{III}(SO_4)(OH) \bullet 7H_2O$		Present		?

Table 6.6-1
Loading Calculations - Railroad Creek, May 1997
Holden Mine RI/FS
Dames & Moore Job No. 17693-005-019

		Magnesium				Zinc				Cadmium				Copper				Iron			
Station	Flows L/s	Conc. mg/L	Load mg/s	% Load of RC-2	Cumulative Load	Conc. mg/L	Load mg/s	% Load of RC-2	Cumulative Load	Conc. mg/L	Load mg/s	% Load of RC-2	Cumulative Load	Conc. mg/L	Load mg/s	% Load of RC-2	Cumulative Load	Conc. mg/L	Load mg/s	% Load of RC-2	Cumulative Load
RC-6	**14159***	**0.360**	**5097**			**0.016**	**226**	**17.9**		**0.00002**	**0.28**	**3.6**		**0.0007**	**9.91**	**2.8**		**0.03**	**425**	**9.4**	
RC-1	**14161.1**	**0.36**	**5098**	**53.9**	**5098**	**0.01**	**184**	**14.6**	**184**	**0.00002**	**0.28**	**3.5**	**0.28**	**0.0011**	**16**	**4.5**	**16**	**0.03**	**425**	**9.4**	**425**
SP-23	14.2	5.13	73	0.8	5171	5.00	71	5.6	255	0.0389	0.55	6.9	0.84	6.85	97	27.4	113	0.01	0	0	425
SP-23B	1.9	3.92	7	0.1	5178	3.61	7	0.6	262	0.0280	0.05	0.6	0.89	4.90	9	2.5	122	0.01	0	0	425
SP-12	1.9	1.47	3	0.03	5181	2.00	4	0.3	266	0.0141	0.03	0.4	0.92	2.0	4	1.1	126	0.01	0	0	425
P-5	96.3	9.29	894	9.5	6075	8.82	849	67.3	1115	0.0525	5.05	63.4	5.97	2.34	225	63.6	351	0.19	18	0.4	443
SP-9	0.5	2.09	1	0.01	6076	0.27	0	0	1115	0.0008	0.00	0	5.97	0.003	0	0	351	0.01	0	0	443
SP-11	0.5	3.18	2	0.02	6078	2.34	1	0.1	1116	0.0128	0.01	0.1	5.98	0.46	0	0	351	0.01	0	0	443
SP-24	0.9	6.24	6	0.1	6084	7.56	7	0.6	1123	0.0477	0.05	0.6	6.02	3.66	3	0.8	355	0.22	0	0	444
Reach 1 Balance	*25.5*	*22.45*	*572*	*6.0*	*6656*	*#N/A*	*-90*	*-7.1*	*1034*	*0.0080*	*0.20*	*2.5*	*6.23*	*0.77*	*20*	*5.6*	*374*	*#N/A*	*-160*	*-3.5*	*283*
RC-4	**14161.1**	**0.47**	**6658**	**70.4**		**0.07**	**1034**	**82.0**		**0.0004**	**6.23**	**78.3**		**0.0264**	**374**	**105.6**		**0.02**	**283**	**6.2**	
SP-10W	0.3	3.87	1	0.01	6657	3.21	1	0.1	1035	0.0257	0.01	0.1	6.23	2.21	1	0.3	375	0.03	0	0	283
SP-10E	0.3	1.4	0	0	6658	0.71	0	0	1035	0.0070	0.00	0	6.24	0.76	0	0	375	14.10	4	0.1	288
CCD	198.2	0.66	131	1.4	6789	0.17	34	2.7	1069	0.0018	0.35	4.4	6.58	0.046	9	2.5	385	0.23	46	1.0	334
SP-1	0.9	53.5	51	0.5	6839	3.49	3	0.2	1072	0.0227	0.02	0.3	6.61	0.698	1	0.3	385	542.00	513	11.3	847
SP-2	0.9	96.8	92	1.0	6931	5.60	5	0.4	1077	0.0228	0.02	0.3	6.63	0.914	1	0.3	386	487.00	461	10.2	1308
Copper Creek	424.8	0.55	234	2.5	7164	0.01	6	0.5	1083	0.000020	0.01	0.1	6.64	0.0010	0	0	386	0.04	17	0.4	1325
SP-3	4.7	47.9	227	2.4	7391	4.03	19	1.5	1102	0.0403	0.19	2.4	6.83	1.28	6	1.7	393	154.00	723	16.0	2048
Reach 2 Balance	*59.5*	*26.1*	*1550*	*16.4*	*8941*	*2.5*	*146*	*11.6*	*1248*	*0.0173*	*1.03*	*12.9*	*7.86*	*#N/A*	*-48*	*-13.6*	*345*	*23.74*	*1412*	*31.2*	*3460*
RC-7	**14867.8**	**0.59**	**8772**	**92.8**		**0.09**	**1264**	**100.2**		**0.00058**	**8.62**	**108.3**		**0.023**	**342**	**96.6**		**0.48**	**7132**	**157.4**	
SP-4	14.2	36.3	515	5.4	9456	0.90	12.8	1.0	1261	0.0073	0.10	1.3	7.96	0.670	10	2.8	354	74.90	1065	23.5	4524
RC-2	**15009.5**	**0.63**	**9456**	**100**		**0.08**	**1261**	**100**		**0.00053**	**7.96**	**100**		**0.024**	**354**	**100**		**0.30**	**4530**	**100**	
Total Balance	*85.0*	*24.97*	*2122*	*22.4*		*0.66*	*56*	*4.4*		*0.015*	*1.23*	*15.5*		*-0.32913*	*-28*	*-7.9*		*14.728*	*1252*	*27.6*	

Notes
1. Rows shown in **bold** are data for Railroad Creek monitoring stations.
2. Rows shown in *italics* are loads required balance the total load . The concentration and flow are set so that the load added (or subtracted) equals the load measured in Railroad Creek.
3. #N/A indicates a negative concentration required to produce a negative load.
4. "*Total balance*" is the sum of loads required to balance loads in both reaches.
5. The RC-6 station is required to balance upstream of RC-1 and not considered part of Reach 1. It is shown for comparison only to RC-1.
* Estimated Flow 500cfs

Table 6.6-2
Loading Calculations - Railroad Creek, September 1997
Holden Mine RI/FS
Dames & Moore Job No. 17693-005-019

		Magnesium				Zinc				Cadmium				Copper				Iron			
Station	Flows L/s	Conc. mg/L	Load mg/s	% Load of RC-2	Cumulative Load	Conc. mg/L	Load mg/s	% Load of RC-2	Cumulative Load	Conc. mg/L	Load mg/s	% Load of RC-2	Cumulative Load	Conc. mg/L	Load mg/s	% Load of RC-2	Cumulative Load	Conc. mg/L	Load mg/s	% Load of RC-2	Cumulative Load
RC - 6	**3710****	**0.35**	**1299**	**59.2**		**0.004**	**15**	**16.9**		**0.00002**	**0.074**	**19.1**		**0.0004**	**1.5**	**32.6**		**0.040**	**148**	**3.6**	
SP-26	0.3**	0.54	0.14	0.006		0.022	0.006	0.007		0.0003	0.00008	0.020		0.022	0.006	0.1		0.010	0.003	0.00007	
RC-1	**3737.1**	**0.35**	**1308**	**59.6**	**1308**	**0.0020**	**7**	**7.9**	**7**	**0.000020**	**0.07**	**17.9**	**0.07**	**0.00040**	**1.5**	**32.6**	**1.5**	**0.04**	**149**	**3.6**	**149**
SP-23	0.0		0	0	1308		0	0	7		0.00	0	0.07		0.0	0	1.5		0	0	149
SP-23B	0.0		0	0	1308		0	0	7		0.00	0	0.07		0.0	0	1.5		0	0	149
SP-12	0.0		0	0	1308		0	0	7		0.00	0	0.07		0.0	0	1.5		0	0	149
P-5	5.7	9.85	56	2.6	1364	2.98	17	19.1	24	0.008000	0.05	12.8	0.12	0.02800	0.2	4.3	1.7	0.01	0	0	150
SP-9	0.0		0	0	1364		0	0	24		0.00	0	0.12		0.0	0	1.7		0	0	150
SP-11	0.0		0	0	1364		0	0	24		0.00	0	0.12		0.0	0	1.7		0	0	150
SP-24	0.0		0	0	1364		0	0	24		0.00	0	0.12		0.0	0	1.7		0	0	150
Reach 1 Balance	*8.5*	*#N/A*	*-74.8*	*-3.4*	*1289*	*1.60*	*14*	*15.7*	*38*	*0.010000*	*0.08*	*20.5*	*0.21*	*0.70000*	*4.6*	*100*	*6.3*	*#N/A*	*-10*	*0.2*	*139*
RC-4	**3483.8**	**0.37**	**1289**	**58.7**		**0.011**	**38**	**42.7**		**0.000060**	**0.21**	**53.8**		**0.00180**	**6.3**	**137.0**		**0.04**	**139**	**3.3**	
SP-10W	0.0		0	0	1289		0	0	38		0.00	0	0.21		0.0	0	6.3		0	0	139
SP-10E	0.0		0	0	1289		0	0	38		0.00	0	0.21		0.0	0	6.3		0	0	139
CCD	198.2	0.46	91	4.1	1380	0.002	0	0	38	0.000100	0.02	5.1	0.22	0.00100	0.2	4.3	6.5	0.01	2	0.05	141
SP-1	0.0		0	0	1380		0	0	38		0.00	0	0.22		0.0	0	6.5		0	0	141
SP-2	0.1	94.20	12	0.5	1392	5.70	1	1.1	39	0.003900	0.00	0	0.23	0.10100	0.0	0	6.5	685.00	86	2.1	228
Copper Creek	141.6	0.47	67	3.1	1459	0.002	0	0	39	0.000020	0.00	0	0.23	0.00030	0.0	0	6.5	0.01	1	0.02	229
SP-3	0.4	62.30	26	1.2	1484	0.611	0	0	40	0.002000	0.00	0	0.23	0.09000	0.0	0	6.5	251.00	103	2.5	332
Reach 2 Balance	*34.0*	*20.92*	*711*	*32.4*	*2195*	*1.45*	*49*	*55.1*	*89*	*0.004600*	*0.16*	*41.0*	*0.39*	*#N/A*	*-2.0*	*-43.5*	*4.6*	*112.63*	*3827*	*92.0*	*4159*
RC-7	**4134.0**	**0.53**	**2191**	**99.8**		**0.02**	**79**	**88.9**		**0.000090**	**0.37**	**94.9**		**0.00130**	**5.4**	**117.4**		**1.15**	**4754**	**114.3**	
SP-4	0.0		0	0	2195		0	0	89		0.00	0	0.39		0.0	0	4.6		0	0	4159
RC-2	**3850.9**	**0.57**	**2195**	**100**		**0.02**	**89**	**100**		**0.000100**	**0.39**	**100**		**0.00120**	**4.6**	**100**		**1.08**	**4159**	**100**	
Total Balance	*42.5*	*14.98*	*636*	*29*		*1.48*	*63*	*70.8*		*0.0057*	*0.24*	*61.5*		*0.06*	*2.6*	*56.5*		*89.86*	*3817*	*91.8*	

Notes
1. Rows shown in **bold** are data for Railroad Creek monitoring stations.
2. Rows shown in *italics* are loads required to balance the total load . The concentration and flow are set so that the load added (or subtracted) equals the load measured in Railroad Creek.
3. #N/A indicates a negative concentration required to produce a negative load.
4. A zero flow indicates no flow measured.
5. Concentrations are not shown if no flow was noted.
6. "*Total balance*" is the sum of loads required to balance loads in both reaches.
7. The RC-6 station is upstream of RC-1. SP-26 is located between RC-6 and RC-1. RC-6 and SP-26 are not considered part of Reach 1 in the loading calculations. They are provided for comparison only to RC-1.
** Average Flow

TABLE 6.6-3
LOADING CALCULATIONS – RAILROAD CREEK, MAY 1998

Station	Flow	Copper		Zinc		Cadmium		Iron	
Sample Date	(cfs)	Load (mg/s)	Conc. (ug/l)	Load (mg/s)	Conc. (ug/l)	Load (mg/s)	Conc. (ug/l)	Load (mg/s)	Conc. (ug/l)
HC-4 4/30/98	3	0.04	0.5	<.34	4U	<0.01	0.06	2.5	30
HC-3 4/30/98	7	0.12	0.6	<.78	4U	<0.01	0.04U	3.9	20
HC-2 4/30/98	13	0.25	0.7	<1.5	4U	0.02	0.05	<7.3	20U
HC-1 5/1/98	18	0.30	0.6	<2.0	4U	<0.02	0.04U	<10.1	20U
Big-1 5/2/98	86[1]	0.72	0.3	<9.6	4U	<0.1	0.04U	<48	20U
RC-11 5/1/98	150[2]	2.9	0.7	<17	4U	<0.17	0.04U	126	30
RC-6 5/3/98	500e	8.4	0.6	<56	4U	1.12	0.08	420	30
RC-1 5/3/98	500e	11.2	0.8	<56	4U	<0.56	0.04U	280	20
P-1 5/1/98	2.6	750	10300	2002	27500	11.6	160	31	430
P-5 5/1/98	3.8	510	4790	1351	12700	7.4	70	16	150
RC-4 5/3/98	508	593	41.7	1621	114	9.4	0.66	<285	20U
CC-D1 5/2/98	6.1	27	155	64	372	0.44	2.6	<3.4	20U
CC-2 5/2/98	42	0.59	0.5	<4.7	4U	<0.05	0.04U	<24	20U
RC-7 5/3/98	640e	672	37.5	2061	115	12	0.67	6810	380
RC-2 5/3/98	643	643	35.7	2034	113	12.2	0.68	6301	350
RC-3 5/5/98	1105	390	12.6	1392	45	8.0	0.26	5260	170

1 = Includes both Big Creek Channels
2 = Estimated from field observations
e = Estimated from 1997 flow relationships
U = Undetected above indicated level

Table 6.6-4
Loading Calculations - Additional Source Areas, Spring and Fall 1997
Holden Mine RI/FS
Dames & Moore Job No. 17693-005-019

Seep	Site Location	Date Collected	Flows L/s	Zinc Conc. mg/L	Zinc Load mg/s	Zinc % Load of RC-2	Cadmium Conc. mg/L	Cadmium Load mg/s	Cadmium % Load of RC-2	Copper Conc. mg/L	Copper Load mg/s	Copper % Load of RC-2	Iron Conc. mg/L	Iron Load mg/s	Iron % Load of RC-2
SP-6	West Waste Rock Pile	5/21/97	0.439	22.1	9.70	0.8	0.173	0.076	1.0	12.7	5.58	1.6	0.030	0.013	0.0002
SP-7	Mill Building	5/21/97	4.267	4.33	18.5	1.5	0.034	0.15	1.8	2.81	12	3.4	0.12	0.51	0.01
SP-7	Mill Building	9/19/97	--	3.47	N/A	N/A	0.026	N/A	N/A	1.93	N/A	N/A	0.22	N/A	N/A
SP-8	East Waste Rock Pile	5/21/97	0.568	11.2	6.36	0.5	0.088	0.050	0.6	7.88	4.48	1.3	0.030	0.017	0.0004
SP-15 W	Below SP6 at south end of lagoon	5/22/97	2.112	2.26	4.77	0.4	0.094	0.0198	0.2	0.21	0.435	0.1	0.010	0	0
SP-15 E	Below SP6 at south end of lagoon	5/22/97	4.267	7.97	34.0	2.7	0.055	0.233	2.9	3.56	15.2	4.3	0.080	0.34	0.008
SP-22	Below SP7/Mill Mtc yard	5/23/97	0.943	7.35	6.9	0.5	0.048	0.045	0.6	2.14	2.02	0.6	0.010	0	0
SP-21	East of Tailing Pile 3	5/22/97	55.5	0.11	6.05	0.5	0.001	0.06	0.8	0.052	2.87	0.8	1.00	55.5	1.2
SP-21	East of Tailing Pile 3	9/15/97	0.109	0.13	0.015	0.02	0.0011	0.00012	0.031	0.034	0.004	0.1	1.53	0.167	0.004

Notes

* Flow measurement not available.

Flow data for seeps taken from Table 4.4-8a. RC-2 Loading values for % loading calculation taken from Tables 6.6-1 and 6.6-2.

N/A = Not Applicable.

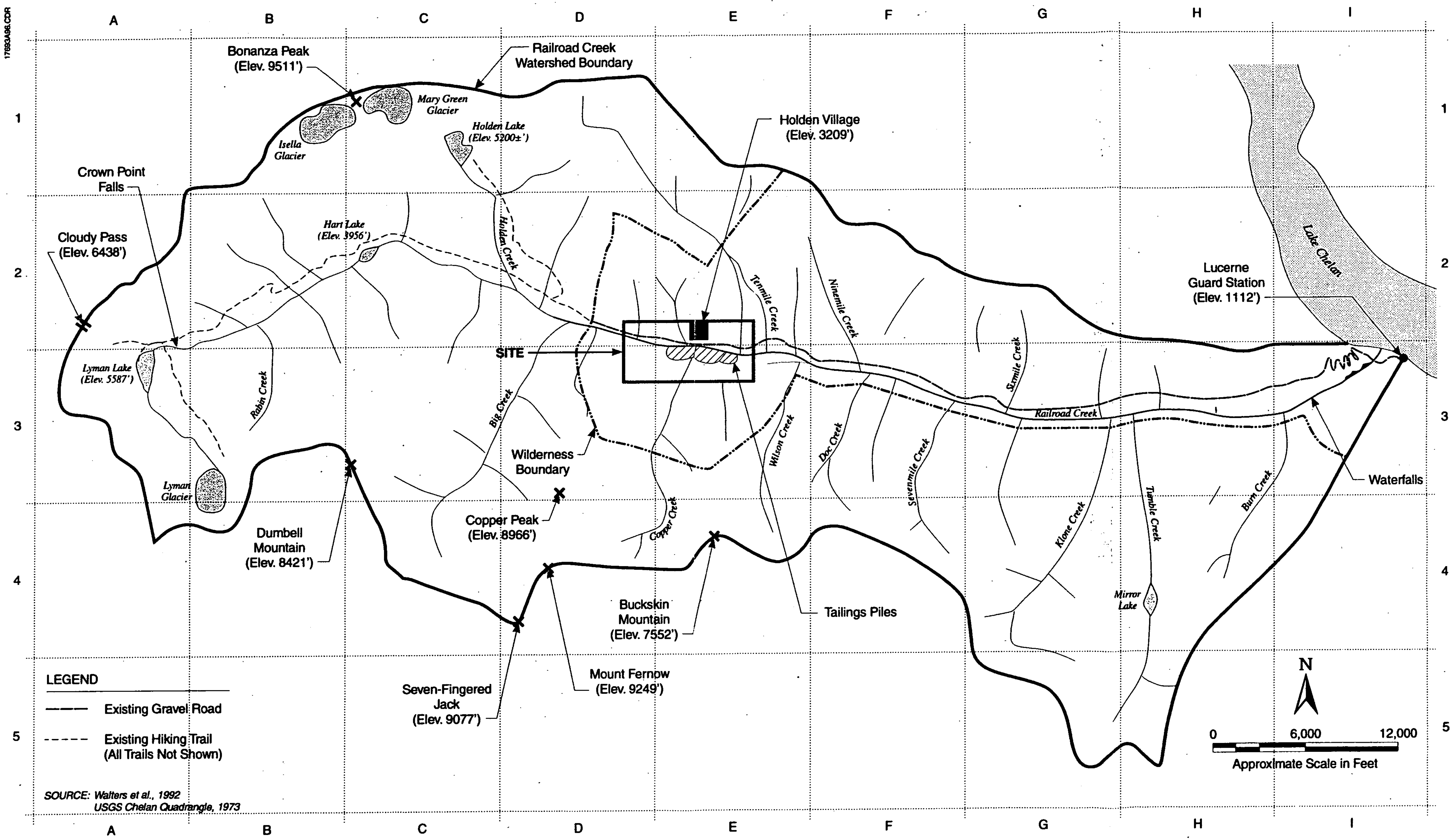

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Figure 6.1-1

RAILROAD CREEK WATERSHED MAP

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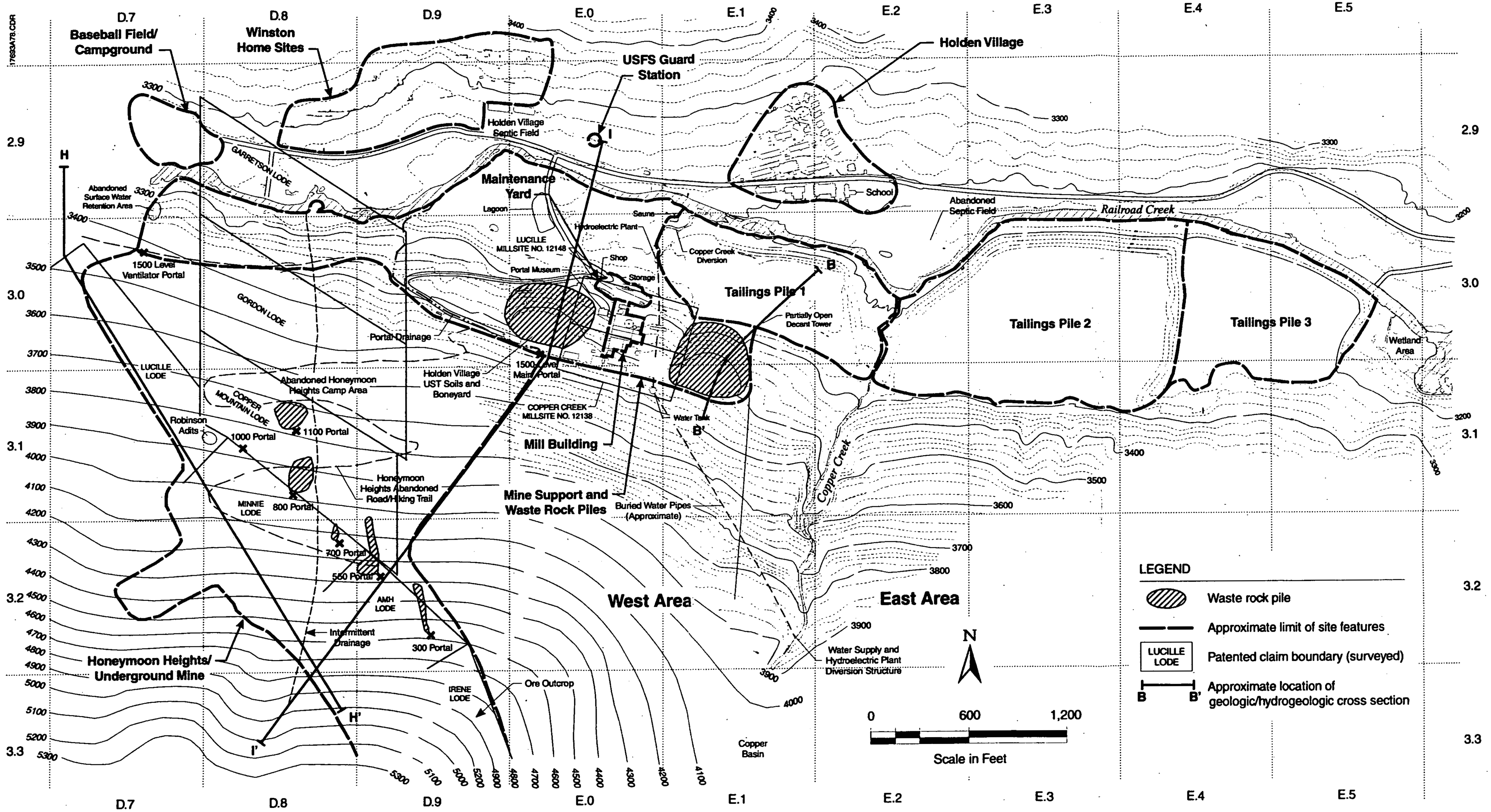

SOURCE: Base map information from USFS and Washington DNR, DEM CD ROM

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Figure 6.1-1a
HOLDEN MINE SITE MAP

Holden Mine RI/FS
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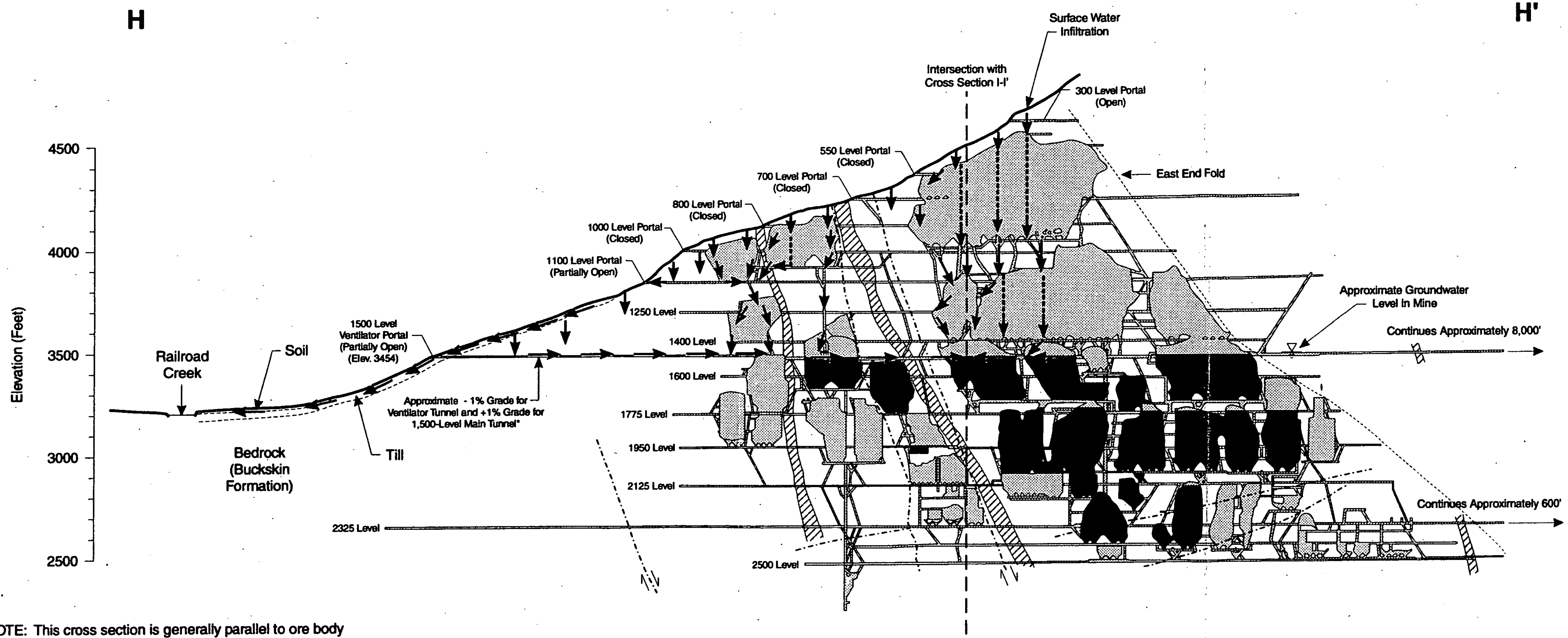
17693A69.CDR



* NOTE: This cross section is generally parallel to ore body and 1500-level ventilator tunnel. Due to 1500-level main tunnel having +1% grade, water flow is toward main portal opening but not shown on this figure. (See Figures 6.1-2a and 6.1-2b)

SOURCES: *Northwest Geophysical Associates, 1997, Seismic Line A-A', B-B', Holden Mine Geophysical Investigation.*

Youngberg, E. A., Wilson, T. L., 1952, The Geology of the Holden Mine, Economic Geology, V. 47, No. 1, 1952, pp. 1-12.

W.A.B., 1942, Detailed Surface Geology Map, Howe Sound Co., Chelan Division

F.E., H.B.S., 1938, Geology of 1500 Level, Howe Sound Company Chelan Division

LEGEND

░	Open stope
■	Backfilled stope
▨	Dike
-·-·-·-	Transform fault
→	Direction of inferred water movement

0 500 1,000

Approximate Horizontal and Vertical Scale in Feet

Figure 6.1-2

HOLDEN MINE SITE
CONCEPTUAL TRANSPORT PATHWAY OF MINE CROSS SECTION H-H'

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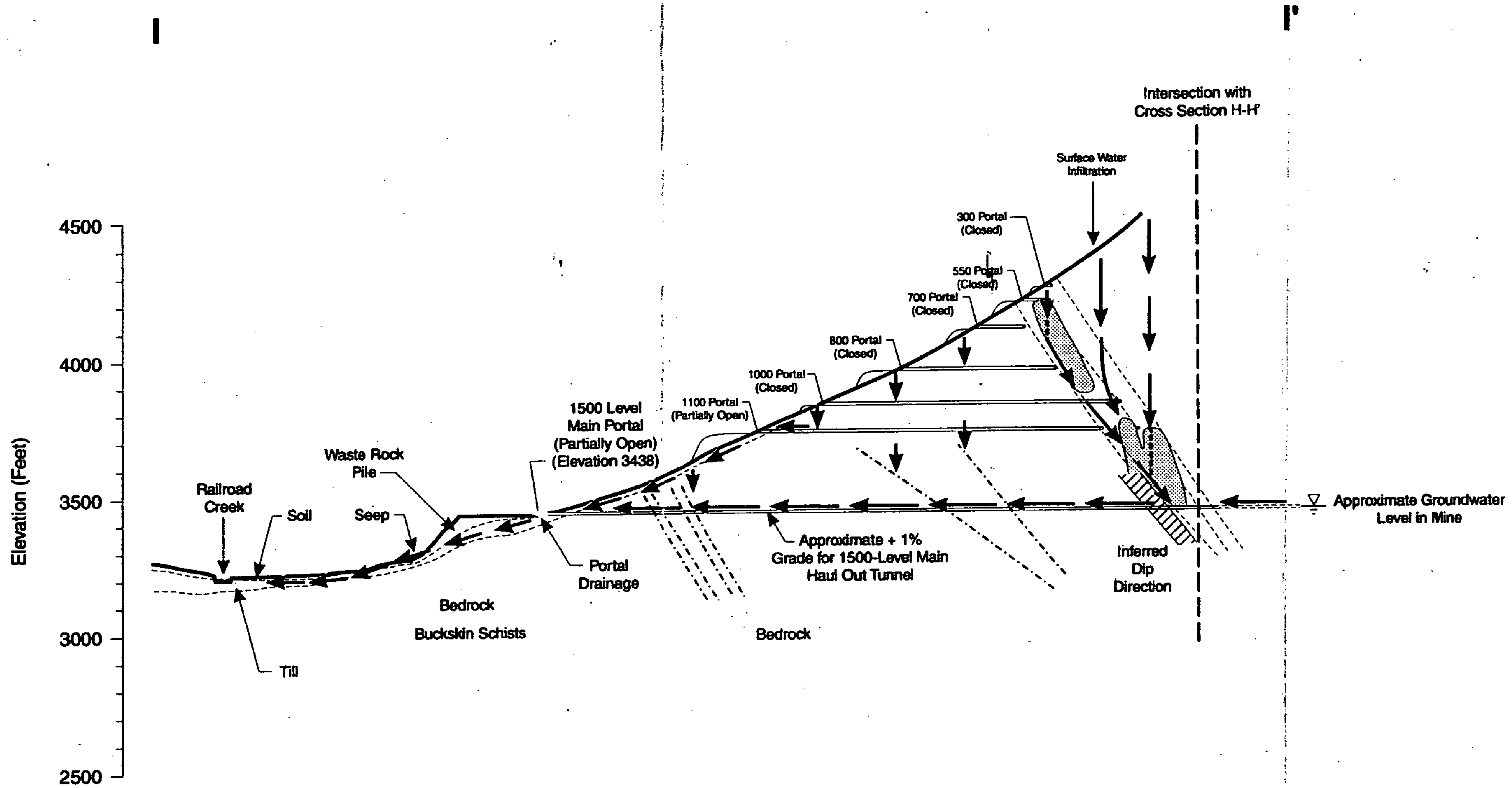
17693B90.CDR



SOURCES: *Northwest Geophysical Associates, 1997, Seismic Line A-A', B-B', Holden Mine Geophysical Investigation.*

Youngberg, E. A., Wilson, T. L., 1952, The Geology of the Holden Mine, Economic Geology, V. 47, No. 1, 1952, pp. 1-12.

W.A.B., 1942, Detailed Surface Geology Map, Howe Sound Co., Chelan Division

F.E., H.B.S., 1938, Geology of 1500 Level, Howe Sound Company Chelan Division

LEGEND

▒ Open stope

▨ Dike

-·-·-·- Trasform fault

→ Direction of inferred water movement

0 500 1,000

Approximate Horizontal and Vertical Scale in Feet

Figure 6.1-2a

HOLDEN MINE SITE
CONCEPTUAL TRANSPORT PATHWAY OF MINE CROSS SECTION I-I'

Holden Mine RI/FS
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17693B81.CDR

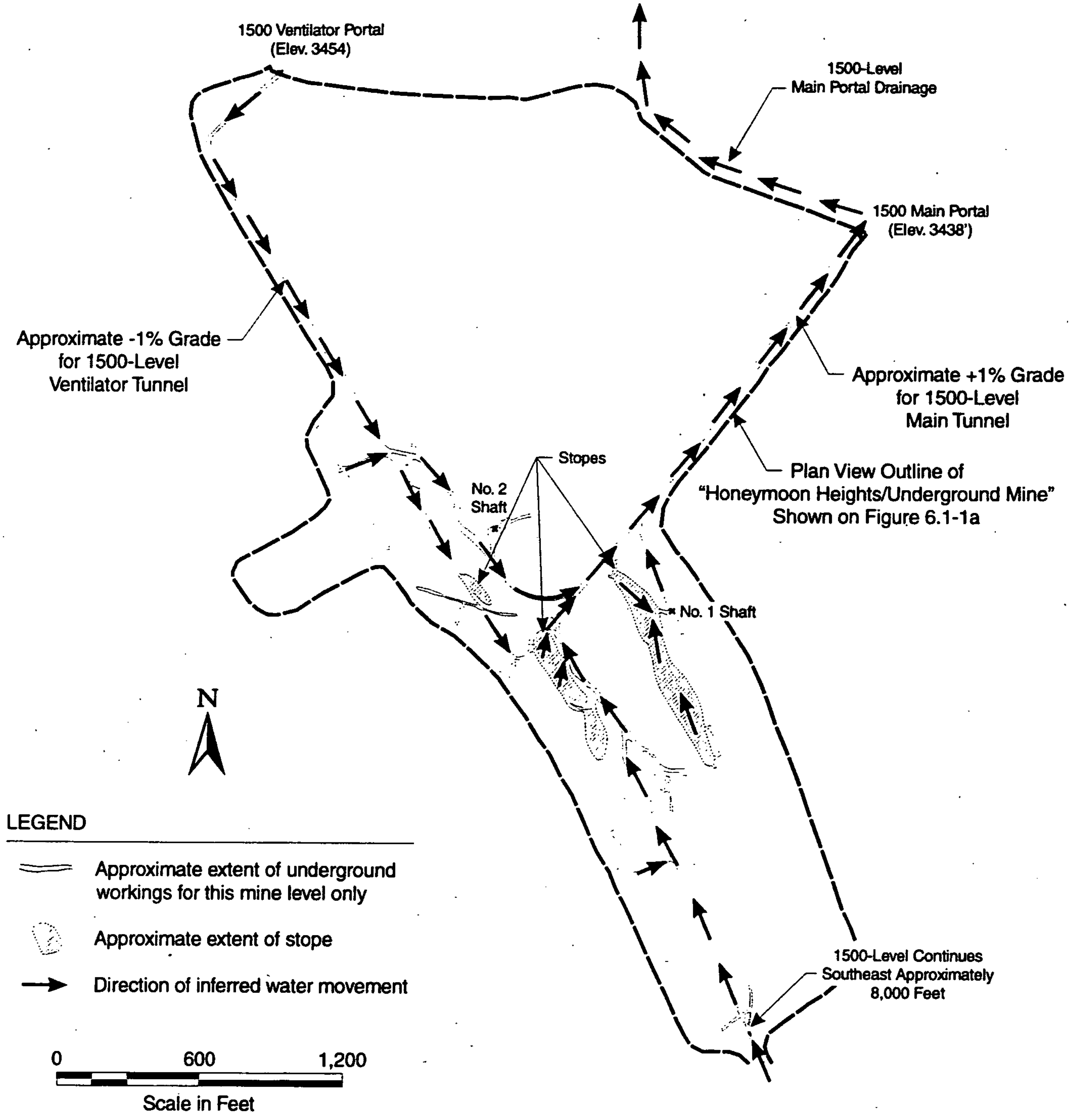

Figure 6.1-2b

HOLDEN MINE SITE
CONCEPTUAL TRANSPORT PATHWAY OF MINE
PLAN VIEW OF 1500 LEVEL

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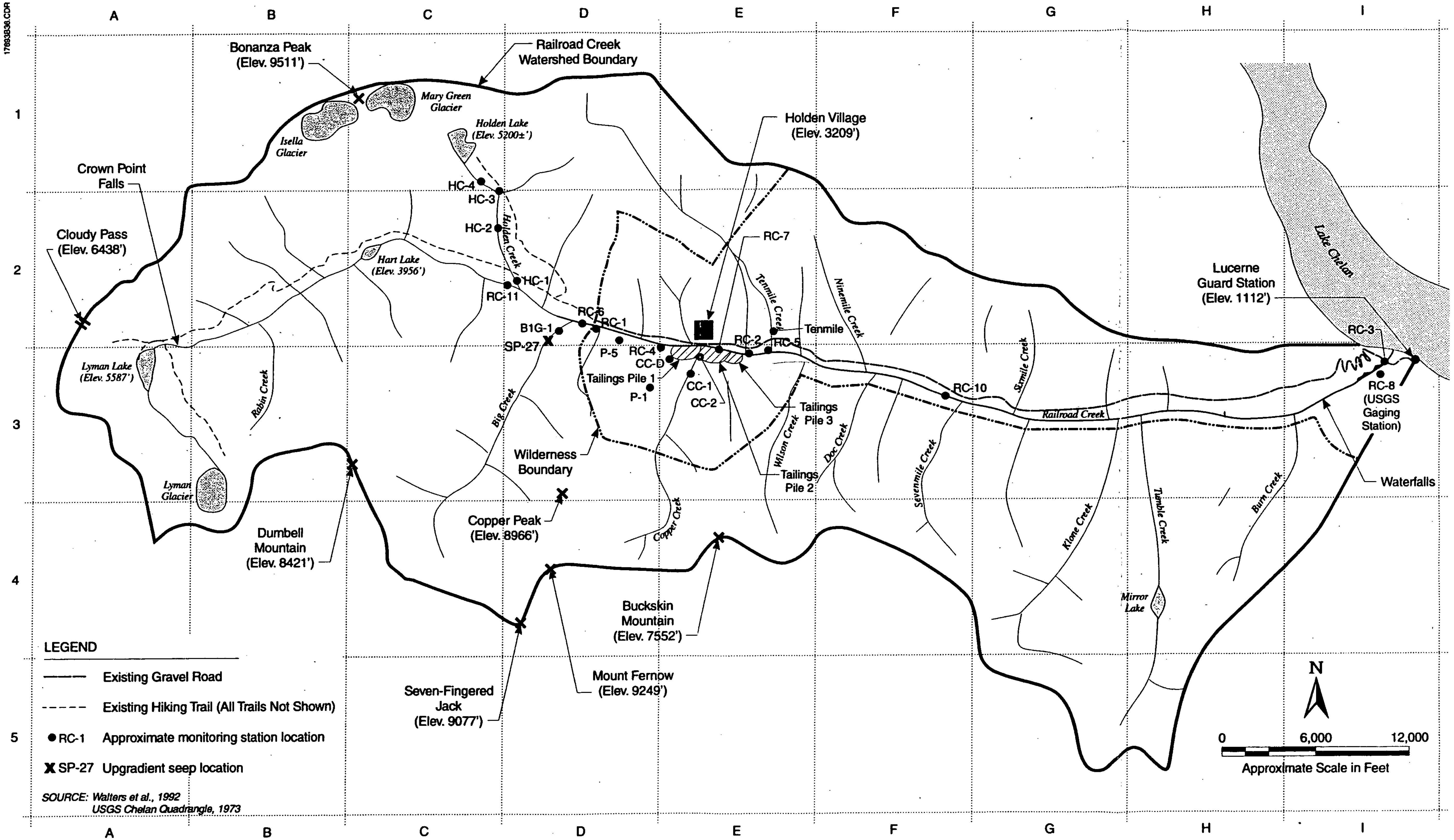

SOURCE: Walters et al., 1992
USGS Chelan Quadrangle, 1973

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Figure 6.1-3

STREAMFLOW AND WATER QUALITY MONITORING STATIONS - RAILROAD CREEK

Holden Mine RI/FS
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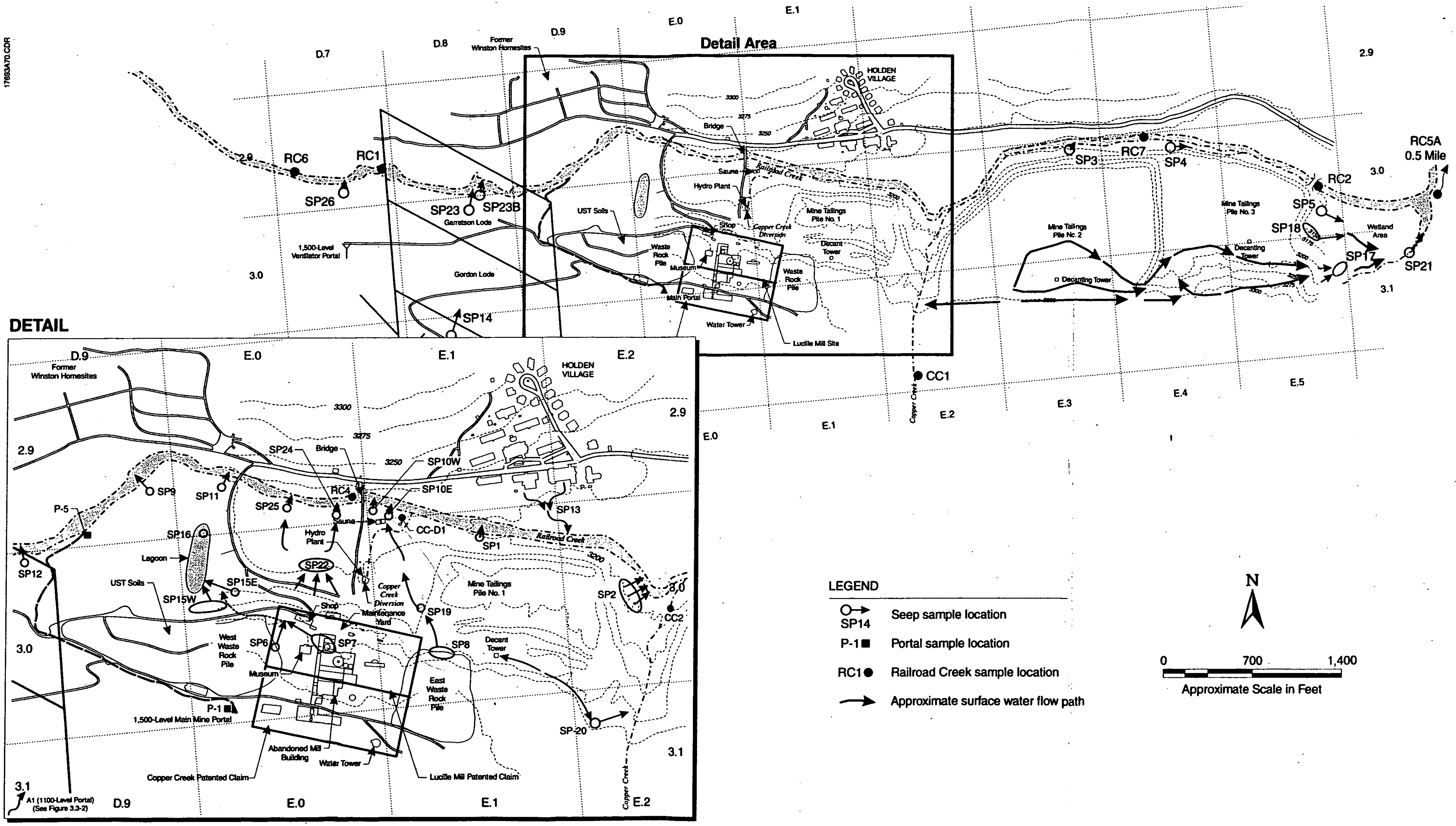
17693A70.CDR



SOURCE: ORB, 1975

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Figure 6.1-3a

APPROXIMATE LOCATIONS OF SURFACE WATER RUNON AND RUNOFF

Holden Mine RI/FS
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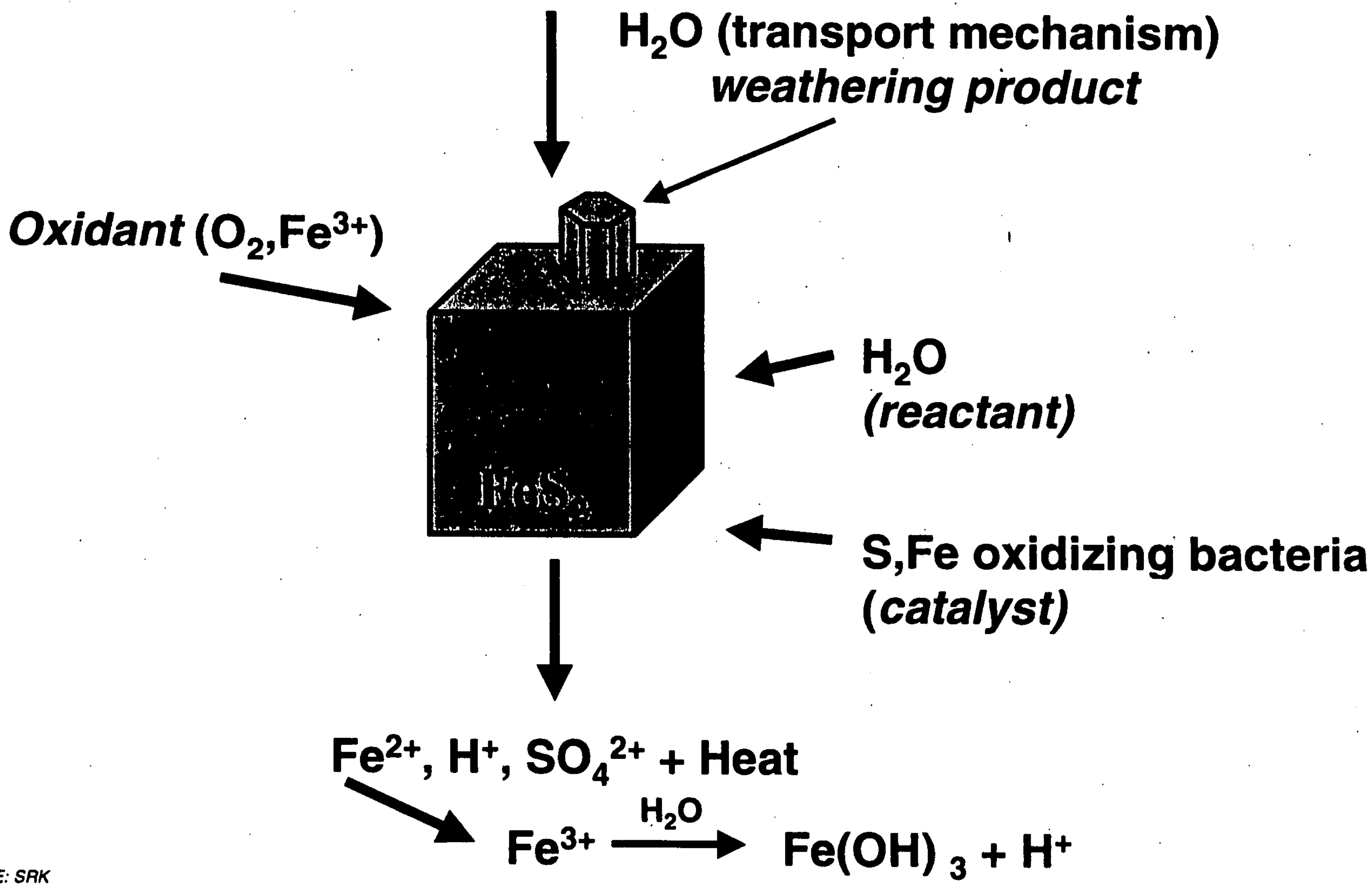
17693_01.PPT



H_2O (transport mechanism)
weathering product

Oxidant (O_2,Fe^{3+})

H_2O
(reactant)

S,Fe oxidizing bacteria
(*catalyst)*

Fe^{2+}, H^+, SO_4^{2+} + Heat

$$Fe^{3+} \xrightarrow{H_2O} Fe(OH)_3 + H^+$$

SOURCE: SRK

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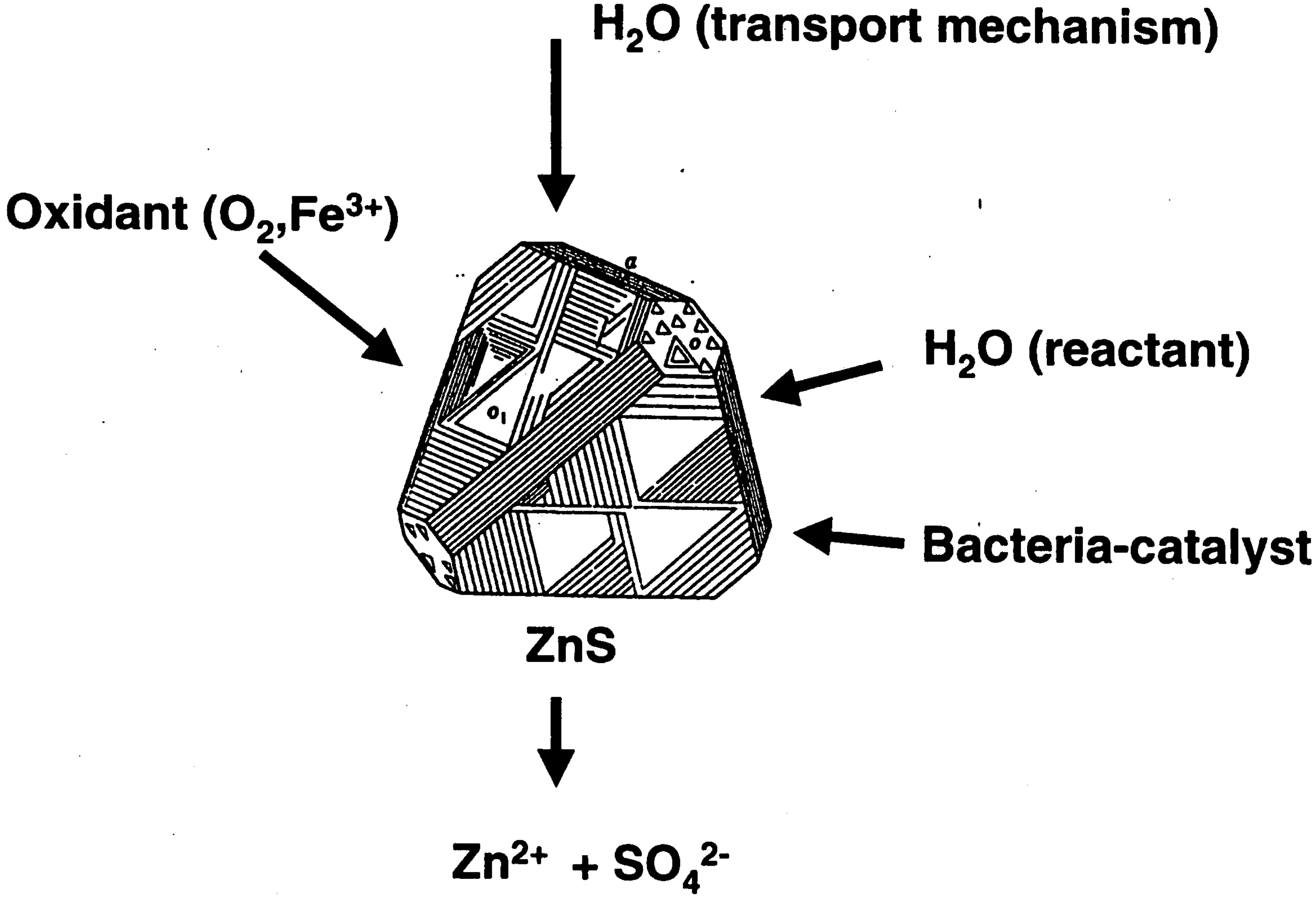
Figure 6.3-1
SULFIDE OXIDATION



H_2O (transport mechanism)

Oxidant (O_2,Fe^{3+})

H_2O (reactant)

Bacteria-catalyst

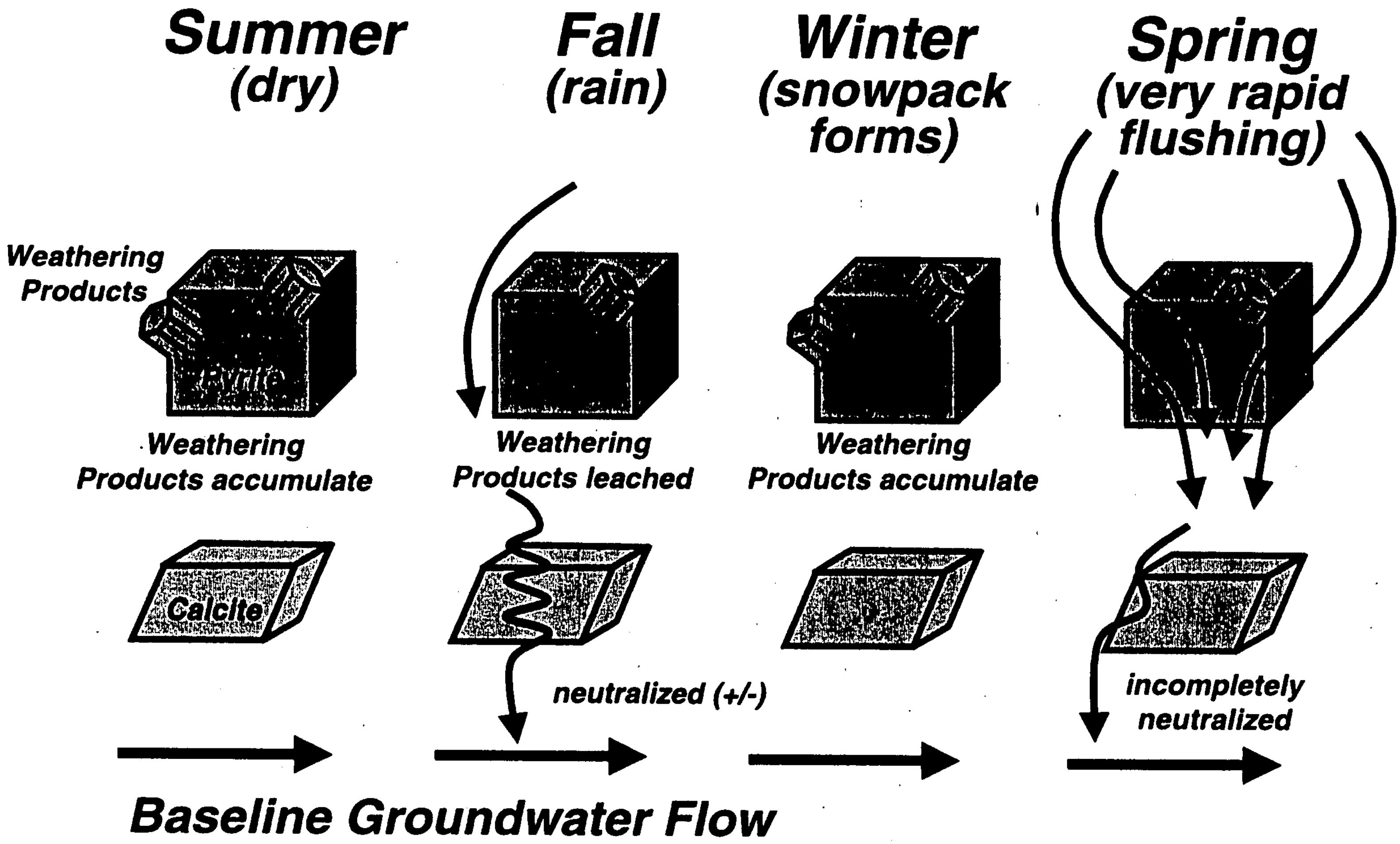
ZnS

$Zn^{2+} + SO_4^{2-}$

SOURCE: SRK

Figure 6.3-2
OXIDATIVE DISSOLUTION

17693_01.PPT



Summer (dry)

Fall (rain)

Winter (snowpack forms)

Spring (very rapid flushing)

Weathering Products

Pyrite

Weathering Products accumulate

Weathering Products leached

Weathering Products accumulate

Calcite

neutralized (+/-)

incompletely neutralized

Baseline Groundwater Flow

SOURCE: SRK

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Figure 6.3-3

STORAGE AND TRANSPORT OF WEATHERING PRODUCTS

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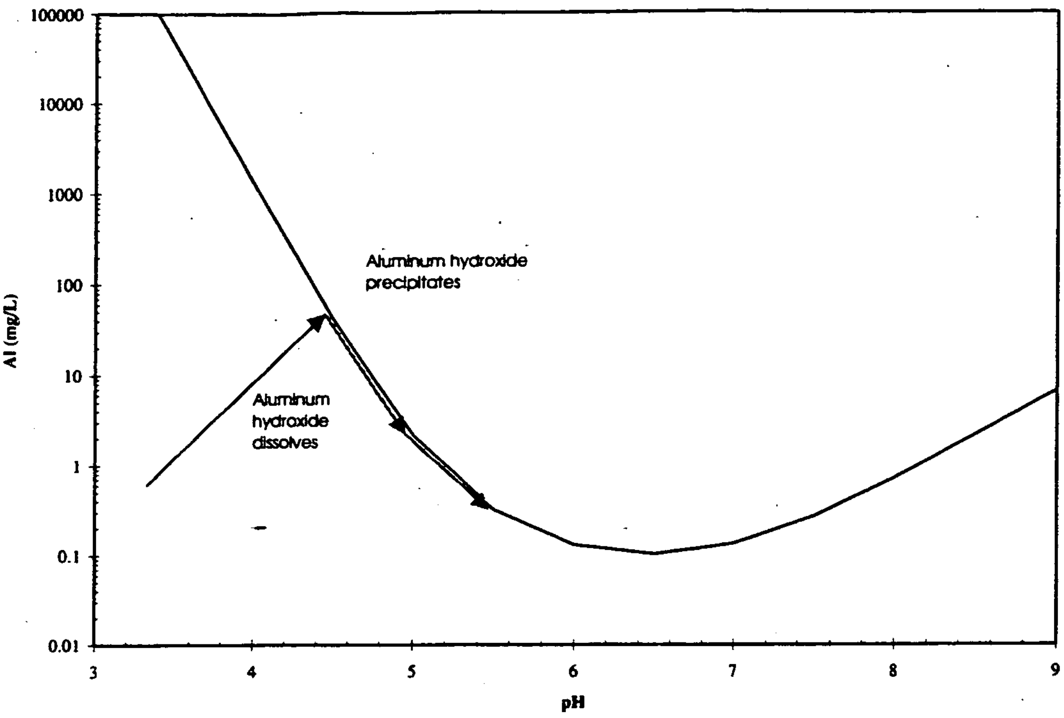
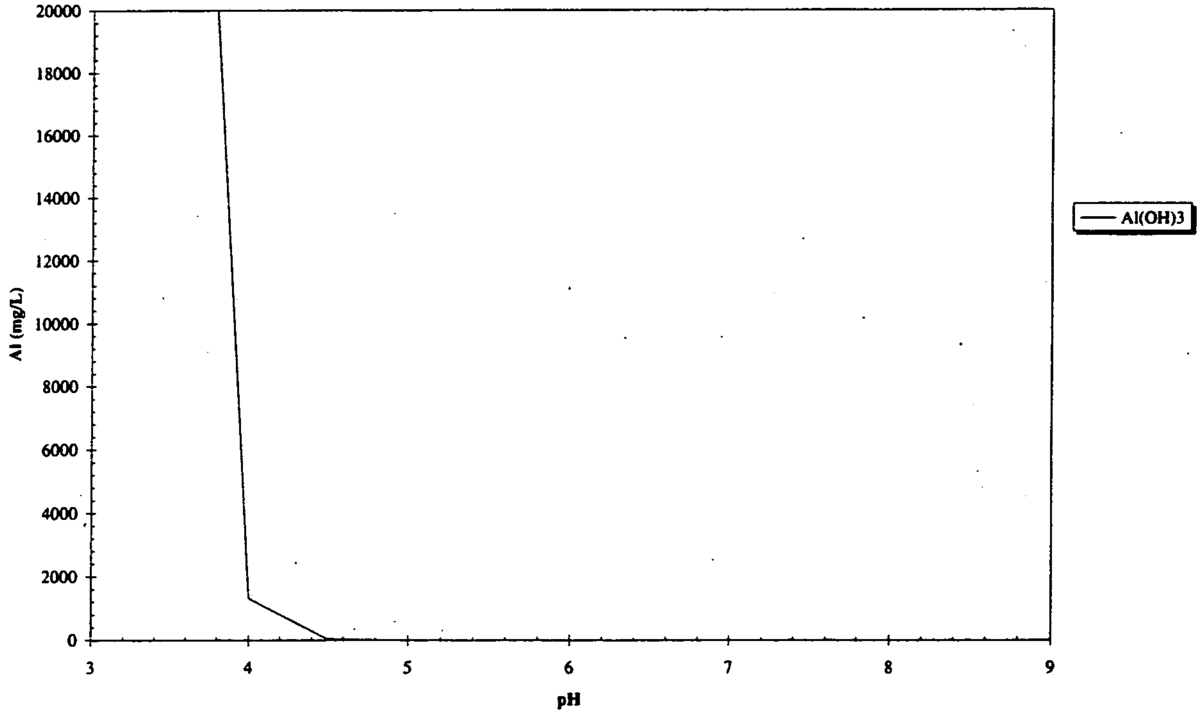


Figure 6.3-4a



SOURCE: SRK

Figure 6.3-4b

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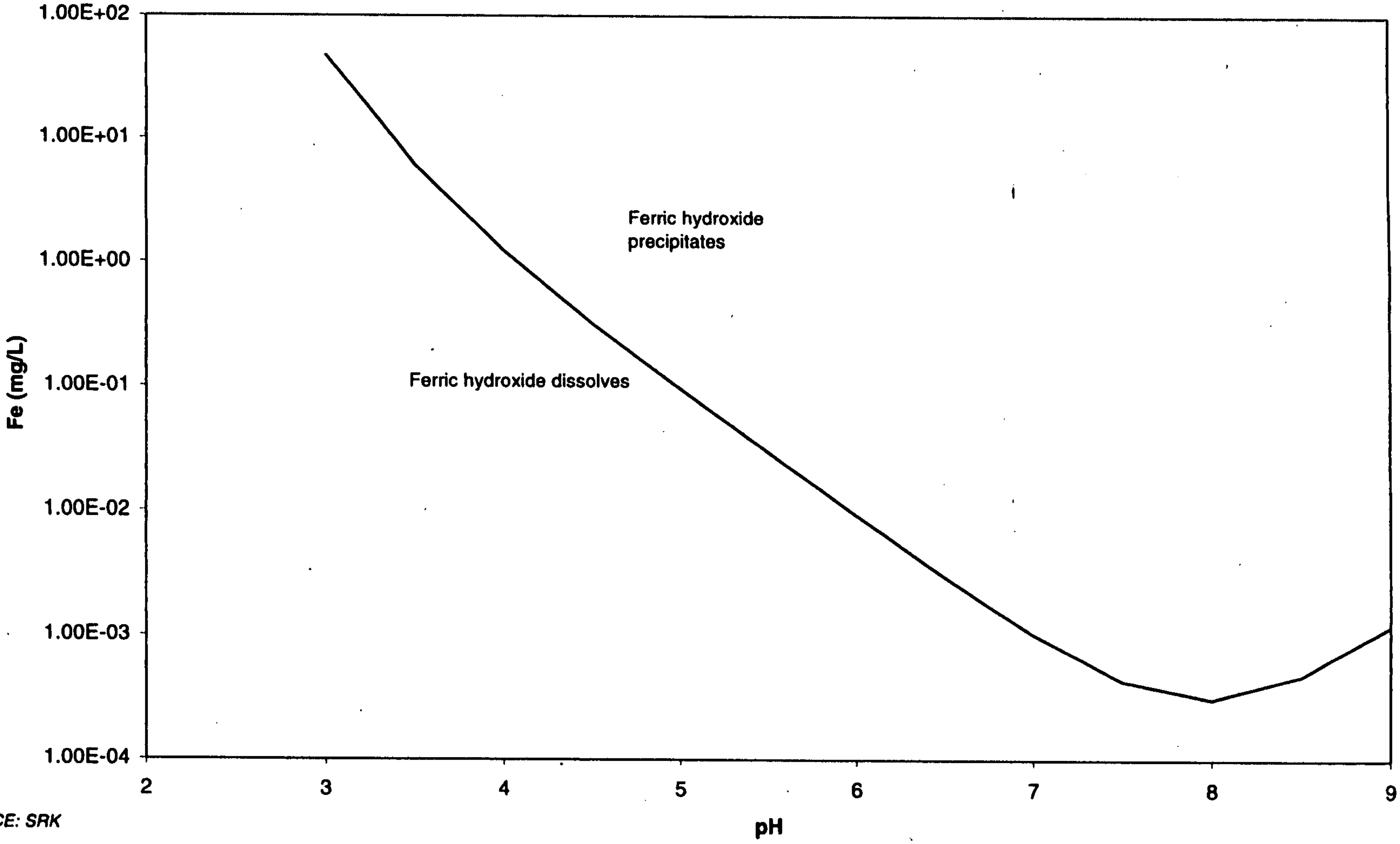
Figure 6.3-4

Al $(OH)_3$ STABILITY DIAGRAM

Holden Mine RI/FS
Draft Final RI Report

Job No. 17693-005-019



SOURCE: SRK

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Figure 6.3-5

Fe (OH)$_3$ STABILITY DIAGRAM

Holden Mine RI/FS
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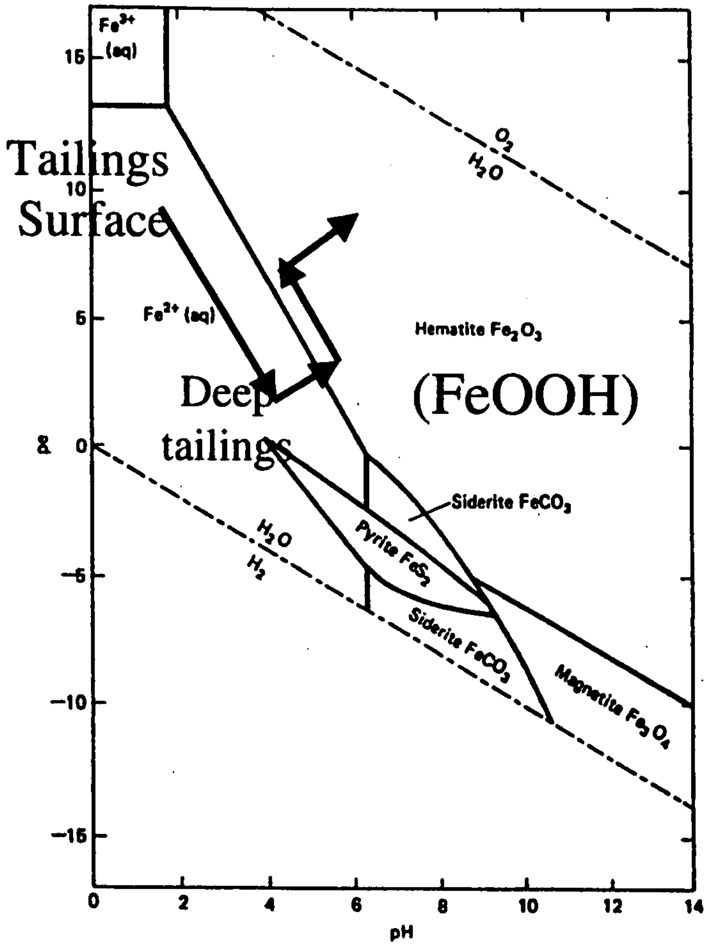

SOURCE: Garrels and Christ, 1965

Figure 6.3-6

pH-Eh CONTROL ON PRECIPITATION/DISSOLUTION OF IRON MINERALS AND IONS

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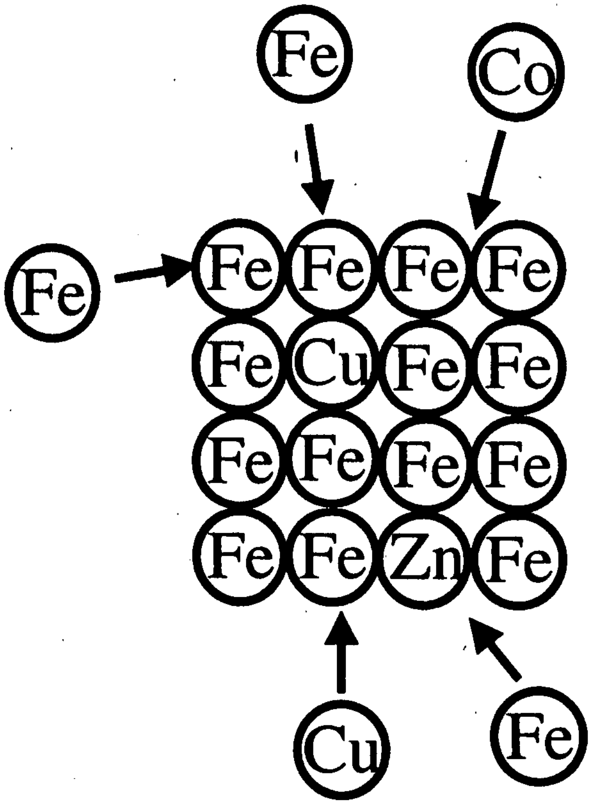

Trace elements are co-precipitated with iron, manganese and aluminum oxyhydroxides

SOURCE: SRK

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Figure 6.3-7

CO-PRECIPITATION

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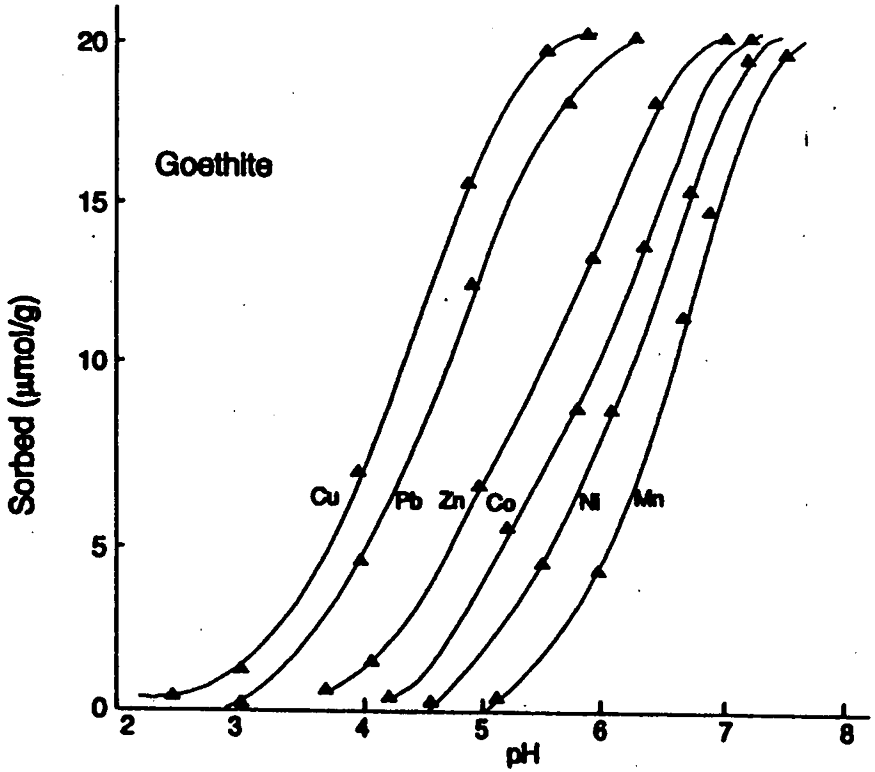

SOURCE: Schwertman and Taylor, 1989

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Figure 6.3-8

ADSORPTION OF GOETHITE

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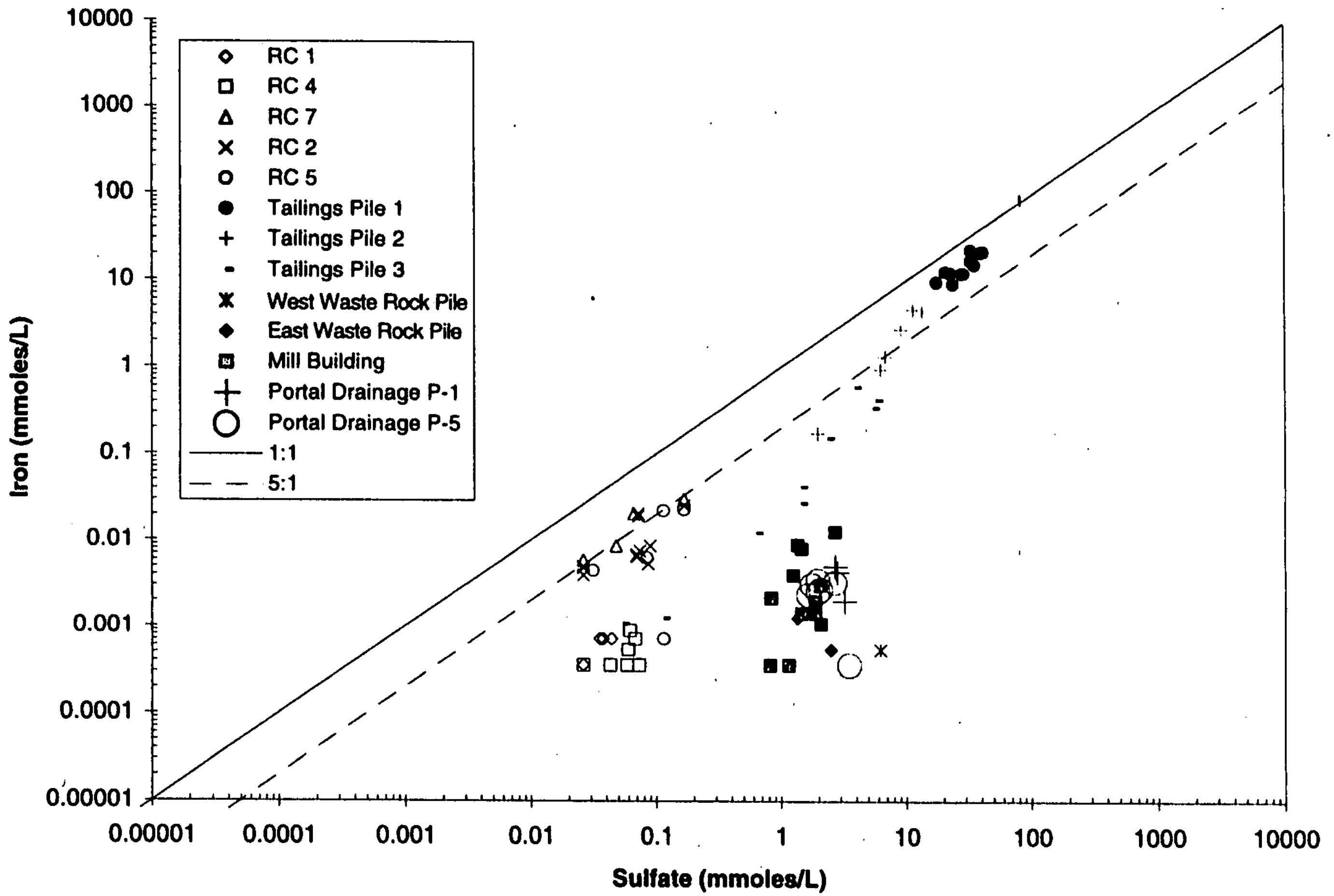

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Figure 6.4-1

SURFACE AND SEEPAGE WATER SAMPLES IRON VS SULFATE SCATTER PLOT

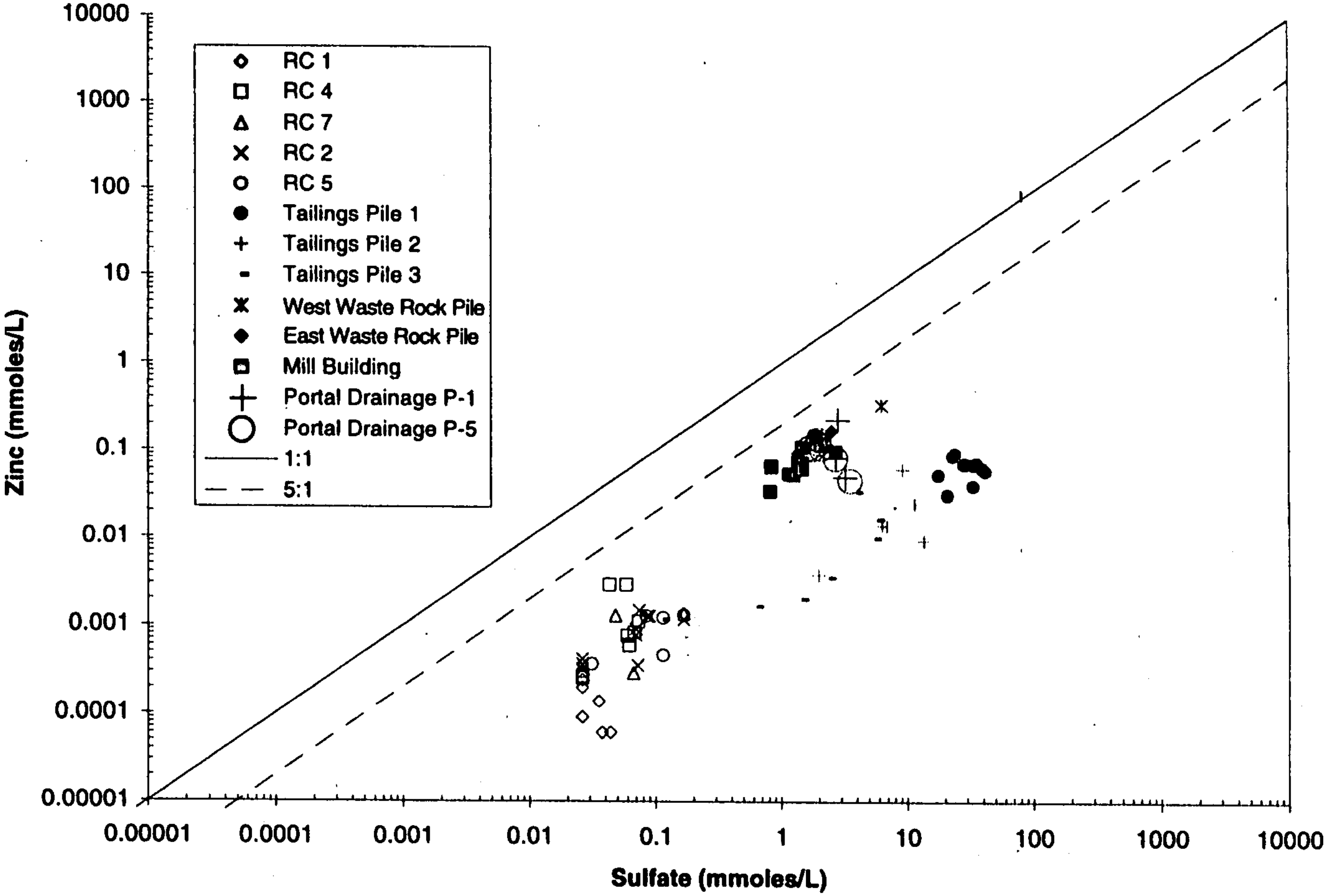

Figure 6.4-2

SURFACE AND SEEPAGE WATER SAMPLES ZINC VS SULFATE SCATTER PLOT

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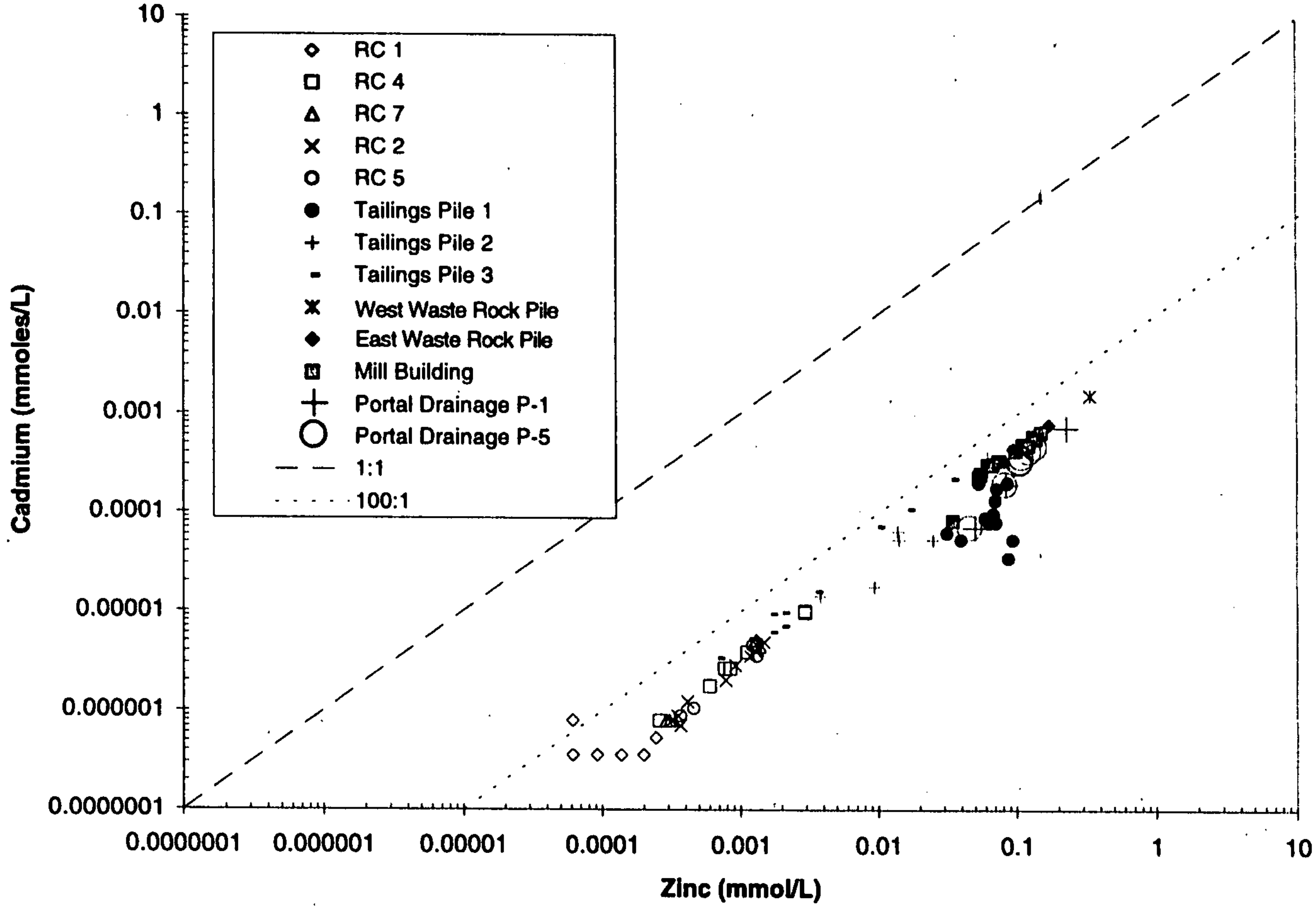

Figure 6.4-3

SURFACE AND SEEPAGE WATER SAMPLES
ZINC VS CADMIUM SCATTER PLOT

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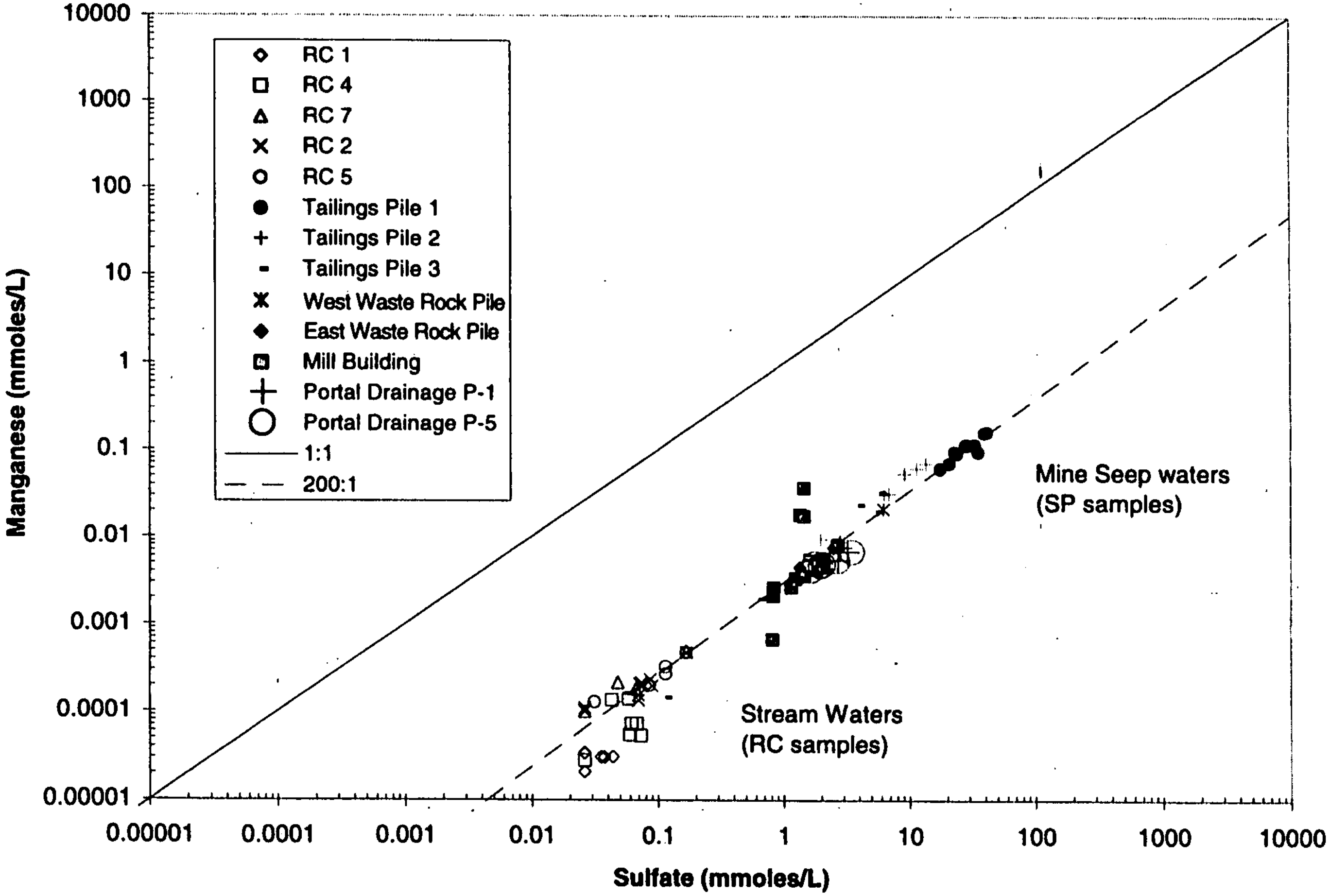

Figure 6.4-4

SURFACE AND SEEPAGE WATER SAMPLES MANGANESE VS SULFATE SCATTER PLOT

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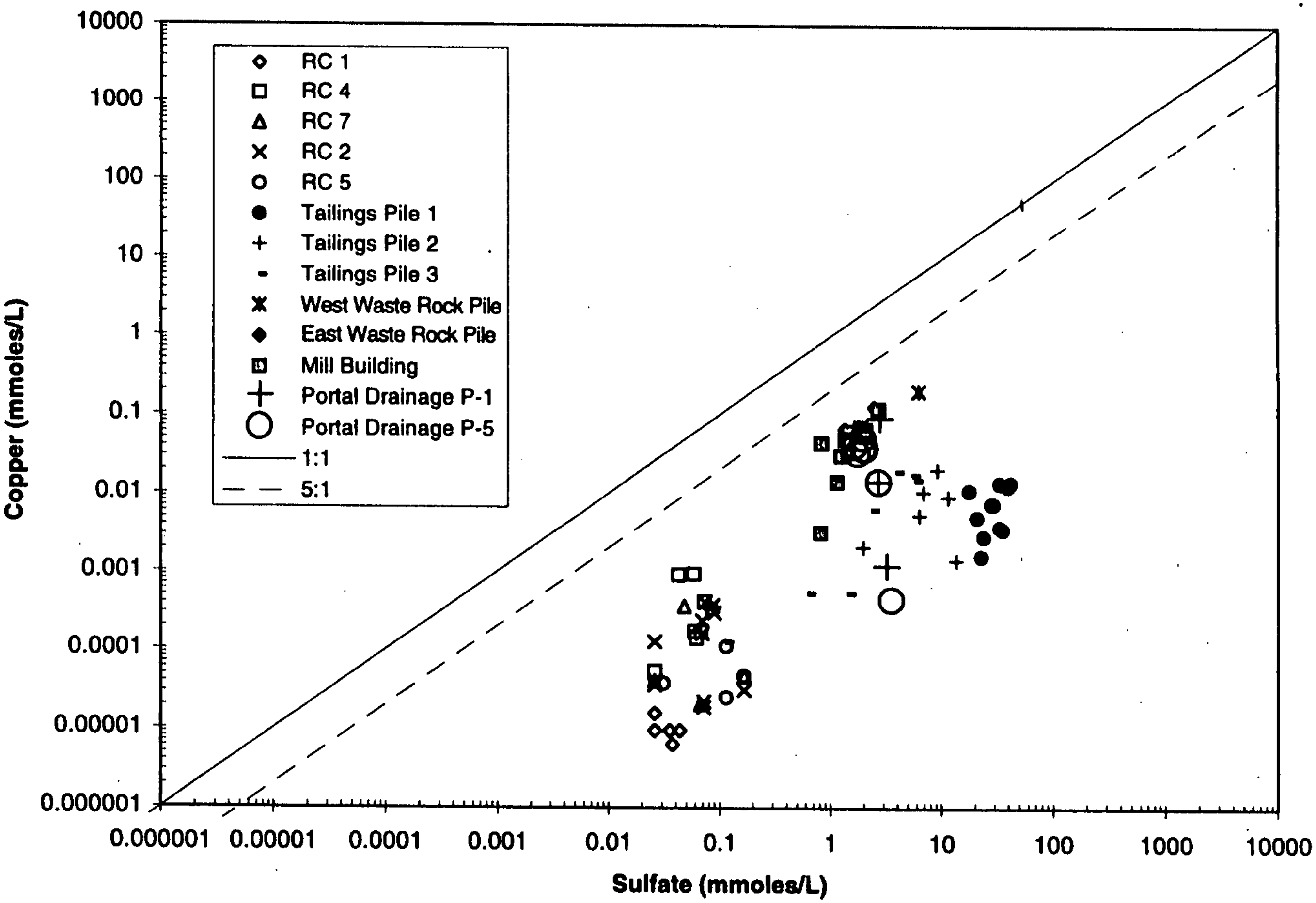

Figure 6.4-5

SURFACE AND SEEPAGE WATER SAMPLES COPPER VS SULFATE SCATTER PLOT

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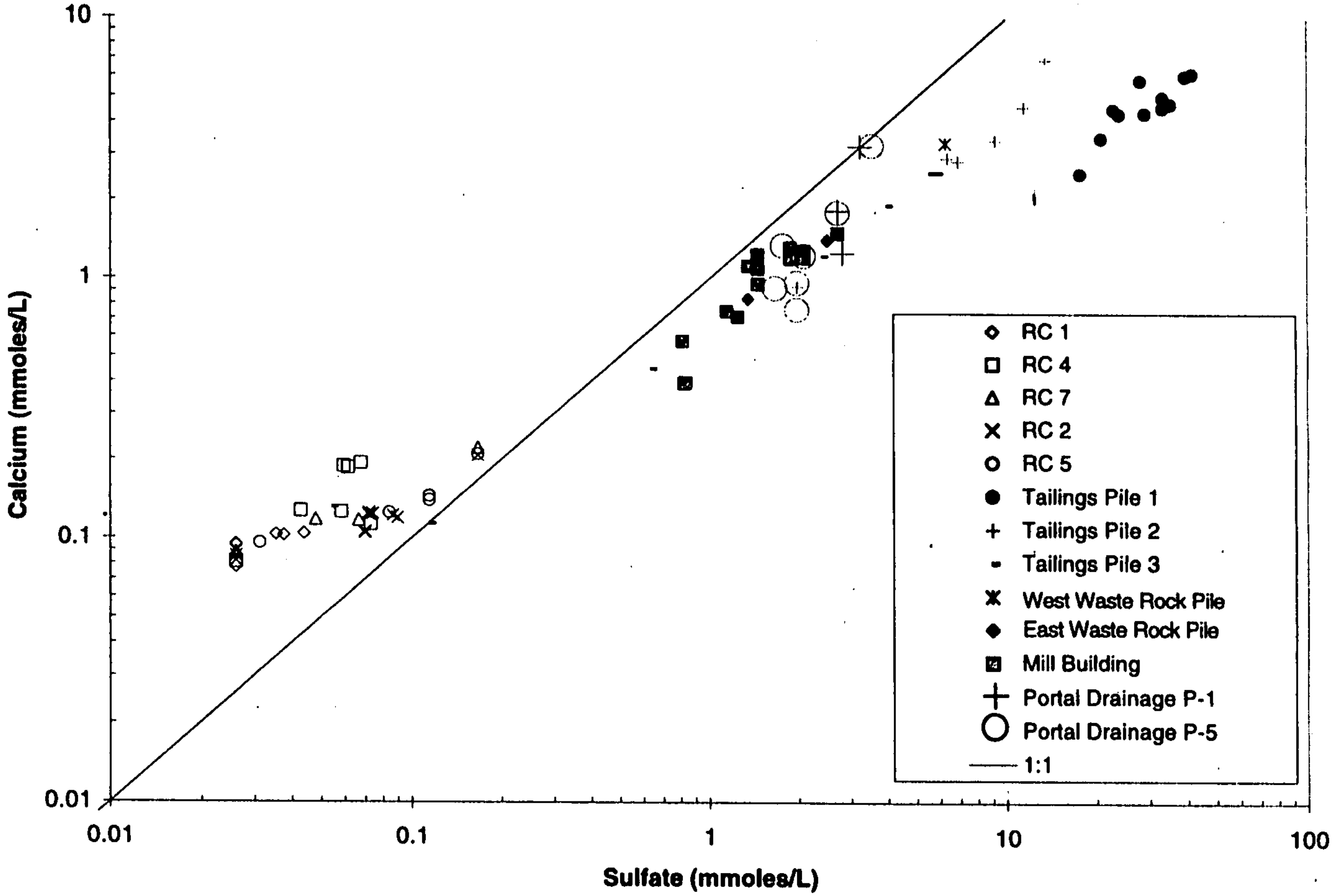

Figure 6.4-6

SURFACE AND SEEPAGE WATER SAMPLES CALCIUM VS SULFATE SCATTER PLOT

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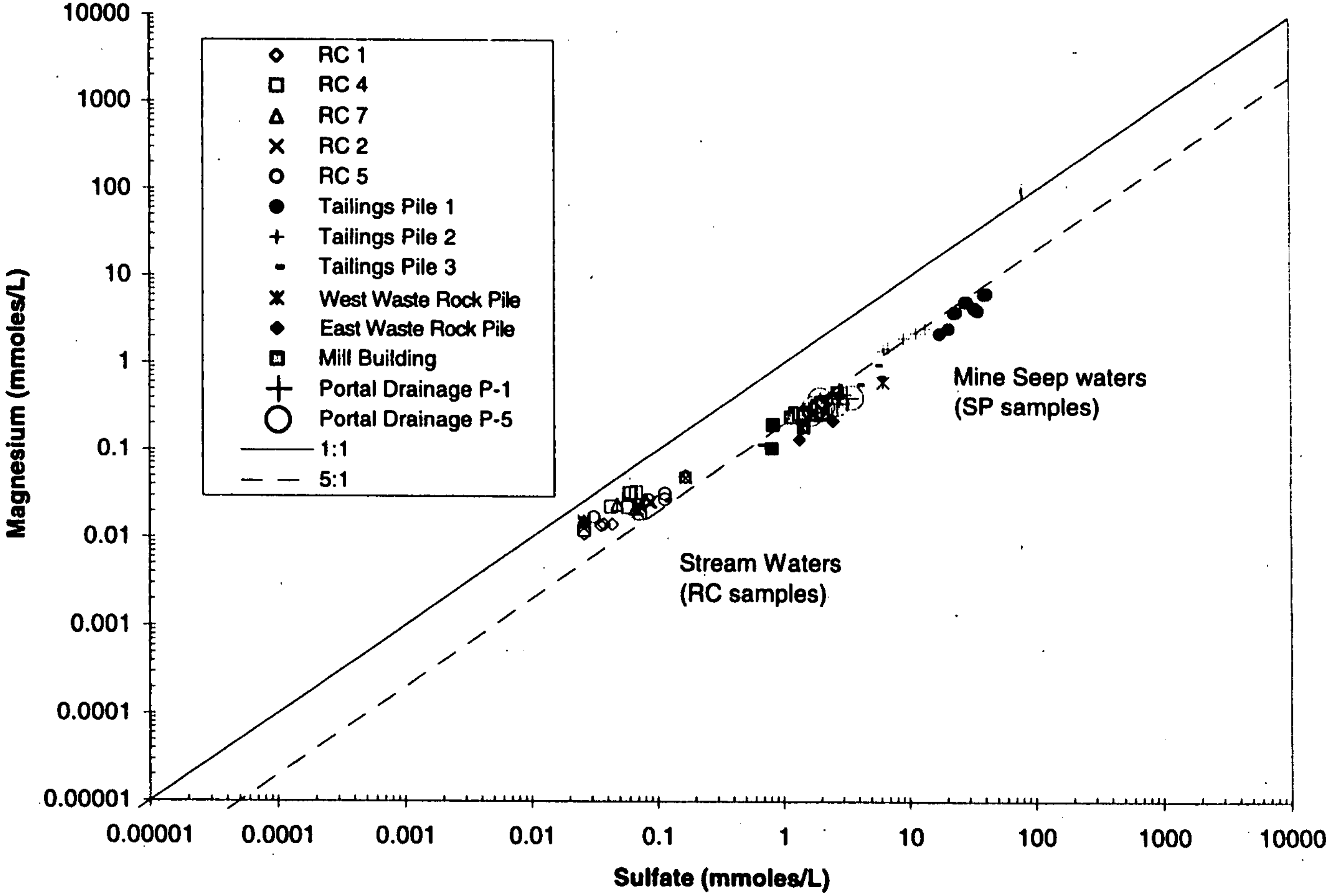

Figure 6.4-7

SURFACE AND SEEPAGE WATER SAMPLES
MAGNESIUM VS SULFATE SCATTER PLOT

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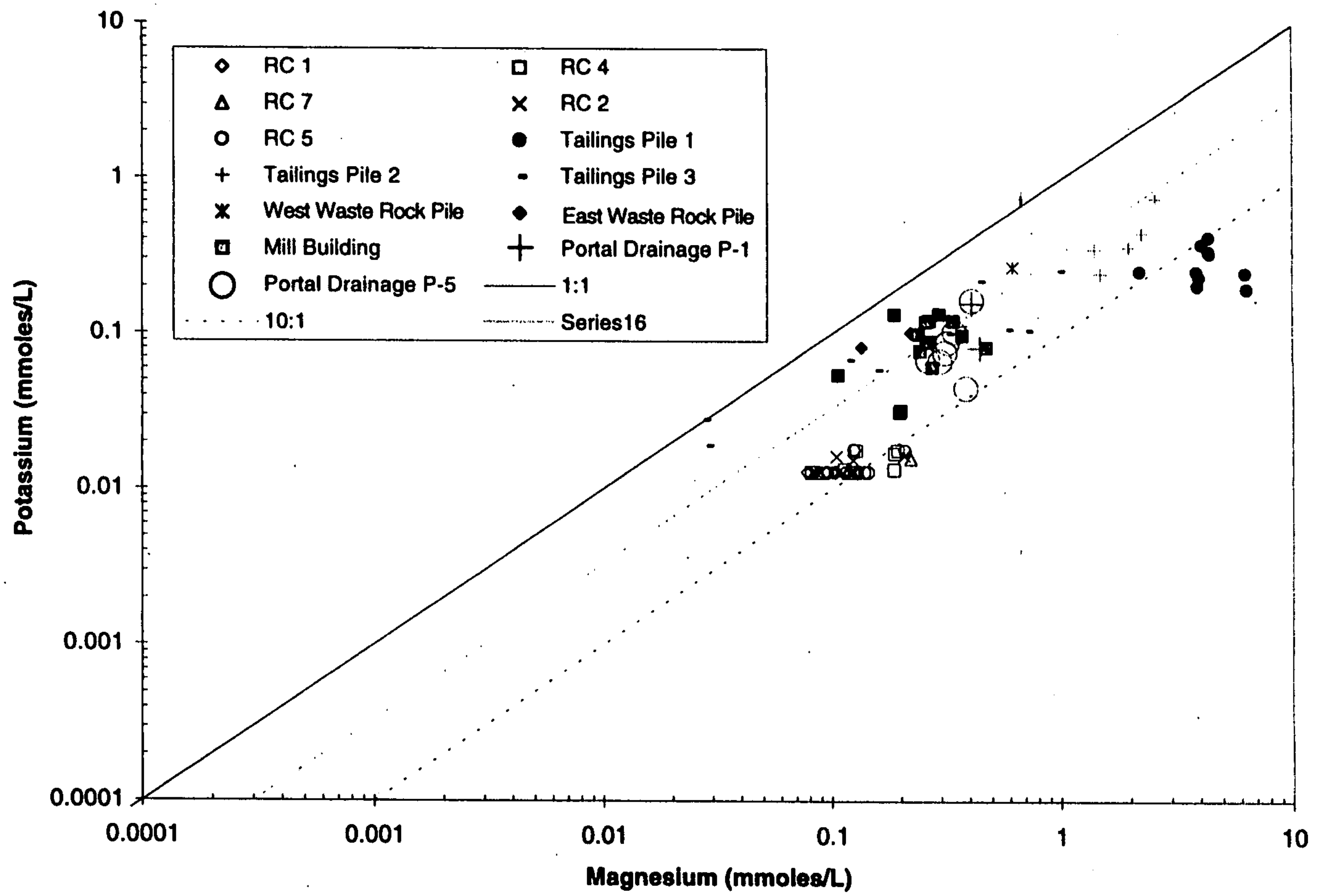

Figure 6.4-8

SURFACE AND SEEPAGE WATER SAMPLES POTASSIUM VS MAGNESIUM SCATTER PLOT

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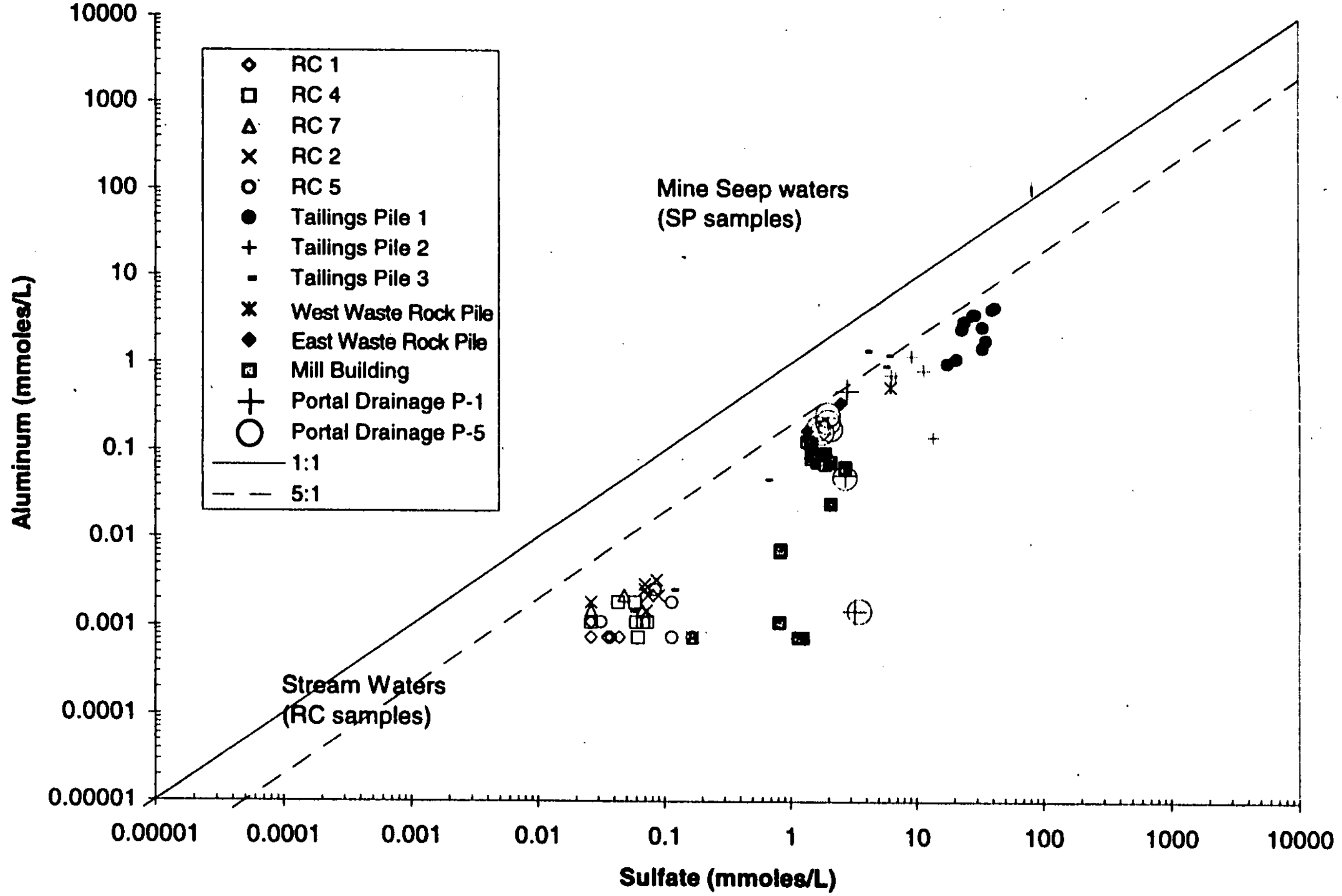

Figure 6.4-9

SURFACE AND SEEPAGE WATER SAMPLES ALUMINUM VS SULFATE SCATTER PLOT

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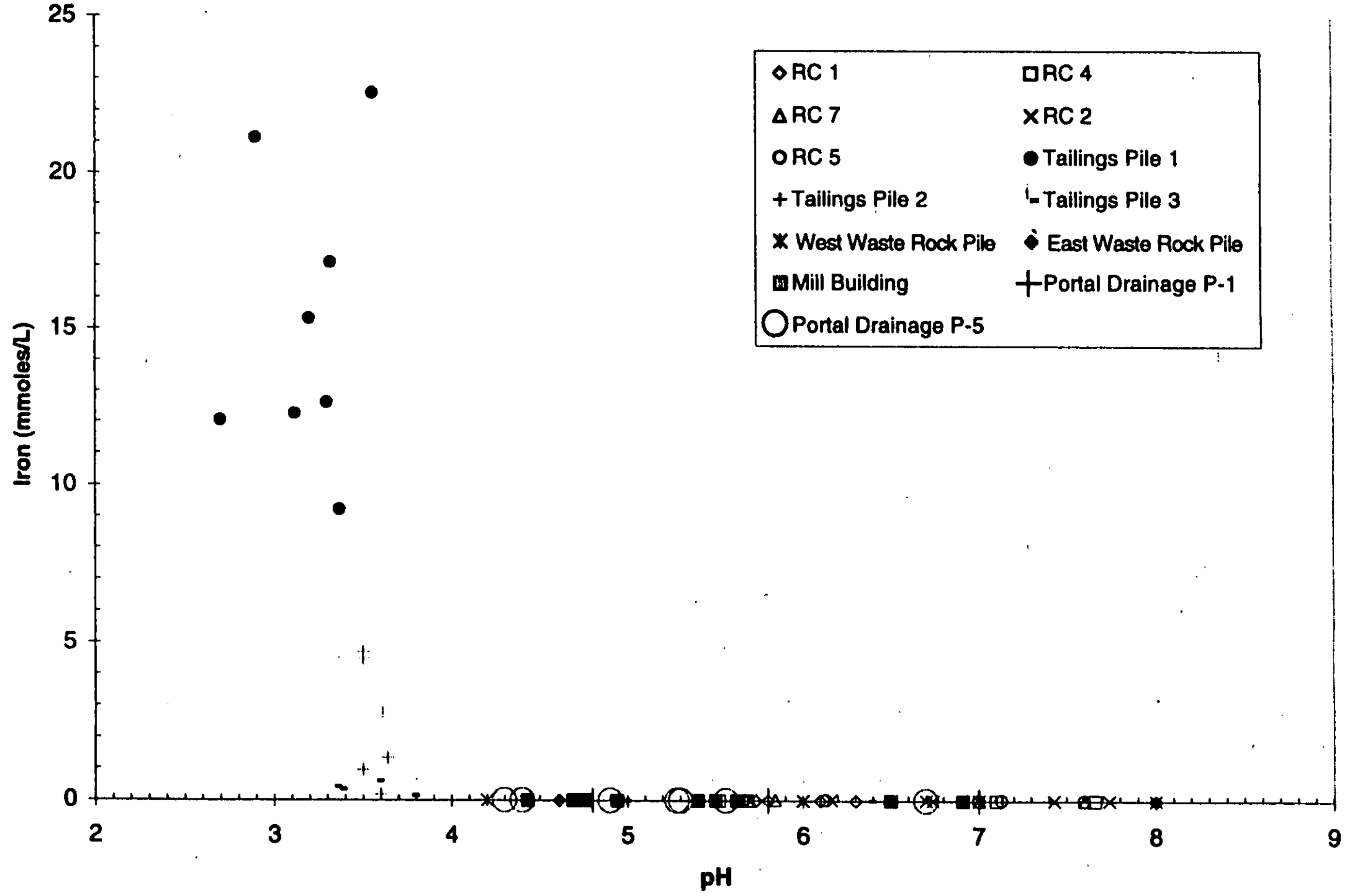

Figure 6.4-10

SURFACE AND SEEPAGE WATER SAMPLES IRON VS pH SCATTER PLOT

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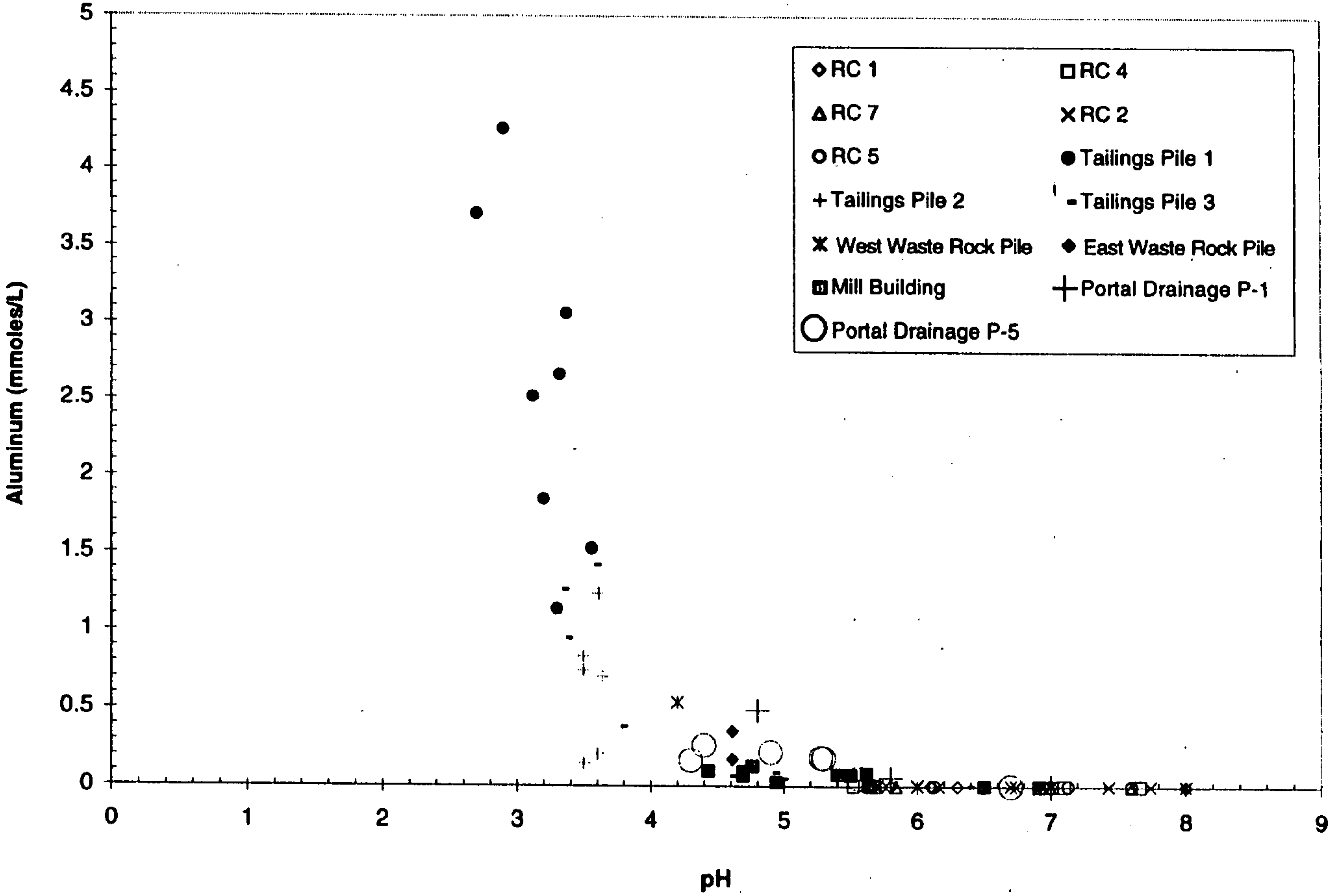

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Figure 6.4-11

SURFACE AND SEEPAGE WATER SAMPLES ALUMINUM VS pH SCATTER PLOT

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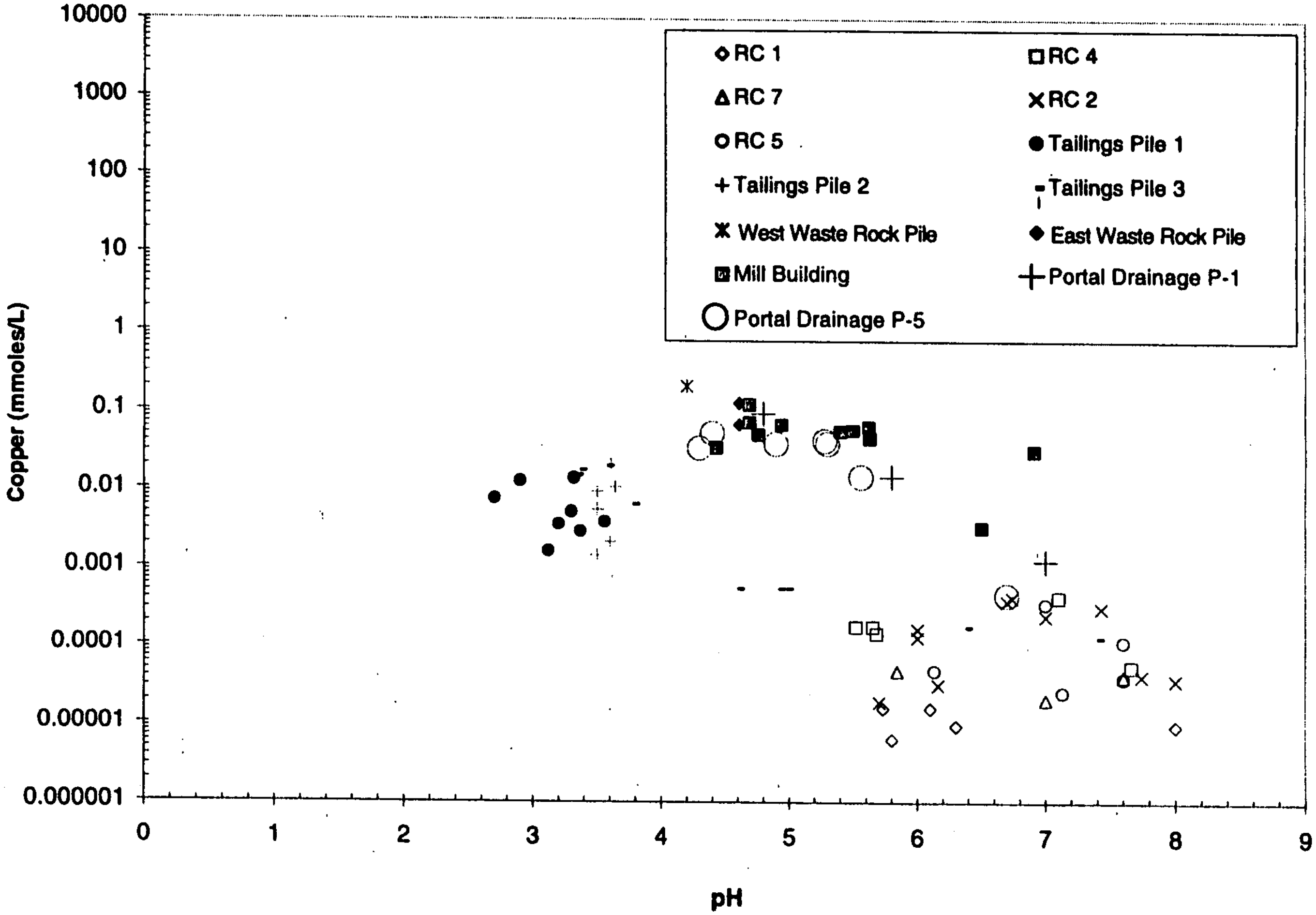

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Figure 6.4-12

SURFACE AND SEEPAGE WATER SAMPLES COPPER VS pH SCATTER PLOT

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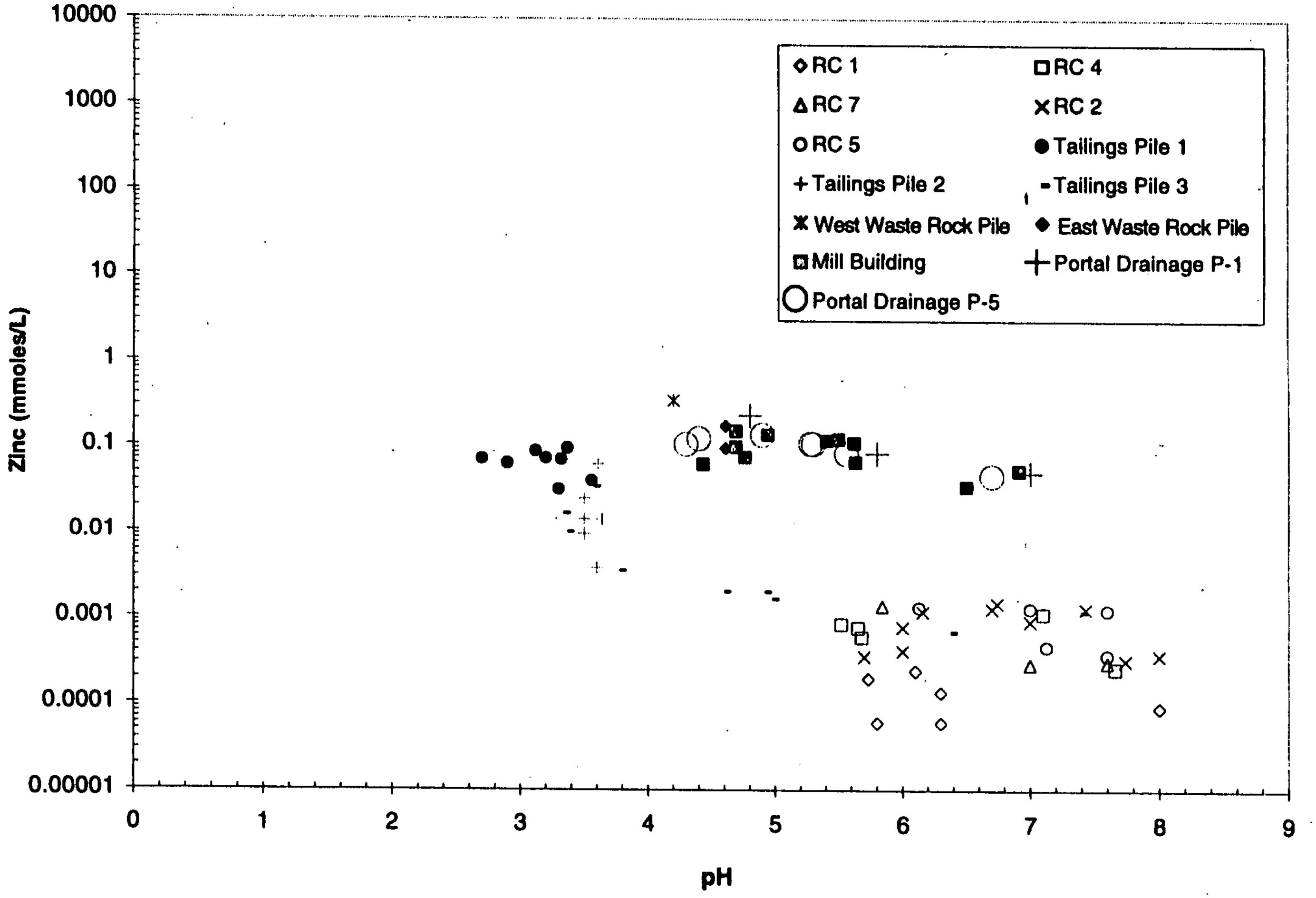

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Figure 6.4-13

SURFACE AND SEEPAGE WATER SAMPLES
ZINC VS pH SCATTER PLOT

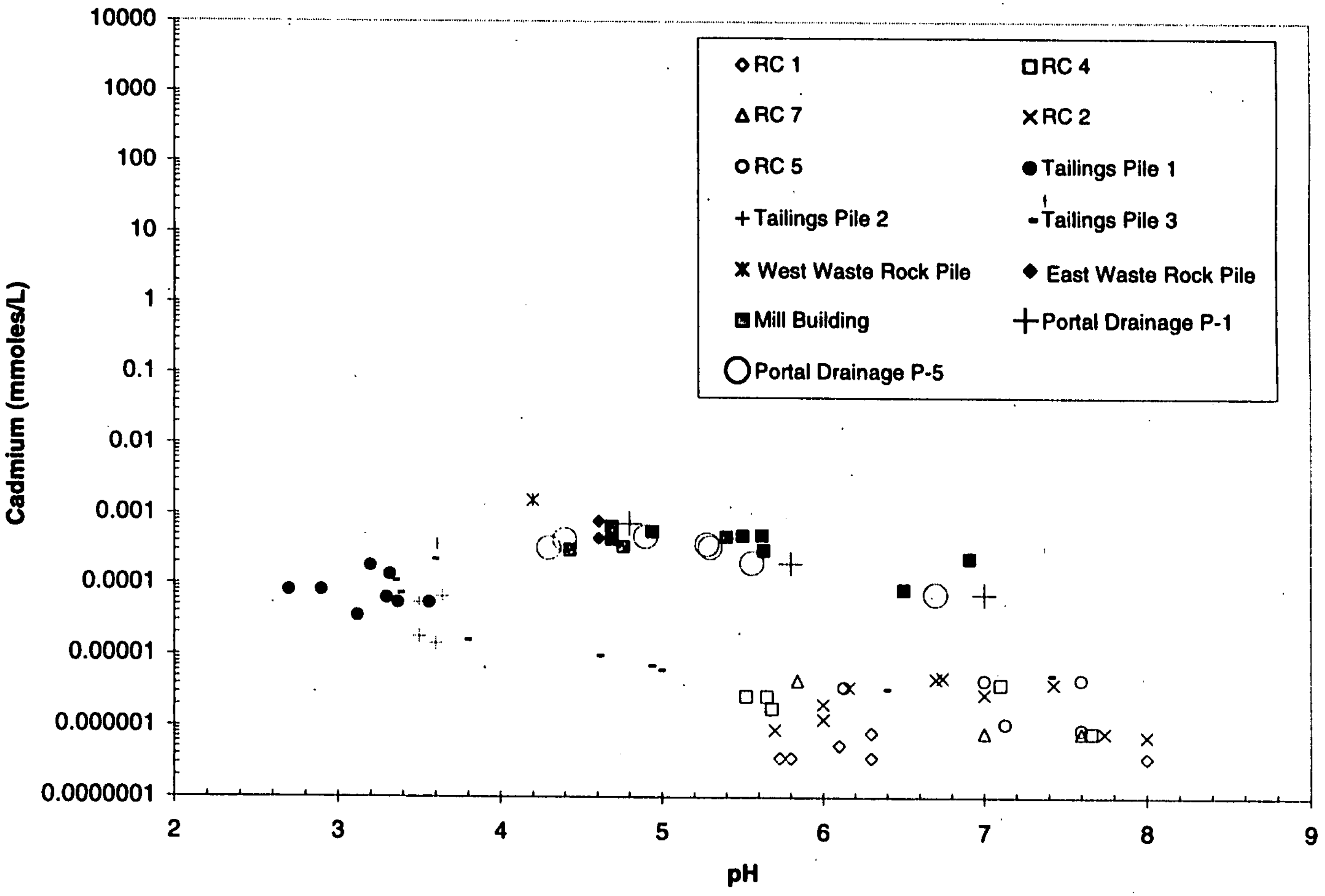

Figure 6.4-14

SURFACE AND SEEPAGE WATER SAMPLES CADMIUM VS pH SCATTER PLOT

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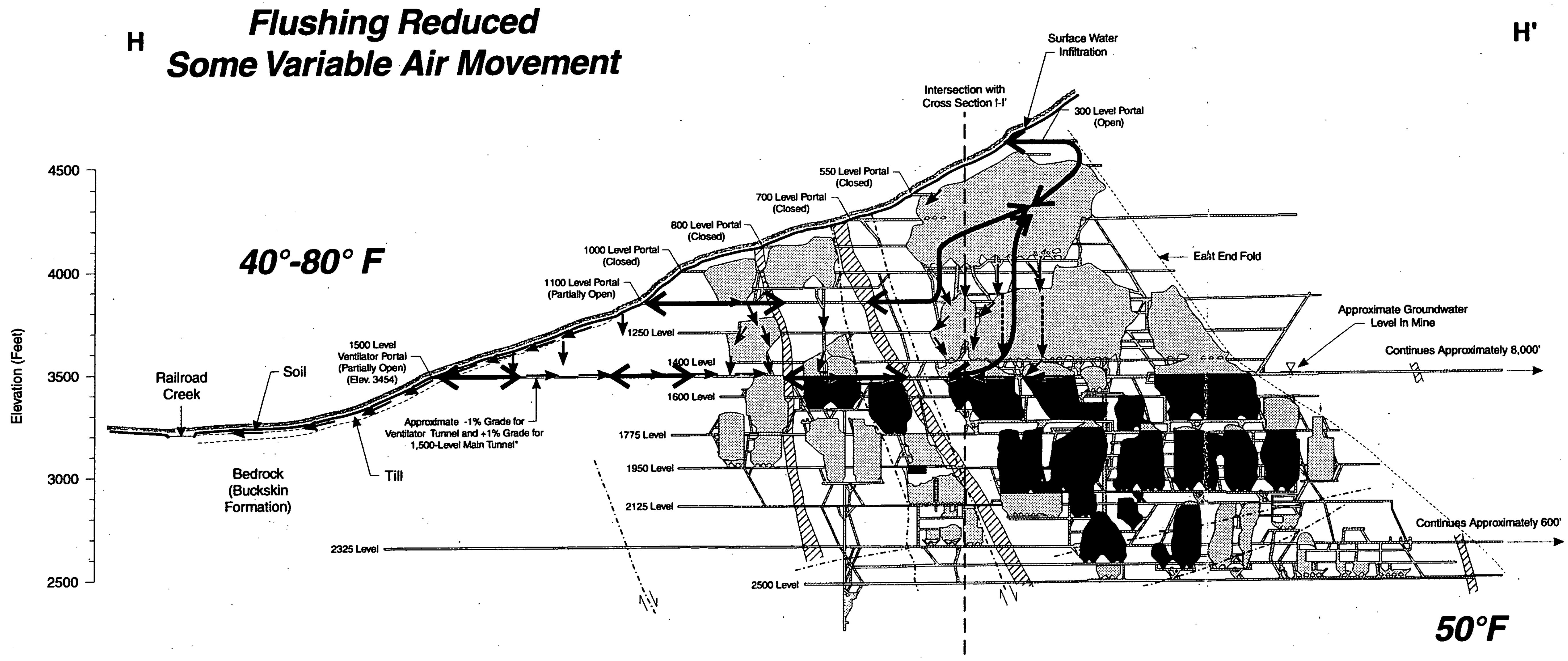

SOURCES: SRK

Northwest Geophysical Associates, 1997, Seismic Line A-A', B-B', Holden Mine Geophysical Investigation.

Youngberg, E. A., Wilson, T. L., 1952, The Geology of the Holden Mine, Economic Geology, V. 47, No. 1, 1952, pp. 1-12.

W.A.B., 1942, Detailed Surface Geology Map, Howe Sound Co., Chelan Division

F.E., H.B.S., 1938, Geology of 1500 Level, Howe Sound Company Chelan Division

LEGEND

- ▨ Open stope
- ■ Backfilled stope
- ▨ Dike
- -·-·-· Transform fault
- → Direction of water movement
- ➔ Direction of air movement

* NOTE:
This cross section is generally parallel to ore body and 1500-level ventilator tunnel. Due to the 1500-level main tunnel having +1% grade, water flow is toward main portal opening but not shown on this figure. (See Figures 6.1-2a and 6.1-2b)

0 500 1,000
Approximate
Horizontal and Vertical
Scale in Feet

Figure 6.5-1
GENERAL WATER AND AIR FLOW FEATURES
IN THE UNDERGROUND MINE—SUMMER

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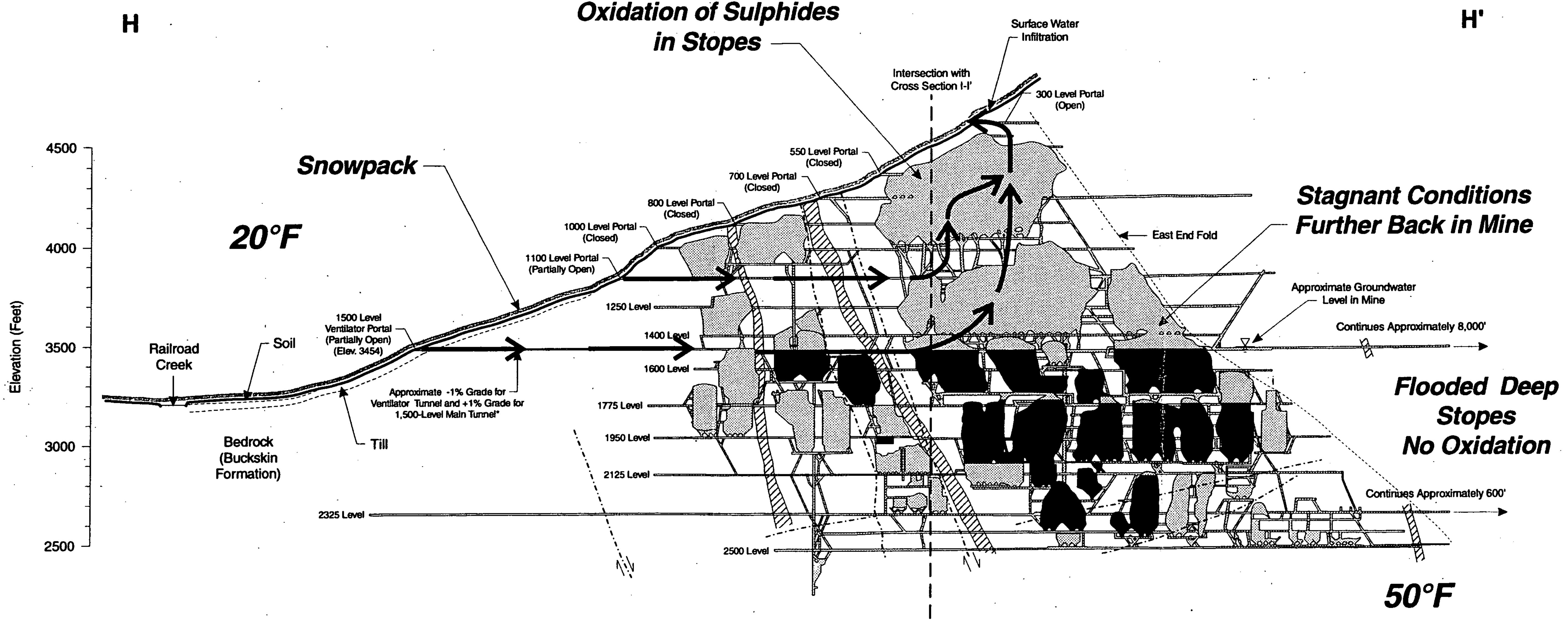

SOURCES: SRK

Northwest Geophysical Associates, 1997, Seismic Line A-A', B-B', Holden Mine Geophysical Investigation.

Youngberg, E. A., Wilson, T. L., 1952, The Geology of the Holden Mine, Economic Geology, V. 47, No. 1, 1952, pp. 1-12.

W.A.B., 1942, Detailed Surface Geology Map, Howe Sound Co., Chelan Division

F.E., H.B.S., 1938, Geology of 1500 Level, Howe Sound Company Chelan Division

LEGEND

- ▒ Open stope
- ■ Backfilled stope
- ▨ Dike
- -·-·-· Transform fault
- → Direction of water movement
- ➔ Direction of air movement

* NOTE:
This cross section is generally parallel to ore body and 1500-level ventilator tunnel. Due to the 1500-level main tunnel having +1% grade, water flow is toward main portal opening but not shown on this figure. (See Figures 6.1-2a and 6.1-2b)

0 500 1,000

Approximate Horizontal and Vertical Scale in Feet

Figure 6.5-2

GENERAL WATER AND AIR FLOW FEATURES IN THE UNDERGROUND MINE—WINTER

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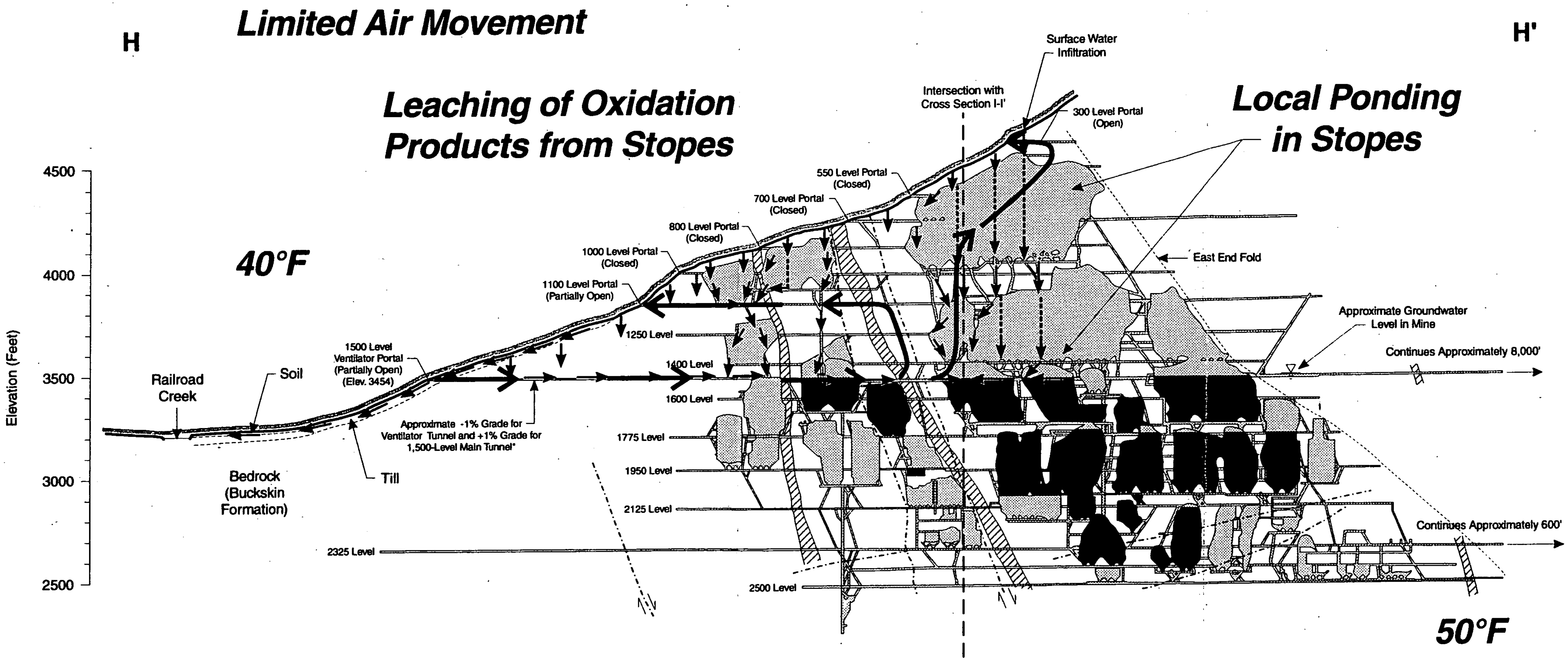

SOURCES: SRK

Northwest Geophysical Associates, 1997, Seismic Line A-A', B-B', Holden Mine Geophysical Investigation.

Youngberg, E. A., Wilson, T. L., 1952, The Geology of the Holden Mine, Economic Geology, V. 47, No. 1, 1952, pp. 1-12.

W.A.B., 1942, Detailed Surface Geology Map, Howe Sound Co., Chelan Division

F.E., H.B.S., 1938, Geology of 1500 Level, Howe Sound Company Chelan Division

LEGEND

░ Open stope
■ Backfilled stope
▨ Dike
-·-·- Transform fault
→ Direction of water movement
⇒ Direction of air movement

* NOTE:
This cross section is generally parallel to ore body and 1500-level ventilator tunnel. Due to the 1500-level main tunnel having +1% grade, water flow is toward main portal opening but not shown on this figure. (See Figures 6.1-2a and 6.1-2b)

0 500 1,000
Approximate Horizontal and Vertical Scale in Feet

Figure 6.5-3

GENERAL WATER AND AIR FLOW FEATURES IN THE UNDERGROUND MINE—SPRING

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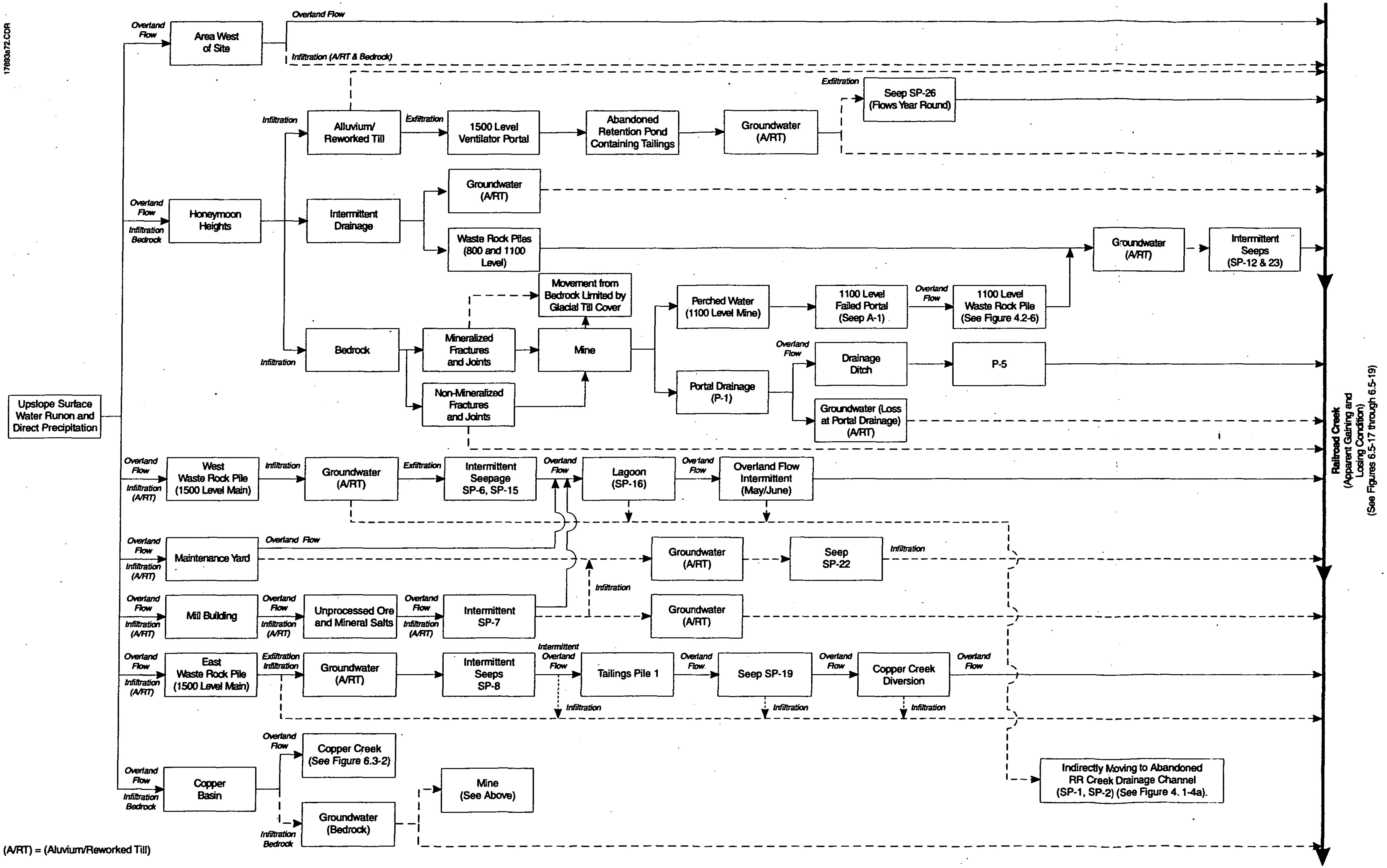

(A/RT) = (Aluvium/Reworked Till)

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Figure 6.5-4

HONEYMOON HEIGHTS AND MINE SUPPORT AREAS CONCEPTUAL TRANSPORT PATHWAYS

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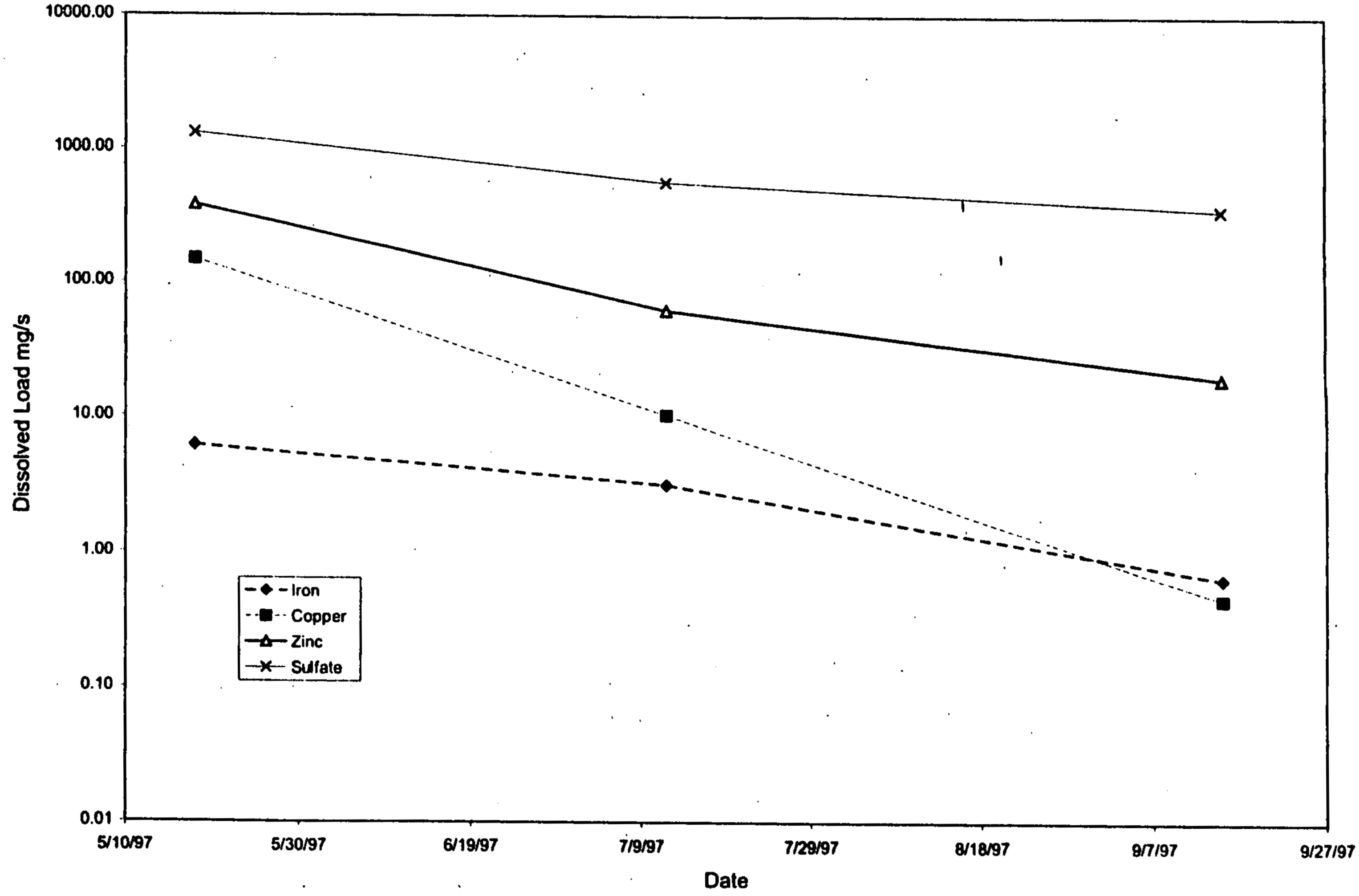

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Figure 6.5-5

1997 PORTAL DRAINAGE SULFATE AND METALS LOAD

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Holden Mine RI/FS
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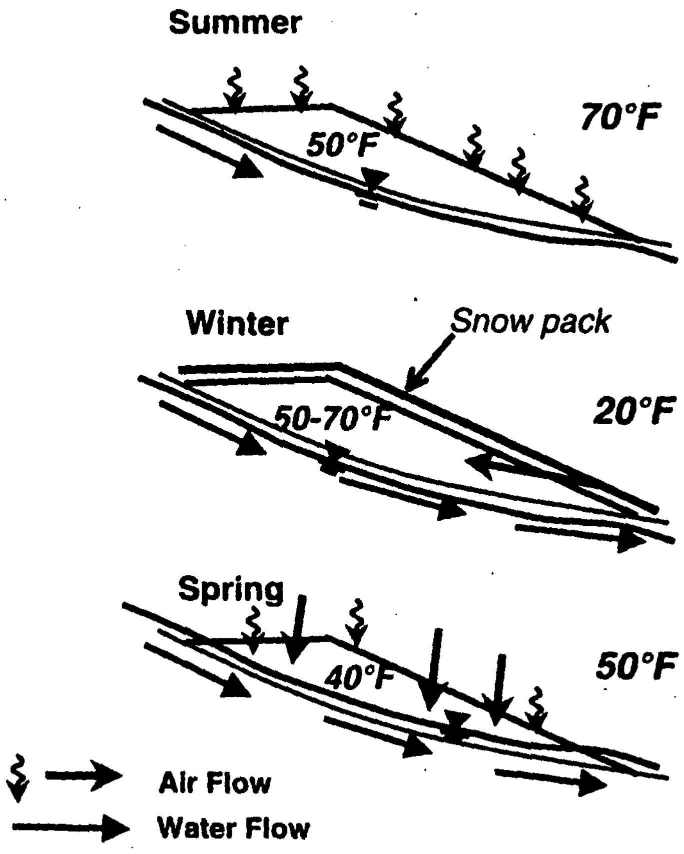

Oxygen movement by diffusion
Oxidation in surface only
Water table low

Oxygen movement by convection or diffusion
Limited leaching

Snow pack melts
Leaching of salts by rising water table and infiltration

SOURCE: SRK

Figure 6.5-6

GENERAL WATER AND AIR FLOW FEATURES IN THE SIDE-HILL WASTE ROCK PILES

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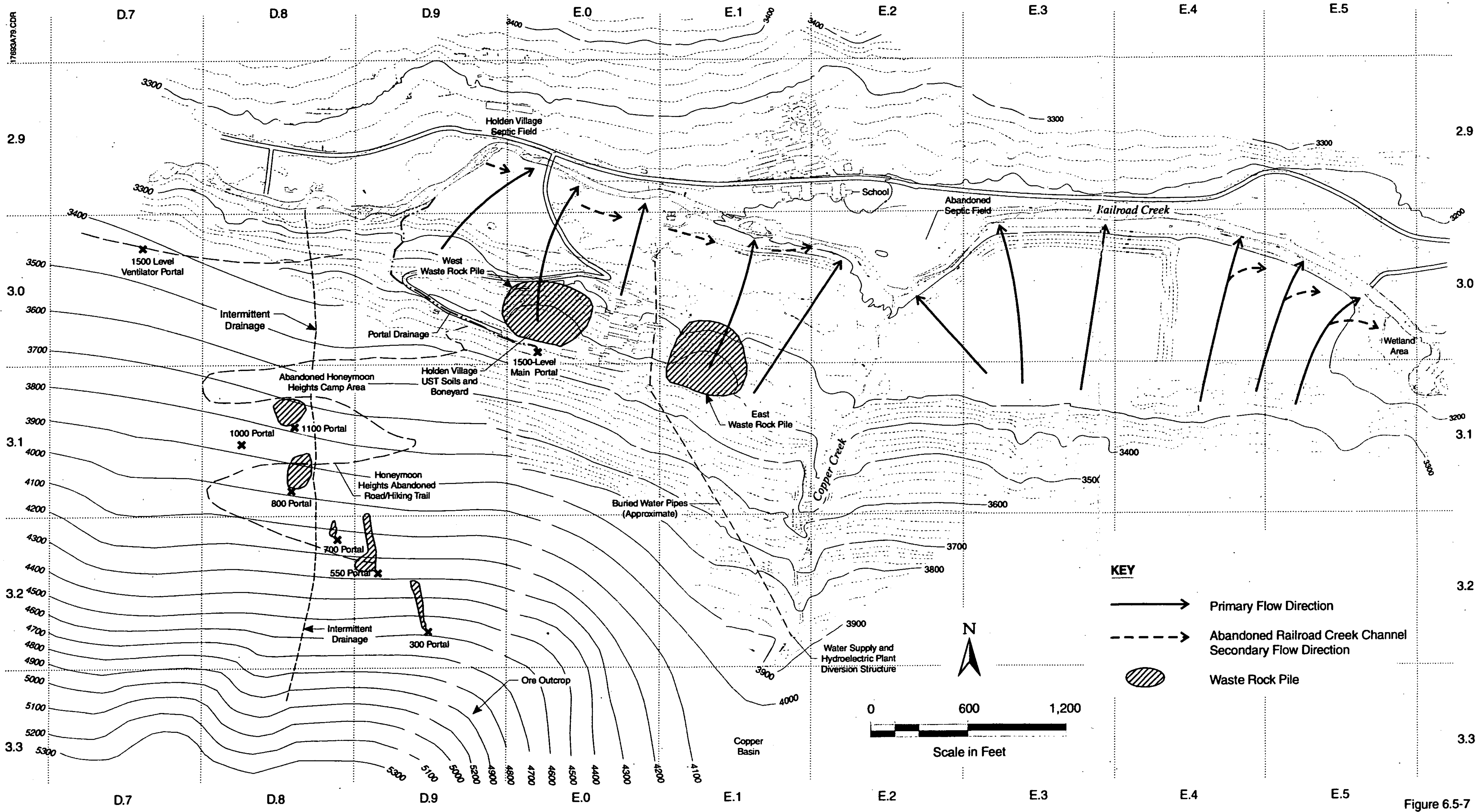

SOURCE: Base map information from USFS and Washington DNR, DEM CD ROM

Figure 6.5-7

CONCEPTUAL GROUNDWATER FLOWPATHS
HOLDEN MINE SITE
SPRING CONDITIONS

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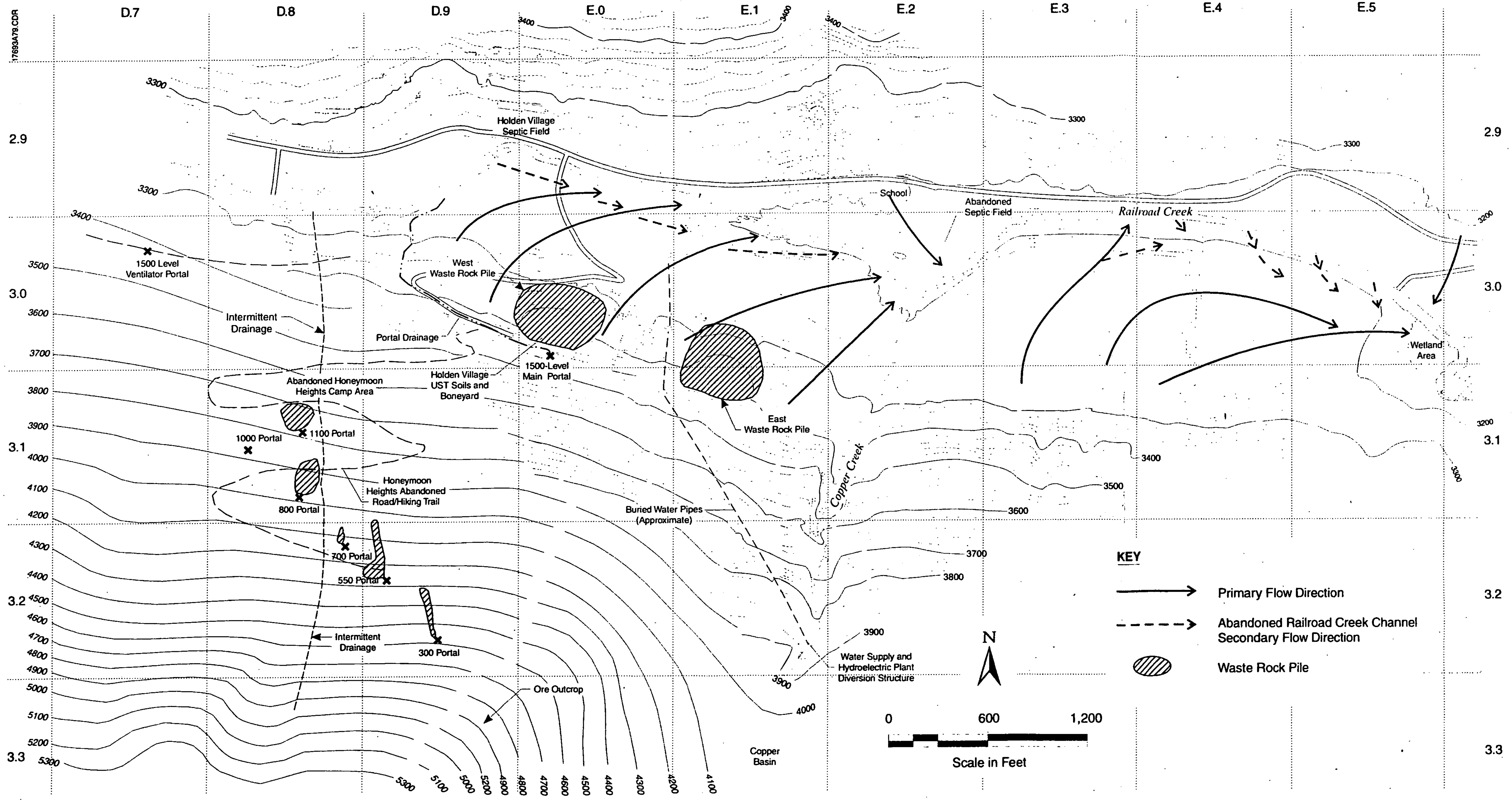

SOURCE: Base map information from USFS and
Washington DNR, DEM CD ROM

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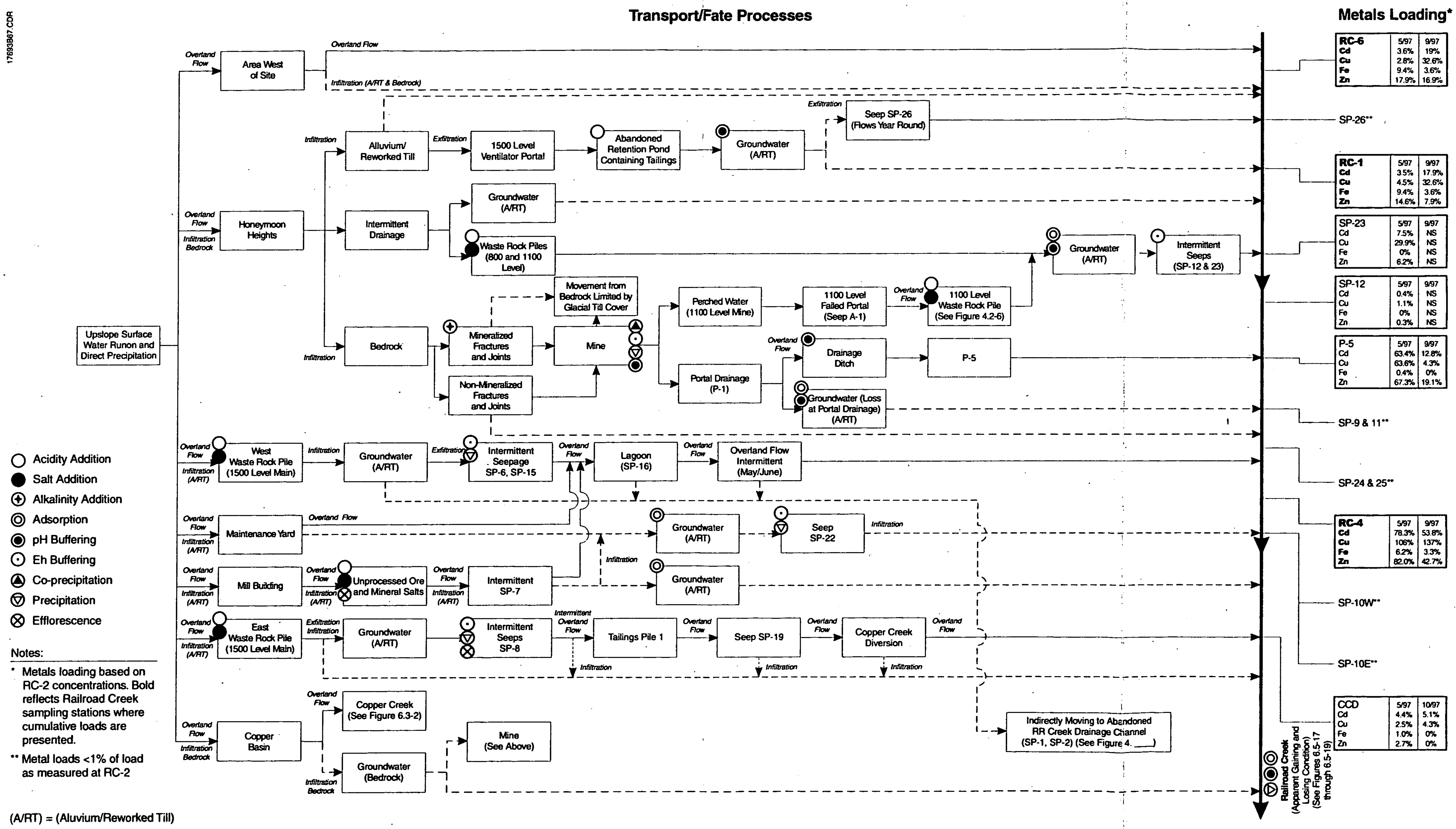
Figure 6.5-8

CONCEPTUAL GROUNDWATER FLOWPATHS
HOLDEN MINE SITE
FALL CONDITIONS

Holden Mine RI/FS
Draft Final RI Report

17693B87.CDR



RC-6	5/97	9/97
Cd	3.6%	19%
Cu	2.8%	32.6%
Fe	9.4%	3.6%
Zn	17.9%	16.9%

SP-26**

RC-1	5/97	9/97
Cd	3.5%	17.9%
Cu	4.5%	32.6%
Fe	9.4%	3.6%
Zn	14.6%	7.9%

SP-23	5/97	9/97
Cd	7.5%	NS
Cu	29.9%	NS
Fe	0%	NS
Zn	6.2%	NS

SP-12	5/97	9/97
Cd	0.4%	NS
Cu	1.1%	NS
Fe	0%	NS
Zn	0.3%	NS

P-5	5/97	9/97
Cd	63.4%	12.8%
Cu	63.6%	4.3%
Fe	0.4%	0%
Zn	67.3%	19.1%

SP-9 & 11**

SP-24 & 25**

RC-4	5/97	9/97
Cd	78.3%	53.8%
Cu	106%	137%
Fe	6.2%	3.3%
Zn	82.0%	42.7%

SP-10W**

SP-10E**

CCD	5/97	10/97
Cd	4.4%	5.1%
Cu	2.5%	4.3%
Fe	1.0%	0%
Zn	2.7%	0%

Notes:

- * Metals loading based on RC-2 concentrations. Bold reflects Railroad Creek sampling stations where cumulative loads are presented.
- ** Metal loads <1% of load as measured at RC-2

(A/RT) = (Aluvium/Reworked Till)

Figure 6.5-9

HONEYMOON HEIGHTS AND MINE SUPPORT AREAS CONCEPTUAL TRANSPORT/FATE PROCESSES AND RAILROAD CREEK METALS LOADING

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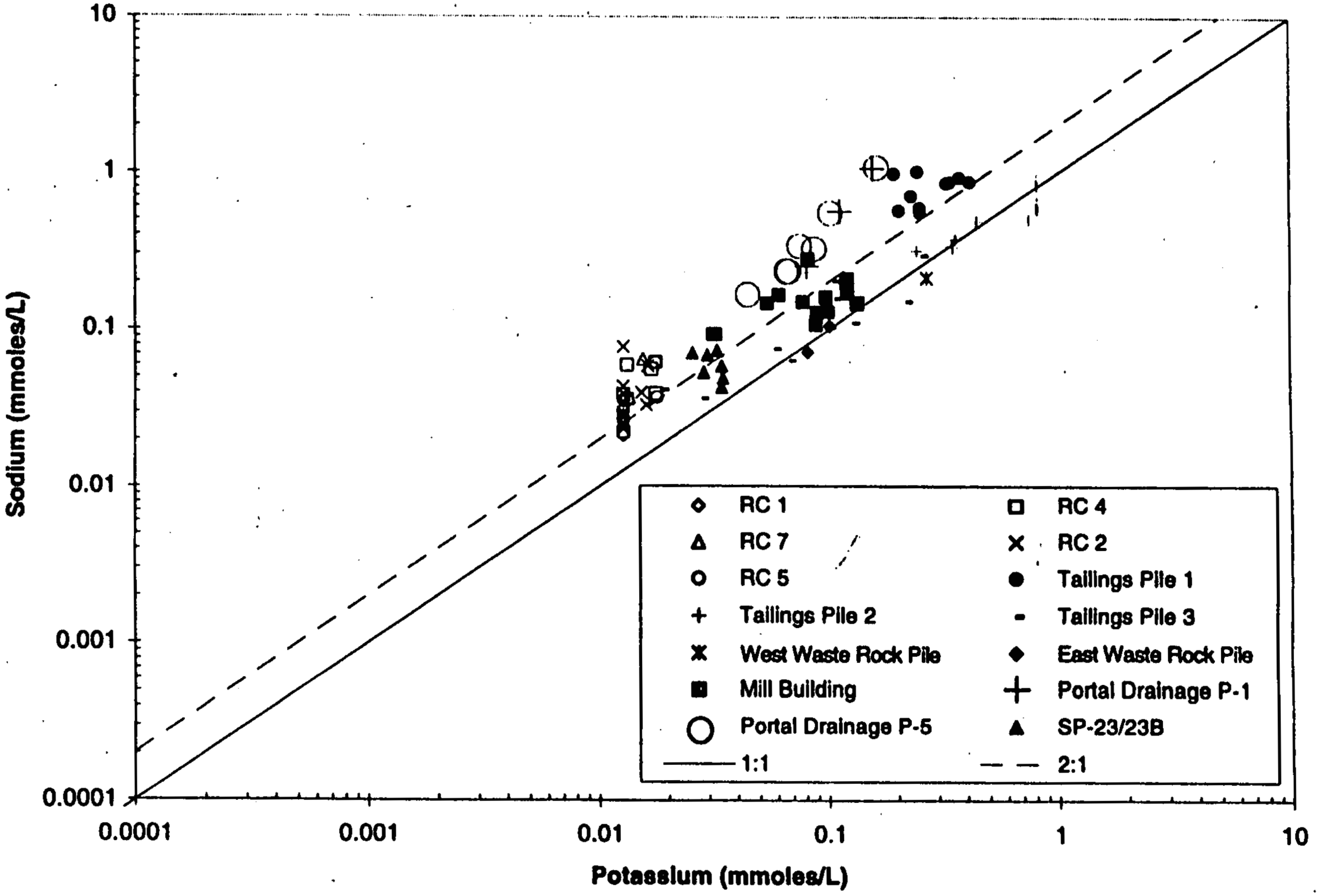

Figure 6.5-10

SURFACE AND SEEPAGE WATER SAMPLES POTASSIUM VS SODIUM SCATTER PLOT

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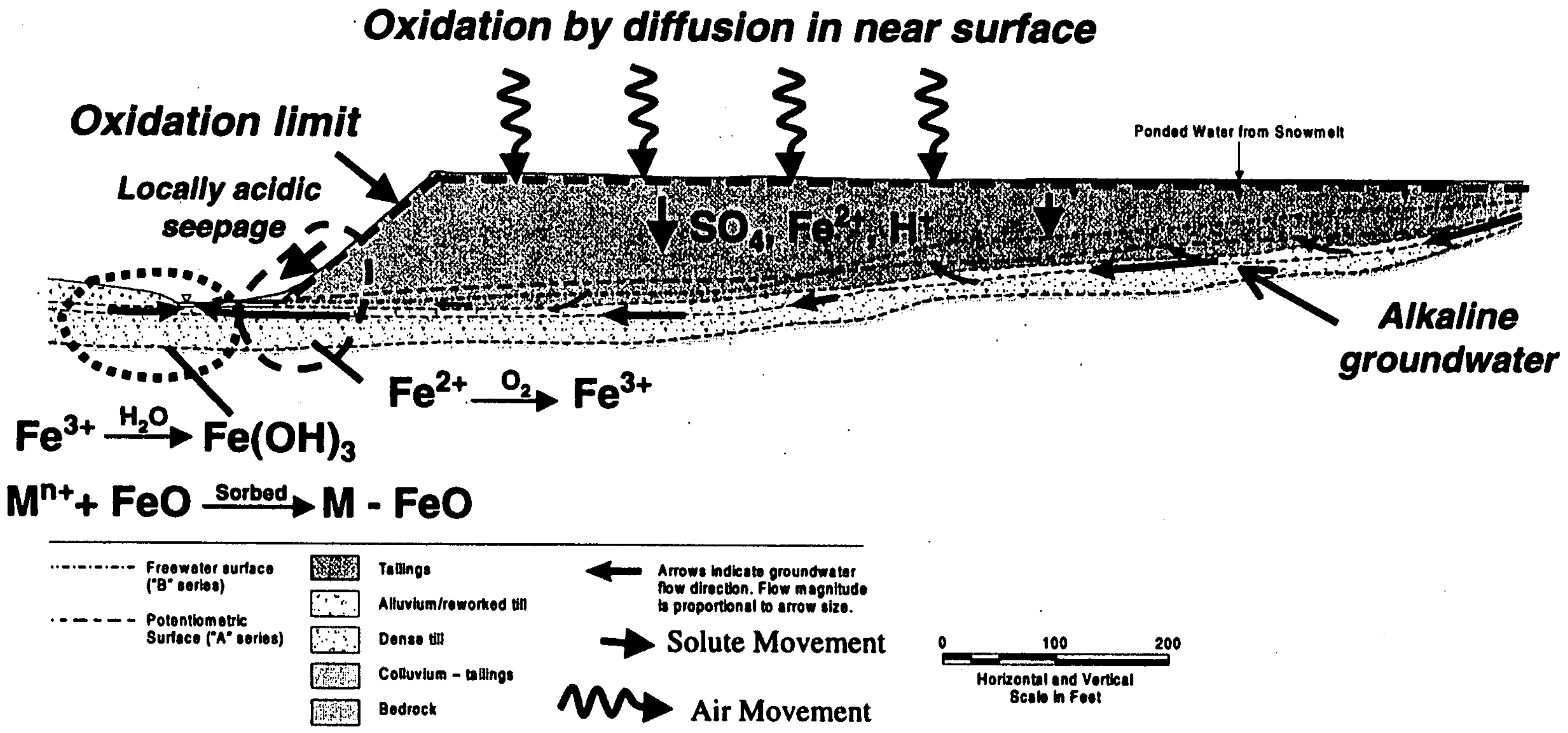

SOURCE: SRK

Figure 6.5-11

GENERAL WATER AND AIR FLOW FEATURES IN TAILINGS

17693a74.CDR

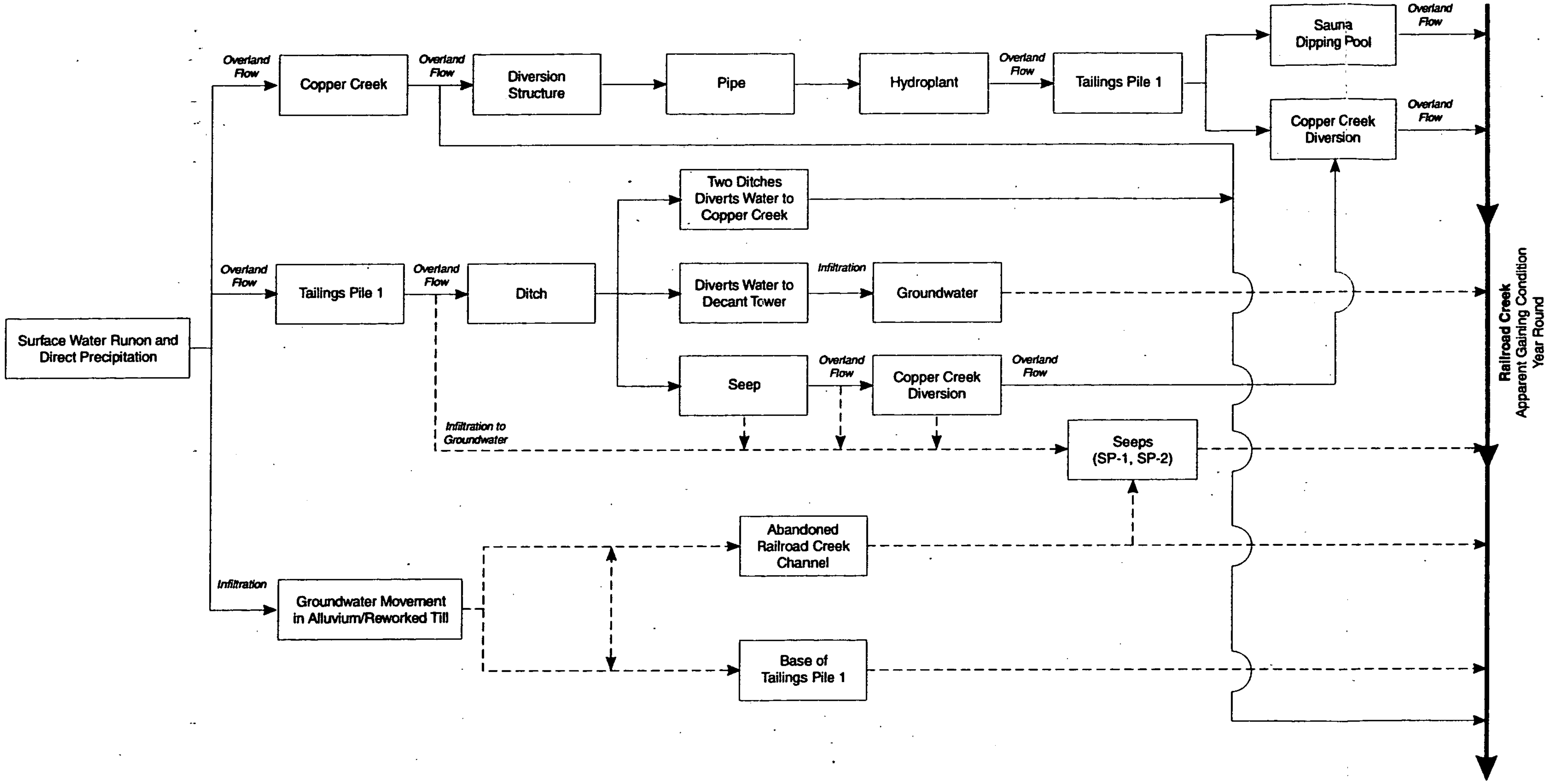

Figure 6.5-12

TAILINGS PILE 1
CONCEPTUAL TRANSPORT PATHWAYS

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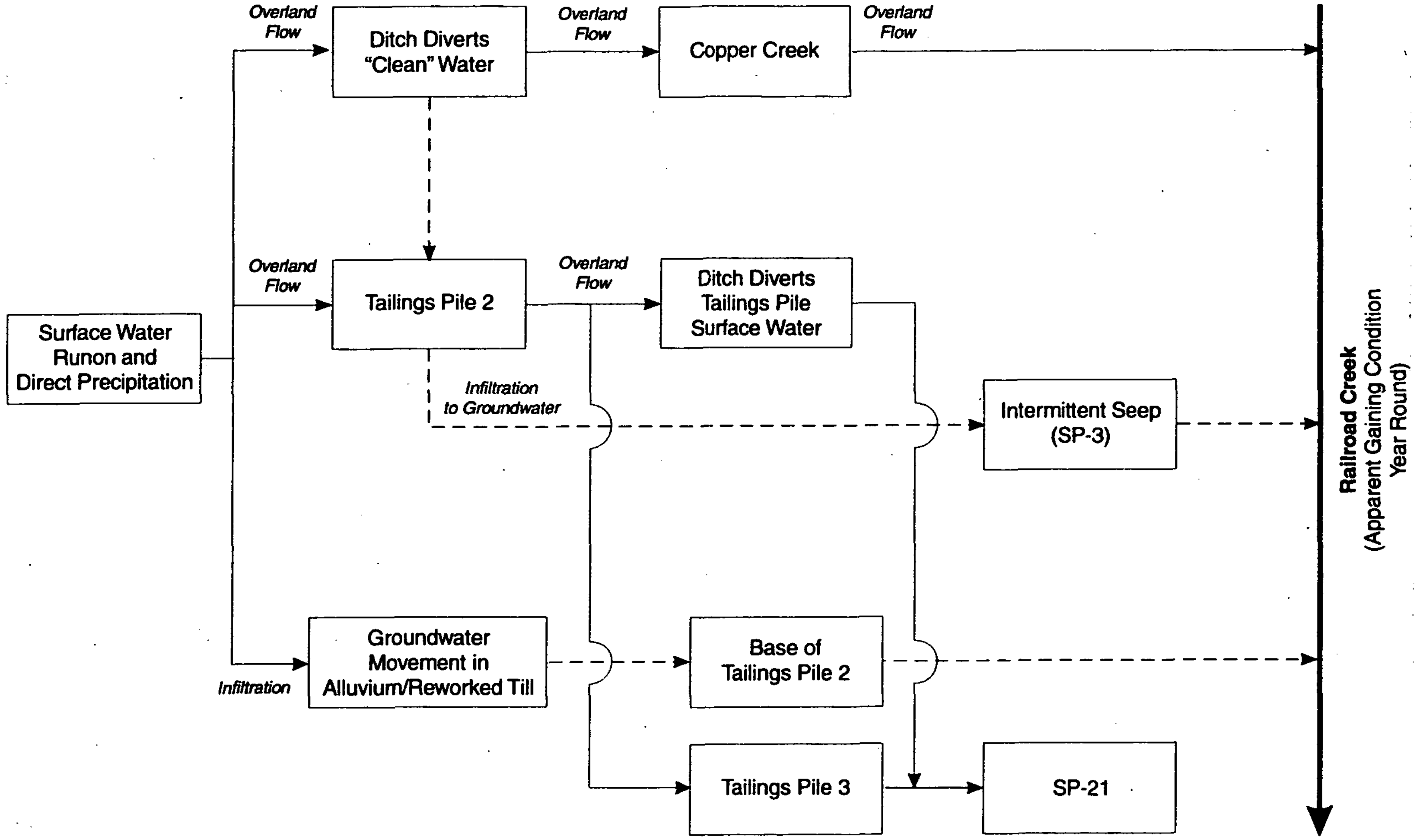


Figure 6.5-13

TAILINGS PILE 2
CONCEPTUAL TRANSPORT PATHWAYS

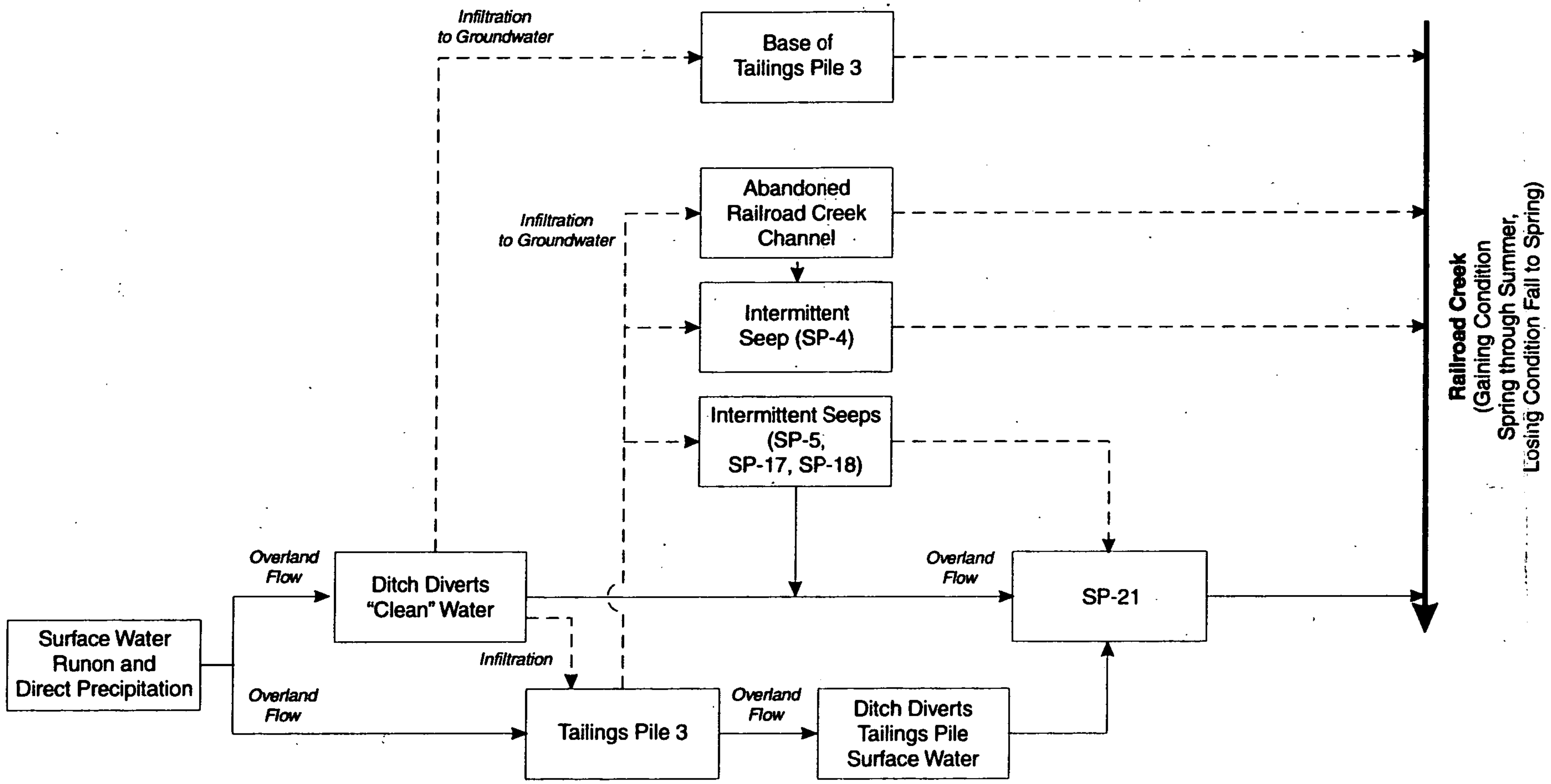


Figure 6.5-14

TAILINGS PILE 3
CONCEPTUAL TRANSPORT PATHWAYS

17693A77.CDR

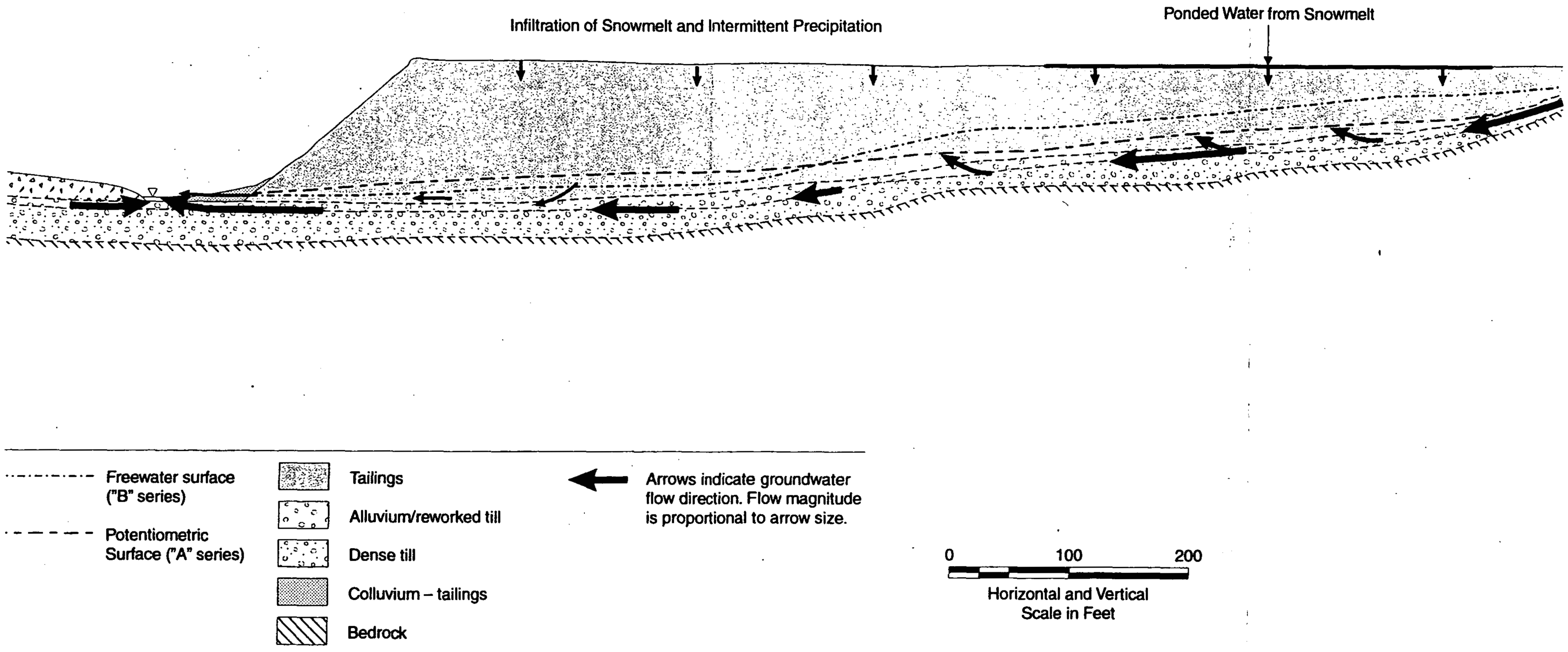
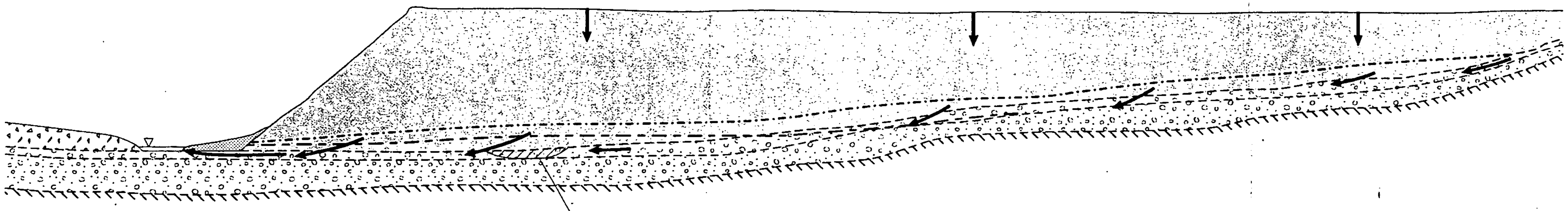


Figure 6.5-15

CONCEPTUAL HYDROGEOLOGIC CROSS SECTION
TAILINGS PILES #1, 2, AND 3—MAY

17693A77.CDR

Infiltration of Intermittent Rainfall



Note: Some flow lost into plane of figure, travels through old stream channel.

-·-·-·- Freewater surface ("B" series)

-·- - - - Potentiometric Surface ("A" series)

▨	Tailings
○	Alluvium/reworked till
○	Dense till
▒	Colluvium – tailings
▧	Bedrock

← Arrows indicate groundwater flow direction. Flow magnitude is proportional to arrow size.

0 100 200

Horizontal and Vertical Scale in Feet

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Figure 6.5-16

CONCEPTUAL HYDROGEOLOGIC CROSS SECTION TAILINGS PILES #1, 2, AND 3—SEPTEMBER

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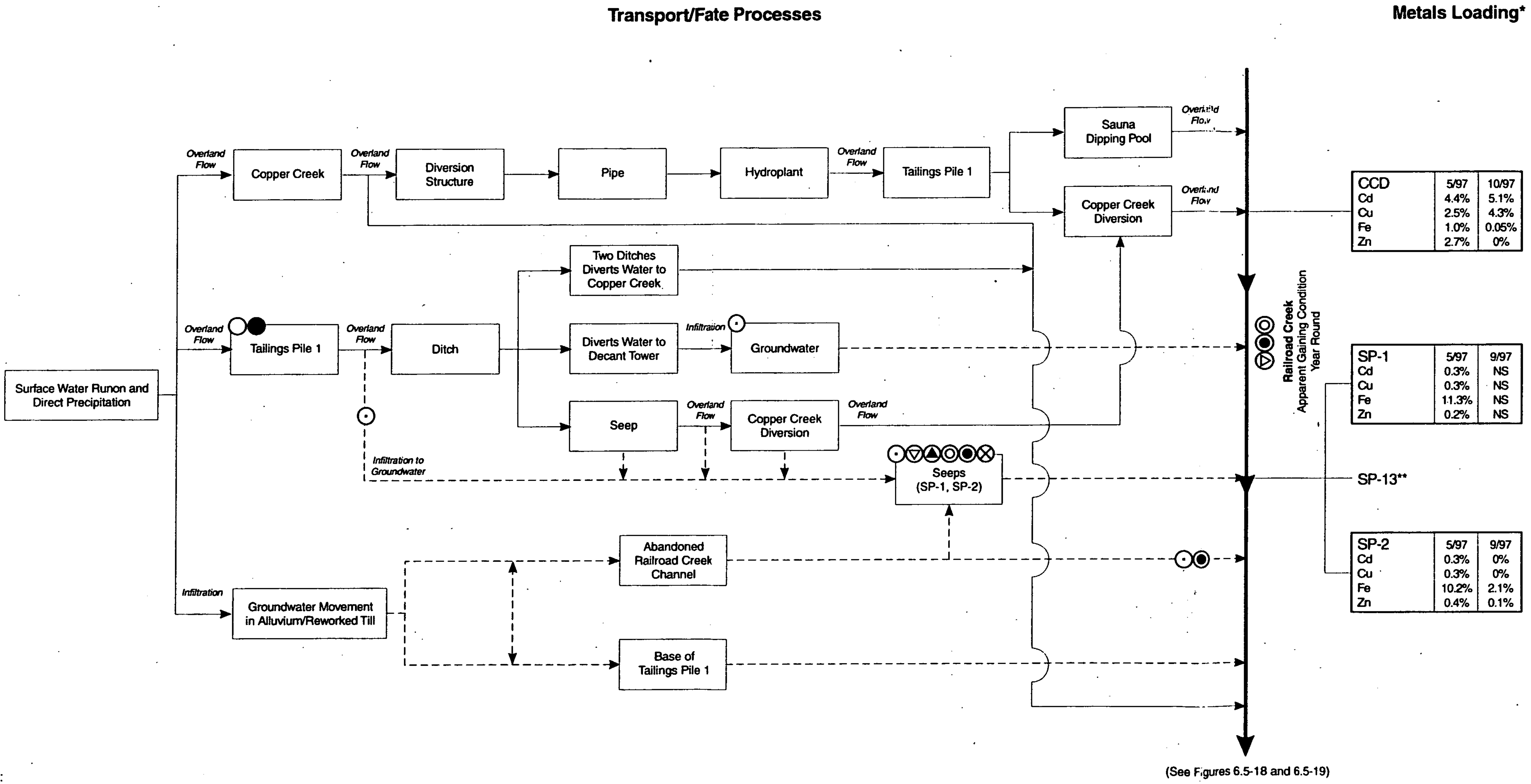
17693s68.CDR



CCD	5/97	10/97
Cd	4.4%	5.1%
Cu	2.5%	4.3%
Fe	1.0%	0.05%
Zn	2.7%	0%

SP-1	5/97	9/97
Cd	0.3%	NS
Cu	0.3%	NS
Fe	11.3%	NS
Zn	0.2%	NS

SP-13**

SP-2	5/97	9/97
Cd	0.3%	0%
Cu	0.3%	0%
Fe	10.2%	2.1%
Zn	0.4%	0.1%

Notes:

- * Metals loading based on RC-2 concentrations. Bold reflects Railroad Creek sampling stations where cumulative loads are presented.
- ** Metal loads <1% of load as measured at RC-2.

○ Acidity Addition
● Salt Addition
⊕ Alkalinity Addition
◎ Adsorption
◉ pH Buffering
⊙ Eh Buffering
▲ Co-precipitation
▽ Precipitation
⊗ Efflorescence

Figure 6.5-17

TAILINGS PILE 1
CONCEPTUAL TRANSPORT/FATE PROCESSES

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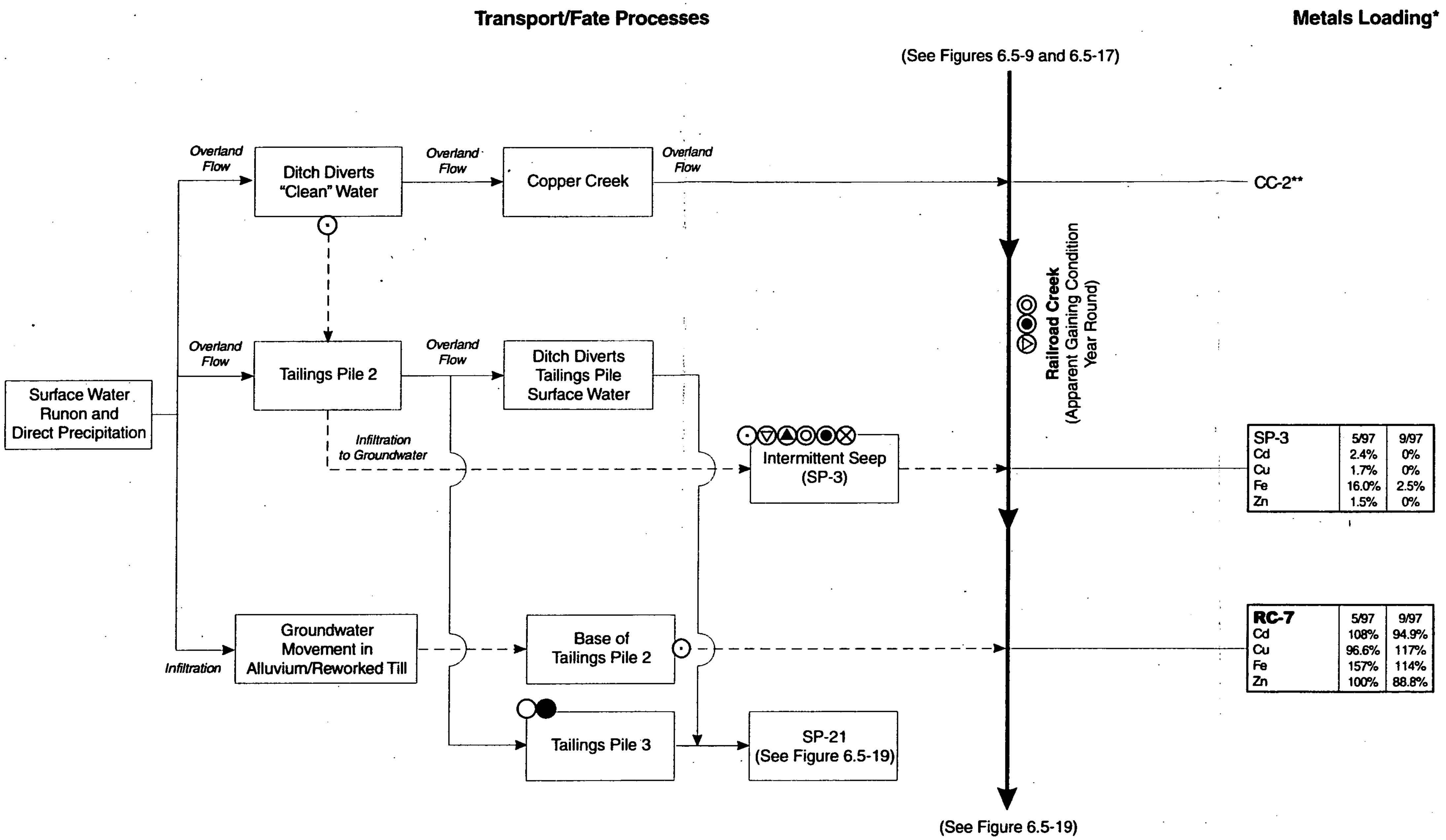

SP-3	5/97	9/97
Cd	2.4%	0%
Cu	1.7%	0%
Fe	16.0%	2.5%
Zn	1.5%	0%

RC-7	5/97	9/97
Cd	108%	94.9%
Cu	96.6%	117%
Fe	157%	114%
Zn	100%	88.8%

Notes:

* Metals loading based on RC-2 concentrations. Bold reflects Railroad Creek sampling stations where cumulative loads are presented.

** Metal loads <1% of load as measured at RC-2.

○ Acidity Addition
● Salt Addition
⊕ Alkalinity Addition
◎ Adsorption
◉ pH Buffering
⊙ Eh Buffering
▲ Co-precipitation
▽ Precipitation
⊗ Efflorescence

Figure 6.5-18

TAILINGS PILE 2
CONCEPTUAL TRANSPORT/FATE PROCESSES

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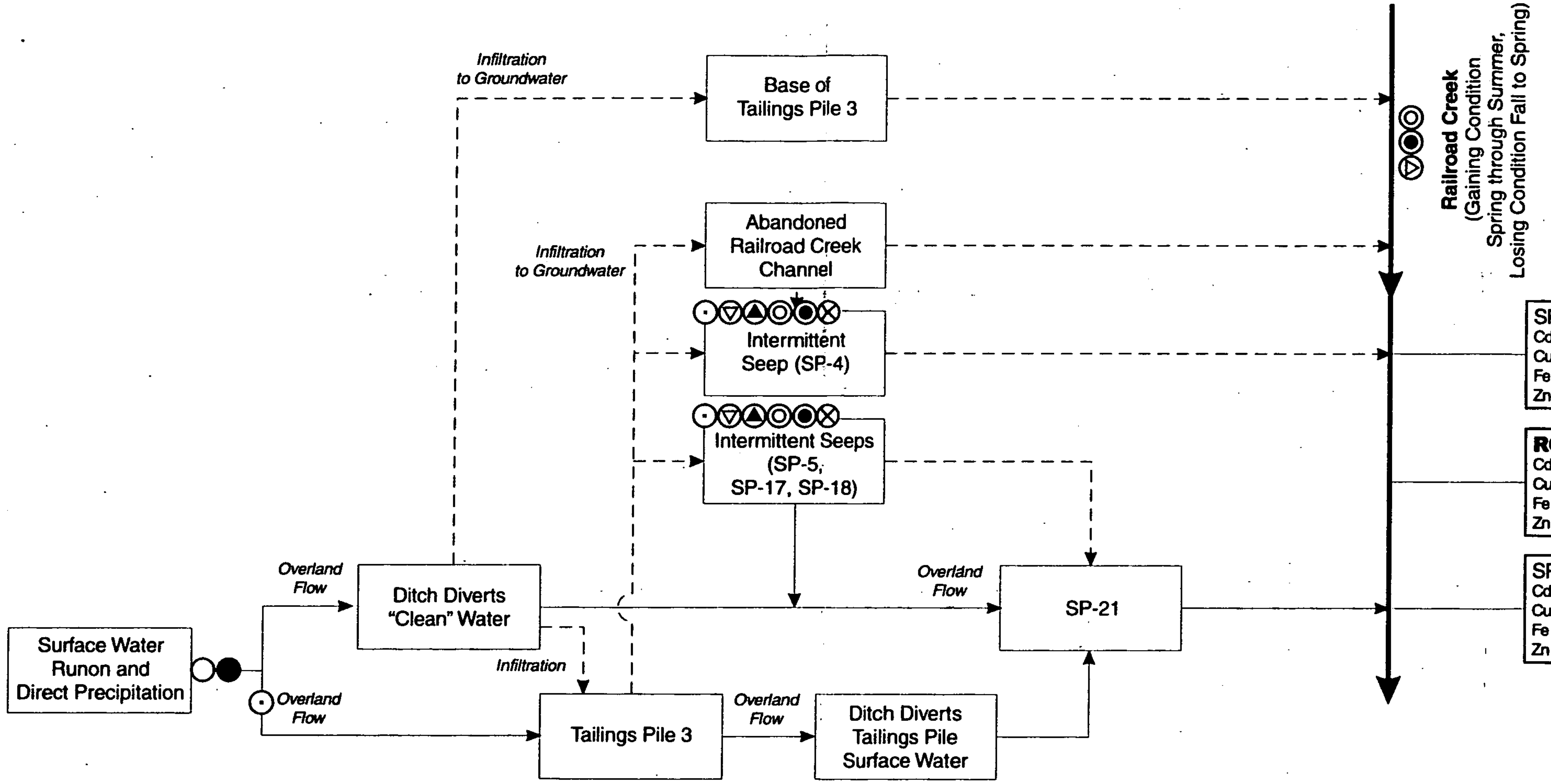
Transport/Fate Processes

Metals Loading*

(See Figures 6.5-9, 6.5-17 and 6.5-18)



SP-4	5/97	9/97
Cd	1.3%	NS
Cu	2.8%	NS
Fe	23.5%	NS
Zn	1.0%	NS

RC-2	5/97	9/97
Cd	100%	100%
Cu	100%	100%
Fe	100%	100%
Zn	100%	100%

SP-21	5/97	9/97
Cd	0.8%	0%
Cu	0.8%	0%
Fe	1.2%	0%
Zn	0.5%	0%

* Note:
Metals loading based on RC-2 concentrations. Bold reflects Railroad Creek sampling stations where cumulative loads are presented.

○ Acidity Addition	◎ Adsorption	▲ Co-precipitation
● Salt Addition	◉ pH Buffering	▽ Precipitation
⊕ Alkalinity Addition	⊙ Eh Buffering	⊗ Efflorescence

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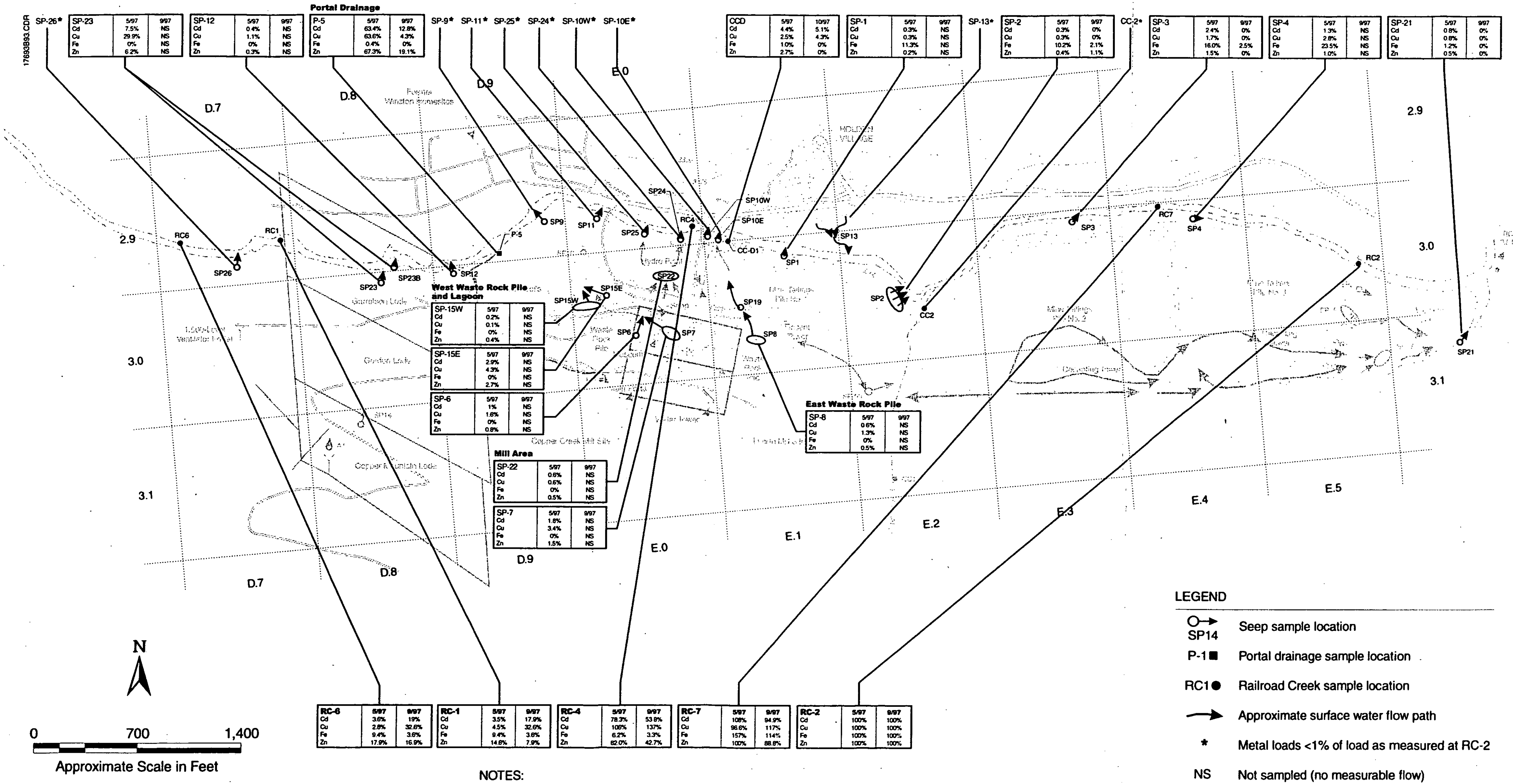
Figure 6.5-19

TAILINGS PILE 3
CONCEPTUAL TRANSPORT/FATE PROCESSES



SP-23	5/97	9/97
Cd	7.5%	NS
Cu	29.9%	NS
Fe	0%	NS
Zn	6.2%	NS

SP-12	5/97	9/97
Cd	0.4%	NS
Cu	1.1%	NS
Fe	0%	NS
Zn	0.3%	NS

Portal Drainage

P-5	5/97	9/97
Cd	63.4%	12.8%
Cu	63.6%	4.3%
Fe	0.4%	0%
Zn	67.3%	19.1%

CCD	5/97	10/97
Cd	4.4%	5.1%
Cu	2.5%	4.3%
Fe	1.0%	0%
Zn	2.7%	0%

SP-1	5/97	9/97
Cd	0.3%	NS
Cu	0.3%	NS
Fe	11.3%	NS
Zn	0.2%	NS

SP-2	5/97	9/97
Cd	0.3%	0%
Cu	0.3%	0%
Fe	10.2%	2.1%
Zn	0.4%	1.1%

SP-3	5/97	9/97
Cd	2.4%	0%
Cu	1.7%	0%
Fe	16.0%	2.5%
Zn	1.5%	0%

SP-4	5/97	9/97
Cd	1.3%	NS
Cu	2.8%	NS
Fe	23.5%	NS
Zn	1.0%	NS

SP-21	5/97	9/97
Cd	0.8%	0%
Cu	0.8%	0%
Fe	1.2%	0%
Zn	0.5%	0%

West Waste Rock Pile and Lagoon

SP-15W	5/97	9/97
Cd	0.2%	NS
Cu	0.1%	NS
Fe	0%	NS
Zn	0.4%	NS

SP-15E	5/97	9/97
Cd	2.9%	NS
Cu	4.3%	NS
Fe	0%	NS
Zn	2.7%	NS

SP-6	5/97	9/97
Cd	1%	NS
Cu	1.6%	NS
Fe	0%	NS
Zn	0.8%	NS

Mill Area

SP-22	5/97	9/97
Cd	0.6%	NS
Cu	0.6%	NS
Fe	0%	NS
Zn	0.5%	NS

SP-7	5/97	9/97
Cd	1.8%	NS
Cu	3.4%	NS
Fe	0%	NS
Zn	1.5%	NS

East Waste Rock Pile

SP-8	5/97	9/97
Cd	0.6%	NS
Cu	1.3%	NS
Fe	0%	NS
Zn	0.5%	NS

RC-6	5/97	9/97
Cd	3.6%	19%
Cu	2.8%	32.6%
Fe	9.4%	3.6%
Zn	17.9%	16.9%

RC-1	5/97	9/97
Cd	3.5%	17.9%
Cu	4.5%	32.6%
Fe	9.4%	3.6%
Zn	14.6%	7.9%

RC-4	5/97	9/97
Cd	78.3%	53.8%
Cu	106%	137%
Fe	6.2%	3.3%
Zn	82.0%	42.7%

RC-7	5/97	9/97
Cd	108%	94.9%
Cu	96.6%	117%
Fe	157%	114%
Zn	100%	88.8%

RC-2	5/97	9/97
Cd	100%	100%
Cu	100%	100%
Fe	100%	100%
Zn	100%	100%

LEGEND

○→ SP14	Seep sample location
P-1■	Portal drainage sample location
RC1●	Railroad Creek sample location
→	Approximate surface water flow path
*	Metal loads <1% of load as measured at RC-2
NS	Not sampled (no measurable flow)

NOTES:

Seep (SP) and portal loading is point source contribution to Railroad Creek as compared to RC-2.

Railroad Creek loading is representative of cumulative load.

Loading balance data are provided in Section 6.0 of the report.

SOURCE: ORB, 1975

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Figure 6.5-20

LOADING OF SELECT METALS IN RAILROAD CREEK - SITE

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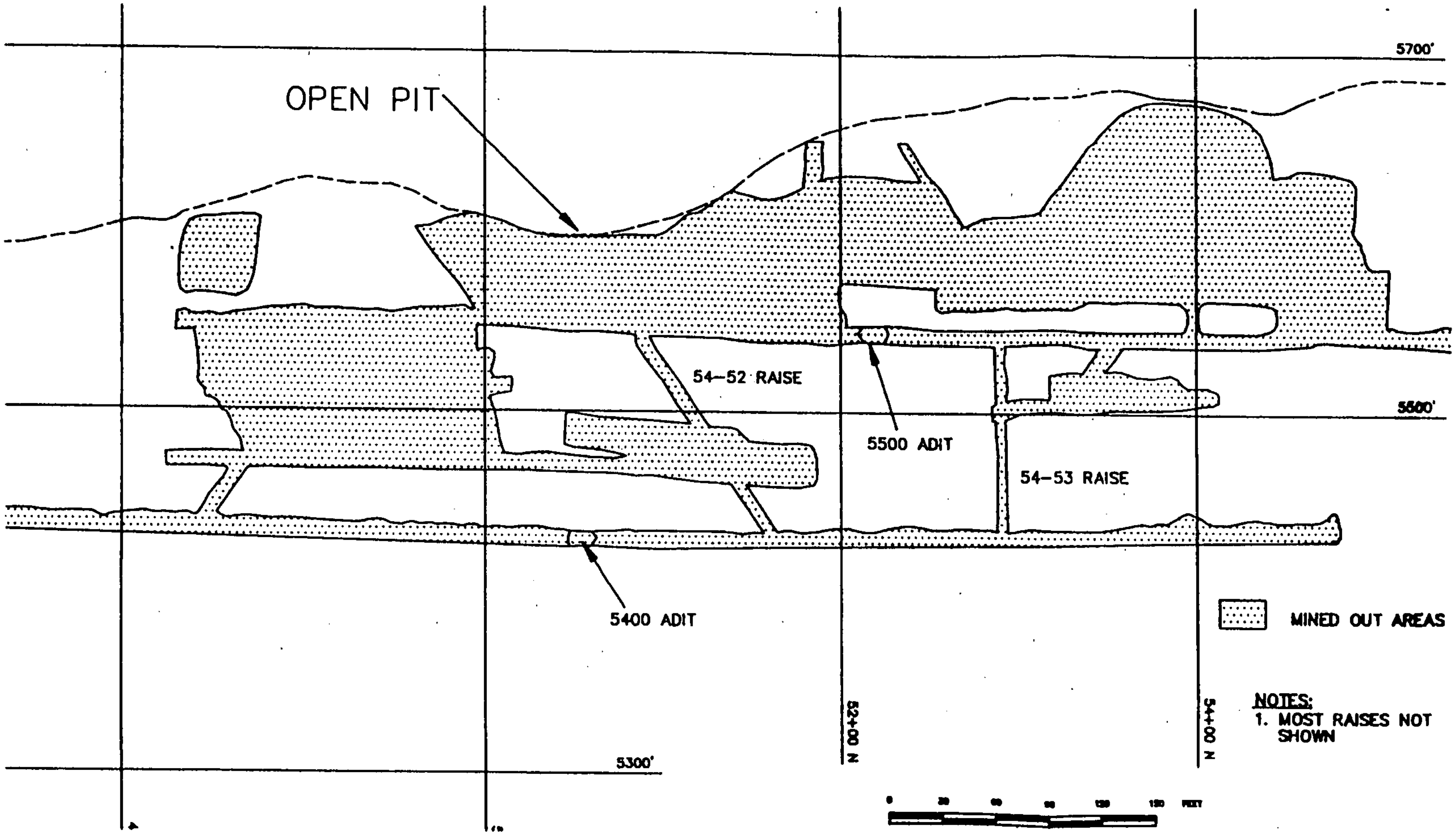

SOURCE: SRK

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Figure 6.7-1

CROSS SECTION OF BAKER MINE

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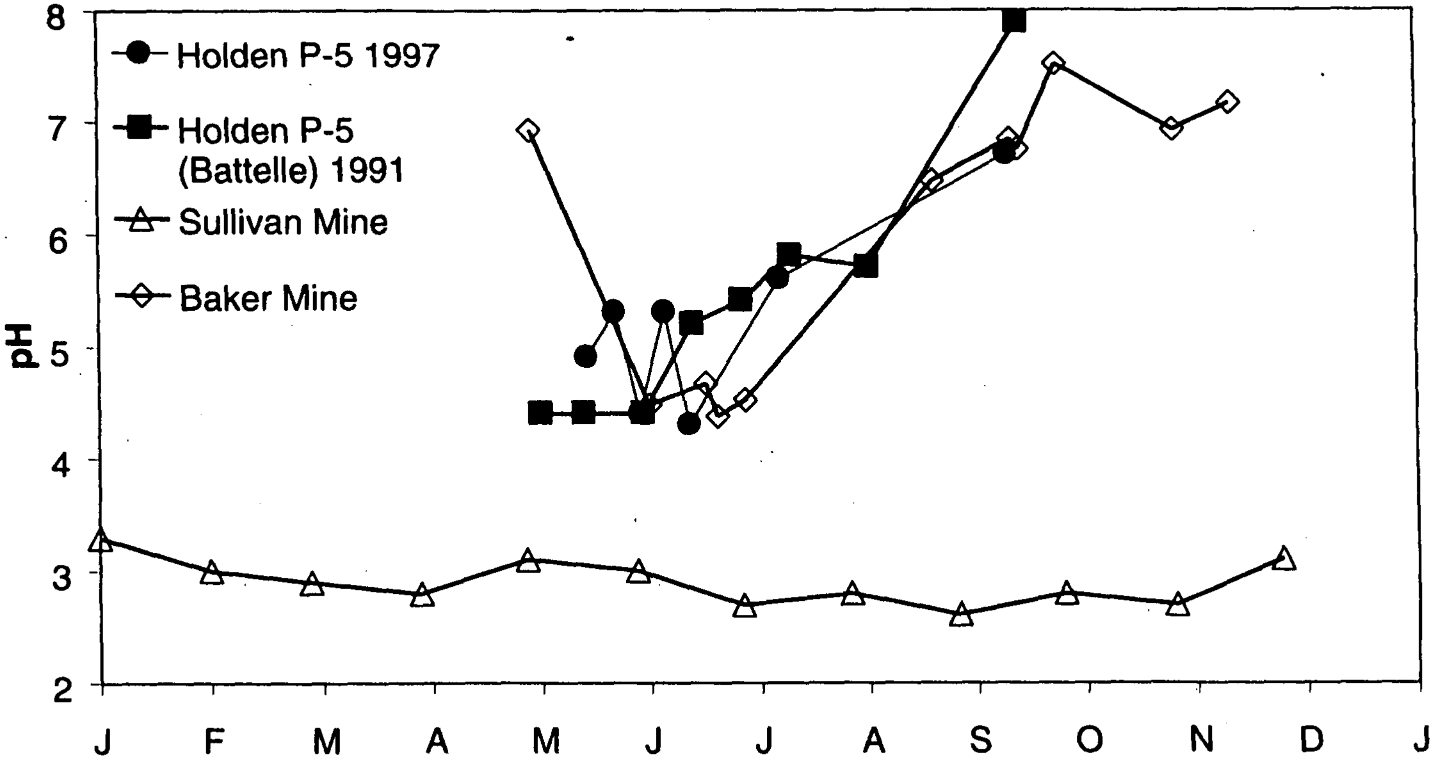

SOURCE: SRK

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Figure 6.7-2

PORTAL DISCHARGE pH FROM SELECTED MINES

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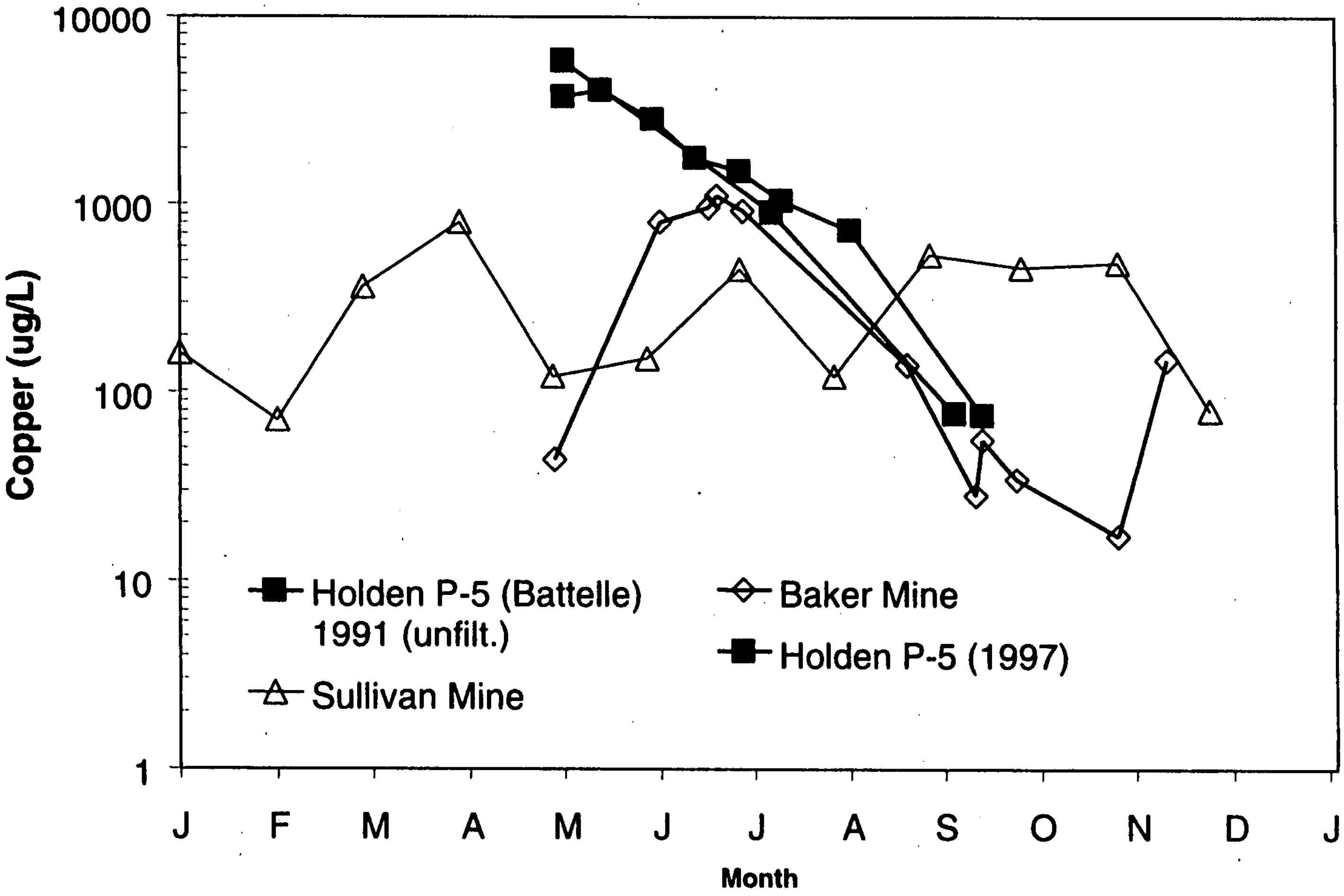

SOURCE: SRK

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Figure 6.7-3

COPPER DISCHARGE CONCENTRATIONS FROM SELECTED MINES

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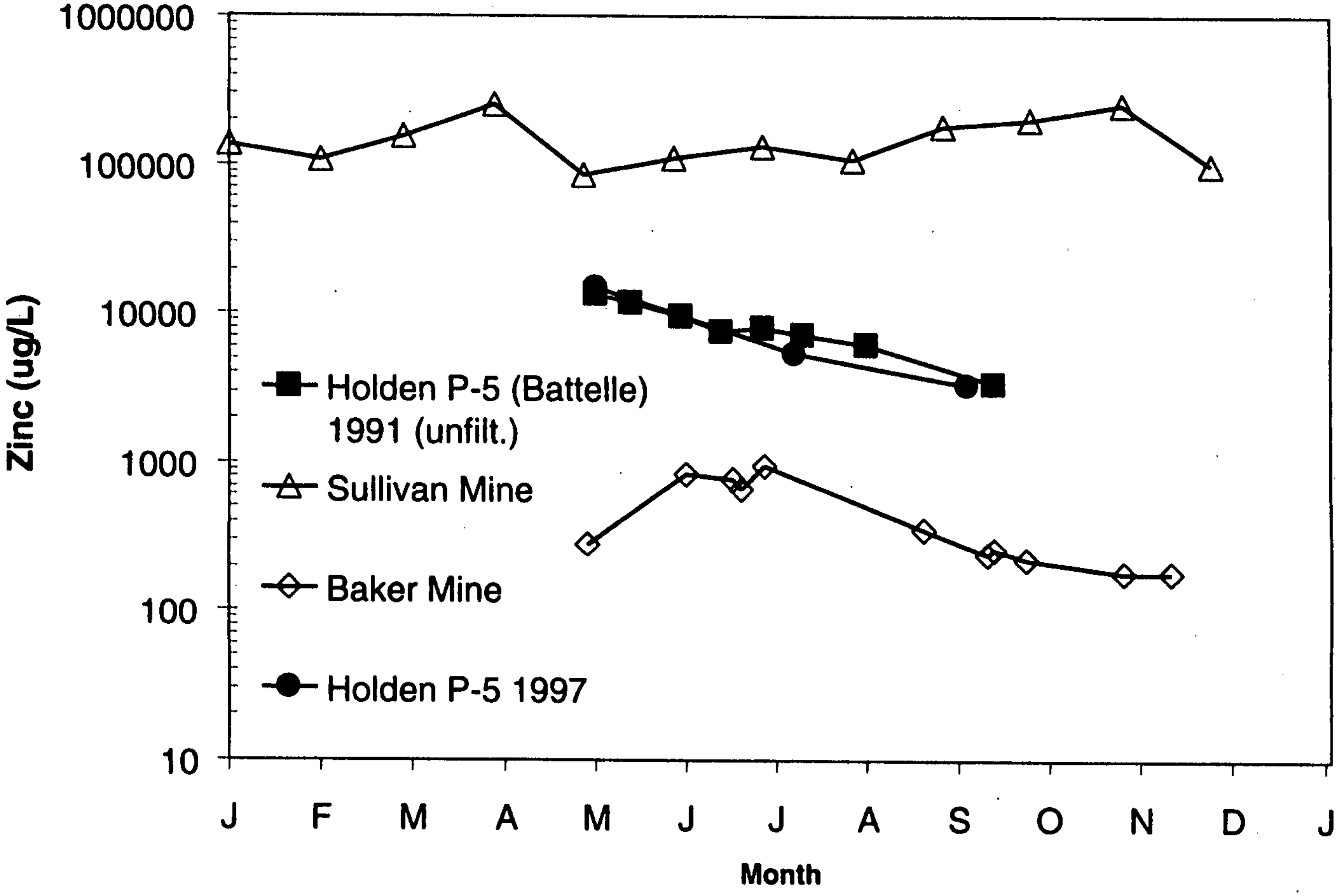

SOURCE: SRK

Figure 6.7-4

ZINC DISCHARGE CONCENTRATIONS FROM SELECTED MINES

7.0 BASELINE RISK ASSESSMENT

Both a Baseline Human Health Risk Assessment (HHRA) and Baseline Ecological Risk Assessment (ERA) were prepared for the Holden Mine Site and nearby Holden Village in Chelan County, Washington (Figures 7.0-1 through 7.0-3 and Table 7.0-1). The overall approach and methodology for evaluating the risks associated with the Site are discussed below.

7.1 HUMAN HEALTH RISK ASSESSMENT

7.1.1 Methodology

The intent of the HHRA is to evaluate the potential for threats to human health based on available information collected by the USGS, USFS, Ecology, and Dames & Moore.

A systematic evaluation of the potential risks to human health was conducted in accordance with guidelines outlined in the following Ecology and U.S. Environmental Protection Agency (USEPA) documents: *Washington State Model Toxics Control Act-Cleanup* (WAC 173-340); *Model Toxics Control Act Cleanup Levels and Risk Calculations (CLARC II) Update* (Ecology, 1996); *Statistical Guidance for Ecology Site Managers* (Ecology, 1992); *Supplement to Statistical Guidance for Ecology Site Managers* (Ecology, 1993); *Risk Assessment Guidance for Superfund, Volume I, Human Health Evaluation Manual (Part A)* (USEPA, 1989) and *Part B* (USEPA, 1991b); *Office of Solid Waste and Emergency Response (OSWER) Directive 9285.6-03, Supplemental Guidance: Standard Default Exposure Factors* (USEPA, 1991a); *Guidance for Data Usability in Risk Assessment* (USEPA, 1992b); *and Soil Screening Guidance: Technical Background Document* (USEPA, 1996).

The human health risk assessment process typically involves five basic elements:

1. **Data Review and Evaluation.** Available data were reviewed to characterize the Site and its associated constituents, define the nature and magnitude of constituent releases to environmental media (soil, air and water), and identify site-related indicator hazardous substances (IHSs).

2. **Exposure Assessment.** The exposure assessment defines the amount, frequency, duration, and routes of receptor exposure to site-related IHSs. The exposure assessment considers both current and likely future site uses, and is based on complete exposure pathways to actual or probable receptors (i.e., the people that could come in contact with site-related IHSs). Exposure scenarios are summarized in the Exposure Pathways Model. Exposure point concentrations representative of upper-bound exposure conditions in each affected medium are also estimated in the exposure assessment. In this baseline risk assessment, the exposure assessment is conducted in the screening level human health assessment and then refined in the site-specific HHRA.

3. **Toxicity Assessment.** The toxicity assessment serves to (1) identify the nature and degree of toxicity of each IHS, and (2) characterize the dose-response relationship (the relationship between magnitude of exposure and magnitude of adverse health effects) for each IHS. Two kinds of effects are recognized: (1) non-carcinogenic effects, and (2) carcinogenic

effects. The same constituent may exert both kinds of effects. USEPA has developed toxicity criteria for most of the constituents detected at the site.

4. **Risk Characterization.** In risk characterization, exposure and toxicity data were combined to define site-specific cleanup criteria and estimate the nature and magnitude of potential risks to defined receptor populations. Non-carcinogenic risks to human receptors were quantified by the hazard quotient (HQ), the ratio of IHS concentration in site media to the corresponding non-cancer risk-based level multiplied by the acceptable hazard. Cumulative hazard is expressed as a hazard index (HI). Carcinogenic risks were quantified by estimating the excess cancer risks, expressed by the ratio of the IHS concentration to the cancer risk-based levels multiplied by the acceptable cancer risk.

5. **Uncertainty Analysis.** Like any other form of modeling, risk assessment relies on a set of assumptions and estimates, each of which has some element of uncertainty. The uncertainty analysis accounts for both variability in and lack of knowledge about measured and estimated parameters, allowing decision makers to better evaluate risk estimates in the context of the assumptions and data used in the assessment.

This Human Health Baseline Risk Assessment was performed in two stages: 1) screening level human health assessment, and 2) site-specific human health risk assessment. The purpose of the screening level human health assessment was to produce a comprehensive conceptual site model in order to select appropriate IHSs. The site-specific HHRA quantified risks and hazards for those pathways considered significant.

7.1.1.1 Screening Level Human Health Assessment

The methodology for conducting the screening level human health assessment was applied sequentially, as follows:

- Develop a comprehensive, preliminary conceptual site model for the site
- Develop criteria for screening data
- Conduct data evaluation
- Refine the exposure pathways model
- Select IHSs

The results of these steps were used to select significant exposure pathways for the site-specific HHRA. Each step of the screening human health assessment is discussed in detail in Section 7.1.3.

7.1.1.2 Site-Specific Human Health Risk Assessment

The site-specific HHRA was conducted for those constituents and exposure pathways which significantly contributed to the risk at the site as determined in the screening level human health assessment. The methodology for the site-specific HHRA was performed in the following steps:

- Characterize the relevant exposure pathways
- Develop exposure concentrations based on statistical evaluation of the data
- Characterize the toxicity of the IHSs
- Develop site-specific cleanup levels
- Characterize risks associated with the site
- Discuss uncertainties in the risk characterization

Each step of the site-specific HHRA is discussed in detail in Section 7.1.4.

7.1.2 Data Evaluation

The purpose of the data evaluation section is to summarize the types of data utilized in the risk assessment and to evaluate specific data sets as they pertain to the selection of indicator hazardous substances (IHS).

7.1.2.1 Source Characterization by Media

Holden Mine was a copper, zinc, gold and silver mine located to the west of Lake Chelan in the Railroad Creek watershed of Chelan County, Washington. The mine operated from 1938 to 1957 and generated approximately 10 million tons of tailings materials. Approximately 8.5 million tons of the tailings were deposited in three impoundments constructed adjacent to Railroad Creek (i.e., tailings piles 1, 2 and 3). The remainder of the material was backfilled in the underground mine workings. The USFS has completed a number of site reclamation efforts, including the covering of the tailings piles with gravel to mitigate dust emissions, the installation of surface water interceptor swales, bank protection for Railroad and Copper Creek, and the revegetation of the surface of the tailings piles. Additional details on the mine and its environs can be found in Sections 1, 2 and 4.

The Site has been extensively studied by others since mine and mill closure in 1957. The investigations have included sampling and analytical testing of surface water, sediments, groundwater, soil, tailings, seeps, mine portal drainage, air, and aquatic macroinvertebrates and fish. The primary focus of the studies was to assess the impacts of the tailings piles and mine discharge on the above-mentioned media. Detailed tables containing sample results for recent and historic samples can be found in Section 5. All 1997 and 1998 data collected by Dames & Moore were validated as discussed in Section 5. Data which has been used for the risk assessment is discussed below by media, and includes 1997 and 1998 Dames & Moore data and, in some cases, historical data collected by others from 1991 to 1997. Data tables for the risk assessment are included in Tables 7.1-A through 7.1-K of this risk assessment.

Surface Soil

For the purposes of the human health risk assessment, surface soil data collected from the upper six inches of soil was divided into the following areas based on physical location and/or exposure characteristics:

- Holden Village (historic and 1997 data)
- Holden Village vegetable garden (1997 data)
- Baseball field (1997 data)
- Wilderness boundary (1997 data
- Maintenance yard (1997 data)
- Lagoon area (1997 and 1998 data)
- USFS guard station (historic data only)

Subsurface Soil

Subsurface soil data was not used in the baseline risk assessment because there is no current or reasonably foreseeable future exposure to subsurface soil. There is no anticipated future change in the current land uses that would indicate future exposures to subsurface soil.

Tailings

Historic and 1997 data from all three tailings piles were combined for the risk assessment. Subsurface tailing samples were not used in the assessment since there is no reasonably foreseeable exposure. Wind blown tailings sample data were combined with surface tailings data.

Sediment

For the purposes of the human health risk assessment, sediment, flocculent, and concentrate sample data were combined. These three media were assumed to represent human exposure to sediment-like materials during recreational activities. The combined data sets were evaluated for the following exposure areas:

- Railroad Creek adjacent to the Site (historic and 1997 data)
- Railroad Creek downgradient of the Site (historic and 1997 data)
- Copper Creek (historic data)
- Copper Creek Diversion (1993 USGS data)

Surface Water

Historic and 1997-1998 Railroad Creek and Copper Creek analytical results were evaluated for the following areas:

- Railroad Creek adjacent to the Site
- Railroad Creek downgradient of the Site
- Copper Creek
- Copper Creek Diversion

Samples collected from the Copper Creek diversion were assessed in the human health risk assessment to evaluate exposure in the sauna dipping pond. Hydroelectric plant outflow, which originates from the Copper Creek diversion, is discharged to the sauna dipping pond. Surface water concentrations were used to evaluate risks to humans from consuming fish from Railroad Creek.

Groundwater

The only groundwater samples evaluated in the human health risk assessment were those collected in 1997 from the USFS well at Lucerne that is reportedly used seasonally for drinking water. No exposure to ground water at the Site or at Holden Village was expected.

Seeps

Historic and 1997-1998 seep data (all data except non-mine influenced locations) were evaluated.

1500-Level Mine Portal Drainage

Historic and 1997-1998 1500-level mine portal drainage data were evaluated.

1500-Level Ventilator Portal Seepage

One 1998 sample was evaluated.

Air

Post-remediation air monitoring data collected in 1994 by the USFS were evaluated in the human health risk assessment.

Fish

Fish muscle tissue samples were analyzed for metals by Pacific National Laboratories (PNL, 1992) in 1989 and 1991 at four locations: upstream, at the Site, at Lucerne, and at 25-Mile Creek. Fish muscle tissue samples were also analyzed by Ecology in 1992 at approximately the same four locations. Mean muscle concentrations were evaluated in the human health risk assessment.

7.1.2.2 Statistical Analysis of Data

For each data set, summary statistics were calculated for use in the risk assessment. These summary statistics included:

- Number of samples
- Number of detections
- Minimum detected concentration
- Maximum detected concentration
- Range of detection limits
- Distribution (normal, lognormal, or neither)
- Arithmetic mean
- Arithmetic standard deviation
- Median
- Estimate of 95 percent upper confidence limit (UCL) concentration based on appropriate distribution, if available

Statistical calculations were conducted using the Ecology MTCAStat V2.1 Excel Macro. Tables presenting the summary statistics are included as Tables 7.1-A through 7.1-K.

7.1.2.3 Evaluation of Background Data

Twenty background samples were collected in 1998 to characterize area background for soil at the Site. These area background levels are detailed in Table 7.1-1. In addition, Table 7.1-1 shows natural background concentrations for the Yakima Basin which were obtained from Ecology (1994), and Washington State background concentrations obtained from Dragun (1991).

Table 7.1-1 also shows area background concentrations of total metals calculated for surface water. These background data were calculated using Ecology MTCAStat V2.1 Excel Macro, and were used in the risk assessment to evaluate whether detected constituents in surface water were site-related. Upgradient data (assumed to represent background or non-Holden Mine influenced areas) were available for sediment, seeps, fish, and groundwater; however, there were an insufficient number of samples to calculate area background values.

Section 5 describes the statistical derivation of area background concentrations for the site.

7.1.2.4 Process for Selection of Indicator Hazardous Substances

IHSs were selected for evaluation in this Baseline Risk Assessment based on a screening process consistent with Ecology Model Toxics Control Act (MTCA) guidance. IHSs are defined by Ecology as those hazardous substances that can be used to define site cleanup requirements. Hazardous substances not selected as IHSs should contribute a small percentage of the overall threat to human health and the environment. IHSs were selected for the HHRA based on a screening level risk assessment which compared maximum detected concentrations to data evaluation criteria listed below:

- **Essential Nutrients.** If the constituent was considered an essential nutrient, it was eliminated as an IHS. This approach is consistent with USEPA risk assessment guidance (USEPA, 1989) and MTCA (WAC 173-340-708[2][b][i]).
- **Frequency of detection.** If a constituent was detected in less than 5 percent of the samples of a medium (or in an exposure area) it was eliminated as an IHS. This approach is consistent with USEPA risk assessment guidance (USEPA, 1989) and is recommended in MTCA guidance (WAC 173-340-708[2][b][vi]).
- **Background values.** If the maximum detected concentration was less than the corresponding background concentration developed, the constituent was eliminated as an IHS. This approach is consistent with USEPA risk assessment guidance (USEPA, 1989) and is recommended in MTCA guidance (WAC 173-340-708[2][b][iv]).
- **Model Toxics Control Act (MTCA) Method A Levels.** If the maximum concentration of a constituent was less than the relevant MTCA Method A level, it was considered to contribute a small percentage of the overall risk and was eliminated as an IHS. Method A levels are generic cleanup levels which were obtained from MTCA (WAC 173-340-720[2], 173-340-740[2]), amended January 1996.
- **MTCA Method B Levels.** If the maximum concentration of a constituent was less than the relevant MTCA Method B level, it was considered to contribute a small percentage of the overall risk and was eliminated as an IHS. Method B levels are developed using standard equations in MTCA and were obtained from *Model Toxics Control Act Cleanup Levels and Risk Calculations (CLARC II) Update* (Ecology, 1996). When a Method B level was not available in CLARC II for a constituent detected at the site, it was calculated using equations provided by MTCA, if toxicity data were available. For the particulate emissions pathway, soil cleanup levels were calculated using the methodology presented in *Soil Screening Guidance. Technical Background Document* (USEPA, 1996).

The selection of the IHSs is presented in the Screening Level Human Health Assessment in Section J-3.1.

7.1.3 Screening Level Human Health Assessment

A screening level human health assessment was conducted to provide a preliminary evaluation of exposure pathways and analytical data, select indicator hazardous substances (IHSs) to carry through the site-specific human health risk assessment, and define significant exposure pathways. IHSs are defined by Ecology as those hazardous substances that can be used to define site cleanup requirements.

7.1.3.1 Preliminary Exposure Pathway Model

Based on site characteristics and land use, a preliminary exposure pathway model was developed for the Site. The model illustrates our conceptual understanding of the chemical sources, release and transport mechanisms and the potential exposure pathways, exposure routes, and receptors.

The completeness of potential exposure pathways and exposure routes given the current land use and expected future land use were evaluated in order to develop this exposure pathway model. A complete exposure pathway consists of the following four elements: (1) a source of constituent release to the environment, (2) an environmental transport medium (e.g., air, groundwater, fugitive dust emissions, soil runoff into water bodies, etc.), (3) a point of potential contact for receptors (also referred to as an exposure point), and (4) a route of entry into humans, either via inhalation, ingestion, or dermal contact with the affected medium. The presence or absence of any of these elements depends on the specific conditions found at the Site. Those exposure pathways deemed to be potentially complete were evaluated by comparing measured concentrations in media with the corresponding screening level criteria in the screening level human health assessment.

The preliminary exposure pathway model is illustrated in Figure 7.1-1. Land use characteristics and each element of the preliminary exposure pathway model, as well as the reason for selection of complete exposure pathways, are discussed below.

Land Use Characteristics

The Holden Mine is located in the Cascade Mountain Range within the Wenatchee National Forest. The Glacier Peak Wilderness generally bounds the Site to the west, north and south. A large portion of the mine-related facilities and tailings are situated near the floor of a steep-sided glacial valley. The Holden Mine, the abandoned mill building, and the associated tailings are currently not utilized except on an occasional basis by recreational users (i.e., sight-seers). A series of walking trails and roads allow physical access to the mill area and the 1500-level mine portals.

A maintenance yard area is located immediately north of the mill facility. This area was previously utilized for storage of transformers and petroleum hydrocarbons. The maintenance yard buildings are currently utilized by Holden Village for equipment maintenance and storage.

Holden Village is situated immediately to the north of Railroad Creek, which generally bounds the mine property to the north. Holden Village is an interdenominational religious retreat operated under a Conditional Use Permit from the USFS. All of the buildings in the village are located on USFS property. The village includes approximately 25 buildings. The buildings include a school and associated play area, cafeteria, housing for full-time residents, dorm housing for visitors, meeting room, library, art studio, and store. A road from Holden Village to Lucerne is used several times daily by buses operated by the village during the summer months, and on an occasional basis by USFS vehicles. During the winter months, the road is used less frequently and snow is plowed as possible; otherwise, tracked personnel carriers are utilized.

According to Ms. Janet Grant, Holden Village Director, approximately 50 to 60 "long-term" staff have been present in the village at any one time over the last 15 to 20 years. One couple reportedly stayed in Holden Village for 20 years, leaving in 1983. Five people have stayed for over 15 years and 20 to 25 people have stayed for 5 to 10 years. In addition, approximately 5000 to 6000 people visit the facility each year, each staying from an average of two to seven days.

Holden Village maintains a small vegetable garden (approximately 2000 square feet). According to Ms. Grant, the produce harvested from the garden is primarily herbs which are used occasionally in the village kitchen. The garden is tended as a hobby and not for sustenance purposes.

Railroad Creek can be utilized by village residents and visitors for recreational purposes such as tubing and sport fishing. However, according to Mr. Brent Wiersma, Holden Village Business Manager and frequent angler, most of the fishing in the Railroad Creek drainage is catch and release flyfishing and thus very few fish are consumed. Very few people fish Railroad Creek and most fishing is reportedly done in the lakes upstream of the Holden Mine. A vast majority of the fish brought to the Holden Village kitchen for consumption reportedly originate from Hart Lake, approximately four miles upgradient from the mine. Hart Lake is the largest lake in the area and is most accessible. Copper Creek is not expected to support recreational activities due to its limited size and low water flow.

A sauna located next to Railroad Creek is used by village residents and visitors. Hydroelectric plant outflow originates from Copper Creek upslope of the Site which is then tightlighted to the plant and then discharged to the Copper Creek diversion. A portion of Copper Creek diversion flow is channeled to a dipping pool for the sauna facility.

The surfaces of the tailings piles are generally covered with 4 to 6 inches of gravel. The southeastern portion and the northwestern portion of the tailings pile 1 is uncovered due to the relatively steep slope angles. These areas have undergone revegetation wherever possible. The tailings piles are accessible to recreational users. Villagers have bonfires on tailings pile 1 in the summer. Joggers and hikers utilize a road which bounds the tailings piles to the south. Particulate emission from the limited areas of exposed tailings are generated under windy conditions. Some particulates generated from the erosion of the tailings have accumulated at the base of slopes (i.e., Railroad Creek, etc.).

A baseball field is located immediately east of the Glacier Peak Wilderness boundary, approximately one mile west of Holden Village. The field is covered with grass and is utilized intermittently in the summer months only. The USFS and Ecology have indicated that they have heard anecdotally that the baseball field was constructed utilizing tailings and/or mine waste rock material.

A lagoon area is located at the Site which collects seepage from the waste rock piles and mill building area and is accessible to visitors.

A small USFS guard station is located near the road to the former Winston Homes site. USFS volunteers are stationed here during the summer months. According to the USFS, the maximum length of service for volunteers is approximately three seasons.

Holden Village drinking water is obtained from Copper Creek upstream of the influence of the mine. Groundwater is not used in the area and it is highly unlikely that it would be used as a drinking water source in the future because the groundwater flow is low compared with surface water flow in the area. In addition, installation of a drinking water well in the vicinity of the mine or village would be difficult and impractical due to the topography and geology of the area. The only drinking water supply well within the Railroad Creek drainage is located within the alluvial materials at Lucerne, approximately 11 miles east of the Site at the mouth of Railroad Creek. The well provides potable water for and is maintained by the USFS, which utilizes the water primarily and intermittently during the summer months.

Future land use in the area is expected to be similar to current use. Because the site area is located within a designated National Forest and Wilderness Area, an increase in residents or other potential receptors is not expected.

Sources

The mining related waste contained within tailings piles 1, 2 and 3 is assumed to represent the source area for potential human health exposure of metals of concern for the Site. The former mill building may also act as a relatively minor metals source area. In addition, a former storage area immediately north of the mill was identified as a potential source of polychlorinated biphenyl (PCB) and petroleum hydrocarbons.

Potential Migration Pathways

The mining related wastes and former storage area may contribute compounds of concern to air, surface water, seeps, mine portal drainage, sediment, groundwater, and soil (surface and subsurface) at the Site. The potential for site constituents to migrate from source media to points of exposure depends on their distribution, physical and chemical properties of the constituents of concern, and properties of the media. Transfer to these environmental media may occur via one or more of the following general mechanisms:

- **Leaching: Migration of Constituents from Soil or Mining Wastes to Groundwater, Surface Water, and Sediment.** The infiltration of precipitation into the soil and tailings and subsequent leaching into groundwater may result in the transfer of Site constituents to the groundwater. This leaching process depends on several physical and chemical characteristics of the constituents and the soil and tailings, including water solubility, octanol/water partition coefficient, oxidation/reduction potential, mineralogy, organic carbon content, cation exchange capacity, and soil/tailings surface area. PCBs tend to be tightly bound to the soil. The potential for metals to leach depends on the state of the metal and soil/tailings characteristics. Once Site constituents reach groundwater, they can migrate laterally and vertically in groundwater through gross fluid movement and dispersion. The rate of migration is dependent on aquifer characteristics and chemical and physical characteristics of the constituent. Hydrophobic and cationic constituents (e.g., PCBs) will migrate slower than water soluble and nonionic constituents (e.g., metals). Additionally, Site constituents in groundwater can be transferred to surface water through seeps or directly to a surface water body, and, in the case of the Holden Mine, through mine portal drainage. Groundwater at the Site may discharge through these mechanisms into Railroad and Copper Creeks. Once in surface water bodies, some Site constituents have the potential of accumulating in sediment and/or fish.
- **Runoff: Migration of Constituents from Soil or Mining Wastes to Surface Water and Sediment.** Precipitation can carry Site-related constituents or suspended soil or tailings into surface water bodies such as Railroad Creek and Copper Creek through storm water runoff processes. Erosion of the tailings pile also contributes Site constituents to surface water. Once in surface water bodies, some Site constituents have the potential of accumulating in sediment and/or fish.
- **Suspension: Migration of Constituents from Soils or Mining Wastes to Air.** The transfer of constituents present in soils or tailings to the air may occur through agitation of the surface soils resulting in the generation of fugitive particulate emissions. Volatilization is considered an insignificant migration pathway since the constituents associated with the Site are nonvolatile metals and PCBs. Particulate emissions are

expected to be reduced under normal conditions by gravel and vegetative covering of the tailings piles.

- **Suspension and Redeposition: Migration of Constituents from Soils or Mining Wastes to Offsite Surface Soil.** If fugitive particulate emission enter the ambient air through agitation and wind suspension, the particulates will be transferred downwind and eventually settle out of the atmosphere onto ground-level surfaces. These surfaces could include soil, plants, buildings, paved surfaces, and surface water.

Exposure Routes

Exposure routes are the various ways that receptors may come into contact with substances. The determination of potential risk posed by constituents requires an assessment of all potential exposure routes including ingestion, inhalation, and dermal contact. Depending on site-specific conditions, not all exposure routes will apply to every site. Exposure routes may also vary for different receptors based on the different activity patterns for the receptors; thus viable exposure routes will vary by site and may vary by receptors at a particular site. The following exposure routes were evaluated for the Holden Mine Site:

- **Inhalation of Suspended Particulates.** Suspended particulates in ambient air may be inhaled by those persons near the source or downwind of the source. This exposure route is evaluated for the soil and tailings piles. In addition, air monitoring data is evaluated.

- **Ingestion of Soil, Tailings and Sediment.** Ingestion of Site constituents could occur through the incidental ingestion of tailings or surface soil impacted by site constituents (either at a source or downwind of a source). Residents in Holden Village, users of the vegetable garden, workers in the maintenance yard, and recreational users of the wilderness area, lagoon, or tailings piles could incidentally ingest soil when it settles on lips and is ingested, suspended particulates are inhaled and then swallowed when cleared from the lung, or dirt-covered hands touch the mouth or lips. Incidental ingestion of sediment during recreational activities in Railroad Creek, Copper Creek, or the Copper Creek diversion could also occur, although is unlikely. These exposure routes are evaluated in this assessment. Exposure to subsurface soil at the Site is not expected to occur.

- **Ingestion of Homegrown Produce.** Ingestion of Site constituents could occur through ingestion of home-grown produce which has been impacted by deposition of site-related particulates or been grown in soil containing site-related particulates. This route is evaluated; however, exposure to site constituents in home-grown produce is expected to be minimal since a very small portion of the villagers' total diet is attributable to home-grown produce from the garden.

- **Ingestion of Surface Water.** Ingestion of Site constituents could occur through incidental ingestion of surface waters from Railroad Creek, Copper Creek, seeps, 1500-level mine portal drainage, or from the 1500-level ventilator portal. In addition, recreational users of the area may intentionally ingest surface waters. Incidental ingestion of Copper Creek diversion water in the sauna dipping pool could also occur. These routes are evaluated in this assessment.

- **Ingestion of Fish.** Some ingestion of Site-related constituents could occur if recreational users (i.e., fishermen) eat the fish caught in Railroad Creek or Copper Creek. This route is evaluated; however, exposure to Site constituents in fish is expected to be minimal based on the small number of fish caught in the mine influenced areas that are later consumed. Fish may also be ingested from Railroad Creek at Lucerne or from Lake Chelan.
- **Ingestion of Groundwater.** Ingestion of ground water at the Site is not considered a viable exposure route. However, because USFS personnel utilize a well downgradient of the Site, this exposure route is evaluated for the Lucerne well in this assessment. Under certain limited circumstances there could be incidental ingestion of groundwater at the Site, such as during a construction scenario. However, exposure under these circumstances would be considered insignificant considering the likelihood of such scenarios occurring and the length of exposure should such an activity occur.
- **Dermal Absorption Through Soil, Tailings or Sediment.** The dermal exposure route is complete; however, exposure related to dermal absorption was eliminated since this pathway was considered insignificant as compared with risk through ingestion. For dermal exposure to solid media (i.e., sediments, soil, and tailings) to be equal to or greater than the risk posed by ingestion, the absorption fraction, which is an indication of the amount of compounds of concern absorbed through the skin, must be greater than 0.1 (USEPA, 1992a). The absorption fraction is estimated on a compound of concern-specific basis and is dependent upon a compound of concern's permeability coefficient in addition to its soil/water partition coefficient. For inorganics, the absorption fraction can be assumed to range from 0.001 to 0.01 (similar to experimental values for cadmium). For PCBs, the absorption fraction can be assumed to range from 0.006 to 0.06 (similar to experimental values for 3,3',4,4'-tetrachlorobiphenyl). As a result, the dermal exposure route for solid media was considered insignificant and thus eliminated from the preliminary exposure pathways model.
- **Dermal Absorption Through Surface Water and Groundwater.** The dermal exposure route is complete for surface water (i.e., Railroad and Copper Creeks, the sauna, seeps, mine portal drainage); however, exposure related to dermal absorption was eliminated. For dermal exposure in water to be equal to or greater than the risk posed by ingestion of those media, the permeability coefficient for the chemical from the compound of concern through skin must be greater than 0.1 cm/hr (USEPA, 1992a). For inorganics, the permeability coefficient used to estimate dermal exposure is normally assumed to be 0.001 cm/hr, which is two orders of magnitude less than the 0.1 cm/hr level referred to above. Organics have not been detected in aqueous media. As a result, the dermal exposure route for surface water was eliminated from the preliminary exposure pathways model.

Potential Human Receptor Populations

The potential human receptors for the Site were identified based on the land use characteristics. The primary receptors were identified as Holden Village residents, recreational users of the mine area (i.e., an infrequent visitor to the Site such as a hiker or tourist), and USFS personnel utilizing the Lucerne well and the USFS guard station. Holden Village visitors are likely to be exposed to Site-related constituents, but were not evaluated in this assessment since cleanup levels established for Holden Village residents will be health-protective of occasional visitors.

Summary of Exposure Pathways Evaluated in Screening Level Assessment

The exposure pathways evaluated in the screening level human health assessment are summarized below by receptor population:

• Resident	Ingestion	Surface soil (village)
		Surface soil (maintenance yard)
		Home-grown produce
	Inhalation	Suspended particulates (tailings or soil)
• Recreational User	Ingestion	Surface soil (baseball field, lagoon)
		Tailings
		Surface water
		Sauna dipping pool (Copper Creek diversion)
		Seeps
		1500-level main and ventilator portal drainages
		Sediment
		Fish
	Inhalation	Suspended particulates (from tailings)
• USFS Personnel	Ingestion	Surface soil
		Groundwater
	Inhalation	Suspended particulates

7.1.3.2 Data Evaluation Criteria

A conservative screening approach was applied to identify site-specific IHSs: maximum detected concentrations were compared to the data evaluation criteria discussed below. Those constituents with maximum concentrations below the data evaluation criteria were eliminated as IHSs. If all constituents were present at levels below the data evaluation criteria for a specific media and location, exposure to this media/location was considered insignificant.

Essential Nutrients

If the constituent was considered an essential nutrient, it was eliminated as an IHS. This approach is consistent with USEPA risk assessment guidance (USEPA, 1989) and MTCA (WAC 173-340-708[2][b][i]). The following are considered essential nutrients for the purposes of this screening:

- Calcium
- Iron
- Magnesium
- Potassium
- Sodium

Frequency of Detection

If a constituent was detected in less than 5 percent of the samples of a medium within an exposure area, it was eliminated as an IHS. This approach is consistent with USEPA risk assessment guidance (USEPA, 1989) and is recommended in MTCA guidance (WAC 173-340-708[2][b][vi]).

Background Concentrations

In order to determine which constituents are Site-related, analytical data were compared with the statistically-derived background concentration, when available. For soil and tailings, site analytical data were compared with Site-specific area background (Section 5) or natural background concentrations for the Yakima Basin available in *Natural Background Soil Metals Concentrations in Washington State* (Ecology, 1994). Surface water analytical data were also compared with statistically-derived area background concentrations as described in Section 5. If the maximum detected concentration was less than the corresponding background concentration, the constituent was eliminated as an IHS. This approach is consistent with USEPA risk assessment guidance (USEPA, 1989) and is recommended in MTCA guidance (WAC 173-340-708[2][b][iv]).

Method A Levels

If the maximum concentration of a constituent was less than the relevant MTCA Method A level, it was considered to contribute a small percentage of the overall risk and was eliminated as an IHS. Method A levels are generic cleanup levels which were obtained from *The Model Toxics Control Act-Cleanup* (WAC 173-340), amended January 1996. The following MTCA Method A levels were used for each exposure medium:

- **Surface Soil and Home-grown Produce.** Method A levels for residential soil (WAC 173-340-740[2])
- **Tailings.** Method A levels for residential soil (WAC 173-340-740[2])
- **Sediment.** Method A levels for residential soil (WAC 173-340-740[2])
- **Railroad Creek and Copper Creek Water and Fish.** Method A levels for surface water (national ambient water quality criteria for ingestion of water and fish pursuant to Section 304 of the Clean Water Act, as referred to in WAC 173-340-730[2][a][2])
- **Seeps.** Method A levels for groundwater (or Maximum Contaminant Levels if Method A levels not available) (WAC 173-340-720[2])
- **1500-Level Main and Ventilator Portal Drainages.** Method A levels for groundwater (or Maximum Contaminant Levels if Method A levels not available) (WAC 173-340-720[2])
- **Sauna Water (Copper Creek Diversion).** Method A levels for groundwater (or Maximum Contaminant Levels if Method A levels not available) (WAC 173-340-720[2])
- **Groundwater.** Method A levels for groundwater (or Maximum Contaminant Levels if Method A levels not available) (WAC 173-340-720[2])
- **Fish Tissue.** No Method A levels were available for fish tissue. Instead, U.S. EPA Region III Risk-Based Concentrations (Oct. 1998) for fish were used.

No Method A levels are available for air, or home-grown produce. For home-grown produce it was assumed that if the maximum concentration of the constituent was below the Method A level for soil, then ingestion of produce grown in that soil would not present a significant risk. Table 7.1-2 lists the Method A level used for each constituent along with its source. Because of the conservatism used in deriving Method A levels, no adjustments to the cleanup levels to account for exposure to multiple constituents were performed.

Method B Levels

If the maximum concentration of a constituent was less than the relevant MTCA Method B level, it was considered to contribute a small percentage of the overall risk and was eliminated as an IHS. Method B levels are developed using standard equations and were obtained from *Model Toxics Control Act Cleanup Levels and Risk Calculations (CLARC II) Update* (Ecology, 1996). Similar media-specific cleanup levels as discussed above (Section J-3.1.2.4) were used for each exposure medium. MTCA Method B levels for air were also utilized. When a cleanup level was not available for a constituent detected at the Site, it was calculated using equations and standard exposure parameters provided by MTCA if toxicity criteria were available. In addition, all Method B levels for air were calculated because the 1996 CLARC II tables do not include air cleanup levels. Table 7.1-3 lists the Method B criteria used for each constituent along with its source. Table 7.1-4 details the toxicity criteria and bioconcentration factors used in calculating cleanup criteria for non-published constituents. Toxicity criteria are discussed in more detail in the site-specific HHRA.

Adjustment for Total Risk and Hazard Index

The total risk associated with a site must not exceed 1 x 10^{-5} and the hazard index for each target organ must not exceed one (WAC 173-340-708[5]). Therefore, Method B criteria were reduced to account for the number of constituents in each group potentially found at the site. Table 7.1-5 lists the carcinogen classification and toxic effects endpoints, where available, for the constituents detected at the site.

Based on the carcinogen classifications, the following constituents are considered carcinogens by MTCA: arsenic, beryllium, cadmium, chromium VI, lead, nickel (refinery dust), and PCBs. For each constituent, the acceptable risk level on which the Method B level is based (and thus the resulting screening level) was divided by the number of carcinogens at the site (seven constituents) to assure that the aggregate risk does not exceed 1 x 10^{-5}. The Method B levels listed in the screening tables reflect this adjustment.

For non-cancer effects, the analytes can be grouped together by toxic effects endpoints as follow:

- Hemotoxicity: antimony, zinc (2 constituents)
- Skin toxicity: arsenic, silver (2 constituents)
- Nephrotoxicity: cadmium, mercury, molybdenum, uranium (4 constituents)
- Neurotoxicity: lead, manganese, mercury, cyanide (4 constituents)
- Weight effects: nickel, uranium, cyanide, Aroclor 1016 (4 constituents)

For each constituent, the acceptable hazard index on which the Method B level is based (e.g., acceptable hazard index of one), and thus the resulting screening level, was divided by the number of chemicals in the corresponding grouping. The Method B levels listed in the screening tables have been adjusted in this manner.

Method B Criteria for Manganese

The CLARC II Method B levels for manganese for soil and water are based on an oral reference dose (RfD) developed by USEPA. The RfD was derived from data on total dietary intake of manganese. USEPA (IRIS, 1998) and MTCA (Ecology, 1996) recommend that a modifying factor of three be applied to the RfD if it is used for assessments involving nondietary exposures. Since exposure to manganese at the Site would primarily be nondietary, the RfD, and thus the cleanup criteria listed in CLARC II, have been adjusted downward by a factor of three. This adjustment is reflected in the cleanup levels shown in Table 7.1-3.

Soil to Air Pathway

For the soil to air pathway (i.e., particulate emissions from soil), soil cleanup criteria were calculated using the methodology in *Soil Screening Guidance: Technical Background Document* (USEPA, 1996). The MTCA Method B levels for air were considered to be the acceptable air concentration. A particulate emission factor (PEF) was then calculated that relates the concentration of compound of concern in soil to the concentration of dust particles in air. The PEF represents an annual average emission rate based on wind erosion that can be compared with chronic health criteria. The equation for calculating the PEF is as follows:

$$\text{PEF}\ (m^3/kg) = Q/C \times \frac{3600}{0.036 \times (1 - V) \times (U_m / U_t)^3 \times F(x)} \qquad 7\text{-}1$$

where:

PEF = Particulate emission factor (m^3/kg)

Q/C = Inverse of mean concentration at center of source (g/m^2-s per kg/m^3) = 42.86

V = Fraction of vegetative cover = 0.5

Um = Mean annual windspeed (m/s) = 4.69

Ut = Equivalent threshold value of windspeed at 7 m (m/s) = 11.32

F(x) = Function dependent on Um/Ut = 0.194

Q/C was selected from the Soil Screening Guidance for the closest geographical area (Seattle) and the largest source size (30 acre). Default values given in the Soil Screening Guidance were used for all other variables. Based on this equation, the calculated PEF for the site was 6.21×10^8 m^3/kg. The acceptable air concentration (Method B level for air) was multiplied by the PEF to derive the Method B levels for soil based on protection of air. The Method B levels for soil based on protection of air are listed in Table 7.1-3.

7.1.3.3 Screening Level Evaluation of Data

The screening level evaluation of data consisted of data segregation by exposure pathway, followed by a six step comparative evaluation which served as the primary basis of the screening. Criteria used for the comparative evaluation are discussed above.

The screening tables summarize the results of the data evaluation. As noted above, the maximum concentrations presented in the source concentration columns of the tables represent the maximum observed for the medium of interest from the available data. If no toxicity criteria (and thus no Method A or Method B level) were available for a constituent, it was discussed qualitatively. Each exposure medium is discussed individually below.

Surface Soil

The maximum concentrations observed for each location were used as the source concentrations for comparison to the screening criteria based on soil ingestion. The background concentrations used for screening were statistically derived or obtained from *Natural Background Soil Metals Concentrations in Washington State* (Ecology, 1994) for the Yakima basin and Dames & Moore 1998 data. In addition, for those constituents which did not have an available area background or Ecology natural background level, background levels for the State of Washington (Dragun, 1991) are presented for comparison purposes. No constituents were eliminated as IHSs based on the Dragun ranges, however.

Holden Village

Soil samples were collected throughout Holden Village. The samples were collected randomly throughout the village and at the closest proximity to the tailings piles. Given the spatial distribution of the soil samples, the results should adequately represent surface soil in and around Holden Village. The results of the screening for this exposure area are presented in Table 7.1-6. The only constituent selected as an IHS based on the screening was beryllium.

Holden Village Vegetable Garden

One soil sample was collected in the Holden Village vegetable garden. This sample result was used to evaluate both soil ingestion and ingestion of home-grown produce. The site measurements were compared against soil cleanup levels based on protection of residential receptors who may contact site-related constituents through ingestion. Comparisons against these criteria were considered conservative for the produce ingestion route since these cleanup levels were developed using exposure assumptions that are more conservative than those that would reasonably be assumed for ingestion of home-grown produce. The results of the screening for this exposure area are presented in Table 7.1-7. All constituents were eliminated as IHSs based on this screening.

Baseball Field

One soil sample was collected in the baseball field. The results of the screening for this exposure area are presented in Table 7.1-8. All constituents were eliminated as IHSs based on this screening.

Wilderness Boundary

Two soil samples were collected near the wilderness boundary. The results of the screening for this exposure area are presented in Table 7.1-9. All constituents were eliminated as IHSs based on this screening.

Maintenance Yard

Four surface soil samples were collected throughout the maintenance yard and in the storage area. The results of the screening for this exposure area are presented in Table 7.1-10. Based on this screening, the following constituents were selected as IHSs: arsenic, cadmium, copper, lead, and total petroleum hydrocarbons (gasoline range, diesel range, and motor oil range).

Lagoon Area

Two soil samples were collected in the lagoon area. The results of the screening for this exposure area are presented in Table 7.1-11. Based on this screening, the following constituents were selected as IHSs: beryllium, cadmium, copper, lead, and zinc and total petroleum hydrocarbons (diesel range and motor oil range).

USFS Guard Station

One historical sample was collected near the USFS guard station (sample designated as Winston Homesite). The results of the screening for this exposure area are presented in Table 7.1-12. Based on this screening, the only constituents selected as an IHS for this area were arsenic and beryllium.

Particulate Emissions from Surface Soil

Each soil exposure area screened for ingestion (Section J-3.1.3.1) was also screened for particulate emissions potential. Results are detailed below.

Holden Village

The results of the particulate emissions screening for this exposure area are presented in Table 7.1-13. The only constituent selected as an IHS based on the screening was chromium. Copper, lead, molybdenum, silver, zinc and cyanide did not have health-based MTCA Method A or Method B levels (due to an absence of inhalation toxicity criteria) which could be used for screening. While these constituent concentrations appear to be elevated, they are not expected to present an unacceptable risk to receptors via the inhalation route at the concentrations present particularly, given the short expected exposure period and ground covers present in this area.

Village Vegetable Garden

The results of the particulate emissions screening for this exposure area are presented in Table 7.1-14. All constituents were eliminated as IHSs based on this screening. Copper, lead, molybdenum, silver, and zinc did not have health-based MTCA Method A or Method B levels (due to an absence of inhalation toxicity criteria) which could be used for screening. While these constituent concentrations appear to be elevated, they are not expected to present an unacceptable risk to receptors via the inhalation route at the concentrations present particularly given the short expected exposure period for this area.

Baseball Field

The results of the particulate emissions screening for this exposure area are presented in Table 7.1-15. All constituents were eliminated as IHSs based on this screening. Copper, and silver did not have health-based MTCA Method A or Method B levels (due to an absence of inhalation toxicity criteria) which could be used for screening. While these constituent concentrations appear to be elevated, they are not expected to present an unacceptable risk to receptors via the inhalation route at the concentrations present particularly given the short expected exposure period for this area.

Wilderness Boundary

The results of the particulate emissions screening for this exposure area are presented in Table 7.1-16. All constituents were eliminated as IHSs based on this screening. Copper, lead, molybdenum, silver, uranium and zinc did not have health-based MTCA Method A or Method B levels (due to an absence of inhalation toxicity criteria) which could be used for screening. While these constituent concentrations appear to be elevated, they are not expected to present an unacceptable risk to receptors via the inhalation route at the concentrations present, particularly given the short expected exposure period and extensive vegetative cover present in this area.

Maintenance Yard

The results of the particulate emissions screening for this exposure area are presented in Table 7.1-17. The sample from the storage area was not used in this screening because the location is covered and will not generate particulate emissions. All constituents were eliminated as IHSs based on this screening. Copper, lead, molybdenum, silver, and zinc did not have health-based MTCA Method A or Method B levels (due to an absence of inhalation toxicity criteria) which could be used for screening. While these constituent concentrations appear to be elevated, they are not expected to present an unacceptable risk to receptors via the inhalation route at the concentrations present, particularly given the short expected exposure period for this area.

Lagoon Area

The results of the particulate emissions screening for this exposure area are presented in Table 7.1-18. The only constituent selected as an IHS based on the screening was cadmium. Aluminum, copper, lead, molybdenum, silver, thallium, uranium and zinc did not have health-based MTCA Method A or Method B levels (due to an absence of inhalation toxicity criteria) which could be used for screening. While these constituent concentrations appear to be elevated, they are not expected to present an unacceptable risk to receptors via the inhalation route at the concentrations present, particularly given the short expected exposure period for this area.

USFS Guard Station

The results of the particulate emissions screening for this exposure area are presented in Table 7.1-19. Based on this screening, the only constituent selected as an IHS for this area was arsenic. Copper and lead did not have health-based MTCA Method A or Method B levels (due to an absence of inhalation toxicity criteria) which could be used for screening. While these constituent concentrations appear to be elevated, they are not expected to present an unacceptable risk to receptors via the inhalation route at the concentrations present, particularly given the short expected exposure period for this area and likely ground cover in the area.

Tailings

Historical and 1997 tailings samples from tailings piles 1, 2 and 3 were collected and analyzed. The maximum concentrations observed, regardless of location, were used as the source concentrations for comparison to the screening criteria based on soil ingestion. The background concentrations used for screening were statistically derived or obtained from *Natural Background Soil Metals Concentrations in Washington State* (Ecology, 1994) for the Yakima basin. In addition, for those constituents which did not have an available area background or Ecology natural background level, background levels for the State of Washington (Dragun, 1991) are presented for comparison purposes. No constituents are eliminated as IHSs based on the Dragun ranges, however.

The tailings have been adequately characterized to complete the screening assessment. All results were assumed to represent near surface conditions on the tailings piles. The results of the screening for this exposure area are presented in Table 7.1-20. All constituents were eliminated as IHSs based on this screening.

Particulate Emissions from Tailings

The tailings data were also screened for particulate emissions potential. The results of the particulate emissions screening for this exposure area are presented in Table 7.1-21. All constituents were eliminated as IHSs based on this screening. Aluminum, copper, lead, molybdenum, selenium, silver, thallium, zinc, and cyanide did not have health-based MTCA Method A or Method B levels (due to an absence of inhalation toxicity criteria) which could be used for screening. Silver concentrations appear to be within the background range for the State of Washington. While other constituent concentrations appear to be elevated, they are not expected to present an unacceptable risk to receptors via the inhalation route at the concentrations present, particularly given the short expected exposure period for this area.

Air

Post-remediation air monitoring data collected in 1994 by the USFS were screened. All data collected was used in the screening and the maximum detected concentrations were used as the source concentrations. The data were collected from locations onsite, downwind, and upwind and are assumed to be representative of conditions onsite and in and around Holden Village. Background air concentrations were not evaluated in the screening due to a lack of information on site conditions at the time of sampling. It should be noted that short-term air concentrations measured during this monitoring event are not necessarily comparable to cleanup levels based on long-term exposures; however, the cleanup levels were utilized anyway as a very conservative screening tool. The results of the screening for this exposure medium are presented in Table 7.1-22. Manganese was the only constituent selected as an IHS based on this screening.

Sediment

Railroad Creek and Site

Historical and 1997 sediment data were segregated to represent sediments in Railroad Creek within the area of influence from the mine, sediments in Railroad Creek downgradient of the Site, and sediments within Copper Creek. There was insufficient data to calculate area background concentrations for sediment in Railroad and Copper Creeks; however, background ranges are presented in the screening tables for comparison purposes. It should be noted that analytical data from the various sampling events are not always comparable. The detection limits and range of detection appear inconsistent for some events, even though the samples were presumably analyzed by the same method. However, for the purposes of screening, all sample data were combined. It should also be noted that screening criteria for soil ingestion were applied to sediment data due to a lack of sediment cleanup levels. The exposure assumptions used in the soil ingestion cleanup levels (i.e., ingestion of 100 mg/day) are expected to significantly overestimate the potential risks based on ingestion of sediment.

Railroad Creek Adjacent to Site

The results of the screening for this exposure area are presented in Table 7.1-23. Based on the screening, aluminum, arsenic, beryllium, chromium, manganese, and molybdenum were selected as IHSs. However, aluminum, beryllium, chromium and manganese were within the range of background concentrations measured in Railroad Creek.

Railroad Creek Downgradient of Site

The results of the screening for this exposure area are presented in Table 7.1-24. Based on the screening, aluminum, beryllium, chromium and manganese were selected as IHSs. However, beryllium and manganese were within the range of background concentrations measured in Railroad Creek.

Copper Creek

The results of the screening for this exposure area are presented in Table 7.1-25. Based on the screening, beryllium, chromium and manganese were selected as IHSs. However, concentrations of all of these constituents were within the range of background concentrations measured in Copper Creek.

Copper Creek Diversion

The results of the screening for this exposure area are presented in Table 7.1-26. Based on the screening, only chromium was selected as an IHS. However, the concentration of chromium was below the range of background concentrations measured in Copper Creek.

Surface Water and Fish

As with sediment, historical and 1997 surface water data were segregated to represent conditions in Railroad Creek within the area of influence from the mine, Railroad Creek downgradient of the site, and Copper Creek. Area background concentrations of total metals in surface water were statistically derived in Section 5. For the purposes of the screening, analytical results for total metals were evaluated because total metals content is more appropriate for evaluating health risks than filtered (dissolved) metals content.

Railroad Creek Adjacent to Site

The results of the screening for this exposure area are presented in Table 7.1-27. All constituents were eliminated as IHSs based on this screening.

Railroad Creek Downgradient of Site

The results of the screening for this exposure area are presented in Table 7.1-28. All constituents were eliminated as IHSs based on this screening.

Copper Creek

The results of the screening for this exposure area are presented in Table 7.1-29. The only constituent selected as an IHS based on this screening was molybdenum.

Elimination of most of the constituents in surface water for the fish ingestion pathway is supported by data collected in 1989 and 1991 by PNL and in 1992 by Ecology, which indicated that concentrations of metals in trout muscle were below levels of concern for human health (PNL, 1992). PNL and Ecology collected fish muscle tissue from three locations in Railroad Creek, including at Lucerne, and from 25-Mile Creek. PNL concluded there were no significant overall locational differences in metal concentrations for muscle tissue, and that results indicated little risk to human health through consumption of trout. This fish tissue data screening is described below.

Seeps

Historical and 1997 analytical data collected for seeps were screened against the appropriate screening criteria. There was insufficient data to calculate area background concentrations for seeps; however, the concentration detected in the one background sample is presented in the screening table for comparison purposes. The conservatism in the seep screening significantly overestimates potential risk to human health posed by this medium because the screening criteria are for tap water consumption. Incidental ingestion of water generating from the seeps is not presumed to occur at this rate. The results of the screening for this medium are presented in Table 7.1-30. Based on the screening, aluminum, cadmium, lead, manganese, selenium and zinc were selected as IHSs.

1500-Level Main Portal Drainage

Historical and 1997/1998 analytical data collected for the 1500-level main portal drainage were screened against the appropriate screening criteria. The conservatism in the mine portal drainage screening significantly overestimates potential risk to human health posed by this medium because the screening criteria are for tap water consumption. Incidental ingestion of water generating from the drainage is not presumed to occur at this rate. The results of the screening for this medium are presented in Table 7.1-31. Based on the screening, aluminum, cadmium, copper, lead, manganese and zinc were selected as IHSs.

1500-Level Ventilator Portal Seepage

One 1998 sample was screened against the appropriate screening criteria. The conservatism in the ventilator portal drainage screening significantly overestimates potential risk to human health posed by this medium because the screening criteria are for tap water consumption. Incidental ingestion of water generating from the ventilator portal drainage is not presumed to occur at this rate. The results of the screening for this medium are presented in Table 7.1-32. All constituents were eliminated as IHSs based on this screening.

Sauna Water (Copper Creek Diversion)

Historical and 1997 analytical data collected for the Copper Creek diversion were screened against the appropriate screening criteria to evaluate risks associated with the sauna dipping pool. Area background concentrations of total metals in surface water were statistically derived in Section 5. Total and dissolved metals data were combined for this screening since very few total metals data were available. The conservatism in the sauna screening significantly overestimates potential risk to human health posed by this medium because the screening criteria are for tap water consumption. Incidental ingestion of water in the sauna dipping pool is not presumed to occur at this rate. The results of the screening for this medium are presented in 7.1-33. All constituents were eliminated as IHSs based on this screening.

Groundwater

Two samples were collected from the Lucerne USFS well in 1997. These sample results were screened against drinking water criteria. There was insufficient data to calculate area background concentrations for groundwater; however, the concentrations detected in background samples are presented in the screening table for comparison purposes. The results of the screening for this medium are presented in Table 7.1-34. All constituents were eliminated as IHSs based on this screening.

Fish Muscle Tissue

PNL and Ecology fish muscle tissue data were screened against U.S. EPA Region III Risk-Based Concentrations for fish. None of the muscle concentrations exceeded the screening concentrations. The results of this screening are presented in Table 7.1-35. There were insufficient data to calculate background concentrations for fish tissue; however, the concentrations detected in the upstream samples are presented in the screening table for comparison purposes. Based on this screening, all constituents were eliminated as IHSs. Fish ingestion was also evaluated using surface water data particularly because not all metals were analyzed during the PNL and Ecology sampling efforts.

7.1.3.4 Refined Exposure Pathway Model

Results of the screening level human health assessment were used to refine the exposure pathway model (Figure 7.1-2). For exposure routes with all source concentrations (i.e., the maximum observed for the appropriate medium) below the screening criteria, the risk to a human receptor from that route was considered negligible. These exposure routes, and if appropriate the corresponding exposure pathway, were eliminated from the exposure model. As illustrated, exposure to IHSs in soil, air, sediments, surface water, seeps, and mine portal drainage is assumed to represent potential exposure routes of concern for the Site and were subject to additional evaluation.

7.1.3.5 Indicator Hazardous Substances

Based on the results of the screening level human health assessment, IHSs were selected for each media. IHSs selected for each exposure route are detailed in Table 7.1-36. Site-specific cleanup levels and risk estimates for these IHSs were calculated in the site-specific human health risk assessment.

7.1.4 Site-specific Human Health Risk Assessment

The site-specific HHRA was conducted for those IHSs and exposure pathways (Table 7.1-36. Figure 7.1-2) which significantly contributed to the risk at the site as determined in the screening level human health assessment. The methodology for the site-specific HHRA followed the following steps:

- Characterize the relevant exposure pathways
- Develop exposure concentrations based on statistical evaluation of the data
- Characterize the toxicity of the IHSs
- Develop site-specific (MTCA Method C) levels
- Characterize risks associated with the site
- Discuss uncertainties in the risk characterization

Each step of the site-specific HHRA is discussed in detail in below.

7.1.4.1 Exposure Assessment for Refined Exposure Pathways

Exposure Pathways

Exposure pathways evaluated in the site-specific HHRA are shown conceptually in the exposure pathway model (Figure 7.1-2) and detailed, along with IHSs, in Table 7.1-36. Exposure to IHSs in soil, air, sediments, surface water, seeps, and mine portal drainage is assumed to represent potential exposure routes of concern for the site.

Development of Exposure Point Concentrations

The potential magnitude of exposure is determined by measuring or estimating the exposure point concentrations of IHSs available in various media at "exchange boundaries" (e.g., the lungs, gastrointestinal tract, or skin). For the purposes of the site-specific HHRA, the exposure concentration was estimated to be the 95 percent upper confidence limit (UCL) concentration for the data set. When there was an insufficient number of samples or a high percentage of uncensored data (data reported as below the detection limit), 95 percent UCL concentrations could not be calculated. For these data sets, the maximum detected concentration was used for the exposure concentration. The method for calculating the 95 percent UCL was dependent on the distribution of the data (i.e., normal, lognormal, or neither). The distribution of the data and the 95 percent UCL concentrations were calculated using the Ecology MTCAStat V2.1 Excel Macro. The statistical tables included in this section (tables 7.1A through 7.1K) show the distributions and 95 percent UCL concentrations, when calculated, for each media. Table 7.1-37 details the exposure concentrations for each IHS used in the site-specific HHRA.

7.1.4.2 Toxicity Characterization

The toxicity assessment determines the relationship between the magnitude of exposure to an IHS and the nature and magnitude of adverse health effects that may result from such exposure. Chemical toxicity is divided into two categories, carcinogenic and non-carcinogenic, based on the type of adverse health effect exerted. Health risks are calculated differently for these two types of effects because their toxicity criteria are based on different mechanistic assumptions and expressed in different units. The two approaches are discussed below. Available toxicity criteria for humans are summarized in Table 7.1-38, and brief toxicological profiles for the IHSs are presented in Table 7.1-44.

Non-Carcinogenic Effects

Non-carcinogenic cleanup levels were calculated using reference doses (RfDs) developed by USEPA. An RfD is an estimate of the daily lifetime exposure level to humans (expressed in units of mg of chemical/kg of body weight/day), including sensitive subgroups, that is likely to be without appreciable risk of deleterious effects (USEPA, 1989). RfDs are usually derived from oral exposure studies with the most sensitive species, strain and sex of experimental animal known, the assumption being that humans are as sensitive as the most sensitive organism tested. They are based on the assumption that thresholds (exposure levels below which no adverse effect is expected) exist for non-carcinogenic effects, and incorporate uncertainty factors to account for the required extrapolations from animal studies and to ensure protection of sensitive human subpopulations. RfDs for constituents considered in the HHRA were obtained, whenever possible, from CLARC II. Table 7.1-38 summarizes both oral and inhalation RfDs and the toxic effects endpoint for IHSs.

Carcinogenic Effects

In contrast to non-carcinogenic effects, USEPA typically assumes that there is no threshold for carcinogenic responses; that is, any dose of a carcinogen is considered to pose some finite risk of cancer. The evidence for human carcinogenicity of a chemical is derived from two sources: chronic studies with laboratory animals, and human epidemiological studies where an increased incidence of cancer is associated with exposure to the chemical. As with the non-cancer toxicity studies, the most sensitive laboratory species is generally used in cancer protocols.

Since risks at the low levels of exposure usually encountered by humans are difficult to quantify directly by either animal or epidemiological studies, mathematical models are used to extrapolate from high experimental to low environmental doses. The slope of the extrapolated dose-response curve is used to calculate the cancer slope factor or potency factor (CPF), which defines the incremental lifetime cancer risk per unit of carcinogen (in units of risk per mg/kg/day). The linearized multi-stage model for low-dose extrapolation most often used by USEPA (USEPA, 1986a) is one of the most conservative available, and leads to a upper-bound estimate of risk (the upper 95 percent confidence limit on the modeled animal dose-response slope). The probability that the true risk is higher than that estimated is thus only 5 percent. Actual risk is likely to be lower, and could even be zero (USEPA, 1986a).

Each tested chemical is assigned a weight-of-evidence classification that expresses its potential for human carcinogenicity. The USEPA's weight-of-evidence classification system is shown below:

USEPA's Weight-of-Evidence Carcinogenicity Classification System

Group	Description
A	Human carcinogen
B1	Probable human carcinogen - limited human data are available
B2	Probable human carcinogen - sufficient evidence in animals and inadequate or no evidence in humans
C	Possible human carcinogen
D	Not classifiable as to human carcinogenicity
E	Evidence of non-carcinogenicity for humans

USEPA recommends that the weight-of-evidence classification be presented for each potential carcinogen to indicate the strength of evidence that it may be a human carcinogen (USEPA, 1986a; USEPA, 1989). Table 7.1-38 summarizes the oral and inhalation CPFs and carcinogen classification for each IHS.

Constituents for Which No Toxicity Values are Available

Neither lead nor total petroleum hydrocarbons have toxicity criteria which can be used to calculate site-specific Method C criteria. Therefore, these constituents are discussed qualitatively in the risk characterization.

7.1.4.3 Development of Site-specific Method C Levels

For each exposure pathway, site-specific Method C levels were calculated. The equations for calculating these cleanup levels are based on the equations presented in MTCA.

Selection of Exposure Parameters

Exposure assumptions utilized in calculation of the site-specific Method C criteria were based on a reasonable maximum exposure (RME) scenario, and included assumptions regarding the types of exposure that may occur and the frequency and duration of those exposures. To conduct the site-specific assessment, assumptions were made such that exposure to these media more closely reflect actual conditions, but still reflect an RME scenario. The exposure parameters applied in the screening level assessment's Method A and B criteria are conservative with respect to the living habits of potential receptors at the Site and Holden Village. The Method A and B levels presented in the screening tables (Tables 7.1-6 to 7.1-35) generally represent risk to a receptor resulting from continuous exposure over a 30-year period. In the site-specific HHRA, the exposure duration was modified to reflect actual exposure conditions of the Holden Village residents. The occupants of Holden Village are transient, with a maximum known residence time of 20 years, according to Ms. Janet Grant (Holden Village Director). Therefore, as a conservative measure, the exposure duration was assumed to be 20 years for adult residential exposures. For those cleanup criteria based on exposures in a child, the default exposure duration of six years was used. For the USFS personnel, a maximum exposure duration of three years was assumed based on information provided by the USFS. Frequency of exposure was also adjusted to reflect the likely seasonal nature of exposures, i.e., the presence of snow-cover for approximately eight months of the year. The exposure parameters used to calculate cleanup levels, and their sources, are provided in Table 7.1-39.

Selection of Target Risk and Hazard Index

As specified in MTCA, a target risk level of 1×10^{-5} and a target hazard quotient of one were selected for development of the Method C levels (WAC 173-340-700[3][c]). Cumulative risk is also evaluated in the risk characterization section. MTCA specifies that the cumulative cancer risk must not exceed 1×10^{-5} and the cumulative hazard index for each toxic effect endpoint must not exceed one.

Development of Method C Levels

Method C levels are summarized in Table 7.1-40. The following equations were utilized for calculating site-specific Method C criteria:

Ingestion of Soil and Sediment

Screening criteria cleanup levels based on ingestion of soil in a residential setting are developed assuming a child's exposure. Screening criteria for the maintenance area and USFS guard station were developed assuming adult exposures. Equations for this pathway are as follows:

Carcinogens:

$$\text{Screening Criteria (mg/kg)} = \frac{\text{RISK} \times \text{ABW1} \times \text{LIFE} \times \text{UCF}}{\text{CPF} \times \text{SIR} \times \text{AB1} \times \text{DUR1} \times \text{FOC1}} \qquad \text{7-2}$$

Noncarcinogens:

$$\text{Screening Criteria (mg/kg)} = \frac{\text{RfD} \times \text{ABW1} \times \text{UCF} \times \text{HQ}}{\text{SIR} \times \text{AB1} \times \text{FOC1}} \qquad \text{7-3}$$

where:

RISK = Acceptable cancer risk level (unitless)
ABW1 = Average body weight over period of exposure (kg)
LIFE = Lifetime (years)
UCF = Unit conversion factor (1,000,000 mg/kg)
CPF = Cancer potency factor (kg-day/mg)
RfD = Reference dose (mg/kg-day)
SIR = Soil ingestion rate (mg/day)
AB1 = Gastrointestinal absorption rate (unitless)
DUR1 = Duration of exposure (years)
FOC1 = Frequency of contact (unitless)

Ingestion of Water

Screening criteria based on ingestion of water are developed assuming a child's exposure. Equations for this pathway are as follows:

Carcinogens:

$$\text{Screening Criteria (ug/l)} = \frac{\text{RISK x ABW1 x LIFE x UCF}}{\text{CPF x DWIR x DUR1 x INH x FOC1}} \qquad 7\text{-}4$$

Noncarcinogens:

$$\text{Screening Criteria (ug/l)} = \frac{\text{RfD x ABW1 x UCF x HQ}}{\text{DWIR x INH x FOC1}} \qquad 7\text{-}5$$

where:

RISK = Acceptable cancer risk level (unitless)
ABW1 = Average body weight over period of exposure (kg)
LIFE = Lifetime (years)
UCF = Unit conversion factor (1,000 μg/mg)
RfD = Reference dose (mg/kg-day)
DWIR = Water ingestion rate (l/day)
DUR1 = Duration of exposure (years)
FOC1 = Frequency of contact (unitless)
INH = Inhalation correction factor (unitless)
CPF = Cancer potency factor (kg-day/mg)

Ingestion of Fish

Screening criteria based on ingestion of fish in surface water are developed assuming an adult's exposure. Equations for this pathway are as follows:

Carcinogens:

$$\text{Screening Criteria (ug/l)} = \frac{\text{RISK x ABW1 x LIFE x UCF1 x UCF2}}{\text{CPF x BCF x FCR x FDF x DUR1}} \qquad 7\text{-}6$$

Noncarcinogens:

$$\text{Screening Criteria (ug/l)} = \frac{\text{RfD x ABW1 x UCF1 x UCF2 x HQ}}{\text{BCF x FCR x FDF}} \qquad 7\text{-}7$$

where:

RISK = Acceptable cancer risk level (unitless)
ABW1 = Average body weight over period of exposure (kg)
LIFE = Lifetime (years)
UCF1 = Unit conversion factor (1,000 µg/mg)
UCF2 = Unit conversion factor (1,000 µg/l)
RfD = Reference dose (mg/kg-day)
BCF = Fish bioconcentration factor (unitless)
FCR = Fish consumption rate (g/day)
FDF = Fish diet fraction (unitless)
DUR1 = Duration of exposure (years)
CPF = Cancer potency factor (kg-day/mg)

Inhalation of Air

Screening criteria based on inhalation of air in a residential setting are developed assuming a child's exposure. Equations for this pathway are as follows:

Carcinogens:

$$\text{Screening Criteria (ug/}m^3) = \frac{\text{RISK x ABW2 x LIFE x UCF}}{\text{CPF x BR x AB2 x DUR2}} \qquad 7\text{-}8$$

Noncarcinogens:

$$\text{Screening Criteria (ug/}m^3) = \frac{\text{RfD x ABW2 x UCF x HQ}}{\text{BR x AB2}} \qquad 7\text{-}9$$

where:

RISK = Acceptable cancer risk level (unitless)
ABW2 = Average body weight over period of exposure (kg)
LIFE = Lifetime (years)
UCF = Unit conversion factor (1,000 µg/mg)
CPF = Cancer potency factor (kg-day/mg)
RfD = Reference dose (mg/kg-day)

BR = Breathing rate (m3/day)

AB2 = Inhalation absorption percentage (unitless)

DUR2 = Duration of exposure (years)

Inhalation of Particulates

Soil criteria were calculated using the methodology in *Soil Screening Guidance: Technical Background Document* (USEPA, 1996) assuming adult exposures. Equations for this pathway are as follows:

Carcinogens:

$$\text{Screening Criteria (ug/m}^3) = \frac{\text{RISK x ABW2 x LIFE x UCF}}{\text{CPF x BR x AB2 x DUR2 x FOC2 x } \frac{1}{\text{PEF}}} \qquad \text{7-10}$$

Noncarcinogens:

$$\text{Screening Criteria (ug/m}^3) = \frac{\text{RfD x ABW2 x UCF x HQ}}{\text{BR x AB2 x FOC2 x } \frac{1}{\text{PEF}}} \qquad \text{7-11}$$

where:

RISK = Acceptable cancer risk level (unitless)

ABW2 = Average body weight over period of exposure (kg)

LIFE = Lifetime (years)

UCF = Unit conversion factor (1,000 μg/mg)

CPF = Cancer potency factor (kg-day/mg)

BR = Breathing rate (m3/day)

AB2 = Inhalation absorption percentage (unitless)

DUR2 = Duration of exposure (years)

FOC2 = Frequency of contact (unitless)

PEF = Particulate emission factor (m3/kg)

RfD = Reference dose (mg/kg-day)

PEF relates the concentration of compounds of concern in soil to the concentration of dust particles in air. The PEF represents an annual average emission rate based on wind erosion that can be compared with chronic health criteria. The equation for calculating the PEF is as follows:

$$\text{PEF (m}^3\text{/kg)} = \text{Q/C x } \frac{3600}{0.036 \text{ x } (1 - V) \text{ x } (U_m / U_t)^3 \text{ x } F(x)} \qquad \text{7-12}$$

where:

PEF = Particulate emission factor (m3/kg)
Q/C = Inverse of mean concentration at center of source (g/m2-s per kg/m3)
V = Fraction of vegetative cover
Um = Mean annual windspeed (m/s)
Ut = Equivalent threshold value of windspeed at 7 m (m/s)
F(x) = Function dependent on Um/Ut (unitless)

Q/C was selected from the Soil Screening Guidance (USEPA, 1996) for the closest geographical area (Seattle).

7.1.4.4 Risk Characterization

Risk characterization involves estimating the magnitude of the potential adverse health effects of the hazardous chemicals under study and making summary judgements about the nature of the health threat to the defined receptor populations. It combines the results of the toxicity assessment and exposure assessment.

Exposure Concentrations vs. Method C Levels

Table 7.1-41 compares exposure concentrations for each exposure pathway to the corresponding Method C levels. Exposure concentrations for all IHSs for each exposure pathway are below their corresponding Method C levels.

Human Health Risk Estimates

The site-specific risks and hazard quotients for each IHS and each exposure pathway are detailed in Table 7.1-42. Cancer risk was evaluated by comparing the exposure point concentration to the Method C criteria based on carcinogenic effects, as follows:

$$\text{Cancer Risk} = \frac{\text{Exposure Concentration}}{\text{Method C Criteria (cancer)}} \text{x} (1 \text{x} 10^{-5}) \qquad 7\text{-}13$$

Noncancer hazard quotients were evaluated by comparing the exposure point concentration to the Method C criteria based on noncarcinogenic effects, as follows:

$$\text{Hazard Quotient} = \frac{\text{Exposure Concentration}}{\text{Method C Criteria (noncancer)}} \qquad 7\text{-}14$$

The results shown in Table 7.1-42 indicate that carcinogenic risk and noncarcinogenic hazard to receptors is acceptable (i.e., the cancer risk is less than 1 x 10^{-5} and the hazard quotient is below one). Risks and hazard quotients for each exposure media are summarized below:

Surface Soil

Cancer risks and noncancer hazard quotients ingestion of all IHSs in all exposure areas were below the allowable MTCA cancer risk and hazard quotient. The cancer risks ranged from 8.91 x 10^{-10} for beryllium at the USFS guard station to 5.66 x 10^{-6} for arsenic in the maintenance area. The hazard quotients ranged from 4.15 x 10^{-6} for beryllium at the USFS guard station soil to 2.04 x 10^{-1} for copper in the lagoon area soil.

Lead was detected in maintenance yard and lagoon area soil at concentrations exceeding the screening criteria (1070 mg/kg in the maintenance yard and 620 mg/kg in the lagoon area). However, because no toxicity criteria exist for this constituent, site-specific risks could not be evaluated. USEPA guidelines recommend a cleanup level of 400 mg/kg for lead in soil at residential sites based on prediction of blood lead levels in children. Neither of these sites is residential and exposure time is expected to be significantly less than an assumed residential exposure duration of 7 day per week exposures for 30 years. The highest exposure concentrations are less than three times higher than the USEPA recommended levels. Therefore, concentrations of lead in soil in these two areas are not expected to cause effects in exposed populations. In addition, remedial actions in these two areas will likely significantly reduce the concentrations present.

Total petroleum hydrocarbons were present in soil at the maintenance yard and lagoon area at levels exceeding MTCA Method A level. Exposure concentrations ranged from 140 mg/kg gasoline range hydrocarbons in the maintenance yard to 12,000 mg/kg diesel range hydrocarbons in the maintenance yard. Because no toxicity criteria exist for these complex mixtures, site-specific risks were not evaluated. However, as with lead, exposure times and durations at the maintenance yard and lagoon area are expected to be significantly lower than would be assumed for development of the Method A level, and therefore TPH is soil at these locations are not expected to be of concern for the limited time period that maintenance workers and recreational users are exposed populations. In addition, remedial actions in these areas should significantly reduce soil TPH concentrations.

Sediment

Cancer risks and noncancer hazard quotients for all IHSs in all exposure areas were below the allowable MTCA cancer risk and hazard quotients. Cancer risks ranged from 1.08 x 10^{-7} for beryllium in all three areas to 4.72 x 10^{-6} for arsenic in Railroad Creek sediments adjacent to the site. The hazard quotients ranged from 6.25 x 10^{-5} for beryllium in all three areas to 1.68 x 10^{-1} for molybdenum in Railroad Creek sediments adjacent to the site.

Air

The site-specific hazard quotients calculated for manganese in air was 4.0 x 10^{-1}, which is below the allowable MTCA hazard quotient. There were no cancer risks calculated for this media since manganese was not a carcinogen.

Particulate Emissions from Soil

In order to evaluate current conditions and the potential for soil/tailings in each exposure area to be transported to air via fugitive dust emissions, a simple USEPA model was utilized to develop a particulate emission factor (PEF) for each exposure area. Cancer risks based on transfers from soil to air for all IHSs in all exposure areas were below the allowable MTCA cancer risk. Cancer risks ranged from 3.96 x 10^{-9} for arsenic in the USFS guard station soil (transferred to air) to 5.69×10^{-8} for chromium in Holden Village soil (transferred to air). There were no hazard quotients calculated for this pathway.

Surface Water and Fish

Hazard quotients for molybdenum in Copper Creek were 6.44×10^{-2} for ingestion of water and 3.18×10^{-1} for ingestion of fish, both of which are below the allowable MTCA hazard quotient. There were no cancer risks calculated for this media since the IHS was not a carcinogen.

Seeps and Mine Portal Drainage

Seep and portal drainage data were evaluated separately. Noncancer hazard quotients for all IHSs in both media were below the allowable MTCA hazard quotient. There were no cancer risks calculated for these media since IHSs were not carcinogens. The hazard quotients ranged from 1.15×10^{-2} for manganese in the 1500-level main portal drainage to 5.31×10^{-1} for cadmium in the 1500-level main portal drainage.

Lead was present in both seeps and the 1500-level main portal drainage at concentrations exceeding the MTCA Method A level; however, because no toxicity criteria exist for this constituent, site-specific risks could not be evaluated. While exposure concentrations exceed MTCA Method A level, the exposure frequencies and water ingestion rates expected at the site are significantly less than those upon which the cleanup criteria is based. Therefore, concentrations of lead in seeps and portal drainage are not expected to cause effects in potentially exposed populations.

Cumulative Risk

MTCA requires the evaluation of cumulative risk when Method C levels are used. Evaluation of cumulative cancer risk was accomplished by summing all cancer risks for each receptor population. Cumulative risk for noncancer effects was evaluated by summing hazard quotients for each IHS associated with the same toxic effect endpoint

Cumulative cancer risks for forest service workers (1.16×10^{-7}) are less than the acceptable level of 1×10^{-5} (Table 7.1-43). Cumulative cancer risks for village residents/recreational users are 1.10×10^{-5}. Ingestion of soil from the "storage" location in the maintenance yard is the primary contributor to the cumulative risk within the rounding error of 1×10^{-5}. When adjusted to the appropriate number of significant digits, the cumulative risk is the same as the acceptable level of 1×10^{-5}. In addition, this cumulative risk assumes that the children exposed recreationally during the summertime grow up to become residents of Holden Village who work in the maintenance yard. This assumption is obviously extremely conservative.

All noncancer hazard quotients are less than the acceptable level of one, with one exception. Using a combination of extremely conservative exposure assumptions that are unlikely to occur resulted in the cumulative hazard quotient for nephrotoxic effects (non-cancer kidney effects) for village residents/recreational users of 1.26. This is due primarily to cadmium in portal drainage. This cumulative conservative risk evaluation assumes that the receptor is daily drinking one-half liter of 1500-level main portal drainage water, one-half liter of seep water, and one-half liter of Copper Creek water, as well as ingesting soil from the lagoon area and maintenance area, ingesting soil, and eating fish caught from onsite areas on exposed days. This combination of exposures is extremely conservative and highly unlikely to occur. The water ingestion rates used in the calculation of Method B criteria assumed that one-half of a child's daily ingestion rate (1 liter) came from the mine-impacted area. Summing risks for surface water risks results in an added conservative assumption that a child is ingesting 1.5 liters of mine-impacted surface water. Obviously, this assumption is unrealistic and overly conservative. Cumulative risks for mine-impacted surface water ingestion are therefore adjusted downwards by a factor of three to result in an ingestion rate of 0.5 liters, which is still unrealistic.

Table 7.1-43 shows the cumulative risks, summed across all IHSs and exposure routes, for Holden Village residents and for USFS workers. Table 7.1-43 also shows the adjusted cumulative hazard indices for each toxic effect endpoint for Holden Village residents/recreational users and for USFS workers. Cancer risks and cumulative hazard indices are less than the acceptable level of one.

7.1.4.5 Uncertainty Analysis

Like all modeling efforts, the results of a health risk assessment rely on a set of assumptions and estimates with varying degrees of certainty and variability. Major sources of uncertainty in risk assessment include: (1) natural variability (e.g., differences in body weight in a population), (2) lack of knowledge about basic physical, chemical, and biological properties and processes (e.g., the affinity of a chemical for soil and its solubility in water), (3) assumptions in the models used to estimate key inputs (e.g., dose-response models), and (4) measurement error. Perhaps the greatest single source of uncertainty in risk-based assessment is the chemicals' dose-response relationships, particularly carcinogenic potency factors. Additional uncertainty may also be associated with analytical data, which are subject to both systematic error (bias) and random error (imprecision). Other major sources of uncertainty include computation of representative concentrations using conservative fate and transport assumptions, and estimation of dose rate via default exposure assumptions. These and other sources of uncertainty and their anticipated effect in estimated risks associated with the site are summarized below.

- It has been assumed for the purposes of this risk assessment that constituents detected in various media are related to operations at the Holden Mine unless adequate data was available to show that concentrations were below naturally occurring background concentrations. However, this assumption was not valid for all media. Site-specific background data for sediments, air, seeps, and groundwater were insufficient for determining area background concentrations. Other mining-related activities occurring in the vicinity of the Holden Mine may have impacted these media. Including non-site-related constituents as IHSs overestimates the risks associated with Holden Mine.
- Estimation of the exposure point concentrations was conservatively based on 95 percent UCL concentrations or maximum detected values in the media of interest. Use of these exposure concentrations is likely to overestimate the chronic intake of a chemical, and may not be realistic for long-term exposures.
- Exposure assumptions utilized in the calculation of site-specific Method C criteria were based on a reasonable maximum exposure scenario, and included assumptions regarding the types of exposure that may occur, the frequency and duration of those exposures, and the concentration of chemicals at the point of exposure. Even the use of estimated site-specific activity patterns are meant to be conservative worst-case exposure assumptions and as such, are intended to provide a conservative estimate of intake, more likely to overestimate than to underestimate exposure and risk.

- Use of toxicity criteria (CPFs and RfDs) intentionally designed to be conservative is likely to overestimate the IHSs' toxic potency. For example, the extrapolation of animal carcinogen bioassay results to human risk at much lower levels of exposure involves a number of assumptions regarding effect threshold, interspecies extrapolation, high- to low-dose extrapolation, and route-to-route extrapolation. The scientific validity of these assumptions is uncertain; because each of the individual extrapolations are designed to prevent underestimation of risk, in concert they result in unquantifiable but potentially very significant overestimation of risk. Specifically, the extrapolation of cancer potency from laboratory animals to humans, which forms the basis for the cancer risk estimates, may be associated with uncertainties ranging from as much as three to five orders of magnitude (1,000 to 100,000-fold) for selected chemicals.
- The risk analysis does not include a likelihood evaluation. For example, it is unlikely that the same recreational users will chronically utilize the lagoon area, Railroad Creek, Copper Creek, seeps, and portal drainage for recreational purposes. Thus, the actual risk for recreational users is likely to be significantly lower than estimated in this HHRA.

In summary, because the majority of assumptions regarding representative concentrations and contact rates made in this assessment are conservative, tending to overestimate exposure and risk, the incremental risks to the defined receptor populations from exposure to IHSs at the site are likely to be significantly overestimated.

7.1.5 Conclusions of Baseline Human Health Risk Assessment

Human health risks were evaluated through a conservative screening process and a site-specific risk assessment for those constituents exceeding the screening criteria. Site-specific risk assessment results were evaluated in light of acceptable risk levels defined by MTCA (i.e., a cumulative excess cancer risk of less than 1 x 10^{-5} and a cumulative hazard index of less than 1.0 for constituents with effects on the same target organ). Results for each media are summarized below.

7.1.5.1 Surface Soil and Tailings

Surface soil sample results were divided into seven areas based on exposure characteristics, population exposed, and/or physical location, as follows: 1) Holden Village, 2) vegetable garden, 3) baseball field, 4) wilderness boundary, 5) maintenance yard, 6) lagoon area, and 7) USFS guard station. Screening of constituent concentrations resulted in the elimination of the vegetable garden, baseball field, and wilderness area as areas of concern for ingestion of surface soil. In addition, the screening resulted in the elimination of the tailings piles as an area of concern for ingestion. Constituents exceeding screening criteria in the remaining four surface soil areas were selected as indicator hazardous substances (IHSs) and evaluated in the site-specific risk assessment.

Cancer risks and noncancer hazard quotients for ingestion of all IHSs in all exposure areas were below the MTCA cancer risk and hazard quotient guidelines. The cancer risks ranged from 8.91 x 10^{-10} for beryllium at the USFS guard station to 5.66 x 10^{-6} for arsenic in the maintenance yard. The hazard quotients ranged from 4.15 x 10^{-6} for beryllium at the USFS guard station soil to 2.04 x 10^{-1} for copper in the lagoon area soil.

Lead was present in the maintenance yard and lagoon area soil at concentrations exceeding MTCA Method A level; however, because no toxicity criteria exist for this constituent, site-specific risks could not be evaluated. While exposure concentrations exceed MTCA Method A and USEPA guidelines for residential sites, the exposure times expected at the site are significantly less than the assumed residential exposure time upon which the guidelines are based. Therefore, concentrations of lead in soil in these two areas are not expected to cause effects in exposed populations.

Total petroleum hydrocarbons were present in soil at the maintenance yard and lagoon area at levels exceeding MTCA Method A level. Because no toxicity criteria exist for these complex mixtures, site-specific risks were not evaluated. However, as with lead, exposure times and durations in these areas are expected to be significantly lower than would be assumed for development of the Method A level, and therefore TPH is soil at these locations is not expected to be of concern for the limited time period that maintenance workers and recreational users are exposed populations. In addition, remedial actions in these areas should significantly reduce soil TPH concentrations.

7.1.5.2 Sediment

Sediment sample results were divided into four areas based on physical location, as follows: 1) Railroad Creek adjacent to the Site, 2) Railroad Creek downgradient of the Site, 3) Copper Creek, and 4) Copper Creek diversion. Constituents exceeding screening criteria in the four areas were selected as IHSs and evaluated in the site-specific risk assessment.

Cancer risks and noncancer hazard quotients for all IHSs in all exposure areas were below the allowable MTCA cancer risk and hazard quotient. Cancer risks ranged from 1.08×10^{-7} for beryllium in all three areas to 4.72×10^{-6} for arsenic in Railroad Creek sediments adjacent to the site. The hazard quotients ranged from 6.25×10^{-5} for beryllium in all four areas to 1.68×10^{-1} for molybdenum in Railroad Creek sediments adjacent to the site.

7.1.5.3 Air

Based on historical air monitoring data, the only constituent selected as an IHS for air during the screening process was manganese. The site-specific hazard quotient calculated for manganese in air was 4.0×10^{-1}, which is below the allowable MTCA hazard quotient. There were no cancer risks calculated for this media since the IHS was not a carcinogen.

In order to evaluate current conditions and the potential for soil/tailings in each exposure area to be transported to air via fugitive dust emissions, a simple USEPA model was utilized to develop a particulate emission factor (PEF) for each exposure area. Each exposure area was then screened using conservative cleanup criteria calculated from the PEF. Screening of constituent concentrations resulted in the elimination of the vegetable garden, baseball field, wilderness area, maintenance yard, and tailings as areas of concern. Constituents exceeding screening criteria in the remaining three surface soil areas were selected as IHSs and evaluated in the site-specific risk assessment for transfers to air.

Cancer risks based on transfers from soil to air for all IHSs in all exposure areas were below the allowable MTCA cancer risk and hazard quotient. Cancer risks ranged from 3.96×10^{-9} for arsenic in the USFS guard station soil (transferred to air) to 5.69×10^{-8} for chromium in Holden Village soil (transferred to air). There were no hazard quotients calculated for this exposure pathway.

7.1.5.4 Surface Water and Fish

Surface water sample results were divided into three areas based on physical location, as follows: 1) Railroad Creek adjacent to the Site, 2) Railroad Creek downgradient of the Site, and 3) Copper Creek. Screening of constituent concentrations resulted in the elimination of Railroad Creek as an area of concern. Only one constituent (molybdenum) exceeded screening criteria in Copper Creek and was selected as an IHS for surface water and fish. Risks for Copper Creek surface water were evaluated for both incidental ingestion of surface water during recreational activities, and ingestion of fish by sport fishermen. Hazard quotients for molybdenum were 6.44×10^{-2} for ingestion of water and 3.18×10^{-1} for ingestion of fish, both of which are below the allowable MTCA hazard quotient. There were no cancer risks calculated for this media since the IHS was not a carcinogen.

The findings of no significant risk for ingestion of fish is supported by the data collected in 1989/1991 and 1992 by PNL and Ecology. PNL and Ecology collected fish muscle tissue from three locations in Railroad Creek, including at Lucerne, and from 25-Mile Creek (a reference site south of Lucerne). PNL concluded there were no significant overall locational differences in metal concentrations for muscle tissue, and that results indicated little risk to human health through consumption of trout. Screening of this muscle tissue data against U.S. EPA risk-based concentrations confirmed that residual metals in edible tissues are well below levels of concern, both at the site and downgradient of the site. {287}

7.1.5.5 Seeps, 1500-Level Main Portal Drainage, and 1500-Level Ventilator Portal Seepage

Seep, 1500-level main portal drainage and 1500-level ventilator portal seepage data were evaluated separately. No constituents were selected as IHSs for ventilator portal drainage. Constituents exceeding screening criteria in seeps and mine portal drainage were selected as IHSs and evaluated in the site-specific risk assessment. Noncancer hazard quotients for all IHSs in both media were below the allowable MTCA hazard quotient. There were no cancer risks calculated for these media since IHSs were not carcinogens. The hazard quotients ranged from 1.15×10^{-2} for manganese in the 1500-level main drainage to 5.21×10^{-1} for cadmium in the 1500-level main portal drainage.

Lead was present in both seeps and the 1500-level main portal drainage at concentrations exceeding the MTCA Method A level; however, because no toxicity criteria exist for this constituent, site-specific risks could not be evaluated. While exposure concentrations exceed MTCA Method A level, the exposure frequencies and water ingestion rates expected at the site are significantly less than those upon which the cleanup criteria is based. Therefore, concentrations of lead in seeps and 1500-level main portal drainage are not expected to cause effects in potentially exposed populations.

7.1.5.6 Sauna Dipping Pool (Copper Creek Diversion)

Risks associated with the sauna dipping pool were evaluated by screening water from the Copper Creek diversion against drinking water criteria. No constituents detected in the Copper Creek diversion exceeded screening criteria and therefore this route of exposure was eliminated from further evaluation.

7.1.5.7 Groundwater

Groundwater at the site is not considered useable for drinking water purposes and therefore was not screened for exceedances of drinking water criteria. Groundwater collected at the Lucerne USFS well was evaluated by screening constituent concentrations against drinking water criteria. No constituents detected in the Lucerne well exceeded screening criteria and therefore this route of exposure was eliminated from further evaluation.

7.1.5.8 Fish Muscle Tissue

PNL and Ecology fish muscle tissue data were screened against U.S. EPA Region III Risk-Based Concentrations for ingestion of fish. None of the muscle concentrations exceeded the screening criteria and therefore no risk to human health exists due to ingestion of the detected metals in edible fish tissue.

7.1.5.9 Summary of Conclusions

Figure 7.1-3 illustrates the combined results of the screening level human health assessment and the site-specific human health risk assessment. Figure 7.1-3 shows that the environmental conditions at the Site and Holden Village do not pose an unacceptable risk to potentially exposed populations, i.e., residents and recreational users of the Site, and USFS personnel. Table 7.1-42 summarizes the risks associated with each exposure area and IHS at the site. An evaluation of the cumulative risks for each potentially exposed population also demonstrates that cumulative cancer and noncancer risks are acceptable (see Section Cumulative Risk 4.3).

All conclusions are based upon very conservative screening criteria and site-specific assumptions which, for all practical purposes, overestimate the risk posed by the Site.

7.2 ECOLOGICAL RISK ASSESSMENT

7.2.1 Methodology

The intent of this risk assessment is to:

- Address protection of the environment under the State of Washington Model Toxics Control Act, Chapter 173-340 Washington Administrative Code (WAC), CERCLA, and the National Contingency Plan (NCP) through assessment of ecological risk
- Provide a risk assessment and risk management framework that will support decision making and/or identification of further data gaps (if any) for the RI/FS and remedy selection
- Support an injury determination to focus further studies that may evaluate any loss of resources or services under NRDA rules

The objectives were developed using the most recent concepts and available guidance on ecological risk assessment (USEPA 1994; 1998). In keeping with current guidance and the NCP, the specific objectives of the study were to:

- Characterize the nature and extent of previous human activity-related conditions at the Site
- Provide a limited characterization of the ecological populations, communities, and ecosystem at the Site

- Identify distributions of compounds of potential concern (PCOCs) and quantify, to the extent practicable, impacts of those PCOCs to the ecology of the Site
- Support development and evaluation of risk management alternatives and provide a risk-based framework for identifying further data needs (if any)

The baseline ecological risk assessment (ERA) was performed in accordance with the Washington State MTCA (1997) and USEPA (1994; 1998) guidance and followed section headings of Problem Formulation, Analysis, Risk Characterization, and Uncertainty Analysis.

- **Baseline Problem Formulation.** Based upon the Tiers I and II ERA, the PCOC list was delineated for both aquatic and terrestrial habitats. Receptors of concern (ROCs) were selected according to the guild concept where one animal with particular feeding habitat can represent all similar animals with the same feeding habits. The conceptual site model (CSM) included representative invertebrates, fish, birds, and mammals in the aquatic habitat, and plants, birds, and mammals in the terrestrial habitat.
- **Analysis.** Potential compounds of concern (PCOCs) were selected by comparison against screening benchmarks and/or toxicity data compiled for site-specific conditions and are consistent with the list of PCOCs identified in Section 5.0. Potentially complete exposure pathways included surface water and food in the aquatic habitat, and surface water, soil, and food in the terrestrial habitat. Concentrations of COCs in invertebrates, plants, and small mammals were modeled and used in the dose component of the hazard quotient (HQ). Toxicity reference values (TRVs) were calculated using data provided by Oak Ridge National Laboratory (1984, 1996a, 1996b, 1997a, 1997b, 1997c, 1997d, 1998a, 1998b) and USEPA (1993) as well as other published literature. Assessment endpoints reflect the protection of plant and animal populations, and measurement endpoints reflect the measured and/or modeled COC concentrations in the appropriate media. Measurement endpoints were related to assessment endpoints by using the concentration that causes no chronic effect on growth, reproduction, or development as the toxicity benchmark.
- **Risk Characterization.** Risk was estimated as an HQ greater than 1.0, where:

  HQ = Dose or exposure/TRV or criteria.

  Worst case exposures were used as the primary measure of risk. If no risk was found under these conditions, there was no need to conduct a more reasonable risk assessment. If risk to a mobile ROC was found under worst case conditions, exposures were further evaluated based upon median exposure conditions.
- **Uncertainty Analysis.** Sources of variance and inadequate knowledge were identified and discussed in reference to the findings of the risk characterization and ecological studies.

7.2.2 Baseline Problem Formulation

The goals of the Baseline ERA are to refine and focus the description of conditions, stressors, and ecological resources potentially at risk, and to quantitatively characterize stressor magnitude and the hazard these stressors present to the values resources of the site. To accomplish these goals, PCOCs were evaluated, habitats were investigated, ROCs were selected, assessment and measurement endpoints were selected, and the CSM was refined. A review of historical data, identification of potentially complete exposure pathways, and identification of preliminary compounds of potential concern (PCOCs) is presented in Section 5.0.

7.2.2.1 Potential Compounds of Concern

Since the mine closure, a large number of studies and activities have been completed at the Site. Summaries of documented studies and activities completed at the Site that were relevant to this ERA and considered to be representative of current site conditions are provided below. The data presented include only those compounds that were detected consistently over time and that represent compounds typically associated with copper and zinc mining in sulfide deposits prevalent at the Holden Mine Site.

The summary of historical and data collected during the RI as presented in Section 5.0 and other studies associated with the Holden Mine Site (Section 2.0) reveals a wide array of analyses have been conducted over time to evaluate individual study-specific objectives. The following is a summary, by media, of the highest, lowest, mean, and median concentrations of all measured PCOCs (Table 7.2-2-1a through 7.2-2-lh).

Table 7.2.2-1A - Surface Water

Tables 7.2.2-1B1, 7.2.2-1B2, 7.2.2-1B3 - Surface Water

Table 7.2.2-1C - Sediments

Table 7.2.2-1D - Flocculent

Table 7.2.2-1E - Soils

Table 7.2.2-1F - Tailings

Table 7.2.2-1G - Portal Drainage

Table 7.2.2-1H - Seeps

The data presented in these tables serve as the basis for the ERA risk characterization.

7.2.2.2 Habitats and Potential Receptors of Concern

There are two basic habitats present at Holden Mine, the aquatic and the terrestrial. In this ERA, the aquatic habitat is limited to the surface waters and sediments that lie beneath surface waters. The terrestrial habitat includes sediments that are exposed to air, riverine and riparian habitats, and terrestrial habitats such as tailings piles and soils. Within each of these habitats, different plant and animal species exist. The following is an exposition of the major observed habitats and receptors associated with each habitat, as well as a listing of rare or endangered species that may exist at the site.

Aquatic Areas

A number of studies have characterized the aquatic insect and fish communities in Railroad Creek (Dames & Moore 1996). These studies found a variety of benthic macroinvertebrate species in Railroad Creek, including Ephemeroptera (mayflies), Plecoptera (stoneflies), Trichoptera (caddis flies), and Diptera (flies). Investigators observed rainbow trout, cutthroat trout, kokanee, and sculpin, with cutthroat trout being the most abundant species in Railroad Creek. A more detailed analyses of benthic and fish community structure was previously discussed in Section 4.6 (Ecological Conditions).

Bald eagle, osprey, and American dipper are birds that are relatively common in the area and make extensive use of aquatic resources. American dippers have occasionally been observed feeding on aquatic invertebrates at the base of the tailings pile by Railroad Creek. Mink are probably present in the area, but have not been observed, probably because of their size and foraging habits. Bats are also likely to feed on emergent aquatic insects.

Black bear, mule deer, black-tailed deer, blue grouse, chipmunk, ground squirrel, garter snake, long-toed salamander were observed in the up- and downstream riparian habitat along Railroad Creek.

Terrestrial Areas

Surface Soils

The dominant habitat types in and around Holden Village are Douglas fir/alder forest, riparian willow thickets, and man-impacted disturbed soils. Soils were collected from Holden Village, the maintenance yard near the mine site, and the lagoon near Railroad Creek, downgradient from the mine portal. Soils within Holden Village are fully vegetated with grasses and trees. The maintenance yard is heavily used by maintenance vehicles and is devoid of vegetation and habitat for wildlife. The low area by Railroad Creek, known as the lagoon, collects surface runoff and, although devoid of vegetation, is surrounded by willow thickets.

The dominant megafauna, utilizing Holden Village and the surrounding area, are black bear, mule deer and black-tailed deer. A large number of smaller species are also common, including Douglas squirrel, Townsend's chipmunk, yellow pine chipmunk, golden-mantled ground squirrel, and unidentified bats. Deer mice and shrews are probably present. Birds, including the red-breasted nuthatch, mountain chickadee, dark-eyed junco, American robin, golden-crowned kinglet, chestnut-sided nuthatch, Townsend's warbler, white-crowned sparrow, hermit thrush, cedar waxwing, crossbill and numerous fiches were observed within Holden Village and the surrounding area. Pileated woodpecker, sharp-shined hawk, varied thrush, Clark's nutcracker were observed near the mine workings.

Tailings Piles

The tailings piles are located along Railroad Creek west of the mine portal. Beginning in 1973, the USFS and University of Washington (UW) conducted a number of re-vegetation projects on the tailings piles. The tailings piles consist of fine-ground bedrock and ore and are sparsely vegetated by a combination of planted and wild plant species.

A number of plant species including, perennial grasses, alfalfa, and various pine trees, alders and snowbush, have been planted during previous revegetation studies on the tailings piles. Various grasses, forbs, and sedges cover approximately five to ten percent of the tops of the tailings piles. Wild tree species, including Douglas fir, subalpine fir, and Engleman spruce grow on the steep sides of the tailings. Slopes to the terraces were planted with Douglas fir. Along the tailings pile edges near Railroad Creek, large red cedar, cottonwood, spruce willow and alder are common.

The most visible large game animals are mule deer, black-tailed deer, and black bear (Dames & Moore 1996). Smaller species of interest, that have not been observed, could include beaver, marten, wolverine, cougar, lynx, and various rodents. Deer mice and shrews are probably present. Mule deer tracks and scat are common on the tailings piles, especially where the cover is better established. Golden-mantled ground squirrels and chipmunks were also common in these areas, and a marmot was observed on one occasion. Mink are likely to be present in the area, although they have not been observed, probably because of their nocturnal behavior.

The birds common to the area included bald eagles, hawks, owls, grouse, and woodpeckers. Violet-green swallows and barn swallows forage for insects over the tailings piles, and a flock of American pipits was observed foraging on the tailings piles. Immature red-tailed hawks were observed hunting over the tailings piles and may nest in the area.

1500-Level Main Portal Drainage and Seep Areas

Bats have been observed foraging for insects and touching the surface of the stream that flows from the main mine portal. On one occasion, Mule deer were also observed drinking from the 1500-level main portal drainage.

Rare, Threatened, and Endangered Species

Dames & Moore (1996) indicated that only two plants with state sensitive status had been identified in the valley by the Washington Natural Heritage Program (Brewer's cliff-brake and Steller's rock-brake). The report also noted that the U.S. Fish and Wildlife Service Endangered Species Team had determined that to the best of their knowledge there are no listed or proposed threatened or endangered animal species in the Railroad Creek area. However, wolverines were noted as a state sensitive species by the USFS. Table 7.2.2-2 is a listing of the threatened and/or endangered species known to inhabit the Railroad Creek drainage area.

7.2.2.3 Potential Complete Exposure Pathways

The analysis of exposure pathways is critical to an ERA because, by definition, there can be no risk without exposure. The lack of complete exposure pathways may be due to the absence of a bioavailable form of the compound of concern, the absence of a transport pathway, or the absence of a receptor. The analysis of exposure pathways consists of three major elements:

- Source of constituent of PCOC and release mechanism
- Transport media (or medium) and mechanism of transfer from one medium to another
- Point (or area) of potential receptor contact with PCOC

The primary sources of PCOCs considered in this assessment are those associated with the existing source areas associated with mining activities at the Holden Mine, including the underground mine, waste rock piles, the mill area, lagoon, and the tailings piles. Potential release mechanisms from these source areas include surface water runoff, leaching of groundwater from seeps, subsurface interaction with groundwater and air transport of particulates from these source areas that contain PCOCs. Through these release mechanisms, PCOCs originating from past activities at the Site could be potentially transported to ecological receptors.

PCOCs present in primary and secondary source materials (surface water, sediment, soil, and biota that have been exposed to primary source materials including tailings) may be released via several mechanisms, including incorporation into the food-web. PCOCs released to surface water and/or sediment can be contacted or ingested by aquatic and terrestrial receptors. Terrestrial receptors may directly contact or ingest surface soil at the site. Surface runoff could transport surface soil PCOCs to surface water and sediment, potentially exposing aquatic receptors. Through predation, compounds of concern in plant or animal tissues can be acquired by other animals.

EPA (1994) indicates that for ecological receptors, dermal exposure pathways to media such as sediment are very difficult to document as complete and that for many receptors (e.g., small mammals grooming fur) ingestion of PCOCs will likely occur before actual dermal contact. This is especially true for metals which are not permeable to the skin except in ionic form. For this reason, dermal exposure will be considered to be adequately addressed for ecological receptors as modeled oral doses.

Likewise, inhalation exposure pathways are not well characterized for ecological receptors, no dust measurements were available, and there is no data for absorbance efficiency for wildlife. Because PCOC exposure for ecological receptors cannot be accurately quantified, potential exposure via this route will be considered as an uncertainty to the risk characterization.

Exposure Pathways Analysis

Exposure pathways that are potentially complete at the Site include:

- **Surface Water.** Direct surface water contact (dermal and respiratory) and ingestion are potentially complete pathways to aquatic and terrestrial receptors, respectively.
- **Sediment.** Limited sediment accumulation exists in Railroad Creek because of the high gradient and water flows. However, in those small area where sediment does exist, it could pose an exposure pathway to certain benthic invertebrates. Because sediment will be substantially washed off food items consumed by terrestrial receptors (Beyer 1994), sediment ingestion is not of concern for these animals.
- **Tailings Piles and Soil.** Ingestion of tailings pile surface soil by biota and uptake of PCOCs by vegetation are potentially complete exposure pathways at these sites.
- **Ground Water.** Ground water pathways are not complete for ecological receptors (as it is not directly contacted until it becomes surface water) and will not be considered further because surface water is addressed directly.
- **Biota.** Direct ingestion of biota (including vegetation, aquatic insects, fish, small mammals, etc.) by higher trophic level ecological receptors is a potentially complete exposure pathway at this site. Concentrations of PCOCs measured in fish tissues (PNL, 1992; Ecology, 1993; Ecology, 1994) are the integrated products of the complete exposure pathways and also reflect physiological processes such as elimination and depuration. As such, this pathway was accounted for by direct sampling (by others).

Concentrations of PCOCs in other media, such as vegetation, aquatic insects, earthworms, and small mammals, were accounted for by modeling.

In summary, the exposure pathways that are potentially complete at these sites and that will be quantitatively considered in this ERA are:

- Surface water to benthic organisms and fish
- Sediment to benthic organisms and fish
- Soil to terrestrial vegetation
- Soil to other terrestrial receptors
- Vegetation to terrestrial herbivores and omnivores
- Terrestrial and aquatic biota to upper trophic level consumers

7.2.2.4 Sentinel, Indicator, and Surrogate Species - The Guild Approach

Receptor guilds (organisms with similar life histories or niches in the environment) have been used rather than individual species for this assessment because the general characteristics of each guild will provide risk estimates that are representative of the entire guild. As such, these can be extrapolated more broadly than single species estimates. The underlying concept is that each receptor of particular concern falls into a group of potential receptors that function in similar ecological niches ("guilds"). For example, many species of hawk feed on small mammals and require trees or cliffs for roosts. As such, each of these hawks display similar life-histories and would be anticipated to have similar exposures to PCOCs at the sites. A single surrogate, for example the red-tailed hawk, for which good life-history information, or toxicological data is available, may be used for modeling purposes and results may be extrapolated to the "mammal-eating hawk guild" as a whole. This allows the risk assessment models to directly evaluate species for which the best exposure information is available, but allows results to be extrapolated to a broader range of potential receptors, thereby maximizing data usage and applicability of results.

Representatives in each identified receptor guild and trophic level are selected below. The fundamental assumption is that if the surrogate receptor is protected, the entire guild is protected. Deviations from this assumption are discussed further in the uncertainty section of this report.

7.2.2.5 Selection of ROCs: Guild Representatives

The broadest classifications of receptors selected for this ERA are aquatic and terrestrial plants and animals. Of the animals, fish, mammals, and birds are the three most prominent general groups at the site. Fish, using salmonids as representative species, were selected as an ROC because they are an important valued resource and because they may provide food for certain birds and mammals, as well as recreation for humans. Benthic insects were also selected as ROCs because they are important food items for fish and some birds. Although periphyton is an important component of aquatic food chains, there are only a few reports of the effects of metals on these communities. Therefore, this trophic level will only be discussed briefly and qualitatively.

Although amphibians may exist at the site, and may be at risk from metals contamination, there is very little toxicological data for these animals. The available mean toxicity data for amphibians exposed to cadmium, copper, lead, and zinc is shown in Table 7.2.2-3. With the exception of one series of tests with one species of amphibian (*Gasterophyene carolinensis)* tested, all other available data shows amphibians to be less sensitive than salmonid fishes (Table 7.2.3-1B). This one amphibian species is native to Kentucky and is not found in Washington. When this species was exposed to mercury at different dates in the same laboratory, much higher (1,300 times) LC50s were obtained (Table 7.2.2-3), and even this higher LC50 was lower than was found for 13 other species, and 16.6 times lower than the mean of all species tested (Table 7.2.2-3). Thus, this species and series of tests are not representative of the majority of amphibians toxicity test results. Therefore, amphibians were considered to be protected by the toxicity reference values used for salmonids and amphibians were not selected as an ROC.

Terrestrial plants were also selected as ROCs because of their major role in primary production, their role of providing food for herbivores, and their scenic and economic value to humans. Likewise, earthworms have been selected to represent terrestrial invertebrates because of their role in nutrient cycling and providing food to birds and mammals.

Mammals and birds were selected as ROCs. Mammals and birds are further subdivided into carnivores (piscivores, invertevores), herbivores, and omnivores. Life history and related information (e.g., Terres, 1982; Palmer and Fowler, 1975; USEPA, 1993) was reviewed to identify surrogates for these receptor guilds for which sufficient ecological and toxicological information exists to perform a quantitative assessment of risk. In keeping with species observed on site and the guild approach discussed above, a list of ROCs was selected for the quantification of risk at the Holden Mine aquatic and terrestrial habitats. The resultant list of receptor guild surrogates is shown in Table 7.2.2-4. These species or guilds were selected for risk characterization in the following sections because 1) they are most likely to be present and because 2) there is an adequate toxicological database to support the analysis.

Sources of Toxicity Data

Risks to trout and benthic invertebrates were estimated using *"Toxicological Benchmarks for Screening Potential Contaminants of Concern for Effects on Aquatic Biota"* (Suter and Tsao, 1996). Grasses and forbs exist on the soils and mine tailings areas and toxicity to such plants can be estimated using the data presented in *"Toxicological Benchmarks for Screening Contaminants of Potential Concern for Effects on Terrestrial Plants"* (Efroymson et al., 1997). Essential ecological data for estimating risk to birds and mammals are available in *"Toxicological Benchmarks for Wildlife"* (Sample et al., 1996), *"Methods and Tools for Estimation of the Exposure of Terrestrial Wildlife to Contaminants"* (Sample et al., 1997), and *"Wildlife Exposure Factors Handbook"* (USEPA, 1993). By using the plant uptake factors in Efroymson et al. (1997), it is possible to estimate risk to herbivores such as the mule deer, and deer mouse. Similarly, by using uptake factors in "*Development and Validation of Bioaccumulation Models for Earthworms*" (Sample et al., 1997b) and "*Development and Validation of Bioaccumulation Models for Small Mammals*" (Sample et al., 1998), it was possible to estimate the doses and risk to shrews, mink, and red-tailed hawk. Estimating risk to American dipper and little brown bat involved simple modeling of body burdens in aquatic insects. Measured body burdens in trout were used to estimate doses to mink and osprey. At each trophic level, these benchmark documents were supplemented with original, peer-reviewed literature and field study results to account for site-specific differences.

7.2.2.6 Conceptual Site Model

The CSM integrates sources, release mechanisms, transport media, transfer mechanisms, and complete receptor exposure pathways. For this Baseline ERA, three relatively distinct exposure sources form the bases of the CSM. These sources are: 1) surface water and sediments, 2) tailings soils, and 3) seep water. The ecological CSM for this site (Figure 7.2-1) provides a pictorial representation of the pathways of potential PCOC movement from primary sources to secondary, and tertiary sources and receptors. It is these relationships that drive potential environmental and exposure risks, as well as risk management decision making.

7.2.3 Analysis

7.2.3.1 Assessment and Measurement Endpoints

Definitions of endpoints and methods of endpoint selection generally follow the guidance and draft guidance provided by EPA (1989, 1994). To determine if adverse impacts have occurred or are occurring as a result of constituents released by past mining activities, it is necessary to determine which assessment endpoints will be used in the evaluation and to understand how the various measurement endpoints relate to the assessment endpoints in the overall weight-of-evidence approach adopted herein.

The process of endpoint selection begins with identification of risk management goals for environmental components and ROC that may be susceptible to chemical substances in the environment. In general, the goal for this site is to protect the populations, communities, and ecosystems that may be exposed to site-related PCOCs.

Assessment Endpoints

Assessment endpoints are general, large-scale expressions of environmental components or characteristics that may be at risk and, therefore, require protection. Although related and highly interdependent, measurement and assessment endpoints are not the same. In general, measurement endpoints are actual measurements of chemical or biological parameters that are used to evaluate the assessment endpoints. This evaluation then forms the basis for extrapolation of results to higher levels of organization or complexity. The assessment endpoints identified for this investigation are:

- Decline in health and viability of populations of avian carnivores
- Decline in health and viability of populations of terrestrial mammals
- Decline in health and viability of populations of fish and other aquatic receptors

These assessment endpoints are evaluated specifically with information obtained from measurement endpoints (below) to determine if reduced survival, impaired reproduction, or growth inhibition in local populations and communities are likely. The assessment endpoints were evaluated as the no observed adverse effect level (NOAEL) from toxicity benchmarks, guidelines, or toxicity reference values (TRVs) for endpoints having potential effects on populations (i.e., growth, reproduction, development) of plants or animals.

Measurement Endpoints

Measurement endpoints are parameters obtained by site-specific environmental sampling or laboratory testing. The measurement endpoints selected for the Site include a variety of analytical and observational data. Information derived from these measurement endpoints were used to evaluate assessment endpoints. The specific measurement endpoints (data) used in this assessment are:

- **Surface water samples.** These provide data on PCOC distributions and concentrations at the Site, and permit evaluation of potential ecological risks to aquatic receptors exposed via PCOCs in surface water and to terrestrial receptors through ingestion (drinking).
- **Sediment samples.** These provide information on PCOC distributions in sediments at the Site, and permit evaluation of ecological risk to aquatic receptors exposed via PCOCs in sediment.
- **Tailings piles and soils samples.** These provide data on PCOC distributions in soils and tailings piles at the Site, and provide an estimate of PCOC concentrations in the soil ingestion fraction in dose modeling for mammals (where applicable).
- **Fish tissue samples.** These provide baseline evidence of presence/absence of PCOCs in the Site's aquatic food-web, can be used to estimate PCOC concentrations in diet for calculating dietary dose to fish-eating birds or mammals, and may be used to directly assess impacts to fish where applicable body burden toxicity information is available.
- **Benthic community assessments.** These are indicative of potential impacts as expressed directly by the characteristics of the benthic communities.
- **Fish community assessments.** These are indicative of potential impacts as expressed directly by the populations in fish communities.

7.2.3.2 Toxicity Benchmarks

Toxicity benchmarks are screening level estimates of the concentrations of chemicals that are expected to cause no adverse effects on plants or animal populations. These generally take the form of state or federal promulgated criteria, but may also include databases or guidelines developed by state, federal, or private organizations which are recognized as estimates of safe concentrations. In this document, several tiers of toxicity analysis were conducted. In the first tier, media concentrations of metals were compared to federal or state screening values. Those metals that were below these screening values were eliminated from further analysis. Those metals that exceeded these screening values were carried through the risk assessment. In the second tier of analysis, more site- and receptor-specific toxicity was sought in the peer-reviewed toxicity literature and these values became the toxicity benchmarks for evaluating risk. The following section deals with tier I, elimination of COCs. The tier II toxicity reference values are also found according to specific receptor, below.

Aquatic Habitats

Surface Water

The potentially complete exposure pathways for PCOCs at the Site include aqueous and sediment contact and ingestion by aquatic receptors. The toxicological benchmarks against which aquatic exposures were to be compared in this baseline ERA included 1) the water hardness adjusted criteria (WAC 173-201A) that were derived to protect aquatic receptors regardless of the specific exposure pathway, and 2) published, species-specific, toxicity test results. Because fish species move within the water column, the 95 percent upper confidence limit (UCL) of the Site data and the median surface water concentrations, were compared to acute and chronic water quality criteria. Where the sample size was too small to calculate the UCL, the highest value was used for screening purposes. Since plants and animals are not directly exposed to groundwater, this media was not considered as an exposure source in itself.

Surface water data were separated into those that are representative of the mainstream of Railroad Creek (not including samples collected adjacent to seeps emanating from the south bank of Railroad Creek) (Tables 7.2.2-1B1, B2, B3), and those that are associated with seeps along the south bank of Railroad Creek (Table 7.2.2-1A). In addition, Railroad Creek was divided into three reaches: (1) upstream of Site (including RC-11, RC-6, RC-1 and USGS and Ecology samples collected within this reach); (2) adjacent to Site (RC-4, RC-7, RC-2 and Ecology samples collected within this reach); and (3) downstream of Site (RC-10, RC-5, RC-8, RC-3 and Ecology samples collected within this reach). As specified in WAC 173-201A, metals concentration criteria were hardness adjusted for the mean measured hardness of 14.5 mg/L for those metals that are hardness dependent: cadmium, copper, lead, nickel, and zinc. These screening values and 95 percent upper confidence levels of surface water data are shown in Table 7.2.3-1A. Elements were eliminated if they did not exceed these criteria, or if there is no toxicity benchmark by which to judge toxicity.

While USGS (1996) samples collected from locations 603 and 628 exceeded water quality criteria for manganese and had the highest concentrations of most other metals analyzed, these samples were collected from the creek bank immediately downstream from seep areas, not in the main stream where fish and invertebrates would be found. Because of the large dilution effect of Railroad Creek, these samples and other samples collected directly from seeps or portals were not considered as riverine habitat for invertebrates or fish. All metals except lead fell below the federal criteria in Copper Creek and were not further analyzed for risk to aquatic or terrestrial receptors.

In summary, there was no need to further evaluate the following metals because concentrations were below federal criteria or toxicity benchmarks are not available to evaluate toxicity.

- **Surface Water** – aluminum; arsenic; barium, beryllium, chromium, iron, mercury; manganese, nickel; and silver.

Fish Bioassays

Comparison of Tables 7.2.2-1B1, B2 and B3 with 7.2.3-1A shows that all of the UCLs for surface waters where copper was detected, including Holden Creek, exceeded the chronic water quality criterion for copper and lead at a hardness of 15 mg $CaCO_3$/L. This was also true for Bridge Creek, Company Creek, and the south fork of Agnes Creek, reference streams at a hardness of 14 mg $CaCO_3$/L. This is largely attributable to the extrapolation to low hardnesses of bioassay data from the U.S. EPA Research Laboratory at Duluth where the hardness is approximately 45 mg $CaCO_3/L$. However, review of the literature concerning the toxicity of PCOCs to trout shows that they are able to survive and reproduce in considerably higher concentrations than would be expected based upon the benchmarks given above. Recent reports from the Clark Fork Superfund Site near Butte, Montana, reveal that the water quality criteria may substantially overpredict toxicity at lower water hardnesses (ARCO, 1996).

The criteria include data for species of animals not found in Railroad Creek. Furthermore, there are many studies of cadmium, copper, lead, and zinc toxicity to salmonid fishes conducted at low water hardness (Table 7.2.3-1B) which are more appropriate for Railroad Creek fish species and water conditions. As a rule, the Salmonidae are generally considered to be the most sensitive family of fish to metals (Spry et al., 1981). These Toxicity Reference Values (TRVs) include both acute and chronic endpoints and full life cycle maximum acceptable toxicant concentration (MATC) values. The mean of the fish bioassay data for each metal was considered to provide a weight of evidence that higher concentrations of metals can be tolerated by salmonid fishes in very soft waters. Because arsenic, mercury, and nickel did not exceed the screening criteria, no site-specific TRVs were developed for these metals.

The chronic value for iron used in this risk assessment (1300 µg/L) is also different from the national NAWQC (1000 µg/L). This is because the federal criteria was established on the basis of a 21-day *Daphnia magna* bioassay using acid mine drainage. This is not a currently accepted method of establishing NAWQC, and daphnids are not found in flowing waters such as Railroad Creek. Therefore, for the purposes of this risk assessment, the lowest value from a rainbow trout embryo-larval bioassay (1300 µg/L) was used as the TRV (ORNL, 1996).

These chronic values are at least an order of magnitude greater than the federal criteria modeled benchmark values listed in Table 7.2.3-1A. Since trout are the major resource to be protected in Railroad Creek, the values in Table 7.2.3-1B and the chronic value NOEC for copper (i.e., 2.3 µg/L) were used as TRVs to evaluate risk to fish.

Sediment

In those portions of Railroad Creek where sediments or flocculent have accumulated, toxicity to benthic invertebrates may be judged by comparison with sediment quality guidance values. Chemicals undetected or found in only trace amounts in the water column can accumulate to relatively high levels in the pore-water between sediment particles.

Sediment concentrations were screened relative to appropriate benchmarks (Table 7.2.3-2A). Among available benchmarks are the marine and estuarine sediment quality guidance values of Long et al. (1995), the freshwater guidelines of the Ontario Ministry of the Environment (Persaud et al., 1993), and the Washington State (Ecology, 1997) guidelines for freshwater sediments. Because the marine and estuarine guidelines (Long et al., 1995) are based on a much larger database than the freshwater guidelines, the potential sediment toxicity of Railroad Creek was assessed using these values.

For Long et al. (1995), the effects range-low (ER-L) is defined as the lower 10th percentile and the effects range-median (ER-M) as the 50th percentile (median) of the chemical concentration data set. Based on a "preponderance of evidence," the ER-L and ER-M values define three concentration ranges that were (1) rarely, (2) occasionally, and (3) frequently associated with adverse effects. These categories are based upon the results of a number of different studies with varying endpoints. Each has its own strengths and weaknesses. For this reason, the USEPA (1992) has recommended that a range of chemical concentrations should be used rather than a single value. Nevertheless, the Long et al. (1995) guidelines only present single values for ER-M and ER-L.

Concentrations below the ER-L (between the above-mentioned "rarely" and "occasionally" categories) represent a "minimal effects" range, while concentrations between the ER-L and the ER-M represent a "possible effects" range where adverse effects were occasionally observed. According to Long et al. (1995), concentrations above the ER-M represent a "probable effects" range within which adverse effects are more likely to occur. Nevertheless, Long et al. (1995) recommended that these sediment quality guidelines should be used as "informal screening tools," and NOAA (O'Connor et al., 1998) has recently reported that fewer than 40 percent of the samples that exceeded the ER-M in an extensive sediment quality assessment program, were actually toxic in bioassays. It is important to note, therefore, that because sediment toxicity is not well understood, neither these guidelines, nor any other sediment quality guidelines (see below), have been promulgated into law (i.e., criteria).

The lowest effect level (LEL) of the Ontario Ministry of the Environment (Persaud et al., 1993) indicates a level of sediment contamination that has no effect on the majority of benthic organisms and is calculated as the 5th percentile using the screening level concentration (SLC) method. The severe effect level (SEL) indicates the concentration of a compound that would likely be detrimental to most benthic species and is calculated as the 95th percentile using the SLC method (Persaud et al., 1993). The LEL and SEL values therefore are generally comparable to those of Long et al. (1995), even though the LEL may be somewhat more conservative and the SEL may be more liberal.

Because sediments account for such a small portion of Railroad Creek and because there is little sediment toxicity data for burrowing freshwater invertebrates, no site-specific TRVs were developed for benthic invertebrates exposed to sediments and default sediment guidance values were used. Because reports have shown that metals may interact either synergistically or antagonistically, depending upon the study selected, it was assumed that all metals act independently of each other.

Comparison of the UCL site data from Table 7.2.2-1C with the ER-L screening guidance values presented in Table 7.2.3-2A shows that several metals in sediments and flocculent fall below the screening values. The sediment sample data collected from Lucerne Bar during the RI (see Section 5.0) was not addressed in the ERA as additional sampling is pending. Elements were eliminated if they did not exceed the screening value (ER-L or LEL) or if there was no toxicity benchmark by which to judge potential toxicity. Screening values are not available for aluminum, barium, beryllium, or selenium and potential toxicity cannot, therefore be assessed. In summary, there was no need to further evaluate:

- **Sediment** – aluminum, barium, beryllium, lead, mercury, and selenium
- **Flocculent** – aluminum, barium, beryllium, lead; manganese; nickel and selenium

Invertebrate Bioassays

Sediment bioassays are very difficult to interpret because of the complex matrix interferences with organic carbon and sulfides, and because it is the pore-water of sediments, not the bulk sediment metals concentration that contains the bioavailable metal that causes toxicity. Furthermore, in high gradient, fast moving stream such as Railroad Creek and Copper Creek, very little sediment accumulates, and the macroinvertebrates that serve as trout and dipper food are largely attached to hard substrates. Therefore, the toxicity to benthic invertebrates (largely insect nymphs) in Railroad Creek is more properly estimated based upon aqueous exposures rather than sediment exposures.

Commonly used bioassay animals such as *Daphnia* magna and *Ceriodaphnia dubia* are not found in flowing waters such as Railroad Creek, but are always included in the calculation of water quality criteria. Therefore, a number of studies with benthic invertebrates similar to those found in Railroad Creek (i.e., stonefly, caddisfly, mayfly, damselfly) were reviewed and compiled (Table 7.2.3-2B). These data, used subsequently as tier II toxicity values, were gathered from experiments for 96 hours (acute) or greater (chronic), and include several no observed effect concentrations (NOECs). Where greater than (">") values were reported these were ignored and the values used were unchanged. Where ranges were reported, both low and high estimates were used. These data were considered to provide a weight of evidence that higher concentrations of metals can be tolerated by benthic macroinvertebrates than is apparent in the water quality criteria. Since most of the benthic invertebrates found in Railroad Creek are insect nymphs that attach to hard substrates, the benthic invertebrate study values in Table 7.2.3-2B were used to evaluate risk to aquatic invertebrates.

Terrestrial Habitats

Soils

Neither the USEPA nor the State of Washington have established ecologically-based screening levels for soils. Therefore, the Oak Ridge National Laboratory toxicological benchmarks for plants (Efroymson et al., 1997) and earthworms (Will and Suter, 1997) were used to screen soils. In addition, because cyanide was not evaluated by ORNL, this value is the target value designated by the Dutch Ministry of Soil Protection (1996). These are used in conjunction with the upper 90th percentile of background soils data compiled by Ecology (1994) for the Yakima Basin, which includes Chelan County, and 1998 background values collected near the site (Dames & Moore, 1997). If the background was higher than the toxicity benchmark, the background concentration became the screening value. If the site data exceeded the natural background values as well as the toxicity benchmark values for plants or earthworms, the hazard analysis proceeded. Metals were eliminated as COCs if: (1) the background data exceeded the site data, (2) there were no phytotoxicity or earthworm data, or (3) there were no background data by which to judge if the site data was greater than background. In addition, chromium was eliminated because there were no Cr^3 toxicity values, and this is the major form available in the natural environment. Silver was eliminated because there is no primary toxicity value available (Efroymson et al. 1997; Will and Sule 1995).

The soil screening values are shown in Table 7.2.3-3A. Comparison of the UCL of the site data from Table 7.2.2-1E with the screening criteria presented in Table 7.2.3-3A shows that several metals in soils and tailings fall below the screening values; therefore, the following metals were not evaluated further:

- **Soil** – aluminum, arsenic, barium, beryllium, iron, manganese, mercury, nickel, selenium, silver and thallium

Since there is little or no toxicity data for mammals or wildlife exposed to metals potentially found in air-borne dust, and no Site dust data exists, this potential exposure pathway was not evaluated for risk, although it was screened against soil criteria. Furthermore, because of the more intricate nasal passageways of most wildlife, it is unlikely that they will be more sensitive to air-borne dust than humans. Since there was no risk to humans, it is unlikely there would be risk to wildlife.

In Situ Bioassays

The Forestry Sciences Laboratory of the USFS and the College of Forest Resources at the UW have conducted a number of revegetation experiments on tailings piles at the Site. In 1973 and 1974, attempts to revegetate tailings piles were influenced by higher than normal temperatures and high winds. This combination of conditions led to desiccation and burial of seedlings. Nevertheless, a variety of grasses germinated and grew. Tailings piles were treated with dolomite or milorganite (limestone) to increase tailings pH, ammonium nitrate as a source of nitrogen, and treble superphosphate as a source of phosphorus (UDFS, 1973). In order of performance, the plants tall wheatgrass (*Agropyron elongatum*), crested wheatgrass (*Agropyrun crestatum*), alta tall fescue (*Festuca arundinacea*), and Regar brome (*Bromus biberstenii*) established well on the treated tailings piles under irrigated conditions. The native plants, *Calamagrostis canadiensis* (a plant in the same tribe as Indian ricegrass), *Juncus lbescens* and *Juncus d. rummondy* (both sedges), and *Salix lasiolepis* (a willow), were found in a spring near plot 9 of this study. Mosquito larvae and tadpoles were also found in a nearby spring.

In 1993, the USFS planted seven different tree seedlings, eight grass species, three shrubs and one forb in combination with different soil amendments. Fertilizing and mulching gave better results than Milorganite or no treatment. Ponderosa pine and lodge pole pine were the best performers on soil islands, and Sitka alder also grew well, despite predation by deer. Over-liming was also thought to be a problem for Sitka alder. The addition of gravel to the tailings piles reduced the wind drift effect found earlier to cause decreased productivity, and provide cracks for seedling germination. Four species of forbs and shrubs were successfully introduced into sewage-treated soils. Growth in lupine was greatest, largely because these plants contain chemicals which are obnoxious to herbivores and the deer graze on penstemon (*Penstemon speciosus*) and alder early in the season.

Despite this success, the USFS noted that natural immigration and establishment of native plants on unamended soils was proceeding at a faster rate than that on amended soils. Natural immigrants of Douglas fir, Ponderosa pine and Sitka alder, as well as numerous individuals of spruce were observed within and outside the transects. At least thirteen species of forbs were also observed to have been successfully been naturally transported to the tailings piles. Along the creekside, 90 percent of the introduced cottonwood (*Populus trachocarpa*) and 35 percent of the alder (*Alnus sinuata*) were successfully introduced into untreated soils.

Zabowski and Everett (1997) concluded that the overburden and tailings contained levels of extractable copper and zinc that should not cause toxicity problems for plants, but that manganese deficiencies might be a problem. Concentrations of cadmium, copper, nickel, and zinc were not sufficient to cause adverse effects on Sitka alder or lupine, and the report stated that the lupine looked particularly healthy.

In addition, Kruckeberg and Wu (1992) reported that seeds of *Arenaria douglasii*, *Bromus mollis*, and *Eschscholtzia caespitosa* collected from soils containing 1680 ppm copper from the Copperopolis Mine site were very tolerant of soil copper concentrations. Several other species (*Vulpia myrous, Lotus purshianus,* *Lupinus bicolor*, and *Trifolium pratens*) were also significantly more tolerant of copper than plants not growing on mine soils.

The information provided above indicates that phytotoxic conditions do not currently exist at several areas at the Holden site. Therefore, it was desirable to develop a tier II set of toxicity benchmarks by which to judge the potential toxicity of the Holden soils to plants. Beyer et al. (1985) reported that a number of plants were able to survive and grow at a site contaminated with cadmium, copper, lead, and zinc (Table 7.2.3-3B). These values were used as TRVs for plants.

Aquatic and Terrestrial Birds and Mammals

Oak Ridge National Laboratory (Sample et al. (1996) has compiled a series of toxicological benchmarks for birds and mammals. However, for certain mammalian species, these benchmarks were supplemented and/or replaced with peer-reviewed published toxicological data. Tables 7.2.3-4A and 7.2.3-4B list the selected ROCs, PCOCs, and benchmark values. If PCOCs were not toxic to plants or earthworms, it was assumed they would not be toxic to birds or mammals.

<u>Birds</u>

Sample et al. (1996) recommended that the TRV for site-specific avian species should be the same as the NOAEL for the surrogate species used. This decision was based upon data developed by Mineau et al. (1996) which showed that scaling factors for body mass in birds were not significantly different from unity. This conclusion is supported by Hancock (1997). Since there is no evidence that scaling is appropriate for birds exposed to metals, no scaling for body size was used in the present document. This was considered a conservative approach since most of the birds used in bioassays are larger than the potentially most exposed ROCs, the American Dipper and the American Robin, and scaled sensitivity increases with decreasing body mass.

Where only LOAEL data were available, ORNL estimated the NOAEL by dividing the LOAEL by 10. In the present study, where the ORNL no effect concentration (NOEC) and the lowest effect concentrations (LOEC) were close, the ORNL NOAEL was accepted without change. However, where there are large gaps between the NOEC and the LOEC, there is a risk that the real NOEC much higher than the lowest concentration tested. Therefore, where the NOEC and the LOEC were separated by a factor of 10-fold or more, the NOAEL was estimated from the LOAEL by dividing by 5. This is justified because Lewis et al. (1990) showed that a factor of 5 is adequate to account for the LOAEL to NOAEL conversion in 96 percent of the 52 species where both LOAEL and NOAEL data were available. Dourson and Stara also found that a factor of 5 <u>or less</u> was sufficient to account for the conversion of LOAELs to NOAELs in 96 percent of chemicals tested (EPA, 1997). Therefore, for this risk assessment, NOAELs were estimated from LOAELs by dividing by 5. The TRVs for birds are shown in Table 7.2.3-4A.

Small Mammals

TRVs for representative mammals were obtained by scaling surrogate toxicity data by body size (EPA, 1993; Sample et al., 1997):

$$NOAEL_W = NOAEL\,(Body\ Weight_S / Body\ Weight_W)^{0.25} \qquad 7\text{-}15$$

where

w = wildlife

s = surrogate

This method was used for calculating the TRVs (Table 7.2.3-4B) for the little brown bat (0.055 kg body weight), deer mouse (0.022 kg body weight) and dusky shrew (0.021 kg body weight) from the mouse and rat data given in Sample et al. (1996).

Large Mammals

The scaling method works well for animals, such as bats, mice, and shrews that are approximately of the same size, but it fails when very large differences in size exist between the surrogate and site-specific ROC. For example, the logical extension of scaling is that shrews can withstand the highest exposures, while elephants will be killed by the smallest exposures.

Therefore, an alternative toxicity data set was needed to supplement that provided by Sample et al. (1996) in order to estimate TRVs for larger animals. These data sets are shown in Table 7.2.3-4B for mink (1 kg body weight), and mule deer (60 kg body weight). For cadmium and lead, where only LOAEL values were available as mammalian benchmarks, the NOAEL was estimated by dividing the LOAEL by 5 based on the rationale discussed above.

7.2.3.3 Exposure Assessment

Aquatic ROCs

The primary aquatic ROCs are trout, benthic macroinvertebrates, and the birds and mammals that feed upon these lower animals. NAWQC were not exceeded for arsenic, manganese, mercury, or nickel. Therefore, these metals and organic compounds were not considered COCs for the baseline risk assessment for aquatic ROCs.

Trout and Benthic Invertebrates

Exposure to trout and benthic invertebrates are predominated by the concentrations of metals and pH in the creek surface waters.

Although trout could acquire metals through the ingestion of contaminated prey, such as benthic invertebrates, previous studies have shown that the assimilation efficiency of the fish gut for metals is very low (Spry et al., 1988; Handy, 1992). Therefore, toxicity was only judged by comparison with site-specific surface water metal concentrations and the estimated toxicity values for metals concentrations causing adverse effects on trout species (Table 7.2.3-1B1, B2, and B3) such as are found in Railroad Creek.

Although certain benthic invertebrates burrow into soft sediments in some environments, the high currents and hard surfaces on Railroad Creek assure that the majority of benthic species are attached to hard surfaces and are only exposed to surface water metal concentrations. Furthermore, although some benthic invertebrates may ingest metal particulates or flocculent with their diet of periphyton, there is no exposure or toxicity data by which to judge the severity of such exposures. However, because of the oxygen requirements of both invertebrates and fish, and the high rates of ventilation as opposed to low rates of gut peristalsis, the aquatic portion of metal body burdens are generally thought to be the more important route of exposure except in waters of very low metals concentrations (Handy, 1992; Spry et al., 1981; Hodson et al., 1980). Therefore, the risk to benthic invertebrates was estimated by comparison with site-specific water concentrations and toxicity values for metals concentrations (Table 7.2.3-2B) causing adverse effects on benthic invertebrates such as are found in Railroad Creek. In addition, however, sediment data collected by USBM (1995), and Ecology (1997) as well as flocculent samples collected by Dames & Moore (1998) in slow moving reaches of Railroad Creek, were compared to sediment quality guideline values (Table 7.2.3-2A). This analysis was not separated from evaluation of the hyporheic zone because it is undefined in Railroad Creek and because the same insect larvae are found in the hyporheic zone as were evaluated for the surface waters.

Because none of the metals in Copper Creek exceeded these receptor-specific benchmarks for either benthic insects or trout, no further analysis of risk was conducted for this stream. In general, metals levels in Copper Creek were the same as the reference stations at Ten-Mile Creek, Bridge Creek, Company Creek, and the South Fork of Agnes Creek.

American Dipper

Dippers are insectivores that feed in riffles on benthic macroinvertebrates such as caddis fly and stonefly nymphs. No measurements were made of the concentrations of metals in benthic invertebrates at the site.

Kemble et al. (1992) reported concentrations of cadmium, copper, lead, and zinc in pore-water and benthic macroinvertebrates collected from the Clark Fork River (CFR), near Butte Montana. Cain et al. (1992) reported that these animals were mainly caddisflies and stoneflies, animals expected to be fed upon by dippers and common in Railroad Creek. To estimate the body burdens of cadmium, copper, lead, and zinc in Railroad Creek invertebrates, a simple ratio of the UCL of Railroad Creek water concentrations divided by the closest concentration of CFR pore-water was multiplied by the CFR body burden (Table 7.2.3-5; 7.2.3-6). There are no data available for iron concentrations in benthic invertebrates.

Exposure to birds was estimated using mass-dependent algorithms (ERA, 1993). The water ingestion rate (W) in birds was estimated as:

$$W\ (L/d) = 0.059 \times (\text{kg Body Weight})^{0.67} \qquad 7\text{-}16$$

where

0.67 = relationship between body mass and water requirements

The food ingestion rate was estimated as:

$$F\ (kg/d) = 0.0582 \times (kg\ Body\ Weight)^{0.651} \qquad 7\text{-}17$$

where

0.651 = relationship between body mass and food requirement

Dippers average about 0.055 kg body weight (Dunning, 1993) and when the results of the algorithms are divided by the body mass (kg), the daily ingestion rates for dippers were estimated to be 0.16 kg food/kg body weight/day and 0.154 L/kg. The total exposure dose (D) from diet, water, and soil (if appropriate) are summed:

$$D = F + W + S \qquad 7\text{-}18$$

The predicted total daily doses to metals through the worst-case dietary and water sources are shown in Table 7.2.3-7.

Osprey

Osprey obtain nearly 100 percent of their caloric requirements from the consumption of fish. Ospreys are migratory and spend the winter months in Latin America and the Caribbean Basin (Poole, 1993). They are not abundant in the Pacific Northwest, except in the Coeur d'Alene area of Idaho. In the west, they are largely dependent upon freshwater lakes, large rivers, and reservoirs for their prey. The southerly migration usually begins in the last two weeks of August in northern latitudes. Winter populations in Oaxaca Mexico reach a plateau between October and March, so that any ospreys feeding in the Lake Chelan area would only be present for about 5 months a year, approximately April 15 to August 15 (Poole, 1993). Since the birds dive into the water to catch the fish, the waters used for fishing must be at least several feet deep. Furthermore, ospreys do not hunt in turbulent waters. Although it is very unlikely that ospreys would forage in Railroad Creek, risk was assessed for ospreys foraging in Railroad Creek.

Ospreys average about 1.55 kg body weight (Dunning, 1993) and consume fish in the 100-300 g weight class and the 10-14 inch length range (Pool, 1993). Using the algorithm for food consumption, this is a daily wet weight ingestion rate of 255 g fish. This agrees well with the data provided by Poole (1984). During the breeding season ospreys need to consume 6 to 8 fish or about 1250 g/day (Poole, 1984). Of this, approximately 400 g is eaten by the male, 360 g by the female, and the remaining 490 g by the young. This is a wet weight food consumption rate of 0.258 kg/kg/day by the adult male.

Pacific Northwest Laboratories (PNL, 1992) measured copper, iron, selenium and zinc concentrations in muscle and liver of cutthroat trout captured at 1) the wilderness area boundary, 2) tailings pile 3) Lucerne, and 4) 25-Mile Creek. Although additional rainbow and cutthroat trout data were collected by Ecology (1993, 1994) at these same locations, and analyzed for aluminum, arsenic, copper, iron, lead, nickel, and zinc, only Cu, Fe, Hg, Se and Zn were measured above detection limits. There are no reliable toxicity benchmarks for iron, and iron is an important micronutrient. Therefore, only copper, mercury, selenium and zinc were evaluated.

The liver of rainbow trout constitutes about a maximum of 2 percent of the total body weight. If it is assumed that muscle constitutes the remaining 98 percent, the whole fish metals concentrations can be estimated from the available liver and muscle data. The whole body copper, mercury, selenium and zinc concentrations that would be consumed by osprey feeding on trout are shown in Table 7.2.3-6. These values agree well with those reported by Harper Owes (1989) for kokanee, chinook salmon, and rainbow trout collected in Lake Chelan. In that study, whole body copper ranged from 0.66 to 2.4 mg copper/kg, and zinc ranged from 5 to 19 mg/kg. Roch et al. (1985) have also shown that liver and muscle cadmium, copper, lead and zinc concentrations do not differ significantly between rainbow and cutthroat trout exposed to mine tailings contaminated water. Therefore, the values for rainbow trout are also applicable to cutthroat trout. While the copper and zinc concentration means increased between the upstream area and the downstream of tailings pile 3, iron, selenium and mercury decreased over the same area.

Ecology (Patmont et al., 1989) also collected fish tissue data on arsenic, cadmium, lead, mercury, and selenium concentrations in kokanee, chinook salmon, and rainbow trout from different areas of Lake Chelan. Arsenic, cadmium, lead, selenium and mercury were below method detection limits. There was no relationship between copper, zinc, or selenium concentrations in these fish and the proximity of the collection area to Railroad Creek.

Using USEPA (1993) algorithms, the concentrations of metals ingested by ospreys through drinking were conservatively estimated from the UCL of the surface water copper, iron, mercury, and zinc (total) concentrations collected in the Fall of 1997. Selenium was never detected. Table 7.2.3-8 shows the estimated doses for a 1.55 kg adult male osprey consuming 0.255 kg of fish per day, and drinking 0.05 L/kg body weight/day.

Mink

Mink are carnivores which feed, in order of importance, on mammals, fish and amphibians, birds, reptiles and invertebrates. Population density depends upon available cover and food, but typically ranges from 0.01 to 0.1 mink per ha. Mink home range depends largely upon food abundance but ranges from 7.8 to 20.4 ha. in heavily vegetated and sparsely vegetated habitats, respectively (Mitchell 1961). Home ranges are usually aligned with waterways and, in Idaho, mink were never observed more than 200 m from water (Melquist et al., 1981).

In some locations, the mink derives a major portion of its diet from fish consumption (Erlinge, 1969; EPA, 1993), but mink are not successful in capturing salmonid or other fast swimming fishes in some areas (Erlinge, 1969). However, in Michigan, Alexander (1977) reported that trout comprised between 52 and 56 percent of the diet during different seasons. Nevertheless, for the purposes of conservatism, it was assumed that trout comprised 100 percent of the diet along Railroad Creek (Table 7.2.3-6).

EPA (1993) algorithms were also used to estimate the doses for mammals. The water ingestion rate (W) in mammals was estimated as:

$$W\ (L/d) = 0.099 \times (\text{kg Body Weight})^{0.90} \qquad 7\text{-}19$$

The food ingestion rate for placental mammals was estimated as:

$$F\ (kg/d) = 0.0687 \times (kg\ Body\ Weight)^{0.822} \qquad 7\text{-}20$$

When these values are divided by the body mass (kg), the daily ingestion rates may be estimated in terms of kg food, or L water consumed per kg body weight per day.

Adult male mink weigh about 1 kg and consume about 0.069 kg food/kg body weight per day, and ingest about 0.099 L/kg body weight per day (EPA, 1993). The estimated doses are shown in Table 7.2.3-9.

Terrestrial ROCs

Plants

Zabowski and Everett (1997) reported that the native vegetation of the Holden Site is classified as Western Hemlock-Pacific Silver Fir habitat type. The Site is located at the 1000 M elevation, and is climatically severe. During the summer, temperatures reach 38°C, and during the winter, snowpacks can be 2-3 M deep. In addition, down-valley winds increase evaporation.

It is important to recognize that soil toxicology is as complex or more complex than sediment toxicology, and that similar problems exist in applying single guidance values to sites with different characteristics. The qualitative and quantitative data presented in Table 7.3.3.3B on native plant growth at Holden Mine should be given equal weighting when judging the potential impacts of mine tailings on plant communities.

Plants may accumulate metals that may be passed on to herbivores. Efroympson et al. (1997) provide algorithms (Table 7.2.3-10) by which the concentrations of metals in plants can be estimated (Table 7.2.3-6).

Earthworms

Earthworms consume soil and extract energy by digesting organic matter and associated microbes. Earthworms are eaten by birds, such as robins, and small mammals, such as shrews. Thus, earthworms are important in the re-cycling nutrients. Earthworms may contain metals in their tissues that can then can be acquired by robins and shrews. Sample et al. (1998) provide algorithms (Table 7.2.3-10) for the concentrations of metals in earthworms (Table 7.2.3-6).

Mule Deer

The mule deer is a medium-sized herbivore. During the summer in Utah, they feed largely upon forbs in dry meadow, wet meadow, mature forest, and stagnated forest lands (Deschamp et al., 1979). In old growth forest in Washington, they feed largely on trees during the winter, but switch to forbs in the spring (Leslie et al., 1984). Deer have been reported to cause significant adverse effects on re-vegetation attempts on the Holden Mine tailings piles.

During the spring and summer, mule deer confine themselves to small, individual home ranges within which very short daily movements are necessary (Mackie et al., 1982). However, migratory movements are characteristic of populations inhabiting mountain-foothill habitats. Fall migrations are forced by snow falls of greater than about 15 to 30 cm. In migratory situations in Colorado, mule deer had winter home ranges of between a low of 34 ha. for does, and an high of 819 ha. for bucks. Summer home ranges of does averaged 92 ha., while adult males ranged over areas of between 52 and 66 ha.

The food ingestion rate for herbivorous mammals was estimated as:

$$F\ (kg/d) = 0.0875 \times (kg\ Body\ Weight)^{0.727} \qquad 7\text{-}21$$

The largest mature male mule deer weigh about 150 kg but the average weight in west coast adult populations is about 60 kg. Mule deer consume about 22 g dry food/kg body weight/day (Alldredge et al., 1974). Mule deer obtain a large portion of their water requirements from vegetation, but consume between 47 and 70 mL/kg body weight/day when confined in pens in the summer. In addition, mule deer are assumed to ingest soil equivalent to about 2 percent of their diet (Sample et al., 1997).

No direct measurements of concentrations of metals in plants were obtained at the Holden Mine site. However, Efroympson et al. (1997) have summarized the available data on soil-to-plant uptake factors (Table 7.2.3-10), and these can be used to estimate concentrations of metals in the plants (Table 7.2.3-6) at the Holden Mine site.

Not all of the metal concentrations found in the diet or in incidentally ingested soil are bioavailable. Table 7.2.3-11 shows the bioavailability of metals from soils and the default bioavailability assumptions for plant matter.

Table 7.2.3-12 uses these soil-plant uptake algorithms, UCL concentrations of metals, and bioavailability from soil and tailings piles at the Holden Mine site to predict potential doses that mule deer may receive.

Deer Mouse

Deer mice are highly opportunistic omnivorous rodents (EPA, 1993) which largely consume seeds during the fall and winter, and arthropods during the summer. They cache food for the winter in the northern extent of their geographical range. They have home ranges from 0.014 to 0.128 ha, depending on population density. Sample et al. (1996) provided an algorithm for the food consumption by rodents:

$$F(kg/d) = 0.0306 \times (kg\ Body\ Weight)^{0.564} \qquad 7\text{-}22$$

Deer mice weigh about 0.022 kg and ingest about 0.16 kg food/kg body weight per day. Non-seed food provides a large portion of the animals water requirement. Incidental soil consumption is less than 2 percent of the diet volume. Although deer mice may ingest arthropods at the site, there are no models by which to estimate the metal concentrations in arthropods. Therefore, it was assumed that their diet was 100 percent plant matter. However, since seeds contain much lower metal concentrations than foliage (Beyer et al., 1985), this was considered a conservative estimate of the dose to a small herbivore. In addition, it was assumed that deer mice obtained all of their water from the highest concentrations in Railroad Creek. The plant uptake models of Efroymson et al. (1997) and bioavailability factors (Table 7.2.3-11) were used to estimate the dose (Table 7.2.3-13).

Deer mice may also serve as food for animals such as mink and hawks. Sample et al. (1998) provide algorithms (Table 7.2.3-10) by which the metal concentration in small mammals may be estimated (Table 7.2.3-6). These concentrations were used in estimating the doses to carnivores, below.

Mink

Mink are carnivores which feed, in order of importance, on mammals, fish and amphibians, birds, reptiles and invertebrates. Population density depends upon available cover and food, but typically ranges from 0.01 to 0.1 mink per ha. Mink home range depends largely upon food abundance but ranges from 7.8 to 20.4 ha. in heavily vegetated and sparsely vegetated habitats, respectively (Mitchell, 1961). Home ranges are usually aligned with waterways and, in Idaho, mink were never observed more than 200 m from water (Melquist et al., 1981). Adult male mink weigh about 1 kg and consume about 0.069 kg food/kg body weight per day, and ingest about 0.099 L/kg body weight per day (EPA, 1993). In Michigan, Sealander (1943) reported that small mammals comprised about 64 percent of the diet.

Metals data in small mammals have not been collected for the Holden Mine site. Therefore, the algorithms provided by, Sample et al. (1998) were used to estimate the secondary exposure minks acquire through consumption of small insectivorous, omnivorous, and herbivorous small mammals (Table 7.2.3-10).

These equations were then used to estimate small animal concentrations at the UCL of Holden Mine soils (Table 7.2.3-6) and the doses to mink (Table 7.2.3-14).

Dusky Shrew

The dusky shrew (*Sorex vagrans obscurus*) is a carnivore which feeds largely on earthworms, insects, slugs and snails (EPA, 1993). They have forage ranges of about 0.03 to 2.2 ha, depending on population density. Shrews have very high metabolic rates and Winter mortality may range up to 90 percent. Dusky shrews weigh about 0.022 kg and consume about 0.56 kg food/kg body weight per day and drinks about 0.22 L/kg body weight per day. Since there are no data or models to estimate metals concentrations in insects, slugs, or snails, it was assumed that the shrew diet is composed 100 percent of earthworms. The equations in Sample et al. (1998) were used to estimate the metals concentrations in earthworms (Table 7.2.3-6) and doses to the shrew (Table 7.2.3-15).

Red-tailed Hawk

The red-tailed hawk is a carnivore which feeds largely on terrestrial rodents (EPA, 1993). Adult male red-tailed hawks weigh about 1.2 kg and consume about 0.049 kg food/kg body weight per day and ingest about 0.056 L/kg body weight per day of water. In Oregon, Janes (1984) reported that small mammals comprised about 76.1 percent of the diet, with the remaining percentage composed of birds and reptiles. Doses for red-tailed hawk (Table 7.2.3-16) were estimated using the small mammal body burdens developed for the mink, above.

American Robin

The American robin is a common omnivore which feeds largely on fruits, ground-dwelling invertebrates, and foliage-dwelling insects (EOA, 1993). Preceding the breeding season, about 90 percent of the diet consists of invertebrates. Robins weigh about 0.078 kg and consume about 0.129 kg food/kg body weight per day and drink about 0.14 L/kg body weight per day. The equations in Sample et al. (1998) were used to estimate the metals concentrations in earthworms and the doses to the robin (Table 7.2.3-17).

Little Brown Bat

The little brown bat is a nocturnal species that feeds exclusively on insects captured in flight, emerging from surface waters, or stationary on vegetation (Sample et al., 1997). Aquatic insects (e.g., Chironomodidae, Diptera, Isoptera, and Trichoptera) are the primary types of insects captured in western Oregon (Whitaker et al., 1977) and collected in Railroad Creek. Reported body weights range from about 3 to 12 g, but average about 8 g (Sample et al., 1997). Bats are active chiefly from March to August, and hibernate during the winter and early Spring.

Using the equations provided by Sample et al. (1997), this is a feeding rate of 0.162 kg/kg body weight per day, and a drinking rate of 0.160 L/kg body weight per day. Although the forage range of this species is not known, a related species, the gray bat may travel as far as 12 km from roost to foraging areas (LaVal et al., 1977).

It was assumed that little brown bats at the Holden Mine site feed on emerging aquatic insects. Therefore, the predicted insect body burdens found in Table 7.2.3-6, were used to estimate the dose received by bats in the area (Table 7.2.3-18).

7.2.4 Risk Characterization

The risk characterization was first evaluated for locations where the highest concentrations of metals were found using worst case exposure assumptions. If risk was found using these worst case exposure assumptions, these assumptions were modified to better reflect more probable exposures. This more refined level of analysis was only conducted where risk was found using the most conservative exposure assumptions.

The hazard quotient (HQ) method of risk characterization was used to assess the potential for existing metal concentrations at the Holden Mine site to pose risks to ecological receptor species. The worst case HQ for each PCOC was determined by dividing the upper 95 percent confidence limit on the mean of the site concentration or estimated dose data by the appropriate toxicity reference value (TRV) for each ROC in a given potentially complete exposure pathway:

$$HQ = \text{concentration or dose/TRV} \qquad 7\text{-}23$$

The total risk for each ROC was determined by summing the hazard quotients for each exposure pathway (ΣHQ). At this time the USEPA and Ecology have not provided specific guidance to interpret hazard quotients. However, it is generally accepted that when $\Sigma HQ > 1.0$, there may be a small potential risk of adverse effects to ecological receptors. The British Columbia Ministry of the Environment, Land, and Planning (BCMELP, 1998) has defined HQs > 1 but <100, as an intermediate risk, and HQs > 100 as high risk. The specific HQ for each PCOC and ROC exposed to the UCL concentrations measured are shown in Tables 7.2.4-1 to 7.2.4-14. Individual HQs were not added to produce hazard indices (HIs) because there is insufficient evidence that metals act synergistically, and sufficient evidence to conclude that at least some metals act antagonistically (Bremmer, 1979; Zmudzki et al., 1984; Edelstein et al., 1984; Carlson et al., 1985; van Barneveld et al., 1985; Turecki et al., 1995).

7.2.4.1 Risk Characterization for Worst-case Current Conditions

For most ROCs, worst case exposures using the UCL or highest value were used as a screening technique to determine if risk was feasible under more ecologically realistic median exposure conditions. However, for sessile ROCs such as benthic invertebrates and terrestrial plants, reasonable worst case exposures may be representative of the risks found at particular localized areas of the site. Since all the remaining ROCs are free roaming and integrate their respective exposures through their home range, exposures to median concentrations are more ecologically realistic and representative. Even for benthic invertebrates and plants, the median concentrations are more indicative of conditions experienced by plant and animal populations in the local environment. In fact, since these data were collected only from areas expected to be contaminated, the median probably exceeds that which would be contacted by foraging animals, as well as much of the vegetation. Therefore, median exposures were utilized and are likely to be conservative as well as more ecologically relevant than UCLs. This is certainly true at the population level of organization.

The tiered risk characterization for aquatic and terrestria exposure pathways are described below.

Aquatic Exposure Pathways

Risks to aquatic ROCs were evaluated in tiers of analysis, proceeding from worst case exposures to more reasonable exposures. In the first tier of analysis, only the UCL of the data collected from the South Bank of Railroad Creek was used. This data ensures a worst case estimation of risk since the water samples were collected from the creek bank where metals from seeps from the tailings piles have just begun to mix with the main stream of Railroad Creek. If risk was found under these conditions, the UCL data for the main stream of Railroad Creek were evaluated. The main stream samples were collected across the span of the creek and represent a more accurate "worst case" scenario of well mixed waters of Railroad Creek. If risk was still apparent, the median concentrations of the main stream were evaluated. This is a more accurate picture of the exposures encountered by pelagic invertebrates and fish as they move about in the creek.

Fish

From Table 7.2.4-1A, it is apparent that trout may be at risk in the highest concentrations of copper (and possibly of zinc) along the South Bank of Railroad Creek. Therefore, since trout are not restricted to the worst case exposure conditions, further risk analysis is justified for the UCL of the main stream of Railroad Creek.

From Table 7.2.4-1B, it may be seen that trout could be at risk from copper in the main stream of Railroad Creek. Further analysis of median water concentrations (Table 7.2.4-1C), showed that trout could be at risk from copper in the area of the mine site, and downstream.

Benthic Invertebrates - Surface Water

Hazard quotients (Table 7.2.4-2A and 7.2.4-2B) for benthic invertebrates exposed to metals in surface waters were estimated by dividing the UCL of surface water concentrations along the South Bank of Railroad Creek found in Table 7.2.2-1A, below, by the chronic TRVs found in Table 7.2.3-2B.

Since none of the UCL concentrations exceeded the acute or chronic benchmarks calculated in Table 7.2.3-2B, there is no need to conduct a further analysis of risk to benthic invertebrates in South Bank or mainstream of Railroad Creek from these metals.

Benthic Invertebrates- Sediments

In addition to the benthic macroinvertebrates that are attached to hard substrates, there may be benthic invertebrates that burrow in the sediments of Railroad Creek. Sediment samples were collected by USGS (1994) and analyzed in by a non-standard method that provided worst possible conditions for comparison with sediment quality benchmarks. Because there is relatively little sediment in Railroad Creek, the samples were collected from behind boulders, and from sandbars. The samples were sieved, air dried, and then pulverized to a fine flour prior to extraction and analysis by ICP-AES. Pulverizing the sediments would have increased the amount of metal in contact with the strong acid and resulted in an apparent higher concentration than normal extraction procedures. USBM (1995) and Ecology (1997) collected sediment in Railroad Creek. With the exception of silver, the USGS data were the highest sediment values available.

In Table 7.2.4-2C, the results of this analysis are compared against the sediment quality guideline values. The most conservative guidelines (ER-L) were used for screening purposes, although it must be noted that none of the samples exceeded the Ecology (1991) guidelines for freshwater sediments. Exceedances of the ER-Ls for cadmium, copper, iron, manganese and zinc are shown on Table 7.24-2C.

Since risk was found for the UCLs of sediments, the median sediment concentrations were evaluated. There were insufficient data points to calculate median concentrations in upstream sediments.

Exceedance of the ER-L means that sediments may "occasionally" be toxic (Long et al., 1995). Therefore, it is not appropriate to use these exceedances as evidence of adverse effects to the benthic communities at the sites where data was collected or for Railroad Creek in general. Because of the uncertainty associated with interpretation of sediment quality guidelines, it may be more appropriate to assess the potential toxicity of Railroad Creek sediments by exceedance of the ER-M, those concentration "frequently" associated with toxicity. When this is done, exceedances are only found for manganese downstream from the mining site, and HQ is only slightly greater than 1.0.

Washington State (Ecology, 1997) has recently developed freshwater sediment quality values (FSQVs). The FSQVs (freshwater sediment quality values) are probable apparent effects thresholds (PAETs). PAETs are the 95th percentile concentrations of compounds of concern from field collected studies above the highest concentration where no significant biological effects were found. The PAET is the concentration in freshwater sediments below which biological effects are unlikely to occur. When the concentrations are compared to FSQVs, only manganese and silver present risk to benthic invertebrates (Table 7.2.4-2C). In support of this usage of sediment quality guidelines, it is noteworthy that Ecology (1997) found sediments from the mine site area were non-toxic to the sensitive bioassay animal (*Hyalelle azteca*). Toxicity test data are generally believed to be a more reliable indicator of potential toxicity than comparison to sediment toxicity "guidance" values due to site-specific variations in conditions.

Harper Owes (1989) sampled sediments 170 m offshore of the mouth of Railroad Creek in Lake Chelan. These sediments exceeded sediment quality guidelines for arsenic, iron, and zinc. However, it is important to note that Ecology (1997) found that sediments collected from the delta at the mouth of Railroad Creek were no more toxic than sediments collected from their reference location upstream of the mine site. They also reported there was no relationship between toxicity and metal concentration.

Sediment sampling was performed at Lucerne Bar as part of the RI field effort. The results were previously discussed in Section 5.0. With the exception of zinc concentrations at one sample location, metal levels in sediments were below Ecology's FSQV. The zinc levels at this location do not appear to represent adverse effects; however, additional sediment sampling will be performed to define the metal chemical concentrations at this one location.

Benthic Invertebrates- Flocculent

In addition to the benthic macroinvertebrates that are attached to hard substrates, or sediments, there may be benthic invertebrates that are exposed to flocculents near the portal drainages and downstream. Samples were collected near the portal drainages in the belief that these areas would contain the highest concentrations of precipitated metals. Two of the samples were measured wet (RC-2 and RC-5) and one sample was measured dry. The median values of these three measurements in flocculent were found in the sample from RC-5. HQs greater than 1.0 are shown in bold in Table 7.2.4-2D.

As with sediment samples, exceedance of the ER-L means that flocculents may "occasionally" be toxic. Therefore, it may not be appropriate to use these exceedances as evidence of potential adverse effects to the benthic communities at the sites where data were collected or for Railroad Creek in general. In fact, data reported elsewhere in this report shows that metal-sensitive insect nymphs are present in the same areas as the flocculent was collected. Comparison of flocculent concentrations to sediment quality guideline values may not be appropriate because flocculent is not sediment. For example, its natural state, is a dispersion of colloidal metals which contain much more water than solid, while sediments contain much more solid than water. Furthermore, the bioavailability and toxicity of the metals in flocculent is unknown.

Because of the uncertainty associated with interpretation of sediment quality guidelines, it may be more appropriate to assess the potential toxicity of flocculents by exceedance of the ER-M, those concentration "frequently" associated with toxicity. When this was done, exceedances were only found for arsenic, copper, iron, silver and zinc at locations adjacent to the mining site, and HQs range from 1.8 to 3.1.

American Dipper

Hazard quotients for American dipper (Table 7.2.4-5) were calculated by dividing the doses estimated in Table 7.2.3-7 by the TRVs in Table 7.2.3-4A. The default assumptions were:

- dippers fed only on aquatic insects from the South Bank of Railroad Creek
- dippers drink only the UCL concentrations from Railroad Creek
- the modeled insect metal concentrations were accurate for Railroad Creek

From Table 7.2.4-5, it is apparent that American dipper is not at risk even under the worst case exposure assumptions. Therefore, there is no need to conduct further analyses of risk to this ROC.

Osprey

Hazard quotients for osprey consuming copper-contaminated trout (Table 7.2.4-6) were calculated by dividing the doses estimated in Table 7.2.3-8 by the TRVs in Table 7.2.3-4A. The default assumptions were:

- osprey fed only on trout from Railroad Creek and its tributaries
- ospreys drink only the UCL concentrations from Railroad Creek
- the modeled whole body trout concentrations are accurate

From Table 7.2.4-6, it is apparent that there is no risk to osprey under worst case exposure conditions to copper, mercury or zinc. Therefore, there is no need to conduct further analyses of risk to this ROC.

Mink

Hazard quotients for mink feeding on trout (Table 7.2.4-7) were calculated by dividing the doses estimated in Table 7.2.3-9 by the TRVs in Table 7.2.3-4B. The default assumptions were:

- mink fed only on trout from Railroad Creek and its tributaries
- mink drink only the UCL concentrations from Railroad Creek
- the modeled whole body trout concentrations are accurate

From Table 7.2.4-7 it is apparent that there is no risk to mink under worst case exposure conditions to copper, mercury or zinc. Therefore, there is no need to conduct further analyses of risk to this ROC in the aquatic habitat.

Terrestrial Exposure Pathways

Bioavailability of Metals

Although there are many studies that show low food to tissue relationships for metals (Pascoe et al., 1994; Stevens, 1992; Connor et al., 1994; Beyer et al., 1985) there are few studies that analyzed the bioavailable dose from food. Custer et al., 1984 showed that kestrels fed biologically-incorporated lead were able to withstand 10 times the dose that caused adverse effects when dosed as lead acetate. Similarly, NAS (1989) reported that the bioavailability of zinc from meat is about 20 percent. Therefore, the dietary doses of lead and zinc were so adjusted. However, for the remaining metals, no such data was found. Therefore, it was assumed that the bioavailability of cadmium and copper from the diet was 100 percent.

There are however, several studies that show that the bioavailability of metals from soils ingestion is far lower than 100 percent (Owens, 1964; Dodds-Smith et al., 1992; Talmadge and Walton, 1993; Davis et al., 1992; Hamel et al., 1998). At least some of this results from the presence of insoluble metals salts in the soil matrix. Ore bodies, such as that at Holden Mine, were deposited on the sea floor as sulfide salts. The sulfide salts are particularly insoluble and probably form the bulk of the metal salts still found at the site. Therefore, the bioavailability of the soils that may be ingested incidentally by wildlife, was adjusted as shown in Table 7.2.3-11.

Plants

Hazard quotients for plants (Table 7.2.4-6A) were calculated by dividing the UCL of soil concentrations in Table 7.2.3-3A by the plant toxicity benchmarks in Table 7.2.3-3A. In the case of cadmium, copper, lead and zinc, an alternative hazard quotient is calculated based upon the field data found in Table 7.2.3-3B. The default assumptions were:

- the soils used for the plant toxicity benchmarks have the same bioavailability of metals as the site soils
- the site plants are as sensitive as the plants used to derive the benchmarks

Table 7.2.4-6A shows that plants may experience toxicity from cadmium, copper, lead, and zinc in Holden Village and the surface soils, subsurface soils, tailings piles 1, 2 and 3, the lagoon and the maintenance yard. When compared to median soil concentrations, copper exceeded the TRVs for plants exposed to copper in all areas, and for lead in tailings pole 3 and in dust samples (Table 7.2.4-6B) However, when compared against soil metals concentrations from other mining sites where plants were found growing successfully, TRVs were exceeded only for copper in subsurface soils, the lagoon, and the maintenance yard (Table 7.2.4-6C). When compared against median soil concentrations, no soils exceeded the field data from other mining sites (Table 7.2.4-6D).

It is not clear that many of the sampling locations provide adequate habitat for plants, because of the physical qualities of the substrate. This is particularly true of tailings piles which are typically devoid of the moisture required by plants. Plants are unlikely to inhabit dry soils even if no metals were present. Therefore, although metals concentrations in these areas may exceed the plant TRVs, it is unlikely that there is a complete exposure pathway for the plants or herbivores.

In the Holden Village soils, metals may be less bioavailable than in bioassay soils. Janssen et al. (1997a; 1997b) have recently shown that the bioavailability of metals in soils is governed by soil pH, amorphous iron content, organic carbon content, and temperature (Marinussen et al. 1997). Therefore, the degree of risk from copper is likely to be lower in soils containing high levels of amorphous iron and/or organic matter, and higher where pH is low. Therefore, since these soils come from lawns and gardens that have been amended with organic matter, the actual risk is likely to be less than the predicted risk, which was already relatively low.

Earthworms

Hazard quotients for earthworms (Table 7.2.4-7A) were calculated using the UCL of soil concentrations in Table 7.2.3-3A by the worm toxicity benchmarks in Table 7.2.3-3A. The default assumptions were:

- the soils for the earthworm toxicity benchmarks have the same bioavailability of metals as the Site soils
- the site earthworms are as sensitive as the earthworms used to derive the benchmarks
- earthworms would have been found at the Site in the absence of elevated levels of metals

Table 7.2.4-7A shows that some TRVs for earthworms were exceeded at all locations sampled. Only the TRV for copper was exceeded by the median copper concentration (Table 7.2.4-7B) which is a more appropriate metric for protection of earthworm populations. However, as described below, several of the default assumptions may not be true.

It is not clear that many of the sampling locations provide adequate habitat for earthworms, because of the physical qualities of the substrate. This is particularly true of tailings piles which are typically devoid of the organic matter that earthworms feed upon. Organic matter also enhances moisture holding capacity that is needed for earthworm survival. Earthworms are unlikely to inhabit such soils even if no metals were present. Therefore, although metals concentrations in these areas may exceed the earthworm TRVs, it is unlikely that there is a complete exposure pathway for these organisms or their predators.

In Holden Village soils, only copper presents a potential risk to earthworms (Table 7.2.4-7A and B). However, Janssen et al. (1997a; 1997b) have recently shown that the uptake of metals by earthworms is governed by soil pH, amorphous iron content, organic carbon content, and temperature (Marinussen et al. 1997). Therefore, the degree of risk is likely to be lower in soils containing high levels of amorphous iron and/or organic matter, and higher where pH is low. Therefore, since these soils come from lawns and gardens that have been amended with organic matter, the actual risk is likely to be less than the predicted risk, which was already relatively low.

Mule Deer

Hazard quotients for mule deer (Table 7.2.4-8) were calculated by dividing the doses estimated in Table 7.2.3-12 by the TRVs in Table 7.2.3-4B.

The default assumptions were:

- mule deer fed only on plants from locations where soil samples were collected
- mule deer fed only on plants growing in the UCL metal concentrations areas
- mule deer consumed soil equivalent to 2 percent of their plant ingestion rate
- deer drink only the UCL concentrations from Railroad Creek
- the modeled plant metal concentrations were accurate

Table 7.2.4-8 shows that there is no risk to mule deer from the consumption of plants growing at even the worst case locations. Therefore, there is no need to conduct further analyses of risk to this ROC.

Seeps contained higher concentrations of metals than the creek. If it was assumed that mule deer might consume the highest median of the seep water as 1 percent of their daily water intake, this had no effect on the estimated risk.

Deer Mice

Hazard quotients for deer mice (Table 7.2.4-9) were calculated by dividing the doses estimated in Table 7.2.3-13 by the TRVs in Table 7.2.3-4B.

The default assumptions were:

- deer mice fed only on plants from locations where soil samples were collected

- deer mice fed only on plants growing in the UCL metal concentrations areas
- deer mice consumed soil equivalent to 2 percent of their plant ingestion rate
- deer mice drink only the UCL concentrations from Railroad Creek
- the modeled plant metal concentrations were accurate

Table 7.2.4-9 shows that there is no risk to deer mice from the consumption of plants growing at even the worst case locations. Therefore, there is no need to conduct further analyses of risk to this ROC.

Mink

Hazard quotients for mink feeding on small mammals (Table 7.2.4-10A) were calculated by diving the doses estimated in Table 7.2.3-14 by the TRVs in Table 7.2.3-4B. The default assumptions were:

- mink feed only on small mammals from locations where soil samples were collected
- mink feed only on small mammals found in the highest metal concentrations areas
- mink drink only the UCL concentrations from Railroad Creek
- the modeled small mammal metal concentrations were accurate

Table 7.2.4-10A shows that mink feeding on small insectivorous mammals could be at risk from cadmium in the subsurface tailings piles, and the lagoon.

Since mink are not restricted to feeding in only the worst case locations, risk was further characterized at median metals concentrations in small mammals. When mink were exposed to small mammals living on median subsurface soil concentrations there was no risk from the subsurface tailings (Table 7.2.4-10B).

However, because of the limited data for the lagoon and maintenance yard soils, it was not possible to further estimate risk in these areas. It should be noted however, that since the soils are probably toxic to plants and earthworms, it is likely that there is not a complete exposure pathways from small mammals to mink in these areas. Furthermore, since carnivorous animals are usually only about 10 percent as abundant and as herbivores, it is also unlikely that mink could feed 100 percent on insectivores. When the mink diet is 10 percent insectivores and 90 percent herbivores (or omnivores), there is no risk to mink even in the lagoon and maintenance yard.

Red-Tailed Hawk

Hazard quotients for red-tailed hawk feeding on small mammals (Table 7.2.4-11) were calculated by dividing the doses estimated in Table 7.2.3-16 by the TRVs in Table 7.2.3-4A. The default assumptions were:

- hawks feed only on small mammals from locations where soil samples were collected
- hawks feed only on small mammals found in the highest metal concentrations areas
- hawks drink only the UCL concentrations from Railroad Creek
- the modeled small mammal metal concentrations were accurate

Table 7.2.4-11A shows that red-tailed hawks could be at risk from the consumption of insectivorous small mammals exposed to cadmium in the subsurface tailings and the lagoon.

Since red-tailed hawk are not restricted to the tailings piles, but are free roaming animals, further analysis under more realistic exposure conditions was conducted. When hawks were exposed to insectivorous small mammals living on median subsurface soils, no risk was found (Table 7.2.4-11B).

However, because of the limited data for the lagoon and maintenance yard soils, it was not possible to further estimate risk in these areas. It should be noted however, that since the soils are probably toxic to plants and earthworms, it is likely that there is not a complete exposure pathways from small mammals to mink in these areas. Furthermore, since carnivorous animals are usually only about 10 percent as abundant and herbivores, it is also unlikely that mink could feed 100 percent on insectivores. When the hawk diet is 10 percent insectivores and 90 percent herbivores (or omnivores), there is no risk to hawks even in the lagoon and maintenance yard.

Dusky Shrew

Hazard quotients for Dusky shrews feeding on earthworms (Table 7.2.4-12) were calculated by dividing the doses estimated in Table 7.2.3-15 by the TRVs in Table 7.2.3-4B. The default assumptions were:

- shrews feed only on earthworms from locations where soil samples were collected
- shrews feed only on earthworms found in the highest metal concentrations areas
- shrews drink only the UCL concentrations from Railroad Creek
- the modeled small mammal metal concentrations were accurate

Table 7.2.4-12A shows that Least shrews could be at risk from the consumption of earthworms exposed to cadmium in the subsurface tailings, tailings pile 1, tailings pile 2, the lagoon, and the maintenance yard, and to zinc in the lagoon.

Although Least shrews have small forage ranges, they are not restricted to the tailings piles, but are free roaming animals. When shrews are exposed to the median concentrations in subsurface soils, and tailings piles 1 and 2, there is no risk (Table 7.2.4-12B).

However, because of the limited data for the lagoon and maintenance yard soils, it was not possible to further estimate risk in these areas. It should be noted however, that since the soils are probably toxic to plants and earthworms, it is likely that there is not a complete exposure pathways to shrews in these areas.

American Robin

Hazard quotients for robins feeding on earthworms (Table 7.2.4-13) were calculated by dividing the doses estimated in Table 7.2.3-17 by the TRVs in Table 7.2.3-4A.

.The default assumptions were:

- Robins feed only on earthworms from locations where soil samples were collected
- Robins feed only on earthworms found in the highest metal concentrations areas

- Robins drink only the UCL concentrations from Railroad Creek
- the modeled earthworm metal concentrations were accurate

Table 7.2.4-13A shows that Robins could be at risk from cadmium in the subsurface tailings, lagoon, and maintenance yard, and from zinc in the subsurface soils, tailings pile 3, the lagoon, and the maintenance yard, and from lead in the lagoon and maintenance yard.

When robins were exposed to the median concentrations in the subsurface soils, and tailings pile 3, there was no risk from either cadmium or zinc (Table 7.2.4-13B). It is highly likely that the input parameters for the robin vastly overestimate the actual exposure conditions because risk was also shown for robins feeding on earthworms exposed to site background concentrations of cadmium and the risk characterization does not account for robins relatively large forage ranges.

However, because of the limited data for the lagoon and maintenance yard soils, it was not possible to further estimate risk in these areas. It should be noted however, that since earthworms were not observed in the areas where metal concentrations were elevated, it is likely that there is not a complete exposure pathways to robins in these areas.

Little Brown Bat

Hazard quotients for little brown bats feeding on emergent aquatic insects (Table 7.2.4-14) were calculated by dividing the doses estimated in Table 7.2.3-18 by the TRVs in Table 7.2.3-4B. The default assumptions were:

- bats fed only on aquatic insects from Railroad Creek
- bats drink only the UCL concentrations from Railroad Creek
- the modeled insect metal concentrations were accurate for Railroad Creek

It is apparent that little brown bat is not at risk from consumption of emergent insects or surface waters (Table 7.2.4-14). Therefore, there was no need to further evaluate risk to bats along Railroad Creek.

7.2.4.2 Modifying Factors

Because the most difficult aspect of risk characterization is the quantification of the effect of home range on exposure, median exposure concentrations were used. However, is should be noted that the red-tailed hawk, and mule deer also move seasonally. The red-tailed hawk is only a visitor during the summer months and then migrates to Central and South America. Although the mule deer does not migrate *per se*, it does move to lower elevations during the winter when snow fall exceeds its ability to reach grasses and forbs, or to move about easily. The little brown bat is only active during the summer, and hibernates during the winter. While mink do not migrate or hibernate, the onset of cold weather is likely to reduce the consumption of aquatic species. This assures that none of the terrestrial ROCs will be exposed to the worst case or median exposure conditions used for risk characterization in Section 7.2.4.1 above.

7.2.5 SOURCES OF UNCERTAINTY

Limitations associated with any risk assessment have a number of components, including degree of success in meeting objectives, the range of conditions over which conclusions can be applied, and the certainty with which conclusions can be drawn (EPA 1989a). The conclusions of a risk assessment are useful only once they have been placed in perspective relative to the uncertainties associated with the evaluation.

7.2.5.1 General Components of Uncertainty

Toxicology and risk assessment are relatively new sciences, and, as with all risk assessments, there are a variety of uncertainties in this baseline ERA. The ERA process relies on assumptions that have varying degrees of accuracy and validity. Uncertainty in risk estimation has both qualitative and quantitative components. In general, the uncertainty surrounding a risk estimate consists of:

- real variation, reflecting actual ranges in biological responses
- lack of certainty, regarding basic physical, chemical, and biological properties and processes (e.g., bioavailability, bioaccumulation)
- assumptions in the models used to approximate key input values (e.g., dose-response an exposure "models" used for criteria derivation)
- measurement error

It is important to understand that uncertainty includes both real variation (reflecting actual, mechanistic biological response ranges and variability in ecosystem conditions) and error. Thus, because biological systems are inherently uncertain and variable, some component of variability in risk estimation is due to a realistic reflection of ecological conditions, while another component is due to "error" or uncertainty introduced by the overall analytical process. However, it is critically important to understand that natural ecosystem variability represents an important source of uncertainty to the evaluation of the ecosystem. While this parameter is paramount to the making of risk management decisions, it cannot be controlled. Therefore, "error" is the component to be minimized, because this encompasses undesirable uncertainty that has been introduced by the assessment process and can, to some degree, be controlled.

Database

The analytical database has inherent uncertainties. For example, sampling was generally concentrated in areas of known elevated concentration so that estimates of the actual underlying distribution of PCOCs made from the dataset may be biased conservatively. In addition, when analytes were not detected in environmental media, these data points were not included in the statistical analysis. Although this conclusion is based upon the available evidence, it is possible that metals could have been present at concentrations below the method detection limit. This was not felt to impact the conclusions reached because the detection limits were always lower than the concentrations known to cause adverse effects. Nevertheless, this method introduces uncertainty which cannot be quantified. An attempt to limit this source of uncertainty was made by using the median concentrations rather than the means. Medians are an expression of central tendency which is less biased by either high or low values and is more appropriate for animals which may or may not contact a specific area where data were collected.

Finally, the analysis performed for this assessment did not account for site-specific factors such as natural attenuation of PCOCs over time, adaptive tolerance, reproductive potential, the relatively small size of the affected area, and recruitment from similar adjoining areas. Such factors would tend to mitigate the degree and ecological significance of loss or impairment of a portion of ecological population(s) due to both chemical and physical stressors in the area. As a result, the approach used in this assessment necessarily results in overestimation of risk.

Exposure

While aquatic insects and fish are restricted to relatively constant exposures from surface waters and sediments, those for terrestrial receptors, with the exception of plants and earthworms are highly variable. Birds and mammals have home ranges and forage ranges which would not restrict them to the worst case exposures at the site, but it is difficult to estimate actual exposure rates. Although home and forage ranges are available for each of the selected ROCs, these areas are usually given in square units such as hectares. In a glacial valley such as the Railroad Creek drainage, animals are restricted to smaller ranges by the topographical relief. Furthermore, migratory patterns probably also have an effect on the potential doses received from ingestion within the Holden Mine area, and further up or down the valley. Quantification of such ranges typically takes years of study and is beyond the scope of the present ERA. An attempt was made to account for at least a portion of this uncertainty by using median exposure estimates in addition to the worst case estimates.

An additional source of uncertainty associated with estimated exposures is a lack of knowledge concerning the bioavailability of metals to either plants or from food items. There is a large literature which shows that metals incorporated into either soils, minerals, or biological tissues are much less bioavailable than those present as water-soluble salts. Since nearly all the bioassays used to construct the TRVs and criteria were based upon the use of water-soluble salts, this source of uncertainty is most likely very conservative.

Animals such as deer may or may not be selective feeders at the Holden Mine site, and may or may not consume the plant species present on the tailings piles or Holden Village soils. Similarly, osprey could possibly catch trout from Railroad Creek, but it is much more likely that they forage over the open waters of Lake Chelan. Mink may or may not be present adjacent to Railroad Creek, but it is likely they would use trout only as a supplement to the more abundant and more easily acquired small mammals which are ubiquitous in the edge zone of clearings and forests.

Toxicity Benchmarks

Uncertainties regarding the screening toxicity benchmarks (National Ambient Water Quality Criteria, and NOAA sediment quality guidelines) derive principally from the fact that they are conservative and generic, protective of all species, including the most sensitive, rather than site-specific indicators of potential risk to ecological receptors present at the Site. NAWQC are derived from the highest quality and most applicable data that were available at the time of development. However, the physiology and toxicology/pharmacology of COPCs, particularly in relation to the fish and wildlife taxa identified as ROCs, is known only with some certainty. These differences are shown to some degree by the differences between the NAWQC and the site-specific TRVs for trout, for instance. This bias has an unquantifiable, but likely large effect on risk estimates. This conservatively biased uncertainty cannot be quantified, but incorporates both error and biological variation. The latter is likely the largest component of uncertainty, because organisms have highly variable responses to toxicants, and extrapolation from laboratory studies to field exposure estimates incorporates this conservatively biased uncertainty into the risk estimates.

Assumptions regarding the protectiveness of aquatic life criteria and sediment screening guidance imparts an unknown degree of conservative bias to the assessment because these criteria are intentionally derived to incorporate "safety factors" or margins-of-safety. The level of conservative bias introduced by conclusions based on these criteria is generally not quantifiable because both types of criteria are driven largely by numbers of studies evaluated rather than a possibly more appropriate evaluation of actual results variability and differential receptor sensitivities. An attempt has been made to reduce these sources of uncertainty by incorporating surrogate-specific bioassay results and deriving guild-specific TRVs. In most cases it was possible to focus on the specific guild to be protected (i.e., aquatic insects and trout) at Holden Mine, and to reduce the uncertainty associated with scaling for mammals. However, because of site-specific conditions, both known and unknown, there is a degree of uncertainty associated with the TRVs, doses, and risk estimated for all potential exposure pathways.

The use of the Long et al. (1995) sediment quality guidelines is an exception to this rule. They were used in the present document without change because there are few areas of Railroad Creek where sediments accumulate and because there is little sediment data in the published literature for most of the COCs. There are a number of uncertainties associated with the use of the Long et al. (1995) ER-M and ER-L values:

- The guideline values were derived from a number of different studies with different species and different endpoints
- The guidelines were derived in marine and estuarine waters where sediment communities are well developed
- The guideline values do not account for sulfide binding to metals

Because many of the different studies used by Long et al. (1995) were field studies, there is no unambiguous way of knowing which chemicals in these sediments were actually responsible for the apparent adverse effects. Furthermore, although the SEL guideline values for freshwater developed by Persaud et al. (1993) are generally lower than the ER-M values of Long et al. (1995), the freshwater PAETs developed by Ecology (1991) are higher than the ER-Ms for copper (1.3x), lead (2.2x), mercury (2.3x) and zinc (2.4x). This adds credence to DiToro et al. (1991) conclusion that sediment quality guidelines that do not account for sulfide binding are indefensible. This is particularly relevant to Holden Mine and Railroad Creek where the source of the metals are sulfide ores which require strong acid digestion to enable measurement. Simpson et al. (1998) have shown that pure copper and nickel sulfides are not digested by extraction in 1 M HCL after 30 minutes, while cadmium, zinc, manganese and iron sulfides are digested by this treatment. However, Long et al. (1995) rejected all sediment data in which strong acid was not used. Therefore, it is important to note that pH in Railroad Creek ranges between about 5.5 and 7.8, a range where none of these sulfide-bound metals would be bioavailable.

To date, no acceptable sediment quality criteria exist against which to compare concentrations of COPCs to definitively evaluate potential risks (O'Connor et al., 1998; O'Connor, 1999). This is because the cumulative uncertainties, inherent measurement errors, and differences between laboratory and *in situ* conditions in current approaches (*e.g.*, apparent effects thresholds, spiked sediment bioassays, equilibrium partitioning) make them far too imprecise for regulatory use as more than very generally applicable screening values. Recent efforts to base sediment quality criteria for nonionic organic chemicals on equilibrium partitioning have been relatively more successful, as have partitioning between acid-volatile sulfides (AVS) and TOC and the sediment pore water.

Models

Only the simplest of models were used in this ERA. They consisted of soil-to-plant uptake factors, pore water-to-insect extrapolations, and soil-to-small mammal extrapolations. While the soil-to-plant factors are based upon a number of studies, there are large interspecies differences in the efficiency with which metals are taken up from soils. Some of the factors that drive these differences are: soil moisture, organic content, metal complex, and weather conditions. In addition, most plants only bioaccumulate metals in the roots and pass very little on to the leaves, and less on to the seeds. This is not reflected in the soil-to-plant uptake factors used.

The remaining extrapolations were based upon a single study and must be used with caution. The conditions in the original studies from which these were extrapolated may have been very different from the conditions at Holden Mine. For instance, the Clark Fork River pore-waters used to extrapolate metals concentrations in Railroad Creek insects may have had higher concentrations of dissolved organic matter than Railroad Creek. They may also have had relatively high levels of acid-soluble sulfides. Both of these factors could reduce the apparent bioavailability of metals to insects.

The extrapolation of soil-to small mammals relied on the only known database for this type of information, but suffers from the same kinds of potential uncertainties as the soil-to-plant and pore water-to-insect extrapolations.

Risk Characterization

It is important to note that no one approach to risk characterization is adequate for all sites and chemicals. For instance, the toxicity benchmarks used in this assessment are all chemical-specific and, as such, cannot address the additive, antagonistic, or synergistic effects of the mixtures of chemicals typically found in the environment. Further, they do not take into account the nature and constitution of the ecosystem present at the Site, site-specific conditions regulating chemical contact and bioavailability, the potential toxicity of other constituents that were not quantified, or the pervasive influence of physical stressors associated with natural conditions in severe climates.

In the present ERA, risks were characterized using the quotient method. This method relies upon a single value of dose and TRV and provides only a single estimate of risk. Given the uncertainties and variances presented above, it is apparent that the hazard quotients could be in error. An attempt was made to reduce this source of error by deriving site-specific TRVs, and overestimating exposures, but the quotient method does not yield a measure of central tendency. Probabilistic methods provide such as measure of central tendency but are only as good as the input data. For the purposes of the RI, the hazard quotients were determined to provide sufficient conservatism as to protect the receptor guilds identified in this ERA.

In the present ERA, it was assumed that metals were the only and most serious sources of risk to plant and animal populations. However, there is good evidence that physical factors may also contribute to adverse effects on both plant and animal populations. For instance, it is known that tailings piles have limited amounts of organic matter and nutrients and have small water holding capacities. In addition, severe winter and summer weather conditions and cropping by herbivores make re-establishment of vegetation on these tailings piles difficult. Likewise, the presence of iron oxyhydroxide precipitates or "flocculent" in slow moving reaches of Railroad Creek may suffocate invertebrates and developing fish eggs and/or alevins. The precipitation of metals on creek sediments may also reduce the productivity of reaches of Railroad Creek where cementation is found. It is also possible that the ecological effects found on invertebrate populations may be explained by adverse effects on periphyton, food source of invertebrates, and unsuitable habitat which could have implications for trout populations. This receptor was not addressed because of the lack of available toxicity data and the probable lack of impact on selection of the appropriate remedial solution. Leland et al. (1984) showed that the standing crop of periphyton was not reduced in an experimental stream chronically exposed to copper, but that the species composition changed. The impact of this effect on invertebrate and fish population is unknown.

Although it was assumed that flocculent may be a source of toxicity to benthic invertebrates, the potential toxicity of flocculent is not well understood. Most reports of flocculent suggest that it produces adverse effects by suffocation, not toxicity. This conclusion is supported by the use of metals precipitation in settling ponds as a method for reducing the toxicity of metals at mining sites. At the Warm Springs Ponds near Butte, Montana, metals from Silverbow Creek are precipitated by additions of lime for pH adjustment and the toxicity of Silver Bow Creek is substantially reduced. Metals are incorporated into flocculent which settles out and is incorporated into the sediments in the ponds. Biological studies in the ponds revealed that invertebrate density and diversity immediately downstream from the lime addition system ranked among the highest found (ARCO 1997). This strongly suggests that metal precipitates such as flocculent are not toxic.

7.2.6 Conclusions

The ERA included a tiered risk characterization that included the evaluation of a list of species observed on-site (using the guild approach), site-specific potential compounds of concern, and potential exposure pathways. The receptors of concern (ROC) evaluated included aquatic and terrestrial invertebrates, plants, and animals. Specific ROC include: (1) Aquatic: Mink, Osprey, Trout, Dipper, Caddisfly, and Periphyton, and (2) Terrestrial: Mink, Red-Tailed Hawk, Bat, Dusky Shrew, Earthworm, Deer Mouse, Mule Deer, American Robin, and Grasses/Forbes.

The risk characterization proceeded from the worst-case exposure scenario to more reasonable exposure scenarios. The conclusions for potential risks to aquatic and terrestrial ROC are described below.

7.2.6.1 Aquatic Exposure Pathway and Receptors of Concern

Hazard Quotients calculated in the risk characterization to aquatic ROC proceeded from the worst-case exposure scenario, the water quality data from the South Bank of Railroad Creek, to the reasonable exposure scenario, median water quality in the mainstream of Railroad Creek.

Trout

- An intermediate potential risk for adverse effects (HQ>1 but <100) to trout may be present due to copper concentrations in surface water in Railroad Creek adjacent to the site under both the worst-case and reasonable exposure scenarios. A downstream intermediate potential risk for adverse effects due to copper was identified only using the mainstream Railroad Creek water quality data.

- Trout may possibly be at risk due to iron concentrations in surface water adjacent to the site under a worst-case scenario; however, no risk was identified using the median mainstream data.
- The combined results of the ERA and ecological survey suggest that reduced trout population adjacent to the Site near RC-9 to downstream of tailings pile 3 is more attributable to the lack of suitable habitat or food items due to the presence of flocculent, although some potential risk for adverse effects due to dissolved metals was identified.
- HQs were less than or equal to 1 for all other metals for trout.

Benthic Invertebrates

- A metals toxicity risk to benthic invertebrates under the worst-case and reasonable exposure scenarios in surface water of Railroad Creek does not exist.
- A small potential risk of adverse effects may be present for benthic invertebrates due to metal concentrations (copper, iron, manganese, and zinc) in sediment from Railroad Creek adjacent to and downstream of the site (HQs ranged from 1.0 to 3.0). Exceedances of sediment quality guidelines have been shown to be unreliable predictors of toxic conditions. However, bioassays conducted by Ecology (1997) did not show toxicity due to metals concentrations in Railroad Creek sediment.
- An intermediate potential risk of adverse effects to benthic invertebrates may be present due to metal concentrations (arsenic, cadmium, copper, iron, silver, and zinc) in flocculent adjacent to the site in Railroad Creek. It should be noted that the bioavailability and toxicity of metals in flocculent is unknown. Data from other mine sites suggest that flocculent may not be toxic. The benthic macroinvertebrate community assessment conducted during the RI within Railroad Creek, both upstream and downstream of site influences, exhibited a wide range of conditions. The presence of flocculent on and in the substrate in Railroad Creek from the lower portion of station RC-9 to downstream stations (except RC-3) has influenced the substrate by infilling the interstitial spaces and coating the surface of substrate which generally limits the establishment of periphyton. However, three new genera of pollution sensitive organisms are present at RC-7 and RC-9 and are assumed to be present due to the alteration in habitat. The benthic community at station RC-3 indicates recovering conditions. The combined results of the ERA and benthic community evaluation suggest that the reduced benthic community adjacent to the Site near RC-9 to downstream of tailings pile 2 (RC-7) is more attributable to the lack of suitable habitat due to the presence of flocculent, although some potential risk for adverse effects from metal flocculent concentrations was identified.
- Under a reasonable scenario condition, there is no risk due to metals toxicity to the birds or mammals associated with aquatic habitat near the site.

7.2.6.2 Terrestrial Exposure Pathway and Receptors of Concern

- Plants may experience toxicity from cadmium, copper, lead, and zinc in Holden Village surface soil and in the surface soils and subsurface soils of tailings piles 1, 2 and 3, the lagoon and the maintenance yard; however, when compared to soil metals concentrations at other mine sites where plants are successfully growing, only copper concentration in subsurface soils, the lagoon, and maintenance yard may present a risk of phytotoxicity.

- Earthworms may be at risk from cadmium, copper, lead and/or zinc in surface and subsurface soils at Holden Village, tailings piles, dust, lagoon and the Maintenance Yard under the worst-case scenario; however, suitable earthworm habitat may not exist due to the physical qualities of the substrate at the sample locations.
- Robins could be at risk from cadmium in the subsurface tailings, lagoon and maintenance yard, and from zinc in the subsurface soils, tailings pile 3, the lagoon and the maintenance yard, and from lead in the lagoon and maintenance yard based on the worst-case scenario. However, under the reasonable scenario (median concentration), there was no risk from cadmium or zinc. It is highly likely that the input parameters for the robin, overestimate the actual exposure conditions because a risk was also shown for robins feeding on earthworms exposed to background concentrations of cadmium and the exposure assessment does not account for the robins relatively large forage range.
- Under normally expected condition, there is no risk due to metals toxicity to mammals associated with terrestrial habitat near Holden Mine.

TABLE 7.0-1
KEY OF SITE FEATURES & MEDIA SAMPLING/DATA COLLECTION LOCATIONS
HOLDEN MINE RI/FS
DAMES & MOORE JOB NO. 17693-005-019

Feature/Area or Media	Station No.	Location by Area	Coordinate	Comments
Feature/Area				
1500-Level Main Portal	N/A	Mine Support & Waste Rock	E.0-3.0	Near southern boundary
1500-Level Ventilator Portal	N/A	Mine Support & Waste Rock	D.7-3.0	Near western boundary
1100-Level Portal	N/A	Honeymoon Heights	D.8-3.1	
1000-Level Portal	N/A	Honeymoon Heights	D.8-3.1	
800-Level Portal	N/A	Honeymoon Heights	D.8-3.1	
700-Level Portal	N/A	Honeymoon Heights	D.8-3.2	
550-Level Portal	N/A	Honeymoon Heights	D.9-3.2	
300-Level Portal	N/A	Honeymoon Heights	D.9-3.2	
Abandoned Septic Field	N/A	SE of Holden Village	E.2-3.0	
Abandoned Surface Water Ret.	N/A	Mine Support & Waste Rock	D.7-2.9	
Baseball Field/Campground	N/A	Baseball Field/Campground	D.7-2.9, D.8-2.9	
Copper Creek	N/A	S. of Tailings Piles 1 & 2	E.1-3.1, E.1-3.2, E.2-3.0, E.3-3.1	
Copper Creek Diversion	N/A	W. of Tailings Pile 1	E.0-3.0, E.1-3.0	
East Waste Rock Pile	N/A	Mine Support & Waste Rock	E.1-3.0, E.1-3.1	
Holden Village	N/A	Holden Village	E.1-2.9, E.2-2.9	
Holden Village Septic Field	N/A	SE of Winston Home Sites	D.9-2.9, E.0-2.9	
Honeymoon Heights	N/A	Honeymoon Heights	D.7-3.0, 3.1, 3.2; D.8-3.0, 3.1, 3.2, 3.3; D.9-3.0, 3.1, 3.2, 3.3	
Hydroelectric Plant	N/A	W. of Tailings Pile 1	E.0-3.0	
Intermittent Drainage	N/A	Honeymoon Heights	D.8-3.0, D.8-3.1, D.8-3.2, D.8-3.3	
Lagoon	N/A	Mine Support & Waste Rock	E.0-2.9, E.0-3.0	
Lucerne Bar	N/A	Lucerne		
Lucerne Guard Station	N/A	Lucerne	I-3	
Maintenance Yard	N/A	Maintenance Yard	E.0-3.0	
Mill Building	N/A	Mill Building	E.0-3.0	
Mine Support and Waste Rock	N/A	Mine Support & Waste Rock	D.7-2.9, 3.0; D.8-2.9, 3.0; D.9-2.9, 3.0; E.0-2.9, 3.0, 3.1; E.1-3.0, 3.1, 2.9	
Portal Museum	N/A	Mine Support & Waste Rock	E.0-3.0	
Sauna	N/A	NW of Tailings Pile 1	E.1-3.0	
Shop	N/A	Maintenance Yard	E.0-3.0	
Storage	N/A	Maintenance Yard	E.0-3.0	
Tailings Pile 1	N/A	Tailings Pile 1	E.1-3.0, E.2-3.0, E.2-3.1	
Tailings Pile 2	N/A	Tailings Pile 2	E.2-3.0, E.2-3.1, E.3-3.0, E.3-3.1, E.4-3.0, E.4-3.1	
Tailings Pile 3	N/A	Tailings Pile 3	E.4-3.0, E.4-3.1, E.5-3.0, E.5-3.1	
USFS Guard Station	N/A	USFS Guard Station	E.0-2.9	
West Waste Rock Pile	N/A	Mine Support & Waste Rock	E.0-3.0	
Winston Home Sites	N/A	Winston Home Sites	D.8-2.9; D.9-2.8, 2.9; E.0-2.8, 2.9	
Geophysical Survey Lines				
A-A'	N/A	North of West Waste Rock Pile	E.0-2.9, E.0-3.0	
B1-B1'	N/A	Tailings Pile 1	E.1-3.0	
B2-B2'	N/A	East Waste Rock Pile	E.1-3.1	
C-C'	N/A	Tailings Pile 2	E.3-3.0, E.3-3.1	
D-D'	N/A	Tailings Pile 3	E.4-3.0, E.4-3.1	
E-E'	N/A	East of Tailings Pile 3	E.5-3.0, E.5-3.1	

TABLE 7.0-1
KEY OF SITE FEATURES & MEDIA SAMPLING/DATA COLLECTION LOCATIONS
HOLDEN MINE RI/FS
DAMES & MOORE JOB NO. 17693-005-019

Feature/Area or Media	Station No.	Location by Area	Coordinate	Comments
EM1-EM1'	N/A	Western Mine Support Area	D.8-2.9, D.8-3.0. D.9-2.9, D.9-3.0, E.0-2.9	
EM2-EM2'	N/A	Western Mine Support Area	D.8-3.0, D.9-3.0, E.0-3.0, E.1-3.0	
EM3-EM3'	N/A	East of Tailings Pile 3	E.5-3.0, E.5-3.1	
F-F'	N/A	North of Tailings Piles 2 & 3	E.4-3.0	
G-G'	N/A	Between Tailings Piles 1 & 2	E.2-3.0, E.2-3.1	
Sample Locations				
Groundwater Monitoring Wells				
	HBKG-1	W. of Tailings Pile 1	E.0-3.0	Potential background
	HBKG-2	E. of Baseball Field/Campgr.	D.8-2.9	Potential background
	CC-BKG	SW Tailings Pile 2	E.2-3.1	Background
	H-1	Holden Village	E.1-2.9	
	H-2	Holden Village	E.2-2.9	
	HV-3/H-3	Holden Village	E.1-2.9	Background
	DS-1	East of Tailings Pile 3	E.5-3.0	Downstream Wells:
	DS-2	East of Tailings Pile 3	E.5-3.0	Downstream Wells:
	TP1-1A	Tailings Pile 1	E.1-3.0	
	TP1-2A	Tailings Pile 1	E.1-3.0	
	TP1-2L	Tailings Pile 1	E.1-3.0	
	TP1-3A	Tailings Pile 1	E.1-3.0	
	TP1-3L	Tailings Pile 1	E.1-3.0	
	TP1-4A	Tailings Pile 1	E.1-3.0	
	TP1-4L	Tailings Pile 1	E.1-3.0	
	TP1-5A	Tailings Pile 1	E.2-3.0	
	TP1-6A	Tailings Pile 1	E.1-3.0	
	TP1-6L	Tailings Pile 1	E.1-3.0	
	PZ-1A	Tailings Pile 2	E.3-3.1	
	PZ-1B	Tailings Pile 2	E.3-3.1	
	PZ-1C	Tailings Pile 2	E.3-3.1	
	PZ-2A	Tailings Pile 2	E.3-3.0	
	PZ-2B	Tailings Pile 2	E.3-3.0	
	PZ-2C	Tailings Pile 2	E.3-3.0	
	PZ-3A	Tailings Pile 2	E.3-3.0	
	PZ-3B	Tailings Pile 2	E.3-3.0	
	PZ-3C	Tailings Pile 2	E.3-3.0	
	TP2-1L	Tailings Pile 2	E.3-3.1	
	TP2-2L	Tailings Pile 2	E.3-3.0	
	TP2-4A	Tailings Pile 2	E.3-3.0	
	TP2-4B	Tailings Pile 2	E.3-3.0	
	TP2-5A	Tailings Pile 2	E.3-3.0	
	TP2-5B	Tailings Pile 2	E.3-3.0	
	TP2-6L	Tailings Pile 2	E.3-3.1	
	TP2-7N&S	Tailings Pile 2	E.4-3.0	
	TP2-8A	Tailings Pile 2	E.4-3.0	
	TP2-8B	Tailings Pile 2	E.4-3.0	
	TP2-9L	Tailings Pile 2	E.4-3.1	
	TP2-10L	Tailings Pile 2	E.2-3.1	
	TP2-11	Tailings Pile 2	E.2-3.0	
	TP2-11L	Tailings Pile 2	E.2-3.0	
	TP3-4	Tailings Pile 3	E.4-3.0	

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HOLDEN MINE RI/FS
DAMES & MOORE JOB NO. 17693-005-019

Feature/Area or Media	Station No.	Location by Area	Coordinate	Comments
	TP3-4L	Tailings Pile 3	E.4-3.0	
	TP3-5A	Tailings Pile 3	E.5-3.0	
	TP3-6A	Tailings Pile 3	E.5-3.0	
	TP3-6BL	Tailings Pile 3	E.5-3.0	
	TP3-7	Tailings Pile 3	E.4-3.0	
	TP3-8	Tailings Pile 3	E.4-3.0	
	TP3-9	Tailings Pile 3	E.5-3.0	
	TP3-10	Tailings Pile 3	E.5-3.0	
	TP3-10L	Tailings Pile 3	E.5-3.0	
	PZ-4A	Tailings Pile 3	E.4-3.0	
	PZ-4B	Tailings Pile 3	E.4-3.0	
	PZ-4C	Tailings Pile 3	E.4-3.0	
	PZ-5A	Tailings Pile 3	E.4-3.0	
	PZ-5B	Tailings Pile 3	E.4-3.0	
	PZ-5C	Tailings Pile 3	E.4-3.0	
	PZ-6A	Tailings Pile 3	E.4-3.0	
	PZ-6B	Tailings Pile 3	E.4-3.0	
	PZ-6C	Tailings Pile 3	E.4-3.0	
	Lucerne Well	Lucerne	I-3	Lucerne Guard Station
Subsurface/Surface Soil				
	DMSS-1	Holden Village	E.2-2.9	Surface soil
	DMSS-2	Holden Village	E.2-2.9	Surface soil
	DMSS-3	Holden Village	E.1-2.9	Surface soil
	DMSS-4	Holden Village	E.1-2.9	Surface soil
	DMSS-5	Holden Village	E.1-2.9	Surface soil
	DMSS-6	Holden Village	E.2-2.9	Surface soil
	DMSS-7	Holden Village	E.1-2.9	Surface soil
	DMSS-8	Maintenance Yard	E.0-3.0	Surface soil
	DMSS-9	Maintenance Yard	E.0-3.0	Surface soil
	DMSS-10	Maintenance Yard	E.0-3.0	Surface soil
	DMSS-11	Tailings Pile 1	E.1-3.0	Surface soil
	DMSS-12	Tailings Pile 1	E.1-3.0	Surface soil
	DMSS-13	Tailings Pile 1	E.2-3.0	Surface soil
	DMSS-14	Tailings Pile 2	E.2-3.0	Surface soil
	DMSS-15	Tailings Pile 2	E.3-3.0	Surface soil
	DMSS-16	Tailings Pile 2	E.4-3.0	Surface soil
	DMSS-17	Tailings Pile 3	E.4-3.0	Surface soil
	DMSS-18	Tailings Pile 3	E.4-3.0	Surface soil
	DMSS-19	Tailings Pile 3	E.5-3.0	Surface soil
	DMSS-20	East of Tailings Pile 3	E.5-3.0	Windblown tailings
	DMSS-21	East of Tailings Pile 3	E.6-3.0	Windblown tailings
	DMSS-22	East of Tailings Pile 3	E.6-3.0	Windblown tailings
	DMSS-23	East of Tailings Pile 3	E.7-3.0	Windblown tailings
	DMSS-24	East of Tailings Pile 3	E.5-3.0	Windblown tailings
	DMSS-25	Baseball Field	D.7-2.9	Surface soil
	DMSS-26	Wilderness Area	D.7-2.9	Surface soil
	DMSS-27	Wilderness Area	D.7-2.9	Surface soil
	Lagoon 6"	Lagoon	E.0-2.9	Surface soil
	Lagoon 2'	Lagoon	E.0-2.9	Subsurface soil sample
	DMLG1	Lagoon	E.0-3.0	Subsurface soil sample
	DMLG2	Lagoon	E.0-2.9	Subsurface soil sample
	DMLG3	Lagoon	E.0-2.9	Subsurface soil sample

TABLE 7.0-1
KEY OF SITE FEATURES & MEDIA SAMPLING/DATA COLLECTION LOCATIONS
HOLDEN MINE RI/FS
DAMES & MOORE JOB NO. 17693-005-019

Feature/Area or Media	Station No.	Location by Area	Coordinate	Comments
	DMLG4	Lagoon	E.0-3.0	Subsurface soil sample
	DMLG5	Lagoon	E.0-2.9	Subsurface soil sample
	DMBG1	Approximately 1-mile West of Site	D-2	Background surface soil
	DMBG2	Holden Creek Drainage	D-2	Background surface soil
	DMBG3	Between Holden Creek & Hart Lake	C-2	Background surface soil
	DMBG4	East of Hart Lake	C-2	Background surface soil
	DMBG5	Between Hart Lake & Crown Point	B-2	Background surface soil
	DMBG6	Lyman Lakes	A-3	Background surface soil
	DMBG7	West of Hart Lake	B-2	Background surface soil
	DMBG8	West of Holden Creek	C-2	Background surface soil
	DMBG9	West of Big Creek	D-2	Background surface soil
	DMBG10	Copper Basin	E-3	Background surface soil
	DMBG11	Southwest of Site	D-3	Background surface soil
	DMBG12	South of Site	D-3	Background surface soil
	DMBG13	Near South Site Boundary	E-3	Background surface soil
	DMBG14	Near Holden Creek	D-2	Background surface soil
	DMBG15	Near Holden Creek	D-2	Background surface soil
	DMBG16	West of Site Boundary	D-2	Background surface soil
	DMBG17	Near Winston Home Sites	D-2	Background surface soil
	DMBG18	Northeast of Site	E-2	Background surface soil
	DMBG19	North of Holden Village	E-2	Background surface soil
	DMTP1-2	Tailings Pile 1	E.1-3.0	Test pit excavation
	DMTP1-3	Tailings Pile 1	E.1-3.0	Test pit excavation
	DMTP1-4	Tailings Pile 1	E.1-3.0	Test pit excavation
	DMTP1S-1	Tailings Pile 1	E.1-3.0	Test pit excavation
	DMTP2-1	Tailings Pile 2	E.2-3.0	Test pit excavation
	DMTP2-2	Tailings Pile 2	E.3-3.0	Test pit excavation
	DMTP2S-1	Tailings Pile 2	E.3-3.1	Test pit excavation
	DMTP3-1	Tailings Pile 3	E.4-3.0	Test pit excavation
	DMTP3-2	Tailings Pile 3	E.5-3.0	Test pit excavation
	DMTP3-3	Tailings Pile 3	E.5-3.0	Test pit excavation
	DMTP3-4	Tailings Pile 3	E.5-3.0	Test pit excavation
	DMTP3S-1	Tailings Pile 3	E.4-3.1	Test pit excavation
	DMTP3E-1	Immed. east of Tailings Pile 3	E.5-3.0	Test pit excavation
	DMTP3E-2	Immed. east of Tailings Pile 3	E.5-3.0	Test pit excavation
	DMTP3E-3	Immed. east of Tailings Pile 3	E.5-3.0	Test pit excavation
	DMTP3E-4	Immed. east of Tailings Pile 3	E.5-3.0	Test pit excavation
	DMTP3E-5	Immed. east of Tailings Pile 3	E.5-3.1	Test pit excavation
	DMTP3E-6	Immed. east of Tailings Pile 3	E.5-3.1	Test pit excavation
	DMTPW-1	Winston home sites	D.8-2.9	Test pit excavation
	DMTPW-2	Winston home sites	D.8-2.9	Test pit excavation
	DMTPW-3	Winston home sites	D.8-2.9	Test pit excavation
	DMTPW-4	Winston home sites	D.8-2.9	Test pit excavation
	DMTPW-5	Winston home sites	D.9-2.9	Test pit excavation
	DMTPW-6	Winston home sites	D.9-2.9	Test pit excavation
	DMTPW-7	Winston home sites	D.9-2.9	Test pit excavation
Surface Water				
	RC-1	Railroad Creek	D.7-2.9	
	RC-1 North Bank	Railroad Creek	D.7-2.9	
	RC-1 South Bank	Railroad Creek	D.7-2.9	
	RC-2	Railroad Creek	E.5-3.0	
	RC-2 South Bank	Railroad Creek	E.5-3.0	

TABLE 7.0-1
KEY OF SITE FEATURES & MEDIA SAMPLING/DATA COLLECTION LOCATIONS
HOLDEN MINE RI/FS
DAMES & MOORE JOB NO. 17693-005-019

Feature/Area or Media	Station No.	Location by Area	Coordinate	Comments
	RC-3	Railroad Creek	I-3	
	RC-4	Railroad Creek	E.0-2.9	
	RC-4 South Bank	Railroad Creek	E.0-2.9	
	RC-5	Railroad Creek	E-3	
	RC-5A	Railroad Creek	E-3	
	RC-6	Railroad Creek	D.7-2.9	
	RC-6 North Bank	Railroad Creek	D.7-2.9	
	RC-7	Railroad Creek	E.4-3.0	
	RC-8	Railroad Creek	I-3	
	RC-8 North Bank	Railroad Creek	I-3	
	RC-10	Near Seven Mile Creek	F-3	
	RC-11	Upstream of Holden Creek	D-2	
	CC-1	Copper Creek	E.2-3.1	
	CC-2	Copper Creek	E.2-3.0	
	CC-D	Copper Creek Diversion	E.1-3.0	
	CC-D1	Copper Creek Diversion	E.1-3.0	
	P-1	Mine Support & Waste Rock	E.0-3.0	Portal Drainage/1500 Main
	P-5	Mine Support & Waste Rock	D.9-2.9	Portal Drainage/RR Creek
	HC-1	Holden Creek	D-2	
	HC-2	Holden Creek	C-2	
	HC-3	Holden Creek	C-2	
	HC-4	Holden Creek	C-1	
	Big-1	Big Creek	D-2	
	Tenmile Creek	Tenmile Creek	E-2	
Seeps				
	A1	Honeymoon Heights	D.B-3.1	1100 Level Portal
	SP1	Tailings Pile 1	E.1-3.0	
	SP2	Tailings Pile 1	E.2-3.0	
	SP3	Tailings Pile 2	E.3-3.0	
	SP4	Tailings Pile 3	E.4-3.0	
	SP5	East of Tailings Pile 3	E.5-3.0	
	SP6	West Waste Rock Pile	E.0-3.0	
	SP7	West Waste Rock Pile	E.0-3.0	
	SP8	East Waste Rock Pile	E.1-3.0	
	SP9	Between P-5 & RC-4	D.9-2.9	
	SP10W	River Sauna	E.1-2.9	
	SP10E	River Sauna	E.1-2.9	
	SP11	West of Vehicle Bridge	E.0-2.9	
	SP12	West of P-5	D.9-3.0	
	SP13	South of Holden Village	E.1-2.9, 3.0; E.2-2.9, 3.0	"Black Seep"
	SP14	Honeymoon Heights	D.8-3.1	
	SP15W	North of West Waste Rock Pile	E.0-3.0	
	SP15E	North of West Waste Rock Pile	E.0-3.0	
	SP16	Lagoon	E.0-2.9	
	SP17	East of Tailings Pile 3	E.5-3.1	
	SP18	East of Tailings Pile 3	E.5-3.0	Bank sample
	SP19	Tailings Pile 1	E.1-3.0	
	SP20	Tailings Pile 1 (Near Copper Creek)		
	SP21	East of Tailings Pile 3	2.6-3.1	
	SP22	North of Maintenance Yard	E.0-3.0	
	SP23	Between RC-1 and P-5	D.8-3.0	
	SP23B	Between RC-1 and P-5	D.8-3.0	

TABLE 7.0-1
KEY OF SITE FEATURES & MEDIA SAMPLING/DATA COLLECTION LOCATIONS
HOLDEN MINE RI/FS
DAMES & MOORE JOB NO. 17693-005-019

Feature/Area or Media	Station No.	Location by Area	Coordinate	Comments
	SP24	West of RC-4	E.0-2.9	
	SP25	Between Vehicle Bridge & RC-4	E.0-2.9	
	SP26	Between RC-1 and RC-6	D.7-2.9	
	SP-27	Near Big Creek	D-2	
	CC-D1	Copper Creek Diversion	E.1-2.9	
Sediment - Lake Chelan				
	1-1	Lucerne	N/A	
	1-2	Lucerne	N/A	
	2-1	Lucerne	N/A	
	2-2	Lucerne	N/A	
	3-1	Lucerne	N/A	
	3-1A	Lucerne	N/A	
	3-1B	Lucerne	N/A	
	3-1C	Lucerne	N/A	
	3-2	Lucerne	N/A	
	3.5-1	Lucerne	N/A	
	3.5-2	Lucerne	N/A	
	5-1	Lucerne	N/A	
	5-2	Lucerne	N/A	
	1	Stehekin	N/A	
	2	Stehekin	N/A	
	3A	Stehekin	N/A	
	3B	Stehekin	N/A	
	3C	Stehekin	N/A	
	4	Stehekin	N/A	
USGS Select Samples				
	344	Ten Mile Creek	E.6-2.9	
	345	Railroad Creek near RC-2	E.5-3.0	
	346	Copper Creek Diversion	E.1-3.0	
	347	Railroad Creek at Vehicle Bridge	E.0-2.9	
	350	East of Tailings Pile 3	E.5-3.0	
	351	Nine Mile Creek	F-3	
	352	Railroad Creek near Seven Mile Creek	F-3	
	353	Seven Mile Creek	F-3	
	354	Railroad Creek at Lucerene	N/A	
	355	Holden Creek	D-2	
	356	Railroad Creek West of Site	D-2	
	MP-7	Railroad Creek at Mile Post 7	G-3	
USBM Select Samples				
	BKG 1/2	Downstream of Vehicle Bridge	E.0-2.9	
	DG-1	Downstream of Tailings Pile 3	E.6-3.0	
	TP1-2	Adjacent to Tailings Pile1	E.1-3.0	
	TP2-1	Downstream of Copper Creek	E.2-3.0	
	TP2-2	Adjacent to Tailings Pile 2	E.3-3.0	
	TP3-1	Adjacent to Tailings Pile 3	E.4-3.0	
	RC-2	At Railroad Creek RC-2 Station	E.5-3.0	

TABLE 7.1-A
OFF-SITE SOIL CHEMICAL DATA
HOLDEN MINE RI/FS
DAMES & MOORE JOB NO. 17693-005-019

Parameters	Location	"OFF-SITE" AREA			
	Sample ID	Winston Homesite* (HW-1A)	Baseball Field (DMSS-25)	Wilderness Boundary (DMSS-26)	Wilderness Boundary (DMSS-27)
	Sample Date	7/95*	10/5/97	10/5/97	10/5/97
<u>Metals (mg/kg)</u>					
Aluminum		20,100	20,300	15,200	17,500
Arsenic		25.2	10.8	10.7	11.4
Barium		80.4	101	93.1	72.5
Beryllium		0.22	0.2	0.1	0.2
Cadmium		2.1	1.3	3.1	0.9
Calcium		4,260	5,770	5,160	6,440
Chromium		21.7	29.4	20.8	27.8
Copper		61.8	63.0	147	81.4
Iron		27,600	26,600	24,200	26,500
Lead		84.1	15	37	16
Magnesium		8,930	7,640	7,470	8,980
Manganese		580	537	365	455
Mercury		0.02	▨	▨	▨
Molybdenum		▨	1.0	1.5	2.4
Nickel		18.2	18	12	17
Potassium		997	1,270	1,290	940
Selenium		0.94 U	▨	▨	▨
Silver		0.55 U	0.5	0.5	0.6
Sodium		448	605	647	573
Thallium		0.11	0.6 U	0.6U	0.6U
Uranium		▨	2U	2U	4
Zinc		125	129	303	121

<u>Data Notes:</u>

J - Estimated value.

U - Parameter was analyzed for, but not detected above the reporting limit shown.

UJ - Parameter was analyzed for, but not detected. Detection limit is an estimated value.

* Sample collected at USFS guardstation, west of Holden Village area.

No statistical analysis prepared for this data table

▨ Grey shading indicates the concentration of analyte was not established, therefore not reported nor analyzed.

<u>Data Source:</u>

(a) Lambeth, R.H. 1995. Transmittal of laboratory data from samples collected at Holden Mine site by the US Bureau of Mines. (Data collected in 1995.)

TABLE 7.1-B
STATISTICAL ANALYSIS AND COMPARISON OF SURFACE SOIL CHEMICAL DATA AT HOLDEN VILLAGE
HOLDEN MINE RI/FS
DAMES & MOORE JOB NO. 17693-005-019

Parameters	Location	HOLDEN VILLAGE AREA														
	Sample ID	HV-1A	HV-2A	HV-3A	HV-4A	HV-5A	HV-6A	HV-7	DMSS-1	DMSS-2	DMSS-3	DMSS-4	DMSS-5	DMSS-6	DMSS-6X	DMSS-7
	Sample Date	6/1/94 [a]	6/1/94 [a]	6/1/94 [a]	6/1/94 [a]	6/1/94 [a]	6/1/94 [a]	11/94 [a]	9/20/97	9/20/97	9/20/97	9/20/97	9/20/97	9/20/97	9/20/97	9/20/97
Metals (mg/kg)																
Aluminum		21,400	18,400	21,600	22,300	15,300	25,100	10,100	19,100	16,800	23,500	16,200	17,900	25,900	26,300	15,500
Arsenic		3	3.1	2	4.5	1.3	1.1	1.7	2.1	3.3	1.6	5.1	1.3	3.5	3.7	2.3
Barium		124	126	161	102	171	127	297	102	380	156	333	136	104	104	116
Beryllium		0.19	0 16	0.23	0.32	0 22	0.29	0.11	0.3	0.2	0 3	0 2	0.2	0.3	0.3	0.2
Cadmium		2	1.1	1.2	0.97	0.77	1.5	1.6	0.8	1 5	0 9	2.1	1.4	1.6	1.2	0.7
Calcium		6,090	5,090	5,370	6,670	3,380	4,210	2,370	4,480	5,320	6,070	12,400	4,020	8,310	8,790	4,360
Chromium		14.5	10.7	57 7	30.5	21.3	36.6	4.3	39.4	23.8	48.3	28 7	29.1	26.3	26.5	24
Copper		210	150	53.4	33.6	49	47.5	229	83	523	86.2	155	412	216	245	112
Iron		23,600	24,100	26,200	26,400	17,400	28,400	19,800	24,000	29,600	28,200	26,300	26,100	25,200	24,600	22,600
Lead		23	21	18	14	23	5	99	21	103	12	61	34	10	11	45
Magnesium		7,950	6,610	10,200	8,620	5,770	10,500	4,950	8,450	7,200	10,800	5,860	8,040	8,980	9,230	6,750
Manganese		363	301	562	463	1,270	621	205	435	315	542	613	637	427	419	317
Mercury		0.03	0.06	0.02	0.03	▨	0.02	0.08	▨	▨	▨	▨	▨	▨	▨	▨
Molybdenum		▨	▨	▨	▨	▨	▨	▨	0.9	4.5	0.9	5.0	2.4	0.6	0.6	1 9
Nickel		15	11	27	26	17	27	6	22	13	27	16	17	18	18	14
Potassium		1,830	1,380	1,060	813	748	1,050	1,660	1,300	1,740	1,430	2,110	1,660	1,710	1,590	1,360
Selenium		0 99 U	1.0 U	1 0 U	1 U	1.1 U	0.95 U	1.1 U	▨	▨	▨	▨	▨	▨	▨	▨
Silver		0.69 U	0 58 U	0 76 U	0.79 U	0.68	0 58 U	0.56 U	0.4U	1.2	0.4U	2	0.4	0.3U	0 3U	0.3
Sodium		652	711	522	841	471	450	303	612	728	531	777	600	1,080	1,090	533
Thallium		0.13	0.32	0 10 U	0.10	0.11 U	0.10	0.35	0.1U	0.6U	0.1U	0 8U	0.1U	0.1U	0.1U	0.6U
Uranium		▨	▨	▨	▨	▨	▨	▨	2U	2U	3U	3U	2U	2U	2U	2U
Zinc		204	171	169	106	456	90	184	132	284	112	356	137	201	161	145

Data Notes:

J - Estimated value.
U - Parameter was analyzed for, but not detected above the reporting limit shown
UJ - Parameter was analyzed for, but not detected. Detection limit is an estimated value.
▨ Grey shading ▨ indicates the concentration of analyte was not established, therefore not reported nor analyzed.

Data Source:

(a) Lambeth, R.H. 1995. Transmittal of laboratory data from samples collected at Holden Mine site by the US Bureau of Mines.

TABLE 7.1-B
STATISTICAL ANALYSIS AND COMPARISON OF SURFACE SOIL CHEMICAL DATA AT HOLDEN VILLAGE
HOLDEN MINE RI/FS
DAMES & MOORE JOB NO. 17693-005-019

Parameters	STATISTICAL CALCULATIONS FOR SURFACE SOIL									
	# of Analyses	# of Detections	Maximum Conc.	Minimum Conc.	Range of RL	Approximate Distribution	Mean	Standard Deviation	Median	UCL (95%)
Metals (mg/kg)										
Aluminum	15	15	26,300	10,100		Lognormal	19778	4582	19100	22437
Arsenic	15	15	5.1	1.1		Lognormal	2.6	1.2	2.3	3.4
Barium	15	15	380	102		Neither	169	91	127	**380**
Beryllium	15	15	0.32	0.11		Normal	0.23	0.06	0.22	0.26
Cadmium	15	15	2.1	0 7		Lognormal	1 3	0.43	1 2	1.54
Calcium	15	15	12,400	2370		Lognormal	5944	2558	5345	7490
Chromium	15	15	57.7	4.3		Normal	28.1	13.7	26.5	34 3
Copper	15	15	523	33.6		Lognormal	180.3	140.5	150	311 3
Iron	15	15	29,600	17,400		Normal	24833	3200	25200	26288
Lead	15	15	103	5.0		Lognormal	33.9	31.1	21	61.4
Magnesium	15	15	10,800	4950		Lognormal	8015	1792	8040	8989
Manganese	15	15	1,270	205		Lognormal	499	250	435	627
Mercury	6	6	0.08	0.02		Neither	0.04	0.02	0.03	**0.08**
Molybdenum	8	8	5 0	0.6		Lognormal	2.2	1.8	1.4	6
Nickel	15	15	27	6		Normal	18.5	6.4	17	21.1
Potassium	15	15	2,110	748		Lognormal	1438	385	1430	1671
Selenium	7	0			0.95-1.1					
Silver	15	5	2	0 3	0.3-0.79				0.68	
Sodium	15	15	1,090	303		Lognormal	660	220	612	788
Thallium	15	5	0.35	0.1	0.1-0.8				0.13	
Uranium	8	0			2-3					
Zinc	15	15	456	90		Lognormal	194	100	169	246

Statistical Notes: (Statisical calculations were performed using Washington Department of Ecology's MTCAStat Excel V.5 Macro (Module 2 1), downloaded from their web site.)
Maximum and minimum concentrations are based on detected values only.
Range of reporting limits (RL) are based on results reported as not detected.
Distribution is determined based on the MTCA stat program by analyzing the data through the "W-Test" or "D'Agostino's test". Where data is not lognormally nor normally distributed, the distribution is noted as "Neither".
When approximate distribution is reported as "neither", the maximum concentration is reported as the 95% UCL and is presented in **BOLD** font.
The mean is an arithmetic mean if data are normally distributed or if distribution is indicated as "Neither". The reported mean for lognormally distributed data is a lognormal mean.
Statistical analysis was not performed on data sets where 50% or greater of the results were reported as not detected. Only maximum and minimum concentrations are reported, if applicable.
For these data sets, a calculated median is based on detected values only.

TABLE 7.1-C
STATISTICAL EVALUATION AND COMPARISON OF SURFACE TAILING METAL CONCENTRATIONS
HOLDEN MINE RI/FS
DAMES & MOORE JOB NO. 17693-005-019

Parameters	Location	SURFACE TAILINGS (TP-1)								
	Sample ID	HT1-2A	HT1-2B	503T	504T	505TA	505TB	DMSS-11	DMSS-12	DMSS-13
	Sample Date	6/1/94[b]	6/1/94[b]	7/95[c]	7/95[c]	7/95[c]	7/95[c]	9/20/97	9/20/97	9/20/97
Total Metals (mg/kg)										
Aluminum		5,280	5,410	39,000	32,000	37,000	37,000	8,220	8,700	7,350
Arsenic		5.5	5.8	3.2	6.5	3.1	2.6	3.3	4	5
Barium		361	450	860	790	780	850	395	394	375
Beryllium		0.09	0.08	1 U	1 U	1 U	1 U	0.2U	0.1	0.2U
Cadmium		0.95	1.3	0.14	0.08U	0.08U	0.08U	0.50	0.60	0.4U
Calcium		1,910	1,940	12,000	11,000	11,000	11,000	1180	1820	1310
Chromium		19.6U	13.6U	13	10	12	10	8.0	9.5	6.0
Copper		423	436	260	230	330	240	382	239	442
Iron		54,500	59,800	62,000	74,000	73,000	59,000	65,100	58,500	63,700
Lead		112	110	97	140	100	100	83	59	95
Magnesium		3,170	3,220	9,800	7,100	8,400	7,600	4,910	4,910	3,960
Manganese		113	117	470	420	460	420	169	167	148
Mercury		0.35	0.33	▨	▨	▨	▨	▨	▨	▨
Molybdenum		▨	▨	26	25	30	25	27	21.4	26
Nickel		1.3	1.3	▨	▨	▨	▨	2U	4	2U
Potassium		2,180	2,360	8,800	7,300	8,100	8,000	3,280	2,710	3,000
Selenium		28	19 8	▨	▨	▨	▨	▨	▨	▨
Silver		1.6	2	2	3.4	2.8	2.3	3 1	2.0	3.3
Sodium		750	820	11,000	10,000	11,000	11,000	790	795	700
Thallium		1.2	1.1	▨	▨	▨	▨	2U	1U	2U
Uranium		▨	▨	100 U	100 U	100 U	100 U	2U	2U	2U
Zinc		76.1	82.6	260	200	200	220	157	187	124

Data Notes:

J - Estimated value.
U - Parameter was analyzed for, but not detected above the reporting limit shown.
UJ - Parameter was analyzed for, but not detected. Detection limit is an estimated value.
▨ **Grey shading** ▨ indicates the concentration of analyte was not established, therefore not reported nor analyzed.

Data Source:

(a) Kilburn, et al. 1994. *Geochemical data and sample locality maps for stream-sediment, heavy-mineral-concentrate, mill tailing, water, and precipitate samples collected in and around the Holden mine, Chelan County, Washington.* USGS Open File Report 94-680A Paper Version, 94-680B Diskette version (Data Collected in 1994).
(b) Lambeth, R.H. 1995. Transmittal of laboratory data from samples collected at Holden Mine site by the US Bureau of Mines. (Data collected in 1995).
(c) Kilburn, J.E. & S.J. Sutley. 1996. *Characterization of acid mine drainage at the Holden mine, Chelan, Washington*. USGS Open File Report 96-531 (Data collected in 1995).

TABLE 7.1-C
STATISTICAL EVALUATION AND COMPARISON OF SURFACE TAILING METAL CONCENTRATIONS
HOLDEN MINE RI/FS
DAMES & MOORE JOB NO. 17693-005-019

Parameters	STATISTICAL CALCULATIONS FOR TAILINGS PILE 1 (TP-1)									
	# of Analyses	# of Detections	Maximum Conc.	Minimum Conc.	Range of RL	Approximate Distribution	Mean	Standard Deviation	Median	UCL (95%)
Total Metals (mg/kg)										
Aluminum	9	9	39,000	5,280		Neither	19,995	15,568	8,700	**39,000**
Arsenic	9	9	6.5	2.6		Lognormal	4.4	1.4	4	5.5
Barium	9	9	860	361		Neither	584	227	450	**860**
Beryllium	9	3	0.1	0.08	0.2-1				0 09	
Cadmium	9	5	1.3	0.14	0.08-0.4	Lognormal	0.56	0 46	0.20	4.51
Calcium	9	9	12,000	1,180		Neither	5,907	5,085	1,940	**12,000**
Chromium	9	7	13	6	13.6-19.6	Lognormal	9.5	2.3	9.8	11.3
Copper	9	9	442	230		Neither	331	91	330	**442**
Iron	9	9	74,000	54,500		Lognormal	63,321	6,566	62,000	67,607
Lead	9	9	140	59		Lognormal	100	22	100	118
Magnesium	9	9	9,800	3,170		Lognormal	5,964	2,402	4,910	8,217
Manganese	9	9	470	113		Neither	276	160	169	**470**
Mercury	2	2	0.35	0.33					0.34	
Molybdenum	7	7	30	21		Lognormal	26	2 6	26	28
Nickel	5	3	4	1.3	2-2	Neither	1.7	1.3	1.3	**4**
Potassium	9	9	8,800	2,180		Neither	5,081	2,859	3,280	**8,800**
Selenium	2	2	28	19.8					23.9	
Silver	9	9	3.4	1.6		Lognormal	2.50	0 66	2 30	3.00
Sodium	9	9	11000	700		Neither	5206	5268	820	**11000**
Thallium	5	2	1.2	1.1	1-2				1.15	
Uranium	7	0			2-100					
Zinc	9	9	260	76.1		Lognormal	170.6	62.6	187	238.5

Statistical Notes: (Statisical calculations were performed using Washington Department of Ecology's MTCAStat Excel V.5 Macro (Module 2 1), downloaded from their web site.)
Maximum and minimum concentrations are based on detected values only.
Range of reporting limits (RL) are based on results reported as not detected.
Distribution is determined based on the MTCA stat program by analyzing the data through the "W-Test" or "D'Agostino's test". Where data is not lognormally nor normally distributed, the distribution is noted as "Neither"
When approximate distribution is reported as "neither", the maximum concentration is reported as the 95% UCL and is presented in BOLD font.
The mean is an arithmetic mean if data are normally distributed or if distribution is indicated as "Neither". The reported mean for lognormally distributed data is a lognormal mean
Statistical analysis was not performed on data sets where 50% or greater of the results were reported as not detected. Only maximum and minimum concentrations are reported, if applicable
For these data sets, a calculated median is based on detected values only.

TABLE 7.1-C
STATISTICAL EVALUATION AND COMPARISON OF SURFACE TAILING METAL CONCENTRATIONS
HOLDEN MINE RI/FS
DAMES & MOORE JOB NO. 17693-005-019

Parameters	Location	SURFACE TAILINGS (TP-2)						STATISTICAL CALCULATIONS TAILINGS PILE 2 (TP-2)									
	Sample ID	502T	HT2-2A	HT2-2B	DMSS-14	DMSS-15	DMSS-16										
	Sample Date	7/95[c]	6/1/94[b]	6/1/94[b]	9/21/97	9/21/97	9/21/97	# of Analyses	# of Detections	Maximum Conc.	Minimum Conc.	Range of RL	Approximate Distribution	Mean	Standard Deviation	Median	UCL (95%)
Total Metals (mg/kg)																	
Aluminum		38000	9750	10900	8,450	17,300	11,000	6	6	38,000	8,450	▨	Neither	15900	11249	10950	**38000**
Arsenic		1.5U	0.5	0.5	*1.4*	*1*	*2.8*	6	5	2.8	0.5	1.5	Lognormal	1.2	0.9	0.9	2.94
Barium		1200	239	275	339	535	286	6	6	1200	239	▨	Lognormal	481	368	312	1057
Beryllium		1 U	0.1	0.11	0.2U	0.1U	0.2	6	3	0.2	0.1	0.1-1	▨	▨	▨	0.11	▨
Cadmium		0.08 U	0.85	1.3	0.5	0.3	0.4	6	5	1.3	0.3	0.08	Lognormal	0.78	0.45	0.45	10.87
Calcium		11000	1110	1250	1,290J	1,920J	2,200J	6	6	11000	1110	▨	Neither	3128	3880	1605	**11,000**
Chromium		8	23 U	10.7 U	8	15.5	19.1	6	4	19.1	8	10.7-23	Lognormal	11.5	5.2	9.8	19.71
Copper		250	226	261	199	299	161	6	6	299	161	▨	Lognormal	234	48.6	238	287
Iron		54000	60400	68700	71,100	53,400	56,800	6	6	71100	53400	▨	Lognormal	60804	7558	5860	67717
Lead		83	34.1	39	41	51	80	6	6	83	34.1	▨	Neither	55	22	46	**83**
Magnesium		11000	6710	7390	5,340	11,700	6,810	6	6	11700	5340	▨	Lognormal	8216	2572	7100	11168
Manganese		430	230	257	208	385	220	6	6	430	208	▨	Neither	288	95	244	**430**
Mercury		▨	0.23	0.25	▨	▨	▨	2	2	0.25	0.23	▨	▨	▨	▨	0.24	▨
Molybdenum		8	▨	▨	16	17.3	25.9	4	4	25.9	8	▨	Lognormal	17.4	7.3	16.6	48
Nickel		▨	2.4	2.4	2	3	5	5	5	5	2	▨	Lognormal	3	1.2	2.4	4.7
Potassium		8100	3650	4020	3,810	5,040	3,930	6	6	8100	3650	▨	Neither	4758	1709	3975	**8100**
Selenium		▨	17.9	16.8	▨	▨	▨	2	2	17.9	16.8	▨	▨	▨	▨	17.4	▨
Silver		1.2	0.66 U	0.61 U	2.2	2.0	2.5	6	4	2.5	1.2	0.61-0.66	Neither	1.4	1	1.6	**2.5**
Sodium		10000	433	479	570	652	551	6	6	10000	433	▨	Neither	2114	3864	560	**10000**
Thallium		▨	0.73	0.74	2U	1U	1U	5	2	0.74	0.73	1-2	▨	▨	▨	0.74	▨
Uranium		100 U	▨	▨	2U	2U	3U	4	0	▨	▨	2-100	▨	▨	▨	▨	▨
Zinc		270	216	249	198	163	176	6	6	270	163	▨	Lognormal	213	41.6	207	255

Data Notes:

J - Estimated value.

U - Parameter was analyzed for but not detected for, but not detected above the reporting limit shown.

UJ - Parameter was analyzed for, but not detected. Detection limit is an estimated value.

Grey shading indicates the concentration of analyte was not established, therefore not reported nor analyzed.

Statistical Notes: (Statisical calculations were performed using Washington Department of Ecology's MTCAStat Excel V.5 Macro (Module 2.1), downloaded from their web site.)

Maximum and minimum concentrations are based on detected values only.

Range of reporting limits (RL) are based on results reported as not detected.

Distribution is determined based on the MTCA stat program by analyzing the data through the "W-Test" or "D'Agostino's test". Where data is not lognormally nor normally distributed, the distribution is noted as "Neither".
When approximate distribution is reported as "neither", the maximum concentration is reported as the 95% UCL and is presented in BOLD font.

The mean is an arithmetic mean if data are normally distributed or if distribution is indicated as "Neither". The reported mean for lognormally distributed data is a lognormal mean

Statistical analysis was not performed on data sets where 50% or greater of the results were reported as not detected. Only maximum and minimum concentrations are reported, if applicable
For these data sets, a calculated median is based on detected values only.

TABLE 7.1-C
STATISTICAL EVALUATION AND COMPARISON OF SURFACE TAILING METAL CONCENTRATIONS
HOLDEN MINE RI/FS
DAMES & MOORE JOB NO. 17693-005-019

Parameters	Location	SURFACE TAILINGS (TP-3)								STATISTICAL CALCULATIONS FOR TAILINGS PILE 3 (TP-3)									
	Sample ID	360	500T	501T	HT3-2A	HT3-2B	DMSS-17	DMSS-18	DMSS-19										
	Sample Date	7/1/94[a]	7/1/95[c]	7/1/95[c]	6/1/94[b]	6/1/94[d]	9/21/97	9/21/97	9/21/97	# of Analyses	# of Detections	Maximum Conc.	Minimum Conc.	Range of RL	Approximate Distribution	Mean	Standard Deviation	Median	UCL (95%)
Total Metals (mg/kg)																			
Aluminum		44000	44000	43000	6210	7000	10,500	12,800	7,210	8	8	44000	6210		Neither	21840	18200	11650	**44000**
Arsenic		1U	1.5U	1.5U	0.44	0.37	1.7J	2.9J	1.0J	8	5	2.9	0.37	1-1.5	Lognormal	1.1	0.9	0.8	2.2
Barium		172	900	680	220	301	272	397	302	8	8	900	172		Lognormal	409	253	301	687
Beryllium		1 U	1 U	1 U	0.11	0.1	0.2	0.2U	0.2U	8	3	0.2	0.1	0.2-1				0.11	
Cadmium		0.05 U	0.08U	0.08U	1	1	0.3	0.5U	0.5U	8	3	1	0.3	0.05-0.5				1	
Calcium		16000	16000	14000	568	753	2,100J	1,870J	1,090J	8	8	16000	568		Neither	6548	7319	1985	**16,000**
Chromium		24	24	19	11.3 U	50.4 U	18.2	17	11	8	6	24	11	11.3-50.4	Neither	18	6.9	18.6	**24**
Copper		110	110	86	294	355	154	147	154	8	8	355	86		Lognormal	178	96	150	274
Iron		47000	50000	45000	64000	85300	54,300	64,900	73,700	8	8	85300	45000		Lognormal	60697	14102	59150	71894
Lead		75	76	74	41.8	55.9	77	77	70	8	8	77	41.8		Neither	68.3	12.8	74.5	**77**
Magnesium		8800	8900	7700	4040	4180	6,480	8,690	4,730	8	8	8900	4040		Neither	6690	2123	7090	**8900**
Manganese		480	500	390	166	175	210	277	156	8	8	500	156		Lognormal	298	143	243.5	456.2
Mercury					0.27	0.25				2	2	0.27	0.25					0.26	
Molybdenum		20	23	16			24.6	26	30	6	6	30	16		Lognormal	23.4	4.9	23.8	28.7
Nickel		3			0.99	1.8	5	4	3	6	6	5	0.99		Lognormal	3.1	1.4	3	6.6
Potassium		7400	7100	7500	3240	4600	3,730	3,580	3,430	8	8	7500	3430		Neither	5073	1917	4165	**7500**
Selenium					17.1	13.3				2	2	17.1	13.3					15.2	
Silver		0.91	1.1	1	0.65 U	0.58 U	2.3	2.3	2.6	8	6	2.6	0.91	0.58-0.65	Neither	1.4	0.9	1.1	**2.6**
Sodium		14000	14000	13000	497	684	525	550	500	8	8	14000	497		Neither	5470	6795	617	**14000**
Thallium					0.51	0.86	1U	1U	2U	5	2	0.86	0.51	1-2				0.69	
Uranium		100 U	100 U	100 U			2U	3U	2U	6	0			2-100					
Zinc		123	147	78.3	569	767	169	283	305	8	8	767	78.3		Lognormal	316.9	242.5	226	744.6

Data Notes:

J - Estimated value.

U - Parameter was analyzed for but not detected for, but not detected above the reporting limit shown.

UJ - Parameter was analyzed for, but not detected. Detection limit is an estimated value.

Grey shading indicates the concentration of analyte was not established, therefore not reported nor analyzed.

Statistical Notes: (Statisical calculations were performed using Washington Department of Ecology's MTCAStat Excel V.5 Macro (Module 2.1), downloaded from their web site.)

Maximum and minimum concentrations are based on detected values only.

Range of reporting limits (RL) are based on results reported as not detected.

Distribution is determined based on the MTCA stat program by analyzing the data through the "W-Test" or "D'Agostino's test". Where data is not lognormally nor normally distributed, the distribution is noted as "Neither"
When approximate distribution is reported as "neither", the maximum concentration is reported as the 95% UCL and is presented in BOLD font

The mean is an arithmetic mean if data are normally distributed or if distribution is indicated as "Neither". The reported mean for lognormally distributed data is a lognormal mean.

Statistical analysis was not performed on data sets where 50% or greater of the results were reported as not detected. Only maximum and minimum concentrations are reported, if applicable
For these data sets, a calculated median is based on detected values only.

TABLE 7.1-C
STATISTICAL EVALUATION AND COMPARISON OF SURFACE TAILING METAL CONCENTRATIONS
HOLDEN MINE RI/FS
DAMES & MOORE JOB NO. 17693-005-019

Parameters	Location	WIND BLOWN TAILINGS					STATISTICAL CALCULATIONS FOR WINDBLOWN TAILINGS									
	Sample ID	DMSS-20	DMSS-21	DMSS-22	DMSS-23	DMSS-24										
	Sample Date	9/21/97	9/21/97	9/21/97	9/21/97	9/21/97	# of Analyses	# of Detections	Maximum Conc.	Minimum Conc.	Range of RL	Approximate Distribution	Mean	Standard Devation	Median	UCL(95%)
Total Metals (mg/kg)																
Aluminum		6,510	9,740	20,700	12,900	8,330	5	5	20700	6510		Lognormal	11622	5580	9740	21924
Arsenic		1.9	2.2	2.3	2.0	3.1	5	5	3.1	1.9		Lognormal	2.3	0.47	2.2	2.8
Barium		321	327	79.0	388	380	5	5	388	79		Neither	299	127	327	**388**
Beryllium		0.2U	0.1U	0.2	0.1U	0.1U	5	1	0.2	0.2	0.1-0.2				0.2	
Cadmium		0.5	0.5	0.4	0.6	0.5	5	5	0.6	0.4		Lognormal	0.5	0.07	0.5	0.58
Calcium		1,190	2,140	5,870	3,880	1,790	5	5	5870	1190		Lognormal	3094	1903	2140	9133
Chromium		10	14.7	29.0	18.2	11.8	5	5	29	10		Lognormal	17	7.5	15	30
Copper		107	151	159	332	149	5	5	332	107		Lognormal	181	88	151	319
Iron		65,000	63,500	24,100	40,400	66,200	5	5	66200	24100		Lognormal	53358	18813	63500	98314
Lead		49	52	7	62	59	5	5	62	7		Neither	46	22	52	**62**
Magnesium		3,810	5,840	6,070	6,570	4,860	5	5	6570	3810		Lognormal	5461	1098	5840	6968
Manganese		135	197	292	203	165	5	5	292	135		Lognormal	200	59	197	280
Mercury																
Molybdenum		30	31.7	0.7U	10.7	29.4	5	4	31.7	10.7	0.7	Neither	20.4	14.1	29.4	**31.7**
Nickel		3	6	17	9	4	5	5	17	3		Lognormal	8.1	5.6	6	27.8
Potassium		2,850	2,990	580U	1,340	3,510	5	4	3510	1340	580	Neither	2196	1337	2850	**3510**
Selenium																
Silver		2.8	2.3	0.4U	1.2	2.4	5	4	2.8	1.2	0.4	Neither	1.8	1.1	2.3	**2.8**
Sodium		550	597	1,130	611	774	5	5	1130	550		Lognormal	737	238	611	1044
Thallium		2U	3U	0.7U	2U	3U	5	0			0.7-3					
Uranium		2U	3U	3U	2U	3U	5	0			2-3					
Zinc		246	256	75.3	107	260	5	5	260	75.3		Lognormal	198	90	246	509

Data Source:

(a) Kilburn, et al. 1994. *Geochemical data and sample locality maps for stream-sediment, heavy-mineral-concentrate, mill tailing, water, and precipitate samples collected in and around the Holden mine, Chelan County, Washington.* USGS Open File Report 94-680A Paper Version, 94-680B Diskette version (Data Collected in 1995). 94-680B Diskette version. (Data collected in 1994).

(b) Lambeth, R.H. 1995. Transmittal of laboratory data from samples collected at Holden Mine site by the US Bureau of Mines. (Data collected in 1994)

(c) Kilburn, J.E. & S.J. Sutley. 1996. *Characterization of acid mine drainage at the Holden mine, Chelan, Washington*. USGS Open File Report 96-531. (Data collected in 1995).

Statistical Notes: (Statisical calculations were performed using Washington Department of Ecology's MTCAStat Excel V.5 Macro (Module 2.1), downloaded from their web site.)
Maximum and minimum concentrations are based on detected values only.
Range of reporting limits (RL) are based on results reported as not detected.
Distribution is determined based on the MTCA stat program by analyzing the data through the "W-Test" or "D'Agostino's test". Where data is not lognormally nor normally distributed, the distribution is noted as "Neither".
When approximate distribution is reported as "neither", the maximum concentration is reported as the 95% UCL and is presented in **BOLD** font
The mean is an arithmetic mean if data are normally distributed or if distribution is indicated as "Neither". The reported mean for lognormally distributed data is a lognormal mean.
Statistical analysis was not performed on data sets where 50% or greater of the results were reported as not detected. Only maximum and minimum concentrations are reported, if applicable
For these data sets, a calculated median is based on detected values only.

TABLE 7.1-D
COMPARISON OF SEDIMENTARY TOTAL METAL CONCENTRATIONS FROM RAILROAD CREEK
(BASED ON SAMPLES COLLECTED FROM 1991-1997)
HOLDEN MINE RI/FS
DAMES & MOORE JOB NO. 17693-005-019

Parameters	ROAD CREEK UPSTREAM OF MINE (RC-1 AREA BACKGRO				STATISTICAL CALCULATIONS FOR RC-AREA BACKGROUND									
	355	356	367	ECOLOGY RC-1 STATION										
	7/94[a]	7/94[a]	7/94[a]	6/12/96[c]	# of Analyses	# of Detections	Maximum Conc.	Minimum Conc.	Range of RL	Approximate Distribution	Mean	Standard Deviation	Median	UCL (95%)
	Sediment	Sediment	Sediment	Sediment										
Total Metals (mg/kg)														
Aluminum	86000	87000	78000	10400	4	4	87000	10400		Neither	65350	36854	82000	**87000**
Arsenic	3.1	1U	12		3	2	12	3.1	1	Neither	5.2	6	3.1	**12**
Barium	470	480	340		3	3	480	340		Neither	430	78.1	470	**480**
Beryllium	1	1	1		3	3	1	1		Neither	1	0	1	**1**
Cadmium	0.552	0.085	2	0.3 U	4	3	2	0.085	0.3	Neither	0.69	0.89	0.35	**2**
Calcium	37000	37000	37000		3	3	37000	37000		Neither	37000	0	37000	**37000**
Chromium	79	36	97		3	3	97	36		Neither	70.7	31.3	74	**97**
Copper	74	12	37	29	4	4	74	12		Neither	38	26.2	33	**74**
Iron	63000	47000	99000	15700	4	4	99000	15700		Neither	56175	34655	55000	**99000**
Lead	17	7	11	4.9	4	4	17	4.9		Lognormal	10.36	5.3	9	34 8
Magnesium	24000	20000	22000		3	3	24000	20000		Neither	22000	2000	22000	**24000**
Manganese	1300	980	1600	271	4	4	1600	271		Neither	1037.8	570.4	1140	**1600**
Mercury														
Molybdenum	0.076	0.58	1.3		3	3	1 3	0.076		Neither	0.7	0 6	0.58	**1.3**
Nickel	31	20	28		3	3	31	20		Neither	26.3	5.7	28	**31**
Potassium	8800	12000	7300		3	3	12000	7300		Neither	9366.7	2400.7	8800	**12000**
Selenium				0.3 U	1	0			0.3					
Silver	0.067	0.067U	0.067U		3	1	0.067	0.067	0.067					
Sodium	23000	29000	24000		3	3	29000	23000		Neither	25333.3	3214.5	24000	**29000**
Thallium														
Uranium	100 U	100 U	100 U		3	0			100					
Zinc	180	110	130	62	3	7	180	62		Neither	120.5	48.8	120	**180**

Data Notes:
J - Estimated value.
U - Parameter was analyzed for, but not detected above the reporting limit shown.
UJ - Parameter was analyzed for but not detected. Detection limit is an estimated value.
Grey shading indicates the concentration of analyte was not established, therefore not reported nor analyzed.

Data Source:
(a) Kilburn, et al. 1994. *Geochemical data and sample locality maps for stream-sediment, heavy-mineral-concentrate, mill tailing, water, and precipitate samples collected in and around the Holden mine, Chelan County, Washington.* USGS Open File Report 94-680A Paper Version, 94-680B Diskette version (Data Collected in 1994)
(b) Lambeth, R.H. 1995. Transmittal of laboratory data from samples collected at Holden Mine site by the US Bureau of Mines.
(c) Johnson, A., et al. 1997. *Effects of Holden Mine on the Water, Sediments and Benthic Invertebrates of Railroad Creek (Lake Chelan).* Environmental Investigations and Laboratory Services Program. Water Body No. WA-47-1020. Publication No. 97-330 (data collected in Spring and Fall 1996)

Statistical Notes: (Statisical calculations were performed using Washington Department of Ecology's MTCAStat Excel V.5 Macro (Module 2.1), downloaded from their web site.)
Maximum and minimum concentrations are based on detected values only.
Range of reporting limits (RL) are based on results reported as not detected.
Distribution is determined based on the MTCA stat program by analyzing the data through the "W-Test" or D'Agostino's test. Where data is not lognormally nor normally distributed, the distribution is noted as "Neither".
When approximate distribution is reported as "neither", the maximum concentration is reported as the 95% UCL and is presented in **BOLD** font.
If UCL is reported in brackets {*UCL*}, this indicates that the calculated result from MTCAStat was reported to be unusually high. Therefore, the calculated 95% UCL is suspect.
The mean is an arithmetic mean if data are normally distributed or if distribution is indicated as "Neither". The reported mean for lognormally distributed data is a lognormal mean.
Statistical analysis was not performed on data sets where 50% or greater of the results were reported as not detected. Only maximum and minimum concentrations are reported, if applicable.
For these data sets, a calculated median is based on detected values only.

TABLE 7.1-D
COMPARISON OF SEDIMENTARY TOTAL METAL CONCENTRATIONS FROM RAILROAD CREEK
(BASED ON SAMPLES COLLECTED FROM 1991-1997)
HOLDEN MINE RI/FS
DAMES & MOORE JOB NO. 17693-005-019

Parameters	RAILROAD CREEK ADJACENT TO SITE (RC-2)												
	345	347	350	BKG 1/2	DG-1	TP1-2	TP2-1	TP2-2	TP3-1	ECOLOGY RC-2	Floc1-RC-2	Floc2-RC-5	Floc3-RC-9
	7/94^a	7/94^a	7/94^a	3/24/94^b	3/24/94^b	3/24/94^b	3/24/94^b	3/24/94^b	3/24/94^b	9/11/96^c	10/4/97	10/4/97	10/4/97
	Sediment	Sediment	Sediment	Sediment	Sediment	Sediment	Sediment	Sediment	Sediment	Sediment	Flocculent	Flocculent	Flocculent
Total Metals (mg/kg)													
Aluminum	78000	83000	34000	11300	9380	10800	10400	9330	11700	8540	3,240	5,410	16,600
Arsenic	10	13	1U	11.5	3.8	11.2	7.5	9.2	11.4	▨	20.1	47	126
Barium	540	390	220	26.3	78.8	30.1	19.3	41.7	39.3	▨	14.5	24.1	31
Beryllium	1	1	1 U	0.08	0.07	0.1	0.11	0.14	0.13	▨	0.2U	0.5U	2U
Cadmium	0.6	2	0.05U	0.93	1.1	1.8	1.2	1.8	1.3	0.3 U	1.3J	4J	5J
Calcium	29000	39000	10000	4600	2820	3800	3090	2950	3630	▨	602	710	1,090
Chromium	70	85	18	16.9	4.4	7.3	7.9	1.3	12.9	▨	2.9	5	10
Copper	140	240	200	76.6	184	9.1	8.5	7.1	11.1	101	164	492	982
Iron	50000	71000	150000	17000	20600	41300	30800	38400	27700	19000	84,400J	125,000J	434,000J
Lead	24	14	66	7.1	4.2	6.5	4.4	5 6	6.3	5.6	4U	10U	40U
Magnesium	20000	24000	8200	6940	5590	6570	6980	5270	8940	▨	588	570	1,220
Manganese	860	1400	380	308	242	6.5	4.4	5.6	6.3	217	53.4J	182J	331J
Mercury	▨	▨	▨	0.02	0.02 U	0.02 U	0.02 U	0.02 U	0.02 U	▨	▨	▨	▨
Molybdenum	2	0.93	12	▨	▨	▨	▨	▨	▨	▨	11.1	9	70
Nickel	30	29	2	15	21.6	16.2	12.5	10.7	25.7	▨	2	5U	20U
Potassium	10000	8200	7500	455	888	631	547	718	723	▨	220	440	1,050U
Selenium	▨	▨	▨	0.95	0.10 U	0.95	0.12	0.14	0.93	0.5	▨	▨	▨
Silver	0.17	0.067U	1.2	0.64	0.73	5.6	0.6	0.72	0.76	▨	1.2	2	11
Sodium	24000	25000	9800	345	318	336	312	294	368	▨	63U	70	210
Thallium	▨	▨	▨	0.15	0.14	0.14	0.1	0.13	0.12	▨	0 10U	0.2U	0.4U
Uranium	100 U	100 U	100 U	▨	▨	▨	▨	▨	▨	▨	2U	4U	8U
Zinc	280	270	250	110	126	106	75	118	152	113	145J	320J	481J

Data Notes:
J - Estimated value.
U - Parameter was analyzed for, but not detected above the reporting limit shown.
UJ - Parameter was analyzed for but not detected. Detection limit is an estimated value.
▨ Grey shading ▨ indicates the concentration of analyte was not established, therefore not reported nor analyzed.

Data Source:
(a) Kilburn, et al. 1994. *Geochemical data and sample locality maps for stream-sediment, heavy-mineral-concentrate, mill tailing, water, and precipitate samples collected in and around the Holden mine, Chelan County, Washington.* USGS Open File Report 94-680A Paper Version, 94-680B Diskette version (Data Collected in 1994)
(b) Lambeth, R.H. 1995. Transmittal of laboratory data from samples collected at Holden Mine site by the US Bureau of Mines
(c) Johnson, A., et al. 1997. *Effects of Holden Mine on the Water, Sediments and Benthic Invertebrates of Railroad Creek (Lake Chelan)*
Environmental Investigations and Laboratory Services Program. Water Body No. WA-47-1020. Publication No. 97-330 (data collected in Spring and Fall 1996).

TABLE 7.1-D
COMPARISON OF SEDIMENTARY TOTAL METAL CONCENTRATIONS FROM RAILROAD CREEK
(BASED ON SAMPLES COLLECTED FROM 1991-1997)
HOLDEN MINE RI/FS
DAMES & MOORE JOB NO. 17693-005-019

Parameters	**STATISTICAL CALCULATIONS FOR RC-SITE**									
	# of Analyses	**# of Detections**	**Maximum Conc.**	**Minimum Conc.**	**Range of RL**	**Approximate Distribution**	**Mean**	**Standard Deviation**	**Median**	**UCL (95%)**
Total Metals (mg/kg)										
Aluminum	13	13	83000	3240		Lognormal	21755	26827.2	10800	46297
Arsenic	12	11	13	3.8	1	Lognormal	26.36	34.6	11.3	108.54
Barium	12	12	540	14.5		Neither	121.3	172.9	33.15	**540**
Beryllium	12	8	1	0.07	0.2-2.0	Neither	0.37	0.39	0.14	**1**
Cadmium	13	11	2	0.6	0.05-0.3	Neither	1.63	1.42	1.3	**2**
Calcium	12	12	39000	602		Lognormal	8767.6	12373.1	3360	34219
Chromium	12	12	85	1.3		Lognormal	20.9	27.48	8.95	69.9
Copper	13	13	982	7.1		Neither	201.2	269 9	140	**982**
Iron	13	13	434000	17000		Lognormal	81570	112722	41300	172447
Lead	13	10	66	4.2	4.0-40.0	Lognormal	12.47	17.2	6.3	25.54
Magnesium	12	12	24000	570		Lognormal	10088.7	7226.2	6755	34714
Manganese	13	13	1400	4.4		Neither	307.4	404.3	217	**1400**
Mercury	6	1	0.02	0.02	0.02		0.01	0.004	0.01	
Molybdenum	6	6	70	0.93		Neither	17 5	26..1	10	**70**
Nickel	12	10	30	2	5.0-20.0	Normal	14.8	10.1	13.8	20
Potassium	12	11	10000	220	1050	Neither	2570.6	3661.1	674.5	**10000**
Selenium	7	6	0.95	0.12	0.1	Lognormal	0.67	0.4	0.5	5.63
Silver	12	11	5.6	0.17	0.067	Neither	2.1	3.2	0.7	**11**
Sodium	12	11	25000	70	63	Neither	5090.4	9471.5	327	**25000**
Thallium	9	6	0.2	0.05	0.1-0.4	Lognormal	0.13	0.04	0.13	0.17
Uranium	6	0			2-100					
Zinc	13	13	481	75		Lognormal	196.7	117.1	145	277.4

Statistical Notes: (Statisical calculations were performed using Washington Department of Ecology's MTCAStat Excel V.5 Macro (Module 2 1), downloaded from their web site)
Maximum and minimum concentrations are based on detected values only.
Range of reporting limits (RL) are based on results reported as not detected.
Distribution is determined based on the MTCA stat program by analyzing the data through the "W-Test" or D'Agostino's test. Where data is not lognormally nor normally distributed, the distribution is noted as "N
When approximate distribution is reported as "neither", the maximum concentration is reported as the 95% UCL and is presented in **BOLD** font.
If UCL is reported in brackets {*UCL*}, this indicates that the calculated result from MTCAStat was reported to be unusually high. Therefore, the calculated 95% UCL is suspect
The mean is an arithmetic mean if data are normally distributed or if distribution is indicated as "Neither". The reported mean for lognormally distributed data is a lognormal mean
Statistical analysis was not performed on data sets where 50% or greater of the results were reported as not detected. Only maximum and minimum concentrations are reported, if applicable.
For these data sets, a calculated median is based on detected values only.

TABLE 7.1-D
COMPARISON OF SEDIMENTARY TOTAL METAL CONCENTRATIONS FROM RAILROAD CREEK
(BASED ON SAMPLES COLLECTED FROM 1991-1997)
HOLDEN MINE RI/FS
DAMES & MOORE JOB NO. 17693-005-019

Parameters	RAILROAD CREEK DOWNSTREAM OF MINE (RC-3)					
	351	352	353	354	ECOLOGY MP-7	ECOLOGY RC-3
	7/94[a]	7/94[a]	7/94[a]	7/94[a]	9/11/96[c]	9/11/96[c]
	Sediment	Sediment	Sediment	Sediment	Sediment	Sediment
Total Metals (mg/kg)						
Aluminum	89000	75000	88000	76000	13300	7890
Arsenic	1U	3.1	1U	3.5	▨	▨
Barium	350	410	450	480	▨	▨
Beryllium	1	1	1	1	▨	▨
Cadmium	0.063	0.49	0.05U	0.63	0.9	0.5
Calcium	40000	36000	36000	32000	▨	▨
Chromium	44	93	52	74	▨	▨
Copper	26	130	13	150	147	59
Iron	66000	71000	40000	60000	26300	14800
Lead	5	18	8	25	11	2.4
Magnesium	23000	24000	18000	19000	▨	▨
Manganese	900	1200	790	980	289	285
Mercury	▨	▨	▨	▨	▨	▨
Molybdenum	0.43	1.8	0.35	4	▨	▨
Nickel	20	32	22	25	▨	▨
Potassium	7500	7600	12000	9200	▨	▨
Selenium	▨	▨	▨	▨	0.6	0.3 U
Silver	0.067	0.11	0.45	0.098	▨	▨
Sodium	24000	22000	28000	23000	▨	▨
Thallium	▨	▨	▨	▨	▨	▨
Uranium	100 U	100 U	100 U	100 U	▨	▨
Zinc	110	230	82	330	216	144

Data Notes:
J - Estimated value.
U - Parameter was analyzed for, but not detected above the reporting limit shown.
UJ - Parameter was analyzed for but not detected. Detection limit is an estimated value.
▨ Grey shading indicates the concentration of analyte was not established, therefore not reported nor analyzed

Data Source:
(a) Kilburn, et al. 1994 *Geochemical data and sample locality maps for stream-sediment, heavy-mineral-concentrate, mill tailing, water, and precipitate samples collec in and around the Holden mine, Chelan County, Washington* USGS Open File Report 94-680A Paper Version, 94-680B Diskette version (Data Collected in 1994)
(b) Lambeth, R.H. 1995. Transmittal of laboratory data from samples collected at Holden Mine site by the US Bureau of Mines
(c) Johnson, A., et al. 1997. *Effects of Holden Mine on the Water, Sediments and Benthic Invertebrates of Railroad Creek (Lake Chelan)* Environmental Investigations and Laboratory Services Program. Water Body No. WA-47-1020. Publication No. 97-330 (data collected in Spring and Fall 1996)

TABLE 7.1-D
COMPARISON OF SEDIMENTARY TOTAL METAL CONCENTRATIONS FROM RAILROAD CREEK
(BASED ON SAMPLES COLLECTED FROM 1991-1997)
HOLDEN MINE RI/FS
DAMES & MOORE JOB NO. 17693-005-019

Parameters	STATISTICAL CALCULATIONS FOR RC-DOWNSTREAM									
	# of Analyses	# of Detections	Maximum Conc.	Minimum Conc.	Range of RL	Approximate Distribution	Mean	Standard Deviation	Median	UCL (95%)
Total Metals (mg/kg)										
Aluminum	6	6	89000	7890		Neither	58198	37371	75500	**89000**
Arsenic	4	2	3.5	3.1	1		1.9	1.6	1.8	
Barium	4	4	480	350		Normal	422.5	56.2	430	488.6
Beryllium	4	4	1	1						
Cadmium	6	5	0.9	0.063	0.05	Neither	0.71	0.3	0.5	**0.9**
Calcium	4	4	40000	32000		Lognormal	36037.8	3266	36000	40463.7
Chromium	4	4	93	44		Lognormal	66.7	22.2	63	118.2
Copper	6	6	150	13		Neither	87.5	62.3	94.5	**150**
Iron	6	6	71000	14800		Lognormal	48948	22881	50000	110.33
Lead	6	6	25	2.4		Lognormal	12.7	8.5	9.5	51.76
Magnesium	4	4	24000	18000		Lognormal	21052	2943.9	21000	25431.8
Manganese	6	6	1200	285		Normal	783.8	376.2	845	1837
Mercury										
Molybdenum	4	4	4	0.35		Neither	1.6	1.7	1.1	**4**
Nickel	4	4	32	20		Lognormal	24.8	5.3	23.5	33.3
Potassium	4	4	12000	7500		Lognormal	9124	2099.8	8400	12565
Selenium	2	1	0.6	0.6	0.3					
Silver	4	4	0.45	0.067		Normal	0.18	0.18	0.1	0.39
Sodium	4	4	28000	22000		Lognormal	24250	2630	23500	27797
Thallium										
Uranium	4	0			100					
Zinc	6	6	330	82		Lognormal	190.3	91.6	180	353.43

Statistical Notes: {Statisical calculations were performed using Washington Department of Ecology's MTCAStat Excel V.5 Macro (Module 2.1), downloaded from their web site.}
Maximum and minimum concentrations are based on detected values only.
Range of reporting limits (RL) are based on results reported as not detected.
Distribution is determined based on the MTCA stat program by analyzing the data through the "W-Test" or D'Agostino's test. Where data is not lognormally nor normally distributed, the distribution is noted as "N
When approximate distribution is reported as "neither", the maximum concentration is reported as the 95% UCL and is presented in **BOLD** font.
If UCL is reported in brackets {*UCL*}, this indicates that the calculated result from MTCAStat was reported to be unusually high. Therefore, the calculated 95% UCL is suspect.
The mean is an arithmetic mean if data are normally distributed or if distribution is indicated as "Neither". The reported mean for lognormally distributed data is a lognormal mean.
Statistical analysis was not performed on data sets where 50% or greater of the results were reported as not detected. Only maximum and minimum concentrations are reported, if applicable
For these data sets, a calculated median is based on detected values only.

TABLE 7.1-E
SURFACE WATER AREA BACKGROUND STATISTICAL ANALYSIS
HOLDEN MINE RI/FS
DAMES & MOORE JOB NO. 17693-005-019

	DAMES & MOORE RI DATA										
* Parameters	Holden Creek	HC-1	HC-2	HC-3	HC-4	Big-1	CC-1	CC-1	CC-1	CC-1	Ten-Mile Creek
	10/4/97	5/1/98	4/30/98	4/30/98	4/30/98	5/2/98	5/23/97	7/11/97	9/15/97	5/2/98	9/16/97
Total Metals (ug/L)											
Aluminum	40U	80U	240	70U	50U	30U	20U	40	20	100J	30
Arsenic	0.54	0.52	0.65	0.78	1.33	0.33				0.04U	0.14
Barium	4.27	5.04	6.17	5.76	6.82	7.09	6	4.99	4.61	5.64	6.17
Beryllium	0.08U	0.04U	0.04U	0.04U	0.04U	0.04U	0.04U	0.04U	0.04U	0.04U	0.04U
Cadmium	0.05	0.04U	0.07U	0.07U	0.06U	0.04U	0.04U	0.04U	0.04U	0.04U	0.04U
Calcium	3,600	5,180	5,690	5,010	4,150	7,050	4,400	3,110	3,720	3,980	10,200
Chromium	1U	0.2U	0.3	0.2U	0.2U	0.2U	5U	0.2U	0.2U	0.3	0.2U
Copper	0.7	1.2U	1.6J	1U	0.9U	0.5U	2U	0.3	0.3	0.6U	0.4
Iron	50	70	230	100	100	20U	20U	30	20U	100	20U
Lead	0.3	0.054	0.129	0.067	0.069	0.011U	0.4U	0.3UJ	0.2UJ	0.06	0.2UJ
Magnesium	330	560	670	580	260	360	550	410	450	490	760
Manganese	3.5	2.69	6.8	3.95	2.87	0.73	1U	0.63	0.22	2.96	0.31
Mercury											
Molybdenum	0.43	0.5	0.53	0.45	0.69	0.35				0.49	0.69
Nickel	0.2	0.2U	0.5	0.2U	0.2U	0 2U	10U	0.2	0.2	0.4	0.3
Potassium	500U	500U	500U	600	500U	500U	530	710	500U	500U	500U
Selenium											
Silver	0.04U	0.04U	0.04U	0.04U	0.04U	0.04U	0.04U	0.04U	0.04U	0.04U	0.04U
Sodium	630U	850	880	880	640	660	740	540	610	640	740
Thallium											0.04U
Uranium											0.06
Zinc	4U	5	5	4U	4	4U	4U	4U	4U	5	4U
Dissolved Metals (ug/L)											
Aluminum	30U	50	30	20	20U	30	20U	20U	20U	20U	20U
Arsenic	0.5	0.39	0.45	0.61	1	0.29				0.04U	0.14
Barium	4.19	4.27	4.56	4.88	6.19	6.51	23	13.6	4.73	4.96	6.42
Beryllium	0.04U	0.04U	0.04U	0.04U	0.04U	0.04U	0.04U	0.04U	0.04U	0.04U	0.04U
Cadmium	0.05	0.04U	0.05	0.04U	0.06	0.04U	0.04U	0.08	0.04U	0.04U	0.04U
Calcium	3,550	4,980	5,340	5,030	3,990	6,730	4,390	3,110	3,780	3,790	10,600
Chromium	0.2U	0.2U	0.2U	0.2U	0.2U	0.2U	5U	0.2U	0.2U	0.2U	0.2U
Copper	0.9	0.6	0.7	0.6	0.5	0.3	2U	0.3	0.2	0.5	0.3
Iron	20U	20U	20U	20	30	20U	20U	20U	20U	20U	20U
Lead	0.3	0.018	0.011U	0.011U	0.011U	0.011U	0.4U	1.8J	0.2U	0.011U	0.2U
Magnesium	330	520	580	570	230	350	550	390	470	430	790
Manganese	1.80	0.78	2.91	1.32	1.05	0.29U	1U	0.13	0.13U	0.82	0.14U
Mercury											
Molybdenum	0.5	0.46	0.49	0.43	0.64	0.33				0.48	0.70
Nickel	0.2U	0.2U	0.2	0.2U	0.2U	0.2U	10U	0.2U	0.2U	0.3	0.4
Potassium	500U	500U	500U	500U	500U	500U	650	500U	630	500U	500U
Selenium											
Silver	0.04U	0.04U	0 04U	0.04U	0.04U	0.04U	0.04U	0.04U	0.04U	0.04U	0.04U
Sodium	640U	850	820	880	610	640	800	570	620	600	790
Thallium											0.04U
Uranium											0.06
Zinc	6	4U	4U	4U	4U	4U	12	10	4U	4U	4U

Data Notes:

U - Parameter was analyzed for, but not detected above the reporting limit shown.

J - Estimated Value.

UJ - Parameter was analyzed for, but not detected. Detection limit is an estimated value.

* indicates that highest value from range of replicated samples were represented.

Shading	Indicates that this value was not included in the statistical analysis
Blank Cell	Indicates that the data was not available for this parameter

Data Source:

(a) Walters, et al. 1992. *Holden Mine Reclamation Project Final Report.* Pacific Northwest Laboratories,Richland, WA. (Data collected in 1991).

(b) Kilburn, et al. 1994. *Geochemical data and sample locality maps for stream-sediment, heavy-mineral-concentrate, mill tailing, water, and precipitate samples collected in and around the Holden mine, Chelan County, Washington.* USGS Open File Report 94-680A Paper Version, 94-680B Diskette version (Data Collected in 1994).

(c) Anderson, Keith A. (USFS Chelan Ranger District). Compilation of Data for Preliminary Assessment of the Holden Mine Site.

(d) Kilburn, J.E. & S.J. Sutley. 1996. *Characterization of acid mine drainage at the Holden mine; Chelan, Washington.* USGS Open File Report 96-531. (Data collected in 1995).

(e) Kilburn, J.E. & S.J. Sutley. 1997. *Analytical results and comparative overview of geochemical studies conducted at the Holden Mine*, spring 1996. USGS Open File Report 97-128 (Data collected in Spring 1996).

(f) Kilburn, J.E. & S.J. Sutley. 1997. Preliminary data (no report attached, data collected in Fall 1996).

(g) Johnson, A., et al. 1997. *Effects of Holden Mine on the Water, Sediments and Benthic Invertebrates of Railroad Creek (Lake Chelan).* Environmental Investigations and Laboratory Services Program. Water Body No. WA-47-1020. Publication No. 97-330 (data collected in Spring and Fall 1996).

TABLE 7.1-E
SURFACE WATER AREA BACKGROUND STATISTICAL ANALYSIS
HOLDEN MINE RI/FS
DAMES & MOORE JOB NO. 17693-005-019

							DAMES & MOORE RI DATA				
Parameters	**367**	**546**	**600**	**DEPT. OF ECOLOGY (RC-STATION SAMPLES)[g]**		**707**	**RC-11**		**RC-6A**	**RC-6B**	**RC-6C**
	USGS 7/94[b]	**USGS 7/95[d]**	**USGS 5/96[e]**	**6/12/96**	**9/10/96**	**USGS 1996[f]**	**10/4/97**	**5/1/98**	**4/15/97**	**4/15/97**	**4/15/97**
Total Metals (ug/L)											
Aluminum				13	32	46	140U	70U	20U	20U	20
Arsenic				0.69	0.88		1.56	1.12	1U	1U	1U
Barium						5.4	4.13	4.14	3	3	4
Beryllium						10 U	0.08U	0.04U	1U	1U	1U
Cadmium				0.02 U	0.1 U	10 U	0.04U	0.04U	0.2U	0.2U	0.2U
Calcium						5,900	2,540	2,410	6,720	6,660	6,740
Chromium						10 U	0.2U	0.2U	5U	5U	5U
Copper				1.4	3.7	10 U	1.2	1	2U	2U	2U
Iron				71	77	110	220	90	70	70	70
Lead				0.13	0.12	50 U	0.4	0.139	1U	1U	1U
Magnesium						1000 U	290	240	680	670	670
Manganese				1.3	1.9	10 U	6.02	3.83	2	2	2
Mercury				0.001 U					0.1U	0.1U	0.1U
Molybdenum						20 U	0.66	0.65			
Nickel				0.34		10 U	0.4	0.3	10U	10U	10U
Potassium						1000 U	500U	500U	600	810	650
Selenium					0.4 U				1U	1U	1U
Silver				0.02			0.04U	0.04U	0.2U	0.2U	0.2U
Sodium						1,100	540U	670	1,120	1,120	1,140
Thallium									1U	1U	1U
Uranium											
Zinc				3.7	3	10 U	5	4U	4U	4U	4U
Dissolved Metals (ug/L)											
Aluminum	20	20	20 U		7.4 *	11	40U	30	20	40	20U
Arsenic	2 U	1 U	4 U				0.94	0.73	1U	1U	1U
Barium	4.1	3.8	6.5			5.1	3.42	3.61	5	5	5
Beryllium	1 U	0.3 U	0.4 U			10 U	0.04U	0.04U	1U	1U	1U
Cadmium	1 U	1 U	0.7 U	0.05	0.02 *	10 U	0.04U	0.04U	0.2U	0.2U	0.2U
Calcium	6000 U	3900	5900			5,800	2,520	2,310	6,750	6,810	6,490
Chromium	1 U	0.9 U	0.5 U			10 U	0.2U	0.2U	5U	5U	5U
Copper	0.62	3	6.5	0.96	0.26 *	10 U	1.1	0.7	2U	2U	2U
Iron	100 U	40	91			100 U	60	30	30	40	40
Lead	0.2 U	0.3 U	0.2	0.02	0.02 *	50 U	0.2U	0.5J	1U	1U	1U
Magnesium	270	280	1000 U			1000 U	260	230	640	650	660
Manganese	2	1.6	3 U			10 U	3.17	2.88	2	1	1
Mercury									0.1UJ	0.1UJ	0.1UJ
Molybdenum	0.5	0.3	0.6			20 U	0.67	0.59			
Nickel	3 U	0.5	1 U	0.22		0.01 U	0.3	0.3	10U	10U	10U
Potassium	200 U					1000 U	500U	500U	780	660	500U
Selenium									1U	1U	1U
Silver	0.1 U	0.1 U	0.2 U	0.02			0.04U	0.04U	0.2U	0.2U	0.2U
Sodium	300	500				1000 U	560U	630	1,100	1,160	1,120
Thallium	0.1 U	0.6 U	4 U						1U	1U	1U
Uranium	0.1 U	0.1 U	0.4 U								
Zinc	4	10	3.4	1.3	0.85 *	10 U	5	4U	6	6	5

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TABLE 7.1-E
SURFACE WATER AREA BACKGROUND STATISTICAL ANALYSIS
HOLDEN MINE RI/FS
DAMES & MOORE JOB NO. 17693-005-019

Parameters	DAMES & MOORE RI DATA								
	RC-6							RC-6 N.Bank	RC-6 N.Bank X
	5/19/97	5/26/97	6/2/97	6/9/97	6/16/97	7/10/97	5/3/98	9/15/97	9/15/97
Total Metals (ug/L)									
Aluminum	90	40J	160	80J	180	150	150J	60	60
Arsenic	0.80					0.76	1.07	1.07	1.09
Barium	4.92	4.43	4.87	4.43J	5	4.61	5.1	4.38	4.52
Beryllium	0.04U	0.2U	0.04U	0.04U	0.2U	0.04U	0.04U	0.04U	0.04U
Cadmium	0.04U	0.04U	0.04	0.04U	0.2U	0.04U	0.04U	0.04U	0.04U
Calcium	3,820	4,020	3,430	3,530J	2,820	3,030	3,800	4,100	4,020
Chromium	0.2U	0.2U	0.2U	0.2U	5U	0.2U	0.2U	0.2U	0.2U
Copper	0.9U	0.7	1.3	0.8J	4	1.1	1.8J	0.6	1.0
Iron	140	80J	150	70J	170	150	180	110	120
Lead	0.3U	0.3	4.8	0.3J	1U	0.3UJ	0.124	0.2UJ	0.3UJ
Magnesium	360	400	340	340J	310	310	360	360	360
Manganese	3.7	1.67	4.41	1.95J	5	3.90	6.52	3.02	3.53
Mercury	0.00046J					0.00064			
Molybdenum	0.49					0.39	0.53	0.74	0.74
Nickel	0.3J	0.4	0.4	0.2U	10U	0.3	0.3	0.2	0.3
Potassium	500U	500U	500U	510J	500U	500U	500U	500U	500U
Selenium	0.2U					0.2U			
Silver	0.04U	0.04U	0.04U	0.04UJ	0.2U	0.04U	0.04U	0.04U	0.04U
Sodium	760	810	610	610J	600	700	690	580	570
Thallium	0.04U					0.04U		0.04U	0.04U
Uranium	0.04U					0.04U		0.04U	0.04U
Zinc	4U	4U	4U	4U	11	4U	4U	5	4U
Dissolved Metals (ug/L)									
Aluminum	30U	20	60	40J	30	30U	40	30	20U
Arsenic	0.50					0.52	0.54	0.81	0.82
Barium	15.4J	24.3	17.6	16.0J	14	10.9	4.14	4.33	4.33
Beryllium	0.04U	0.04U	0.04U	0.04U	0.04U	0.04U	0.04U	0.04U	0.04U
Cadmium	0.04U	0.04U	0.04U	0.04U	0.04U	0.04U	0.08	0.04U	0.08
Calcium	3,870	3,780	3,510	3,480J	2,800	3,000	3,630	4,170	4,150
Chromium	0.2U	0.2U	0.2U	0.2U	5U	0.2U	0.2U	0.2U	0.2U
Copper	0.7	1.0	0.9	1.2U	2U	0.6	0.6	0.4	0.5
Iron	30	30J	30	20U	20U	20U	30	40	40
Lead	0.9U	0.3U	1.8U	0.2U	0.2U	0.2J	0.011U	0.2U	0.9
Magnesium	360	370	340	310J	250	260	320	350	350
Manganese	1.94	1.40	1.23	0.96J	1	1.18	2.08	1.74	1.72
Mercury	0.00003J					0.00033J			
Molybdenum	0.51					0.41	0.48	0.73	0.73
Nickel	0.3	0.6	0.4	0.2U	10U	0.2U	0.2U	0.2	0.2
Potassium	500U	500U	710	500U	500U	500U	500U	500U	500U
Selenium	0.2U					0.2U			
Silver	0.04U	0.04U	0.04UJ	0.04UJ	0.04U	0.04U	0.04U	0.04U	0.04U
Sodium	800J	820	660	660J	570U	490	700	600	610
Thallium	0.04U					0.04U		0.04U	0.04U
Uranium	0.04U					0.04U		0.04U	0.04U
Zinc	16	14U	13U	16U	12	6	4U	16	4

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TABLE 7.1-E
SURFACE WATER AREA BACKGROUND STATISTICAL ANALYSIS
HOLDEN MINE RI/FS
DAMES & MOORE JOB NO. 17693-005-019

Parameters	DAMES & MOORE RI DATA												
	RC-1A	RC-1B	RC-1C	RC-1				RC-1 North Bank		RC-1 South Bank		SF Agnes Creek	Company Creek
	4/16/97	4/16/97	4/16/97	5/19/97	7/10/97	9/15/97	5/3/98	5/19/97	9/15/97	5/19/97	9/15/97	9/30/97	10/2/97
Total Metals (ug/L)													
Aluminum	20	20U	20U	90	160	70	100J	100	40	100U	60	110U	30U
Arsenic	1	1	2	0.72	0.76	1.07	0.86					2.84	0.14
Barium	3	3	4	4.98	4.62	4.42	4.91	5.02	4.40	4.80	4.39	4.91	6.27
Beryllium	1U	1U	1U	0.04U	0.04U	0.04U	0.04U	0.04U	0.04U	0.04U	0.04U	0.04U	0.08U
Cadmium	0.2U	0.2U	0.2U	0.04U	0.04U	0.04U	0.04U	0.05	0.04U	0.04U	0.04U	0.04U	0.04U
Calcium	6,480	6,480	6,470	3,800	3,050	4,080	3,860	3,850	4,060	3,840	4,100	2,420	6,980
Chromium	5U	5U	5U	0.2U	0.2U	0.2U	0.2U	0.2U	0.2U	0.2U	0.2U	0.2U	1U
Copper	2U	2U	2U	1.1U	1.0	0.6	1.1	1.2U	0.6	1.1U	0.7	0.4	0.4
Iron	70	90	70	120	160	110	110	130	100	140	110	90	20U
Lead	1U	1U	1U	0.2U	0.3UJ	0.2UJ	0.103	0.3U	0.3UJ	0.4U	0.2UJ	0.2U	0.3
Magnesium	650	640	650	360	320	350	360	370	360	390	360	340	570
Manganese	2	2	2	4.70	3.87	3.09	4.45	3.49	2.70	3.30	3.20	1.79	0.9
Mercury	0.1U	0.1U	0.1U	0.00039	0.00032J								
Molybdenum				0.49	0.39	0.74	0.52					0.98	0.60
Nickel	10U	10U	10U	0.3J	0.3	0.2	0.3	0.3J	0.2	0.3J	0.2	0.2U	0.3
Potassium	780	630	730	500U	500U	500U	500U	500U	500U	610	500U	500U	500U
Selenium	1U	1U	1U	0.2U	0.2U								
Silver	0 2U	0.2U	0.2U	0.14U	0.04U	0.04U	0.04U	0.12U	0.12	0.05U	0.04U	0.15J	0.04U
Sodium	1,090	1,090	1,090	780	490	580	730	750	590	800	590	610U	840U
Thallium	1U	1U	1U	0.04U	0.04U	0.04U							
Uranium				0.04U	0.04U	0.04U							
Zinc	4U	4U	4U	4U	5	4U	4U	4U	4U	5	4U	4U	4U
Dissolved Metals (ug/L)													
Aluminum	20	20U	20	30	20U	20U	30	30U	20U	30	20U	20U	20U
Arsenic	1U	1U	1U	0.50	0.51	0.82	0.53					2.58	0.13
Barium	5	6	6	22.0J	10.4	4.32	4.38	17.2J	4.30	15.0J	4.29	4.36	6.14
Beryllium	1U	1U	1U	0.04U	0.04U	0.04U	0.04U	0.04U	0.04U	0.04U	0.04U	0.08U	0.04U
Cadmium	0.2U	0.2U	0.2U	0.04U	0.04U	0.04U	0.04U	0.06	0.04U	0.04	0.09	0.04U	0.04U
Calcium	6,430	6,430	6,400	3,770	3,120	4,120	3,730	3,800	4,150	3,760	4,180	2,350	6,890
Chromium	5U	5U	5U	0.2U	0.2U	0.2U	0.2U	0.2U	0.2U	0.2U	0.2U	0.2U	0.2U
Copper	2U	2U	2U	1.1	0.6	0.4	0.8	1.0	0.6	1.0	0.6	0.5	0.4
Iron	40	40	40	30	20U	40	20	20U	40	20U	40	20U	20U
Lead	1U	1U	1U	0.2U	0.3J	0.5	0.011U	1.1U	0.2U	0.7U	0.2	0.2U	0.2U
Magnesium	660	660	660	360	270	350	330	360	340	360	350	300	560
Manganese	2	1	1	1.82	1.13	1.65	2	1.86	1.67	1.83	1.68	0.62	0.29
Mercury	0.1UJ	0.1UJ	0.1UJ	0.00031J	0.00028J								
Molybdenum				0.49	0.40	0.82	0.49					1.02	0.61
Nickel	10U	10U	10U	0.2	0.2U	0.2	0.2U	0.3	0.2	0.2	0.2	0.2	0.2
Potassium	690	500	500	500U	500U	500U	500U	500U	500U	500U	500U	560	500U
Selenium	1U	1U	1U	0.2U	0.2U								
Silver	0.2U	0.2U	0.2U	0.04U	0.04U	0.04U	0.04U	0.04U	0.04U	0.04U	0.04U	0.04U	0.04U
Sodium	1,240	1,220	1,280	810J	490	620	690	850J	600	780U	630	590U	880U
Thallium	1U	1U	1U	0.04U	0.04U	0.04U							
Uranium				0.04U	0.04U	0.04U							
Zinc	5	5	4U	13	6	4U	4U	16	9	13	4U	11	7

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TABLE 7.1-E
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HOLDEN MINE RI/FS
DAMES & MOORE JOB NO. 17693-005-019

Parameters	STATISTICAL CALCULATIONS									
	# Analyses	# of Detections	Maximum Conc.	Minimum Conc.	Range of RL	Approximate Distribution	Mean	Standard Deviation	Median	90th Percentile
Total Metals (ug/L)										
Aluminum	41	26	240	13	20-140	Lognormal	86.1	58.9	65	144
Arsenic	25	24	2	0.14	0.04	Normal	0.87	0.415	0.83	1.44
Barium	39	39	7.09	3	None	Lognormal	4.8	0.97	4.8	6.24
Beryllium	32	0	NA	NA	0.04 - 0.2	NA	NA	NA	NA	NA
Cadmium	40	3	0.05	0.04	0.02 - 0.2	Non-Parametric	0.047	0.006	0.05	0.10
Calcium	39	39	10200	2410	None	Lognormal	4589	1659	4020	6814
Chromium	31	2	0.3	0.3	0.2-10	Non-Parametric	0.3	0	0.3	0.46
Copper	33	24	4	0.3	0.5-1.2	Lognormal	1.1	0.936	0.9	1.83
Iron	41	36	230	30	20	Lognormal	110	44.5	100	177
Lead	33	16	4.8	0.054	0.2-0.4	Non-Parametric	0.46	1.16	0.1295	0.3
Magnesium	38	38	760	240	None	Lognormal	443	144.5	360	647
Manganese	39	39	6.8	0.22	None	Normal	2.95	1.59	2.96	5.06
Mercury	11	4	0.00064	0.000032	0.001-0.1	Lognormal	0.00046	0.00014	0.000425	0.00066
Molybdenum	21	21	0.98	0.35	None	Lognormal	0.57	0.154	0.53	0.79
Nickel	31	25	0.5	0.2	0.2	Non-Parametric	0.3	0.08	0.3	0.4
Potassium	38	11	810	510	500	Lognormal	652	96.7	630	672
Selenium	10	0	NA	NA	0.2-1	NA	NA	NA	NA	NA
Silver	38	2	0.15	0.12	0.04-0.2	Non-Parametric	0.135	0.021	0.135	0.1
Sodium	39	35	1140	490	540-840	Lognormal	767	196.7	730	1034
Thallium	14	0	NA	NA	0.04-1	NA	NA	NA	NA	NA
Uranium	8	1	0.06	0.06	0.04	Non-Parametric	0.06	NA	0.06	NA
Zinc	41	11	11	3	4-10	Non-Parametric	5.2	2.1	5	5
Dissolved Metals (ug/L)										
Aluminum	43	22	60	7.4	20 - 40	Lognormal	29	12.2	30	37.4
Arsenic	19	19	1	0.13	None	Normal	0.565	0.242	0.52	0.9
Barium	42	42	24.3	3.42	None	Non-Parametric	8.22	5.9	5	17.5
Beryllium	34	0	NA	NA	0.04 - 0.4	NA	NA	NA	NA	NA
Cadmium	41	11	0.09	0.02	0.04 -0.7	Lognormal	0.061	0.021	0.06	0.07
Calcium	42	41	10600	2310	6000	Lognormal	4564	1653	3990	6703
Chromium	34	0	NA	NA	0.2 -10	NA	NA	NA	NA	NA
Copper	32	31	1.1	0.2	1.2	Lognormal	0.64	0.26	0.6	1.06
Iron	40	23	91	20	20	Non-Parametric	37.87	14.3	40	40
Lead	35	12	1.8	0.018	0.011 - 0.9	Lognormal	0.602	0.505	0.25	0.54
Magnesium	40	40	790	230	None	Lognormal	417	151	355	626
Manganese	39	36	3.17	0.13	0.13 - 0.29	Normal	1.507	0.677	1.625	2.42
Mercury	10	4	0.00033	0.00003	0.1	Non-Parametric	0.00024	0.00014	0.000295	0.05
Molybdenum	24	24	1.02	0.3	None	Lognormal	0.56	0.16	0.5	0.78
Nickel	32	20	0.6	0.2	0.2	Lognormal	0.28	0.11	0.21	0.39
Potassium	39	9	780	500	200 - 500	Non-Parametric	631	95	650	660
Selenium	10	0	NA	NA	0.2 - 1	NA	NA	NA	NA	NA
Silver	41	0	NA	NA	0.04	NA	NA	NA	NA	NA
Sodium	41	34	1280	300	560-1000	Lognormal	759	237	675	1078
Thallium	17	0	NA	NA	0.04-4	NA	NA	NA	NA	NA
Uranium	11	1	0.06	0.06	0.04-0.4	Non-Parametric	0.06	NA	0.06	0.172
Zinc	44	15	16	0.85	4	Lognormal	7.184	4.203	5	7.81

Statistical Notes: (Statistical calculations were performed using Washington Department of Ecology's MTCAStat Excel V.5 Macro (Background Module 2.1), downloaded from their web site.)

Maximum and minimum concentrations are based on detected values only.

Range of reporting limits (RL) are based on results reported as not detected.

Distribution is determined based on the MTCA stat program by analyzing the data through the "Distribution Decision Probability Plot". Where data is not lognormally nor normally distributed, the distribution is noted as "Non-parametric".

The mean is an arithmetic mean if data are normally distributed or if distribution is indicated as "non-parametric". The reported mean for lognormally distributed data is a lognormal mean.

NA indicates that the data set contained too many results reported as not detected to perform a statistical analysis for background concentrations.

TABLE 7.1-F
STATISTICAL ANALYSIS AND COMPARISON OF SURFACE WATER DATA FROM RAILROAD CREEK
(DATA COLLECTED FROM STATION RC-2 ADJACENT TO SITE, 1991 - 1998)
HOLDEN MINE RI/FS
DAMES & MOORE JOB NO. 17693-005-019

Parameters	BATTELLE WATER QUALITY MONITORING DATA 1991 [a]								USFS WATER QUALITY MONITORING DATA 1992 [c]							
	5/10/91	5/18/91	6/3/91	6/18/91	7/2/91	7/16/91	8/6/91	9/17/91	5/14/92	6/2/92	6/16/92	7/1/92	7/14/92	7/29/92	8/11/92	9/8/92
Total Metals (ug/L)																
Aluminum	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨
Arsenic	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨
Barium	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨
Beryllium	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨
Cadmium	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨
Calcium	7246	4818	4535	5180	3484	3443	3573	5487	5522	3290	3891	3847	4487	4544	4631	4530
Chromium	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨
Copper	1.1 U	34	14	9	1.1 U	1.1 U	1.1 U	1.1 U	4 U	8 U	0.8 U	1 U	1 U	1 U	0.9 U	10.5 U
Iron	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨
Lead	10.4 U	10.4 U	10.4 U	10.4 U	10.4 U	15	10.4 U	10.4 U	14.9 U	30 U	16.5 U	10.4 U	10.4 U	10.4 U	11.7 U	85.5 U
Magnesium	926	600	507	596	359	382	373	626	674	240	400	384	472	505	549	47.5 U
Manganese	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨
Mercury	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨
Molybdenum	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨
Nickel	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨
Potassium	658	516	503	581	110	189	521	506	520	124 U	464	328	317	300	317	533.5 U
Selenium	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨
Silver	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨
Sodium	1006	746	747	720	465	463	494	811	760	500	621	478	640	560	675	480
Thallium	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨
Uranium	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨
Zinc	79	98	54	47	0.7 U	0.7 U	14	25	68	30	18	7	9	8	0.8 U	20
Dissolved Metals (ug/L)																
Aluminum	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨
Arsenic	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨
Barium	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨
Beryllium	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨
Cadmium	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨
Calcium	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨
Chromium	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨
Copper	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨
Iron	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨
Lead	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨
Magnesium	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨
Manganese	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨
Mercury	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨
Molybdenum	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨
Nickel	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨
Potassium	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨
Selenium	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨
Silver	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨
Sodium	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨
Thallium	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨
Uranium	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨
Zinc	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨

Data Notes:

U - Parameter was analyzed for, but not detected above the reporting limit shown.
J - Estimated Value.
UJ - Parameter was analyzed for, but not detected. Detection limit is an estimated value.
* indicates that highest value from range of replicated samples were represented.
▨ Grey shading ▨ Indicates that the data was not available for this parameter

Data Source:

(a) Walters, et al. 1992. *Holden Mine Reclamation Project Final Report.* Pacific Northwest Laboratories,Richland, WA. (Data collected in 1991).
(b) Kilburn, et al. 1994. *Geochemical data and sample locality maps for stream-sediment, heavy-mineral-concentrate, mill tailing, water, and precipitate samples collected in and around the Holden mine, Chelan County, Washington.* USGS Open File Report 94-680A Paper Version, 94-680B Diskette version (Data Collected in 1994).
(c) Anderson, Keith A. (USFS Chelan Ranger District). Compilation of Data for Preliminary Assessment of the Holden Mine Site.
(d) Kilburn, J.E. & S.J. Sutley. 1996. *Characterization of acid mine drainage at the Holden mine, Chelan, Washington*. USGS Open File Report 96-531. (Data collected in 1995).
(e) Kilburn, J.E. & S.J. Sutley. 1997. *Analytical results and comparative overview of geochemical studies conducted at the Holden Mine*, spring 1996. USGS Open File Report 97-128 (Data collected in Spring 1996).
(f) Kilburn, J.E. & S.J. Sutley. 1997. Preliminary data (no report attached, data collected in Fall 1996).
(g) Johnson, A., et al. 1997. *Effects of Holden Mine on the Water, Sediments and Benthic Invertebrates of Railroad Creek (Lake Chelan).* Environmental Investigations and Laboratory Services Program. Water Body No. WA-47-1020. Publication No. 97-330 (data collected in Spring and Fall 1996).

TABLE 7.1-F
STATISTICAL ANALYSIS AND COMPARISON OF SURFACE WATER DATA FROM RAILROAD CREEK
(DATA COLLECTED FROM STATION RC-2 ADJACENT TO SITE, 1991 - 1998)
HOLDEN MINE RI/FS
DAMES & MOORE JOB NO. 17693-005-019

Parameters	USFS WATER QUALITY MONITORING DATA 1993[c]							USFS WATER QUALITY MONITORING DATA 1994[c]							USFS WATER QUALITY MONITORING DATA 1995 [c]			
	5/21/93	6/9/93	6/23/93	7/7/93	7/21/93	8/4/93	9/1/93	6/8/94	7/5/94	7/19/94	8/3/94	8/29/94	9/14/94	9/28/94	6/20/95	7/26/95	8/9/95	9/27/95
Total Metals (ug/L)																		
Aluminum																		
Arsenic																		
Barium																		
Beryllium																		
Cadmium																		
Calcium	3800	4500	5100	5500	4400	4900	6500	5100	4000	4600	4800	5800	6400	5900	5000	3100	4400	5500
Chromium																		
Copper	10	10	10	10	10 U	10	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U
Iron								440	340	390	320	1500	10 U	1500	430	480	400	1300
Lead	10	10	10	10	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U
Magnesium	410	530	570	590	480	520	810	640	500	480	440	640	710	700	480	350	540	690
Manganese																		
Mercury																		
Molybdenum																		
Nickel																		
Potassium	210	450	500	520	420	480	220	500	280	280	370	460	490	490	310	300	710	500
Selenium																		
Silver																		
Sodium	1700	590	1300	1300	890	840	1600	830	600	800	460	590	630	770	960	520	800	770
Thallium																		
Uranium																		
Zinc	40	30	40	30	20	30	130	60	20	10	20	30	40	40	50	10 U	20	30
Dissolved Metals (ug/L)																		
Aluminum																		
Arsenic																		
Barium																		
Beryllium																		
Cadmium																		
Calcium																		
Chromium																		
Copper																		
Iron																		
Lead																		
Magnesium																		
Manganese																		
Mercury																		
Molybdenum																		
Nickel																		
Potassium																		
Selenium																		
Silver																		
Sodium																		
Thallium																		
Uranium																		
Zinc																		

Data Notes:

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Data Source:

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(b) Kilburn, et al. 1994. *Geochemical data and sample locality maps for stream-sediment, heavy-mineral-concentrate, mill tailing, water, and precipitate samples collected in and around the Holden mine, Chelan County, Washington.* USGS Open File Report 94-680A Paper Version, 94-680B Diskette version (Data Collected in 1994).
(c) Anderson, Keith A. (USFS Chelan Ranger District). Compilation of Data for Preliminary Assessment of the Holden Mine Site.
(d) Kilburn, J.E. & S.J. Sutley. 1996. *Characterization of acid mine drainage at the Holden mine, Chelan, Washington.* USGS Open File Report 96-531. (Data collected in 1995).
(e) Kilburn, J.E. & S.J. Sutley. 1997. *Analytical results and comparative overview of geochemical studies conducted at the Holden Mine*, spring 1996.
USGS Open File Report 97-128 (Data collected in Spring 1996).
(f) Kilburn, J.E. & S.J. Sutley. 1997. Preliminary data (no report attached, data collected in Fall 1996).
(g) Johnson, A., et al. 1997. *Effects of Holden Mine on the Water, Sediments and Benthic Invertebrates of Railroad Creek (Lake Chelan).*
Environmental Investigations and Laboratory Services Program. Water Body No. WA-47-1020. Publication No. 97-330 (data collected in Spring and Fall 1996).

TABLE 7.1-F
STATISTICAL ANALYSIS AND COMPARISON OF SURFACE WATER DATA FROM RAILROAD CREEK
(DATA COLLECTED FROM STATION RC-2 ADJACENT TO SITE, 1991 - 1998)
HOLDEN MINE RI/FS
DAMES & MOORE JOB NO. 17693-005-019

Parameters	RC-SITE E												
	USGS 7/94 [b]	USGS 7/95 [d]					USGS 5/96 [e]		USGS 9/96 [f]			DEPT. OF ECOLOGY (RC-STATION SAMPLES) [g]	
	345	510	513	540	544	545	613	618	700	722	727	6/12/96	9/10/96
Total Metals (ug/L)													
Aluminum	▨	▨	▨	▨	▨	▨	▨	▨	140	190	300	44	96 *
Arsenic	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	0.63	0.68
Barium	▨	▨	▨	▨	▨	▨	▨	▨	5.7	6.0	6.2	▨	▨
Beryllium	▨	▨	▨	▨	▨	▨	▨	▨	10 U	10 U	10 U	▨	▨
Cadmium	▨	▨	▨	▨	▨	▨	▨	▨	10 U	10 U	10 U	0.21	0.12 *
Calcium	▨	▨	▨	▨	▨	▨	▨	▨	7,400	8,500	10,000	▨	▨
Chromium	▨	▨	▨	▨	▨	▨	▨	▨	10 U	10 U	10 U	▨	▨
Copper	▨	▨	▨	▨	▨	▨	▨	▨	10 U	10 U	10 U	14	2.4 *
Iron	▨	▨	▨	▨	▨	▨	▨	▨	3,500	5,200	7,000	599	1970 *
Lead	▨	▨	▨	▨	▨	▨	▨	▨	50 U	50 U	50 U	0.21	0.10 U
Magnesium	▨	▨	▨	▨	▨	▨	▨	▨	1,100	1,400	1,900	▨	▨
Manganese	▨	▨	▨	▨	▨	▨	▨	▨	37	44	65	8.2	20 *
Mercury	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	0.001	▨
Molybdenum	▨	▨	▨	▨	▨	▨	▨	▨	20 U	20 U	20 U	▨	▨
Nickel	▨	▨	▨	▨	▨	▨	▨	▨	10 U	10 U	10 U	0.44	▨
Potassium	▨	▨	▨	▨	▨	▨	▨	▨	1000 U	1000 U	1000 U	▨	▨
Selenium	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	0.4 U
Silver	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	0.01 U	▨
Sodium	▨	▨	▨	▨	▨	▨	▨	▨	1,200	1,200	1,300	▨	▨
Thallium	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨
Uranium	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨
Zinc	▨	▨	▨	▨	▨	▨	▨	▨	49	49	58	36	30
Dissolved Metals (ug/L)													
Aluminum	20	30	51	20	30	30	45	70	18	36	40	▨	5.4 *
Arsenic	2 U	1 U	1 U	1 U	1 U	1 U	4U	4U	▨	▨	▨	▨	▨
Barium	4.4	4.1	4.3	4.3	4.3	4	6.1	5.8	5.4	5.5	6.0	▨	▨
Beryllium	1 U	0.3 U	0.3 U	0.3 U	0.3 U	0.3 U	0.4U	0.4U	10 U	10 U	10 U	▨	▨
Cadmium	1 U	1 U	1 U	1 U	1 U	1 U	0.7	0.8	10 U	10 U	10 U	0.29	0.13 *
Calcium	6000 U	4900	5400	4200	4000	4400	5300	5900	7,300	8,700	10,000	▨	▨
Chromium	1 U	0.9 U	0.9 U	0.9 U	0.9 U	0.9 U	0.5U	0.5U	10 U	10 U	10 U	▨	▨
Copper	2.3	3	4	3	3	3	26	38	10 U	10 U	10 U	10	0.93 *
Iron	320	560	1200	600	680	760	940	1700	2,500	3,400	5,000	▨	▨
Lead	0.2 U	0.3 U	0.3 U	0.3 U	0.3 U	0.3 U	0.3	0.4	50 U	50 U	50 U	0.07	0.06 *
Magnesium	360	390	490	380	390	420	1000 U	1000 U	1,000	1,300	1,700	▨	▨
Manganese	5.4	6.4	9.7	6.2	7.3	7.6	15	24	36	40	66	▨	▨
Mercury	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨
Molybdenum	0.5	0.3	0.3	0.3	0.2	0.1 U	0.4	0.5	20 U	20 U	20 U	▨	▨
Nickel	3 U	0.3	0.7	0.4	0.3	0.8	1U	1U	0.01 U	0.01 U	0.01 U	0.36	▨
Potassium	200	▨	▨	▨	▨	▨	540	660	1000 U	1000 U	1000 U	▨	▨
Selenium	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨
Silver	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.2U	0.2U	▨	▨	▨	0.01 U	▨
Sodium	400	580	700	520	510	540	1000	1100	1,200	1,000	1,400	▨	▨
Thallium	0.1 U	0.6 U	0.6 U	0.6 U	0.6 U	0.6 U	4U	4U	▨	▨	▨	▨	▨
Uranium	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.4U	0.4U	▨	▨	▨	▨	▨
Zinc	18	22	30	260	20	20	110	120	40	54	54	40	30 *

Data Notes:
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* indicates that highest value from range of replicated samples were represented.
▨ Grey shading ▨ Indicates that the data was not available for this parameter

Data Source:
(a) Walters, et al. 1992. *Holden Mine Reclamation Project Final Report.* Pacific Northwest Laboratories,Richland, WA. (Data collected in 1991).
(b) Kilburn, et al. 1994. *Geochemical data and sample locality maps for stream-sediment, heavy-mineral-concentrate, mill tailing, water, and precipitate samples collected in and around the Holden mine, Chelan County, Washington.* USGS Open File Report 94-680A Paper Version, 94-680B Diskette version (Data Collected in 1994).
(c) Anderson, Keith A. (USFS Chelan Ranger District). Compilation of Data for Preliminary Assessment of the Holden Mine Site.
(d) Kilburn, J.E. & S.J. Sutley. 1996. *Characterization of acid mine drainage at the Holden mine, Chelan, Washington*. USGS Open File Report 96-531. (Data collected in 1995).
(e) Kilburn, J.E. & S.J. Sutley. 1997. *Analytical results and comparative overview of geochemical studies conducted at the Holden Mine*, spring 1996. USGS Open File Report 97-128 (Data collected in Spring 1996).
(f) Kilburn, J.E. & S.J. Sutley. 1997. Preliminary data (no report attached, data collected in Fall 1996).
(g) Johnson, A., et al. 1997. *Effects of Holden Mine on the Water, Sediments and Benthic Invertebrates of Railroad Creek (Lake Chelan).* Environmental Investigations and Laboratory Services Program. Water Body No. WA-47-1020. Publication No. 97-330 (data collected in Spring and Fall 1996).

TABLE 7.1-F

STATISTICAL ANALYSIS AND COMPARISON OF SURFACE WATER DATA FROM RAILROAD CREEK

(DATA COLLECTED FROM STATION RC-2 ADJACENT TO SITE, 1991 - 1998)

HOLDEN MINE RI/FS

DAMES & MOORE JOB NO. 17693-005-019

Parameters	RC-SITE W																
	USGS 7/94 [b]	USGS 7/95[d]							USGS 5/96 [e]						USGS 9/97 [f]		
	347	517	519	522	526	530	531	532	602	603	604	628	635	636	705	708	709
Total Metals (ug/L)																	
Aluminum															72	86	52
Arsenic																	
Barium															5.5	5.5	5.4
Beryllium															10 U	10 U	10 U
Cadmium															10 U	10 U	10 U
Calcium															6,000	8,500	6,200
Chromium															10 U	10 U	10 U
Copper															10 U	10 U	10 U
Iron															140	120	110
Lead															50 U	50 U	50 U
Magnesium															1000 U	1000 U	1000 U
Manganese															10 U	10	10 U
Mercury																	
Molybdenum															20 U	20 U	20 U
Nickel															10 U	10 U	10 U
Potassium															1000 U	1000 U	1000 U
Selenium																	
Silver																	
Sodium															1,100	1,500	1,100
Thallium																	
Uranium																	
Zinc															10 U	64	14
Dissolved Metals (ug/L)																	
Aluminum	10	3000	86	40	40	40	10	61	1000	5600	82	3600	67	62	13	15	13
Arsenic	2 U	1 U	1 U	1 U	1 U	1 U	1 U	1	4 U	4 U	4 U	4 U	4 U	4 U			
Barium	4.2	3.9	4.1	4.1	4.4	4.4	4	4.6	8.1	13	6.5	5.7	6.2	6.6	5.2	5.2	5.1
Beryllium	1 U	0.3 U	0.3 U	0.3 U	0.3 U	0.3 U	0.3 U	0.3 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	10 U	10 U	10 U
Cadmium	1 U	1	1 U	1 U	1 U	1 U	1 U	5	13	45	5.8	2	2	1	10 U	10 U	10 U
Calcium	6000 U	11000	6400	7300	5000	3600	3600	20000	13000	32000	7400	14000	5100	5500	6,000	8,400	6,200
Chromium	1 U	0.9 U	0.9 U	0.9 U	0.9 U	0.9 U	0.9 U	0.9 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	10 U	10 U	10 U
Copper	5	48	5	3	4	7.4	4	160	970	3100	320	73	89	68	10 U	10 U	10 U
Iron	100 U	35000	13000	20000	3200	140	240	30	51	150	50 U	43000	70	55	100 U	100 U	100 U
Lead	0.2 U	0.3 U	0.3 U	0.3 U	0.3 U	0.3 U	0.3 U	2	6.5	25	2.3	0.4	0.4	0.4	50 U	50 U	50 U
Magnesium	320	4000	1200	1600	620	290	260	1800	2100	5700	1000	6100	1000 U	1000 U	1000 U	1000 U	1000 U
Manganese	3	240	68	88	19	3.5	2.4	59	73	260	32	380	8	5	10 U	10 U	10 U
Mercury																	
Molybdenum	0.5	0.1 U	0.2	0.2	0.2	0.2	0.4	0.2	0.5	0.4 U	0.5	0.4 U	0.5	0.5	20 U	20 U	20 U
Nickel	3 U	4.8	1	0.5	0.5	0.3	0.4	1.2	2	5.8	1 U	7.8	1	1 U	0.01 U	0.01 U	0.01 U
Potassium	200 U								1000	2200	610	970	500	500 U	1000 U	1000 U	1000 U
Selenium																	
Silver	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U			
Sodium	400	1200	650	780	660	470	480	2900	2200	5100	1300	1700	1000	1000 U	1000 U	1,600	1,100
Thallium	0.1 U	0.6 U	0.6 U	0.6 U	0.6 U	0.6 U	0.6 U	0.6 U	4 U	4 U	4 U	4 U	4 U	4 U			
Uranium	0.1 U	0.6	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1	0.4	2.4	0.4 U	0.5	0.4 U	0.4 U			
Zinc	37	690	90	60	60	30	10	1200	2500	8500	1000	590	260	210	10 U	60	11

Data Notes:

U - Parameter was analyzed for, but not detected above the reporting limit shown.

J - Estimated Value.

UJ - Parameter was analyzed for, but not detected. Detection limit is an estimated value.

* indicates that highest value from range of replicated samples were represented.

▨ Grey shading Indicates that the data was not available for this parameter

Data Source:

(a) Walters, et al. 1992. *Holden Mine Reclamation Project Final Report.* Pacific Northwest Laboratories,Richland, WA. (Data collected in 1991).

(b) Kilburn, et al. 1994. *Geochemical data and sample locality maps for stream-sediment, heavy-mineral-concentrate, mill tailing, water, and precipitate samples collected in and around the Holden mine, Chelan County, Washington.* USGS Open File Report 94-680A Paper Version, 94-680B Diskette version (Data Collected in 1994).

(c) Anderson, Keith A. (USFS Chelan Ranger District). Compilation of Data for Preliminary Assessment of the Holden Mine Site.

(d) Kilburn, J.E. & S.J. Sutley. 1996. *Characterization of acid mine drainage at the Holden mine, Chelan, Washington.* USGS Open File Report 96-531. (Data collected in 1995).

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(f) Kilburn, J.E. & S.J. Sutley. 1997. Preliminary data (no report attached, data collected in Fall 1996).

(g) Johnson, A., et al. 1997. *Effects of Holden Mine on the Water, Sediments and Benthic Invertebrates of Railroad Creek (Lake Chelan).* Environmental Investigations and Laboratory Services Program. Water Body No. WA-47-1020. Publication No. 97-330 (data collected in Spring and Fall 1996).

TABLE 7.1-F
STATISTICAL ANALYSIS AND COMPARISON OF SURFACE WATER DATA FROM RAILROAD CREEK
(DATA COLLECTED FROM STATION RC-2 ADJACENT TO SITE, 1991 - 1998)
HOLDEN MINE RI/FS
DAMES & MOORE JOB NO. 17693-005-019

Parameters	DAMES & MOORE RI DATA (RC-SITE E)																	
	4/17/97	5/19/97	5/26/97	6/2/97	6/9/97	6/16/97	7/10/97	9/15/97	5/3/98	9/15/97	5/19/97	7/10/97	9/15/97	4/16/97	5/20/97	7/10/97	9/15/97	5/3/98
	RC-2A	RC-2								RC-2X	RC-2 South Bank			RC-7A	RC-7			
Total Metals (ug/L)																		
Aluminum	160	230	160	190	150J	220	210	90	250	90	240	140	90	160	180	190	100	220
Arsenic	1U	0.61	▨	▨	▨	▨	0.66	0.87	0.83	0.88	0.65	0.58	0.85	1U	▨	▨	▨	0.76
Barium	6	5.51	5.08	5.11	4.87J	5	5.04	4.71	5.75	4.71	5.74	4.70	4.61	4	5.16	4.91	4.54	5.48
Beryllium	1U	0.04U	0.04U	0.04U	0.04U	0.2U	0.04U	0.04U	0.04U	0.04U	0.04U	0.04U	0.04U	1U	0.04U	0.04U	0.04U	0.04U
Cadmium	0.5	0.52	0.44	0.33	0.25J	0.2U	0.10U	0.11	0.77J	0.11	0.55	0.08U	0.14	0.4	0.51	0.10	0.10	0.75J
Calcium	8,150	4,800	4,890	4,180	4,260J	3,330	3,510	4,750	4,700	4,740	4,800	3,450	4,920	8,720	4,500	3,550	4,770	4,670
Chromium	5U	0.2U	0.2U	0.2U	0.2U	5U	0.2U	0.2U	0.2	0.2U	0.2U	0.2U	0.2U	5U	0.2U	0.2U	0.2U	0.2U
Copper	14	33.2	30.2	23.2	15.0J	10	3.8	2.2	52.3	2.2	38	3.7	2.2	15	33.7	3.9	2.1	52.8
Iron	2,250	600	710J	510J	520J	440	500	1,330	630	1,340	620	440	1,350	2,290	650	530	1,280	590
Lead	1U	1.4U	0.3	0.6	1.4J	1U	0.6UJ	0.3UJ	0.284	0.7	0.5U	0.2UJ	0.8UJ	1U	0.2U	0.7UJ	0.2UJ	0.295
Magnesium	1,170	610	670	550	540J	410	440	540	570	560	640	410	570	1,190	580	440	540	550
Manganese	26	11.6	11.6	9.82	8.06J	9	8.61	12.2	12.7	12.2	12.4	6.82	12.3	26	9.44	7.91	10.8	11.8
Mercury	0.1U	0.00039J	▨	▨	▨	▨	0.00029J	▨	▨	▨	0.00066J	0.00021J	▨	0.1U	▨	▨	▨	▨
Molybdenum	▨	0.46	▨	▨	▨	▨	0.36	0.73	0.53	0.72	0.48	0.43	0.71		▨	▨	▨	0.52
Nickel	10U	2.3J	0.5	0.6	0.4J	10U	0.4	0.4	0.6	0.4	0.5J	0.4	0.4	10U	0.5	0.4	0.3	0.6
Potassium	640	500U	590	770	880J	500U	500U	500U	500U	500U	530	500U	500U	1,010	780	590	500U	500U
Selenium	1U	0.2U	▨	▨	▨	▨	0.2U	▨	▨	▨	0.2U	0.2U	▨	1U	▨	▨	▨	▨
Silver	0.2U	0.04U	0.04U	0.04U	0.04U	0.2U	0.14	0.11	0.04U	0.07	0.04U	0.04	0.04U	0.2U	0.06	0.04U	0.04U	0.04U
Sodium	1,270	840	880	750	820J	590U	530	640	790	670	840	520	660	1,310	810	540	650	770
Thallium	1U	0.2U	▨	▨	▨	▨	0.04U	0.04U	▨	0.04U	0.04U	0.04U	0.04U	1U	▨	▨	▨	▨
Uranium	▨	0.4U	▨	▨	▨	▨	0.04	0.04U	▨	0.04U	0.05	0.04U	0.04U	▨	▨	▨	▨	▨
Zinc	76	86	76	52	43J	24	16	21	116	20	87	15	21	85	79	15	25	119
Dissolved Metals (ug/L)																		
Aluminum	20U	90	60	70	80J	50	50U	40	100	40	60U	50U	40	20U	60	40U	40	90
Arsenic	1U	0.30	▨	▨	▨	▨	0.33	0.49	0.35	0.50	0.22	0.36	0.52	1U	▨	▨	▨	0.36
Barium	6	10.6J	18.2	31.1	20.2J	15	17.7	4.55	5.02	4.5	12.1J	14.2	4.56	6	10.7	12.6	4.52	4.88
Beryllium	1U	0.04U	0.04U	0.04U	0.04U	0.04U	0.04U	0.08U	0.04U	0.04U	0.04U	0.04U	0.04U	1U	0.04U	0.04U	0.04U	0.04U
Cadmium	0.4	0.53	0.45	0.32	0.23J	0.14	0.08	0.10	0.68	0.11	0.55	0.09	0.10	0.5	0.58	0.09	0.09	0.67
Calcium	8,320	4,900	4,800	4,260	4,200J	3,280	3,560	4,940	4,680	5,120	4,970	3,420	5,020	8,880	4,740	3,540	4,720	4,520
Chromium	5U	0.4	0.2U	0.2U	0.2U	5U	0.2U	0.2U	0.2U	0.2	0.2U	0.2U	0.2U	5U	0.2U	0.2U	0.2U	0.2U
Copper	2	23.6	19.1	15.1	10.3J	8	2.3	1.2	35.7	1.3	26	2.6	1.4	3	23.0	2.6	1.3	37.5
Iron	1,430	300	480J	360J	380J	220	270	1,080	350	1,160	420	280	1,150	1,680	480	330	1,150	380
Lead	1U	1.4U	0.7U	1.4U	0.4J	0.4U	0.2UJ	0.2U	0.107	0.3	0.6U	0.2J	0.2U	1U	0.5J	0.5J	0.4	0.126
Magnesium	1,190	630	640	530	490J	350	370	570	550	590	650	380	580	1,250	590	380	530	510
Manganese	26	12.8	10.9	8.47	7.42J	6	5.52	11.1	9.9	11.4	11.7	5.64	11.4	27	11.8	5.48	9.96	9.6
Mercury	0.1UJ	0.00047J	▨	▨	▨	▨	0.00053	▨	▨	▨	0.00036J	0.00030J	▨	0.1UJ	▨	▨	▨	▨
Molybdenum		0.47	▨	▨	▨	▨	0.37	0.71	0.48	0.72	0.48	0.41	0.70	▨	▨	▨	▨	0.48
Nickel	10U	0.9	0.6	0.4	0.4J	10U	0.2	0.4	0.4	0.4	0.6	0.2	0.4	10U	0.4	0.2	0.4	0.4
Potassium	640	500U	500U	500U	630J	500U	500U	500U	500U	500U	600	500U	500U	610	530	500U	500U	500U
Selenium	1U	0.2U	▨	▨	▨	▨	0.2U	▨	▨	▨	0.2U	0.2U	▨	1U	▨	▨	▨	▨
Silver	0.2U	0.07	0.04U	0.04UJ	0.04U	0.04U	0.04U	0.04U	0.04U	0.04U	0.04U	0.04U	0.04U	0.2U	0.54U	0.04U	0.04U	0.04U
Sodium	1,360	1,800J	910	1,010	770J	590U	580	670	800	730	920J	550	690	1,500	830	590	660	760
Thallium	1U	0.04U	▨	▨	▨	▨	0.04U	0.04U	▨	0.04U	0.04U	0.04U	0.04U	1U	▨	▨	▨	▨
Uranium	▨	0.2U	▨	▨	▨	▨	0.04U	0.04U	▨	0.04U	0.04U	0.04U	0.04U	▨	▨	▨	▨	▨
Zinc	77	84	84	60	51J	27	24	23	113	28	97	21	23	90	85	20	19	115

Data Notes:

U - Parameter was analyzed for, but not detected above the reporting limit shown.
J - Estimated Value.
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* indicates that highest value from range of replicated samples were represented.
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Data Source:

(a) Walters, et al. 1992. *Holden Mine Reclamation Project Final Report.* Pacific Northwest Laboratories,Richland, WA. (Data collected in 1991).
(b) Kilburn, et al. 1994. *Geochemical data and sample locality maps for stream-sediment, heavy-mineral-concentrate, mill tailing, water, and precipitate samples collected in and around the Holden mine, Chelan County, Washington.* USGS Open File Report 94-680A Paper Version, 94-680B Diskette version (Data Collected in 1994).
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(e) Kilburn, J.E. & S.J. Sutley. 1997. *Analytical results and comparative overview of geochemical studies conducted at the Holden Mine*, spring 1996. USGS Open File Report 97-128 (Data collected in Spring 1996).
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TABLE 7.1-F
STATISTICAL ANALYSIS AND COMPARISON OF SURFACE WATER DATA FROM RAILROAD CREEK
(DATA COLLECTED FROM STATION RC-2 ADJACENT TO SITE, 1991 - 1998)
HOLDEN MINE RI/FS
DAMES & MOORE JOB NO. 17693-005-019

Parameters	DAMES & MOORE RI DATA (RC-SITE W)											
	4/16/97	4/16/97	4/16/97	5/21/97	7/16/97	9/1/97	5/3/98	5/3/98	5/21/97	7/10/97	9/15/97	5/21/97
	RC-4A	RC-4X	RC-4 Grab	RC-4				RC-4X	RC-4 South Bank			RC-4X South Bank
Total Metals (ug/L)												
Aluminum	40	40	40	100	160	50	200J	160J	170	170	50	160
Arsenic	1U	1U	1				0.93	0.85				
Barium	3	4	3	4.90	4.77	4.36	5.48	5.32	5.30	4.75	4.45	5.03
Beryllium	1U	1U	1U	0.04U	0.04U	0.04U	0.04U	0.04U	0.04U	0.04U	0.04U	0.04U
Cadmium	0.2	0.3	0.2	0.47	0.08U	0.07	0.73J	0.75J	1.09	0.12U	0.12	1.08
Calcium	7,490	7,470	7,410	4,350	3,310	4,360	4,370	4,310	4,870	3,340	4,400	4,980
Chromium	5U	5U	5U	0.2U	0.2U	0.2U	0.2U	0.2U	0.2U	0.2U	0.2U	0.2U
Copper	12	11	9	32.4	4.4	2.3	56.7	58.6	79	6.8	4.9	77
Iron	60	60	60	90	170	90	140	100	90	180	100	90
Lead	1U	1U	1U	0.7J	0.4UJ	0.5UJ	0.276	0.279	0.4J	0.3UJ	0.2UJ	0.4J
Magnesium	770	770	760	460	350	380	450	450	550	350	380	560
Manganese	3	3	3	3.58	4.34	2.75	8.22	7.53	6.08	4.83	3.51	5.86
Mercury	0.1U	0.1U	0.1U									
Molybdenum							0.52	0.53				
Nickel	10U	10U	10U	0.4	0.3	0.2	0.5	0.5	0.6	0.4	0.3	0.6
Potassium	660	660	880	500U	500U	500U	500U	500U	560	500U	500U	850
Selenium	1U	1U	1U									
Silver	0.2U	0.2U	0.2U	0.04U	0.04U	0.04U	0.04U	0.04U	0.17	0.04U	0.04U	0.12
Sodium	1,230	1,230	1,210	800	510	650	780	740	910	520	640	890
Thallium	1U	1U	1U									
Uranium												
Zinc	48	48	34	67	12	18	115	114	177	22	20	185
Dissolved Metals (ug/L)												
Aluminum	30	30	20	30	30U	20U	60	70	50	30U	20U	50
Arsenic	1U	1U	1U				0.46	0.45				
Barium	6	6	6	9.90	13.4	4.37	4.69	4.6	10.2	13.0	4.31	11.2
Beryllium	1U	1U	1U	0.04U	0.04U	0.04U	0.04U	0.04U	0.04U	0.04U	0.04U	0.04
Cadmium	0.3	0.3	0.2	0.44	0.09	0.06	0.66	0.67	1.10	0.11	0.14	1.14
Calcium	7,760	7,550	7,470	4,540	3,260	4,390	4,250	4,240	5,110	3,230	4,420	5,050
Chromium	5U	5U	5U	0.2U	0.2U	0.2U	0.2U	0.2U	0.2U	0.2U	0.2U	0.2
Copper	11	11	9	26.4	3.4	1.8	41.7	41.9	58.5	5.3	3.9	59.8
Iron	40	30	50	20	20U	40	20U	20U	20	20U	40	20U
Lead	1U	1U	1U	0.6J	0.4J	0.3	0.088	0.085	0.6J	0.2UJ	0.4	0.2
Magnesium	810	790	790	470	300	370	420	420	560	290	390	550
Manganese	4	3	4	2.94	1.53	1.86	4.83	4.94	7.46	1.81	2.10	7.68
Mercury	0.1UJ	0.1UJ	0.1UJ									
Molybdenum							0.49	0.61				
Nickel	10U	10U	10U	0.3	0.2	0.2	0.5	0.5	1.0	0.2U	0.3	0.6
Potassium	690	660	520	520	500U	500U	500U	500U	690	500U	500U	500U
Selenium	1U	1U	1U									
Silver	0.2U	0.2U	0.2U	0.08U	0.04U	0.04U	0.04U	0.04U	0.14U	0.04U	0.04U	0.10
Sodium	1,440	1,300	1,380	840	520	650	740	750	910	530	640	890
Thallium	1U	1U	1U									
Uranium												
Zinc	55	50	39	73	17	11	114	114	191	24	20	191

Data Notes:

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(g) Johnson, A., et al. 1997. *Effects of Holden Mine on the Water, Sediments and Benthic Invertebrates of Railroad Creek (Lake Chelan).* Environmental Investigations and Laboratory Services Program. Water Body No. WA-47-1020. Publication No. 97-330 (data collected in Spring and Fall 1996).

TABLE 7.1-F
STATISTICAL ANALYSIS AND COMPARISON OF SURFACE WATER DATA FROM RAILROAD CREEK
(DATA COLLECTED FROM STATION RC-2 ADJACENT TO SITE, 1991 - 1998)
HOLDEN MINE RI/FS
DAMES & MOORE JOB NO. 17693-005-019

Parameters	STATISTICAL CALCULATIONS									
	# Analyses	# of Detections	Maximum Conc.	Minimum Conc.	Range of RL	Approximate Distribution	Mean	Standard Deviation	Median	UCL (95%)
Total Metals (ug/L)										
Aluminum	38	38	300	40	None	Normal	142	69	160	161
Arsenic	18	14	1	0.58	1	Lognormal	0.71	0.16	0.67	0.79
Barium	36	36	6.2	3	None	Neither	5.0	0.72	5.04	**6.2**
Beryllium	36	0	NA	NA	0.04-10	NA	NA	NA	NA	NA
Cadmium	38	27	1.09	0.07	0.08-10	Lognormal	1.08	1.74	0.37	{2.18}
Calcium	70	70	10000	3100	None	Lognormal	5075	1477	4745	5363
Chromium	36	1	0.2	0.2	0.2-10	Neither	NA	NA	0.2	**0.2**
Copper	72	40	79	2.1	0.8-10.5	Lognormal	14.4	17.8	5.0	21.9
Iron	49	48	7000	60	10	Lognormal	1031	1311	480	1770
Lead	71	18	15	0.21	0.1-85.5	NA	NA	NA	0.6	**15**
Magnesium	70	66	1900	240	47.5-1000	Lognormal	601	267	540	674
Manganese	38	36	65	2.75	10	Lognormal	11.97	12.53	8.80	15.55
Mercury	10	5	0.001	0.00021	0.1	Lognormal	0.12	0.03	0.025	{33.49}
Molybdenum	17	11	0.73	0.36	20	Lognormal	4.32	4.66	0.71	{14.96}
Nickel	37	25	2.3	0.2	10	Neither	1.97	2.15	0.5	**2.3**
Potassium	70	45	1010	110	124-1000	Lognormal	439	199	462	491
Selenium	10	0	NA	NA	0.2-1	NA	NA	NA	NA	NA
Silver	31	7	0.17	0.04	0.04-0.2	NA	NA	NA	0.11	**0.17**
Sodium	70	69	1700	460	590	Lognormal	817.4	270	770	881
Thallium	12	0	NA	NA	0.04-1	NA	NA	NA	NA	NA
Uranium	7	2	0.05	0.04	0.04-0.4	NA	NA	NA	0.05	**0.05**
Zinc	72	67	185	7	0.7-10	Lognormal	56	39.2	30	77.14
Dissolved Metals (ug/L)										
Aluminum	59	49	5600	5.4	20-60	Neither	311	136	40	**5600**
Arsenic	38	12	1	0.22	1-4	NA	NA	NA	0.41	**1**
Barium	58	58	31.1	3.9	None	Neither	7.7	5.2	5.6	**31.1**
Beryllium	58	1	0.04	0.04	0.04-10	NA	NA	NA	0.04	**0.04**
Cadmium	60	42	45	*0.06*	*1 - 10*	*Lognormal*	*1.56*	*6.06*	0.5	2.57
Calcium	58	56	32000	3230	6000	Neither	6375	4545	4985	**32000**
Chromium	58	3	0.4	0.2	0.2-10	NA	NA	NA	0.20	**0.4**
Copper	60	54	3100	0.93	10	Lognormal	40.6	416	5.01	78.24
Iron	58	48	43000	20	20-100	Lognormal	2449	7669	325	6693
Lead	60	27	25	0.06	0.2-50	NA	NA	NA	0.40	**25**
Magnesium	58	51	6100	260	1000	Neither	894	1124	520	**6100**
Manganese	58	55	380	1.53	10	Lognormal	23.03	66.5	7.84	34.94
Mercury	9	4	0.00053	0.0003	0.1	NA	NA	NA	0.000415	**0.00053**
Molybdenum	39	29	0.72	0.2	0.1-20	Normal	1.87	3.52	0.48	{2.82}
Nickel	59	40	7.8	0.2	0.01-10	Lognormal	2.21	1.84	0.5	4.78
Potassium	46	18	2200	200	200-1000	NA	NA	NA	620	**2200**
Selenium	9	0	NA	NA	0.2-1	NA	NA	NA	NA	NA
Silver	53	2	0.1	0.07	0.01-0.2	NA	NA	NA	0.850	**0.1**
Sodium	58	55	5100	400	590-1000	Lognormal	971	726	775	1104
Thallium	34	0	NA	NA	0.04-4	NA	NA	NA	NA	NA
Uranium	29	5	2.4	0.1	0.04-0.4	NA	NA	NA	0.50	**2.4**
Zinc	60	59	8500	10	10	Lognormal	168	1141	54.5	271.21

Statistical Notes: (Statistical calculations were performed using Washington Department of Ecology's MTCAStat Excel V.5 Macro (Module 2.1), downloaded from their web site.)

Maximum and minimum concentrations are based on detected values only.

Range of reporting limits (RL) are based on results reported as not detected.

Distribution is determined based on the MTCA stat program by analyzing the data through the "W-Test" or "D'Agostino's test". Where data is not lognormally nor normally distributed, the distribution is noted as "Neither".

When approximate distribution is reported as "neither", the maximum concentration is reported as the 95% UCL and is presented in BOLD font.

If UCL is reported in brackets {UCL value}, this indicates that the calculated result from MTCAStat was reported to be unusually high.

The mean is an arithmetic mean if data are normally distributed or if distribution is indicated as "Neither". The reported mean for lognormally distributed data is a lognormal mean.

Statistical analysis was not performed on data sets where 50% or greater of the results were reported as not detected. Only maximum and minimum concentrations are reported, if applicable.

For these data sets, a calculated median is based on detected values only.

TABLE 7.1-G
STATISTICAL ANALYSIS AND COMPARISON OF SURFACE WATER DATA FROM RAILROAD CREEK
(DATA COLLECTED FROM STATION RC-3 DOWNSTREAM, 1991 - 1998)
HOLDEN MINE RI/FS
DAMES & MOORE JOB NO. 17693-005-019

Parameters	BATTELLE WATER QUALITY MONITORING DATA 1991[a]								USFS WATER QUALITY MONITORING DATA 1992[c]							
	5/10/91	5/18/91	6/3/91	6/18/91	7/2/91	7/16/91	8/6/91	9/17/91	5/14/92	6/2/92	6/16/92	7/1/92	7/14/92	7/29/92	8/11/92	9/8/92
Total Metals (ug/L)																
Aluminum																
Arsenic																
Barium																
Beryllium																
Cadmium																
Calcium	8076	5657	5340	6161	4197	4229	4350	7103	6462	4130	4645	4737	5653	5836	6310	6340
Chromium																
Copper	1.1 U	9	7	5	1.1 U	1.1 U	1.1 U	1.1 U	4 U	8 U	0.8 U	1 U	1 U	1 U	0.9 U	10.5 U
Iron																
Lead	10.4 U	3	10.4 U	10.4 U	10.4 U	11	10.4 U	10.4 U	14.9 U	30 U	16.5 U	10.4 U	10.4 U	10.4 U	11.7 U	85.5 U
Magnesium	1047	728	626	747	467	493	481	836	850	360	504	517	640	672	760	310
Manganese																
Mercury																
Molybdenum																
Nickel																
Potassium	703	549	528	570	248	279	510	643	694	140	442	419	385	509	473	533.5 U
Selenium																
Silver																
Sodium	1166	882	798	852	554	557	561	970	1019	930	646	617	705	724	934	610
Thallium																
Uranium																
Zinc	0.7 U	42	28	28	0.7 U	0.7 U	9	11	34	30	9	2.8 U	2.8 U	0.4	0.8 U	4 U
Dissolved Metals (ug/L)																
Aluminum																
Arsenic																
Barium																
Beryllium																
Cadmium																
Calcium																
Chromium																
Copper																
Iron																
Lead																
Magnesium																
Manganese																
Mercury																
Molybdenum																
Nickel																
Potassium																
Selenium																
Silver																
Sodium																
Thallium																
Uranium																
Zinc																

Data Notes:

U - Parameter was analyzed for, but not detected above the reporting limit shown.

J - Estimated Value.

UJ - Parameter was analyzed for, but not detected. Detection limit is an estimated value.

* indicates that highest value from range of replicated samples were represented.

▨ Grey shading indicates that the data was not available for this parameter

Data Source:

(a) Walters, et al. 1992. *Holden Mine Reclamation Project Final Report.* Pacific Northwest Laboratories,Richland, WA. (Data collected in 1991).

(b) Kilburn, et al. 1994. *Geochemical data and sample locality maps for stream-sediment, heavy-mineral-concentrate, mill tailing, water, and precipitate samples collected in and around the Holden mine, Chelan County, Washington.* USGS Open File Report 94-680A Paper Version, 94-680B Diskette version (Data Collected in 1994).

(c) Anderson, Keith A. (USFS Chelan Ranger District). Compilation of Data for Preliminary Assessment of the Holden Mine Site.

(d) Kilburn, J.E. & S.J. Sutley. 1996. *Characterization of acid mine drainage at the Holden mine, Chelan, Washington*. USGS Open File Report 96-531. (Data collected in 1995).

(e) Kilburn, J.E. & S.J. Sutley. 1997. *Analytical results and comparative overview of geochemical studies conducted at the Holden Mine*, spring 1996. USGS Open File Report 97-128 (Data collected in Spring 1996).

(f) Kilburn, J.E. & S.J. Sutley. 1997. Preliminary data (no report attached, data collected in Fall 1996).

(g) Johnson, A., et al. 1997. *Effects of Holden Mine on the Water, Sediments and Benthic Invertebrates of Railroad Creek (Lake Chelan).* Environmental Investigations and Laboratory Services Program. Water Body No. WA-47-1020. Publication No. 97-330 (data collected in Spring and Fall 1996).

TABLE 7.1-G
STATISTICAL ANALYSIS AND COMPARISON OF SURFACE WATER DATA FROM RAILROAD CREEK
(DATA COLLECTED FROM STATION RC-3 DOWNSTREAM, 1991 - 1998)
HOLDEN MINE RI/FS
DAMES & MOORE JOB NO. 17693-005-019

Parameters	USFS WATER QUALITY MONITORING DATA 1993^c							USFS WATER QUALITY MONITORING DATA 1994^c							USFS WATER QUALITY MONITORING DATA 1995 ^c				
	5/21/93	6/9/93	6/23/93	7/7/93	7/21/93	8/4/93	9/1/93	6/8/94	7/5/94	7/19/94	8/3/94	8/29/94	9/14/94	9/28/94	6/20/95	7/26/95	8/9/95	8/23/95	9/1/95
Total Metals (ug/L)																			
Aluminum																			
Arsenic																			
Barium																			
Beryllium																			
Cadmium																			
Calcium	4600	5500	6300	6700	5800	6100	8700	6500	5300	4900		7600	9400	8100	5700	3800	5400	6700	
Chromium																			
Copper	10	10	10	10	10 U	10 U	10 U	10 U	10 U	10 U		10 U	10 U	10 U	10 U	10 U	10 U	10 U	
Iron	460	210	260	300	920	330	320	290	210	220		320	40	510	200	380	320	470	
Lead	10	10	10	10	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	
Magnesium	550	700	750	780	650	670	1000	830	610	650		640	980	890	630	430	680	890	
Manganese																			
Mercury																			
Molybdenum																			
Nickel																			
Potassium	430	420	570	650	470	530	290	500	310	370		540	630	600	340	350	530	600	
Selenium																			
Silver																			
Sodium	1800	700	1400	1500	920	920	2100	1000	700	800		880	980	860	1100	520	670	920	
Thallium																			
Uranium																			
Zinc	40	20	30	30	20	20	140	30	10	10 U	10	20	20	30	40	10 U	10 U	20	
Dissolved Metals (ug/L)																			
Aluminum																			
Arsenic																			
Barium																			
Beryllium																			
Cadmium																			
Calcium																			
Chromium																			
Copper																			
Iron																			
Lead																			
Magnesium																			
Manganese																			
Mercury																			
Molybdenum																			
Nickel																			
Potassium																			
Selenium																			
Silver																			
Sodium																			
Thallium																			
Uranium																			
Zinc																			

Data Notes:
U - Parameter was analyzed for, but not detected above the reporting limit shown.
J - Estimated Value.
UJ - Parameter was analyzed for, but not detected. Detection limit is an estimated value.
* indicates that highest value from range of replicated samples were represented.
▨ Grey shading indicates that the data was not available for this parameter

Data Source:
(a) Walters, et al. 1992. *Holden Mine Reclamation Project Final Report*. Pacific Northwest Laboratories,Richland, WA. (Data collected in 1991).
(b) Kilburn, et al. 1994. *Geochemical data and sample locality maps for stream-sediment, heavy-mineral-concentrate, mill tailing, water, and precipitate samples collected in and around the Holden mine, Chelan County, Washington*. USGS Open File Report 94-680A Paper Version, 94-680B Diskette version (Data Collected in 1994).
(c) Anderson, Keith A. (USFS Chelan Ranger District). Compilation of Data for Preliminary Assessment of the Holden Mine Site.
(d) Kilburn, J.E. & S.J. Sutley 1996. *Characterization of acid mine drainage at the Holden mine, Chelan, Washington*. USGS Open File Report 96-531. (Data collected in 1995).
(e) Kilburn, J.E. & S.J. Sutley. 1997. *Analytical results and comparative overview of geochemical studies conducted at the Holden Mine*, spring 1996. USGS Open File Report 97-128 (Data collected in Spring 1996).
(f) Kilburn, J.E. & S.J. Sutley. 1997. Preliminary data (no report attached, data collected in Fall 1996).
(g) Johnson, A., et al. 1997. *Effects of Holden Mine on the Water, Sediments and Benthic Invertebrates of Railroad Creek (Lake Chelan)*. Environmental Investigations and Laboratory Services Program. Water Body No. WA-47-1020. Publication No. 97-330 (data collected in Spring and Fall 1996).

TABLE 7.1-G
STATISTICAL ANALYSIS AND COMPARISON OF SURFACE WATER DATA FROM RAILROAD CREEK
(DATA COLLECTED FROM STATION RC-3 DOWNSTREAM, 1991 - 1998)
HOLDEN MINE RI/FS
DAMES & MOORE JOB NO. 17693-005-019

Parameters	RC-DOWNSTREAM EAST			RC-DOWNSTREAM WEST			DAMES & MOORE RI DATA (RC-DOWNSTREAM EAST)										DAMES & MOORE RI DATA (RC-DOWNSTREAM WEST)							
	USGS 7/94 [b]	DEPT. OF ECOLOGY RC-STATION [g]		USGS 7/94 [b]		DEPT. OF ECOLOGY MP-STATION [e]	4/18/97	5/22/97	7/11/97	9/16/97	5/5/98	5/22/97	7/11/97	9/16/97	4/18/97	4/18/97	4/17/97	5/20/97	5/22/97	7/10/97	9/16/97	5/4/98	9/16/97	5/4/98
	4chc354	6/12/96	9/10/96	4chc352	4chc353	9/10/96	RC-3A	RC-3				RC-3X		RC-8	RC-8A	RC-8B	RC-5A	RC-5	RC-5A				RC-10	
Total Metals (ug/L)																								
Aluminum		37	50			110	100	170	160	70	250	150	150	70	110		160	210	240	200	120	250	80	300
Arsenic		0.42	0.32			0.51	1U	0.35	0.40	0.46	0.5	0.33	0.39		1U		1U					0.76		0.72
Barium							10	7	5.62	6.47	7.07	7	5.63	6.47	10		6	5.68	6	5.27	5.01	6.22	5.60	6.74
Beryllium							1U	0.04U	0.04U	0.04U	0.04U	0.04U	0.04U	0.04U	1U		1U	0.04U	0.04U	0.04U	0.04U	0.04U	0.04U	0.04U
Cadmium		0.13	0.1 U			0.12	0.3	0.27	0.07U	0.09	0.37	0.34	0.08U	0.10	0.2		0.4	0.50	0.54	0.11U	0.13	0.66J	0.11	0.45
Calcium							9,740	6,350	4,620	6,570	5,520	6,420	4,800	6,540	9,950		8,280	4,940	6,070	3,840	5,570	5,210	6,480	5,730
Chromium							5U	5U	0.2U	0.2U	0.2	5U	0.2U	0.2U	5U		5U	0.2U	5U	0.2U	0.2U	0.2U	0.2U	0.2
Copper		7.9	1.4			1.8	6	16	3.2	1.6	19.7	16	3.3	1.7	7		14	32.3	32	4.2	2.4	43.5	2.3	30.3
Iron		438	684			1240	870	450	330	620	580	430	330	640	900		2,300	580	750	500	1,440	650	990	790
Lead		0.17	0.1 U			0.10 U	1U	0.5U	0.3UJ	0.2UJ	0.159	0.9U	0.3UJ	0.2UJ	1U		1U	0.3J	0.5U	0.4UJ	0.2UJ	0.249	0.2UJ	0.201
Magnesium							1,480	850	570	810	700	850	580	800	1,490		1,190	660	850	490	690	660	780	720
Manganese		7.9	13			19	14	11	6.66	10.1	10.7	10	6.46	10.7	15		26	12.3	20	9.72	15.4	15	14.0	13.4
Mercury		0.002					0.1U	0.00034J	0.00014J			0.00047J	0.00015J		0.1U		0.1U							
Molybdenum								0.55J	0.47	0.68	0.55	0.57J	0.54									0.52		0.55
Nickel		0.43					10U	10U	0.4	0.4	0.5	10U	0.4	0.4	10U		10U	0.6	10U	0.4	0.4	0.6	0.5	0.6
Potassium							640	500U	500U	630	530	590	610	500U	850		810	870	560	690	620	500U	500U	500U
Selenium			0.4 U			0.4 U	1U	0.2U	0.2U			0.2U	0.2U		1U		1U							
Silver		0.03					0.2U	0.04U	0.04U	0.04U	0.04U	0.09J	0.04U	0.04U	0.2U		0.2U	0.04U	0.20J	0.04U	0.04U	0.04U	0.04U	0.04U
Sodium							1,570	1,070	700	860	930	1,070	750	860	1,610		1,290	840	910	560	730	820	780	850
Thallium							1U	0.04U	0.04U	0.04U		0.04U	0.04U		1U		1							
Uranium								0.10	0.06	0.06		0.09	0.05											
Zinc		22	21			28	36	45	14	22	56	47	13	25	40		78	81	88	18	33	101	25	75
Dissolved Metals (ug/L)																								
Aluminum	21		6.4 *	20	6 U	3 2 *	50	70	30U	40	70	80	30U	50	50	20U	20U	70	20U	30U	50	90	40	80
Arsenic	2 U			2 U	2 U		1U	0.19	0.23	0.31	0.2	0.18	0.23		1U	1U	1U					0.28		0.26
Barium	5.3			4.7	6.1		9	7	16.2	6.95	5.8	7	14.8	6.43	9	9	6	10.8	6	15.9	5.00	5.4	5.56	5.51
Beryllium	1 U			1 U	1 U		1U	0.2U	0.04U	0.04U	0.04U	0.2U	0.04U	0.04U	1U	1U	1U	0.04U	4U	0.04U	0.04U	0.04U	0.04U	0.04U
Cadmium	1 U	0.16	0.08 *	1 U	1 U	0.13 *	0.2U	0.24	0.07	0.10	0.26	0.24	0.08	0.72	0.2U	0.2U	0.4	0.50	0.51	0.10	0.12	0.58	0.12	0.4
Calcium	6000 U			6000 U	6000 U		10,100	6,070	4,630	6,690	5,250	6,220	4,720	6,640	10,000	10,100	8,370	5,010	5,800	3,830	5,600	5,040	6,580	5,410
Chromium	1 U			1 U	1 U		5U	5U	0.2U	0.2U	0.2U	5U	0.2U	0.2U	5U	5U	5U	0.2U	5U	0.2U	0.2U	0.2U	0.2U	0.2U
Copper	1.4	5.2	0.4 *	1.6	0.1 U	0.39 *	4	10	1.9	1.2	12.6	11	2.0	1.4	4	3	3	21.5	7	2.4	1.6	26.9	1.3	18.5
Iron	200			200	100 U		370	230	140	420	170	240	140	420	430	60	1,290	350	40	250	1,250	300	740	220
Lead	0.2 U	0.04	0.09 *	0.2 U	0.2 U	0.06 *	1U	0.4U	0.2UJ	0.2	0.053	0.6U	0.2UJ	0.5	1U	1U	1U	0.2J	0.2U	0.2UJ	0.2U	0.106	0.2	0.082
Magnesium	490			480	540		1,510	800	540	820	620	810	540	800	1,510	1,520	1,210	670	780	420	680	620	800	640
Manganese	3.5			5.5	0.9 U		15	10	4.96	9.83	6.48	9	4.88	9.97	15	14	26	10.9	18	7.04	14.8	12	13.5	9.29
Mercury							0.1UJ	0.00064	0.00019J			0.00040J	0.00007J		0.1UJ	0.1UJ	0.1UJ							
Molybdenum	0.4			0.5	0.2			0.54J	0.54	0.64	0.51	0.54J	0.54									0.45		0.43
Nickel	3 U	0.26		3 U	3 U		10U	10U	0.2U	0.4	0.3	10U	0.2U	0.5	10U	10U	10U	0.6	10U	0.2	0.4	0.4	0.4	0.5
Potassium	300			200	200		810	510	500U	500U	500U	500U	520	500U	880	930	690	700	500U	500U	500U	500U	550	500U
Selenium							1U	0.2U	0.2U			0.2U	0.2U		1U	1U	1U							
Silver	0.1 U	0.01 U		0.1 U	0.1 U		0.2U	0.04U	0.04U	0.04U	0.04U	0.04U	0.08	0.04U	0.2U	0.2U	0.2U	0.14U	0.04U	0.04U	0.04U	0.04U	0.09J	0.04U
Sodium	500			400	400		1,660	1,020	730	870	870	1,100	740	860	1,750	1,740	1,430	860	900	630	700	780	800	810
Thallium	0.1 U			0.1 U	0.1 U		1U	0.04U	0.04U	0.04U		0.04U	0.04U		1U	1U	1U							
Uranium	0.1 U			0.1 U	0.1 U			0.07	0.04U	0.04		0.07	0.04U											
Zinc	14	20	19 *	13	2 U	25 *	41	38	17	20	45	40	16	20	37	32	86	84	80	24	30	98	22	69

Data Notes:

U - Parameter was analyzed for, but not detected above the reporting limit shown.

J - Estimated Value.

UJ - Parameter was analyzed for, but not detected. Detection limit is an estimated value.

* indicates that highest value from range of replicated samples were represented.

▨ Grey shading indicates that the data was not available for this parameter

Data Source:

(a) Walters, et al. 1992. *Holden Mine Reclamation Project Final Report.* Pacific Northwest Laboratories,Richland, WA. (Data collected in 1991).

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(c) Anderson, Keith A. (USFS Chelan Ranger District). Compilation of Data for Preliminary Assessment of the Holden Mine Site.

(d) Kilburn, J.E. & S.J. Sutley. 1996. *Characterization of acid mine drainage at the Holden mine, Chelan, Washington.* USGS Open File Report 96-531. (Data collected in 1995).

(e) Kilburn, J.E. & S.J. Sutley. 1997. *Analytical results and comparative overview of geochemical studies conducted at the Holden Mine*, spring 1996. USGS Open File Report 97-128 (Data collected in Spring 1996).

(f) Kilburn, J.E. & S.J. Sutley 1997. Preliminary data (no report attached, data collected in Fall 1996).

(g) Johnson, A., et al. 1997. *Effects of Holden Mine on the Water, Sediments and Benthic Invertebrates of Railroad Creek (Lake Chelan).* Environmental Investigations and Laboratory Services Program. Water Body No. WA-47-1020. Publication No. 97-330 (data collected in Spring and Fall 1996).

TABLE 7.1-G
STATISTICAL ANALYSIS AND COMPARISON OF SURFACE WATER DATA FROM RAILROAD CREEK
(DATA COLLECTED FROM STATION RC-3 DOWNSTREAM, 1991 - 1998)
HOLDEN MINE RI/FS
DAMES & MOORE JOB NO. 17693-005-019

Parameters	STATISTICAL CALCULATIONS RC-3									
	# Analyses	# of Detections	Maximum Conc.	Minimum Conc.	Range of RL	Approximate Distribution	Mean	Standard Deviation	Median	UCL (95%)
Total Metals (ug/L)										
Aluminum	20	20	300	37	None	Lognormal	153	74.11	150	201
Arsenic	14	11	0.76	0.32	1	Lognormal	0.48	0.13	0.48	0.54
Barium	17	17	10	5.01	None	Neither	6.58	1.43	6.22	**10**
Beryllium	17	0	NA	NA	0.04 - 1	NA	NA	NA	NA	NA
Cadmium	20	16	0.66	0.09	0.07 - 0.11	Lognormal	0.26	0.19	0.16	0.45
Calcium	50	50	9950	3800	None	Lognormal	6059	1465	5818	6417
Chromium	17	2	0.2	0.2	0.12 - 5	NA	NA	NA	0.2	**0.2**
Copper	53	27	43.5	1.4	0.8 -10.5	Lognormal	8.28	9.05	5	12.85
Iron	37	37	2300	40	None	Lognormal	592	419	460	755
Lead	54	11	11	0.159	0.1 - 16.5	NA	NA	NA	3	**11**
Magnesium	50	50	1490	310	None	Lognormal	731	232	695	790
Manganese.	20	20	26	6.46	None	Lognormal	13.05	4.71	12.65	15.19
Mercury	8	5	0.002	0.00014	0.1	Lognormal	0.08	0.03	0.0012	{279}
Molybdenum	8	8	0.68	0.47	None	Lognormal	0.55	0.06	0.55	0.6
Nickel	18	12	0.6	0.4	10	Neither	1.98	2.20	0.55	**0.6**
Potassium	50	43	870	140	500 - 533.5	Lognormal	492	174	519	547
Selenium	9	0	NA	NA	0.2 - 1	NA	NA	NA	NA	NA
Silver	18	3	0.2	0.03	0.04 - 0.2	NA	NA	NA	0.09	**0.2**
Sodium	50	50	2100	520	None	Lognormal	928	329	860	1004
Thallium	8	1	1	1	0.04 - 1	NA	NA	NA	1	**1**
Uranium	5	5	0.1	0.05	None	Lognormal	0.07	0.02	0.06	0.1
Zinc	54	44	140	0.4	0.7 - 10	Neither	28.9	27.93	22	**140**
Dissolved Metals (ug/L)										
Aluminum	23	16	90	3.2	6 - 30	Normal	37.77	28.5	40	47.97
Arsenic	15	8	0.31	0.18	1 - 2	Lognormal	0.46	0.30	0.31	0.66
Barium	21	21	16.2	4.7	None	Neither	7.97	3.57	6.4	**16.2**
Beryllium	21	0	NA	NA	0.04 - 4	NA	NA	NA	NA	NA
Cadmium	24	18	0.72	0.07	0.2 - 1	Lognormal	0.28	0.20	0.20	0.41
Calcium	21	18	10100	3830	6000	Lognormal	5981	2176	5600	6982
Chromium	21	0	NA	NA	0.2 - 5	NA	NA	NA	NA	NA
Copper	24	23	26.9	0.39	0.1	Lognormal	7.73	7.27	2.7	19.62
Iron	21	20	1290	40	100	Lognormal	373	343	240	612
Lead	24	10	0.5	0.04	0.2 - 1	NA	NA	NA	0.098	**0.50**
Magnesium	21	21	1520	420	None	Neither	800	344	630	**1520**
Manganese	21	20	26	3.5	0.9	Lognormal	11.96	5.7	9.97	18.49
Mercury	8	4	0.00064	0.00007	0.1	Lognormal	0.25	0.03	0.025	{3954}
Molybdenum	11	11	0.64	0.2	None	Normal	0.48	0.11	0.51	0.54
Nickel	23	10	0.6	0.2	0.2 - 10	NA	NA	NA	0.4	**0.6**
Potassium	21	11	930	200	500	Lognormal	417	246	250	531
Selenium	8	0	NA	NA	0.2 - 1	NA	NA	NA	NA	NA
Silver	22	2	0.09	0.08	0.01 - 0.2	NA	NA	NA	0.085	**0.09**
Sodium	21	21	1750	400	None	Lognormal	935	399	860	1117
Thallium	12	0	NA	NA	0.04 - 1	NA	NA	NA	NA	NA
Uranium	8	3	0.07	0.01	0.04 - 0.1	NA	NA	NA	0.07	**0.07**
Zinc	24	23	98	13	2	Lognormal	42.6	26.7	28	68.25

Statistical Notes: {Statistical calculations were performed using Washington Department of Ecology's MTCAStat Excel V.5 Macro (Module 2.1), downloaded from their web site.}

Maximum and minimum concentrations are based on detected values only.

Range of reporting limits (RL) are based on results reported as not detected.

Distribution is determined based on the MTCA stat program by analyzing the data through the "W-Test" or "D'Agostino's test". Where data is not lognormally nor normally distributed, the distribution is noted as "Neither".

When approximate distribution is reported as "neither", the maximum concentration is reported as the 95% UCL and is presented in **BOLD** font.

If UCL is reported in brackets {*UCL value*}, this indicates that the calculated result from MTCAStat was reported to be unusually high. Therefore, the calculated 95% UCL is suspect.

The mean is an arithmetic mean if data are normally distributed or if distribution is indicated as "Neither". The reported mean for lognormally distributed data is a lognormal mean.

Statistical analysis was not performed on data sets where 50% or greater of the results were reported as not detected. Only maximum and minimum concentrations are reported, if applicable.

For these data sets, a calculated median is based on detected values only.

TABLE 7.1-H
STATISTICAL ANALYSIS AND COMPARISON OF CHEMICAL DATA FROM GROUNDWATER SEEPAGE
HOLDEN MINE RI/FS
DAMES & MOORE JOB NO. 17693-005-019

Parameters	Location	TAILINGS PILE (TP-1) AREA																								
	Sample ID	364	515	516	518	520	521	523	524	525	527	528	529	536	537	538	623	625	626	627	629	630	654	655	656	657
	Sample Date	7/94[a]	7/95[b]	7/95[b]	7/95[b]	7/95[b]	7/95[b]	7/95[b]	7/95[b]	7/95[b]	7/95[b]	7/95[b]	7/95[b]	7/95[b]	7/95[b]	7/95[b]	5/96[c]	5/96[c]	5/96[c]	5/96[c]	5/96[c]	5/96[c]	5/96[c]	5/96[c]	5/96[c]	5/96[c]
Total Metals, (ug/L)																										
Aluminum																										
Arsenic																										
Barium																										
Beryllium																										
Cadmium																										
Calcium																										
Chromium																										
Copper																										
Iron																										
Lead																										
Magnesium																										
Manganese																										
Mercury																										
Molybdenum																										
Nickel																										
Potassium																										
Selenium																										
Silver																										
Sodium																										
Thallium																										
Uranium																										
Zinc																										
Dissolved Metals (ug/L)																										
Aluminum		> 6000	> 10,00	>10000	>10000	2600	>10000	4800	>10000	>10000	>10000	>10000	>10000	>10000	>10000	3800	550	95000	120000	57000	61000	12000	49000	53000	39000	15000
Arsenic		2 U	1 U	1 U	1 U	4.8	1 U	5.4	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	4 U	4 U	4 U	4 U	4 U	4 U	4 U	4 U	4 U	4 U
Barium		13	0.62	4	2.6	11	5.6	9.5	6.1	5.4	0.52	2.1	6	10	10	18	13	3.6	2	8.9	9.8	22	3.2	1	3.4	130
Beryllium		1 U	0.5	0.8	1.2	0.3 U	0.3 U	0.3 U	0.3 U	0.4	0.9	0.8	0.8	0.91	0.3 U	0.3	0.4 U	1.9	2.2	0.8	1	0.4 U	1	0.8	0.5	0.5
Cadmium		6.8	8.1	11	19	2	2	2	13	22	13	22	28	29	17	20	21	6.8	6.6	24	11	14	16	11	12	6.7
Calcium		39000	130000	99000	190000	110000	140000	130000	130000	130000	140000	130000	84000	80000	46000	21000	15000	140000	190000	110000	90000	14000	120000	95000	120000	15000
Chromium		1 U	2	2	6.1	0.9 U	1	0.9 U	2	1	2	2	2	1	0.9 U	0.9 U	0.5 U	7.7	8.4	5.7	3.8	0.5 U	8.6	10	5.4	2
Copper		53	270	410	780	4	59	36	200	140	170	330	300	410	160	1700	1500	490	480	1200	550	500	1100	1300	560	630
Iron		50000	>	>50000	340000	>50000	>50000	>50000	>50000	480000	>50000	390000	110000	160000	110000	650	60	760000	990000	530000	390000	300	800000	950000	1E+06	22000
Lead		2.7	0.3 U	0.3 U	0.3	0.5	4.6	0.6	0.9	0.3 U	0.3 U	0.3 U	0.3 U	1.7	0.4	0.3	2.1	0.6	0.5	1.5	0.4	0.5	0.82	1.9	0.5	0.84
Magnesium		17000	70000	47000	51000	39000	47000	51000	50000	47000	50000	44000	28000	30000	17000	2400	1700	120000	150000	64000	69000	5200	110000	97000	120000	10000
Manganese		1000	5100	3800	3900	3500	4100	4500	4400	2900	3300	2700	1500	1400	780	120	110	6300	7600	3600	3600	250	6600	6000	7200	730
Mercury																										
Molybdenum		0.1 U	0.1 U	0.1 U	0.1 U	0.1	0.1 U	0.2	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U
Nickel		18	100	75	43	12	15	13	15	26	25	28	23	18	13	6.8	20 U	150	170	14	87	12	18	11	14	5.8
Potassium		2000 U															1600	5500	8000	4100	3500	1100	3100	1600	7600	6900
Selenium																										
Silver		0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U
Sodium		4200	9900	8500	9200	6800	8100	7800	8900	>10000	>10000	>10000	9000	7300	4300	1500	1500	15000	19000	9400	12000	2000	17000	14000	17000	2700
Thallium		0.2	0.6 U	0.6 U	0.6 U	0.6 U	0.6 U	0.6 U	0.6 U	0.6 U	0.6 U	0.6 U	0.6 U	0.6 U	0.6 U	0.6 U	4 U	4 U	4 U	4 U	4 U	4 U	4 U	4 U	4 U	4 U
Uranium		1.2	23	14	31	1.1	8.8	1.3	6.7	2	1.8	2.9	2.2	5.8	3.5	1.1	0.7	16	18	7.4	7.2	0.8	4.2	5.7	3.1	2.6
Zinc		3800	7300	7200	4000	1200	1700	1400	2600	4900	5300	6000	4800	6200	3800	1800	2700	9500	11000	3100	7300	2700	2600	3300	4100	1100

Data Notes:
J - Estimated Value.
U - Parameter was analyzed for, but not detected above the reporting limit shown.
UJ - Parameter was analyzed for, but not detected. Detection limit is an estimated value.
Grey shading Indicates that the data was not available for this parameter.

Data Source:
(a) Kilburn, et al. 1994. *Geochemical data and sample locality maps for stream-sediment, heavy-mineral-concentrate, mill tailing, water, and precipitate samples collected in and around the Holden mine, Chelan County, Washington.* USGS Open File Report 94-680A Paper Version, 94-680B Diskette version (Data Collected in 1994).
(b) Kilburn, J.E. & S.J. Sutley. 1996. *Characterization of acid mine drainage at the Holden mine, Chelan, Washington*. USGS Open File Report 96-531. (Data collected in 1995).
(c) Kilburn, J.E. & S.J. Sutley. 1997. *Analytical results and comparative overview of geochemical studies conducted at the Holden Mine*, spring 1996.
USGS Open File Report 97-128 (Data collected in Spring 1996).
(d) Kilburn, J.E. & S.J. Sutley. 1997. Preliminary data (no report attached, data collected in Fall 1996).
(e) Johnson, A., et al. 1997. *Effects of Holden Mine on the Water, Sediments and Benthic Invertebrates of Railroad Creek (Lake Chelan).*
Environmental Investigations and Laboratory Services Program. Water Body No. WA-47-1020. Publication No. 97-330 (data collected in Spring and Fall 1996).

TABLE 7.1-H
STATISTICAL ANALYSIS AND COMPARISON OF CHEMICAL DATA FROM GROUNDWATER SEEPAGE
HOLDEN MINE RI/FS
DAMES & MOORE JOB NO. 17693-005-019

Parameters	Location	TAILINGS PILE (TP-1) AREA																					STATISTICAL CALCULATIONS FOR TAILINGS PILE (TP-1) AREA			
	Sample ID	710	711	712	713	714	715	716	SP-1			SP-2								SP-2X		SP-10E	SP-19				
	Sample Date	9/96[d]	9/96[d]	9/96[d]	9/96[d]	9/96[d]	9/96[d]	9/96[d]	5/23/97	7/12/97	5/2/98	5/18/97	6/2/97	6/9/97	6/16/97	7/12/97	9/16/97	10/5/97	5/2/98	7/12/97	5/2/98	5/21/97	5/21/97	# Analyses	# of Detections	Maximum Conc.	Minimum Conc.
Total Metals, (ug/L)																											
Aluminum		54000	36000	95000	23000	20000	64000	570																7	7	95000	570
Arsenic																								0	0		
Barium		5.1	9.7	5	9.5	5 U	36	6.7																7	6	36	5
Beryllium		10 U	10 U	10 U	10 U	10 U	10 U	10 U																7	0		
Cadmium		44	22	17	18	36	36	10 U																7	6	44	17
Calcium		300000	260000	250000	340000	330000	410000	15000																7	7	410000	15000
Chromium		10 U	10 U	10 U	10 U	10 U	10 U	10 U																7	0		
Copper		10 U	10 U	160	10 U	10 U	220	10 U																7	2	220	160
Iron		1700000	1600000	1300000	1500000	1600000	1600000	44000																7	7	1700000	44000
Lead		57	76	50 U	50 U	68	.50	50 U																7	4	76	50
Magnesium		200000	170000.	150000	220000	220000	240000	4900																7	7	240000	4900
Manganese		13000	11000	10000	15000	16000	16000	240																7	7	16000	240
Mercury																								0	0		
Molybdenum		20 U	20 U	20 U	20 U	20 U	20 U	20 U																7	0		
Nickel		10 U	10 U	10 U	10 U	10 U	45	10 U																7	1	45	45
Potassium		15000	16000	9500	20000	19000	30000	1200																7	7	30000	1200
Selenium																								0	0		
Silver																								0	0		
Sodium		27000	23000	23000	21000	22000	31000	1300																7	7	31000	1300
Thallium																								0	0		
Uranium																								0	0		
Zinc		7700	5000	8100	5700	6900	7900	300																7	7	8100	300
Dissolved Metals (ug/L)																											
Aluminum		54,000	36,000	96,000	23,000	20,000	110,000	53	27,100	41,200	30,700	94,600	71,800	70,000J	49,800	115,000	67,900	82,500	100,000	121,000	99,800	9,850	4,640	47	47	121000	53
Arsenic											1U	1 5				5U	5U		5U	5U	5U			32	3	5.4	1.5
Barium		5.4	11	5 U	8.9	5 U	16	5.8	15	13	11	15.2J	19	14J	9	12	5	5	2	10	3	18.4	21.3	47	45	130	0.52
Beryllium		10 U	10 U	10 U	10 U	10 U	10 U	10 U	0.7	5U	2U	1.7	20U	20U	20U	5U	2U	2U	2U	5U	2U	0.2U	0.8U	47	19	2.2	0.3
Cadmium		50	26	21	23	34	43	10 U	22.7	6	7	22.8	15	11J	20U	9	3.9	6	9	10	9	7.0	50.1	47	45	50.1	2
Calcium		300,000	260,000	250,000	340,000	340,000	470,000	16,000	102,000	200,000	140,000	155,000	183,000	188,000J	189,000	241,000	180,000	173,000	232,000	246,000	174,000	5,780	33,600	47	47	470000	5780
Chromium		10 U	10 U	10 U	10 U	10 U	10 U	10 U	10U	20U	10U	5	20U	20U	10U	20U	10U	10U	10U	20U	10U	1U	4U	47	19	10	1
Copper		10 U	10 U	180	10 U	10 U	450	10 U	698	240	321	914	860	660J	224	790	101	181	475	870	474	760	4,180	47	42	4180	4
Iron		1600000	1500000	1300000	1400000	1600000	1500000	44000	542,000	1,260,000	705,000	487,000	956,000J	925,000J	856,000	1,180,000	685,000	515,000	673,000	1,200,000	675,000	14,100	70	47	47	1600000	60
Lead		73	50 U	50 U	50 U	50 U	56	50 U	1U	10U	5U	4U	20U	20U	100U	10U	10U	5U	5U	10U	5U	20J	6J	47	23	73	0.3
Magnesium		180000	150000	140000	200000	210000	270000	4700	53,500	106,000	61,200	96,800	107,000	106,000J	99,000	153,000	94,200	95,100	125,000	155,000	125,000	1,400	3,290	47	47	270000	1400
Manganese		13,000	11,000	9,800	15,000	16,000	19,000	200	3,380	6,310	3,870	6,120	6,280	5,890J	5,220	8,570	5,250	4,980	6,260	8,780	6,280	58.9	247	47	47	19000	58.9
Mercury												0.00244				0 00309				0.00308				3	3	0.00309	0.00244
Molybdenum		20 U	20 U	20 U	20 U	20 U	20 U	20 U			10U	0.8U				20U	10U		10U	20U	10U			36	2	0.2	0.1
Nickel		0.01 U	0.01 U	0.01 U	10	11	54	0.01 U	20	50U	20U	119	60	60J	100	70	100	120	190	50U	200	3	29	47	39	170	3
Potassium		14000	15000	9200	19000	18000	26000	1200	9,870	16,300	11,100	9,040	12,900	13,300J	14,700	9,640	9,840	7,380	9,990	7,620	10,100	3,650	3,190	33	32	26000	1100
Selenium												4				5U				5U				3	1	4	4
Silver									0.2U	0.2U	0.2U	0.8U	4U	4U	20U	0.2U	0.2U	0.2U	0.2U	0.2U	0.2U	0.2U	0.8U	40	0		
Sodium		28000	24000	24000	22000	23000	37000	1700	12,800	20,100	14,400	16,200	19,700	19,900J	21,300	23,300	13,600	13,100	19,800	22,700	19,600	1400	1,670	47	47	37000	1400
Thallium												0.8U				50U	10U			50U				29	1	0.2	0.2
Uranium												10.2				50U	50U			50U				29	26	31	0.7
Zinc		7,800	5,000	8,300	6,000	7,300	8,700	330	3,490	2,590	2,050	5,600	4,570	4,430J	4,700	4,120	5,700	6,120	4,630	3,890	4,620	714	6,170	47	47	11000	330

Data Notes:

J - Estimated Value.

U - Parameter was analyzed for, but not detected above the reporting limit shown.

UJ - Parameter was analyzed for, but not detected. Detection limit is an estimated value.

▨ **Grey shading** Indicates that the data was not available for this parameter.

Statistical Notes:

Maximum and minimum concentrations are based on detected values only.

Data Source:

(a) Kilburn, et al. 1994. *Geochemical data and sample locality maps for stream-sediment, heavy-mineral-concentrate, mill tailing, water, and precipitate samples collected in and around the Holden mine, Chelan County, Washington.* USGS Open File Report 94-680A Paper Version, 94-680B Diskette version (Data Collected in 1994).

(b) Kilburn, J.E. & S.J. Sutley. 1996. *Characterization of acid mine drainage at the Holden mine, Chelan, Washington*. USGS Open File Report 96-531. (Data collected in 1995).

(c) Kilburn, J.E. & S.J. Sutley. 1997. *Analytical results and comparative overview of geochemical studies conducted at the Holden Mine*, spring 1996. USGS Open File Report 97-128 (Data collected in Spring 1996).

(d) Kilburn, J.E. & S.J. Sutley. 1997. Preliminary data (no report attached, data collected in Fall 1996).

(e) Johnson, A., et al. 1997. *Effects of Holden Mine on the Water, Sediments and Benthic Invertebrates of Railroad Creek (Lake Chelan).* Environmental Investigations and Laboratory Services Program. Water Body No. WA-47-1020. Publication No. 97-330 (data collected in Spring and Fall 1996).

TABLE 7.1-H
STATISTICAL ANALYSIS AND COMPARISON OF CHEMICAL DATA FROM GROUNDWATER SEEPAGE
HOLDEN MINE RI/FS
DAMES & MOORE JOB NO. 17693-005-019

Location	TAILINGS PILE (TP-2) AREA																									STATISTICAL CALCULATIONS FOR TAILINGS PILE-2 AREA			
Parameters Sample ID	511	541	542	543	614	615	616	617	ECOLOGY TP#2	717	718	719	720	721	723	724	725	726	728	SP-3			SP-4						
Sample Date	7/95^{b}	7/95^{b}	7/95^{b}	7/95^{b}	5/96^{c}	5/96^{c}	5/96^{c}	5/96^{c}	9/10/96^{e}	9/96^{d}	9/96^{d}	9/96^{d}	9/96^{d}	9/96^{d}	9/96^{d}	9/96^{d}	9/96^{d}	9/96^{d}	9/96^{d}	5/20/97	7/12/97	9/16/97	5/20/97	7/12/97	5/2/98	# Analyses	# of Detections	Maximum Conc.	Minimum Conc.
Total Metals, (ug/L)																													
Aluminum									22600	59000	19000	14000	62000	19000	86000	18000	13000	10000	53000							11	11	86000	10000
Arsenic																										0	0		
Barium										26	5.9	6.4	18	28	10	30	36	42	44							10	10	44	5.9
Beryllium										10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U							10	0		
Cadmium									4	11	10 U	10 U	13	10 U	14	10 U	10 U	10 U	22							11	5	22	4
Calcium										360000	410000	340000	360000	320000	300000	300000	310000	370000	300000							10	10	410000	300000
Chromium										10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U							10	0		
Copper									209	1300	120	58	640	95	140	280	190	160	180							11	11	1300	58
Iron									279000	320000	440000	230000	740000	310000	750000	210000	210000	260000	870000							11	11	870000	210000
Lead									20 U	50 U	50 U	50 U	50 U	50 U	50 U	50 U	50 U	50 U	50 U							11	0		
Magnesium										110000	130000	110000	140000	100000	140000	78000	79000	94000	110000							10	10	140000	78000
Manganese									5030	4900	6700	5200	8000	4900	8600	5200	5200	5200	8000							11	11	8800	4900
Mercury																										0	0		
Molybdenum										20 U	20 U	20 U	20 U	20 U	20 U	20 U	20 U	20 U	20 U							10	0		
Nickel										10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U							10	0		
Potassium										24000	28000	27000	32000	29000	31000	28000	29000	25000	32000							10	10	32000	24000
Selenium									93																	1	1	93	93
Silver																										0	0		
Sodium										16000	16000	14000	20000	15000	19000	12000	12000	14000	18000							10	10	20000	12000
Thallium																										0	0		
Uranium																										0	0		
Zinc									1150	3400	1200	470	2100	730	7700	940	690	1200	3900							11	11	7700	470
Dissolved Metals (ug/L)																													
Aluminum	8400	540	6500	2100	98	25000	18000	7700		56000	19000	13000	59000	19000	88000	17000	12000	10000	51000	33,400	22,500	3,920	19,000	20,100	5,570	24	24	88000	98
Arsenic	1 U	1 U	1 U	1 U	4 U	4 U	4 U	4 U												1.6	1U	2U			1U	12	1	1.6	1.6
Barium	3.5	24	23	26	200	9.9	12	23		19	5 U	5	7.1	20	11	28	32	48	41	14.7	21	23	36.7	30	61	24	23	200	3.5
Beryllium	0.3 U	0.3 U	0.3 U	0.3 U	0.4 U	0.6	0.4	0.4 U		10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	0.6	1U	1U	4U	1U	1U	24	3	0.6	0.4
Cadmium	5.9	2	7.4	4.1	0.8	8.9	16	10 U		11	10 U	10 U	14	10 U	18	10 U	10 U	10 U	24	40.3	6	2.0	7.3	6	1.6	24	17	40.3	0.8
Calcium	130000	24000	120000	47000	2700	130000	120000	90000		380000	410000	350000	380000	330000	300000	310000	320000	300000	300000	137,000	184,000	278,000	114,000	117,000	37,500	24	24	410000	2700
Chromium	0.9 U	0.9 U	0.9 U	0.9 U	0.5 U	2.6	0.8	0.5 U		10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	1	5U	5U	2U	5U	5U	24	3	2.6	0.8
Copper	200	46	310	130	34	1100	740	20		1300	120	57	630	73	110	280	200	150	160	1,280	583	90	670	344	133	24	24	1300	20
Iron	270000	1900	10000	5400	49	170000	140000	59000		290000	430000	230000	740000	290000	800000	210000	210000	210000	880000	154,000	263,000	251,000	74,900	53,000	9,730	24	24	880000	49
Lead	0.3 U	0.3	2.7	1	0.2	0.65	1.2	0.5		50 U	50 U	50 U	50 U	50 U	50 U	50 U	50 U	50 U	50 U	1J	5U	5U	2U	2U	1U	24	8	2.7	0.2
Magnesium	27000	4200	24000	9600	1000 U	44000	28000	18000		100000	130000	100000	140000	92000	130000	74000	74000	73000	100000	47,900	54,400	62,300	36,300	34,100	9,840	24	23	14000	4200
Manganese	2100	180	1000	410	80	2500	2000	940		5000	6700	5200	8000	5000	9000	5200	5200	5200	7900	3,000	3,410	3,850	1,750	1,710	522	24	24	9000	80
Mercury			0.1 U																	0.00193J	0.00072					3	2	0.00193	0.00072
Molybdenum	0.1 U	0.1 U	0.1 U	0.1 U	0.4 U	0.4 U	0.4 U	0.4 U		20 U	20 U	20 U	20 U	20 U	20 U	20 U	20 U	20 U	20 U	0.2UJ	5U	5U			5U	22	0		
Nickel	11	2.4	14	7.5	2	12	9.8	4.8		10	0.01 U	0.01 U	0.01 U	0.01 U	0.01 U	0.01 U	0.01 U	0.01 U	0.01 U	17	10U	10U	13	10	10U	24	12	17	2
Potassium					1100	14000	12000	5000		23000	28000	27000	28000	27000	32000	28000	27000	28000	32000	14,100	17,400	29,300	9,530	13,700	3,550	20	20	32000	1100
Selenium																				1J	2U					2	1	1	1
Silver	0.1 U	0.1 U	0.1 U	0.1 U	0.2 U	0.2 U	0.2 U	0.2 U												0.2U	0.2U	0.2U	4U	0.2U	0.2U	14	0		
Sodium	6700	2000	6500	3000	1000 U	7700	6500	7900		16000	18000	16000	19000	14000	21000	13000	12000	13000	18000	8,610	11,300	11,500	7,310	7,760	2,190	24	23	21000	2000
Thallium	0.6 U	0.6 U	0.6 U	0.6 U	4 U	4 U	4 U	4 U												0.2UJ	5U	5U				11	0		
Uranium	3.2	0.2	1.9	0.5	0.4 U	2.6	3.6	0.5												2.9J	50U	50U				11	8	3.6	0.2
Zinc	1000	120	800	500	77	1300	3000	400		3700	1300	510	2400	760	8000	950	780	960	4100	4,030	1,620	611	904	921	248	24	24	8000	77

Data Notes:
J - Estimated Value.
U - Parameter was analyzed for, but not detected above the reporting limit shown.
UJ - Parameter was analyzed for, but not detected. Detection limit is an estimated value.
▨ Grey shading: Indicates that the data was not available for this parameter.

Statistical Notes:
Maximum and minimum concentrations are based on detected values only.

Data Source:
(a) Kilburn, et al. 1994. *Geochemical data and sample locality maps for stream-sediment, heavy-mineral-concentrate, mill tailing, water, and precipitate samples collected in and around the Holden mine, Chelan County, Washington.* USGS Open File Report 94-680A Paper Version, 94-680B Diskette version (Data Collected in 1994).
(b) Kilburn, J.E. & S.J. Sutley. 1996. *Characterization of acid mine drainage at the Holden mine, Chelan, Washington*. USGS Open File Report 96-531. (Data collected in 1995).
(c) Kilburn, J.E. & S.J. Sutley. 1997. *Analytical results and comparative overview of geochemical studies conducted at the Holden Mine*, spring 1996. USGS Open File Report 97-128 (Data collected in Spring 1996).
(d) Kilburn, J.E. & S.J. Sutley. 1997. Preliminary data (no report attached, data collected in Fall 1996).
(e) Johnson, A., et al. 1997. *Effects of Holden Mine on the Water, Sediments and Benthic Invertebrates of Railroad Creek (Lake Chelan).* Environmental Investigations and Laboratory Services Program. Water Body No. WA-47-1020. Publication No. 97-330 (data collected in Spring and Fall 1996).

TABLE 7.1-H
STATISTICAL ANALYSIS AND COMPARISON OF CHEMICAL DATA FROM GROUNDWATER SEEPAGE
HOLDEN MINE RI/FS
DAMES & MOORE JOB NO. 17693-005-019

Parameters Location	TAILINGS PILE (TP-3) AREA																			STATISTICAL CALCULATIONS FOR TAILINGS PILE-3 AREA [d]			
Sample ID	350	506	508	509	539	607	608	609	610	611	ECOLOGY TP#3	SP-17		SP-18		SP-21							
Sample Date	7/94[a]	7/95[b]	7/95[b]	7/95[b]	7/95[b]	5/96[c]	5/96[c]	5/96[c]	5/96[c]	5/96[c]	6/12/96[e]	5/20/97	7/12/97	5/19/97	7/12/97	5/22/97	7/12/97	9/15/97	10/5/97	# Analyses	# of Detections	Maximum Conc.	Minimum Conc.
Total Metals, (ug/L)																							
Aluminum											25700					1,890				2	2	25700	1890
Arsenic											0.35					0.04U				2	1	0.35	0.35
Barium																13.9				1	1	13.9	13.9
Beryllium																0.06				1	1	0.06	0.06
Cadmium											5.5					1.11				2	2	5.5	1.11
Calcium																21,200				1	1	21200	21200
Chromium																0.2U				1	0		
Copper											191					54.0				2	2	191	54
Iron											39900					1,020				2	2	39900	1020
Lead											2					2.1J				2	2	2.1	2
Magnesium																3,490				1	1	3490	3490
Manganese											2140					164				2	2	2140	164
Mercury											0.015					0.1U				2	1	0.015	0.015
Molybdenum																0.34J				1	1	0.34	0.34
Nickel											36					4.5				2	2	36	4.5
Potassium																2,490				1	1	2490	2490
Selenium																0.2UJ				1	0		
Silver											0.1 U					0.17J				2	1	0.17	0.17
Sodium																1,560				1	1	1560	1560
Thallium																0.04UJ				1	0		
Uranium																0.13J				1	1	0.13	0.13
Zinc											522					113				2	2	522	113
Dissolved Metals (ug/L)																							
Aluminum	1500	> 10,000	9000	5300	40	27000	27000	15000	23000	18000		40	70	34,100	38,300	1,500	1,300	1,800	2,410	18	18	38300	40
Arsenic	2 U	1 U	1 U	1 U	1 U	4 U	4 U	4 U	4 U	4 U										10	0		
Barium	58	12	8.8	12	14	54	0.6 U	10	12	16		18.7	23	33.1	21	14.0	22	21	26	18	17	58	8.8
Beryllium	1 U	0.4	0.3	0.3 U	0.3 U	0.4 U	0.4 U	0.9	0.6	0.8		0.04U	1U	0.84	1	0.06	1U	1U	1U	18	8	1	0.06
Cadmium	1 U	15	4.9	2	1 U	3.5	0.7 U	11	9.8	4.6		0.38	0.6	12.3	25	1.06	0.7	1.1	0.8	18	15	25	0.38
Calcium	62000	110000	66000	40000	3600	79000	83000	49000	98000	95000		5,290	4,570	103,000	77,000	22,800	18,000	44,800	42,100	18	18	110000	3600
Chromium	1 U	0.9 U	0.9 U	0.9 U	0.9 U	0.5 U	0.5 U	0.6	0.5 U	0.6		0.2U	5U	0.6	5U	0.2U	5U	5U	5U	18	3	0.6	0.6
Copper	21	890	310	350	9.4	730	2 U	1100	730	300		11.0	8	950	1,220	51.8	34	34	34	18	17	1220	8
Iron	23000	100000	52000	6000	400	2800	3100	16000	42000	81000		60	70	23,900	33,700	1,000	690	1,530	2,370	18	18	100000	60
Lead	1.4	0.6	0.3	0.9	0.3 U	3	0.4	0.6	0.68	1.1		0.2U	1U	1U	2U	0.5J	1U	1U	1U	18	10	3	0.3
Magnesium	8900	15000	13000	7000	390	23000	12000	11000	16000	19000		690	670	17,300	14,200	3,820	2,870	7,630	7,810	18	18	23000	390
Manganese	140	1800	590	300	6.8	1200	3 U	1700	1900	2000		8.94	8	1,810	1,290	174	108	304	348	18	17	2000	6.8
Mercury		0.1	0.1 U	0.1 U												0.1U				4	1	0.1	0.1
Molybdenum	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4										10	1	0.4	0.4
Nickel	4	27	9.7	6.9	0.5	16	1 U	48	34	21		0.7	10U	26.1	40	4.3	10U	10U	10	18	14	48	0.5
Potassium	2000 U					6600	3500	4200	4700	7200		740	1,100	4,140	4,210	2290	2,660	5,030	3,960	14	13	7200	740
Selenium																				0	0		
Silver	0.1 U	0.1	0.1 U	0.1 U	0.1 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U		0.04U	0.2U	0.04U	0.2U	0.2U	0.2U	0.2U	0.2U	18	1	0.1	0.1
Sodium	2900	4300	3700	2700	600	7700	5600	4800	6200	6300		960	850	4,670	3,640	1750	1,470	2,550	2,390	18	18	7700	600
Thallium	0.3	0.6 U	0.6 U	0.6 U	0.6 U	4 U	4 U	4 U	4 U	4 U										10	1	0.3	0.3
Uranium	0.4	1.3	1.1	0.7	0.1 U	1.6	0.4 U	2.8	1.6	1.4										10	8	2.8	0.4
Zinc	130	1200	730	160	30	360	0.8 U	360	660	330		45	77	1,080	2,230	109	109	133	132	18	17	2230	30

Data Notes:
J - Estimated Value.
U - Parameter was analyzed for, but not detected above the reporting limit shown.
UJ - Parameter was analyzed for, but not detected. Detection limit is an estimated value.
▨ Grey shading Indicates that the data was not available for this parameter.

Statistical Notes:
Maximum and minimum concentrations are based on detected values only

Data Source:
(a) Kilburn, et al. 1994. *Geochemical data and sample locality maps for stream-sediment, heavy-mineral-concentrate, mill tailing, water, and precipitate samples collected in and around the Holden mine, Chelan County, Washington.* USGS Open File Report 94-680A Paper Version, 94-680B Diskette version (Data Collected in 1994).
(b) Kilburn, J.E. & S.J. Sutley. 1996. *Characterization of acid mine drainage at the Holden mine, Chelan, Washington.* USGS Open File Report 96-531. (Data collected in 1995).
(c) Kilburn, J.E. & S.J. Sutley. 1997. *Analytical results and comparative overview of geochemical studies conducted at the Holden Mine*, spring 1996. USGS Open File Report 97-128 (Data collected in Spring 1996).
(d) Kilburn, J E. & S.J. Sutley. 1997. Preliminary data (no report attached, data collected in Fall 1996).
(e) Johnson, A., et al. 1997. *Effects of Holden Mine on the Water, Sediments and Benthic Invertebrates of Railroad Creek (Lake Chelan).* Environmental Investigations and Laboratory Services Program. Water Body No. WA-47-1020. Publication No. 97-330 (data collected in Spring and Fall 1996).

TABLE 7.1-H
STATISTICAL ANALYSIS AND COMPARISON OF CHEMICAL DATA FROM GROUNDWATER SEEPAGE
HOLDEN MINE RI/FS
DAMES & MOORE JOB NO. 17693-005-019

Parameters	Location	MILL AREA													STATISTICAL CALCULATIONS FOR MILL AREA			
	Sample ID	549 A	549 B	643	646	647	649	651	652	653	SP-7			SP-7X				
	Sample Date	7/95[b]	7/95[b]	5/96[c]	5/96[c]	5/96[c]	5/96[c]	5/96[c]	5/96[c]	5/96[c]	5/21/97	7/12/97	9/19/97	5/21/97	# Analyses	# of Detections	Maximum Conc.	Minimum Conc.
Total Metals, (ug/L)																		
Aluminum		▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨				
Arsenic		▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨				
Barium		▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨				
Beryllium		▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨				
Cadmium		▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨				
Calcium		▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨				
Chromium		▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨				
Copper		▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨				
Iron		▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨				
Lead		▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨				
Magnesium		▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨				
Manganese		▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨				
Mercury		▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨				
Molybdenum		▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨				
Nickel		▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨				
Potassium		▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨				
Selenium		▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨				
Silver		▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨				
Sodium		▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨				
Thallium		▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨				
Uranium		▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨				
Zinc		▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨				
Dissolved Metals (ug/L)																		
Aluminum		> 10,000	> 10,000	280000	260000	760000	2800	32	620000	560000	190	20	1,790	200	13	13	760000	20
Arsenic		1	1	4 U	4 U	4 U	4 U	4 U	4 U	5	0.2U	1U	1U	0.2U	13	3	5	1
Barium		6.4	2.8	4.8	5.6	6.9	12	10	14	10	12.9	27	21	12.5	13	13	27	2.8
Beryllium		2.6	3.2	5.1	4.2	7.2	0.4 U	0.4 U	5.9	4.6	0.2U	1U	1U	0.04	13	8	7.2	0.04
Cadmium		1500	2300	2300	980	3000	79	22	1100	1000	34.0	26	48	35.3	13	13	3000	22
Calcium		160000	130000	270000	300000	400000	22000	6900	300000	320000	15,800	28,700	60,100	15,900	13	13	400000	6900
Chromium		31	120	34	21	100	0.5 U	0.5 U	130	61	1U	5U	5U	1U	13	7	130	21
Copper		> 40,000	> 40,000	270000	240000	650000	9200	540	560000	540000	2,810	1,930	7,560	2,800	13	13	650000	540
Iron		440,000	> 500,000	25000	77000	290000	770	50 U	340000	260000	120	220	710	120	13	12	500000	120
Lead		26	23	5.3	5.1	7.4	6.5	1	54	19	3J	3	13	4J	13	13	54	1
Magnesium		> 100,000	> 100,000	140000	150000	510000	7900	2300	370000	340000	4,810	6,680	11,500	4,860	13	13	510000	2300
Manganese		> 6,000	> 6,000	8300	13000	33000	290	56	14000	13000	116	185	451	144	13	13	33000	56
Mercury		▨	▨	▨	▨	▨	▨	▨	▨	▨	0.00068J	0.00023J	▨	0.00051J	3	3	0.00068	0.00023
Molybdenum		0.1 U	0.1 U	0.4 U	0.4 U	0.4	0.4 U	0.4 U	0.4	0.6	0.2UJ	5U	5U	0.2UJ	13	3	0.6	0.4
Nickel		150	180	260	220	720	11	2	190	190	6	10U	10	7	13	12	720	2
Potassium		▨	▨	490	700	500 U	1300	660	770	690	1,230	2,390	3,200UJ	1,260	11	9	2390	490
Selenium		▨	▨	▨	▨	▨	▨	▨	▨	▨	1UJ	1U	▨	1UJ	3	0		
Silver		1.5	5.7	2.8	0.74	2.7	0.2 U	0.2 U	2.4	2.4	0.2U	0.2U	0.2U	0.13U	13	7	5.7	0.74
Sodium		6000	9200	12000	7800	16000	3000	1400	16000	15000	2,170	3,830	6,470J	2,170	13	13	16000	1400
Thallium		0.6	0.6	4 U	4 U	4 U	4 U	4 U	4 U	4 U	0.2UJ	1U	1U	0.2UJ	13	2	0.6	0.6
Uranium		210	600	110	70	250	0.8	0.4 U	110	96	0.3J	20U	1U	0.33J	13	10	600	0.3
Zinc		81000	140000	160000	92000	610000	9200	3200	110000	86000	4,330	3,470	6,430	4,390	13	13	610000	3200

Data Notes:
J - Estimated Value.
U - Parameter was analyzed for, but not detected above the reporting limit shown.
UJ - Parameter was analyzed for, but not detected. Detection limit is an estimated value.
▨ Grey shading Indicates that the data was not available for this parameter.

Statistical Notes:
Maximum and minimum concentrations are based on detected values only.

Data Source:
(a) Kilburn, et al. 1994. *Geochemical data and sample locality maps for stream-sediment, heavy-mineral-concentrate, mill tailing, water, and precipitate samples collected in and around the Holden mine, Chelan County, Washington.* USGS Open File Report 94-680A Paper Version, 94-680B Diskette version (Data Collected in 1994).
(b) Kilburn, J.E. & S.J. Sutley. 1996. *Characterization of acid mine drainage at the Holden mine, Chelan, Washington*. USGS Open File Report 96-531. (Data collected in 1995).
(c) Kilburn, J.E. & S.J. Sutley. 1997. *Analytical results and comparative overview of geochemical studies conducted at the Holden Mine*, spring 1996. USGS Open File Report 97-128 (Data collected in Spring 1996).
(d) Kilburn, J.E. & S.J. Sutley. 1997. Preliminary data (no report attached, data collected in Fall 1996).
(e) Johnson, A., et al. 1997. *Effects of Holden Mine on the Water, Sediments and Benthic Invertebrates of Railroad Creek (Lake Chelan).* Environmental Investigations and Laboratory Services Program. Water Body No. WA-47-1020. Publication No. 97-330 (data collected in Spring and Fall 1996).

TABLE 7.1-H
STATISTICAL ANALYSIS AND COMPARISON OF CHEMICAL DATA FROM GROUNDWATER SEEPAGE
HOLDEN MINE RI/FS
DAMES & MOORE JOB NO. 17693-005-019

Location	MINE INFLUENCED AREA																							
Parameters Sample ID	547	548	622	624	631	632	633	634	637	638	639	640	650	658	SP-6	SP-8	SP-9	SP-9X	SP-10W		SP-11	SP-11X	SP-12	
Sample Date	7/95[b]	7/95[b]	5/96[c]	5/96[c]	5/96[c]	5/96[c]	5/96[c]	5/96[c]	5/96[c]	5/96[c]	5/96[c]	5/96[c]	5/96[c]	5/96[c]	5/21/97	5/21/97	5/23/97	5/23/97	5/21/97	7/12/97	5/22/97	5/22/97	5/23/97	7/12/97
Total Metals, (ug/L)																								
Aluminum	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨
Arsenic	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨
Barium	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨
Beryllium	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨
Cadmium	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨
Calcium	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨
Chromium	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨
Copper	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨
Iron	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨
Lead	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨
Magnesium	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨
Manganese	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨
Mercury	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨
Molybdenum	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨
Nickel	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨
Potassium	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨
Selenium	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨
Silver	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨
Sodium	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨
Thallium	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨
Uranium	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨
Zinc	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨
Dissolved Metals (ug/L)																								
Aluminum	1200	2200	9800	620	24000	34000	65000	4000	160	3100	3400	2800	5000	10000	14,600	9,620	30	20	4,740	3,530	150	150	1,380	1,590
Arsenic	1 U	1	4 U	4 U	4 U	4 U	4 U	4 U	4 U	4 U	4 U	4 U	4 U	4 U	▨	▨	▨	▨	▨	▨	0.3	0.2U	▨	▨
Barium	22	11	15	12	4.8	4.9	2	15	25	17	16	16	14	20	12.0	22.2	30	29	15.4	27	44.6	45.3	50	27
Beryllium	0.3 U	0.3 U	0.6	0.4 U	0.8	0.8	1.4	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	8U	0.8U	0.8U	0.04U	0.8U	1U	0.04U	0.2U	0.8U	1U
Cadmium	24	62	110	22	5.6	12	5.5	33	9.2	66	68	71	78	22	173	87.8	0.75	0.76	25.7	36	12.8	13.2	14.1	18
Calcium	41000	78000	67000	15000	110000	140000	130000	31000	23000	49000	52000	36000	77000	9500	134,000	56,500	19,000	18,600	27,400	30,600	25,300	24,100	9,610	16,200
Chromium	0.9 U	0.9 U	0.5 U	0.5 U	3.7	3.7	6.8	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	2.5	4U	4U	5U	5U	4U	5U	1U	1U	5U	5U
Copper	2300	3000	8500	1700	320	310	570	1900	410	4600	4900	5000	6000	800	12,700	7,880	3	2	2.210	2,110	460	472	2,000	1,910
Iron	190	20 U	51	50 U	800000	1200000	600000	160	50 U	110	110	180	50 U	15000	30	30	20U	20U	30	30	20U	20U	20U	20U
Lead	7.9	0.6	12	2.1	0.79	0.4	0.6	0.3	0.2 U	5.8	7.2	7.8	0.6	36	15J	13J	0.4U	0.3U	4U	1U	1U	1U	0.2U	1U
Magnesium	4400	9600	7200	1600	74000	130000	78000	4600	2800	7700	8200	7300	12000	2100	15,000	5,380	2,090	2,070	3,870J	4,270	3,180	3,000	1,470	2,920
Manganese	50	320	570	110	5100	8800	5000	200	19	320	330	280	580	130	1,160	419	1U	1U	160	191	37.3	36.3	53	93
Mercury	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨
Molybdenum	0.1 U	0.1 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨
Nickel	10	78	48	11	8.4	15	16	12	3	41	44	17	140	5.6	86	46	10U	10U	11	10	6	5	10U	10U
Potassium	▨	▨	4700	1500	10000	12000	1300	2100	1900	4000	4300	3300	6400	4300	10,500	3,980	1,010	1,020	2,500	3,490	2,410	2,060	1,140	1,840
Selenium	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨
Silver	0.1 U	0.1 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	8U	0.8U	0.8U	0.8U	0.8U	0.2U	0.05U	0.2U	0.04U	0.2U
Sodium	5500	5800	4800	1500	12000	16000	14000	3400	4600	5100	4300	3500	5900	1900	4,910	2,440	3,470	3,440	2,760	2,920	3,650	3,410	1,630	3,130
Thallium	0.6 U	0.6 U	4 U	4 U	4 U	4 U	4 U	4 U	4 U	4 U	4 U	4 U	4 U	4 U	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨
Uranium	0.4	0.7	5.1	0.6	3.2	2.6	4.3	0.4 U	0.4 U	0.4 U	0.4	0.4	0.9	4.8	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨
Zinc	2700	6500	14000	2800	1200	2400	2400	4300	1500	7500	7800	7800	8900	1400	22,100	11,200	267	267	3,210	4,350	2,340	2,280	2,230	2,720

Data Notes:

J - Estimated Value.
U - Parameter was analyzed for, but not detected above the reporting limit shown.
UJ - Parameter was analyzed for, but not detected. Detection limit is an estimated value.
▨ Grey shading: Indicates that the data was not available for this parameter.

Data Source:

(a) Kilburn, et al. 1994. *Geochemical data and sample locality maps for stream-sediment, heavy-mineral-concentrate, mill tailing, water, and precipitate samples collected in and around the Holden mine, Chelan County, Washington.* USGS Open File Report 94-680A Paper Version, 94-680B Diskette version (Data Collected in 1994).
(b) Kilburn, J.E. & S.J. Sutley. 1996. *Characterization of acid mine drainage at the Holden mine, Chelan, Washington*. USGS Open File Report 96-531. (Data collected in 1995).
(c) Kilburn, J.E. & S.J. Sutley. 1997. *Analytical results and comparative overview of geochemical studies conducted at the Holden Mine*, spring 1996.
USGS Open File Report 97-128 (Data collected in Spring 1996).
(d) Kilburn, J.E. & S.J. Sutley. 1997. Preliminary data (no report attached, data collected in Fall 1996).
(e) Johnson, A., et al. 1997. *Effects of Holden Mine on the Water, Sediments and Benthic Invertebrates of Railroad Creek (Lake Chelan).*
Environmental Investigations and Laboratory Services Program. Water Body No. WA-47-1020. Publication No. 97-330 (data collected in Spring and Fall 1996).

TABLE 7.1-H
STATISTICAL ANALYSIS AND COMPARISON OF CHEMICAL DATA FROM GROUNDWATER SEEPAGE
HOLDEN MINE RI/FS
DAMES & MOORE JOB NO. 17693-005-019

Parameters	Location	MINE INFLUENCED AREA																							
	Sample ID	547	548	622	624	631	632	633	634	637	638	639	640	650	658	SP-6	SP-8	SP-9	SP-9X	SP-10W		SP-11	SP-11X	SP-12	
	Sample Date	7/95[b]	7/95[b]	5/96[c]	5/96[c]	5/96[c]	5/96[c]	5/96[c]	5/96[c]	5/96[c]	5/96[c]	5/96[c]	5/96[c]	5/96[c]	5/96[c]	5/21/97	5/21/97	5/23/97	5/23/97	5/21/97	7/12/97	5/22/97	5/22/97	5/23/97	7/12/97
Total Metals, (ug/L)																									
Aluminum		▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨
Arsenic		▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨
Barium		▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨
Beryllium		▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨
Cadmium		▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨
Calcium		▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨
Chromium		▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨
Copper		▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨
Iron		▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨
Lead		▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨
Magnesium		▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨
Manganese		▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨
Mercury		▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨
Molybdenum		▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨
Nickel		▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨
Potassium		▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨
Selenium		▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨
Silver		▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨
Sodium		▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨
Thallium		▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨
Uranium		▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨
Zinc		▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨
Dissolved Metals (ug/L)																									
Aluminum		1200	2200	9800	620	24000	34000	65000	4000	160	3100	3400	2800	5000	10000	14,600	9,620	30	20	4,740	3,530	150	150	1,380	1,590
Arsenic		1 U	1	4 U	4 U	4 U	4 U	4 U	4 U	4 U	4 U	4 U	4 U	4 U	4 U	▨	▨	▨	▨	▨	▨	0.3	0.2U	▨	▨
Barium		22	11	15	12	4.8	4.9	2	15	25	17	16	16	14	20	12.0	22.2	30	29	15.4	27	44.6	45.3	50	27
Beryllium		0.3 U	0.3 U	0.6	0.4 U	0.8	0.8	1.4	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	8U	0.8U	0.8U	0.04U	0.8U	1U	0.04U	0.2U	0.8U	1U
Cadmium		24	62	110	22	5.6	12	5.5	33	9.2	66	68	71	78	22	173	87.8	0.75	0.76	25.7	36	12.8	13.2	14.1	18
Calcium		41000	78000	67000	15000	110000	140000	130000	31000	23000	49000	52000	36000	77000	9500	134,000	56,500	19,000	18,600	27,400	30,600	25,300	24,100	9,610	16,200
Chromium		0.9 U	0.9 U	0.5 U	0.5 U	3.7	3.7	6.8	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	2.5	4U	4U	5U	5U	4U	5U	1U	1U	5U	5U
Copper		2300	3000	8500	1700	320	310	570	1900	410	4600	4900	5000	6000	800	12,700	7,880	3	2	2,210	2,110	460	472	2,000	1,910
Iron		190	20 U	51	50 U	800000	1200000	600000	160	50 U	110	110	180	50 U	15000	30	30	20U	20U	30	30	20U	20U	20U	20U
Lead		7.9	0.6	12	2.1	0.79	0.4	0.6	0.3	0.2 U	5.8	7.2	7.8	0.6	36	15J	13J	0.4U	0.3U	4U	1U	1U	1U	0.2U	1U
Magnesium		4400	9600	7200	1600	74000	130000	78000	4600	2800	7700	8200	7300	12000	2100	15,000	5,380	2,090	2,070	3,870J	4,270	3,180	3,000	1,470	2,920
Manganese		50	320	570	110	5100	8800	5000	200	19	320	330	280	580	130	1,160	419	1U	1U	160	191	37.3	36.3	53	93
Mercury		▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨
Molybdenum		0.1 U	0.1 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨
Nickel		10	78	48	11	8.4	15	16	12	3	41	44	17	140	5.6	86	46	10U	10U	11	10	6	5	10U	10U
Potassium		▨	▨	4700	1500	10000	12000	1300	2100	1900	4000	4300	3300	6400	4300	10,500	3,980	1,010	1,020	2,500	3,490	2,410	2,060	1,140	1,840
Selenium		▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨
Silver		0.1 U	0.1 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	8U	0.8U	0.8U	0.8U	0.8U	0.2U	0.05U	0.2U	0.04U	0.2U
Sodium		5500	5800	4800	1500	12000	16000	14000	3400	4600	5100	4300	3500	5900	1900	4,910	2,440	3,470	3,440	2,760	2,920	3,650	3,410	1,630	3,130
Thallium		0.6 U	0.6 U	4 U	4 U	4 U	4 U	4 U	4 U	4 U	4 U	4 U	4 U	4 U	4 U	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨
Uranium		0.4	0.7	5.1	0.6	3.2	2.6	4.3	0.4 U	0.4 U	0.4 U	0.4	0.4	0.9	4.8	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨
Zinc		2700	6500	14000	2800	1200	2400	2400	4300	1500	7500	7800	7800	8900	1400	22,100	11,200	267	267	3,210	4,350	2,340	2,280	2,230	2,720

Data Notes:
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▨ **Grey shading:** Indicates that the data was not available for this parameter.

Data Source:
(a) Kilburn, et al. 1994. *Geochemical data and sample locality maps for stream-sediment, heavy-mineral-concentrate, mill tailing, water, and precipitate samples collected in and around the Holden mine, Chelan County, Washington.* USGS Open File Report 94-680A Paper Version, 94-680B Diskette version (Data Collected in 1994).
(b) Kilburn, J.E. & S.J. Sutley. 1996. *Characterization of acid mine drainage at the Holden mine, Chelan, Washington*. USGS Open File Report 96-531. (Data collected in 1995).
(c) Kilburn, J.E. & S.J. Sutley. 1997. *Analytical results and comparative overview of geochemical studies conducted at the Holden Mine*, spring 1996. USGS Open File Report 97-128 (Data collected in Spring 1996).
(d) Kilburn, J.E. & S.J. Sutley. 1997. Preliminary data (no report attached, data collected in Fall 1996).
(e) Johnson, A., et al. 1997. *Effects of Holden Mine on the Water, Sediments and Benthic Invertebrates of Railroad Creek (Lake Chelan).* Environmental Investigations and Laboratory Services Program. Water Body No. WA-47-1020. Publication No. 97-330 (data collected in Spring and Fall 1996).

TABLE 7.1-H
STATISTICAL ANALYSIS AND COMPARISON OF CHEMICAL DATA FROM GROUNDWATER SEEPAGE
HOLDEN MINE RI/FS
DAMES & MOORE JOB NO. 17693-005-019

Location	MINE INFLUENCED AREA																								STATISTICAL CALCULATIONS FOR MINE INFLUENCED AREA			
Parameters Sample ID	SP-15E						SP-15W	SP-16			SP-16X	SP-22	SP-23							SP-23 UP	SP-23 Vent Rd	SP-23B	SP-24	SP-25				
Sample Date	5/22/97	6/2/97	6/9/97	6/16/97	7/12/97	10/5/97	5/22/97	5/22/97	7/12/97	9/16/97	7/12/97	5/23/97	5/23/97	5/26/97	6/2/97	6/9/97	6/16/97	10/5/97	5/2/98	7/11/97	10/5/97	5/23/97	5/23/97	5/23/97	# Analyses	# of Detections	Maximum Conc.	Minimum Conc.
Total Metals, (ug/L)																												
Aluminum																												
Arsenic																												
Barium																												
Beryllium																												
Cadmium																												
Calcium																												
Chromium																												
Copper																												
Iron																												
Lead																												
Magnesium																												
Manganese																												
Mercury																												
Molybdenum																												
Nickel																												
Potassium																												
Selenium																												
Silver																												
Sodium																												
Thallium																												
Uranium																												
Zinc																												
Dissolved Metals (ug/L)																												
Aluminum	1,940	2,240	3,350J	2,560	20U	680	30	2,040	3,490	2,630	3,350	190	7,890	7,940	7,440	6,850J	5,390	4,670	5,620	5,820	4,520	5,250	2,410	890	48	47	65000	20
Arsenic								0.8U	1U	1U	1U								1U						21	2	1	0.3
Barium	18	36.1	34.6J	43	43	36	23	21.6	37	24	37	33	33	40.0	26.5	28.5J	23	27	22	32	20	35	36	42	48	48	50	2
Beryllium	0.09	4U	0.3J	4U	1U	1U	0.04U	0.8U	1U	1U	1U	20U	20U	0.2	4U	0.3J	4U	1U	1U	1U	1U	4U	20U	4U	48	8	1.4	0.09
Cadmium	54.6	55.8	66.9J	74	28	63	9.37	53.5	38	34	38	47.5	38.9	41.8	32.0	27.1J	22	23	34	26	22	28.0	47.7	34.1	48	48	173	0.75
Calcium	47,900	38,300	46,800J	52,900	30,100	51,500	23,000	48,300	44,900	49,800	43,900	58,000	17,000	15,900	11,100	10,300J	7,940	11,200	15,500	10,900	10,500	14,100	45,300	37,400	48	48	140000	7940
Chromium	5U	1U	1U	5U	5U	5U	5U	4U	5U	5U	5U	5U	5U	1U	1U	1U	5U	5U	5U	5U	5U	5U	5U	5U	48	4	6.8	2.5
Copper	3,560	3,950	4,930J	4,470	899	4,180	206	3,450	3,100	2,110	2,970	2,140	6,850	6,470	6,100	5,940J	4,880	4,920	5,340	5,560	4,520	4,900	3,660	1,880	48	48	12700	2
Iron	80	80J	100J	110	20U	170	20U	60	500	80	450	20U	20U	20U	20U	20U	20U	20U	20U	20U	20U	20U	220	20U	48	24	1200000	30
Lead	6.7U	8	14J	20U	1U	6	1.4U	5J	9	8	10	2.8U	20U	1U	1U	3J	20U	1U	0.22	1U	1U	4U	4.3U	2.2U	48	23	36	0.22
Magnesium	6,330	5,820	7,170J	8,260	5,930	9,040	2,590	6,530	6,500	4,560	6,270	6,880	5,130	4,660	2,660	2,500J	1,630	2,290	3,620	2,540	2,150	3,920	6,240	5,090	48	48	130000	1470
Manganese	247	198	250J	295	148	312	37	253	993	2,030	960	264	248	223	130	115J	79	128	199	114	109	177	270	157	48	46	8800	19
Mercury								0.00056J	0.00093		0.00067														3	3	0.00093	0.00056
Molybdenum								0.8UJ	5U	5U	5U								5U						19	0		
Nickel	20	16	20J	20	10U	20	10U	28	30	20	30	20	20	22	14	12J	10U	10	20	10	10	10	20	10	48	41	140	3
Potassium	3,460	3,910	5,270J	4,760	3,040	3,830	2,120	3,500	4,760	5,230	4,700	3,980	1,160	1,280	1,360	1,120J	840	1,340	1,110	1,420	890	1,000	3,730	2,700	46	46	12000	840
Selenium								4UJ	1U		1U														3	0		
Silver	0.05U	0.2U	0.2U	4U	0.2U	0.2U	0.8U	0.04U	0.2U	0.2U	0.2U	0.04U	0.04U	0.2UJ	0.2U	0.2U	4U	0.2U	0.2U	0.2U	0.2U	0.04U	0.14	0.08	48	2	0.14	0.08
Sodium	2,500	3,010	3,420J	3,940	3,450	3,710	3,380	2,980	4,820	3,350	4,600	3,340	1,600	1,710	1,140	1,240J	1,000	1,360	1,430	1,380	1,330	1,650	3,140	3,300	48	48	16000	1000
Thallium								0.8UJ	1U	1U	1U														18	0		
Uranium								0.8UJ	20U	20U	20U														18	11	5.1	0.4
Zinc	7,970	7,210	8,580J	9,810	3,590	8,960	2,260	7,690	4,920	4,050	4,810	7,350	5,000	5,020	3,400	2,870J	2,250	2,460	4,110	2,610	2,570	3,610	7,560	5,550	48	48	22100	267

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Data Source:
(a) Kilburn, et al. 1994. *Geochemical data and sample locality maps for stream-sediment, heavy-mineral-concentrate, mill tailing, water, and precipitate samples collected in and around the Holden mine, Chelan County, Washington.* USGS Open File Report 94-680A Paper Version, 94-680B Diskette version (Data Collected in 1994).
(b) Kilburn, J.E. & S.J. Sutley. 1996. *Characterization of acid mine drainage at the Holden mine, Chelan, Washington*. USGS Open File Report 96-531. (Data collected in 1995).
(c) Kilburn, J.E. & S.J. Sutley. 1997. *Analytical results and comparative overview of geochemical studies conducted at the Holden Mine*, spring 1996. USGS Open File Report 97-128 (Data collected in Spring 1996).
(d) Kilburn, J.E. & S.J. Sutley. 1997. Preliminary data (no report attached, data collected in Fall 1996).
(e) Johnson, A., et al. 1997. *Effects of Holden Mine on the Water, Sediments and Benthic Invertebrates of Railroad Creek (Lake Chelan).* Environmental Investigations and Laboratory Services Program. Water Body No. WA-47-1020. Publication No. 97-330 (data collected in Spring and Fall 1996).

Statistical Notes:
Maximum and minimum concentrations are based on detected values only.

TABLE 7.1-H
STATISTICAL ANALYSIS AND COMPARISON OF CHEMICAL DATA FROM GROUNDWATER SEEPAGE
HOLDEN MINE RI/FS
DAMES & MOORE JOB NO. 17693-005-019

Parameters	NON-MINE INFLUENCED AREAS														
	USGS 1995 b		DAMES & MOORE RI DATA									STATISTICAL CALCULATIONS			
			SP-14 Upper	SP-26		SP-14		SP-14 Lower	SP-13	A-1	SP-27	# Analyses	# of Detections	Maximum Conc.	Minimum Conc.
	515	507	10/3/97	7/11/97	9/16/97	5/23/97	9/18/97	10/3/97	6/2/97	7/11/97	5/7/98				
Total Metals, (ug/L)															
Aluminum						440						1	1	440	440
Arsenic															
Barium						18						1	1	18	18
Beryllium						4U						1	0		
Cadmium						3.46						1	1	3.46	3.46
Calcium						1,830						1	1	1830	1830
Chromium						5U						1	0		
Copper						830						1	1	830	830
Iron						20						1	1	20	20
Lead						6.0						1	1	6	6
Magnesium						300						1	1	300	300
Manganese						9						1	1	9	9
Mercury															
Molybdenum															
Nickel						10U						1	0		
Potassium						500U						1	0		
Selenium															
Silver						0.05J						1	1	0.05	0.05
Sodium						700						1	1	700	700
Thallium															
Uranium															
Zinc						446						1	1	446	446
Dissolved Metals (ug/L)															
Aluminum		1300	70	30	20U	410	160U	900	20U	20U	20U	10	5	1300	30
Arsenic		1 U									1U	2	0		
Barium		47	2	14	3	33	20	51	41	14.4	1U	10	9	51	2
Beryllium		0.3 U	1U	1U	1U	4U	1U	1U	0.8U	0.04U	1U	10	0		
Cadmium		2	0.2U	0.3	0.3	3.46	1.2	12	0.31	2.32	0.2U	10	8	12	0.3
Calcium		13000	700	3,760	4,640	1,800	1,730	5,020	10,400	20,100	4,610	10	10	20100	700
Chromium		0.9 U	5U	5U	5U	5U	5U	5U	5U	0.2U	5U	10	0		
Copper		48	2U	28	22	788	52	1,410	2U	120	2U	10	7	1410	22
Iron		100	20U	20U	20U	20	480	30	330	20U	20U	10	5	480	20
Lead		0.4	1U	1U	1U	4.8U	3	11	0.8U	0.4U J	1U	10	3	11	0.4
Magnesium		1700	130	470	540	290	350	910	1,460	1,910	430	10	9	1910	130
Manganese		370	1U	1U	1U	8	4	43	74	27.8	1	10	6	370	1
Mercury															
Molybdenum		0.1 U									5U	2	0		
Nickel		9.8	10U	10U	10U	10U	10U	10U	10U	1.0	10U	10	2	9.8	1
Potassium			500U	640	790	500U	750UJ	560	1,010	1,770	500U	9	5	1770	560
Selenium															
Silver		0.1 U	0.2U	0.2U	0.2U	0.04U	0.2U	0.2U	1.1U	0.04U	0.2U	10	0		
Sodium		1000	310U	970	1,020	730	590UJ	650	1,950	1,220	1,110	10	8	1950	650
Thallium		0.6 U										1	0		
Uranium		0.2										1	0		
Zinc		170	5	32	22	423	151	1,610	71	257	4U	10	9	1610	5

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Statistical Notes:
Maximum and minimum concentrations are based on detected values only.

Data Source:
(a) Kilburn, et al. 1994. *Geochemical data and sample locality maps for stream-sediment, heavy-mineral-concentrate, mill tailing, water, and precipitate samples collected in and around the Holden mine, Chelan County, Washington.* USGS Open File Report 94-680A Paper Version, 94-680B Diskette version (Data Collected in 1994).
(b) Kilburn, J.E. & S.J. Sutley. 1996. *Characterization of acid mine drainage at the Holden mine, Chelan, Washington.* USGS Open File Report 96-531. (Data collected in 1995).
(c) Kilburn, J.E. & S.J. Sutley. 1997. *Analytical results and comparative overview of geochemical studies conducted at the Holden Mine*, spring 1996.
USGS Open File Report 97-128 (Data collected in Spring 1996).
(d) Kilburn, J.E. & S.J. Sutley. 1997. Preliminary data (no report attached, data collected in Fall 1996).
(e) Johnson, A., et al. 1997. *Effects of Holden Mine on the Water, Sediments and Benthic Invertebrates of Railroad Creek (Lake Chelan).*
Environmental Investigations and Laboratory Services Program. Water Body No. WA-47-1020. Publication No. 97-330 (data collected in Spring and Fall 1996).

TABLE 7.1-I
STATISTICAL ANALYSIS AND COMPARISON OF CHEMICAL DATA FOR STATIONS ALONG PORTAL DRAINAGE
HOLDEN MINE RI/FS
DAMES & MOORE JOB NO. 17693-005-019

Parameters	Location	P-1																		P-2		
	Sample ID	BATTELLE WATER QUALITY MONITORING DATA 1991 [a]								357	USFS 1995		534	605	702	DAMES & MOORE RI DATA				535	606	703
	Sample Date	5/9/91	5/17/91	6/3/91	6/17/91	7/1/91	7/15/91	8/6/91	9/18/91	7/94[b]	6/1/95[c]	9/1/95[c]	7/95[d]	5/96[e]	9/96[f]	5/97	7/97	9/97	5/98	7/95[d]	5/96[e]	9/96[f]
Total Metals (µg/L)																						
Aluminum															2400	13,400	4,850	2,570	22,600			4700
Arsenic																0.3	1U	1U	1U			
Barium															10	12.1	13	10	12			11
Beryllium															10 U	0.3	1U	1U	1U			10 U
Cadmium															10 U	82.2	23	8	170			10 U
Calcium		59046	58695	61285	68580	73610	88632	106150	125615		73000				150000	50,600	70,300	130,000	58,400			150000
Chromium															10 U	1U	5U	5U	5U			10 U
Copper		3780	4086	2867	1746	1498	1048	730	75		1900				160	6,350	912	235	10,400			260
Iron											570				1100	960	540	930	2,030			1800
Lead		62	51	46	50	38	58	52	52		30				50 U	57J	20	8	64			50 U
Magnesium		9768	9909	9074	8888	9000	9502	10200	9450		9600				12000	10,800	8,210	9,820	14,500			12000
Manganese															390	444	287	373	703			380
Mercury																0.00313	0.00024J					
Molybdenum															20 U	0.4	5U	5U	5U			20 U
Nickel															10 U	8J	10U	10U	10U			10 U
Potassium		3510	3285	3529	3834	3704	4254	5505	6250		3500				6300	2,620	4,100	6,300	3,460			6400
Selenium																1U	1U					
Silver																0.2U	0.2U	0.2U	0.2			
Sodium		7392	8081	8373	10190	11212	14818	19345	25700		10000				26000	5,670	12,600	24,600	6,310			26000
Thallium																0.3	1U	1U				
Uranium																4.6	20U	20U				
Zinc		13530	11797	9484	7576	7918	7136	6215	3365		7800				3600	14,900	5,270	3,380	27,800			3600
Dissolved Metals (µg/L)																						
Aluminum										1000			2400	7700	44	13,200	1,460	40U	21,100	2200	6600	43
Arsenic										2 U			1 U	4 U		0.25	1U	1U	1U	1 U	4 U	
Barium										12			12	11	10	23.0J	20	11	12	11	12	11
Beryllium										1 U			0.3 U	0.4 U	10 U	0.34	1U	1U	1U	0.3 U	0.4 U	10 U
Cadmium										21			29	58	10 U	81.2	22	8	160	29	53	10 U
Calcium										72000			94000	42000	160000	50,300	73,200	130,000	57,300	97000	42000	160000
Chromium										1 U			0.9 U	0.5 U	10 U	0 3U	5U	5U	5U	0.9 U	0.5 U	10 U
Copper										570			900	3700	62	5,780	907	77	10,300	910	3500	23
Iron										580			940	230	280	240	280	110	430	430	230	100 U
Lead										21			22 U	35	50 U	48J	19	5U	58	19	31	50 U
Magnesium										7900			8800	7900	11000	10,700	8,430	9,840	14,600	8800	7900	11000
Manganese										350			320	340	420	420	299	374	695	330	310	400
Mercury													0.1 U			0.00257	0.00038J					
Molybdenum										0.6			0.4	0.4 U	20 U	0.05	5U	5U	5U	0.2	0.4 U	20 U
Nickel										4			7.2	5.8	0.01 U	7.7	10U	10U	10U	6.5	5.9	0.01 U
Potassium										2000 U				2700	6200	3,160	4,420	6,150	3,430		2700	6400
Selenium																1.1	1U					
Silver										0.1 U			0.1 U	0.2 U		0.04U	0.2U	0 2U	0.2U	0.1 U	0.2 U	
Sodium										> 5000			> 10000	6300	27000	5,800	13,000	24,600	6,340	> 10000	6300	28000
Thallium										0.1			0.6 U	4 U		0.29	1U	1U		0.6U	4 U	
Uranium										2.7			2.5	3.7		3.95	20U	20U		2.4	3	
Zinc										4800			6000	9600	3600	14,900	5,440	3,280	27,500	6000	8600	3300

Data Notes:

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UJ - Parameter was analyzed for, but not detected. Detection limit is an estimated value.
▨ Grey shading indicates that the data was not available for this parameter

Data Source:

(a) Walters, et al. 1992. *Holden Mine Reclamation Project Final Report.* Pacific Northwest Laboratories, Richland, WA. (Data collected in 1991)
(b) Kilburn, et al 1994. *Geochemical data and sample locality maps for stream-sediment, heavy-mineral-concentrate, mill tailing, water, and precipitate samples collected in and around the Holden mine, Chelan County, Washington.* USGS Open File Report 94-680A Paper Version, 94-680B Diskette version (Data Collected in 1994).
(c) Anderson, Keith A. (USFS Chelan Ranger District). Compilation of Data for Preliminary Assessment of the Holden Mine Site.
(d) Kilburn, J.E. & S.J. Sutley. 1996. *Characterization of acid mine drainage at the Holden mine, Chelan, Washington.* USGS Open File Report 96-531. (Data collected in 1995)
(e) Kilburn, J.E. & S.J. Sutley. 1997. *Analytical results and comparative overview of geochemical studies conducted at the Holden Mine*, spring 1996. USGS Open File Report 97-128 (Data collected in Spring 1996).
(f) Kilburn, J.E. & S.J. Sutley. 1997. Preliminary data (no report attached, data collected in Fall 1996).
(g) Johnson, A., et al. 1997. *Effects of Holden Mine on the Water, Sediments and Benthic Invertebrates of Railroad Creek (Lake Chelan).* Environmental Investigations and Laboratory Services Program. Water Body No WA-47-1020. Publication No. 97-330 (data collected in Spring and Fall 1996).

TABLE 7.1-I
STATISTICAL ANALYSIS AND COMPARISON OF CHEMICAL DATA FOR STATIONS ALONG PORTAL DRAINAGE
HOLDEN MINE RI/FS
DAMES & MOORE JOB NO. 17693-005-019

Location	P-5																			
Parameters Sample ID	BATTELLE/USFS WATER QUALITY MONITORING DATA 1991 ^{a}								USFS WATER MONITORING DATA 1995 ^{c}					358	533	ECOLOGY MINE PORTAL DRAINAGE STATION		601	704	706
Sample Date	5/9/91	5/17/91	6/3/91	6/17/91	7/1/91	7/15/91	8/6/91	9/18/91	6/95	7/95	8/95	8/95	9/95	7/94^{b}	7/95^{d}	6/12/96^{g}	9/10/96^{g}	5/96^{e}	9/96^{f}	9/96^{f}
Total Metals (µg/L)																				
Aluminum																6650	3970		9400	3000
Arsenic																0.23	0.02 U			
Barium																			11	11
Beryllium																			10 U	10 U
Cadmium																35	7.4 U		10 U	10 U
Calcium	48744	52350	61235	68616	71380	88266	107190	125725	73000	95000	110000	110000							150000	14000
Chromium																			10 U	10 U
Copper	3066	3790	2852	1736	1504	1052	715	5.5 U	1900	770	660	410				2040	291		450	160
Iron									640	420	1200	850				591	1370		3500	1100
Lead	62.4 U	45 U	46 U	54 U	38 U	56 U	52 U	52 U	30U	20 U	10 U	10 U				31 U	20 U		50 U	50 U
Magnesium	8124	9010	9113	8948	8924	9458	10060	9440	9600	10000	10000	11000							12000	11000
Manganese																299	358		390	330
Mercury																0.0024				
Molybdenum																			20 U	20 U
Nickel																4.1U			10 U	10 U
Potassium	3366	3169	3551	3632	3522	4092	5300	6615	3500	4400	5300	5300							6300	5600
Selenium																	40 U			
Silver																0.1 U				
Sodium	6294	7072	8466	9736	10898	15038	19405	24590	10000	19000	21000	22000							26000	23000
Thallium																				
Uranium																				
Zinc	11148	10782	9498	7500	7870	7178	6265	2975	7700	6200	6300	5200				6840	3300		3800	3000
Dissolved Metals (µg/L)																				
Aluminum														940	2200			6300	34	23
Arsenic														2 U	1 U			4 U		
Barium														11	10			14	10	8.6
Beryllium														1 U	0.3 U			0.4 U	10 U	10 U
Cadmium														21	28			50	10 U	10 U
Calcium														73000	99000			36000	150000	11000
Chromium														1 U	0.9 U			0.5 U	10 U	10 U
Copper														580	940			3400	12	11
Iron														370	250			180	100 U	100 U
Lead														22 U	19			28	50 U	50 U
Magnesium														8000	9100			6.3	11000	7700
Manganese														350	330			290	380	270
Mercury																				
Molybdenum														0.5U	0.3			0.4 U	20 U	20 U
Nickel														4U	6.3			7.5	0.01 U	0.01 U
Potassium														2000U				2300	6300	4400
Selenium																				
Silver														1 U	0.1 U			0.2 U		
Sodium														5000 U	> 10000			5500	27000	18000
Thallium														0 1 U	0.6 U			4 U		
Uranium														2.5	2.6			2.6		
Zinc														4900	6200			8000	2900	2200

Data Notes:

J - Estimated value.
U - Parameter was analyzed for, but not detected above the reporting limit shown.
UJ - Parameter was analyzed for, but not detected. Detection limit is an estimated value.
▨ Grey shading ▨ indicates that the data was not available for this parameter

Data Source:

(a) Walters, et al. 1992. *Holden Mine Reclamation Project Final Report.* Pacific Northwest Laboratories,Richland, WA. (Data collected in 1991).
(b) Kilburn, et al. 1994. *Geochemical data and sample locality maps for stream-sediment, heavy-mineral-concentrate, mill tailing, water, and precipitate samples collected in and around the Holden mine, Chelan County, Washington.* USGS Open File Report 94-680A Paper Version, 94-680B Diskette version (Data Collected in 1994).
(c) Anderson, Keith A. (USFS Chelan Ranger District). Compilation of Data for Preliminary Assessment of the Holden Mine Site.
(d) Kilburn, J.E. & S.J. Sutley. 1996. *Characterization of acid mine drainage at the Holden mine, Chelan, Washington*. USGS Open File Report 96-531. (Data collected in 1995)
(e) Kilburn, J.E. & S.J. Sutley. 1997. *Analytical results and comparative overview of geochemical studies conducted at the Holden Mine*, spring 1996. USGS Open File Report 97-128 (Data collected in Spring 1996)
(f) Kilburn, J.E. & S.J. Sutley. 1997. Preliminary data (no report attached, data collected in Fall 1996).
(g) Johnson, A., et al. 1997. *Effects of Holden Mine on the Water, Sediments and Benthic Invertebrates of Railroad Creek (Lake Chelan).* Environmental Investigations and Laboratory Services Program. Water Body No WA-47-1020 Publication No. 97-330 (data collected in Spring and Fall 1996).

TABLE 7.1-I
STATISTICAL ANALYSIS AND COMPARISON OF CHEMICAL DATA FOR STATIONS ALONG PORTAL DRAINAGE
HOLDEN MINE RI/FS
DAMES & MOORE JOB NO. 17693-005-019

Parameters	P-5								STATISTICAL CALCULATIONS FOR PORTAL DRAINAGE										
	DAMES & MOORE RI DATA								# Analyses	# of Detections	Maximum Conc.	Minimum Conc.	Range of RL	Approximate Distribution	Mean	Standard Deviation	Median	UCL (95%)
	5/97	5/97	6/97	6/97	6/97	7/97	9/97	5/98										
Total Metals (µg/L)																		
Aluminum	7,290	6,320	8,270	6,650J	6,500	3,790	2,810	13,600	18	18	22,600	2,400	None	Lognormal	7,155	5,085	6,410	9,884
Arsenic	0.2U	▨	▨	▨	▨	1U	1U	1U	10	2	0.3	0.23	0.02 - 1	NA	NA	NA	0.265	0.3
Barium	14.3	13.3	14.4	13.0J	13	13	10	19	16	16	19	10	None	Lognormal	12.51	2.26	12.55	13.51
Beryllium	0.2U	0.2U	4U	0.2U	4U	1U	1U	1U	16	1	0.3	0.3	0.2 - 10	NA	NA	NA	0.3	0.3
Cadmium	49.7	40.7	45.4	35.8J	36	23	8	80	18	13	170	8	7.4 - 10	Neither	36.7	41.4	29	170
Calcium	30,200	37,000	38,300	48,000J	52,000	71,400	128,000	28,000	37	37	150,000	14,000	None	Lognormal	80,748	36,321	71,380	95,399
Chromium	1U	1U	1U	1U	5U	5U	5U	5U	16	0	NA	NA	1 - 10	NA	NA	NA	NA	NA
Copper	4,040	2,620	3,200	2,270J	2,000	914	237	4,800	39	38	10,400	75	5.5	Lognormal	3,186	2,050	1,504	6,599
Iron	480	440J	830J	500J	520	390	970	2,320	23	23	3,500	390	None	Lognormal	1,036	750	850	1,346
Lead	29J	30	37	29J	30	18	8	36	39	21	64	8	10 - 62	Lognormal	31.2	16.2	27	38.7
Magnesium	8,540	6,400	7,020	7,540J	7,590	8,310	9,630	6,620	37	37	14,500	6,400	None	Lognormal	9,491	1,589	8,458	9953
Manganese	239	229	259	260J	267	291	365	321	18	18	703	229	None	Lognormal	343	108	326	386
Mercury	0.00249	▨	▨	▨	▨	0.00031J	▨	▨	5	5	0.00313	0.00024	None	Neither	0.002	0.001	0.00024	0.00313
Molybdenum	0.2U	▨	▨	▨	▨	5U	5U	10	12	2	10	0.4	0.2 - 20	NA	NA	NA	5.2	10
Nickel	5J	5	6	5J	10U	10U	10U	10U	17	5	8	5	4.1 - 10	NA	NA	NA	5	8
Potassium	2,110	2,480	2,970	3,280J	2,990	4,300	5,810	1,920	37	37	6,615	1,920	None	Lognormal	4,228	1,328	3,704	4,656
Selenium	1U	▨	▨	▨	▨	1U	▨	▨	5	0	NA	NA	1 - 40	NA	NA	NA	NA	NA
Silver	0.2U	0.2UJ	0.2U	0.2U	4U	0.2U	0.2U	0.2U	13	1	0.2	0.2	0.1 - 4	NA	NA	NA	0.2	0.2
Sodium	3,700	5,380	5,180	7,140J	7,800	12,700	24,200	3,310	37	37	26,000	3,310	None	Neither	13,735	7,627	10,898	26,000
Thallium	0.2U	▨	▨	▨	▨	1U	1U	▨	6	1	0.3	0.3	1	NA	NA	NA	0.3	0.3
Uranium	2.4	▨	▨	▨	▨	20U	2U	▨	6	2	4.6	2.4	2 - 20	NA	NA	NA	3.5	4.6
Zinc	8,620	7,050	7,930	6,790J	6,880	5,380	3,230	12,300	39	39	27,800	2,975	None	Lognormal	7,592	4,459	7050	8,849
Dissolved Metals (µg/L)																		
Aluminum	5,840	4,910	7,070	4,860J	4,430	1,360	40U	8,960	24	22	21100	23	40	Neither	4,280	5,001	2,300	21,100
Arsenic	0.15	▨	▨	▨	▨	1U	1U	1U	16	2	0.25	0.15	1 - 4	NA	NA	NA	0.2	0.25
Barium	32.6J	26.4	24.4	26.1J	22	20	10	17	24	24	32.5	8.6	None	Neither	15.71	6.8	12	32.5
Beryllium	0.4U	0.2U	4U	0.2U	4U	1U	1U	1U	24	1	0.34	0.34	0.3 - 10	NA	NA	NA	0.34	0.34
Cadmium	52.5	41.0	47.0	37.0J	36	22	8	70	24	20	160	8	10	Lognormal	40.65	33.84	29	67 7
Calcium	30,500	36,900	38,700	49,100J	53,800	71,900	131,000	28,300	24	24	160000	11000	None	Lognormal	76,645	43,959	64,600	101,940
Chromium	0.2U	1U	1U	1U	5U	5U	5U	5U	24	0	NA	NA	0.2 - 5	NA	NA	NA	NA	NA
Copper	2,340	2,570	3,240	2,360J	2,060	901	28	4,790	24	24	10300	11	None	Neither	2081.7	2406 1	925	10,300
Iron	190	130J	140J	150J	170	180	20U	150	24	20	940	110	20 - 100	Lognormal	271	201	185	439
Lead	27J	28	33	28J	30	17	1U	22	24	16	58	17	1 - 50	Lognormal	30.89	12.45	25	31.34
Magnesium	9,290	6,350	7,160	7,730J	7,530	8,280	9,850	6,650	24	24	14600	6.3	None	Neither	8563.2	2562.5	8355	14,600
Manganese	255	228	261	267J	274	293	372	314	24	24	695	228	None	Neither	339.25	92.21	325	695
Mercury	0.00069	▨	▨	▨	▨	0.00039J	▨	▨	5	4	0.00257	0.00038	0.1	Neither	0.011	0.022	0.00069	0.00257
Molybdenum	0.09	▨	▨	▨	▨	5U	5U	5U	20	6	0.6	0.05	0.4 - 20	NA	NA	NA	0.25	0.6
Nickel	5.0	5	5	5J	10U	10U	10U	10U	24	12	7.7	4	0.01 - 10	Lognormal	56.2	2.4	5	(961)
Potassium	1,750	2,640	2,590	3,420J	2,950	4,020	6,400	1,880	21	19	6400	1750	2000	Lognormal	3,689	1,783	3,160	4,752
Selenium	0.6	▨	▨	▨	▨	1U	▨	▨	4	2	1.1	0.6		Neither	0.68	0.29	0.55	1.1
Silver	0.16	0.2UJ	0.2	0.2U	4U	0.2U	0.2	0.2U	20	3	0.2	0.16	0.10 - 4	NA	NA	NA	0.2	0.2
Sodium *	3,830	5,380	5,390	7,470J	7,770	12,600	24,800	3,290	24	24	28000	2500	None	Neither	10,765	8,854	6,300	28,000
Thallium	0.16	▨	▨	▨	▨	1U	1U	▨	14	3	0.29	0.1	0.6 - 4	NA	NA	NA	0.16	0.29
Uranium	2.04	▨	▨	▨	▨	20U	20U	▨	14	10	3.95	2.04	20	Lognormal	4.8	3.4	2.8	7.2
Zinc	8,820	7,020	7,970	6,960J	6,820	5,330	2,980	12,700	24	24	27500	2200	None	Lognormal	7,263	5,273	6,100	9,256

Data Notes:
J - Estimated value.
U - Parameter was analyzed for, but not detected above the reporting limit shown.
UJ - Parameter was analyzed for, but not detected. Detection limit is an estimated value.
▨ Gray shading ▨ indicates that the data was not available for this parameter

Statistical Notes: (Statistical calculations were performed using Washington Department of Ecology's MTCAStat Excel V.5 Macro (Module 2.1), downloaded from their web site.)
Maximum and minimum concentrations are based on detected values only.
Range of reporting limits (RL) are based on results reported as not detected.
Distribution is determined based on the MTCA stat program by analyzing the data through the "W-Test" or "D'Agostino's test". Where data is not lognormally nor normally distributed, the distribution is noted as "Neither".
When approximate distribution is reported as "neither", the maximum concentration is reported as the 95% UCL and is presented in **BOLD** font.
If UCL is reported in brackets (*UCL value*), this indicates that the calculated result from MTCAStat was reported to be unusually high.
The mean is an arithmetic mean if data are normally distributed or if distribution is indicated as "Neither". The reported mean for lognormally distributed data is a lognormal mean
Statistical analysis was not performed on data sets where 50% or greater of the results were reported as not detected. Only maximum and minimum concentrations are reported, if applicable
For these data sets, a calculated median is based on detected values only.
* Values with 'greater than' sign were reported as shown in the applicable report(s) referenced. The actual value was used as an estimate of the lowest concentration in the sample.

TABLE 7.1-J
HISTORICAL AIR MONITORING DATA
HOLDEN MINE RI/FS
DAMES & MOORE JOB NO. 17693-005-019

Parameters	#1 Ballpark	#1 Ballpark	#2 Upstream Tailings	#2 Upstream Tailings	#3 Upstream Tailings	#3 Upstream Tailings	#4 Streamside	#4 Streamside	#5 Volleyball Court	#5 Volleyball Court	#6 Downstream Tailings	#6 Downstream Tailings	#9 Chalet Hill	#9 Chalet Hill
	9/23/94	9/29/94	9/23/94	9/29/94	9/23/94	9/29/94	9/23/94	9/29/94	9/23/94	9/29/94	9/23/94	9/29/94	9/23/94	9/29/94
Metals, (ug/m^3)														
Aluminum	0.067	0.137	0.280	0.197	0.313	0.374	0.117	0.184	0.464	1.564	0.023	0.451	0.483	1.037
Arsenic	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨
Barium	*0.001*	*0.001*	*0.004*	0.006	0.003	0.007	0.001	0.005	0.006	0.061	0.002	0.062	0.008	0.012
Beryllium	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨
Cadmium	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨
Calcium	0.122	0.280	0.070	0.233	0.090	0.406	0.080	NR	0.226	0.167	NR	NR	0.155	0.167
Chromium	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨
Copper	0.020	0.022	0.020	0.017	0.036	0.053	0.00144 U	0.030	0.031	0.060	0.012	0.043	0.039	0.051
Iron	0.052	0.105	0.458	0.540	0.411	0.814	0.136	0.661	0.538	4.443	0.160	4.000	0.886	1.603
Lead	0.001	0.001	0.003	0.003	0.003	0.004	0.001	0.005	0.005	0.021	0.004	0.021	0.005	0.018
Magnesium	0.007	0.051	0.064	0.030	0.072	0.119	0.031	NR	0.122	0.484	NR	0.110	0.144	0.276
Manganese	0.002	0.003	0.005	0.004	0.005	0.007	0.002	0.004	0.008	0.028	0.002	0.010	0.014	0.028
Mercury	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨
Molybdenum	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨
Nickel	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨
Potassium	NR	NR	0.140	NR	NR	0.325	0.148	NR	NR	0.292	NR	0.139	0.138	NR
Selenium	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨
Silver	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨
Sodium	0.058	NR	NR	NR	NR	1.248	NR	NR	NR	NR	NR	NR	NR	NR
Thallium	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨
Uranium	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨
Zinc	0.004	0.002	0.011	0.011	0.012	0.017	0.006	0.021	0.023	0.073	0.023	0.067	0.021	0.495

Data Notes:

NR - Not Reported

U - Parameter was analyzed for but not detected for, but not detected above the reporting limit shown.

▨ Grey shading ▨ indicates the concentration of analyte was not established, therefore not reported nor analyzed.

Data Source:

Air Resource Specialist, Inc. (Data collected in 1994 and prepared for the U.S. Forest Service-Region 6-Wenatchee National Forest)

TABLE 7.1-K
MEAN METAL CONCENTRATIONS IN FISH MUSCLE TISSUE (mg/kg wet weight)
HOLDEN MINE RI/FS
DAMES & MOORE JOB NO. 17693-005-019

	Copper	Zinc	Iron	Mercury	Selenium
Pacific Northwest Laboratories - 1989-1991					
Upstream	0.98	8.65	8.83	na	0.85
Site (TP-3	0.87	8.85	6.63	na	0.74
Lucerne	0.98	10.83	6.09	na	0.54
25-Mile Creek	0.78	7.30	4.91	na	0.65
WADOE 1992					
Upstream	0.58	9.74	8.83	0.038	na
Site (TP-3)	4.44	6.65	6.06	0.018	na
Lucerne	0.5	10.24	7.1	0.016	na
25-Mile Creek	0.6	7.46	6.95	0.015	na

Note: only those constituents detected above detection limits are shown
Units converted from dry weight for PNL samples

TABLE 7.1-1
AREA AND NATURAL BACKGROUND SOIL AND SURFACE WATER TOTAL METALS CONCENTRATIONS
HOLDEN MINE
BASELINE RISK ASSESSMENT

	Soil			Surface Water
Parameter	Area Background for Site (90th %)	MTCA Natural Background (Yakima Basin)	Range for Washington State (Dragun)	Area Background for Site (90th%)
Total Metals mg/kg				
Aluminum	20,870	33400		144
Arsenic	12	5		1.44
Barium	310		300 - 1000	6.24
Beryllium	0.2	2		
Cadmium	5	1		0.1
Calcium	12,140			6814
Chromium	37	38		0.46
Copper	57	27		1.83
Iron	24,098	51500		177
Lead	21	11		0.3
Magnesium	9,199			647
Manganese	1,425	1100		5.06
Mercury		0.05		0.00066
Molybdenum	1.2		n.d. - 5.0	0.79
Nickel	23	46		0.4
Potassium	1,263			672
Selenium			0.1 - 1.5	
Silver	0.5		<0.5 - 5.0 (Western U.S.)	0.1
Sodium	827.0			1034
Thallium	0.4			
Uranium	1.0		0.96 - 2.66	
Zinc	253	79		5

TABLE 7.1-2
METHOD A LEVELS USED IN SCREENING LEVEL HUMAN HEALTH ASSESSMENT
HOLDEN MINE
BASELINE RISK ASSESSMENT

Parameter	Soil Method A Cleanup Levels (mg/kg)[a]	Surface Water Method A Cleanup Levels (ug/l)[b]	Groundwater Method A Cleanup Levels (ug/l)[a]	Maximum Contaminant Level for Drinking Water (ug/l)[c]
Total Metals				
Aluminum				
Arsenic	20		5	50
Barium		1000		2000
Beryllium		0.0037		4
Cadmium	2	10	5	5
Calcium				
Chromium III		170000		
Chromium VI		50		
Chromium, total	100		50	100
Copper		1300		1300
Iron		300		
Lead	250	50	5	
Magnesium				
Manganese		50		
Mercury	1	0.14	2	2
Molybdenum				
Nickel		610		100
Potassium				
Selenium		10		50
Silver				
Sodium				
Thallium		1.7		2
Uranium				
Zinc				
Conventional Analyses				
Cyanide, Total		700		200
Polychlorinated Biphenyls				
Aroclor 1016		0.000044		
Aroclor 1221		0.000044		
Aroclor 1232		0.000044		
Aroclor 1242		0.000044		
Aroclor 1248		0.000044		
Aroclor 1254		0.000044		
Aroclor 1260		0.000044		
PCBs, total	1	0.000079	0.1	0.5
Total Petroleum Hydrocarbons				
Gasoline Range Hydrocarbons	100		1000	
Diesel Range Hydrocarbons	200		1000	
Motor Oil	200		1000	

Notes:

[a]Model Toxics Control Act (MTCA)

[b]Ambient Water Quality Criteria for Human Health based on ingestion of water and fish

[c]Safe Drinking Water Act MCLs or Proposed MCLs

TABLE 7.1-3
METHOD B LEVELS USED IN SCREENING LEVEL HUMAN HEALTH ASSESSMENT
HOLDEN MINE
BASELINE RISK ASSESSMENT

Parameter	Adjustment Factor for Aggregate Risk	Soil		Surface Water		Groundwater		Air		Soil (Protection of Air)	
		Method B Cleanup Level (mg/kg)	Basis	Cleanup Level (ug/l)	Basis	Cleanup Level (ug/l)	Basis	Cleanup Level (mg/m3)	Basis	Cleanup Level (mg/kg)	Basis
Total Metals											
Aluminum		8.00E+04	Calculated	1.12E+04	Calculated	1.60E+04	Calculated		NA (No tox values)		NA (No tox values)
Arsenic	7 (carcinogenic effects)	1.67E+00	CLARC II (1996)	9.82E-02	CLARC II (1996)	5.83E-02	CLARC II (1996)	1.75E-07	Calculated	1.09E+02	Calculated
Barium		5.60E+03	CLARC II (1996)	1.81E+03	Calculated (Assumed BCF=100)	1.12E+03	CLARC II (1996)	1.60E-04	Calculated	9.94E+04	Calculated
Beryllium	7	2.33E-01	CLARC II (1996)	7.93E-02	CLARC II (1996)	2.03E-02	CLARC II (1996)	1.04E-06	Calculated	6.47E+02	Calculated
Cadmium	7 (carcinogenic effects) 4 (noncarc. effects)	8.00E+01	CLARC II (1996)	2.03E+01	CLARC II (1996)	8.00E+00	CLARC II (1996)	1.43E-06	Calculated	8.91E+02	Calculated
Calcium			NA (No tox values)		NA (No tox values)		NA (No tox values)		NA (No tox values)		NA (No tox values)
Chromium III		8.00E+04	CLARC II (1996)	1.62E+05	CLARC II (1996)	1.60E+04	CLARC II (1996)		NA (No tox values)		NA (No tox values)
Chromium VI	7	4.00E+02	CLARC II (1996)	8.10E+02	CLARC II (1996)	8.00E+01	CLARC II (1996)	2.13E-07	Calculated	1.33E+02	Calculated
Copper		2.96E+03	CLARC II (1996)	2.66E+03	CLARC II (1996)	5.92E+02	CLARC II (1996)		NA (No tox values)		NA (No tox values)
Iron			NA (No tox values)		NA (No tox values)		NA (No tox values)		NA (No tox values)		NA (No tox values)
Lead	7 (carcinogenic effects)		NA (No tox values)		NA (No tox values)		NA (No tox values)		NA (No tox values)		NA (No tox values)
Magnesium			NA (No tox values)		NA (No tox values)		NA (No tox values)		NA (No tox values)		NA (No tox values)
Manganese*	4	3.73E+03	CLARC II (1996)	1.22E+03	Calculated (Assumed BCF=100)	7.47E+02	CLARC II (1996)	2.29E-05	Calculated	1.42E+04	Calculated
Mercury, inorganic	4	2.40E+01	CLARC II (1996)	1.41E-01	Calculated	4.80E+00	CLARC II (1996)	1.37E-04	Calculated	8.52E+04	Calculated
Molybdenum	4	4.00E+02	CLARC II (1996)	1.30E+02	Calculated (Assumed BCF=100)	8.00E+01	CLARC II (1996)		NA (No tox values)		NA (No tox values)
Nickel	7 (carcinogenic effects) 2 (noncarc effects)	1.60E+03	CLARC II (1996)	1.10E+03	CLARC II (1996)	3.20E+02	CLARC II (1996)	1.04E-05	Calculated (nickel refinery dust)	6.47E+03	Calculated (nickel refinery dust)
Potassium			NA (No tox values)		NA (No tox values)		NA (No tox values)		NA (No tox values)		NA (No tox values)
Selenium		4.00E+02	CLARC II (1996)	8.10E+02	Calculated	8.00E+01	CLARC II (1996)		NA (No tox values)		NA (No tox values)
Silver	2	4.00E+02	CLARC II (1996)	2.59E+04	CLARC II (1996)	8.00E+01	CLARC II (1996)		NA (No tox values)		NA (No tox values)
Sodium			NA (No tox values)		NA (No tox values)		NA (No tox values)		NA (No tox values)		NA (No tox values)
Thallium, soluble salts		5.60E+00	CLARC II (1996)	1.56E+00	CLARC II (1996)	1.12E+00	CLARC II (1996)		NA (No tox values)		NA (No tox values)
Uranium, soluble salts	4	2.40E+02	CLARC II (1996)	7.78E+01	Calculated (Assumed BCF=100)	4.80E+01	CLARC II (1996)		NA (No tox values)		NA (No tox values)
Zinc	2	2.40E+04	CLARC II (1996)	1.65E+04	CLARC II (1996)	4.80E+03	CLARC II (1996)		NA (No tox values)		NA (No tox values)
Conventional Analyses											
Cyanide, Total	4	1.60E+03	CLARC II (1996)	5.19E+04	CLARC II (1996)	3.20E+02	CLARC II (1996)		NA (No tox values)		NA (No tox values)
Polychlorinated Biphenyls											
Aroclor 1016	4	5.60E+00	CLARC II (1996)	2.44E-02	Calculated	1.12E+00	CLARC II (1996)		NA (No tox values)		NA (No tox values)
Aroclor 1221			NA (No tox values)		NA (No tox values)		NA (No tox values)		NA (No tox values)		NA (No tox values)
Aroclor 1232			NA (No tox values)		NA (No tox values)		NA (No tox values)		NA (No tox values)		NA (No tox values)
Aroclor 1242			NA (No tox values)		NA (No tox values)		NA (No tox values)		NA (No tox values)		NA (No tox values)
Aroclor 1248			NA (No tox values)		NA (No tox values)		NA (No tox values)		NA (No tox values)		NA (No tox values)
Aroclor 1254		1.60E+00	Calculated	1.01E-03	Calculated	3.20E-01	Calculated		NA (No tox values)		NA (No tox values)
Aroclor 1260			NA (No tox values)		NA (No tox values)		NA (No tox values)		NA (No tox values)		NA (No tox values)
PCBs, total	7	1.30E-01	CLARC II (1996)	2.70E-05	CLARC II (1996)	1.14E-02	CLARC II (1996)		NA (No tox values)		NA (No tox values)
Total Petroleum Hydrocarbons											
Gasoline Range Hydrocarbons			NA (No tox values)		NA (No tox values)		NA (No tox values)		NA (No tox values)		NA (No tox values)
Diesel Range Hydrocarbons			NA (No tox values)		NA (No tox values)		NA (No tox values)	2.29E-03	Calculated	1.42E+06	Calculated
Motor Oil			NA (No tox values)		NA (No tox values)		NA (No tox values)		NA (No tox values)		NA (No tox values)

Notes:
NA = Not available
*Manganese criteria adjusted downwards by a factor of 3 to account for nondietary exposure

TABLE 7.1-4
TOXICITY CRITERIA AND BIOCONCENTRATION FACTORS USED FOR CALCULATION OF METHOD B LEVELS
HOLDEN MINE
BASELINE RISK ASSESSMENT

Parameter	Bioconcentration Factor (unitless)	Source	Oral Reference Dose (mg/kg-day)	Source	Inhalation Reference Dose (mg/kg-day)	Source	Inhalation Cancer Potency Factor (per mg/kg-day)	Source
Total Metals								
Aluminum	231	ORNL	1	NCEA Support Value				
Arsenic							50	CLARC II (1996)
Barium	100[a]	Conservative estimate	0.07	CLARC II (1996)	0.0001	CLARC II (1996)		
Beryllium							8.40	CLARC II (1996)
Cadmium							6.1	CLARC II (1996)
Chromium VI							41.00	CLARC II (1996)
Manganese	100[a]	Conservative estimate	0.047[b]	CLARC II (1996)	0.0000143	CLARC II (1996)		
Mercury, inorganic	5500	SPHEM			0.0000857	CLARC II (1996)		
Molybdenum	100[a]	Conservative estimate	0.005	CLARC II (1996)				
Nickel							0.84	CLARC II (1996) - Nickel Refinery Dust
Selenium	16	SPHEM	0.005	CLARC II (1996)				
Uranium	100[a]	Conservative estimate	0.003	CLARC II (1996)				
Polychlorinated Biphenyls								
Aroclor 1016	10617	ORNL	0.0001	CLARC II (1996)				
Aroclor 1254	51286	ORNL	0.00002	IRIS				
Total Petroleum Hydrocarbons								
Diesel Range Hydrocarbons					0.001429	CLARC II (1996)		

Notes:
ORNL = Oak Ridge National Laboratory, ES/ER/TM-86/R, 1996..
SPHEM = Superfund Public Health Evaluation Manual. EPA 540/1-86/060. 1986
NCEA = USEPA NCEA support value.
IRIS = Integrated Risk Information System

[a] A very conservative default BCF of 100 was assumed

[b] RfD adjusted downward by a factor of 3 to account for nondietary exposure as discussed in CLARCII

TABLE 7.1-5
CARCINOGEN CLASSIFICATIONS AND TOXIC EFFECTS ENDPOINTS
HOLDEN MINE
BASELINE RISK ASSESSMENT

Parameter	Carcinogen Classification	Toxic Effects Endpoint
Total Metals		
Aluminum		
Arsenic	A	Skin lesions
Barium		Cardiovascular toxicity
Beryllium	B2	
Cadmium	B1	Nephrotoxicity
Calcium		
Chromium III		
Chromium VI	A	
Copper	D	Gastrointestinal toxicity
Iron		
Lead	B2	Neurotoxicity
Magnesium		
Manganese	D	Neurotoxicity
Mercury, inorganic	D	Neurotoxicity, nephrotoxicity
Molybdenum		Nephrotoxicity
Nickel, refinery dust	A	
Nickel, soluble salts		Weight
Potassium		
Selenium	D	Clinical selenosis
Silver	D	Skin lesions
Sodium		
Thallium, soluble salts		
Uranium, soluble salts		Weight, nephrotoxicity
Zinc	D	Hemotoxicity
Conventional Analyses		
Cyanide, Total	D	Weight, thyroid, neurotoxicity
Polychlorinated Biphenyls		
Aroclor 1016		Weight
Aroclor 1221		
Aroclor 1232		
Aroclor 1242		
Aroclor 1248		
Aroclor 1254		Oculartoxicity, immunotoxicity
Aroclor 1260		
PCBs, total	B2	
Total Petroleum Hydrocarbons		
Gasoline Range Hydrocarbons		
Diesel Range Hydrocarbons		
Motor Oil		

TABLE 7.1-6
HUMAN HEALTH SCREENING OF SURFACE SOIL SAMPLE RESULTS - HOLDEN VILLAGE (INGESTION)
HOLDEN MINE
BASELINE RISK ASSESSMENT

		STEP 1		STEP 2			STEP 3			STEP 4			STEP 5					STEP 6
Parameter	Maximum Detected Concentration	Essential Nutrient?	Constituent Eliminated as an IHS?	Frequency of Detection	Does Frequency of Detection Exceed 5%?	Constituent Eliminated as an IHS?	Background Level[b]	Does Maximum Exceed Background?	Constituent Eliminated as an IHS?	Method A Cleanup Level	Does Maximum Exceed Method A?	Constituent Eliminated as an IHS?	Method B Cleanup Level[d]	Adjustment Factor for Aggregate Risk	Site-Specific Method B Cleanup Level	Does Maximum Exceed Method B?	Constituent Eliminated as an IHS?	IHSs for Soil (Holden Village)
Total Metals (mg/kg)																		
Aluminum	26300	No		100%	Yes		20,870	Yes					8.00E+04		8.00E+04	No	ELIMINATED	
Arsenic	5.1	No		100%	Yes		12	No	ELIMINATED									
Barium	380	No		100%	Yes		310	Yes					5.60E+03		5.60E+03	No	ELIMINATED	
Beryllium	0.32	No		100%	Yes		0.2	Yes					2.33E-01	7	3.33E-02	Yes		IHS
Cadmium	2.1	No		100%	Yes		5	No	ELIMINATED									
Calcium	12400	Yes	ELIMINATED															
Chromium[a]	57.7	No		100%	Yes		37	Yes		100	No	ELIMINATED						
Copper	523	No		100%			57	Yes					2.96E+03		2.96E+03	No	ELIMINATED	
Iron	29600	Yes	ELIMINATED															
Lead	103	No		100%	Yes		21	Yes		250	No	ELIMINATED						
Magnesium	10800	Yes	ELIMINATED															
Manganese	1270	No		100%	Yes		1,425	No	ELIMINATED									
Mercury	0.08	No		100%	Yes		0.05[c]	Yes		1	No	ELIMINATED						
Molybdenum	5	No		75%	Yes		1.2	Yes					4.00E+02	4	1.00E+02	No	ELIMINATED	
Nickel	27.1	No		100%	Yes		23	Yes					1.60E+03	7	2.29E+02	No	ELIMINATED	
Potassium	2110	Yes	ELIMINATED															
Selenium	nd																	
Silver	2	No		33%	Yes		0.5	Yes					4.00E+02	2	2.00E+02	No	ELIMINATED	
Sodium	1090	Yes	ELIMINATED															
Thallium	0.35	No		33%	Yes		0.4	No	ELIMINATED									
Uranium	nd																	
Zinc	456	No		100%	Yes		253	Yes					2.40E+04	2	1.20E+04	No	ELIMINATED	
Conventional Analyses (mg/kg)																		
Cyanide, Total	0.07	No		29%	Yes								1.60E+03	4	4.00E+02	No	ELIMINATED	
Polychlorinated Biphenyls (ug/kg)																		
Aroclor 1016																		
Aroclor 1221																		
Aroclor 1232																		
Aroclor 1242																		
Aroclor 1248																		
Aroclor 1254																		
Aroclor 1260																		
PCBs, total																		
Total Petroleum Hydrocarbons (mg/kg)																		
Gasoline Range Hydrocarbons																		
Diesel Range Hydrocarbons																		
Motor Oil																		

Notes:

[a] Screening Criteria for chromium are for total chromium or chromium VI

[b] Area background levels for site unless otherwise noted.

[c] MTCA Natural Background levels for Yakima Basin

[d] Washington State ranges (Dragun, 1991) are shown for comparison purposes only. No constituents are eliminated based on these ranges

nd = not detected

IHS = Indicator Hazardous Substance

"--" = No cleanup levels or toxicity criteria available for risk evaluation. Constituent was not selected as an IHS.

1995 and 1997 Data

TABLE 7.1-7
HUMAN HEALTH SCREENING OF SURFACE SOIL SAMPLE RESULTS - VEGETABLE GARDEN (INGESTION)
HOLDEN MINE
BASELINE RISK ASSESSMENT

		STEP 1		STEP 2			STEP 3			STEP 4			STEP 5					STEP 6
Parameter	Maximum Detected Concentration	Essential Nutrient?	Constituent Eliminated as an IHS?	Frequency of Detection	Does Frequency of Detection Exceed 5%?	Constituent Eliminated as an IHS?	Background Level[b]	Does Maximum Exceed Background?	Constituent Eliminated as an IHS?	Method A Cleanup Level	Does Maximum Exceed Method A?	Constituent Eliminated as an IHS?	Method B Cleanup Level	Adjustment Factor for Aggregate Risk	Site-Specific Method B Cleanup Level	Does Maximum Exceed Method B?	Constituent Eliminated as an IHS?	IHSs for Soil (Vegetable Garden)
Total Metals (mg/kg)																		
Aluminum	16200	No		100%	Yes		20,870	No	ELIMINATED				8.00E+04		8.00E+04	No	ELIMINATED	
Arsenic	5.1	No		100%	Yes		12	No	ELIMINATED									
Barium	333	No		100%	Yes		310	Yes					5.60E+03		5.60E+03	No	ELIMINATED	
Beryllium	0.2	No		100%	Yes		0.2	No	ELIMINATED									
Cadmium	2.1	No		100%	Yes		5	No	ELIMINATED									
Calcium	12400	Yes	ELIMINATED															
Chromium[a]	28.7	No		100%	Yes		37	No	ELIMINATED									
Copper	155	No		100%	Yes		57	Yes					2.96E+03		2.96E+03	No	ELIMINATED	
Iron	26300	Yes	ELIMINATED															
Lead	61	No		100%	Yes		21	Yes		250	No	ELIMINATED						
Magnesium	5860	Yes	ELIMINATED															
Manganese	613	No		100%	Yes		1,425	No	ELIMINATED									
Mercury																		
Molybdenum	5	No		100%	Yes		1.2	Yes					4.00E+02	4	1.00E+02	No	ELIMINATED	
Nickel	16	No		100%	Yes		23	No	ELIMINATED									
Potassium	2110	Yes	ELIMINATED															
Selenium																		
Silver	2	No		100%	Yes		0.5	Yes					4.00E+02	2	2.00E+02	No	ELIMINATED	
Sodium	777	Yes	ELIMINATED															
Thallium	nd																	
Uranium	nd																	
Zinc	356	No		100%	Yes		253	Yes					2.40E+04	2	1.20E+04	No	ELIMINATED	
Conventional Analyses (mg/kg)																		
Cyanide, Total																		
Polychlorinated Biphenyls (ug/kg)																		
Aroclor 1016																		
Aroclor 1221																		
Aroclor 1232																		
Aroclor 1242																		
Aroclor 1248																		
Aroclor 1254																		
Aroclor 1260																		
PCBs, total																		
Total Petroleum Hydrocarbons (mg/kg)																		
Gasoline Range Hydrocarbons																		
Diesel Range Hydrocarbons																		
Motor Oil																		

Notes:

[a] Screening Criteria for chromium are for total chromium or chromium VI

[b] Area background levels for site unless otherwise noted.

[c] MTCA Natural Background levels for Yakima Basin

[d] Washington State ranges (Dragun, 1991) are shown for comparison purposes only. No constituents are eliminated based on these ranges

nd = not detected

IHS = Indicator Hazardous Substance

*** = No cleanup levels or toxicity criteria available for risk evaluation. Constituent was not selected as an IHS.

1997 Data

TABLE 7.1-8
HUMAN HEALTH SCREENING OF SURFACE SOIL SAMPLE RESULTS - BASEBALL FIELD (INGESTION)
HOLDEN MINE
BASELINE RISK ASSESSMENT

		STEP 1		STEP 2			STEP 3			STEP 4			STEP 5					STEP 6
Parameter	Maximum Detected Concentration	Essential Nutrient?	Constituent Eliminated as an IHS?	Frequency of Detection	Does Frequency of Detection Exceed 5%?	Constituent Eliminated as an IHS?	Background Level[b]	Does Maximum Exceed Background?	Constituent Eliminated as an IHS?	Method A Cleanup Level	Does Maximum Exceed Method A?	Constituent Eliminated as an IHS?	Method B Cleanup Level	Adjustment Factor for Aggregate Risk	Site-Specific Method B Cleanup Level	Does Maximum Exceed Method B?	Constituent Eliminated as an IHS?	IHSs for Soil (Baseball Field)
Total Metals (mg/kg)																		
Aluminum	20300	No		100%	Yes		20,870	No	ELIMINATED									
Arsenic	10.8	No		100%	Yes		12	No	ELIMINATED									
Barium	101	No		100%	Yes		310	No	ELIMINATED									
Beryllium	0.2	No		100%	Yes		0.2	No	ELIMINATED									
Cadmium	1.3	No		100%	Yes		5	No	ELIMINATED									
Calcium	5770	Yes	ELIMINATED															
Chromium[a]	29.4	No		100%	Yes		37	No	ELIMINATED									
Copper	63	No		100%	Yes		57	Yes					2.96E+03		2.96E+03	No	ELIMINATED	
Iron	22600	Yes	ELIMINATED															
Lead	15	No		100%	Yes		21	No	ELIMINATED									
Magnesium	7640	Yes	ELIMINATED															
Manganese	537	No		100%	Yes		1,425	No	ELIMINATED									
Mercury																		
Molybdenum	1	No		100%	Yes		1.2	No	ELIMINATED									
Nickel	18	No		100%	Yes		23	No	ELIMINATED									
Potassium	1270	Yes	ELIMINATED															
Selenium																		
Silver	0.5	No		100%	Yes		0.5	No	ELIMINATED									
Sodium	605	Yes	ELIMINATED															
Thallium	nd																	
Uranium	nd																	
Zinc	129	No		100%	Yes		253	No	ELIMINATED									
Conventional Analyses (mg/kg)																		
Cyanide, Total																		
Polychlorinated Biphenyls (ug/kg)																		
Aroclor 1016																		
Aroclor 1221																		
Aroclor 1232																		
Aroclor 1242																		
Aroclor 1248																		
Aroclor 1254																		
Aroclor 1260																		
PCBs, total																		
Total Petroleum Hydrocarbons (mg/kg)																		
Gasoline Range Hydrocarbons																		
Diesel Range Hydrocarbons																		
Motor Oil																		

Notes:

[a] Screening Criteria for chromium are for total chromium or chromium VI

[b] Area background levels for site unless otherwise noted.

[c] MTCA Natural Background levels for Yakima Basin

[d] Washington State ranges (Dragun, 1991) are shown for comparison purposes only. No constituents are eliminated based on these ranges

nd = not detected

IHS = Indicator Hazardous Substance

*** = No cleanup levels or toxicity criteria available for risk evaluation Constituent was not selected as an IHS

1997 Data

TABLE 7.1-9
HUMAN HEALTH SCREENING OF SURFACE SOIL SAMPLE RESULTS - WILDERNESS BOUNDARY (INGESTION)
HOLDEN MINE
BASELINE RISK ASSESSMENT

		STEP 1		STEP 2			STEP 3			STEP 4			STEP 5					STEP 6
Parameter	Maximum Detected Concentration	Essential Nutrient?	Constituent Eliminated as an IHS?	Frequency of Detection	Does Frequency of Detection Exceed 5%?	Constituent Eliminated as an IHS?	Background Level[b]	Does Maximum Exceed Background?	Constituent Eliminated as an IHS?	Method A Cleanup Level	Does Maximum Exceed Method A?	Constituent Eliminated as an IHS?	Method B Cleanup Level	Adjustment Factor for Aggregate Risk	Site-Specific Method B Cleanup Level	Does Maximum Exceed Method B?	Constituent Eliminated as an IHS?	IHSs for Soil (Wilderness Boundary)
Total Metals (mg/kg)																		
Aluminum	17500	No		100%	Yes		20,870	No	ELIMINATED									
Arsenic	11.4	No		100%	Yes		12	No	ELIMINATED									
Barium	93.1	No		100%	Yes		310	No	ELIMINATED									
Beryllium	0.2	No		100%	Yes		0.2	No	ELIMINATED									
Cadmium	3.1	No		100%	Yes		5	No	ELIMINATED									
Calcium	6440	Yes	ELIMINATED															
Chromium[a]	27.8	No		100%	Yes		37	No	ELIMINATED									
Copper	147	No		100%	Yes		57	Yes					2.96E+03		2.96E+03	No	ELIMINATED	
Iron	26500	Yes	ELIMINATED															
Lead	37	No		100%	Yes		21	Yes		250	No	ELIMINATED						
Magnesium	8980	Yes	ELIMINATED															
Manganese	455	No		100%	Yes		1,425	No	ELIMINATED									
Mercury																		
Molybdenum	2.4	No		100%	Yes		1.2	Yes					4.00E+02	4	1.00E+02	No	ELIMINATED	
Nickel	17	No		100%	Yes		23	No	ELIMINATED									
Potassium	1290	Yes	ELIMINATED															
Selenium																		
Silver	0.6	No		100%	Yes		0.5	Yes					4.00E+02	2	2.00E+02	No	ELIMINATED	
Sodium	647	Yes	ELIMINATED															
Thallium	nd																	
Uranium	4	No		50%	Yes		1.0	Yes					2.40E+02	4	6.00E+01	No	ELIMINATED	
Zinc	303	No		100%	Yes		253	Yes					2.40E+04	2	1.20E+04	No	ELIMINATED	
Conventional Analyses (mg/kg)																		
Cyanide, Total																		
Polychlorinated Biphenyls (ug/kg)																		
Aroclor 1016																		
Aroclor 1221																		
Aroclor 1232																		
Aroclor 1242																		
Aroclor 1248																		
Aroclor 1254																		
Aroclor 1260																		
PCBs, total																		
Total Petroleum Hydrocarbons (mg/kg)																		
Gasoline Range Hydrocarbons																		
Diesel Range Hydrocarbons																		
Motor Oil																		

Notes:
[a] Screening Criteria for chromium are for total chromium or chromium VI
[b] Area background levels for site unless otherwise noted.
[c] MTCA Natural Background levels for Yakima Basin
[d] Washington State ranges (Dragun, 1991) are shown for comparison purposes only. No constituents are eliminated based on these ranges
nd = not detected
IHS = Indicator Hazardous Substance
"" = No cleanup levels or toxicity criteria available for risk evaluation. Constituent was not selected as an IHS
1997 Data

TABLE 7.1-10
HUMAN HEALTH SCREENING OF SURFACE SOIL SAMPLE RESULTS - MAINTENANCE YARD (INGESTION)
HOLDEN MINE
BASELINE RISK ASSESSMENT

		STEP 1		STEP 2			STEP 3			STEP 4			STEP 5					STEP 6
Parameter	Maximum Detected Concentration	Essential Nutrient?	Constituent Eliminated as an IHS?	Frequency of Detection	Does Frequency of Detection Exceed 5%?	Constituent Eliminated as an IHS?	Background Level[b]	Does Maximum Exceed Background?	Constituent Eliminated as an IHS?	Method A Cleanup Level	Does Maximum Exceed Method A?	Constituent Eliminated as an IHS?	Method B Cleanup Level	Adjustment Factor for Aggregate Risk	Site-Specific Method B Cleanup Level	Does Maximum Exceed Method B?	Constituent Eliminated as an IHS?	IHSs for Soil (Maintenance Yard)
Total Metals (mg/kg)																		
Aluminum	23900	No		100%	Yes		20,870	Yes					8.00E+04		8.00E+04	No	ELIMINATED	
Arsenic	60	No		100%	Yes		12	Yes		20	Yes		1.67E+00	7	2.39E-01	Yes		IHS
Barium	717	No		100%	Yes		310	Yes					5.60E+03		5.60E+03	No	ELIMINATED	
Beryllium	0.2	No		88%	Yes		0.2	No	ELIMINATED									
Cadmium	21.6	No		100%	Yes		5	Yes		2	Yes		8.00E+01	4	2.00E+01	Yes		IHS
Calcium	6830	Yes	ELIMINATED															
Chromium[a]	33	No		100%	Yes		37	No	ELIMINATED									
Copper	3160	No		100%	Yes		57	Yes					2.96E+03		2.96E+03	Yes		IHS
Iron	60300	Yes	ELIMINATED															
Lead	1070	No		100%	Yes		21	Yes		250	Yes			7				IHS
Magnesium	11400	Yes	ELIMINATED															
Manganese	426	No		100%	Yes		1,425	No	ELIMINATED									
Mercury																		
Molybdenum	16	No		63%	Yes		1.2	Yes					4.00E+02	4	1.00E+02	No	ELIMINATED	
Nickel	23	No		100%	Yes		23	No	ELIMINATED									
Potassium	4600	Yes	ELIMINATED	100%	Yes													
Selenium																		
Silver	5	No		75%	Yes		0.5	Yes					4.00E+02	2	2.00E+02	No	ELIMINATED	
Sodium	872	Yes	ELIMINATED	100%	Yes													
Thallium	nd																	
Uranium	nd																	
Zinc	3240	No		100%	Yes		253	Yes					2.40E+04	2	1.20E+04	No	ELIMINATED	
Conventional Analyses (mg/kg)																		
Cyanide, Total																		
Polychlorinated Biphenyls (ug/kg)																		
Aroclor 1016	nd																	
Aroclor 1221	nd																	
Aroclor 1232	nd																	
Aroclor 1242	nd																	
Aroclor 1248	nd																	
Aroclor 1254	nd																	
Aroclor 1260	46	No		50%	Yes					1000	No	ELIMINATED						***
PCBs, total	46	No		100%	Yes					1000	No	ELIMINATED						
Total Petroleum Hydrocarbons (mg/kg)																		
Gasoline Range Hydrocarbons	1700	No		71%	Yes					100	Yes							IHS
Diesel Range Hydrocarbons	12000	No		88%	Yes					200	Yes							IHS
Motor Oil	9800	No		75%	Yes					200	Yes							IHS

Notes:

[a] Screening Criteria for chromium are for total chromium or chromium VI

[b] Area background levels for site unless otherwise noted.

[c] MTCA Natural Background levels for Yakima Basin

[d] Washington State ranges (Dragun, 1991) are shown for comparison purposes only. No constituents are eliminated based on these ranges

nd = not detected

IHS = Indicator Hazardous Substance

*** = No cleanup levels or toxicity criteria available for risk evaluation. Constituent was not selected as an IHS.

1997 Data. Surface soil samples only.

TABLE 7.1-11
HUMAN HEALTH SCREENING OF SURFACE SOIL SAMPLE RESULTS - LAGOON AREA (INGESTION)
HOLDEN MINE
BASELINE RISK ASSESSMENT

		STEP 1		STEP 2			STEP 3			STEP 4			STEP 5					STEP 6
Parameter	Maximum Detected Concentration	Essential Nutrient?	Constituent Eliminated as an IHS?	Frequency of Detection	Does Frequency of Detection Exceed 5%?	Constituent Eliminated as an IHS?	Background Level[b]	Does Maximum Exceed Background?	Constituent Eliminated as an IHS?	Method A Cleanup Level	Does Maximum Exceed Method A?	Constituent Eliminated as an IHS?	Method B Cleanup Level[c]	Adjustment Factor for Aggregate Risk	Site-Specific Method B Cleanup Level	Does Maximum Exceed Method B?	Constituent Eliminated as an IHS?	IHSs for Soil (Lagoon Area)
Total Metals (mg/kg)																		
Aluminum	33500	No		100%	Yes		20,870	Yes					8.00E+04		8.00E+04	No	ELIMINATED	
Arsenic	5	No		100%	Yes		12	No	ELIMINATED									
Barium	343	No		100%	Yes		310	Yes					5.60E+03		5.60E+03	No	ELIMINATED	
Beryllium	0.3	No		50%	Yes		0.2	Yes					2.33E-01	7	3.33E-02	Yes		IHS
Cadmium	184	No		100%	Yes		5	Yes		2	Yes		8.00E+01	4	2.00E+01	Yes		IHS
Calcium	6120	Yes	ELIMINATED															
Chromium[a]	21	No		100%	Yes		37	No	ELIMINATED									
Copper	24100	No		100%	Yes		57	Yes					2.96E+03		2.96E+03	Yes		IHS
Iron	101000	Yes	ELIMINATED															
Lead	620	No		100%	Yes		21	Yes		250	Yes			7				IHS
Magnesium	18100	Yes	ELIMINATED															
Manganese	625	No		100%	Yes		1,425	No	ELIMINATED									
Mercury																		
Molybdenum	74	No		100%	Yes		1.2	Yes					4.00E+02	4	1.00E+02	No	ELIMINATED	
Nickel	13	No		50%	Yes		23	No	ELIMINATED									
Potassium	4370	Yes	ELIMINATED															
Selenium																		
Silver	27	No		100%	Yes		0.5	Yes					4.00E+02	2	2.00E+02	No	ELIMINATED	
Sodium	931	Yes	ELIMINATED															
Thallium	3	No		50%	Yes		0.4	Yes					5.60E+00		5.60E+00	No	ELIMINATED	
Uranium	7	No		100%	Yes		1.0	Yes					2.40E+02	4	6.00E+01	No	ELIMINATED	
Zinc	23700	No		100%	Yes		253	Yes					2.40E+04	2	1.20E+04	Yes		IHS
Conventional Analyses (mg/kg)																		
Cyanide, Total																		
Polychlorinated Biphenyls (ug/kg)																		
Aroclor 1016	nd																	
Aroclor 1221	nd																	
Aroclor 1232	nd																	
Aroclor 1242	nd																	
Aroclor 1248	nd																	
Aroclor 1254	nd																	
Aroclor 1260	nd																	
PCBs, total	nd																	
Total Petroleum Hydrocarbons (mg/kg)																		
Gasoline Range Hydrocarbons	nd																	
Diesel Range Hydrocarbons	230	No		100%	Yes					200	Yes							IHS
Motor Oil	440	No		100%	Yes					200	Yes							IHS

Notes:

[a] Screening Criteria for chromium are for total chromium or chromium VI

[b] Area background levels for site unless otherwise noted.

[c] MTCA Natural Background levels for Yakima Basin

[d] Washington State ranges (Dragun, 1991) are shown for comparison purposes only. No constituents are eliminated based on these ranges

nd = not detected

IHS = Indicator Hazardous Substance

*** = No cleanup levels or toxicity criteria available for risk evaluation. Constituent was not selected as an IHS.

1997 Data

TABLE 7.1-12
HUMAN HEALTH SCREENING OF SURFACE SOIL SAMPLE RESULTS - FOREST SERVICE GUARD STATION (INGESTION)
HOLDEN MINE
BASELINE RISK ASSESSMENT

		STEP 1		STEP 2			STEP 3			STEP 4			STEP 5					STEP 6
Parameter	Maximum Detected Concentration	Essential Nutrient?	Constituent Eliminated as an IHS?	Frequency of Detection	Does Frequency of Detection Exceed 5%?	Constituent Eliminated as an IHS?	Background Level[b]	Does Maximum Exceed Background?	Constituent Eliminated as an IHS?	Method A Cleanup Level	Does Maximum Exceed Method A?	Constituent Eliminated as an IHS?	Method B Cleanup Level[e]	Adjustment Factor for Aggregate Risk	Site-Specific Method B Cleanup Level	Does Maximum Exceed Method B?	Constituent Eliminated as an IHS?	IHSs for Soil (Forest Service Guard Station)
Total Metals (mg/kg)																		
Aluminum	20100	No		100%	Yes		20,870	No	ELIMINATED									
Arsenic	25.2	No		100%	Yes		12	Yes		20	Yes		1.67E+00	7	2.39E-01	Yes		IHS
Barium	80.4	No		100%	Yes		310	No	ELIMINATED									
Beryllium	0.22	No		100%	Yes		0.2	Yes					2.33E-01	7	3.33E-02	Yes		IHS
Cadmium	2.1	No		100%	Yes		5	No	ELIMINATED									
Calcium	4260	Yes	ELIMINATED															
Chromium[a]	21.7	No		100%	Yes		37	No	ELIMINATED									
Copper	61.8	No		100%	Yes		57	Yes					2.96E+03		2.96E+03	No	ELIMINATED	
Iron	27600	Yes	ELIMINATED															
Lead	84.1	No		100%	Yes		21	Yes		250	No	ELIMINATED						
Magnesium	8930	Yes	ELIMINATED															
Manganese	580	No		100%	Yes		1,425	No	ELIMINATED									
Mercury	0.02	No		100%	Yes		0.05[c]	No	ELIMINATED									
Molybdenum																		
Nickel	18.2	No		100%	Yes		23	No	ELIMINATED									
Potassium	997	Yes	ELIMINATED															
Selenium	nd																	
Silver	nd																	
Sodium	448	Yes	ELIMINATED															
Thallium	0.11	No		100%	Yes		0.4	No	ELIMINATED									
Uranium																		
Zinc	125	No		100%	Yes		253	No	ELIMINATED									
Conventional Analyses (mg/kg)																		
Cyanide, Total																		
Polychlorinated Biphenyls (ug/kg)																		
Aroclor 1016																		
Aroclor 1221																		
Aroclor 1232																		
Aroclor 1242																		
Aroclor 1248																		
Aroclor 1254																		
Aroclor 1260																		
PCBs, total																		
Total Petroleum Hydrocarbons (mg/kg)																		
Gasoline Range Hydrocarbons																		
Diesel Range Hydrocarbons																		
Motor Oil																		

Notes:

[a] Screening Criteria for chromium are for total chromium or chromium VI

[b] Area background levels for site unless otherwise noted.

[c] MTCA Natural Background levels for Yakima Basin

[d] Washington State ranges (Dragun, 1991) are shown for comparison purposes only No constituents are eliminated based on these ranges

nd = not detected

IHS = Indicator Hazardous Substance

*** = No cleanup levels or toxicity criteria available for risk evaluation. Constituent was not selected as an IHS.

1995 Data

TABLE 7.1-13
HUMAN HEALTH SCREENING OF SURFACE SOIL SAMPLE RESULTS FOR PROTECTION OF AIR - HOLDEN VILLAGE (INHALATION)
HOLDEN MINE
BASELINE RISK ASSESSMENT

		STEP 1		STEP 2			STEP 3			STEP 4			STEP 5					STEP 6
Parameter	Maximum Detected Concentration	Essential Nutrient?	Constituent Eliminated as an IHS?	Frequency of Detection	Does Frequency of Detection Exceed 5%?	Constituent Eliminated as an IHS?	Background Level[b]	Does Maximum Exceed Background?	Constituent Eliminated as an IHS?	Method A Cleanup Level	Does Maximum Exceed Method A?	Constituent Eliminated as an IHS?	Method B Cleanup Level	Adjustment Factor for Aggregate Risk	Site-Specific Method B Cleanup Level	Does Maximum Exceed Method B?	Constituent Eliminated as an IHS?	IHSs for Soil - Holden Villag (Inhalation)
Total Metals (mg/kg)																		
Aluminum	26300	No		100%	Yes		20,870	Yes					8.00E+04		8.00E+04	No	ELIMINATED	
Arsenic	5.1	No		100%	Yes		12	No	ELIMINATED									
Barium	380	No		100%	Yes		310	Yes					9.94E+04		9.94E+04	No	ELIMINATED	
Beryllium	0.32	No		100%	Yes		0.2	Yes					6.47E+02	7	9.24E+01	No	ELIMINATED	
Cadmium	2.1	No		100%	Yes		5	No	ELIMINATED									
Calcium	12400	Yes	ELIMINATED															
Chromium[a]	57.7	No		100%	Yes		37	Yes					1.33E+02	7	1.89E+01	Yes		IHS
Copper	523	No		100%			57	Yes										***
Iron	29600	Yes	ELIMINATED															
Lead	103	No		100%	Yes		21	Yes						7				***
Magnesium	10800	Yes	ELIMINATED															
Manganese	1270	No		100%	Yes		1,425	No	ELIMINATED									
Mercury	0.08	No		100%	Yes		0.05[c]	Yes					8.52E+04	4	2.13E+04	No	ELIMINATED	
Molybdenum	5	No		75%	Yes		1.2	Yes						4				***
Nickel	27.1	No		100%	Yes		23	Yes					1.60E+03	7	2.29E+02	No	ELIMINATED	
Potassium	2110	Yes	ELIMINATED															
Selenium	nd																	
Silver	2	No		33%	Yes		0.5	Yes						2				***
Sodium	1090	Yes	ELIMINATED															
Thallium	0.35	No		33%	Yes		0.4	No	ELIMINATED									
Uranium	nd																	
Zinc	456	No		100%	Yes		253	Yes						2				***
Conventional Analyses (mg/kg)																		
Cyanide, Total	0.07	No		29%	Yes									4				***
Polychlorinated Biphenyls (ug/kg)																		
Aroclor 1016																		
Aroclor 1221																		
Aroclor 1232																		
Aroclor 1242		No																
Aroclor 1248		No																
Aroclor 1254		No																
Aroclor 1260		No																
PCBs, total		No																
Total Petroleum Hydrocarbons (mg/kg)																		
Gasoline Range Hydrocarbons		No																
Diesel Range Hydrocarbons		No																
Motor Oil		No																

Notes:

[a] Screening Criteria for chromium are for total chromium or chromium VI

[b] Area background levels for site unless otherwise noted

[c] MTCA Natural Background levels for Yakima Basin

[d] Washington State ranges (Dragun, 1991) are shown for comparison purposes only. No constituents are eliminated based on these ranges

nd = not detected

IHS = Indicator Hazardous Substance

*** = No cleanup levels or toxicity criteria available for risk evaluation. Constituent was not selected as an IHS.

1995 and 1997 Data

TABLE 7.1-14
HUMAN HEALTH SCREENING OF SURFACE SOIL SAMPLE RESULTS FOR PROTECTION OF AIR - VEGETABLE GARDEN (INHALATION)
HOLDEN MINE
BASELINE RISK ASSESSMENT

		STEP 1		STEP 2			STEP 3			STEP 4			STEP 5					STEP 6
Parameter	Maximum Detected Concentration	Essential Nutrient?	Constituent Eliminated as an IHS?	Frequency of Detection	Does Frequency of Detection Exceed 5%?	Constituent Eliminated as an IHS?	Background Level[b]	Does Maximum Exceed Background?	Constituent Eliminated as an IHS?	Method A Cleanup Level	Does Maximum Exceed Method A?	Constituent Eliminated as an IHS?	Method B Cleanup Level	Adjustment Factor for Aggregate Risk	Site-Specific Method B Cleanup Level	Does Maximum Exceed Method B?	Constituent Eliminated as an IHS?	IHSs for Soil - Vegetable Garden (Inhalation)
Total Metals (mg/kg)																		
Aluminum	16200	No		100%	Yes		20,870	No	ELIMINATED									
Arsenic	5.1	No		100%	Yes		12	No	ELIMINATED									
Barium	333	No		100%	Yes		310	Yes					9.94E+04		9.94E+04	No	ELIMINATED	
Beryllium	0.2	No		100%	Yes		0.2	No	ELIMINATED									
Cadmium	2.1	No		100%	Yes		5	No	ELIMINATED									
Calcium	12400	Yes	ELIMINATED															
Chromium[a]	28.7	No		100%	Yes		37	No	ELIMINATED									
Copper	155	No		100%	Yes		57	Yes										***
Iron	26300	Yes	ELIMINATED															
Lead	61	No		100%	Yes		21	Yes						7				***
Magnesium	5860	Yes	ELIMINATED															
Manganese	613	No		100%	Yes		1,425	No	ELIMINATED									
Mercury																		
Molybdenum	5	No		100%	Yes		1.2	Yes						4				***
Nickel	16	No		100%	Yes		23	No	ELIMINATED									
Potassium	2110	Yes	ELIMINATED															
Selenium																		
Silver	2	No		100%	Yes		0.5	Yes						2				***
Sodium	777	Yes	ELIMINATED															
Thallium	nd																	
Uranium	nd																	
Zinc	356	No		100%	Yes		253	Yes						2				***
Conventional Analyses (mg/kg)																		
Cyanide, Total																		
Polychlorinated Biphenyls (ug/kg)																		
Aroclor 1016																		
Aroclor 1221																		
Aroclor 1232																		
Aroclor 1242																		
Aroclor 1248																		
Aroclor 1254																		
Aroclor 1260																		
PCBs, total																		
Total Petroleum Hydrocarbons (mg/kg)																		
Gasoline Range Hydrocarbons																		
Diesel Range Hydrocarbons																		
Motor Oil																		

Notes:
[a]Screening Criteria for chromium are for total chromium or chromium VI
[b]Area background levels for site unless otherwise noted
[c]MTCA Natural Background levels for Yakima Basin
[d]Washington State ranges (Dragun, 1991) are shown for comparison purposes only. No constituents are eliminated based on these ranges
nd = not detected
IHS = Indicator Hazardous Substance
*** = No cleanup levels or toxicity criteria available for risk evaluation. Constituent was not selected as an IHS.
1997 Data

TABLE 7.1-15
HUMAN HEALTH SCREENING OF SURFACE SOIL SAMPLE RESULTS FOR PROTECTION OF AIR - BASEBALL FIELD (INHALATION)
HOLDEN MINE
BASELINE RISK ASSESSMENT

		STEP 1		STEP 2			STEP 3			STEP 4			STEP 5					STEP 6
Parameter	Maximum Detected Concentration	Essential Nutrient?	Constituent Eliminated as an IHS?	Frequency of Detection	Does Frequency of Detection Exceed 5%?	Constituent Eliminated as an IHS?	Background Level[b]	Does Maximum Exceed Background?	Constituent Eliminated as an IHS?	Method A Cleanup Level	Does Maximum Exceed Method A?	Constituent Eliminated as an IHS?	Method B Cleanup Level	Adjustment Factor for Aggregate Risk	Site-Specific Method B Cleanup Level	Does Maximum Exceed Method B?	Constituent Eliminated as an IHS?	IHSs for Soil Baseball Field (Inhalation)
Total Metals (mg/kg)																		
Aluminum	20300	No		100%	Yes		20,870	No	ELIMINATED									
Arsenic	10.8	No		100%	Yes		12	No	ELIMINATED									
Barium	101	No		100%	Yes		310	No	ELIMINATED									
Beryllium	0.2	No		100%	Yes		0.2	No	ELIMINATED									
Cadmium	1.3	No		100%	Yes		5	No	ELIMINATED									
Calcium	5770	Yes	ELIMINATED															
Chromium[a]	29.4	No		100%	Yes		37	No	ELIMINATED									
Copper	63	No		100%	Yes		57	Yes										***
Iron	22600	Yes	ELIMINATED															
Lead	15	No		100%	Yes		21	No	ELIMINATED									
Magnesium	7640	Yes	ELIMINATED															
Manganese	537	No		100%	Yes		1,425	No	ELIMINATED									
Mercury																		
Molybdenum	1	No		100%	Yes		1.2	No	ELIMINATED									
Nickel	18	No		100%	Yes		23	No	ELIMINATED									
Potassium	1270	Yes	ELIMINATED															
Selenium																		
Silver	0.5	No		100%	Yes		0.5							2				***
Sodium	605	Yes	ELIMINATED															
Thallium	nd																	
Uranium	nd																	
Zinc	129	No		100%	Yes		253	No	ELIMINATED									
Conventional Analyses (mg/kg)																		
Cyanide, Total																		
Polychlorinated Biphenyls (ug/kg)																		
Aroclor 1016																		
Aroclor 1221																		
Aroclor 1232																		
Aroclor 1242																		
Aroclor 1248																		
Aroclor 1254																		
Aroclor 1260																		
PCBs, total																		
Total Petroleum Hydrocarbons (mg/kg)																		
Gasoline Range Hydrocarbons																		
Diesel Range Hydrocarbons																		
Motor Oil																		

Notes:

[a] Screening Criteria for chromium are for total chromium or chromium VI

[b] Area background levels for site unless otherwise noted.

[c] MTCA Natural Background levels for Yakima Basin

[d] Washington State ranges (Dragun, 1991) are shown for comparison purposes only. No constituents are eliminated based on these ranges

nd = not detected

IHS = Indicator Hazardous Substance

*** = No cleanup levels or toxicity criteria available for risk evaluation. Constituent was not selected as an IHS.

1997 Data

TABLE 7.1-16
HUMAN HEALTH SCREENING OF SURFACE SOIL SAMPLE RESULTS FOR PROTECTION OF AIR - WILDERNESS BOUNDARY (INHALATION)
HOLDEN MINE
BASELINE RISK ASSESSMENT

		STEP 1		STEP 2			STEP 3			STEP 4			STEP 5					STEP 6
Parameter	Maximum Detected Concentration	Essential Nutrient?	Constituent Eliminated as an IHS?	Frequency of Detection	Does Frequency of Detection Exceed 5%?	Constituent Eliminated as an IHS?	Background Level[b]	Does Maximum Exceed Background?	Constituent Eliminated as an IHS?	Method A Cleanup Level	Does Maximum Exceed Method A?	Constituent Eliminated as an IHS?	Method B Cleanup Level	Adjustment Factor for Aggregate Risk	Site-Specific Method B Cleanup Level	Does Maximum Exceed Method B?	Constituent Eliminated as an IHS?	IHSs for Soil Wilderness Boundary (Inhalation)
Total Metals (mg/kg)																		
Aluminum	17500	No		100%	Yes		20,870	No	ELIMINATED									
Arsenic	11.4	No		100%	Yes		12	No	ELIMINATED									
Barium	93.1	No		100%	Yes		310	No	ELIMINATED									
Beryllium	0.2	No		100%	Yes		0.2	No	ELIMINATED									
Cadmium	3.1	No		100%	Yes		5	No	ELIMINATED									
Calcium	6440	Yes	ELIMINATED															
Chromium[a]	27.8	No		100%	Yes		37	No	ELIMINATED									
Copper	147	No		100%	Yes		57	Yes										***
Iron	26500	Yes	ELIMINATED															
Lead	37	No		100%	Yes		21	Yes						7				***
Magnesium	8980	Yes	ELIMINATED															
Manganese	455	No		100%	Yes		1,425	No	ELIMINATED									
Mercury																		
Molybdenum	2.4	No		100%	Yes		1.2	Yes						4				***
Nickel	17	No		100%	Yes		23	No	ELIMINATED									
Potassium	1290	Yes	ELIMINATED															
Selenium																		
Silver	0.6	No		100%	Yes		0.5	Yes						2				***
Sodium	647	Yes	ELIMINATED															
Thallium	nd																	
Uranium	4	No		50%	Yes		1.0	Yes						4				***
Zinc	303	No		100%	Yes		253	Yes						2				***
Conventional Analyses (mg/kg)																		
Cyanide, Total		No																
Polychlorinated Biphenyls (ug/kg)																		
Aroclor 1016		No																
Aroclor 1221		No																
Aroclor 1232		No																
Aroclor 1242		No																
Aroclor 1248		No																
Aroclor 1254		No																
Aroclor 1260		No																
PCBs, total		No																
Total Petroleum Hydrocarbons (mg/kg)																		
Gasoline Range Hydrocarbons		No																
Diesel Range Hydrocarbons		No																
Motor Oil		No																

Notes:

[a] Screening Criteria for chromium are for total chromium or chromium VI

[b] Area background levels for site unless otherwise noted.

[c] MTCA Natural Background levels for Yakima Basin

[d] Washington State ranges (Dragun, 1991) are shown for comparison purposes only. No constituents are eliminated based on these ranges

nd = not detected

IHS = Indicator Hazardous Substance

*** = No cleanup levels or toxicity criteria available for risk evaluation. Constituent was not selected as an IHS.

1997 Data

TABLE 7.1-17
HUMAN HEALTH SCREENING OF SURFACE SOIL SAMPLE RESULTS FOR PROTECTION OF AIR - MAINTENANCE YARD (INHALATION)
HOLDEN MINE
BASELINE RISK ASSESSMENT

		STEP 1		STEP 2			STEP 3			STEP 4			STEP 5					STEP 6
Parameter	Maximum Detected Concentration	Essential Nutrient?	Constituent Eliminated as an IHS?	Frequency of Detection	Does Frequency of Detection Exceed 5%?	Constituent Eliminated as an IHS?	Background Level[b]	Does Maximum Exceed Background?	Constituent Eliminated as an IHS?	Method A Cleanup Level	Does Maximum Exceed Method A?	Constituent Eliminated as an IHS?	Method B Cleanup Level	Adjustment Factor for Aggregate Risk	Site-Specific Method B Cleanup Level	Does Maximum Exceed Method B?	Constituent Eliminated as an IHS?	IHSs for Soil - Maintenance Yard (Inhalation)
Total Metals (mg/kg)																		
Aluminum	17500	No		100%	Yes		20,670	No	ELIMINATED									
Arsenic	4.3	No		100%	Yes		12	No	ELIMINATED									
Barium	717	No		100%	Yes		310	Yes					9.94E+04		9.94E+04	No	ELIMINATED	
Beryllium	0.1	No		75%	Yes		0.2	No	ELIMINATED									
Cadmium	21.6	No		100%	Yes		5	Yes					8.91E+02	7	1.27E+02	No	ELIMINATED	
Calcium	5790	Yes	ELIMINATED															
Chromium[a]	33	No		100%	Yes		37	No	ELIMINATED									
Copper	3160	No		100%	Yes		57	Yes										***
Iron	60300	Yes	ELIMINATED															
Lead	1070	No		100%	Yes		21	Yes						7				***
Magnesium	11400	Yes	ELIMINATED															
Manganese	426	No		100%	Yes		1,425	No	ELIMINATED									
Mercury																		
Molybdenum	16	No		100%	Yes		1.2	Yes						4				***
Nickel	23	No		100%	Yes		23	No	ELIMINATED									
Potassium	4600	Yes	ELIMINATED															
Selenium																		
Silver	5	No		100%	Yes		0.5	Yes						2				***
Sodium	794	Yes	ELIMINATED															
Thallium	nd																	
Uranium	nd																	
Zinc	3240	No		100%	Yes		253	Yes						2				***
Conventional Analyses (mg/kg)																		
Cyanide, Total																		
Polychlorinated Biphenyls (ug/kg)																		
Aroclor 1016	nd																	
Aroclor 1221	nd																	
Aroclor 1232	nd																	
Aroclor 1242	nd																	
Aroclor 1248	nd																	
Aroclor 1254	nd																	
Aroclor 1260	46	No		75%	Yes													***
PCBs, total	46	No		75%	Yes									7				***
Total Petroleum Hydrocarbons (mg/kg)																		
Gasoline Range Hydrocarbons	140	No		75%	Yes													***
Diesel Range Hydrocarbons	12000	No		100%	Yes								1.42E+06		1.42E+06	No	ELIMINATED	
Motor Oil	9800	No		100%	Yes													***

Notes:

Excludes storage sample because this sample location is not exposed and particulate emissions are not expected

[a] Screening Criteria for chromium are for total chromium or chromium VI

[b] Area background levels for site unless otherwise noted.

[c] MTCA Natural Background levels for Yakima Basin

[d] Washington State ranges (Dragun, 1991) are shown for comparison purposes only. No constituents are eliminated based on these ranges

nd = not detected

IHS = Indicator Hazardous Substance

*** = No cleanup levels or toxicity criteria available for risk evaluation. Constituent was not selected as an IHS.

1997 Data. Surface soil samples only.

TABLE 7.1-18
HUMAN HEALTH SCREENING OF SURFACE SOIL SAMPLE RESULTS FOR PROTECTION OF AIR - LAGOON AREA (INHALATION)
HOLDEN MINE
BASELINE RISK ASSESSMENT

		STEP 1		STEP 2			STEP 3			STEP 4			STEP 5					STEP 6
Parameter	Maximum Detected Concentration	Essential Nutrient?	Constituent Eliminated as an IHS?	Frequency of Detection	Does Frequency of Detection Exceed 5%?	Constituent Eliminated as an IHS?	Background Level[b]	Does Maximum Exceed Background?	Constituent Eliminated as an IHS?	Method A Cleanup Level	Does Maximum Exceed Method A?	Constituent Eliminated as an IHS?	Method B Cleanup Level	Adjustment Factor for Aggregate Risk	Site-Specific Method B Cleanup Level	Does Maximum Exceed Method B?	Constituent Eliminated as an IHS?	IHSs for Soil - Lagoon Area (Inhalation)
Total Metals (mg/kg)																		
Aluminum	33500	No		100%	Yes		20,870	Yes										***
Arsenic	5	No		100%	Yes		12	No	ELIMINATED									
Barium	343	No		100%	Yes		310	Yes					9.94E+04		9.94E+04	No	ELIMINATED	
Beryllium	0.3	No		50%	Yes		0.2	Yes					6.47E+02	7	9.24E+01	No	ELIMINATED	
Cadmium	184	No		100%	Yes		5	Yes					8.91E+02	7	1.27E+02	Yes		IHS
Calcium	6120	Yes	ELIMINATED															
Chromium[a]	21	No		100%	Yes		37	No	ELIMINATED									
Copper	24100	No		100%	Yes		57	Yes										***
Iron	101000	Yes	ELIMINATED															
Lead	620	No		100%	Yes		21	Yes						7				***
Magnesium	18100	Yes	ELIMINATED															
Manganese	625	No		100%	Yes		1,425	No	ELIMINATED									
Mercury																		
Molybdenum	74	No		100%	Yes		1.2	Yes						4				***
Nickel	13	No		50%	Yes		23	No	ELIMINATED									
Potassium	4370	Yes	ELIMINATED															
Selenium																		
Silver	27	No		100%	Yes		0.5	Yes						2				***
Sodium	931	Yes	ELIMINATED															
Thallium	3	No		50%	Yes		0.4	Yes										***
Uranium	7	No		100%	Yes		1.0	Yes						4				***
Zinc	23700	No		100%	Yes		253	Yes						2				***
Conventional Analyses (mg/kg)																		
Cyanide, Total																		
Polychlorinated Biphenyls (ug/kg)																		
Aroclor 1016	nd																	
Aroclor 1221	nd																	
Aroclor 1232	nd																	
Aroclor 1242	nd																	
Aroclor 1248	nd																	
Aroclor 1254	nd																	
Aroclor 1260	nd																	
PCBs, total	nd																	
Total Petroleum Hydrocarbons (mg/kg)																		
Gasoline Range Hydrocarbons	nd																	
Diesel Range Hydrocarbons	230	No		100%	Yes								1.42E+06		1.42E+06	No	ELIMINATED	
Motor Oil	440	No		100%	Yes													***

Notes:

[a]Screening Criteria for chromium are for total chromium or chromium VI

[b]Area background levels for site unless otherwise noted.

[c]MTCA Natural Background levels for Yakima Basin

[d]Washington State ranges (Dragun, 1991) are shown for comparison purposes only. No constituents are eliminated based on these ranges

nd = not detected

IHS = Indicator Hazardous Substance

*** = No cleanup levels or toxicity criteria available for risk evaluation. Constituent was not selected as an IHS.

1997 Data

TABLE 7.1-19
HUMAN HEALTH SCREENING OF SURFACE SOIL SAMPLE RESULTS FOR PROTECTION OF AIR - FOREST SERVICE GUARD STATION (INHALATION)
HOLDEN MINE
BASELINE RISK ASSESSMENT

		STEP 1		STEP 2			STEP 3			STEP 4			STEP 5					STEP 6
Parameter	Maximum Detected Concentration	Essential Nutrient?	Constituent Eliminated as an IHS?	Frequency of Detection	Does Frequency of Detection Exceed 5%?	Constituent Eliminated as an IHS?	Background Level[b]	Does Maximum Exceed Background?	Constituent Eliminated as an IHS?	Method A Cleanup Level	Does Maximum Exceed Method A?	Constituent Eliminated as an IHS?	Method B Cleanup Level	Adjustment Factor for Aggregate Risk	Site-Specific Method B Cleanup Level	Does Maximum Exceed Method B?	Constituent Eliminated as an IHS?	IHSs for Soil - Forest Service Guard Station (Inhalation)
Total Metals (mg/kg)																		
Aluminum	20100	No		100%	Yes		20,870	No	ELIMINATED									
Arsenic	25.2	No		100%	Yes		12	Yes					1.09E+02	7	1.55E+01	Yes		IHS
Barium	80.4	No		100%	Yes		310	No	ELIMINATED									
Beryllium	0.22	No		100%	Yes		0.2	Yes					6.47E+02	7	9.24E+01	No	ELIMINATED	
Cadmium	2.1	No		100%	Yes		5	No	ELIMINATED									
Calcium	4260	Yes	ELIMINATED															
Chromium[a]	21.7	No		100%	Yes		37	No	ELIMINATED									
Copper	61.8	No		100%	Yes		57	Yes										***
Iron	27600	Yes	ELIMINATED															
Lead	84.1	No		100%	Yes		21	Yes						7				***
Magnesium	8930	Yes	ELIMINATED															
Manganese	580	No		100%	Yes		1,425	No	ELIMINATED									
Mercury	0.02	No		100%	Yes		0.05[c]	No	ELIMINATED									
Molybdenum																		
Nickel	18.2	No		100%	Yes		23	No	ELIMINATED									
Potassium	997	Yes	ELIMINATED															
Selenium	nd																	
Silver	nd																	
Sodium	448	Yes	ELIMINATED															
Thallium	0.11	No		100%	Yes		0.4	No	ELIMINATED									
Uranium																		
Zinc	125	No		100%	Yes		253	No	ELIMINATED									
Conventional Analyses (mg/kg)																		
Cyanide, Total	*nd*																	
Polychlorinated Biphenyls (ug/kg)																		
Aroclor 1016																		
Aroclor 1221																		
Aroclor 1232																		
Aroclor 1242																		
Aroclor 1248																		
Aroclor 1254																		
Aroclor 1260																		
PCBs, total																		
Total Petroleum Hydrocarbons (mg/kg)																		
Gasoline Range Hydrocarbons																		
Diesel Range Hydrocarbons																		
Motor Oil																		

Notes:

[a] Screening Criteria for chromium are for total chromium or chromium VI

[b] Area background levels for site unless otherwise noted.

[c] MTCA Natural Background levels for Yakima Basin

[d] Washington State ranges (Dragun, 1991) are shown for comparison purposes only. No constituents are eliminated based on these ranges

nd = not detected

IHS = Indicator Hazardous Substance

*** = No cleanup levels or toxicity criteria available for risk evaluation. Constituent was not selected as an IHS.

1995 Data

TABLE 7.1-20
HUMAN HEALTH SCREENING OF TAILINGS SAMPLE RESULTS (INGESTION)
HOLDEN MINE
BASELINE RISK ASSESSMENT

		STEP 1		STEP 2			STEP 3			STEP 4			STEP 5					STEP 6
Parameter	Maximum Detected Concentration	Essential Nutrient?	Constituent Eliminated as an IHS?	Frequency of Detection	Does Frequency of Detection Exceed 5%?	Constituent Eliminated as an IHS?	Background Level[b]	Does Maximum Exceed Background?	Constituent Eliminated as an IHS?	Method A Cleanup Level	Does Maximum Exceed Method A?	Constituent Eliminated as an IHS?	Method B Cleanup Level	1.00E+01	Site-Specific Method B Cleanup Level	Does Maximum Exceed Method B?	Constituent Eliminated as an IHS?	IHSs for Tailings
Total Metals (mg/kg)																		
Aluminum	44000	No		100%	Yes		20,870	Yes					8.00E+04		8.00E+04	No	ELIMINATED	
Arsenic	6.5	No		86%	Yes		12	No	ELIMINATED									
Barium	1200	No		100%	Yes		310	Yes					5.60E+03		5.60E+03	No	ELIMINATED	
Beryllium	0.2	No		36%	Yes		0.2	No	ELIMINATED									
Cadmium	1.3	No		64%	Yes		5	No	ELIMINATED									
Calcium	16000	Yes	ELIMINATED															
Chromium[a]	29	No		79%	Yes		37	No	ELIMINATED									
Copper	442	No		100%	Yes		57	Yes					2.96E+03		2.96E+03	No	ELIMINATED	
Iron	85300	Yes	ELIMINATED															
Lead	140	No		100%	Yes		21	Yes		250	No	ELIMINATED						
Magnesium	11700	Yes	ELIMINATED															
Manganese	500	No		100%	Yes		1,425	No	ELIMINATED									
Mercury	0.35	No		100%	Yes		0.05[c]	Yes		1	No	ELIMINATED						
Molybdenum	31.7	No		95%	Yes		1.2	Yes					4.00E+02	4	1.00E+02	No	ELIMINATED	
Nickel	17	No		90%	Yes		23	No	ELIMINATED									
Potassium	8800	Yes	ELIMINATED															
Selenium	28	No		100%	Yes		0.1 - 1.5[d]	Yes					4.00E+02		4.00E+02	No	ELIMINATED	
Silver	3.4	No		82%	Yes		0.5	Yes					4.00E+02	2	2.00E+02	No	ELIMINATED	
Sodium	14000	Yes	ELIMINATED															
Thallium	1.2	No		30%	Yes		0.4	Yes					5.60E+00		5.60E+00	No	ELIMINATED	
Uranium	nd																	
Zinc	767	No		100%	Yes		253	Yes					2.40E+04	2	1.20E+04	No	ELIMINATED	
Conventional Analyses (mg/kg)																		
Cyanide, Total	0.59	No		29%	Yes								1.60E+03	4	4.00E+02	No	ELIMINATED	
Polychlorinated Biphenyls (ug/kg)																		
Aroclor 1016																		
Aroclor 1221																		
Aroclor 1232																		
Aroclor 1242																		
Aroclor 1248																		
Aroclor 1254																		
Aroclor 1260																		
PCBs, total																		
Total Petroleum Hydrocarbons (mg/kg)																		
Gasoline Range Hydrocarbons																		
Diesel Range Hydrocarbons																		
Motor Oil																		

Notes:

[a] Screening Criteria for chromium are for total chromium or chromium VI

[b] Area background levels for site unless otherwise noted.

[c] MTCA Natural Background levels for Yakima Basin

[d] Washington State ranges (Dragun, 1991) are shown for comparison purposes only. No constituents are eliminated based on these ranges

nd = not detected

IHS = Indicator Hazardous Substance

"" = No cleanup levels or toxicity criteria available for risk evaluation Constituent was not selected as an IHS.

1991 - 1997 Data. Surface and windblown tailings only.

TABLE 7.1-21
HUMAN HEALTH SCREENING OF TAILINGS SAMPLE RESULTS FOR PROTECTION OF AIR (INHALATION)
HOLDEN MINE
BASELINE RISK ASSESSMENT

		STEP 1		STEP 2			STEP 3			STEP 4			STEP 5					STEP 6
Parameter	Maximum Detected Concentration	Essential Nutrient?	Constituent Eliminated as an IHS?	Frequency of Detection	Does Frequency of Detection Exceed 5%?	Constituent Eliminated as an IHS?	Background Level[b]	Does Maximum Exceed Background?	Constituent Eliminated as an IHS?	Method A Cleanup Level	Does Maximum Exceed Method A?	Constituent Eliminated as an IHS?	Method B Cleanup Level	Adjustment Factor for Aggregate Risk	Site-Specific Method B Cleanup Level	Does Maximum Exceed Method B?	Constituent Eliminated as an IHS?	IHSs for Tailings (Inhalation)
Total Metals (mg/kg)																		
Aluminum	44000	No		100%	Yes		20,870	Yes										***
Arsenic	6.5	No		86%	Yes		12	No	ELIMINATED									
Barium	1200	No		100%	Yes		310	Yes					9.94E+04		9.94E+04	No	ELIMINATED	
Beryllium	0.2	No		36%	Yes		0.2	No	ELIMINATED									
Cadmium	1.3	No		64%	Yes		5	No	ELIMINATED									
Calcium	16000	Yes	ELIMINATED															
Chromium[a]	29	No		79%	Yes		37	No	ELIMINATED									
Copper	442	No		100%	Yes		57	Yes										***
Iron	85300	Yes	ELIMINATED															
Lead	140	No		100%	Yes		21	Yes						7				***
Magnesium	11700	Yes	ELIMINATED															
Manganese	500	No		100%	Yes		1,425	No	ELIMINATED									
Mercury	0.35	No		100%	Yes		0.05[c]	Yes					8.52E+04	4	2.13E+04	No	ELIMINATED	
Molybdenum	31.7	No		95%	Yes		1.2	Yes						4				***
Nickel	17	No		90%	Yes		23	No	ELIMINATED									
Potassium	8800	Yes	ELIMINATED															
Selenium	28	No		100%	Yes		0.1 - 1.5[d]	Yes										***
Silver	3.4	No		82%	Yes		0.5	Yes						2				***
Sodium	14000	Yes	ELIMINATED															
Thallium	1.2	No		30%	Yes		0.4	Yes										***
Uranium	nd																	
Zinc	767	No		100%	Yes		253	Yes						2				***
Conventional Analyses (mg/kg)																		
Cyanide, Total	0.59	No		29%	Yes									4				***
Polychlorinated Biphenyls (ug/kg)																		
Aroclor 1016																		
Aroclor 1221																		
Aroclor 1232																		
Aroclor 1242																		
Aroclor 1248																		
Aroclor 1254																		
Aroclor 1260																		
PCBs, total																		
Total Petroleum Hydrocarbons (mg/kg)																		
Gasoline Range Hydrocarbons																		
Diesel Range Hydrocarbons																		
Motor Oil																		

Notes:

[a] Screening Criteria for chromium are for total chromium or chromium VI

[b] Area background levels for site unless otherwise noted.

[c] MTCA Natural Background levels for Yakima Basin

[d] Washington State ranges (Dragun, 1991) are shown for comparison purposes only. No constituents are eliminated based on these ranges

nd = not detected

IHS = Indicator Hazardous Substance

*** = No cleanup levels or toxicity criteria available for risk evaluation. Constituent was not selected as an IHS.

1991 - 1997 Data. Surface and windblown tailings only.

TABLE 7.1-22
HUMAN HEALTH SCREENING OF AIR SAMPLE RESULTS
HOLDEN MINE
BASELINE RISK ASSESSMENT

		STEP 1		STEP 2			STEP 3			STEP 4			STEP 5					STEP 6
Parameter	Maximum Detected Concentration	Essential Nutrient?	Constituent Eliminated as an IHS?	Frequency of Detection	Does Frequency of Detection Exceed 5%?	Constituent Eliminated as an IHS?	Background Level[b]	Does Maximum Exceed Background?	Constituent Eliminated as an IHS?	Method A Cleanup Level	Does Maximum Exceed Method A?	Constituent Eliminated as an IHS?	Method B Cleanup Level[b]	Adjustment Factor for Aggregate Risk	Site-Specific Method B Cleanup Level	Does Maximum Exceed Method B?	Constituent Eliminated as an IHS?	IHSs for Soil (Holden Village)
Total Metals (mg/m3)																		
Aluminum	1.56E-03	No		100%														***
Arsenic																		
Barium	6.16E-05	No		100%									1.60E-04		1.60E-04	No	ELIMINATED	
Beryllium																		
Cadmium																		
Calcium	4.06E-04	Yes	ELIMINATED															
Chromium[a]																		
Copper	6.00E-05	No		93%														***
Iron	4.44E-03	Yes	ELIMINATED															
Lead	2.09E-05	No		100%														***
Magnesium	4.84E-04	Yes	ELIMINATED															
Manganese	2.78E-05	No		100%									2.29E-05	4	5.72E-06	Yes		IHS
Mercury																		
Molybdenum																		
Nickel																		
Potassium	3.25E-04	Yes	ELIMINATED															
Selenium																		
Silver																		
Sodium	1.25E-03	Yes	ELIMINATED															
Thallium																		
Uranium																		
Zinc	4.95E-04	No		100%														***
Conventional Analyses (mg/kg)																		
Cyanide, Total																		
Polychlorinated Biphenyls (ug/kg)																		
Aroclor 1016																		
Aroclor 1221																		
Aroclor 1232																		
Aroclor 1242																		
Aroclor 1248																		
Aroclor 1254																		
Aroclor 1260																		
PCBs, total																		
Total Petroleum Hydrocarbons (mg/kg)																		
Gasoline Range Hydrocarbons																		
Diesel Range Hydrocarbons																		
Motor Oil																		

Notes:

[a] *Screening Criteria for chromium are for total chromium or chromium VI*

nd = not detected

IHS = Indicator Hazardous Substance

*** = No cleanup levels or toxicity criteria available for risk evaluation. Constituent was not selected as an IHS.

1994 U.S. Forest Service Data

TABLE 7.1-23
HUMAN HEALTH SCREENING OF RAILROAD CREEK SEDIMENT/CONCENTRATE/FLOCCULENT SAMPLE RESULTS - ADJACENT TO SITE
HOLDEN MINE
BASELINE RISK ASSESSMENT

		STEP 1		STEP 2			STEP 3			STEP 4			STEP 5					STEP 6
Parameter	Maximum Detected Concentration	Essential Nutrient?	Constituent Eliminated as an IHS?	Frequency of Detection	Does Frequency of Detection Exceed 5%?	Constituent Eliminated as an IHS?	Background Concentration[b]	Does Maximum Exceed Background?	Constituent Eliminated as an IHS?	Method A Cleanup Level	Does Maximum Exceed Method A?	Constituent Eliminated as an IHS?	Method B Cleanup Level	Adjustment Factor for Aggregate Risk	Site-Specific Method B Cleanup Level	Does Maximum Exceed Method B?	Constituent Eliminated as an IHS?	IHSs for Railroad Creek Sediment Adjacent to Site
Total Metals (mg/kg)																		
Aluminum	83000	No		100%	Yes		10400-87000						8.00E+04		8.00E+04	Yes		IHS
Arsenic	126	No		73%	Yes		3.1-12			20	Yes		1.67E+00	7	2.39E-01	Yes		IHS
Barium	78.8	No		100%	Yes		300-480						5.60E+03		5.60E+03	No	ELIMINATED	
Beryllium	1	No		53%	Yes		1						2.33E-01	7	3.33E-02	Yes		IHS
Cadmium	5	No		69%	Yes		0.085-2			2	Yes		8.00E+01	4	2.00E+01	No	ELIMINATED	
Calcium	70000	Yes	ELIMINATED															
Chromium[a]	300	No		100%	Yes		36-300			100	Yes		4.00E+02	7	5.71E+01	Yes		IHS
Copper	2000	No		100%	Yes		12-74						2.96E+03		2.96E+03	No	ELIMINATED	
Iron	434000	Yes	ELIMINATED															
Lead	66	No		81%	Yes		4.9-50			250	No	ELIMINATED						
Magnesium	24000	Yes	ELIMINATED															
Manganese	1400	No		100%	Yes		271-1600						3.73E+03	4	9.33E+02	Yes		IHS
Mercury																		
Molybdenum	700	No		89%	Yes		0.076-1.3						4.00E+02	4	1.00E+02	Yes		IHS
Nickel	50	No		73%	Yes		20-50						1.60E+03	4	4.00E+02	No	ELIMINATED	
Potassium	10000	Yes	ELIMINATED															
Selenium	0.95	No		86%	Yes								4.00E+02		4.00E+02	No	ELIMINATED	
Silver	11	No		73%	Yes		0.067						4.00E+02	2	2.00E+02	No	ELIMINATED	
Sodium	368	Yes	ELIMINATED															
Thallium																		
Uranium	nd																	
Zinc	2000	No		94%	Yes		62-1500						2.40E+04	2	1.20E+04	No	ELIMINATED	
Conventional Analyses (mg/kg)																		
Cyanide, Total																		
Polychlorinated Biphenyls (ug/kg)																		
Aroclor 1016																		
Aroclor 1221																		
Aroclor 1232																		
Aroclor 1242																		
Aroclor 1248																		
Aroclor 1254																		
Aroclor 1260																		
PCBs, total																		
Total Petroleum Hydrocarbons (mg/kg)																		
Gasoline Range Hydrocarbons																		
Diesel Range Hydrocarbons																		
Motor Oil																		

Notes:

[a] Screening Criteria for chromium are for total chromium or chromium VI

[b] Inadequate number of samples to calculate area background. Ranges of Railroad Creek sediment/concentrate background samples are shown for comparison purposes only. No constituents are eliminated based on these ranges

[c] Method A and Method B Cleanup Levels are for soils.

nd = not detected

IHS = Indicator Hazardous Substance

*** = No cleanup levels or toxicity criteria available for risk evaluation. Constituent was not selected as an IHS

1991 - 1997 Data

TABLE 7.1-24
HUMAN HEALTH SCREENING OF RAILROAD CREEK SEDIMENT/CONCENTRATE/FLOCCULENT SAMPLE RESULTS - DOWNGRADIENT FROM SITE
HOLDEN MINE
BASELINE RISK ASSESSMENT

		STEP 1		STEP 2			STEP 3			STEP 4			STEP 5					STEP 6
Parameter	Maximum Detected Concentration	Essential Nutrient?	Constituent Eliminated as an IHS?	Frequency of Detection	Does Frequency of Detection Exceed 5%?	Constituent Eliminated as an IHS?	Background Concentration[b]	Does Maximum Exceed Background?	Constituent Eliminated as an IHS?	Method A Cleanup Level	Does Maximum Exceed Method A?	Constituent Eliminated as an IHS?	Method B Cleanup Level	Adjustment Factor for Aggregate Risk	Site-Specific Method B Cleanup Level	Does Maximum Exceed Method B?	Constituent Eliminated as an IHS?	IHSs for Railroad Creek Sediment Downgradient from Site
Total Metals (mg/kg)																		
Aluminum	89000	No		100%	Yes		10400-87000						8.00E+04		8.00E+04	Yes		IHS
Arsenic	3.5	No		25%	Yes		3.1-12			20	No	ELIMINATED						
Barium	1500	No		100%	Yes		300-480						5.60E+03		5.60E+03	No	ELIMINATED	
Beryllium	1	No		50%	Yes		1						2.33E-01	7	3.33E-02	Yes		IHS
Cadmium	0.9	No		50%	Yes		0.085-2			2	No	ELIMINATED						
Calcium	150000	Yes	ELIMINATED															
Chromium[a]	500	No		100%	Yes		36-300			100	Yes		4.00E+02	7	5.71E+01	Yes		IHS
Copper	700	No		90%	Yes		12-74						2.96E+03		2.96E+03	No	ELIMINATED	
Iron	71000	Yes	ELIMINATED															
Lead	25	No		70%	Yes		4.9-50			250	No	ELIMINATED						
Magnesium	24000	Yes	ELIMINATED															
Manganese	1200	No		100%	Yes		271-1600						3.73E+03	4	9.33E+02	Yes		IHS
Mercury																		
Molybdenum	20	No		63%	Yes		0.076-1.3						4.00E+02	4	1.00E+02	No	ELIMINATED	
Nickel	32	No		63%	Yes		20-50						1.60E+03	4	4.00E+02	No	ELIMINATED	
Potassium	12000	Yes	ELIMINATED															
Selenium	0.6	No		50%	Yes								4.00E+02		4.00E+02	No	ELIMINATED	
Silver	0.45	No		50%	Yes		0.067						4.00E+02	2	2.00E+02	No	ELIMINATED	
Sodium	28000	Yes	ELIMINATED															
Thallium																		
Uranium	nd																	
Zinc	1500	No		80%	Yes		62-1500						2.40E+04	2	1.20E+04	No	ELIMINATED	
Conventional Analyses (mg/kg)																		
Cyanide, Total																		
Polychlorinated Biphenyls (ug/kg)																		
Aroclor 1016																		
Aroclor 1221																		
Aroclor 1232																		
Aroclor 1242																		
Aroclor 1248																		
Aroclor 1254																		
Aroclor 1260																		
PCBs, total																		
Total Petroleum Hydrocarbons (mg/kg)																		
Gasoline Range Hydrocarbons																		
Diesel Range Hydrocarbons																		
Motor Oil																		

Notes:

[a] Screening Criteria for chromium are for total chromium or chromium VI

[b] Inadequate number of samples to calculate area background. Ranges of Railroad Creek sediment/concentrate background samples are shown for comparison purposes only. No constituents are eliminated based on these ranges

[c] Method A and Method B Cleanup Levels are for soils

nd = not detected

IHS = Indicator Hazardous Substance

"---" = No cleanup levels or toxicity criteria available for risk evaluation. Constituent was not selected as an IHS.

1991 - 1997 Data

TABLE 7.1-25
HUMAN HEALTH SCREENING OF COPPER CREEK SEDIMENT/CONCENTRATE SAMPLE RESULTS
HOLDEN MINE
BASELINE RISK ASSESSMENT

		STEP 1		STEP 2			STEP 3			STEP 4			STEP 5					STEP 6
Parameter	Maximum Detected Concentration	Essential Nutrient?	Constituent Eliminated as an IHS?	Frequency of Detection	Does Frequency of Detection Exceed 5%?	Constituent Eliminated as an IHS?	Background Concentration[b]	Does Maximum Exceed Background?	Constituent Eliminated as an IHS?	Method A Cleanup Level	Does Maximum Exceed Method A?	Constituent Eliminated as an IHS?	Method B Cleanup Level	Adjustment Factor for Aggregate Risk	Site-Specific Method B Cleanup Level	Does Maximum Exceed Method B?	Constituent Eliminated as an IHS?	IHSs for Copper Creek Sediment/ Concentrate
Total Metals (mg/kg)																		
Aluminum	63000	No		100%	Yes		73000						8.00E+04		8.00E+04	No	ELIMINATED	
Arsenic	nd																	
Barium	3000	No		100%	Yes		300-390						5.60E+03		5.60E+03	No	ELIMINATED	
Beryllium	1	No		50%	Yes		nd - 1						2.33E-01	7	3.33E-02	Yes		IHS
Cadmium	0.087	No		33%	Yes		nd - 0.081			2	No	ELIMINATED						
Calcium	32000	Yes	ELIMINATED															
Chromium[a]	1000	No		100%	Yes		280-1000			100	Yes		4.00E+02	7	5.71E+01	Yes		IHS
Copper	300	No		100%	Yes		43-300						2.96E+03		2.96E+03	No	ELIMINATED	
Iron	75000	Yes	ELIMINATED															
Lead	29	No		67%	Yes		nd-7			250	No	ELIMINATED						
Magnesium	40000	Yes	ELIMINATED															
Manganese	1200	No		100%	Yes		700-1300						3.73E+03	4	9.33E+02	Yes		IHS
Mercury																		
Molybdenum	2.7	No		67%	Yes		nd - 20						4.00E+02	4	1.00E+02	No	ELIMINATED	
Nickel	100	No		100%	Yes		140-150						1.60E+03	4	4.00E+02	No	ELIMINATED	
Potassium	7500	Yes	ELIMINATED															
Selenium																		
Silver	0.3	No		33%	Yes		nd						4.00E+02	2	2.00E+02	No	ELIMINATED	
Sodium	20000	Yes	ELIMINATED															
Thallium																		
Uranium	nd																	
Zinc	2000	No		100%	Yes		nd-110						2.40E+04	2	1.20E+04	No	ELIMINATED	
Conventional Analyses (mg/kg)																		
Cyanide, Total																		
Polychlorinated Biphenyls (ug/kg)																		
Aroclor 1016																		
Aroclor 1221																		
Aroclor 1232																		
Aroclor 1242																		
Aroclor 1248																		
Aroclor 1254																		
Aroclor 1260																		
PCBs, total																		
Total Petroleum Hydrocarbons (mg/kg)																		
Gasoline Range Hydrocarbons																		
Diesel Range Hydrocarbons																		
Motor Oil																		

Notes:

[a] Screening Criteria for chromium are for total chromium or chromium VI

[b] Inadequate number of samples to calculate area background. Ranges of Copper Creek sediment/concentrate background samples are shown for comparison purposes only. No constituents are eliminated based on these ranges.

[c] Method A and Method B Cleanup Levels are for soils.

nd = not detected

IHS = Indicator Hazardous Substance

*** = No cleanup levels or toxicity criteria available for risk evaluation. Constituent was not selected as an IHS.

1991-1996 Data

TABLE 7.1-26
HUMAN HEALTH SCREENING OF COPPER CREEK DIVERSION SEDIMENT SAMPLE RESULTS
HOLDEN MINE
BASELINE RISK ASSESSMENT

		STEP 1		STEP 2			STEP 3			STEP 4			STEP 5					STEP 6
Parameter	Maximum Detected Concentration	Essential Nutrient?	Constituent Eliminated as an IHS?	Frequency of Detection	Does Frequency of Detection Exceed 5%?	Constituent Eliminated as an IHS?	Background Concentration[b]	Does Maximum Exceed Background?	Constituent Eliminated as an IHS?	Method A Cleanup Level	Does Maximum Exceed Method A?	Constituent Eliminated as an IHS?	Method B Cleanup Level	Adjustment Factor for Aggregate Risk	Site-Specific Method B Cleanup Level	Does Maximum Exceed Method B?	Constituent Eliminated as an IHS?	IHSs for Copper Creek Sediment/ Concentrate
Total Metals (mg/kg)																		
Aluminum	59000	No		100%	Yes		73000						8.00E+04		8.00E+04	No	ELIMINATED	
Arsenic	nd			0%	No	ELIMINATED												
Barium	210	No		100%	Yes		300-390						5.60E+03		5.60E+03	No	ELIMINATED	
Beryllium	nd	No		0%	No	ELIMINATED												
Cadmium	8	No		100%	Yes		nd - 0.081			2	Yes		8.00E+01	7	1.14E+01	No	ELIMINATED	
Calcium	27000	Yes	ELIMINATED															
Chromium[a]	110	No		100%	Yes		280-1000			100	Yes		4.00E+02	7	5.71E+01	Yes		IHS
Copper	1000	No		100%	Yes		43-300						2.96E+03		2.96E+03	No	ELIMINATED	
Iron	62000	Yes	ELIMINATED															
Lead	66	No		100%	Yes		nd-7			250	No	ELIMINATED						
Magnesium	26000	Yes	ELIMINATED															
Manganese	830	No		100%	Yes		700-1300						3.73E+03	4	9.33E+02	No	ELIMINATED	
Mercury																		
Molybdenum	2.3	No		100%	Yes		nd - 20						4.00E+02	4	1.00E+02	No	ELIMINATED	
Nickel	51	No		100%	Yes		140-150						1.60E+03	4	4.00E+02	No	ELIMINATED	
Potassium	7400	Yes	ELIMINATED															
Selenium																		
Silver	1.2	No		100%	Yes		nd						4.00E+02	2	2.00E+02	No	ELIMINATED	
Sodium	17000	Yes	ELIMINATED															
Thallium																		
Uranium																		
Zinc	1100	No		100%	Yes		nd-110						2.40E+04	2	1.20E+04	No	ELIMINATED	
Conventional Analyses (mg/kg)																		
Cyanide, Total																		
Polychlorinated Biphenyls (ug/kg)																		
Aroclor 1016																		
Aroclor 1221																		
Aroclor 1232																		
Aroclor 1242																		
Aroclor 1248																		
Aroclor 1254																		
Aroclor 1260																		
PCBs, total																		
Total Petroleum Hydrocarbons (mg/kg)																		
Gasoline Range Hydrocarbons																		
Diesel Range Hydrocarbons																		
Motor Oil																		

Notes:

[a] Screening Criteria for chromium are for total chromium or chromium VI

[b] Inadequate number of samples to calculate area background. Ranges of Copper Creek sediment/concentrate background samples are shown for comparison purposes only. No constituents are eliminated based on these ranges.

[c] Method A and Method B Cleanup Levels are for soils.

nd = not detected

IHS = Indicator Hazardous Substance

*** = No cleanup levels or toxicity criteria available for risk evaluation. Constituent was not selected as an IHS.

Data is from 1933 USGS sample number 346

TABLE 7.1-27
HUMAN HEALTH SCREENING OF RAILROAD CREEK SURFACE WATER SAMPLE RESULTS ADJACENT TO SITE
HOLDEN MINE
BASELINE RISK ASSESSMENT

		STEP 1		STEP 2			STEP 3			STEP 4			STEP 5					STEP 6
Parameter	Maximum Detected Concentration	Essential Nutrient?	Constituent Eliminated as an IHS?	Frequency of Detection	Does Frequency of Detection Exceed 5%?	Constituent Eliminated as an IHS?	Background Concentration	Does Maximum Exceed Background?	Constituent Eliminated as an IHS?	Method A Cleanup Level	Does Maximum Exceed Method A?	Constituent Eliminated as an IHS?	Method B Cleanup Level	Adjustment Factor for Aggregate Risk	Site-Specific Method B Cleanup Level	Does Maximum Exceed Method B?	Constituent Eliminated as an IHS?	IHSs for Railroad Creek Surface Water (Adjacent to Site)
Total Metals (ug/l)																		
Aluminum	300	No		100%	Yes		144	Yes					1.12E+04		1.12E+04	No	ELIMINATED	
Arsenic	1	No		78%	Yes		1.44	No	ELIMINATED									
Barium	6.2	No		100%	Yes		6.24	No	ELIMINATED									
Beryllium	nd																	
Cadmium	1.09	No		71%	Yes		0.1	Yes		10	No	ELIMINATED						
Calcium	10000	Yes	ELIMINATED															
Chromium[a]	0.2	No		3%	No	ELIMINATED												
Copper	79	No		56%	Yes		1.83	Yes		1300	No	ELIMINATED						
Iron	7000	Yes	ELIMINATED															
Lead	15	No		25%	Yes		0.3	Yes		50	No	ELIMINATED						
Magnesium	1900	Yes	ELIMINATED															
Manganese	65	No		95%	Yes		5.06	Yes		50	Yes		1.22E+03	4	3.05E+02	No	ELIMINATED	
Mercury	0.001	No		50%	Yes		0.00066	Yes		0.14	No	ELIMINATED						
Molybdenum	0.73	No		65%	Yes		0.79	No	ELIMINATED									
Nickel	2.3	No		68%	Yes		0.4	Yes		610	No	ELIMINATED						
Potassium	1010	Yes	ELIMINATED															
Selenium	nd																	
Silver	0.17	No		23%	Yes		0.1	Yes					2.59E+04	2	1.30E+04	No	ELIMINATED	
Sodium	1700	Yes	ELIMINATED															
Thallium	nd																	
Uranium	0.05	No		29%	Yes								7.78E+01	4	1.95E+01	No	ELIMINATED	
Zinc	185	No		93%	Yes		5	Yes					1.65E+04	2	8.25E+03	No	ELIMINATED	
Conventional Analyses (mg/l)																		
Cyanide, Total																		
Polychlorinated Biphenyls (ug/l)																		
Aroclor 1016																		
Aroclor 1221																		
Aroclor 1232																		
Aroclor 1242																		
Aroclor 1248																		
Aroclor 1254																		
Aroclor 1260																		
PCBs, total																		
Total Petroleum Hydrocarbons (mg/l)																		
Gasoline Range Hydrocarbons																		
Diesel Range Hydrocarbons																		
Motor Oil																		

Notes:

[a] Screening Criteria for chromium are for total chromium or chromium VI

nd = not detected

IHS = Indicator Hazardous Substance

"---" = No cleanup levels or toxicity criteria available for risk evaluation. Constituent was not selected as an IHS

1991 - 1997 Data. Total metals only

TABLE 7.1-28
HUMAN HEALTH SCREENING OF RAILROAD CREEK SURFACE WATER SAMPLE RESULTS DOWNGRADIENT FROM SITE
HOLDEN MINE
BASELINE RISK ASSESSMENT

		STEP 1		STEP 2			STEP 3			STEP 4			STEP 5					STEP 6
Parameter	Maximum Detected Concentration	Essential Nutrient?	Constituent Eliminated as an IHS?	Frequency of Detection	Does Frequency of Detection Exceed 5%?	Constituent Eliminated as an IHS?	Background Concentration	Does Maximum Exceed Background?	Constituent Eliminated as an IHS?	Method A Cleanup Level	Does Maximum Exceed Method A?	Constituent Eliminated as an IHS?	Method B Cleanup Level	Adjustment Factor for Aggregate Risk	Site-Specific Method B Cleanup Level	Does Maximum Exceed Method B?	Constituent Eliminated as an IHS?	IHSs for Railroad Creek Surface Water (Downgradient from Site)
Total Metals (ug/l)																		
Aluminum	300	No		100%	Yes		144	Yes					1.12E+04		1.12E+04	No	ELIMINATED	
Arsenic	0.76	No		79%	Yes		1.44	No	ELIMINATED									
Barium	10	No		100%	Yes		6.24	Yes		1000	No	ELIMINATED						
Beryllium	nd																	
Cadmium	0.66	No		80%	Yes		0.1	Yes		10	No	ELIMINATED						
Calcium	9950	Yes	ELIMINATED															
Chromium[a]	0.2			12%			0.46	No	ELIMINATED									
Copper	43.5	No		51%	Yes		1.83	Yes		1300	No	ELIMINATED						
Iron	2300	Yes	ELIMINATED															
Lead	11	No		20%	Yes		0.3	Yes		50	No	ELIMINATED						
Magnesium	1490	Yes	ELIMINATED															
Manganese	26	No		100%	Yes		5.06	Yes		50	No	ELIMINATED						
Mercury	0.002	No		63%	Yes		0.00066	Yes		0.14	No	ELIMINATED						
Molybdenum	0.68	No		100%	Yes		0.79	No	ELIMINATED									
Nickel	0.6	No		67%	Yes		0.4	Yes		610	No	ELIMINATED						
Potassium	870	Yes	ELIMINATED															
Selenium	nd																	
Silver	0.2	No		17%	Yes		0.1	Yes					2.59E+04	2	1.30E+04	No	ELIMINATED	
Sodium	2100	Yes	ELIMINATED															
Thallium	1	No		13%	Yes					1.7	No	ELIMINATED						
Uranium	0.1	No		100%	Yes								7.78E+01	4	1.95E+01	No	ELIMINATED	
Zinc	140	No		81%	Yes		5	Yes					1.65E+04	2	8.25E+03	No	ELIMINATED	
Conventional Analyses (mg/l)																		
Cyanide, Total																		
Polychlorinated Biphenyls (ug/l)																		
Aroclor 1016																		
Aroclor 1221																		
Aroclor 1232																		
Aroclor 1242																		
Aroclor 1248																		
Aroclor 1254																		
Aroclor 1260																		
PCBs, total																		
Total Petroleum Hydrocarbons (mg/l)																		
Gasoline Range Hydrocarbons																		
Diesel Range Hydrocarbons																		
Motor Oil																		

Notes:

[a] Screening Criteria for chromium are for total chromium or chromium VI

nd = not detected

IHS = Indicator Hazardous Substance

*** = No cleanup levels or toxicity criteria available for risk evaluation. Constituent was not selected as an IHS.

1991 - 1997 Data. Total metals only.

TABLE 7.1-29
HUMAN HEALTH SCREENING OF COPPER CREEK SURFACE WATER SAMPLE RESULTS
HOLDEN MINE
BASELINE RISK ASSESSMENT

		STEP 1		STEP 2			STEP 3			STEP 4			STEP 5					STEP 6
Parameter	Maximum Detected Concentration	Essential Nutrient?	Constituent Eliminated as an IHS?	Frequency of Detection	Does Frequency of Detection Exceed 5%?	Constituent Eliminated as an IHS?	Background Concentration	Does Maximum Exceed Background?	Constituent Eliminated as an IHS?	Method A Cleanup Level	*Does* Maximum Exceed Method A?	Constituent Eliminated as an IHS?	Method B Cleanup Level	*Adjustment* Factor for Aggregate Risk	Site-Specific Method B Cleanup Level	Does Maximum Exceed Method B?	Constituent Eliminated as an IHS?	IHSs for Copper Creek Surface Water
Total Metals (ug/l)																		
Aluminum	170	No		88%	Yes		144	Yes					1.12E+04		1.12E+04	No	ELIMINATED	
Arsenic	nd																	
Barium	20	No		100%	Yes		6.24	Yes		1000	No	ELIMINATED						
Beryllium	nd																	
Cadmium	nd																	
Calcium	6000	Yes	ELIMINATED															
Chromium[a]	0.4	No		11%			0.46	No	ELIMINATED									
Copper	1	No		16%	Yes		1.83	No	ELIMINATED									
Iron	230	Yes	ELIMINATED															
Lead	0.3	No		6%	Yes		0.3	No	ELIMINATED									
Magnesium	540	Yes	ELIMINATED															
Manganese	206	No		50%	Yes		5.06	Yes		50	Yes		1.22E+03	4	3.05E+02	No	ELIMINATED	
Mercury																		
Molybdenum	200	No		33%	Yes		0.79	Yes					1.30E+02	4	3.25E+01	Yes		IHS
Nickel	0.7	No		43%	Yes		0.4	Yes		610	No	ELIMINATED						
Potassium	700	Yes	ELIMINATED															
Selenium	nd																	
Silver	nd																	
Sodium	1100	Yes	ELIMINATED															
Thallium																		
Uranium																		
Zinc	13	No		22%	Yes		5	Yes					1.65E+04	2	8.25E+03	No	ELIMINATED	
Conventional Analyses (mg/l)																		
Cyanide, Total																		
Polychlorinated Biphenyls (ug/l)																		
Aroclor 1016																		
Aroclor 1221																		
Aroclor 1232																		
Aroclor 1242																		
Aroclor 1248																		
Aroclor 1254																		
Aroclor 1260																		
PCBs, total																		
Total Petroleum Hydrocarbons (mg/l)																		
Gasoline Range Hydrocarbons																		
Diesel Range Hydrocarbons																		
Motor Oil																		

Notes:

[a]Screening Criteria for chromium are for total chromium or chromium VI

nd = not detected

IHS = Indicator Hazardous Substance

*** = No cleanup levels or toxicity criteria available for risk evaluation. Constituent was not selected as an IHS.

1991 - 1997 Data. Total metals only.

TABLE 7.1-30
HUMAN HEALTH SCREENING OF SEEP SAMPLE RESULTS
HOLDEN MINE
BASELINE RISK ASSESSMENT

		STEP 1		STEP 2			STEP 3			STEP 4			STEP 5					STEP 6
Parameter	Maximum Detected Concentration	Essential Nutrient?	Constituent Eliminated as an IHS?	Frequency of Detection	Does Frequency of Detection Exceed 5%?	Constituent Eliminated as an IHS?	Background Concentration[c]	11	Constituent Eliminated as an IHS?	Method A Cleanup Level[b]	Does Maximum Exceed Method A?	Constituent Eliminated as an IHS?	Method B Cleanup Level	Adjustment Factor for Aggregate Risk	Site-Specific Method B Cleanup Level	Does Maximum Exceed Method B?	Constituent Eliminated as an IHS?	IHSs for Total Metals in Seeps
Total Metals (ug/l)																		
Aluminum	95000	No		100%	Yes		440						1.60E+04		1.60E+04	Yes		IHS
Arsenic	0.35	No		50%	Yes					5	No	ELIMINATED						
Barium	44	No		94%	Yes		18			2000	No	ELIMINATED						
Beryllium	0.06	No		6%	Yes		<4			4	No	ELIMINATED						
Cadmium	44	No		65%	Yes		3.46			10	Yes		8.00E+00	4	2.00E+00	Yes		IHS
Calcium	410000	Yes	ELIMINATED															
Chromium[a]	nd																	
Copper	1300	No		75%	Yes		830			1300	No	ELIMINATED						
Iron	1700000	Yes	ELIMINATED															
Lead	76	No		30%	Yes		6			5	Yes			7				IHS
Magnesium	240000	Yes	ELIMINATED															
Manganese	16000	No		95%	Yes		9						7.47E+02	4	1.87E+02	Yes		IHS
Mercury	0.015	No		50%	Yes					2	No	ELIMINATED						
Molybdenum	0.34	No		6%	Yes								8.00E+01	4	2.00E+01	No	ELIMINATED	
Nickel	45	No		16%	Yes		<10			100	No	ELIMINATED						
Potassium	32000	Yes	ELIMINATED															
Selenium	93	No		50%						50	Yes		8.00E+01		8.00E+01	Yes		IHS
Silver	0.17	No		50%			0.05						8.00E+01	2	4.00E+01	No	ELIMINATED	
Sodium	31000	Yes	ELIMINATED															
Thallium	nd																	
Uranium	0.13	No		100%	Yes								4.80E+01	4	1.20E+01	No	ELIMINATED	
Zinc	8100	No		100%	Yes		446						4.80E+03	2	2.40E+03	Yes		IHS
Conventional Analyses (mg/l)																		
Cyanide, Total																		
Polychlorinated Biphenyls (ug/l)																		
Aroclor 1016																		
Aroclor 1221																		
Aroclor 1232																		
Aroclor 1242																		
Aroclor 1248																		
Aroclor 1254																		
Aroclor 1260																		
PCBs, total																		
Total Petroleum Hydrocarbons (mg/l)																		
Gasoline Range Hydrocarbons																		
Diesel Range Hydrocarbons																		
Motor Oil																		

Notes:

[a] Screening Criteria for chromium are for total chromium or chromium VI

[b] Maximum Contaminant Level used if Method A cleanup level not available

[c] Only one sample collected. Sample result is shown for comparison purposes only. No constituents are eliminated based on these ranges.

nd = not detected

IHS = Indicator Hazardous Substance

"---" = No cleanup levels or toxicity criteria available for risk evaluation. Constituent was not selected as an IHS.

1991 - 1997 Data. Total metals only.

TABLE 7.1-31
HUMAN HEALTH SCREENING OF MINE PORTAL DRAINAGE SAMPLE RESULTS
HOLDEN MINE
BASELINE RISK ASSESSMENT

		STEP 1		STEP 2			STEP 3			STEP 4			STEP 5					STEP 6
Parameter	Maximum Detected Concentration	Essential Nutrient?	Constituent Eliminated as an IHS?	Frequency of Detection	Does Frequency of Detection Exceed 5%?	Constituent Eliminated as an IHS?	Background Concentration	Does Maximum Exceed Background?	Constituent Eliminated as an IHS?	Method A Cleanup Level[b]	Does Maximum Exceed Method A?	Constituent Eliminated as an IHS?	Method B Cleanup Level	Adjustment Factor for Aggregate Risk	Site-Specific Method B Cleanup Level	Does Maximum Exceed Method B?	Constituent Eliminated as an IHS?	IHSs for Mine Portal Drainage
Total Metals (ug/l)																		
Aluminum	22600	No		100%	Yes								1.60E+04		1.60E+04	Yes		HIS
Arsenic	0.3	No		20%	Yes					5	No	ELIMINATED						
Barium	19	No		100%	Yes					2000	No	ELIMINATED						
Beryllium	0.3	No		6%	Yes					4	No	ELIMINATED						
Cadmium	170	No		72%	Yes					10	Yes		8.00E+00	4	2.00E+00	Yes		IHS
Calcium	150000	Yes	ELIMINATED															
Chromium[a]	nd																	
Copper	10400	No		97%	Yes					1300	Yes		5.92E+02		5.92E+02	Yes		IHS
Iron	3500	Yes	ELIMINATED															
Lead	64	No		54%	Yes					5	Yes			7				IHS
Magnesium	14500	Yes	ELIMINATED															
Manganese	703	No		100%	Yes								7.47E+02	4	1.87E+02	Yes		IHS
Mercury	0.0031	No		100%	Yes					2	No	ELIMINATED						
Molybdenum	10	No		17%	Yes								8.00E+01	4	2.00E+01	No	ELIMINATED	
Nickel	6	No		29%	Yes					100	No	ELIMINATED						
Potassium	6615	Yes	ELIMINATED															
Selenium	nd																	
Silver	0.2	No		8%	Yes								2.59E+04	2	1.30E+04	No	ELIMINATED	
Sodium	26000	Yes	ELIMINATED															
Thallium	0.3	No		17%	Yes					2	No	ELIMINATED						
Uranium	4.6	No		33%	Yes								4.80E+01	4	1.20E+01	No	ELIMINATED	
Zinc	27800	No		100%	Yes								4.80E+03	2	2.40E+03	Yes		IHS
Conventional Analyses (mg/l)																		
Cyanide, Total																		
Polychlorinated Biphenyls (ug/l)																		
Aroclor 1016																		
Aroclor 1221																		
Aroclor 1232																		
Aroclor 1242																		
Aroclor 1248																		
Aroclor 1254																		
Aroclor 1260																		
PCBs, total																		
Total Petroleum Hydrocarbons (mg/l)																		
Gasoline Range Hydrocarbons																		
Diesel Range Hydrocarbons																		
Motor Oil																		

Notes:

[a] Screening Criteria for chromium are for total chromium or chromium VI

[b] Maximum Contaminant Level used if Method A cleanup level not available

nd = not detected

IHS = Indicator Hazardous Substance

"*" = No cleanup levels or toxicity criteria available for risk evaluation Constituent was not selected as an IHS.

1991 - 1997 Data. Total metals only

TABLE 7.1-32
HUMAN HEALTH SCREENING OF VENTILATOR PORTAL SAMPLE RESULTS
HOLDEN MINE
BASELINE RISK ASSESSMENT

		STEP 1		STEP 2			STEP 3			STEP 4			STEP 5					STEP 6
Parameter	Maximum Detected Concentration	Essential Nutrient?	Constituent Eliminated as an IHS?	Frequency of Detection	Does Frequency of Detection Exceed 5%?	Constituent Eliminated as an IHS?	Background Concentration	Does Maximum Exceed Background?	Constituent Eliminated as an IHS?	Method A Cleanup Level[b]	Does Maximum Exceed Method A?	Constituent Eliminated as an IHS?	Method B Cleanup Level	Adjustment Factor for Aggregate Risk	Site-Specific Method B Cleanup Level	Does Maximum Exceed Method B?	Constituent Eliminated as an IHS?	IHSs for Mine Portal Drainage
Total Metals (ug/l)																		
Aluminum	4400	No		100%	Yes								1.60E+04		1.60E+04	No	ELIMINATED	
Arsenic	0.64	No		100%	Yes					5	No	ELIMINATED						
Barium	27.6	No		100%	Yes					2000	No	ELIMINATED						
Beryllium	nd																	
Cadmium	0.09	No		100%	Yes					10	No	ELIMINATED						
Calcium	5400	Yes	ELIMINATED															
Chromium[a]	3	No		100%	Yes					50	No	ELIMINATED						
Copper	9.6	No		100%	Yes					1300	No	ELIMINATED						
Iron	3510	Yes	ELIMINATED															
Lead	2.9	No		100%	Yes					5	No	ELIMINATED						
Magnesium	1870	Yes	ELIMINATED															
Manganese	40.6	No		100%	Yes					50	No	ELIMINATED						
Mercury																		
Molybdenum	0.26	No		100%	Yes								8.00E+01	4	2.00E+01	No	ELIMINATED	
Nickel	3.3	No		100%	Yes					100	No	ELIMINATED						
Potassium	870	Yes	ELIMINATED															
Selenium																		
Silver	nd																	
Sodium	1360	Yes	ELIMINATED															
Thallium																		
Uranium																		
Zinc	13	No		100%	Yes								4.80E+03	2	2.40E+03	No	ELIMINATED	
Conventional Analyses (mg/l)																		
Cyanide, Total																		
Polychlorinated Biphenyls (ug/l)																		
Aroclor 1016																		
Aroclor 1221																		
Aroclor 1232																		
Aroclor 1242																		
Aroclor 1248																		
Aroclor 1254																		
Aroclor 1260																		
PCBs, total																		
Total Petroleum Hydrocarbons (mg/l)																		
Gasoline Range Hydrocarbons																		
Diesel Range Hydrocarbons																		
Motor Oil																		

Notes:

[a] Screening Criteria for chromium are for total chromium or chromium VI

[b] Maximum Contaminant Level used if Method A cleanup level not available

nd = not detected

IHS = Indicator Hazardous Substance

*** = No cleanup levels or toxicity criteria available for risk evaluation. Constituent was not selected as an IHS.

1991 - 1997 Data. Total metals only.

TABLE 7.1-33
HUMAN HEALTH SCREENING OF COPPER CREEK DIVERSION (SAUNA/POND) SAMPLE RESULTS
HOLDEN MINE
BASELINE RISK ASSESSMENT

		STEP 1		STEP 2			STEP 3			STEP 4			STEP 5					STEP 6
Parameter	Maximum Detected Concentration	Essential Nutrient?	Constituent Eliminated as an IHS?	Frequency of Detection	Does Frequency of Detection Exceed 5%?	Constituent Eliminated as an IHS?	Background Concentration	Does Maximum Exceed Background?	Constituent Eliminated as an IHS?	Method A Cleanup Level[b]	Does Maximum Exceed Method A?	Constituent Eliminated as an IHS?	Method B Cleanup Level	Adjustment Factor for Aggregate Risk	Site-Specific Method B Cleanup Level	Does Maximum Exceed Method B?	Constituent Eliminated as an IHS?	IHSs for Copper Creek Diversion (Sauna/Pond)
Metals (ug/l)																		
Aluminum	20	No		25%	Yes		144	No	ELIMINATED									
Arsenic	nd																	
Barium	14	No		89%	Yes		6.24	Yes		2000	No	ELIMINATED						
Beryllium	nd																	
Cadmium	2.57	No		11%	Yes		0.1	Yes		10	No	ELIMINATED						
Calcium	5770	Yes	ELIMINATED															
Chromium[a]	nd																	
Copper	155	No		44%	Yes		1.83	Yes		1300	No	ELIMINATED						
Iron	230	Yes	ELIMINATED															
Lead	0.3	No		11%	Yes		0.3	No	ELIMINATED									
Magnesium	720	Yes	ELIMINATED															
Manganese	15.5	No		11%	Yes		5.06	Yes					7 47E+02	4	1.87E+02	No	ELIMINATED	
Mercury	0 00022	No		25%	Yes		0.00066	No	ELIMINATED									
Molybdenum	0.5	No		22%	Yes		0.79	No	ELIMINATED									
Nickel	2	No		11%	Yes		0.4	Yes		100	No	ELIMINATED						
Potassium	1000	Yes	ELIMINATED															
Selenium	nd																	
Silver	nd																	
Sodium	830	Yes	ELIMINATED															
Thallium	nd																	
Uranium	nd																	
Zinc	372	No		67%	Yes		5	Yes					4.80E+03	2	2.40E+03	No	ELIMINATED	
Conventional Analyses (mg/l)																		
Cyanide, Total	nd																	
Polychlorinated Biphenyls (ug/l)																		
Aroclor 1016																		
Aroclor 1221																		
Aroclor 1232																		
Aroclor 1242																		
Aroclor 1248																		
Aroclor 1254																		
Aroclor 1260																		
PCBs, total																		
Total Petroleum Hydrocarbons (mg/l)																		
Gasoline Range Hydrocarbons																		
Diesel Range Hydrocarbons																		
Motor Oil																		

Notes:

[a] Screening Criteria for chromium are for total chromium or chromium VI

[b] Maximum Contaminant Level used if Method A cleanup level not available

nd = not detected

IHS = Indicator Hazardous Substance

*** = No cleanup levels or toxicity criteria available for risk evaluation. Constituent was not selected as an IHS

1991 - 1997 Data - Total and dissolved metals data were combined.

TABLE 7.1-34
HUMAN HEALTH SCREENING OF GROUNDWATER SAMPLE RESULTS (LUCERNE WELL ONLY)
HOLDEN MINE
BASELINE RISK ASSESSMENT

		STEP 1		STEP 2			STEP 3			STEP 4			STEP 5					STEP 6
Parameter	Maximum Detected Concentration	Essential Nutrient?	Constituent Eliminated as an IHS?	Frequency of Detection	Does Frequency of Detection Exceed 5%?	Constituent Eliminated as an IHS?	Background Concentration[c]	Does Maximum Exceed Background?	Constituent Eliminated as an IHS?	Method A Cleanup Level[b]	Does Maximum Exceed Method A?	Constituent Eliminated as an IHS?	Method B Cleanup Level	Adjustment Factor for Aggregate Risk	Site-Specific Method B Cleanup Level	Does Maximum Exceed Method B?	Constituent Eliminated as an IHS?	IHSs for Groundwater
Total Metals (ug/l)																		
Aluminum	nd																	
Arsenic																		
Barium	30	No		100%	Yes		2 - <14	Yes		*2000*	No	*ELIMINATED*						
Beryllium	nd																	
Cadmium	nd																	
Calcium	14500	Yes	ELIMINATED															
Chromium[a]	nd																	
Copper	nd																	
Iron	310	Yes	ELIMINATED															
Lead	nd																	
Magnesium	2140	Yes	ELIMINATED															
Manganese	8	No		100%	Yes		<1 - 2	Yes					7.47E+02	4	1.87E+02	No	ELIMINATED	
Mercury																		
Molybdenum																		
Nickel	nd																	
Potassium	1470	Yes	ELIMINATED															
Selenium																		
Silver	nd																	
Sodium	3480	Yes	ELIMINATED															
Thallium																		
Uranium																		
Zinc	147	No		100%	Yes		<4 - 7	Yes					4.80E+03	2	2.40E+03	No	ELIMINATED	
Conventional Analyses (mg/l)																		
Cyanide, Total																		
Polychlorinated Biphenyls (ug/l)																		
Aroclor 1016																		
Aroclor 1221																		
Aroclor 1232																		
Aroclor 1242																		
Aroclor 1248																		
Aroclor 1254																		
Aroclor 1260																		
PCBs, total																		
Total Petroleum Hydrocarbons (mg/l)																		
Gasoline Range Hydrocarbons																		
Diesel Range Hydrocarbons																		
Motor Oil																		

Notes:

[a] Screening Criteria for chromium are for total chromium or chromium VI

[b] Maximum Contaminant Level used if Method A cleanup level not available

[c] Inadequate number of samples to calculate area background Ranges of background samples are shown for comparison purposes only. No constituents are eliminated based on these ranges

nd = not detected

IHS = Indicator Hazardous Substance

*** = No cleanup levels or toxicity criteria available for risk evaluation Constituent was not selected as an IHS.

1997 Data. Total metals only.

TABLE 7.1-35
HUMAN HEALTH SCREENING OF FISH MUSCLE TISSUE SAMPLE RESULTS
HOLDEN MINE
BASELINE RISK ASSESSMENT

		STEP 1		STEP 2			STEP 3			STEP 4			STEP 5					STEP 6
Parameter	Maximum Detected Downstream Mean Concentration	Essential Nutrient?	Constituent Eliminated as an IHS?	Frequency of Detection	Does Frequency of Detection Exceed 5%?	Constituent Eliminated as an IHS?	Background Concentration[a]	Does Maximum Exceed Background?	Constituent Eliminated as an IHS?	Region III RBC for Fish	Does Maximum Exceed Method A?	Constituent Eliminated as an IHS?	Method B Cleanup Level	Adjustment Factor for Aggregate Risk	Site-Specific Method B Cleanup Level	Does Maximum Exceed Method B?	Constituent Eliminated as an IHS?	IHSs for Fish Muscle Tissue
Total Metals (mg/kg)																		
Aluminum	nd																	
Arsenic	nd																	
Barium																		
Beryllium																		
Cadmium																		
Calcium																		
Chromium[a]																		
Copper	4.44			100%	Yes		0.58-0.98			54	No	ELIMINATED						
Iron	7.1	Yes	ELIMINATED															
Lead	nd																	
Magnesium																		
Manganese																		
Mercury	0.018			100%	Yes		0.038			0.14	No	ELIMINATED						
Molybdenum																		
Nickel	nd																	
Potassium																		
Selenium	0.74			100%	Yes		0.65			6.8	No	ELIMINATED						
Silver																		
Sodium																		
Thallium																		
Uranium																		
Zinc	10.83			100%	Yes		8.65-9.74			410	No	ELIMINATED						
Conventional Analyses (mg/kg)																		
Cyanide, Total																		
Polychlorinated Biphenyls (mg/kg)																		
Aroclor 1016																		
Aroclor 1221																		
Aroclor 1232																		
Aroclor 1242																		
Aroclor 1248																		
Aroclor 1254																		
Aroclor 1260																		
PCBs, total																		
Total Petroleum Hydrocarbons (mg/kg)																		
Gasoline Range Hydrocarbons																		
Diesel Range Hydrocarbons																		
Motor Oil																		

Notes:

[a] Inadequate number of samples to calculate background. Ranges of background samples are shown for comparison purposes only. No constituents are eliminated based on these ranges.

nd = not detected

IHS = Indicator Hazardous Substance

"--" = No cleanup levels or toxicity criteria available for risk evaluation. Constituent was not selected as an IHS

1989-1992 PNL and WADOE Data - Site and downstream only

TABLE 7.1-36
EXPOSURE PATHWAYS AND INDICATOR HAZARDOUS SUBSTANCES ADDRESSED IN SITE-SPECIFIC HUMAN HEALTH RISK ASSESSMENT
HOLDEN MINE
BASELINE RISK ASSESSMENT

Media	Location	Route	IHS
Soil	Holden Village	Ingestion	Beryllium
		Inhalation of particulates	Chromium
	Maintentance Yard	Ingestion	Arsenic Cadmium Copper Lead Gasoline range hydrocarbons Diesel range hydrocarbons Motor oil range hydrocarbons
	Lagoon	Ingestion	Beryllium Cadmium Copper Lead Zinc Diesel range hydrocarbons Motor oil range hydrocarbons
		Inhalation of particulates	Cadmium
	Forest Service Guard Station	Ingestion	Arsenic Beryllium
		Inhalation of particulates	Arsenic
Sediments	Railroad Creek Adjacent to Site	Ingestion	Aluminum Arsenic Beryllium Chromium Manganese Molybdenum
	Railroad Creek Downgradient	Ingestion	Aluminum Beryllium Chromium Manganese
	Copper Creek	Ingestion	Beryllium Chromium Manganese
	Copper Creek Diversion	Ingestion	Chromium
Air	Throughout Site Area	Inhalation of particulates	Manganese
Surface Water	Copper Creek	Ingestion/Ingestion of fish	Molybdenum
Seeps	Throughout Site Area	Ingestion	Aluminum Cadmium Lead Manganese Selenium Zinc
Portal Drainage	Throughout Site Area	Ingestion	Aluminum Cadmium Copper Lead Manganese Zinc

TABLE 7.1-37
EXPOSURE CONCENTRATIONS USED FOR SITE-SPECIFIC HUMAN HEALTH RISK ASSESSMENT
HOLDEN MINE
BASELINE RISK ASSESSMENT

Parameter	Soil (mg/kg)				Sediments				Air	Surface Water	Seeps	Portal Drainage
	Holden Village[a]	Maintenance Yard[b]	Lagoon[b]	Forest Service Guard Station[b]	Railroad Creek Adjacent to Site[c]	Railroad Creek Downgradient from Site[c]	Copper Creek[b]	Copper Creek Diversion[b]	Throughout Site Area	Copper Creek[b]	Throughout Site	Throughout Site[a]
Metals												
Aluminum					4.63E+04	8.90E+04					4.54E+04	9.88E+03
Arsenic		6.00E+01		2.52E+01	1.26E+02							
Barium												
Beryllium	2.60E-01		3.00E-01	2.20E-01	1.00E+00	1.00E+00	1.00E+00					
Cadmium		2.16E+01	1.84E+02								1.75E+01	1.70E+02
Calcium												
Chromium	3.43E+01				4.06E+02	3.40E+02	1.00E+03	1.10E+02				
Copper		3.16E+03	2.41E+04									6.60E+03
Iron												
Lead		1.07E+03	6.20E+02								7.60E+01	3.87E+01
Magnesium												
Manganese					1.40E+03	1.03E+03	1.20E+03		2.00E-05		9.37E+03	3.86E+02
Mercury, inorganic												
Molybdenum					2.68E+03					2.00E+02		
Nickel												
Potassium												
Selenium											9.30E+01	
Silver												
Sodium												
Thallium, soluble salts												
Uranium, soluble salts												
Zinc			2.37E+04								9.77E+03	8.85E+03
Conventional Analyses												
Cyanide, Total												
Polychlorinated Biphenyls												
Aroclor 1016												
Aroclor 1221												
Aroclor 1232												
Aroclor 1242												
Aroclor 1248												
Aroclor 1254												
Aroclor 1260												
PCBs, total												
Total Petroleum Hydrocarbons												
Gasoline Range Hydrocarbons		1.70E+03										
Diesel Range Hydrocarbons		1.20E+04	2.30E+02									
Motor Oil		9.80E+03	4.40E+02									

[a] Based on UCL value

[b] Insufficient number of samples or detections to calculate UCL value Exposure concentration is the maximum detected concentration

[c] Aluminum, cadmium, chromium, copper, manganese, molybdenum, and zinc based on UCL value. Others based on maximum detected concentration due to insufficient samples or detections

[d] Selenium based on maximum value Others based on UCL value.

TABLE 7.1-38
TOXICITY CRITERIA AND BIOCONCENTRATION FACTORS USED FOR SITE-SPECIFIC HUMAN HEALTH RISK ASSESSMENT
HOLDEN MINE
BASELINE RISK ASSESSMENT

Parameter	Toxic Effects Endpoint	Carcinogen Classification	Oral Reference Dose (mg/kg-day)	Source	Inhalation Reference Dose (mg/kg-day)	Source	Oral Cancer Potency Factor (per mg/kg-day)	Source	Inhalation Cancer Potency Factor (per mg/kg-day)	Source	Bioconcentration Factor (unitless)	Source
Metals												
Aluminum	NA	NA	1	NCEA Support value	NA	NA	NA	NA	NA	NA	231	ORNL
Arsenic	Skin lesions	A	0.0003	CLARC II (1996)	NA	NA	1.5	CLARC II (1996)	50	CLARC II (1996)	44	CLARC II (1996)
Beryllium	NA	B2	0.005	CLARC II (1996)	NA	NA	4.3	CLARC II (1996)	8.4	CLARC II (1996)	19	CLARC II (1996)
Cadmium	Nephrotoxicity	B1	0.0005	CLARC II (1996)	NA	NA	NA	NA	6.1	CLARC II (1996)	64	CLARC II (1996)
Chromium	NA	A	0.005	CLARC II (1996)	NA	NA	NA	NA	41	CLARC II (1996)	16	CLARC II (1996)
Copper	Gastrointestinal toxicity	D	0.037	CLARC II (1996)	NA	NA	NA	NA	NA	NA	36	CLARC II (1996)
Lead	Neurotoxicity	B2	NA	NA	NA	NA	NA	NA	NA	NA	49	SPHEM
Manganese	Neurotoxicity	D	0.047	CLARC II (1996)	0.000014	CLARC II (1996)	NA	NA	NA	NA	100	Conservative estimate
Molybdenum	Nephrotoxicity	NA	0.005	CLARC II (1996)	NA	NA	NA	NA	NA	NA	100	Conservative estimate
Selenium	Clinical selenosis	D	0.005	CLARC II (1996)	NA	NA	NA	NA	NA	NA	16	SPHEM
Zinc	Hemotoxicity	D	0.3	CLARC II (1996)	NA	NA	NA	NA	NA	NA	47	CLARC II (1996)
Total Petroleum Hydrocarbons												
Gasoline Range Hydrocarb	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Diesel Range Hydrocarbon	NA	NA	NA	NA	0.00143	CLARC II (1996)	NA	NA	NA	NA	NA	NA
Motor Oil Range Hydrocarb	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA

Notes:
ORNL = Oak Ridge National Laboratory, ES/ER/TM-86/R, 1996..
SPHEM = Superfund Public Health Evaluation Manual. EPA 540/1-86/060. 1986
NCEA = USEPA NCEA support value.
NA = Not Available

TABLE 7.1-39
EXPOSURE FACTORS USED FOR SITE-SPECIFIC HUMAN HEALTH RISK ASSESSMENT
HOLDEN MINE
BASELINE RISK ASSESSMENT

		Media	Soil (mg/kg)								Sediment		Air		Surface Water				Seeps and Portal Drainage	
		Location	Holden Village		Maintenance Yard		Lagoon		Forest Service Guard Station		Railroad and Copper Creek, and Copper Creek Diversion		Throughout Site		Copper Creek				Throughout Site	
		Receptor	Village Child or Adult Resident		Village Adult Worker		Child or Adult Resident/ Recreational User		Forest Service Adult Worker		Child Resident/ Recreational User		Village Child Resident		Child Resident/ Recreational User (ingestion of water)		Adult Resident/Recreational Angler (ingestion of fish)		Child Resident/ Recreational User	
			Value	Source	Value	Source	Value	Source	Value	Source	Value	Source	Value	Source	Value	Source	Value	Source	Value	Source
Exposure Factor	Abbrev.	Units																		
Average Body Weight (ingestion)	ABW1	kg	16	a	70	a	16	a	70	a	16	a	NA		16	a	70	a	16	a
Average Body Weight (inhalation)	ABW2	kg	70	a	NA		70	a	70	a	NA		16	a	NA		NA		NA	
Soil Ingestion Rate	SIR	mg/day	100	a	50	a	100	a	50	a	100	a	NA		NA		NA		NA	
Water Ingestion Rate	DWIR	l/day	NA		NA		NA		NA		NA		NA		0.5	k	NA		0.5	k
Fish Consumption Rate	FCR	g/day	NA		NA		NA		NA		NA		NA		NA		8	j	NA	
Fish Diet Fraction	FDF	unitless	NA		NA		NA		NA		NA		NA		NA		0.1	l	NA	
Frequency of Contact (ingestion)	FOC1	unitless	0.33	b	0.33	b	0.05	d	0.33	b	0.05	d	NA		0.05	d	NA		0.05	d
Frequency of Contact (inhalation)	FOC2	unitless	0.33	b	NA		0.05	d	0.33	b	NA		NA		NA		NA		NA	
Duration of Exposure (ingestion)	DUR1	years	6	a	20	c	6	a	3	e	6	a	NA		6	a	20	c	6	a
Duration of Exposure (inhalation)	DUR2	years	20	c	NA		20	c	3	e	NA		6	a	NA		NA		NA	
Lifetime	LIFE	years	75	a	75	a	75	a	75	a	75	a	75	a	75	a	75	a	75	a
Gastrointestinal Absorption Rate	AB1	unitless	1	a	1	a	1	a	1	a	1	a	NA		NA		NA		NA	
Inhalation Adjustment Factor	INH	unitless	NA		NA		NA		NA		NA		NA		1	a	NA		1	a
Breathing Rate	BR	m3/day	20	a	NA		20	a	20	a	NA		10	a	NA		NA		NA	
Inhalation Absorption Percentage	AB2	unitless	1	a	NA		1	a	1	a	NA		1	a	NA		NA		NA	
Inverse of mean concentration at center of source	Q/C	g/m2-s per kg/m3	42.86	f	NA		82.72	g	82.72	g	NA		NA		NA		NA		NA	
Fraction of vegetative or gravel cover	V	unitless	0.5	h	NA		0	i	0.5	h	NA		NA		NA		NA		NA	
Function dependent on Um & Ut	F(x)	unitless	0.194	h	NA		0.194	h	0.194	h	NA		NA		NA		NA		NA	
Mean annual windspeed	Um	m/sec	4.69	h	NA		4.69	h	4.69	h	NA		NA		NA		NA		NA	
Equivalent threshold value of Windspeed at 7 m	Ut	m/sec	11.32	h	NA		11.32	h	11.32	h	NA		NA		NA		NA		NA	

NA = This factor not relevent for exposure routes

a MTCA default exposure factors for Method C cleanup levels

b Site-specific based on 120 days (4 months) per year when soil is exposed (i.e., 120 days/year divided by 365 days/year)

c Site-specific based on maximum known length of stay in Holden Village

d Site-specific based on one exposure per week for 4 months (17 weeks) per year (i.e., 17 days/year divided by 365 days/year)

e Site-specific based on information provided by Forest Service - 3 years is the maximum number of years expected for volunteers

f USEPA Soil Screening Guidance Q/C for 30 acre site in Seattle area

g USEPA Soil Screening Guidance Q/C for 0.5 acre site in Seattle area

h USEPA Soil Screening Guidance default value

i Assumes no vegetative cover

j USEPA Exposure Factors Handbook (August, 1996) recommended mean value for recreational freshwater anglers (considered conservative for this site)

k Assumes 1/2 daily intake of 1 liter comes from mine-impacted area

l Assumes half the default MTCA value because site-specific information indicates most fishing from Copper Creek is catch and release

TABLE 7.1-40
SITE-SPECIFIC METHOD C CLEANUP
HOLDEN MINE
BASELINE RISK ASSESSMENT

Media	Location	Route	IHS	Units	Method C Noncarcinogen Cleanup Criteria	Method C Carcinogen Cleanup Criteria	Lowest Method C Cleanup Criteria
Soil	Holden Village	Ingestion	Beryllium	mg/kg	2.42E+03	1.41E+01	1.41E+01
		Inhalation of particulates	Chromium	mg/kg		6.03E+03	6.03E+03
	Maintentance Yard	Ingestion	Arsenic	mg/kg	1.27E+03	1.06E+02	1.06E+02
			Cadmium	mg/kg	2.12E+03		2.12E+03
			Copper	mg/kg	1.57E+05		1.57E+05
			Lead	mg/kg			NA
			Gasoline range hydrocarbons	mg/kg			NA
			Diesel range hydrocarbons	mg/kg			NA
			Motor oil range hydrocarbons	mg/kg			NA
	Lagoon	Ingestion	Beryllium	mg/kg	2.12E+04	3.70E+01	3.70E+01
			Cadmium	mg/kg	1.60E+03		1.60E+03
			Copper	mg/kg	1.18E+05		1.18E+05
			Lead	mg/kg			NA
			Zinc	mg/kg	9.60E+05		9.60E+05
			Diesel range hydrocarbons	mg/kg			NA
			Motor oil range hydrocarbons	mg/kg			NA
		Inhalation of particulates	Cadmium	mg/kg		2.58E+05	2.58E+05
	Forest Service Guard Station	Ingestion	Arsenic	mg/kg	3.18E+03	7.07E+02	7.07E+02
			Beryllium	mg/kg	5.30E+04	2.47E+02	2.47E+02
		Inhalation of particulates	Arsenic	mg/kg		6.36E+04	6.36E+04
Sediments	Railroad Creek Adjacent to Site	Ingestion	Aluminum	mg/kg	3.20E+06		3.20E+06
			Arsenic	mg/kg	2.40E+03	2.67E+02	2.67E+02
			Beryllium	mg/kg	1.60E+04	9.30E+01	9.30E+01
			Chromium	mg/kg	1.60E+04		1.60E+04
			Manganese	mg/kg	1.50E+05		1.50E+05
			Molybdenum	mg/kg	1.60E+04		1.60E+04
	Railroad Creek Downgradient	*Ingestion*	*Aluminum*	*mg/kg*	3.20E+06		3.20E+06
			Beryllium	mg/kg	1.60E+04	9.30E+01	9.30E+01
			Chromium	mg/kg	1.60E+04		1.60E+04
			Manganese	mg/kg	1.50E+05		1.50E+05
	Copper Creek	Ingestion	Beryllium	mg/kg	1.60E+04	9.30E+01	9.30E+01
			Chromium	mg/kg	1.60E+04		1.60E+04
			Manganese	mg/kg	1.50E+05		1.50E+05
	Copper Creek Diversion	Ingestion	Chromium	mg/kg	1.60E+04		1.60E+04
Air	Throughout Site Area	Inhalation of particulates	Manganese	ug/m3	5.01E-05		5.01E-05
Surface Water	Copper Creek	Ingestion of water	Molybdenum	ug/l	3.20E+03		3.20E+03
		Ingestion of fish	Molybdenum	ug/l	6.48E+02		6.48E+02
Seeps	Throughout Site Area	Ingestion	Aluminum	ug/l	6.40E+05		6.40E+05
			Cadmium	ug/l	3.20E+02		3.20E+02
			Lead	ug/l			NA
			Manganese	ug/l	3.01E+04		3.01E+04
			Selenium	ug/l	3.20E+03		3.20E+03
			Zinc	ug/l	1.92E+05		1.92E+05
Portal Drainage	Throughout Site Area	Ingestion	Aluminum	ug/l	6.40E+05		6.40E+05
			Cadmium	ug/l	3.20E+02		3.20E+02
			Copper	ug/l	2.37E+04		2.37E+04
			Lead	ug/l			NA
			Manganese	ug/l	3.01E+04		3.01E+04
			Zinc	ug/l	1.92E+05		1.92E+05

NA = Not available due to lack of toxicity criteria. Discussed qualitatively.

TABLE 7.1-41
COMPARISON OF SITE-SPECIFIC METHOD C CRITERIA TO EXPOSURE CONCENTRATIONS
HOLDEN MINE
BASELINE RISK ASSESSMENT

Media	Location	Route	IHS	Units	Exposure Concentration	Method C Cleanup Criteria	Exceeds Criteria?
Soil	Holden Village	Ingestion	Beryllium	mg/kg	2.60E-01	1.41E+01	NO
		Inhalation of particulates	Chromium	mg/kg	3.43E+01	6.03E+03	NO
	Maintentance Yard	Ingestion	Arsenic	mg/kg	6.00E+01	1.06E+02	NO
			Cadmium	mg/kg	2.16E+01	2.12E+03	NO
			Copper	mg/kg	3.16E+03	1.57E+05	NO
			Lead	mg/kg	1.07E+03	na	na
			Gasoline range hydrocarbons	mg/kg	1.40E+02	na	na
			Diesel range hydrocarbons	mg/kg	1.20E+04	na	na
			Motor oil range hydrocarbons	mg/kg	9.80E+03	na	na
	Lagoon	Ingestion	Beryllium	mg/kg	3.00E-01	3.70E+01	NO
			Cadmium	mg/kg	1.84E+02	1.60E+03	NO
			Copper	mg/kg	2.41E+04	1.18E+05	NO
			Lead	mg/kg	6.20E+02	na	na
			Zinc	mg/kg	2.37E+04	9.60E+05	NO
			Diesel range hydrocarbons	mg/kg	2.30E+02	na	na
			Motor oil range hydrocarbons	mg/kg	4.40E+02	na	na
		Inhalation of particulates	Cadmium	mg/kg	1.84E+02	2.58E+05	NO
	Forest Service Guard Station	Ingestion	Arsenic	mg/kg	2.52E+01	7.07E+02	NO
			Beryllium	mg/kg	2.20E-01	2.47E+02	NO
		Inhalation of particulates	Arsenic	mg/kg	2.52E+01	6.36E+04	NO
Sediments	Railroad Creek Adjacent to Site	Ingestion	Aluminum	mg/kg	4.63E+04	3.20E+06	NO
			Arsenic	mg/kg	1.26E+02	2.67E+02	NO
			Beryllium	mg/kg	1.00E+00	9.30E+01	NO
			Chromium	mg/kg	4.06E+02	1.60E+04	NO
			Manganese	mg/kg	1.40E+03	1.50E+05	NO
			Molybdenum	mg/kg	2.68E+03	1.60E+04	NO
	Railroad Creek Downgradient	Ingestion	Aluminum	mg/kg	8.90E+04	3.20E+06	NO
			Beryllium	mg/kg	1.00E+00	9.30E+01	NO
			Chromium	mg/kg	3.40E+02	1.60E+04	NO
			Manganese	mg/kg	1.03E+03	1.50E+05	NO
	Copper Creek	Ingestion	Beryllium	mg/kg	1.00E+00	9.30E+01	NO
			Chromium	mg/kg	1.00E+03	1.60E+04	NO
			Manganese	mg/kg	1.20E+03	1.50E+05	NO
	Copper Creek Diversion	Ingestion	Chromium	mg/kg	1.10E+02	1.60E+04	NO
Air	Throughout Site Area	Inhalation of particulates	Manganese	ug/m3	2.00E-05	5.01E-05	NO
Surface Water	Copper Creek	Ingestion of water	Molybdenum	ug/l	2.06E+02	3.20E+03	NO
		Ingestion of fish	Molybdenum	ug/l	2.06E+02	6.48E+02	NO
Seeps	Throughout Site Area	Ingestion	Aluminum	ug/l	4.54E+04	6.40E+05	NO
			Cadmium	ug/l	1.75E+01	3.20E+02	NO
			Lead	ug/l	7.60E+01	na	na
			Manganese	ug/l	9.37E+03	3.01E+04	NO
			Selenium	ug/l	9.30E+01	3.20E+03	NO
			Zinc	ug/l	9.77E+03	1.92E+05	NO
Portal Drainage	Throughout Site Area	Ingestion	Aluminum	ug/l	9.88E+03	6.40E+05	NO
			Cadmium	ug/l	1.70E+02	3.20E+02	NO
			Copper	ug/l	6.60E+03	2.37E+04	NO
			Lead	ug/l	3.87E+01	na	na
			Manganese	ug/l	3.86E+02	3.01E+04	NO
			Zinc	ug/l	8.85E+03	1.92E+05	NO

na = Not available due to lack of toxicity criteria. Discussed qualitatively.

TABLE 7.1-42
CALCULATION OF CANCER RISKS AND HAZARD QUOTIENTS
HOLDEN MINE
BASELINE RISK ASSESSMENT

Media	Location	Route	IHS	Units	Exposure Concentration	Method C Noncarcinogen Cleanup Criteria	Method C Carcinogen Cleanup Criteria	Hazard Quotient	Cancer Risk
Soil	Holden Village	Ingestion	Beryllium	mg/kg	2.60E-01	2.42E+03	1.41E+01	1.07E-04	1.84E-07
		Inhalation of particulates	Chromium	mg/kg	3.43E+01		6.03E+03		5.69E-08
	Maintenance Yard	Ingestion	Arsenic	mg/kg	6.00E+01	1.27E+03	1.06E+02	4.71E-02	5.66E-06
			Cadmium	mg/kg	2.16E+01	2.12E+03		1.02E-02	
			Copper	mg/kg	3.16E+03	1.57E+05		2.01E-02	
			Lead	mg/kg	1.07E+03				
			Gasoline range hydrocarbons	mg/kg	1.40E+02				
			Diesel range hydrocarbons	mg/kg	1.20E+04				
			Motor oil range hydrocarbons	mg/kg	9.80E+03				
	Lagoon	Ingestion	Beryllium	mg/kg	3.00E-01	2.12E+04	3.70E+01	1.42E-05	8.11E-08
			Cadmium	mg/kg	1.84E+02	1.60E+03		1.15E-01	
			Copper	mg/kg	2.41E+04	1.18E+05		2.04E-01	
			Lead	mg/kg	6.20E+02				
			Zinc	mg/kg	2.37E+04	9.60E+05		2.47E-02	
			Diesel range hydrocarbons	mg/kg	2.30E+02				
			Motor oil range hydrocarbons	mg/kg	4.40E+02				
		Inhalation of particulates	Cadmium	mg/kg	1.84E+02		2.58E+05		7.13E-09
	Forest Service Guard Station	Ingestion	Arsenic	mg/kg	2.52E+01	3.18E+03	7.07E+02	7.92E-03	3.56E-07
			Beryllium	mg/kg	2.20E-01	5.30E+04	2.47E+02	4.15E-06	8.91E-09
		Inhalation of particulates	Arsenic	mg/kg	2.52E+01		6.36E+04		3.96E-09
Sediments	Railroad Creek Adjacent to Site	Ingestion	Aluminum	mg/kg	4.63E+04	3.20E+06		1.45E-02	
			Arsenic	mg/kg	1.26E+02	2.40E+03	2.67E+02	5.25E-02	4.72E-06
			Beryllium	mg/kg	1.00E+00	1.60E+04	9.30E+01	6.25E-05	1.08E-07
			Chromium	mg/kg	4.06E+02	1.60E+04		2.54E-02	
			Manganese	mg/kg	1.40E+03	1.50E+05		9.33E-03	
			Molybdenum	mg/kg	2.68E+03	1.60E+04		1.68E-01	
	Railroad Creek Downgradient	Ingestion	Aluminum	mg/kg	8.90E+04	3.20E+06		2.78E-02	
			Beryllium	mg/kg	1.00E+00	1.60E+04	9.30E+01	6.25E-05	1.08E-07
			Chromium	mg/kg	3.40E+02	1.60E+04		2.13E-02	
			Manganese	mg/kg	1.03E+03	1.50E+05		6.87E-03	
	Copper Creek	Ingestion	Beryllium	mg/kg	1.00E+00	1.60E+04	9.30E+01	6.25E-05	1.08E-07
			Chromium	mg/kg	1.00E+03	1.60E+04		6.25E-02	
			Manganese	mg/kg	1.20E+03	1.50E+05		8.00E-03	
	Copper Creek Diversion	Ingestion	Chromium	mg/kg	1.10E+02	1.60E+04		6.88E-03	
Air	Throughout Site Area	Inhalation of particulates	Manganese	ug/m3	2.00E-05	5.01E-05		4.00E-01	
Surface Water	Copper Creek	Ingestion of water	Molybdenum	ug/l	2.06E+02	3.20E+03		6.44E-02	
		Ingestion of fish	Molybdenum	ug/l	2.06E+02	6.48E+02		3.18E-01	
Seeps	Throughout Site Area	Ingestion	Aluminum	ug/l	4.54E+04	6.40E+05		7.09E-02	
			Cadmium	ug/l	1.75E+01	3.20E+02		5.47E-02	
			Lead	ug/l	7.60E+01				
			Manganese	ug/l	9.37E+03	3.01E+04		3.11E-01	
			Selenium	ug/l	9.30E+01	3.20E+03		2.91E-02	
			Zinc	ug/l	9.77E+03	1.92E+05		5.09E-02	
Portal Drainage	Throughout Site Area	Ingestion	Aluminum	ug/l	9.88E+03	6.40E+05		1.54E-02	
			Cadmium	ug/l	1.70E+02	3.20E+02		5.31E-01	
			Copper	ug/l	6.60E+03	2.37E+04		2.78E-01	
			Lead	ug/l	3.87E+01				
			Manganese	ug/l	3.86E+02	3.01E+04		1.28E-02	
			Zinc	ug/l	8.85E+03	1.92E+05		4.61E-02	

NA = Not available due to lack of toxicity criteria. Discussed qualitatively.

TABLE 7.1-43
EVALUATION OF CUMULATIVE RISK
HOLDEN MINE
BASELINE RISK ASSESSMENT

Effect	Population	Hazard Quotient	Cancer Risk	Constituent	Exposure Pathway
Carcinogenesis	Village residents/recreational users		1.84E-07	Beryllium	Holden Village ingestion of soil
			5.69E-08	Chromium	Holden Village inhalation of particulates
			8.11E-08	Beryllium	Lagoon area ingestion of soil
			7.13E-09	Cadmium	Lagoon area inhalation of particulates
			5.66E-06	Arsenic	Maintenance Yard ingestion of soil
			4.72E-06	Arsenic	Railroad Creek ingestion of sediments (site)
			1.08E-07	Beryllium	Railroad Creek ingestion of sediments (site)
			1.08E-07	Beryllium	Railroad Creek ingestion of sediments (downgradient)
			1.08E-07	Beryllium	Copper Creek ingestion of sediments
	TOTAL CANCER RISK		**1.10E-05**		
Carcinogenesis	Forest Service workers		3.56E-07	Arsenic	Forest Service guard station ingestion of soil
			8.91E-09	Beryllium	Forest Service guard station ingestion of soil
			3.96E-09	Arsenic	Forest Service guard station inhalation of particulates
	TOTAL CANCER RISK		**3.69E-07**		
Hemotoxicity	Village residents/recreational users	2.47E-02		Zinc	Lagoon area ingestion of soil
		5.09E-02		Zinc	Seeps ingestion of water
		4.09E-02		Zinc	Portal drainage ingestion of water
	TOTAL HAZARD INDEX	**1.16E-01**			
Skin toxicity	Village residents/recreational users	5.25E-02		Arsenic	Railroad Creek ingestion of sediments (site)
		4.71E-02		Arsenic	Maintenance Yard ingestion of soil
	TOTAL HAZARD INDEX	**9.96E-02**			
Skin toxicity	Forest Service workers	7.92E-03		Arsenic	Forest Service guard station ingestion of soil
	TOTAL HAZARD INDEX	**7.92E-03**			
Nephrotoxicity	Village residents/recreational users	1.02E-02		Cadmium	Maintenance yard ingestion of soil
		1.15E-01		Cadmium	Lagoon area ingestion of soil
		1.82E-02		Cadmium	Seeps ingestion of water
		1.77E-01		Cadmium	Portal drainage ingestion of water
		1.68E-01		Molybdenum	Railroad Creek ingestion of sediments (site)
		2.15E-02		Molybdenum	Copper Creek ingestion of water
		3.18E-01		Molybdenum	Copper Creek ingestion of fish
	TOTAL HAZARD INDEX	**8.28E-01**			
Neurotoxicity	Village residents/recreational users	2.75E-02		Manganese	Holden Village ingestion of soil
		9.33E-03		Manganese	Railroad Creek ingestion of sediments (site)
		6.87E-03		Manganese	Railroad Creek ingestion of sediments (downgradient)
		8.00E-03		Manganese	Copper Creek ingestion of sediments
		4.00E-01		Manganese	Inhalation of particulates
		3.11E-01		Manganese	Seeps ingestion of water
		1.15E-02		Manganese	Portal drainage ingestion of water
	TOTAL HAZARD INDEX	**7.74E-01**			

TABLE 7.1-44
TOXICITY PROFILES FOR INDICATOR HAZARDOUS SUBSTANCES

Constituent	Acute Toxicity Summary	Chronic Toxicity Summary	Cancer Potential	Other
Aluminum	Soluble forms of aluminum are potentially toxic; the insoluble forms have no measurable acute response. Acute aluminum toxicity is unlikely. The vast majority of cases of aluminum toxicity in humans fall into one of two categories: 1) patients with chronic renal failure; 2) people exposed to aluminum in the workplace. Aluminum dust may cause eye irritation.	Some aluminum workers are at risk for developing respiratory manifestations of aluminum toxicity, mainly asthma, chronic obstructive lung disease, and pulmonary fibrosis. Serum phosphorus was reduced and urinary phosphorus and calcium were increased with chronic exposure to aluminum aerosol. Delayed hypersensitivity, telangiectases, and granulomas may occur from chronic aluminum skin contact.		Aluminum compounds have been evaluated as non-mutagenic by most standard methods of mutagenic assays.
Arsenic	Acute oral exposure can cause muscular cramps, facial swelling, cardiovascular reactions, severe gastrointestinal damage, and vascular collapse leading to death. Sensory loss and hematopoietic symptoms delayed after exposure to high concentrations are usually reversible. Inhalation exposure can cause severe irritation of nasal lining, larynx, and bronchi.	Chronic oral or inhalation exposure can produce: changes in skin, including hyperpigmentation and hyperkeratosis; peripheral neuropathy; liver injury; cardiovascular disorders; peripheral vascular disease associated with oral exposures; and blackfoot disease. High doses of some inorganic arsenic compounds to pregnant laboratory animals produced malformations in offspring.	Excess skin cancers have been observed in individuals drinking water with elevated levels of arsenic from natural sources. Excess lung cancers have been observed in workers exposed to elevated concentrations of arsenic in air.	Toxicity varies for different compounds; inorganic trivalent arsenic compounds are usually more toxic than pentavalent compounds.

TABLE 7.1-44 (CONTINUED)
TOXICITY PROFILES FOR INDICATOR HAZARDOUS SUBSTANCES

Constituent	Acute Toxicity Summary	Chronic Toxicity Summary	Cancer Potential	Other
Beryllium	Acute lung disease (chemical pneumonitis) has been observed immediately after inhalation of aerosols of soluble and insoluble beryllium compounds in broken fluorescent light tubes. Several months after exposure the entire respiratory tract may become inflamed with fulminating pneumonitis in severe reactions. Recoveries usually occur within weeks, but fatalities have occurred. In studies with monkeys, high concentrations of aerosols of beryllium fluoride or beryllium phosphate produced severe lung reactions in all animals and damaged the liver and kidney as well as affecting adrenals, pancreas, thyroid, and spleen; many lesions were similar to those inpatients who died of pneumonitis. Conjunctivitis and contact dermatitis may follow exposure to beryllium, with skin lesions or ulcerations. Beryllium compounds may produce hypersensitivity with delayed allergic reactions.	The lung is a major target organ for toxic effects of beryllium. Berylliosis, a chronic granulomatous lung disease that is frequently fatal, has been described for over 40 years among workers exposed to insoluble beryllium compounds; symptoms may include shortness of breath, cyanosis, clubbed fingers, and lesions that progress to fibrotic tissue and nodules with respiratory dysfunction.	Beryllium compounds or alloys have produced cancer in rats, rabbits, and monkeys. Lung tumors have been reported in rats and monkeys exposed by inhalation, intratracheally, or intrabronchial implantation, and bone tumors have been produced in rabbits after intravenous or intraosseus administration. Excess lung cancer has been observed in some studies of workers occupationally exposed to beryllium, but data on exposure and confounding factors were lacking. Beryllium and its compounds have been classified by IARC as having sufficient evidence of being carcinogenic in animals and limited evidence in humans, and by EPA as a probable human carcinogen. Some beryllium compounds are mutagenic in vitro.	Wide variations in individual sensitivity have been reported, perhaps because of an immune reaction; individuals exposed to low doses may exhibit severe effects. Beryllium is stored in the body for many years with detectable amounts in lung reported as long as 23 years after exposure.
Cadmium	For acute exposure by ingestion, symptoms of cadmium toxicity included nausea, vomiting, diarrhea, muscular cramps, salivation, spasms, drop in blood pressure, vertigo, loss of consciousness, and collapse. Acute renal failure, liver damage, and death may occur. Exposure by inhalation can cause irritation, coughing, labored respiration, vomiting, acute chemical pneumonitis, and pulmonary edema.	Respiratory and renal toxicity are major effects in workers. Chronic oral exposures can produce kidney damage. Cadmium accumulates in kidney, and nephropathy results after critical concentration in kidney is reached, probably about 200 g/g. Inhalation can cause chronic obstructive pulmonary disease, including bronchitis, progressive fibrosis, and emphysema. Chronic exposure affects calcium metabolism and can cause loss of calcium from bone, bone pain, osteomalacia, and osteoporosis. Chronic exposure may be associated with hypertension. Cadmium can produce testicular atrophy, sterility, and teratogenic effects in experimental animals.	Increased risk of prostate cancer and perhaps respiratory tract cancer have been seen in workers exposed by inhalation. No evidence of carcinogenicity from chronic oral exposure exists.	

TABLE 7.1-44 (CONTINUED)
TOXICITY PROFILES FOR INDICATOR HAZARDOUS SUBSTANCES

Constituent	Acute Toxicity Summary	Chronic Toxicity Summary	Cancer Potential	Other
Chromium	The major acute effect from oral exposure is renal tubular necrosis. Inhalation of chromate salts results in irritation and inflammation of nasal mucosa, ulceration, and perforation of nasal septum.	Chronic exposure to hexavalent chromium has resulted in kidney damage in animals and humans. Inhalation exposures to chromates in industrial settings have resulted in nasal membrane inflammation, chronic rhinitis, laryngitis, and pharyngitis. Exposures to skin can result in allergic skin reactions in sensitive individuals. Overall, hexavalent forms are usually more toxic than trivalent forms.	Hexavalent chromium is considered a known human carcinogen. Excess lung cancer has been associated with workers in the chromate-producing industry. Chromate salts have been shown to be carcinogenic in rats exposed by inhalation in some studies.	Trivalent chromium is an essential element in human nutrition. Chromium toxicity is related to valence state.
Copper	Inhalation of copper dusts results in symptoms similar to metal fume fever. Exposure to metal fumes results in upper respiratory tract irritation, metallic or sweet taste, metal fume fever, and skin and hair discoloration. Exposure to dusts and mists of copper salts result in congestion of nasal mucous membranes, sometimes of the pharynx, and occasional ulceration and perforation of nasal septum. Acute copper sulfate poisoning in humans (oral) is sometimes fatal; symptoms include vomiting, diarrhea, hypotension, coma, and jaundice.	Hemolytic anemia occurs after chronic exposure in some dialysis patients. Sensitive to individuals with metabolism disorders (Wilson's disease and Menke's disease).	Copper is not known to be carcinogenic in humans or laboratory animals.	Copper is an essential nutrient in human nutrition. The organoleptic threshold in water is 1 to 5 mg/l.

TABLE 7.1-44 (CONTINUED)
TOXICITY PROFILES FOR INDICATOR HAZARDOUS SUBSTANCES

Constituent	Acute Toxicity Summary	Chronic Toxicity Summary	Cancer Potential	Other
Lead	Acute inorganic lead intoxication in humans is characterized by encephalopathy, abdominal pain, hemolysis, liver damage, renal tubular necrosis, seizures, coma, and respiratory arrest.	Chronic low levels of exposure to lead can affect the hematopoietic system, the nervous system, and the cardiovascular system. Lead inhibits several key enzymes involved in heme biosyntheses. One characteristic effect of chronic lead intoxication is anemia, by reduction of both hemoglobin production and shortened erythrocyte survival. In humans, lead exposure has resulted in nervous system injury including reduced hand-eye coordination, reaction time, visual motor performance, and nerve conduction velocity. Developing children appear especially sensitive to lead-induced nervous system injury. Lead can also affect the immune system and produce gingival lead lines. Epidemiological studies have indicated that chronic lead exposure may be associated with increased blood pressure in humans. Exposure to lead is associated with sterility, abortion, neonatal mortality, and morbidity. Organolead compounds are neurotoxic.	Lead salts have shown some evidence of carcinogenicity in animals at very high exposure levels.	Children are especially sensitive to low-level exposures to lead.
Manganese	Toxicity following acute ingestion of inorganic manganese salts is unlikely since they are poorly absorbed from the gastrointestinal tract. If dust or fume is inhaled in sufficient quantity, may produce "metal fume fever".	Systemic toxicity is most common following chronic inhalation or ingestion. Two clinical patterns are common: one involving the degeneration of the CNS resulting in manganese psychosis; and the other involving acute pneumonitis.	Existing studies are inadequate to assess the carcinogenicity of manganese.	Manganese is an element considered essential to human health. High levels may interfere with iron absorption. Divalent mangangese (2+) is about 2 to 3 times more toxic than is manganese(3+).
Molybdenum	Toxic effects include damage to liver, kidneys, and sometimes adrenals and spleen. Subchronic exposure can produce decreased growth rate, male infertility, weight loss, and abnormalities of bone or joint in forelegs of animals. Some molybdenum salts are irritating to eyes and mucous membranes. With oral exposures, fatty degeneration of liver and kidney occur in animals.	Joint deformities occur with prolonged exposure. Toxicity depends on many dietary factors that affect trace metals. In most species, toxicity includes loss of appetite, reduced growth, anemia, hair loss, loss of hair color, bone defects. Molybdenum has been implicated in human gout and bone-crippling disease, but its involvement has not been proven.	Cancer potential is not indicated.	Molybdenum is an essential nutrient in humans. Species vary in sensitivity. Ruminants are especially sensitive to molybdenum toxicity. Molybdenum salts differ in toxicity. Copper prevents accumulation of molybdenum in liver. Molybdenum may interact with other metals, and may increase fluoride retention.

TABLE 7.1-44 (CONTINUED)
TOXICITY PROFILES FOR INDICATOR HAZARDOUS SUBSTANCES

Constituent	Acute Toxicity Summary	Chronic Toxicity Summary	Cancer Potential	Other
Selenium	Acute exposure can produce CNS effects including nervousness, drowsiness, and convulsions, and eye and nasal irritation.	Chronic inhalation exposure to selenium-containing compounds can result in pallor, coated tongue, gastrointestinal disorders, nervousness, garlic breath, liver and spleen damage, anemia, and mucosal irritation. Discoloration, decayed teeth, skin eruptions, gastrointestinal distress, and loss of hair and nails have been reported in humans exposed orally. In livestock, excess intake can cause blind staggers--impaired vision, weak limbs, respiratory failure--and alkali disease--hair loss, sterility, atrophy of hooves, lameness, and anemia. Selenium is embryotoxic and teratogenic in animals.	Selenium is carcinogenic in laboratory animals, but may be anticarcinogenic and protective in humans.	Selenium is an essential element in humans. Its toxicity is related to chemical form.
Zinc	Acute adverse effects of zinc include: metal fume fever by inhalation of fumes; and fever, nausea, vomiting, stomach cramps, and diarrhea from ingestion.	Prolonged ingestion of zinc can result in irritability, muscular stiffness and pain, loss of appetite, and nausea. High levels of zinc in diet may retard growth and produce defective mineralization of bone.	Zinc is not known to be carcinogenic in humans or laboratory animals.	Zinc is an essential nutrient in human nutrition. The taste threshold is 15 ppm in water; 40 ppm soluble zinc salts in water imparts a metallic taste.
Gasoline	Acute inhalation exposures to 500 ppm resulted in central nervous system effects including headache, dizziness, nausea and drowsiness. At higher concentrations, anesthesia, loss of reflexes, convulsions, delirium, unconsciousness, and coma may occur.	Animal studies indicate that chronic inhalation exposures to gasoline resulted in a reduction in body weight gain.	Animal studies have shown an increase in renal tumors and sarcomas in rats and hepatocellular tumors in mice. IARC has classified gasoline as a Group 2B possible human carcinogen. USEPA concluded that gasoline is a Group C possible human carcinogen. In vitro assays are generally nonpositive.	There is a possible indication of developmental toxicity associated with gasoline.

TABLE 7.1-44 (CONTINUED)
TOXICITY PROFILES FOR INDICATOR HAZARDOUS SUBSTANCES

Constituent	Acute Toxicity Summary	Chronic Toxicity Summary	Cancer Potential	Other
Diesel Fuel, Light Weight Fuel Oils, and Jet Fuel	Acute inhalation can cause dizziness, headache, nausea, and fatigue in workers.	Chronic inhalation may induce fatigue, anxiety, mood changes and memory difficulties in workers. Animal studies indicate liver effects, reduced red blood cell count, nasal inflammatory changes, and decreased body weight gains occur after chronic inhalation exposures. Dermal exposures in mice have produced kideny lesions.	Tumor promotion and carcinogenesis of the middle distillates after dermal exposures is possibly due to chronic irritation and hyperplasia. IARC has classified marine diesel fuel as possibly carcinogenic to humans (Group 2B) and light diesel fuels and jet fuels as Group 3, not classifiable. USEPA has assigned jet fuels to Group C, possible human carcinogens. In vitro assays are generally nonpositive.	Embryotoxic, fetotoxic, and teratogenic effects have not been seen.
Heavy fuel oils, Residual fuels, No. 6 fuel oil	Acute dermal exposure to heavy No. 6 fuel oil in rabbits caused severe dermal irritateion, weight loss, anorexia, ataxia, lethargy, toxic hepatitis, gastrointestinal irritation and congested lungs. Other grades of No. 6 fuel oil caused irritation but no systemic toxicity.		Cracked bunker fuel produced skin tumors in mice after dermal application. IARC concluded there is sufficient evidence of the carcinogenicity of heavy fuel oils to classify them as Group 2B, possibly carcinogenic to humans. In vitro assays are generally nonpositive.	

TABLE 7.2.2-1A

STATISTICAL ANALYSIS AND COMPARISON OF SURFACE WATER DATA FROM RAILROAD CREEK, SOUTH BANK

(SAMPLES COLLECTED FROM SOUTH BANK UPSTREAM OF SITE, 1991 - 1997)

HOLDEN MINE RI/FS

DAMES & MOORE JOB NO. 17693-005-019

Parameters	USGS DATA				DAMES & MOORE DATA		STATISTICAL CALCULATIONS									
	367	546	600	707	RC-1 South Bank		# Analyses	# of Detections	Maximum Conc.	Minimum Conc.	Range of RL	Approximate Distribution	Mean	Standard Deviation	Median	UCL (95%)
	7/94[a]	7/95 [b]	5/96[c]	9/96[d]	5/19/97	9/15/97										
Total Metals (ug/L)																
Aluminum				46	100U	60	3	2	60	46	100	Neither	52	7.2	50	**60**
Arsenic																
Barium				5.4	4.80	4.39	3	3	5.4	4.39		Neither	4.9	0.5	4.8	**5.4**
Beryllium				10 U	0.04U	0.04U	3	0			0.04-10					
Cadmium				10 U	0.04U	0.04U	3	0			0.04-10					
Calcium				5,900	3,840	4,100	3	3	5900	3840		Neither	4613	1122	4100	**5900**
Chromium				10 U	0.2U	0.2U	3	0			0.2-10					
Copper				10 U	1.1U	0.7	3	1	0.7	0.7	1.1-10					
Iron				110	140	110	3	3	140	110		*Neither*	120	17	110	**140**
Lead				50 U	0.4U	0.2UJ	3	0			0.2-50					
Magnesium				1000 U	390	360	3	2	390	360	1000	Neither	417	74	390	**390**
Manganese				10 U	3.30	3.20	3	2	3.3	3.2	10	Neither	3.8	1	3.3	**3.3**
Mercury																
Molybdenum				20 U			1	0			20					
Nickel				10 U	0.3J	0.2	3	2	0.3	0.2	10	Neither	1.8	2.7	0.3	**0.3**
Potassium				1000 U	610	500U	3	1	610	610	500-1000					
Selenium																
Silver					0.05U	0.04U	2	0			0.04-0.05					
Sodium				1,100	800	590	3	3	1100	590		Lognormal	844	256	800	2145
Thallium																
Uranium																
Zinc				10 U	5	4U	3	1	5	5	4-10					
Dissolved Metals (ug/L)																
Aluminum	20	20	20 U	11	30	20U	6	4	30	11	20	*Normal*	16.8	8	15.5	23.4
Arsenic	2 U	1 U	4 U				3	0			1-4					
Barium	4.1	3.8	6.5	5.1	15.0J	4.29	6	6	15	3.8		Neither	6.5	4.3	4.7	**15**
Beryllium	1 U	0.3 U	0.4 U	10 U	0.04U	0.04U	6	0			0.04-10					
Cadmium	1 U	1 U	0.7 U	10 U	0.04	0.09	6	2	0.09	0.04	0.7-10					
Calcium	6000 U	3900	5900	5,800	3,760	4,180	6	5	5900	3760	6000	Neither	4423	1173	4040	**5900**
Chromium	1 U	0.9 U	0.5 U	10 U	0.2U	0.2U	6	0			0.2-10					
Copper	0.62	3	6.5	10 U	1.0	0.6	6	5	6.5	0.6	10	Lognormal	3.2	2.5	2	25.2
Iron	100 U	40	91	100 U	20U	40	6	3	91	40	20-100				40	
Lead	0.2 U	0.3 U	0.2	50 U	0.7U	0.2	6	2	0.2	0.2	0.2-50					
Magnesium	270	280	1000 U	1000 U	360	350	6	4	360	270	1000	Neither	377	102	355	**360**
Manganese	2	1.6	3 U	10 U	1.83	1.68	6	4	2	1.6	3-10	Lognormal	2.3	1.4	1.8	3.76
Mercury																
Molybdenum	0.5	0.3	0.6	20 U			4	3	0.6	0.3	20	Neither	2.9	4.8	0.6	**0.6**
Nickel	3 U	0.5	1 U	0.01 U	0.2	0.2	6	3	0.5	0.2	0.01-3	Neither	0.5	0.5	0.35	**0.5**
Potassium	200 U			*1000 U*	*500U*	*500U*	*4*	0			200-1000					
Selenium																
Silver	0.1 U	0.1 U	0.2 U		0.04U	0.04U	5	0			0.04-0.2					
Sodium	300	500		1000 U	780U	630	5	3	630	300	780-1000	Neither	464	125	500	**630**
Thallium	0.1 U	0.6 U	4 U				3	0								
Uranium	0.1 U	0.1 U	0.4 U				3	0								
Zinc	4	10	3.4	10 U	13	4U	6	4	13	3.4	4-10	Lognormal	6.5	4.3	4.5	17.5

Data Notes:

J - Estimated Value.

U - Parameter was analyzed for, but not detected above the reporting limit shown.

UJ - Parameter was analyzed for, but not detected. Detection limit is an estimated value.

▨ Grey shading indicates the concentration of analyte was not established, therefore not reported nor analyzed.

Data Source:

(a) Kilburn, et al. 1994. *Geochemical data and sample locality maps for stream-sediment, heavy-mineral-concentrate, mill tailing, water, and precipitate samples collected in and around the Holden mine, Chelan County, Washington.* USGS Open File Report 94-680A Paper Version, 94-680B Diskette version (Data Collected in 1994).

(b) Kilburn, J.E. & S.J. Sutley. 1996. *Characterization of acid mine drainage at the Holden mine, Chelan, Washington*. USGS Open File Report 96-531. (Data collected in 1995).

(c) Kilburn, J.E. & S.J. Sutley. 1997. *Analytical results and comparative overview of geochemical studies conducted at the Holden Mine*, spring 1996. USGS Open File Report 97-128 (Data collected in Spring 1996).

(d) Kilburn, J.E. & S.J. Sutley. 1997. Preliminary data (no report attached, data collected in Fall 1996).

Statistical Notes: {Statisical calculations were performed using Washington Department of Ecology's MTCAStat Excel V.5 Macro (Module 2.1), downloaded from their web site.}

Maximum and minimum concentrations are based on detected values only.

Range of reporting limits (RL) are based on results reported as not detected.

Distribution is determined based on the MTCA stat program by analyzing the data through the "W-Test" or "D'Agostino's test".

Where data is not lognormally nor normally distributed, the distribution is noted as "Neither".

When approximate distribution is reported as "neither", the maximum concentration is reported as the 95% UCL and is presented in **BOLD** font.

The mean is an arithmetic mean if data are normally distributed or if distribution is indicated as "Neither".

The reported mean for lognormally distributed data is a lognormal mean.

Statistical analysis was not performed on data sets where 50% or greater of the results were reported as not detected.

Only maximum and minimum concentrations are reported, if applicable. For these data sets, a calculated median is based on detected values only.

TABLE 7.2.2-1A

STATISTICAL ANALYSIS & COMPARISON OF

SURFACE WATER DATA FROM SOUTHBANK OF RAILROAD CREEK

TABLE 7.2.2-1A
STATISTICAL ANALYSIS AND COMPARISON OF SURFACE WATER DATA FROM RAILROAD CREEK, SOUTH BANK
(SAMPLES COLLECTED FROM SOUTH BANK ADJACENT TO THE SITE, 1997)
HOLDEN MINE RI/FS

DAMES & MOORE JOB NO. 17693-005-019

Parameters	DAMES & MOORE DATA				STATISTICAL CALCULATIONS									
	RC-4 South Bank			RO-4X South Bank	# Analyses	# of Detections	Maximum Conc.	Minimum Conc.	Range of RL	Approximate Distribution	Mean	Standard Deviation	Median	UCL (95%)
	5/21/97	7/10/97	9/15/97	5/21/97										
Total Metals (ug/L)														
Aluminum	170	170	50	160	4	4	170	50					165	
Arsenic														
Barium	5.30	4.75	4.45	5.03	4	4	5.3	4.45					4.89	
Beryllium	0.04U	0.04U	0.04U	0.04U	4	0			0.04					
Cadmium	1.09	0.12U	0.12	1.08	4	3	1.09	0.12	0.12				1.08	
Calcium	4,870	3,340	4,400	4,980	4	4	4980	3340					4635	
Chromium	0.2U	0.2U	0.2U	0.2U	4	0			0.2					
Copper	79	6.8	4.9	77	4	4	79	4.9					41.9	
Iron	90	180	100	90	4	4	180	90					95	
Lead	0.4J	0.3UJ	0.2UJ	0.4J	4	2	0.4	0.4	0.2-0.3				0.4	
Magnesium	550	350	380	560	4	4	560	350					465	
Manganese	6.08	4.83	3.51	5.86	4	4	6.08	3.51					5.35	
Mercury														
Molybdenum														
Nickel	0.6	0.4	0.3	0.6	4	4	0.6	0.3					0.5	
Potassium	560	500U	500U	850	4	2	850	560	500				705	
Selenium														
Silver	0.17	0.04U	0.04U	0.12	4	2	0.17	0.12	0.04				0.15	
Sodium	910	520	640	890	4	4	910	520					775	
Thallium														
Uranium														
Zinc	177	22	20	185	4	4	185	20					99.5	
Dissolved Metals (ug/L)														
Aluminum	50	30U	20U	50	4	2	50	50	20-30				50	
Arsenic														
Barium	10.2	13.0	4.31	11.2	4	4	13	4.31					10.7	
Beryllium	0.04U	0.04U	0.04U	0.04	4	1	0.04	0.04	0.04				0.04	
Cadmium	1.10	0.11	0.14	1.14	4	4	1.14	0.11					0.62	
Calcium	5,110	3,230	4,420	5,050	4	4	5110	3230					4735	
Chromium	0.2U	0.2U	0.2U	0.2	4	1	0.2	0.2	0.2				0.2	
Copper	58.5	5.3	3.9	59.8	4	4	59.8	3.9					31.9	
Iron	20	20U	40	20U	4	2	40	20	20				30	
Lead	0.6J	0.2UJ	0.4	0.2	4	3	0.6	0.2	0.2				0.4	
Magnesium	560	290	390	550	4	4	560	290					475	
Manganese	7.46	1.81	2.10	7.68	4	4	7.68	1.81					4.78	
Mercury														
Molybdenum														
Nickel	1.0	0.2U	0.3	0.6	4	3	1	0.3					0.6	
Potassium	690	500U	500U	500U	4	1	690	690	500				690	
Selenium														
Silver	0.14U	0.04U	0.04U	0.10	4	1	0.1	0.1	0.04-0.14				0.1	
Sodium	910	530	640	890	4	4	910	530					775	
Thallium														
Uranium														
Zinc	191	24	20	191	4	4	191	20					108	

Data Notes:

J - Estimated value.

U - Parameter was analyzed for, but not detected above the reporting limit shown.

UJ - Parameter was analyzed for but not detected. Detection limit is an estimated value.

Grey shading indicates the concentration of analyte was not established, therefore not reported nor analyzed.

Statistical Notes:

Maximum and minimum concentrations are based on detected values only.

Range of reporting limits (RL) are based on results reported as not detected.

Statistical analysis was not performed on data sets where 50% or greater of the results were reported as not detected. Only maximum and minimum concentrations are reported, if applicable.
For these data sets, a calculated median is based on detected values only.

TABLE 7.2.2-1A
STATISTICAL ANALYSIS AND COMPARISON OF SURFACE WATER DATA FROM RAILROAD CREEK, SOUTH BANK
(SAMPLES COLLECTED FROM SOUTH BANK DOWNSTREAM OF SITE IN 1994)
HOLDEN MINE RI/FS
DAMES & MOORE JOB NO. 17693-005-019

Parameters	USGS DATA[a]			STATISTICAL CALCULATIONS		
	354	352	353	Maximum Conc.	Minimum Conc.	Median
	7/94	7/94	7/94			
Total Metals (ug/L)						
Aluminum						
Arsenic						
Barium						
Beryllium						
Cadmium						
Calcium						
Chromium						
Copper						
Iron						
Lead						
Magnesium						
Manganese						
Mercury						
Molybdenum						
Nickel						
Potassium						
Selenium						
Silver						
Sodium						
Thallium						
Uranium						
Zinc						
Dissolved Metals (ug/L)						
Aluminum	21	20	6 U	21	20	20.5
Arsenic	2 U	2 U	2 U			
Barium	5.3	4.7	6.1	6.1	4.7	5.3
Beryllium	1 U	1 U	1 U			
Cadmium	1 U	1 U	1 U			
Calcium	6000 U	6000 U	6000 U			
Chromium	1 U	1 U	1 U			
Copper	1.4	1.6	0.1 U	1.6	1.4	1.5
Iron	200	200	100 U	200	200	200
Lead	0.2 U	0.2 U	0.2 U			
Magnesium	490	480	540	540	480	490
Manganese	3.5	5.5	0.9 U	5.5	3.5	4.5
Mercury						
Molybdenum	0.4	0.5	0.2	0.5	0.2	0.4
Nickel	3 U	3 U	3 U			
Potassium	300	200	200	300	200	200
Selenium						
Silver	0.1 U	0.1 U	0.1 U			
Sodium	500	400	400	500	400	400
Thallium	0.1 U	0.1 U	0.1 U			
Uranium	0.1 U	0.1 U	0.1 U			
Zinc	14	13	2 U	14	13	13.5

Data & Statistical Notes:

U - Parameter was analyzed for, but not detected above the reporting limit shown.
Grey shading indicates the concentration of analyte was not established, therefore not reported nor analyzed.
Total metals were not sampled, therefore only results for dissolved metals are reported on this table.
Maximum and minimum concentrations are based on detected values only.
Calculated median is based on detected values only.

Data Source:

(a) Kilburn, et al. 1994. *Geochemical data and sample locality maps for stream-sediment, heavy-mineral-concentrate, mill tailing, water, and precipitate samples collected in and around the Holden mine, Chelan County, Washington.* USGS Open File Report 94-680A Paper Version, 94-680B Diskette version (Data Collected in 1994).

TABLE 7.2.2-1B1
STATISTICAL ANALYSIS AND COMPARISON OF SURFACE WATER DATA FROM RAILROAD CREEK, MAINSTREAM
SAMPLES FROM MAINSTREAM OF UPSTREAM REACH COLLECTED 1996 - 1998 (EXCLUDES ALL BANK SAMPLES)
HOLDEN MINE RI/FS
DAMES & MOORE JOB NO. 17693-005-019

Parameters	DEPT. OF ECOLOGY (RC-STATION SAMPLES)[a]		DAMES & MOORE DATA																					STATISTICAL CALCULATIONS									
			RC-1A	RC-1B	RC-1C	RC-1				RC-6A	RC-6B	RC-6C	RC-6						RC-6 N.Bank	RC-6 N.Bank X	RC-6	RC-11	RC-11	# Analyses	# of Detections	Maximum Conc.	Minimum Conc.	Range of RL	Approx. Distribution	Mean	Standard Deviation	Median	90th Percentile
	6/12/96	9/10/96	4/16/97	4/16/97	4/16/97	5/19/97	7/10/97	9/15/97	5/3/98	4/15/97	4/15/97	4/15/97	5/19/97	5/26/97	6/2/97	6/9/97	6/16/97	7/10/97	9/15/97	9/15/97	5/3/98	10/4/97	5/1/98										
Total Metals (ug/L)																																	
Aluminum	13	32	20	20U	20U	90	160	70	100J	20U	20U	20	90	40J	160	80J	180	150	60	60	150J	140U	70U	23	17	180	13	20 - 70	Normal	66.75	56.47	60	88.58
Arsenic	0.69	0.88	1	1	2	0.72	0.76	1.07	0.86	1U	1U	1U	0.80					0.76	1.07	1.09	1.07	1.56	1.12	19	16	2	0.69	1	Lognormal	0.93	0.4	0.84	1.13
Barium			3	3	4	4.98	4.62	4.42	4.91	3	3	4	4.92	4.43	4.87	4.43J	5	4.61	4.38	4.52	5.1	4.13	4.14	21	21	5.1	3		Nonparametric	4.18	0.72	4.43	**5**
Beryllium			1U	1U	1U	0.04U	0.04U	0.04U	0.04U	1U	1U	1U	0.04U	0.2U	0.04U	0.04U	0.2U	0.04U	0.04U	0.04U	0.04U	0.08U	0.04U	21	0			0.04-1.0					
Cadmium	0.02 U	0.1 U	0.2U	0.2U	0.2U	0.04U	0.04U	0.04U	0.04U	0.2U	0.2U	0.2U	0.04U	0.04U	0.04	0.04U	0.2U	0.04U	0.04U	0.04U	0.04U	0.04U	0.04U	23	0			0.04-0.2					
Calcium			6,480	6,480	6,470	3,800	3,050	4,080	3,860	6,720	6,660	6,740	3,820	4,020	3,430	3,530J	2,820	3,030	4,100	4,020	3,800	2,540	2,410	21	21	6740	2410		Nonparametric	4488.9	1608.7	4020	**6740**
Chromium			5U	5U	5U	0.2U	0.2U	0.2U	0.2U	5U	5U	5U	0.2U	0.2U	0.2U	0.2U	5U	0.2U	0.2U	0.2U	0.2U	0.2U	0.2U	21	0			0.2-5.0					
Copper	1.4	3.7	2U	2U	2U	1.1U	1.0	0.6	1.1	2U	2U	2U	0.9U	0.7	1.3	0.8J	4	1.1	0.6	1.0	1.8J	1.2	1	23	15	4	0.6	0.9-2.0	Nonparametric	1.22	0.93	1	**4**
Iron	71	77	70	90	70	120	160	110	110	70	70	70	140	80J	150	70J	170	150	110	120	180	220	90	23	23	220	70		Nonparametric	144	156	110	**220**
Lead	0.13	0.12	1U	1U	1U	0.2U	0.3UJ	0.2UJ	0.103	1U	1U	1U	0.3U	0.3	4.8	0.3J	1U	0.3UJ	0.2UJ	0.3UJ	0.124	0.4	0.139	23	9	4.8	0.103	0.2-1.0				0.3	
Magnesium			650	640	650	360	320	350	360	680	670	670	360	400	340	340J	310	310	360	360	360	290	240	21	21	680	240		Nonparametric	447.78	156.53	360	**680**
Manganese	1.3	1.9	2	2	2	4.70	3.87	3.09	4.45	2	2	2	3.7	1.67	4.41	1.95J	5	3.90	3.02	3.53	6.52	6.02	3.83	23	23	6.52	1.3		Lognormal	3.02	1.32	2.51	3.66
Mercury	0.001 U		0.1U	0.1U	0.1U	0.00039	0.00032J			0.1U	0.1U	0.1U	0.00046J	0.00032J				0.00064						12	5	0.00064	0.00032	0.001-0.1				0.00039	
Molybdenum						0.49	0.39	0.74	0.52				0.49					0.39	0.74	0.74	0.53	0.66	0.65	11	11	0.74	0.39		Lognormal	0.58	0.16	0.58	0.73
Nickel	0.34		10U	10U	10U	0.3J	0.3	0.2	0.3	10U	10U	10U	0.3J	0.4	0.4	0.2U	10U	0.3	0.2	0.3	0.3	0.4	0.3	22	15	0.4	0.2	0.2-10.0	Nonparametric	2.03	2.33	0.4	**0.4**
Potassium			780	630	730	500U	500U	500U	500U	600	810	650	500U	500U	500U	510J	500U	500U	500U	500U	500U	500U	500U	21	7	810	600	500				650	
Selenium		0.4 U	1U	1U	1U	0.2U	0.2U			1U	1U	1U	0.2U					0.2U						11	0			0.2-1.0					
Silver	0.02		0.2U	0.2U	0.2U	0.14U	0.04U	0.04U	0.04U	0.2U	0.2U	0.2U	0.04U	0.04U	0.04U	0.04UJ	0.2U	0.04U	0.04U	0.04U	0.04U	0.04U	0.04U	22	1	0.02	0.02	0.04-0.2				0.02	
Sodium			1,090	1,090	1,090	780	490	580	730	1,120	1,120	1,140	760	810	610	610J	600	700	580	570	690	540U	670	21	20	1140	490	540	Normal	778.3	267.37	730	887.99
Thallium			1U	1U	1U	0.04U	0.04U	0.04U		1U	1U	1U	0.04U					0.04U	0.04U	0.04U				13	0			0.04-1.0					
Uranium						0.04U	0.04U	0.04U					0.04U					0.04U	0.04U	0.04U				7	0			0.04					
Zinc	3.7	3	4U	4U	4U	4U	5	4U	4U	4U	4U	4U	4U	4U	4U	4U	11	4U	5	4U	4U	5	4U	23	6	11	3	4				5	
Dissolved Metals (ug/L)																																	
Aluminum		7.4 *	20	20U	20	30	20U	20U	30	20	40	20U	30U	20	60	40J	30	30U	30	20U	40	40U	30	22	14	60	7.4	20-40	Lognormal	22.1	13.61	20	29.47
Arsenic			1U	1U	1U	0.50	0.51	0.82	0.53	1U	1U	1U	0.50					0.52	0.81	0.82	0.54	0.94	0.73	17	11	0.94	0.5	1	Nonparametric	0.6	0.16	6.5	**0.94**
Barium			5	6	6	22.0J	10.4	4.32	4.38	5	5	5	15.4J	24.3	17.6	16.0J	14	10.9	4.33	4.33	4.14	3.42	3.61	21	21	24.3	3.42		Nonparametric	9.94	6.69	6	**24.3**
Beryllium			1U	1U	1U	0.04U	0.04U	0.04U	0.04U	1U	1U	1U	0.04U	0.04U	0.04U	0.04U	0.04U	0.04U	0.04U	0.04U	0.04U	0.04U	0.04U	21	0			0.04-1.0					
Cadmium	0.05	0.02 *	0.2U	0.2U	0.2U	0.04U	0.04U	0.04U	0.04U	0.2U	0.2U	0.2U	0.04U	0.04U	0.04U	0.04U	0.04U	0.04U	0.04U	0.08	0.08	0.04U	0.04U	23	4	0.08	0.02	0.04-0.2				0.05	
Calcium			6,430	6,430	6,400	3,770	3,120	4,120	3,730	6,750	6,810	6,490	3,870	3,780	3,510	3,480J	2,800	3,000	4,170	4,150	3,630	2,520	2,310	21	21	6810	2310		Nonparametric	4533.3	4545.4	1507.9	**6810**
Chromium			5U	5U	5U	0.2U	0.2U	0.2U	0.2U	5U	5U	5U	0.2U	0.2U	0.2U	0.2U	5U	0.2U	0.2U	0.2U	0.2U	0.2U	0.2U	21	0			0.2-5.0					
Copper	0.96	0.26 *	2U	2U	2U	1.1	0.6	0.4	0.8	2U	2U	2U	0.7	1.0	0.9	1.2U	2U	0.6	0.4	0.5	0.6	1.1	0.7	23	15	1.1	0.26	1.2-2.0	Nonparametric	0.81	0.27	0.98	**1.1**
Iron			40	40	40	30	20U	40	20	30	40	40	30	30J	30	20U	20U	20U	40	40	30	60	30	21	17	60	20	20	Nonparametric	31.67	13.83	35	**60**
Lead	0.02	0.02 *	1U	1U	1U	0.2U	0.3J	0.5	0.011U	1U	1U	1U	0.9U	0.3U	1.8U	0.2U	0.2U	0.2J	0.2U	0.9	0.011U	0.2U	0.5J	23	7	0.9	0.02	0.011 - 1.0				0.25	
Magnesium			660	660	660	360	270	350	330	640	650	660	360	370	340	310J	250	260	350	350	320	260	230	21	21	660	230		Nonparametric	431.11	167.15	355	**360**
Manganese			2	1	1	1.82	1.13	1.65	2	2	1	1	1.94	1.40	1.23	0.96J	1	1.18	1.74	1.72	2.08	3.17	2.88	21	21	3.17	0.96		Nonparametric	1.5	0.57	1.32	**3.17**
Mercury			0.1UJ	0.1UJ	0.1UJ	0.00031J	0.00028J			0.1UJ	0.1UJ	0.1UJ	0.00003J					0.00033J						10	4	0.00033	0.00003	0.1				0.0003	
Molybdenum						0.49	0.40	0.82	0.49				0.51					0.41	0.73	0.73	0.48	0.67	0.59	11	11	0.73	0.4		Lognormal	0.56	0.15	0.51	6.7
Nickel	0.22		10U	10U	10U	0.2	0.2U	0.2	0.2U	10U	10U	10U	0.3	0.6	0.4	0.2U	10U	0.2U	0.2	0.2	0.2U	0.3	0.3	22	11	0.6	0.2	0.2-10.0	Lognormal	2.55	2.36	0.3	10.19
Potassium			690	500	500	500U	500U	500U	500U	780	660	500U	500U	500U	710	500U	500U	500U	500U	500U	500U	500U	500U	21	6	780	500	500				675	
Selenium			1U	1U	1U	0.2U	0.2U			1U	1U	1U	0.2U					0.2U						10	0			0.2-1.0					
Silver	0.01 U		0.2U	0.2U	0.2U	0.04U	0.04U	0.04U	0.04U	0.2U	0.2U	0.2U	0.04U	0.04U	0.04UJ	0.04UJ	0.04U	0.04U	0.04U	0.04U	0.04U	0.04U	0.04U	22	0			0.01-0.2					
Sodium			1,240	1,220	1,280	810J	490	620	690	1,100	1,160	1,120	800J	820	660	660J	570U	490	600	610	700	560U	630	21	19	1280	490	560-570	Lognormal	803.95	325.13	730	1006.86
Thallium			1U	1U	1U	0.04U	0.04U	0.04U		1U	1U	1U	0.04U					0.04U	0.04U	0.04U				13	0			0.04-1.0					
Uranium						0.04U	0.04U	0.04U					0.04U					0.04U	0.04U	0.04U				7	0			0.04					
Zinc	1.3	0.85 *	5	5	4U	13	6	4U	4U	6	6	5	16	14U	13U	16U	12	6	16	4	4U	5	4U	23	18	16	0.85	4.0-16.0	Lognormal	7.05	4.42	6	10.66

Data Notes:
J - Estimated value.
U - Parameter was analyzed for, but not detected above the reporting limit shown.
UJ - Parameter was analyzed for but not detected. Detection limit is an estimated value.
* indicates that highest value from range of replicated samples were represented.
▨ Gray shading ▨ indicates the concentration of analyte was not established, therefore not reported nor analyzed.

▨ Statistical Reanalysis pending to include 1998 data

Data Source:
(a) Johnson, A., et al. 1997. *Effects of Holden Mine on the Water, Sediments and Benthic Invertebrates of Railroad Creek (Lake Chelan).*
Environmental Investigations and Laboratory Services Program. Water Body No. WA-47-1020. Publication No. 97-330 (data collected in Spring and Fall 1996).

Statistical Notes: (Statisical calculations were performed using Washington Department of Ecology's MTCAStat Excel V.5 Macro (Background Module 2.1), downloaded from their web site.)
Maximum and minimum concentrations are based on detected values only.
Range of reporting limits (RL) are based on results reported as not detected.
Distribution is determined based on the MTCA stat program by analyzing the data through the "Distribution Decision Probability Plot". Where data is not lognormally nor normally distributed, the distribution is noted as "Nonparametric".
When approximate distribution is reported as "nonparametric", the maximum concentration is reported as the 90th percentile and presented in BOLD font.
The mean is an arithmetic mean if data are normally distributed or if distribution is indicated as "nonparametric". The reported mean for lognormally distributed data is a lognormal mean.
Statistical analysis was not performed on data sets where 50% or greater of the results were reported as not detected. Only maximum and minimum concentrations are reported, if applicable.
For these data sets, a calculated median is based on detected values only.

TABLE 7.2.2-1B2
STATISTICAL ANALYSIS & COMPARISON OF
SURFACE WATER DATA FROM RAILROAD CREEK
(ADJACENT, SAMPLES COLLECTED FROM 1996-1998)

TABLE 7.2.2-1B2
STATISTICAL ANALYSIS AND COMPARISON OF SURFACE WATER DATA FROM RAILROAD CREEK
SAMPLES FROM MAINSTREAM OF ADJACENT REACH, 1996-1998 (EXCLUDES ALL BANK SAMPLES)
HOLDEN MINE RI/FS
DAMES & MOORE JOB NO. 17693-005-019

Parameters			DAMES & MOORE RI DATA (RC-SITE E)															DAMES & MOORE RI DATA (RC-SITE W)							STATISTICAL CALCULATIONS										
	DEPT. OF ECOLOGY (RC-STATION SAMPLES)[a]		RC-2A	RC-2								RC-2X	RC-7A	RC-7				RC-4A	RC-4X	RC-4				RC-4X	# Analyses	# of Detections	Maximum Conc.	Minimum Conc.	Range of RL	Approximate Distribution	Mean	Standard Deviation	Median	UCL (95%)
	6/12/96	9/10/96	4/17/97	5/19/97	5/26/97	6/2/97	6/9/97	6/16/97	7/10/97	9/15/97	5/3/98	9/15/97	4/16/97	5/20/97	7/10/97	9/15/97	5/3/98	4/16/97	4/16/97	5/21/97	7/16/97	9/15/97	5/3/98	5/3/98										
Total Metals (ug/L)																																		
Aluminum	44	96 *	160	230	160	190	150J	220	210	90	250	90	160	180	190	100	220	40	40	100	160	50	200J	160J	24	24	250	40	None	Normal	145	64.9	160	168
Arsenic	0.63	0.68	1U	0.61					0.66	0.87	0.83	0.88	1U				0.76	1U	1U				0.93	0.85	14	10	0.93	0.61	1	Normal	0.69	0.16	0.67	0.77
Barium			6	5.51	5.08	5.11	4.87J	5	5.04	4.71	5.75	4.71	4	5.16	4.91	4.54	5.48	3	4	4.90	4.77	4.36	5.48	5.32	22	22	6	3	None	Normal	4.90	0.66	4.96	5.14
Beryllium			1U	0.04U	0.04U	0.04U	0.04U	0.2U	0.04U	0.04U	0.04U	0.04U	1U	0.04U	0.04U	0.04U	0.04U	1U	1U	0.04U	0.04U	0.04U	0.04U	0.04U	22	0	NA	NA	0.04 - 1	NA	NA	NA	NA	NA
Cadmium	0.21	0.12 *	0.5	0.52	0.44	0.33	0.25J	0.2U	0.10U	0.11	0.77J	0.11	0.4	0.51	0.10	0.10	0.75J	0.2	0.3	0.47	0.08U	0.07	0.73J	0.75J	24	21	0.77	0.07	0.08 - 2	Lognormal	0.36	0.25	0.275	0.56
Calcium			8,150	4,800	4,890	4,180	4,260J	3,330	3,510	4,750	4,700	4,740	8,720	4,500	3,550	4,770	4,670	7,490	7,470	4,350	3,310	4,360	4,370	4,310	22	22	8720	3310	None	Neither	4963	1537	4585	8720
Chromium			5U	0.2U	0.2U	0.2U	0.2U	5U	0.2U	0.2U	0.2	0.2U	5U	0.2U	0.2U	0.2U	0.2U	5U	5U	0.2U	0.2U	0.2U	0.2U	0.2U	22	1	0.2	0.2	0.2 - 5	NA	NA	NA	0.2	0.2
Copper	14	2.4 *	14	33.2	30.2	23.2	15.0J	10	3.8	2.2	52.3	2.2	15	33.7	3.9	2.1	52.8	12	11	32.4	4.4	2.3	56.7	58.6	24	24	58.6	2.1	None	Neither	20.31	18.99	14	58.6
Iron	599	1970 *	2,250	600	710J	510J	520J	440	500	1,330	630	1,340	2,290	650	530	1,280	590	60	60	90	170	90	140	100	24	24	2290	60	None	Neither	727	673	560	2290
Lead	0.21	0.10 U	1U	1.4U	0.3	0.6	1.4J	1U	0.6UJ	0.3UJ	0.284	0.7	1U	0.2U	0.7UJ	0.2UJ	0.295	1U	1U	0.7J	0.4UJ	0.5UJ	0.276	0.279	24	10	1.4	0.21	0.1 - 1.4	NA	NA	NA	0.297	1.4
Magnesium			1,170	610	670	550	540J	410	440	540	570	560	1,190	580	440	540	550	770	770	460	350	380	450	450	22	22	1190	350	None	Neither	590	220	545	1190
Manganese	8.2	20 *	26	11.6	11.6	9.82	8.06J	9	8.61	12.2	12.7	12.2	26	9.44	7.91	10.8	11.8	3	3	3.58	4.34	2.75	8.22	7.53	24	24	26	2.75	None	Lognormal	10.56	6.2	9.22	13.77
Mercury	0.001		0.1U	0.00039J					0.00029J				0.1U					0.1U	0.1U						7	3	0.001	0.00029	0.1	NA	NA	NA	0.00039	0.001
Molybdenum				0.46					0.36	0.73	0.53	0.72					0.52						0.52	0.53	8	8	0.73	0.36	None	Lognormal	0.55	0.12	0.525	0.65
Nickel	0.44		10U	2.3J	0.5	0.6	0.4J	10U	0.4	0.4	0.6	0.4	10U	0.5	0.4	0.3	0.6	10U	10U	0.4	0.3	0.2	0.5	0.5	23	18	2.3	0.2	10	Neither	1.55	2.04	0.4	2.3
Potassium			640	500U	590	770	880J	500U	500U	500U	500U	500U	1,010	780	590	500U	500U	660	660	500U	500U	500U	500U	500U	22	9	1010	590	500	NA	NA	NA	660	1010
Selenium		0.4 U	1U	0.2U					0.2U				1U					1U	1U						7	0	NA	NA	0.2 - 1	NA	NA	NA	NA	NA
Silver	0.01 U		0.2U	0.04U	0.04U	0.04U	0.04U	0.2U	0.14	0.11	0.04U	0.07	0.2U	0.06	0.04U	0.04U	0.04U	0.2U	0.2U	0.04U	0.04U	0.04U	0.04U	0.04U	23	4	0.14	0.06	0.01 - 0.2	NA	NA	NA	0.09	0.14
Sodium			1,270	840	880	750	820J	590U	530	640	790	670	1,310	810	540	650	770	1,230	1,230	800	510	650	780	740	22	21	1310	510	590	Lognormal	800	261	775	919
Thallium			1U	0.2U					0.04U	0.04U		0.04U	1U					1U	1U						8	0	NA	NA	0.04 - 1	NA	NA	NA	NA	NA
Uranium				0.4U					0.04	0.04U		0.04U													4	1	0.04	0.04	0.04 - 0.4	NA	NA	NA	0.04	0.04
Zinc	36	30	76	86	76	52	43J	24	16	21	116	20	85	79	15	25	119	48	48	67	12	18	115	114	24	24	119	0.12	None	Lognormal	57.90	36.21	48	81
Dissolved Metals (ug/L)																																		
Aluminum		5.4 *	20U	90	60	70	80J	50	50U	40	100	40	20U	60	40U	40	90	30	30	30	30U	20U	60	70	23	17	100	5.4	20 - 50	Lognormal	48.56	28.74	40	72.92
Arsenic			1U	0.30					0.33	0.49	0.35	0.50	1U				0.36	1U	1U				0.46	0.45	12	8	0.5	0.3	1	Lognormal	0.44	0.08	0.475	0.49
Barium			6	10.6J	18.2	31.1	20.2J	15	17.7	4.55	5.02	4.5	6	10.7	12.6	4.52	4.88	6	6	9.90	13.4	4.37	4.69	4.6	22	22	31.1	4.37	None	Neither	10.02	6.95	6	31.1
Beryllium			1U	0.04U	0.04U	0.04U	0.04U	0.04U	0.04U	0.08U	0.04U	0.04U	1U	0.04U	0.04U	0.04U	0.04U	1U	1U	0.04U	0.04U	0.04U	0.04U	0.04U	22	0	NA	NA	0.04 - 1	NA	NA	NA	NA	NA
Cadmium	0.29	0.13 *	0.4	0.53	0.45	0.32	0.23J	0.14	0.08	0.10	0.68	0.11	0.5	0.58	0.09	0.09	0.67	0.3	0.3	0.44	0.09	0.06	0.66	0.67	24	24	0.68	0.06	None	Neither	0.33	0.22	0.3	0.68
Calcium			8,320	4,900	4,800	4,260	4,200J	3,280	3,560	4,940	4,680	5,120	8,880	4,740	3,540	4,720	4,520	7,760	7,550	4,540	3,260	4,390	4,250	4,240	22	22	8880	3260	None	Neither	5020	1601	4610	8880
Chromium			5U	0.4	0.2U	0.2U	0.2U	5U	0.2U	0.2U	0.2U	0.2	5U	0.2U	0.2U	0.2U	0.2U	5U	5U	0.2U	0.2U	0.2U	0.2U	0.2U	22	2	0.4	0.2	0.2 - 5	NA	NA	NA	0.3	0.4
Copper	10	0.93 *	2	23.6	19.1	15.1	10.3J	8	2.3	1.2	35.7	1.3	3	23.0	2.6	1.3	37.5	11	11	26.4	3.4	1.8	41.7	41.9	24	24	41.9	0.93	None	Neither	13.92	13.92	10.15	41.9
Iron			1,430	300	480J	360J	380J	220	270	1,080	350	1,160	1,680	480	330	1,150	380	40	30	20	20U	40	20U	20U	22	19	1680	20	20	Normal	464	502	340	648
Lead	0.07	0.06 *	1U	1.4U	0.7U	1.4U	0.4J	0.4U	0.2UJ	0.2U	0.107	0.3	1U	0.5J	0.5J	0.4	0.126	1U	1U	0.6J	0.4J	0.3	0.088	0.085	24	14	0.6	0.06	0.2 - 1.4	Neither	0.34	0.21	0.375	0.6
Magnesium			1,190	630	640	530	490J	350	370	570	550	590	1,250	590	380	530	510	810	790	470	300	370	420	420	22	22	1250	300	None	Lognormal	578	246	530	671
Manganese			26	12.8	10.9	8.47	7.42J	6	5.52	11.1	9.9	11.4	27	11.8	5.48	9.96	9.6	4	3	2.94	1.53	1.86	4.83	4.94	22	22	27	1.53	None	Lognormal	9.18	6.64	7.94	13.14
Mercury			0.1UJ	0.00047J					0.00053				0.1UJ					0.1UJ	0.1UJ						6	2	0.00053	0.00047	0.1	NA	NA	NA	0.0005	0.00053
Molybdenum				0.47					0.37	0.71	0.48	0.72					0.48						0.49	0.61	8	8	0.72	0.37	None	Lognormal	0.54	0.13	0.485	0.64
Nickel	0.36		10U	0.9	0.6	0.4	0.4J	10U	0.2	0.4	0.4	0.4	10U	0.4	0.2	0.4	0.4	10U	10U	0.3	0.2	0.2	0.5	0.5	23	19	0.9	0.2	10	Neither	1.55	2.04	0.4	0.9
Potassium			640	500U	500U	500U	630J	500U	500U	500U	500U	500U	610	530	500U	500U	500U	690	660	520	500U	500U	500U	500U	22	7	690	520	500	NA	NA	NA	630	690
Selenium			1U	0.2U					0.2U				1U					1U	1U						6	0	NA	NA	0.2 - 1	NA	NA	NA	NA	NA
Silver	0.01 U		0.2U	0.07	0.04U	0.04UJ	0.04U	0.04U	0.04U	0.04U	0.04U	0.04U	0.2U	0.54U	0.04U	0.04U	0.04U	0.2U	0.2U	0.08U	0.04U	0.04U	0.04U	0.04U	23	1	0.07	0.07	0.01 - 0.54	NA	NA	NA	0.07	0.07
Sodium			1,360	1,800J	910	1,010	770J	590U	580	670	800	730	1,500	860	590	660	760	1,440	1,300	840	520	650	740	750	22	21	1800	520	590	Lognormal	892	369	765	1057
Thallium			1U	0.04U					0.04U	0.04U		0.04U	1U					1U	1U						8	0	NA	NA	0.04 - 1	NA	NA	NA	NA	NA
Uranium				0.2U					0.04U	0.04U		0.04U													4	0	NA	NA	0.04 - 2	NA	NA	NA	NA	NA
Zinc	40	30 *	77	84	84	60	51J	27	24	23	113	28	90	85	20	19	115	55	50	73	17	11	114	114	24	24	115	11	None	Lognormal	60.78	35.24	53	83.75

Data Notes:
J - Estimated value.
U - Parameter was analyzed for, but not detected above the reporting limit shown.
UJ - Parameter was analyzed for but not detected. Detection limit is an estimated value.
* indicates that highest value from range of replicated samples were represented.
▨ Gray shading indicates that the data was not available for this parameter

Data Source:
(a) Johnson, A., et al. 1997. *Effects of Holden Mine on the Water, Sediments and Benthic Invertebrates of Railroad Creek (Lake Chelan).*
Environmental Investigations and Laboratory Services Program. Water Body No. WA-47-1020. Publication No. 97-330 (data collected in Spring and Fall 1996).

Statistical Notes: (Statistical calculations were performed using Washington Department of Ecology's MTCAStat Excel V.5 Macro (Module 2.1), downloaded from their web site.)
Maximum and minimum concentrations are based on detected values only.
Range of reporting limits (RL) are based on results reported as not detected.
Distribution is determined based on the MTCA stat program by analyzing the data through the "W-Test" or "D'Agostino's test".
Where data is not lognormally nor normally distributed, the distribution is noted as "Neither".
When approximate distribution is reported as "neither", the maximum concentration is reported as the 95% UCL and is presented in BOLD font.
The mean is an arithmetic mean if data are normally distributed or if distribution is indicated as "Neither". The reported mean for lognormally distributed data is a lognormal mean.
Statistical analysis was not performed on data sets where 50% or greater of the results were reported as not detected. Only maximum and minimum concentrations are reported, if applicable.
For these data sets, a calculated median is based on detected values only.

TABLE 7.2.2-1B3
STATISTICAL ANALYSIS AND COMPARISON OF SURFACE WATER DATA FROM RAILROAD CREEK
SAMPLES COLLECTED FROM MAINSTREAM OF DOWNSTREAM REACH, 1996-1998 (EXCLUDES ALL BANK SAMPLES)
HOLDEN MINE RI/FS
DAMES & MOORE JOB NO. 17693-005-019

Parameters	DEPT. OF ECOLOGY			DAMES & MOORE RI DATA (RC-DOWNSTREAM EAST)										DAMES & MOORE RI DATA (RC-DOWNSTREAM WEST)								STATISTICAL CALCULATIONS										
	RC-STATION[a]		MP-STATION[a]	RC-3A	RC-3				RC-3X		RC-8	RC-8A	RC-8B	RC-5A	RC-5	RC-5A				RC-10		# Analyses	# of Detections	Maximum Conc.	Minimum Conc.	Range of RL	Approximate Distribution	Mean	Standard Deviation	Median	UCL (95%)
	6/12/96	9/10/96	9/10/96	4/18/97	5/22/97	7/11/97	9/16/97	5/5/98	5/22/97	7/11/97	9/16/97	4/18/97	4/18/97	4/17/97	5/20/97	5/22/97	7/10/97	9/16/97	5/4/98	9/16/97	5/4/98										
Total Metals (ug/L)																															
Aluminum	37	50	110	100	170	160	70	250	150	150	70	110		160	210	240	200	120	250	80	300	20	20	300	37	None	Lognormal	153	74.11	150	201
Arsenic	0.42	0.32	0.51	1U	0.35	0.40	0.46	0.5	0.33	0.39		1U		1U					0.76		0.72	14	11	0.76	0.32	1	Lognormal	0.48	0.13	0.48	0.54
Barium				10	7	5.62	6.47	7.07	7	5.63	6.47	10		6	5.68	6	5.27	5.01	6.22	5.60	6.74	17	17	10	5.01	None	Neither	6.58	1.43	6.22	**10**
Beryllium				1U	0.04U	0.04U	0.04U	0.04U	0.04U	0.04U	0.04U	1U		1U	0.04U	0.04U	0.04U	0.04U	0.04U	0.04U	0.04U	17	0	NA	NA	0.04 - 1	NA	NA	NA	NA	NA
Cadmium	0.13	0.1 U	0.12	0.3	0.27	0.07U	0.09	0.37	0.34	0.08U	0.10	0.2		0.4	0.50	0.54	0.11U	0.13	0.66J	0.11	0.45	20	16	0.66	0.09	0.07 - 0.11	Lognormal	0.26	0.19	0.165	0.45
Calcium				9,740	6,350	4,620	6,570	5,520	6,420	4,800	6,540	9,950		8,280	4,940	6,070	3,840	5,570	5,210	6,480	5,730	17	17	9950	3840	None	Lognormal	6278	1676	6070	7041
Chromium				5U	5U	0.2U	0.2U	0.2	5U	0.2U	0.2U	5U		5U	0.2U	5U	0.2U	0.2U	0.2U	0.2U	0.2	17	2	0.2	0.2	0.2 - 5	NA	NA	NA	0.2	0.2
Copper	7.9	1.4	1.8	6	16	3.2	1.6	19.7	16	3.3	1.7	7		14	32.3	32	4.2	2.4	43.5	2.3	30.3	20	20	43.5	1.4	None	Lognormal	13.43	12.86	6.5	28.56
Iron	438	684	1240	870	450	330	620	580	430	330	640	900		2,300	580	750	500	1,440	650	990	790	20	20	2300	330	None	Lognormal	771	459	645	963
Lead	0.17	0.1 U	0.10 U	1U	0.5U	0.3UJ	0.2UJ	0.159	0.9U	0.3UJ	0.2UJ	1U		1U	0.3J	0.5U	0.4UJ	0.2UJ	0.249	0.2UJ	0.201	20	5	0.3	0.159	0.1 - 1	NA	NA	NA	0.201	0.3
Magnesium				1,480	850	570	810	700	850	580	800	1,490		1,190	660	850	490	690	660	780	720	17	17	1490	490	None	Lognormal	833	290	780	962
Manganese	7.9	13	19	14	11	6.66	10.1	10.7	10	6.46	10.7	15		26	12.3	20	9.72	15.4	15	14.0	13.4	20	20	26	6.46	None	Lognormal	13.05	4.71	12.65	15.19
Mercury	0.002			0.1U	0.00034J	0.00014J			0.00047J	0.00015J		0.1U		0.1U								8	5	0.002	0.00014	0.1	Lognormal	0.08	0.03	0.0012	(279)
Molybdenum					0.55J	0.47	0.68	0.55	0.57J	0.54									0.52		0.55	8	8	0.68	0.47	None	Lognormal	0.55	0.06	0.55	0.6
Nickel	0.43			10U	10U	0.4	0.4	0.5	10U	0.4	0.4	10U		10U	0.6	10U	0.4	0.4	0.6	0.5	0.6	18	12	0.6	0.4	10	Neither	1.98	2.2	0.55	**0.6**
Potassium				640	500U	500U	630	530	590	610	500U	850		810	870	560	690	620	500U	500U	500U	17	11	870	530	500	Lognormal	533	228	590	687
Selenium		0.4 U	0.4 U	1U	0.2U	0.2U			0.2U	0.2U		1U		1U								9	0	NA	NA	0.2 - 1	NA	NA	NA	NA	NA
Silver	0.03			0.2U	0.04U	0.04U	0.04U	0.04U	0.09J	0.04U	0.04U	0.2U		0.2U	0.04U	0.20J	0.04U	0.04U	0.04U	0.04U	0.04U	18	3	0.2	0.03	0.04 - 0.2	NA	NA	NA	0.09	0.2
Sodium				1,570	1,070	700	860	930	1,070	750	860	1,610		1,290	840	910	560	730	820	780	850	17	17	1610	560	None	Lognormal	953	291	860	1084
Thallium				1U	0.04U	0.04U	0.04U		0.04U	0.04U		1U		1								8	1	1	1	0.04 - 1	NA	NA	NA	1	1
Uranium					0.10	0.06	0.06		0.09	0.05												5	5	0.1	0.05	None	Lognormal	0.07	0.02	0.06	0.1
Zinc	22	21	28	36	45	14	22	56	47	13	25	40		78	81	88	18	33	101	25	75	20	20	101	13	None	Lognormal	43.93	27.17	34.5	59.78
Dissolved Metals (ug/L)																															
Aluminum		6.4 *	3.2 *	50	70	30U	40	70	80	30U	50	50	20U	20U	70	20U	30U	50	90	40	80	20	14	90	3.2	20 - 30	Normal	41.23	28.86	45	52.39
Arsenic				1U	0.19	0.23	0.31	0.2	0.18	0.23		1U	1U	1U					0.28		0.26	12	8	0.31	0.18	1	Lognormal	0.33	0.14	0.27	0.42
Barium				9	7	16.2	6.95	5.8	7	14.8	6.43	9	9	6	10.8	6	15.9	5.00	5.4	5.56	5.51	18	18	16.2	5	None	Neither	8.41	3.68	6.98	**16.2**
Beryllium				1U	0.2U	0.04U	0.04U	0.04U	0.2U	0.04U	0.04U	1U	1U	1U	0.04U	4U	0.04U	0.04U	0.04U	0.04U	0.04U	18	0	NA	NA	0.04 - 4	NA	NA	NA	NA	NA
Cadmium	0.16	0.08 *	0.13 *	0.2U	0.24	0.07	0.10	0.26	0.24	0.08	0.72	0.2U	0.2U	0.4	0.50	0.51	0.10	0.12	0.58	0.12	0.4	21	18	0.72	0.07	0.2	Lognormal	0.24	0.2	0.13	0.36
Calcium				10,100	6,070	4,630	6,690	5,250	6,220	4,720	6,640	10,000	10,100	8,370	5,010	5,800	3,830	5,600	5,040	6,580	5,410	18	18	10100	3830	None	Lognormal	6452	1942	5935	7317
Chromium				5U	5U	0.2U	0.2U	0.2U	5U	0.2U	0.2U	5U	5U	5U	0.2U	5U	0.2U	0.2U	0.2U	0.2U	0.2U	18	0	NA	NA	0.2 - 5	NA	NA	NA	NA	NA
Copper	5.2	0.4 *	0.39 *	4	10	1.9	1.2	12.6	11	2.0	1.4	4	3	3	21.5	7	2.4	1.6	26.9	1.3	18.5	21	21	26.9	0.39	None	Lognormal	7.34	7.52	3	15.82
Iron				370	230	140	420	170	240	140	420	430	60	1,290	350	40	250	1,250	300	740	220	18	18	1290	40	None	Lognormal	412	359	275	708
Lead	0.04	0.09 *	0.06 *	1U	0.4U	0.2UJ	0.2	0.053	0.6U	0.2UJ	0.5	1U	1U	1U	0.2J	0.2U	0.2UJ	0.2U	0.106	0.2	0.082	20	11	0.5	0.04	0.2 - 1	Neither	0.23	0.8	0.106	**0.5**
Magnesium				1,510	800	540	820	620	810	540	800	1,510	1,520	1,210	670	780	420	680	620	800	640	18	18	1520	420	None	Lognormal	849	348	790	1009
Manganese				15	10	4.96	9.83	6.48	9	4.88	9.97	15	14	26	10.9	18	7.04	14.8	12	13.5	9.29	18	18	26	4.88	None	Lognormal	11.79	5.13	10.45	14.51
Mercury				0.1UJ	0.00064	0.00019J			0.00040J	0.00007J		0.1UJ	0.1UJ	0.1UJ								8	4	0.00064	0.00007	0.1	Lognormal	0.25	0.03	0.025	(3954)
Molybdenum					0.54J	0.54	0.64	0.51	0.54J	0.54									0.45		0.43	8	8	0.64	0.43	None	Lognormal	0.52	0.06	0.54	0.57
Nickel	0.26			10U	10U	0.2U	0.4	0.3	10U	0.2U	0.5	10U	10U	10U	0.6	10U	0.2	0.4	0.4	0.4	0.5	19	10	0.6	0.2	0.2 - 10	Normal	2.06	2.31	0.5	(2.98)
Potassium				810	510	500U	500U	500U	500U	520	500U	880	930	690	700	500U	500U	500U	500U	550	500U	18	8	930	510	500	NA	NA	NA	695	930
Selenium				1U	0.2U	0.2U			0.2U	0.2U		1U	1U	1U								8	0	NA	NA	0.2 - 1	NA	NA	NA	NA	NA
Silver	0.01 U			0.2U	0.04U	0.04U	0.04U	0.04U	0.04U	0.08	0.04U	0.2U	0.2U	0.2U	0.14U	0.04U	0.04U	0.04U	0.04U	0.09J	0.04U	19	2	0.09	0.08	0.01 - 0.2	NA	NA	NA	0.085	0.09
Sodium				1,660	1,020	730	870	870	1,100	740	860	1,750	1,740	1,430	860	900	630	700	780	800	810	18	18	1750	630	None	Neither	1014	369	865	**1750**
Thallium				1U	0.04U	0.04U	0.04U		0.04U	0.04U		1U	1U	1U								9	0	NA	NA	0.04 - 1	NA	NA	NA	NA	NA
Uranium					0.07	0.04U	0.04		0.07	0.04U												5	3	0.07	0.02	0.04	Neither	0.4	0.03	0.04	**0.07**
Zinc	20	19 *	25 *	41	38	17	20	45	40	16	20	37	32	86	84	80	24	30	98	22	69	21	21	98	16	None	Lognormal	41.1	26.1	32	53.86

Data Notes:
J - Estimated value.
U - Parameter was analyzed for, but not detected above the reporting limit shown.
UJ - Parameter was analyzed for but not detected. Detection limit is an estimated value.
* indicates that highest value from range of replicated samples were represented.
▨ Gray shading indicates that the data was not available for this parameter

Data Source:
(a) Johnson, A., et al. 1997. *Effects of Holden Mine on the Water, Sediments and Benthic Invertebrates of Railroad Creek (Lake Chelan).* Environmental Investigations and Laboratory Services Program. Water Body No. WA-47-1020. Publication No. 97-330 (data collected in Spring and Fall 1996).

Statistical Notes: (Statistical calculations were performed using Washington Department of Ecology's MTCAStat Excel V.5 Macro (Module 2.1), downloaded from their web site.)
Maximum and minimum concentrations are based on detected values only.
Range of reporting limits (RL) are based on results reported as not detected.
Distribution is determined based on the MTCA stat program by analyzing the data through the "W-Test" or "D'Agostino's test".
Where data is not lognormally nor normally distributed, the distribution is noted as "Neither".
When approximate distribution is reported as "neither", the maximum concentration is reported as the 95% UCL and is presented in **BOLD** font.
If UCL is reported in brackets (UCL value), this indicates that the calculated result from MTCAStat was reported to be unusually high.
The mean is an arithmetic mean if data are normally distributed or if distribution is indicated as "Neither". The reported mean for lognormally distributed data is a lognormal mean.
Statistical analysis was not performed on data sets where 50% or greater of the results were reported as not detected. Only maximum and minimum concentrations are reported, if applicable. For these data sets, a calculated median is based on detected values only.

TABLE 7.2.2-1C
COMPARISON OF TOTAL METAL CONCENTRATIONS IN SEDIMENT COLLECTED FROM RAILROAD CREEK
(BASED ON SAMPLES COLLECTED FROM 1991-1997, EXCLUDES USGS SEDIMENT & CONCENTRATE DATA AND FLOCCULENT DATA)
HOLDEN MINE RI/FS
DAMES & MOORE JOB NO. 17693-005-019

Parameters	ECOLOGY RC-1	STATISTICAL CALCULATIONS FOR RC-AREA BACKGROUND									
	6/12/96[a]	# of Analyses	# of Detections	Maximum Conc.	Minimum Conc.	Range of RL	Approximate Distribution	Mean	Standard Deviation	Median	UCL (95%)
	Sediment										
Total Metals (mg/kg)											
Aluminum	10400	1	1	10400	10400					10400	**10400**
Arsenic											
Barium											
Beryllium											
Cadmium	0.3 U	1	0			0.3					
Calcium											
Chromium											
Copper	29	1	1	29	29					29	**29**
Iron	15700	1	1	15700	15700					15700	**15700**
Lead	4.9	1	1	4.9	4.9					4.9	4.9
Magnesium											
Manganese	271	1	1	271	271					271	**271**
Mercury											
Molybdenum											
Nickel											
Potassium											
Selenium	0.3 U	1	0			0.3					
Silver											
Sodium											
Thallium											
Uranium											
Zinc	62	1	1	62	62					62	**62**

Data Notes:
J - Estimated value
U - Parameter was analyzed for, but not detected above the reporting limit shown.
UJ - Parameter was analyzed for but not detected. Detection limit is an estimated value.
▨ Grey shading indicates the concentration of analyte was not established, therefore not reported nor analyzed.

Data Source:
(a) Johnson, A., et al. 1997. *Effects of Holden Mine on the Water, Sediments and Benthic Invertebrates of Railroad Creek (Lake Chelan).* Environmental Investigations and Laboratory Services Program. Water Body No. WA-47-1020. Publication No. 97-330 (data collected in Spring and Fall 1996)
(b) Lambeth, R.H. 1995. Transmittal of laboratory data from samples collected at Holden Mine site by the US Bureau of Mines. (Data collected in 1995).

TABLE 7.2.2-1C
COMPARISON OF SEDIMENTARY TOTAL METAL CONCENTRATIONS FROM RAILROAD CREEK
(BASED ON SAMPLES COLLECTED FROM 1991-1997, EXCLUDES USGS SEDIMENT & CONCENTRATE DATA AND FLOCCULENT DATA)
HOLDEN MINE RI/FS
DAMES & MOORE JOB NO. 17693-005-019

Parameters	**RAILROAD CREEK ADJACENT TO SITE**						
	BKG 1/2	**DG-1**	**TP1-2**	**TP2-1**	**TP2-2**	**TP3-1**	**ECOLOGY RC-2**
	3/24/94[b]	**3/24/94[b]**	**3/24/94[b]**	**3/24/94[b]**	**3/24/94[b]**	**3/24/94[b]**	**9/11/96[a]**
	Sediment	**Sediment**	**Sediment**	**Sediment**	**Sediment**	**Sediment**	**Sediment**
<u>Total Metals (mg/kg)</u>							
Aluminum	11300	9380	10800	10400	9330	11700	8540
Arsenic	11.5	3.8	11.2	7.5	9.2	11.4	▨
Barium	26.3	78.8	30.1	19.3	41.7	39.3	▨
Beryllium	0.08	0.07	0.1	0.11	0.14	0.13	▨
Cadmium	0.93	1.1	1.8	1.2	1.8	1.3	0.3 U
Calcium	4600	2820	3800	3090	2950	3630	▨
Chromium	16.9	4.4	7.3	7.9	1.3	12.9	▨
Copper	76.6	184	9.1	8.5	7.1	11.1	101
Iron	17000	20600	41300	30800	38400	27700	19000
Lead	7.1	4.2	6.5	4.4	5.6	6.3	5.6
Magnesium	6940	5590	6570	6980	5270	8940	▨
Manganese	308	242	6.5	4.4	5.6	6.3	217
Mercury	0.02	0.02 U	0.02 U	0.02 U	0.02 U	0.02 U	▨
Molybdenum	▨	▨	▨	▨	▨	▨	▨
Nickel	15	21.6	16.2	12.5	10.7	25.7	▨
Potassium	455	888	631	547	718	723	▨
Selenium	0.95	0.10 U	0.95	0.12	0.14	0.93	0.5
Silver	0.64	0.73	5.6	0.6	0.72	0.76	▨
Sodium	345	318	336	312	294	368	▨
Thallium	0.15	0.14	0.14	0.1	0.13	0.12	▨
Uranium	▨	▨	▨	▨	▨	▨	▨
Zinc	110	126	106	75	118	152	113

<u>Data Notes:</u>

J - Estimated value.

U - Parameter was analyzed for, but not detected above the reporting limit shown.

UJ - Parameter was analyzed for but not detected. Detection limit is an estimated value.

▨ Grey shading indicates the concentration of analyte was not established, therefore not reported nor analyzed.

<u>Data Source:</u>

(a) Johnson, A., et al. 1997. *Effects of Holden Mine on the Water, Sediments and Benthic Invertebrates of Railroad Creek (Lake Chelan).* Environmental Investigations and Laboratory Services Program. Water Body No. WA-47-1020. Publication No. 97-330 (data collected in Spring and Fall

(b) Lambeth, R.H. 1995. Transmittal of laboratory data from samples collected at Holden Mine site by the US Bureau of Mines. (Data collected in 1995)

TABLE 7.2.2-1C
COMPARISON OF SEDIMENTARY TOTAL METAL CONCENTRATIONS FROM RAILROAD CREEK
(BASED ON SAMPLES COLLECTED FROM 1991-1997, EXCLUDES USGS SEDIMENT & CONCENTRATE DATA AND FLOCCULENT DATA)
HOLDEN MINE RI/FS
DAMES & MOORE JOB NO. 17693-005-019

Parameters	STATISTICAL CALCULATIONS FOR RC ADJACENT TO SITE									
	# of Analyses	# of Detections	Maximum Conc.	Minimum Conc.	Range of RL	Approximate Distribution	Mean	Standard Deviation	Median	UCL (95%)
Total Metals (mg/kg)										
Aluminum	7	7	11700	8540		Lognormal	10217	1158	10400	11717
Arsenic	6	6	11.5	3.8		Normal	9.1	3.04	10.2	11.6
Barium	6	6	78.8	19.3		Lognormal	39.77	21.07	34.7	69.61
Beryllium	6	6	0.14	0.07		Lognormal	0.11	0.03	0.11	0.14
Cadmium	7	6	1.8	0.93	0.3	Normal	1.18	0.57	1.2	4.41
Calcium	6	6	4600	2820		Lognormal	3490.4	670.51	3360	4137.11
Chromium	6	6	16.9	1.3		Lognormal	9.79	5.66	7.6	47.08
Copper	7	7	184	7.1		Neither	56.77	67.94	11.1	**184**
Iron	7	7	41300	17000		Lognormal	28085	9570.2	27700	38428.9
Lead	7	7	7.1	4.2		Lognormal	5.69	1.07	5.6	6.68
Magnesium	6	6	8940	5270		Lognormal	6732.9	1299.7	6755	7998.54
Manganese	7	7	308	4.4		Neither	112.83	136.34	6.5	**308**
Mercury	6	1	0.02	0.02	0.02				0.01	
Molybdenum										
Nickel	6	6	25.7	10.7		Lognormal	17.1	5.68	15.6	23.91
Potassium	6	6	888	455		Lognormal	663.66	151.63	674.5	829.64
Selenium	7	6	0.95	0.12	0.1	Neither	0.52	0.42	0.5	**0.52**
Silver	6	6	5.6	0.6		Neither	1.51	2.01	0.73	**5.6**
Sodium	6	6	368	294		Lognormal	329.01	26.31	327	357.28
Thallium	6	6	0.15	0.1		Lognormal	0.13	0.02	0.14	0.15
Uranium										
Zinc	7	7	152	75		Lognormal	114.75	23.11	113	136.76

Statistical Notes: (Statisical calculations were performed using Washington Department of Ecology's MTCAStat Excel V.5 Macro (Module 2.1), downloaded from their web site.)
Maximum and minimum concentrations are based on detected values only.
Range of reporting limits (RL) are based on results reported as not detected.
Distribution is determined based on the MTCA stat program by analyzing the data through the "W-Test" or "D'Agostino's test".
Where data is not lognormally nor normally distributed, the distribution is noted as "Neither".
When approximate distribution is reported as "neither", the maximum concentration is reported as the 95% UCL and is presented in **BOLD** font.
The mean is an arithmetic mean if data are normally distributed or if distribution is indicated as "Neither". The reported mean for lognormally distributed data is a lognormal mean.
Statistical analysis was not performed on data sets where 50% or greater of the results were reported as not detected. Only maximum and minimum concentrations are reported, if applicable
For these data sets, a calculated median is based on detected values only

TABLE 7.2.2-1C
COMPARISON OF SEDIMENTARY TOTAL METAL CONCENTRATIONS FROM RAILROAD CREEK
(BASED ON SAMPLES COLLECTED FROM 1991-1997, EXCLUDES USGS SEDIMENT & CONCENTRATE DATA AND FLOCCULENT DATA)
HOLDEN MINE RI/FS
DAMES & MOORE JOB NO. 17693-005-019

Parameters	RC-DOWNSTREAM		STATISTICAL CALCULATIONS FOR RC DOWNSTREAM									
	ECOLOGY MP-7	ECOLOGY RC-3										
	9/11/96^a	9/11/96^a	# of Analyses	# of Detections	Maximum Conc.	Minimum Conc.	Range of RL	Approximate Distribution	Mean	Standard Deviation	Median	UCL (95%)
	Sediment	Sediment										
Total Metals (mg/kg)												
Aluminum	13300	7890	2	2	13300	7890					10595	**13300**
Arsenic												
Barium												
Beryllium												
Cadmium	0.9	0.5	2	2	0.9	0.5					0.7	**0.9**
Calcium												
Chromium												
Copper	147	59	2	2	147	59					103	**147**
Iron	26300	14800	2	2	26300	14800					20550	26300
Lead	11	2.4	2	2	11	2.4					6.7	11
Magnesium												
Manganese	289	285	6	6	1200	285					743	1200
Mercury												
Molybdenum												
Nickel												
Potassium												
Selenium	0.6	0.3 U	2	1	0.6	0.6	0.3					0.6
Silver												
Sodium												
Thallium												
Uranium												
Zinc	216	144	2	2	216	144					180	216

Statistical Notes: (Statisical calculations were performed using Washington Department of Ecology's MTCAStat Excel V.5 Macro (Module 2.1), downloaded from their web site.)
Maximum and minimum concentrations are based on detected values only.
Range of reporting limits (RL) are based on results reported as not detected.
Distribution is determined based on the MTCA stat program by analyzing the data through the "W-Test" or "D'Agostino's test".
Where data is not lognormally nor normally distributed, the distribution is noted as "Neither".
When approximate distribution is reported as "neither", the maximum concentration is reported as the 95% UCL and is presented in **BOLD** font.
The mean is an arithmetic mean if data are normally distributed or if distribution is indicated as "Neither". The reported mean for lognormally distributed data is a lognormal mean.
Statistical analysis was not performed on data sets where 50% or greater of the results were reported as not detected. Only maximum and minimum concentrations are reported, if applicable.
For these data sets, a calculated median is based on detected values only.

TABLE 7.2.2-1D
SUMMARY OF RI FERRICRETE, FLOCCULENT, AND PORTAL FILM DATA
HOLDEN MINE RI/FS
DAMES & MOORE JOB NO. 17693-005-019

Parameters		Ferricrete			Flocculent			Portal Film	
	Sample ID	**DMTP1E-1**	**DMTP1W-1A**	**DMTP1W-1B**	**Floc1-RC-2**	**Floc2-RC-5**	**Floc3-RC-9**	**Portal Film**	**Portal Film**
	Sampling Date	**10/4/97**	**10/4/97**	**10/4/97**	**10/4/97**	**10/4/97**	**10/4/97**	**7/12/97**	**10/4/97**
		mg/kg (dry)	mg/kg (dry)	mg/kg (dry)	mg/kg (wet)	mg/kg (wet)	mg/kg (dry)	mg/L	mg/L
Total Metals									
Aluminum		10,100	15,100	10,900	3,240	5,410	16,600	12,900	6,120
Arsenic		7.8	14.6	1.1	20.1	47	126	2U	1U
Barium		38.8	42.8	1,100	14.5	24.1	31	1.42	0.81
Beryllium		0.5U	0.1U	0.1U	0.2U	0.5U	2U	0 13	0.12
Cadmium		1UJ	0.4J	3.3J	1.3J	4J	5J	0.16	0.26
Calcium		3,790	3,950	2,680	602	710	1,090	389	701
Chromium		16	25.3	9.7	2.9	5	10	0.53	0.3
Copper		101	90.8	2,340	164	492	982	222	346
Iron		111,000J	45,000J	37,500J	84,400J	125,000J	434,000J	1,430	1,650
Lead		10U	6	75	4U	10U	40U	13.8J	16
Magnesium		6,610	9,310	7,690	588	570	1,220	56.5	50
Manganese		230J	313J	232J	53.4J	182J	331J	9.06	4.41
Mercury		▨	▨	▨	▨	▨	▨	0.002U	▨
Molybdenum		3U	1.6	45.0	11.1	9	70	0.85	0.11
Nickel		11	12	4	2	5U	20U	0.4U	0.2U
Potassium		6,160	1,540	3,140	220	440	1,050U	21	20
Selenium		▨	▨	▨	▨	▨	▨	2U	▨
Silver		2	1.5	3.3	1.2	2	11	0.12U	0.07
Sodium		550	538	615	63U	70	210	17.9J	31
Thallium		2U	0.6U	0.9	0.10U	0.2U	0.4U	2U	1U
Uranium		2U	2U	3U	2U	4U	8U	1.13	1.8
Zinc		73J	91.2J	404J	145J	320J	481J	72	228
Conventional Analyses:									
Sulfide (mg/kg)		▨	▨	0.68UJ	▨	▨	▨	▨	▨

Data Notes:

J - Estimated value.

U - Parameter was analyzed for but not detected above the reporting limit shown.

UJ - Parameter was analyzed for but not detected. Detection limit is an estimated value.

▨ Grey shading indicates the concentration of analyte was not established, therefore not reported nor analyzed.

TABLE 7.2.2-1E
STATISTICAL ANALYSIS AND COMPARISON OF SURFACE SOIL CHEMICAL DATA AT HOLDEN VILLAGE
HOLDEN MINE RI/FS
DAMES & MOORE JOB NO. 17693-005-019

Parameters	Location	*HOLDEN VILLAGE AREA*														
	Sample ID	**HV-1A**	**HV-2A**	**HV-3A**	**HV-4A**	**HV-5A**	**HV-6A**	**HV-7**	**DMSS-1**	**DMSS-2**	**DMSS-3**	**DMSS-4**	**DMSS-5**	**DMSS-6**	**DMSS-6X**	**DMSS-7**
	Sample Date	**6/1/94 [a]**	**6/1/94 [a]**	**6/1/94 [a]**	**6/1/94 [a]**	**6/1/94 [a]**	**6/1/94 [a]**	**11/94 [a]**	**9/20/97**	**9/20/97**	**9/20/97**	**9/20/97**	**9/20/97**	**9/20/97**	**9/20/97**	**9/20/97**
Metals (mg/kg)																
Aluminum		21,400	18,400	21,600	22,300	15,300	25,100	10,100	19,100	16,800	23,500	16,200	17,900	25,900	26,300	15,500
Arsenic		3	3.1	2	4.5	1.3	1.1	1.7	2.1	3.3	1.6	5.1	1.3	3.5	3.7	2.3
Barium		124	126	161	102	171	127	297	102	380	156	333	136	104	104	116
Beryllium		0.19	0.16	0.23	0.32	0.22	0.29	0.11	0.3	0.2	0.3	0.2	0.2	0.3	0.3	0.2
Cadmium		2	1.1	1.2	0.97	0.77	1.5	1.6	0.8	1.5	0.9	2.1	1.4	1.6	1.2	0.7
Calcium		6,090	5,090	5,370	6,670	3,380	4,210	2,370	4,480	5,320	6,070	12,400	4,020	8,310	8,790	4,360
Chromium		14.5	10.7	57.7	30.5	21.3	36.6	4.3	39.4	23.8	48.3	28.7	29.1	26.3	26.5	24
Copper		210	150	53.4	33.6	49	47.5	229	83	523	86.2	155	412	216	245	112
Iron		23,600	24,100	26,200	26,400	17,400	28,400	19,800	24,000	29,600	28,200	26,300	26,100	25,200	24,600	22,600
Lead		23	21	18	14	23	5	99	21	103	12	61	34	10	11	45
Magnesium		7,950	6,610	10,200	8,620	5,770	10,500	4,950	8,450	7,200	10,800	5,860	8,040	8,980	9,230	6,750
Manganese		363	301	562	463	1,270	621	205	435	315	542	613	637	427	419	317
Mercury		0.03	0.06	0.02	0.03	▨	0.02	0.08	▨	▨	▨	▨	▨	▨	▨	▨
Molybdenum		▨	▨	▨	▨	▨	▨	▨	0.9	4.5	0.9	5.0	2.4	0.6	0.6	1.9
Nickel		15	11	27	26	17	27	6	22	13	27	16	17	18	18	14
Potassium		1,830	1,380	1,060	813	748	1,050	1,660	1,300	1,740	1,430	2,110	1,660	1,710	1,590	1,360
Selenium		0.99 U	1.0 U	1.0 U	1 U	1.1 U	0.95 U	1.1 U	▨	▨	▨	▨	▨	▨	▨	▨
Silver		0.69 U	0.58 U	0.76 U	0.79 U	0.68	0.58 U	0.56 U	0.4U	1.2	0.4U	2	0.4	0.3U	0.3U	0.3
Sodium		652	711	522	841	471	450	303	612	728	531	777	600	1,080	1,090	533
Thallium		0.13	0.32	0.10 U	0.10	0.11 U	0.10	0.35	0.1U	0.6U	0.1U	0.8U	0.1U	0.1U	0.1U	0.6U
Uranium		▨	▨	▨	▨	▨	▨	▨	2U	2U	3U	3U	2U	2U	2U	2U
Zinc		204	171	169	106	456	90	184	132	284	112	356	137	201	161	145

Data Notes:

J - Estimated value.
U - Parameter was analyzed for but not detected above the reporting limit shown.
UJ - Parameter was analyzed for, but not detected. Detection limit is an estimated value.
▨ Grey shading indicates the concentration of analyte was not established, therefore not reported nor analyzed.

Data Source:

(a) Lambeth, R.H. 1995. Transmittal of laboratory data from samples collected at Holden Mine site by the US Bureau of Mines. (Data collected in 1995).

TABLE 7.2.2-1E
STATISTICAL ANALYSIS AND COMPARISON OF SURFACE SOIL CHEMICAL DATA AT HOLDEN VILLAGE
HOLDEN MINE RI/FS
DAMES & MOORE JOB NO. 17693-005-019

Parameters	STATISTICAL CALCULATIONS FOR SURFACE SOIL									
	# of Analyses	# of Detections	Maximum Conc.	Minimum Conc.	Range of RL	Approximate Distribution	Mean	Standard Deviation	Median	UCL (95%)
Metals (mg/kg)										
Aluminum	15	15	26,300	10,100		Lognormal	19778	4582	19100	22437
Arsenic	15	15	5.1	1.1		Lognormal	2.6	1.2	2.3	3.4
Barium	15	15	380	102		Neither	169	91	127	**380**
Beryllium	15	15	0.32	0.11		Normal	0.23	0.06	0.22	0.26
Cadmium	15	15	2.1	*0.7*		*Lognormal*	1.3	0.43	1.2	1.54
Calcium	15	15	12,400	2370		Lognormal	5944	2558	5345	7490
Chromium	15	15	57.7	4.3		Normal	28.1	13.7	26.5	34.3
Copper	15	15	523	33.6		Lognormal	180.3	140.5	150	311.3
Iron	15	15	29,600	17,400		Normal	24833	3200	25200	26288
Lead	15	15	*103*	*5.0*		*Lognormal*	33.9	31.1	21	61.4
Magnesium	15	15	10,800	4950		Lognormal	8015	1792	8040	8989
Manganese	15	15	1,270	205		Lognormal	499	250	435	627
Mercury	6	6	0.08	0.02		Neither	0.04	0.02	0.03	**0.08**
Molybdenum	8	8	5.0	0.6		Lognormal	2.2	1.8	1.4	6
Nickel	15	15	27	6		*Normal*	18.5	*6.4*	17	21.1
Potassium	15	15	2,110	748		Lognormal	1438	385	1430	1671
Selenium	7	0			0.95-1.1					
Silver	15	5	2	0.3	0.3-0.79				0.68	
Sodium	15	15	1,090	303		Lognormal	660	220	612	788
Thallium	15	5	0.35	0.1	0.1-0.8				0.13	
Uranium	8	0			2-3					
Zinc	15	15	456	90		Lognormal	194	100	169	246

Statistical Notes: *(Statisical calculations were performed using Washington Department of Ecology's MTCAStat Excel V.5 Macro (Module 2.1), downloaded from their web site.)*
Maximum and minimum concentrations are based on detected values only.
Range of reporting limits (RL) are based on results reported as not detected.
Distribution is determined based on the MTCA stat program by analyzing the data through the "W-Test" or "D'Agostino's test". Where data is not lognormally nor normally distributed, the distribution is noted as "Neither". When approximate distribution is reported as "neither", the maximum concentration is reported as the 95% UCL and is presented in **BOLD** font.
The mean is an arithmetic mean if data are normally distributed or if distribution is indicated as "Neither". The reported mean for lognormally distributed data is a lognormal mean.
Statistical analysis was not performed on data sets where 50% or greater of the results were reported as not detected. Only maximum and minimum concentrations are reported, if applicable. For these data sets, a calculated median is based on detected values only.

TABLE 7.2.2-1F
STATISTICAL ANALYSIS AND COMPARISON OF SURFACE AND SUBSURFACE TAILINGS METALS CONCENTRATIONS
HOLDEN MINE RI/FS
DAMES & MOORE JOB NO. 17693-005-019

Parameters	Location	SURFACE TAILINGS (TP-1)								
	Sample ID	HT1-2A	HT1-2B	503T	504T	505TA	505TB	DMSS-11	DMSS-12	DMSS-13
	Sample Date	6/1/94^{b}	6/1/94^{b}	7/95^{c}	7/95^{c}	7/95^{c}	7/95^{c}	9/20/97	9/20/97	9/20/97
Total Metals (mg/kg)										
Aluminum		5,280	5,410	39,000	32,000	37,000	37,000	8,220	8,700	7,350
Arsenic		5.5	5.8	3.2	6.5	3.1	2.6	3.3	4	5
Barium		361	450	860	790	780	850	395	394	375
Beryllium		0 09	0.08	1 U	1 U	1 U	1 U	0.2U	0.1	0.2U
Cadmium		0.95	1.3	0.14	0.08U	0.08U	0.08U	0.50	0.60	0.4U
Calcium		1,910	1,940	12,000	11,000	11,000	11,000	1180	1820	1310
Chromium		19.6U	13.6U	13	10	12	10	8.0	9.5	6.0
Copper		423	436	260	230	330	240	382	239	442
Iron		54,500	59,800	62,000	74,000	73,000	59,000	65,100	58,500	63,700
Lead		112	110	97	140	100	100	83	59	95
Magnesium		3,170	3,220	9,800	7,100	8,400	7,600	4,910	4,910	3,960
Manganese		113	117	470	420	460	420	169	167	148
Mercury		0.35	0.33	▨	▨	▨	▨	▨	▨	▨
Molybdenum		▨	▨	26	25	30	25	27	21.4	28
Nickel		1.3	1.3	▨	▨	▨	▨	2U	4	2U
Potassium		2,180	2,360	8,800	7,300	8,100	8,000	3,280	2,710	3,000
Selenium		28	19.8	▨	▨	▨	▨	▨	▨	▨
Silver		1.6	2	2	3.4	2.8	2.3	3.1	2.0	3.3
Sodium		750	820	11,000	10,000	11,000	11,000	790	795	700
Thallium		1.2	1.1	▨	▨	▨	▨	2U	1U	2U
Uranium		▨	▨	100 U	100 U	100 U	100 U	2U	2U	2U
Zinc		76.1	82.6	260	200	200	220	157	187	124

Data Notes:

J - Estimated value.
U - Parameter was analyzed for, but not detected above the reporting limit shown.
UJ - Parameter was analyzed for, but not detected. Detection limit is an estimated value.
▨ **Grey shading** indicates the concentration of analyte was not established, therefore not reported nor analyzed.

Data Source:

(a) Kilburn, et al. 1994. *Geochemical data and sample locality maps for stream-sediment, heavy-mineral-concentrate, mill tailing, water, and precipitate samples collected in and around the Holden mine, Chelan County, Washington.* USGS Open File Report 94-680A Paper Version, 94-680B Diskette version (Data Collected in 1994).
(b) Lambeth, R.H. 1995. Transmittal of laboratory data from samples collected at Holden Mine site by the US Bureau of Mines. (Data collected in 1995).
(c) Kilburn, J.E. & S.J. Sutley. 1996 *Characterization of acid mine drainage at the Holden mine, Chelan, Washington*. USGS Open File Report 96-531. (Data collected in 1995)

TABLE 7.2.2-1F
STATISTICAL ANALYSIS AND COMPARISON OF SURFACE AND SUBSURFACE TAILINGS METALS CONCENTRATIONS
HOLDEN MINE RI/FS
DAMES & MOORE JOB NO. 17693-005-019

Parameters	STATISTICAL CALCULATIONS FOR TAILINGS PILE 1 (TP-1)									
	# of Analyses	**# of Detections**	**Maximum Conc.**	**Minimum Conc.**	**Range of RL**	**Approximate Distribution**	**Mean**	**Standard Deviation**	**Median**	**UCL (95%)**
Total Metals (mg/kg)										
Aluminum	9	9	39,000	5,280		Neither	19,995	15,568	8,700	**39,000**
Arsenic	9	9	6.5	2.6		Lognormal	4.4	1.4	4	5.5
Barium	9	9	860	361		Neither	584	227	450	**860**
Beryllium	9	3	0.1	0.08	0.2-1				0.09	
Cadmium	9	5	1.3	0.14	0.08-0.4	Lognormal	0.56	0.46	0.20	4.51
Calcium	9	9	12,000	1,180		Neither	5,907	5,085	1,940	**12,000**
Chromium	9	7	13	6	13.6-19.6	Lognormal	9.5	2.3	9.8	11.3
Copper	9	9	442	230		Neither	331	91	330	**442**
Iron	9	9	74,000	54,500		Lognormal	63,321	6,566	62,000	67,607
Lead	9	9	140	59		Lognormal	100	22	100	118
Magnesium	9	9	9,800	3,170		Lognormal	5,964	2,402	4,910	8,217
Manganese	9	9	470	113		Neither	276	160	169	**470**
Mercury	2	2	0.35	0.33					0.34	
Molybdenum	7	7	30	21		Lognormal	26	2.6	26	28
Nickel	5	3	4	1.3	2-2	Neither	1.7	1.3	1.3	**4**
Potassium	9	9	8,800	2,180		Neither	5,081	2,859	3,280	**8,800**
Selenium	2	2	28	19.8					23.9	
Silver	9	9	3.4	1.6		Lognormal	2.50	0.66	2.30	3.00
Sodium	9	9	11000	700		Neither	5206	5268	820	**11000**
Thallium	5	2	1.2	1.1	1-2				1.15	
Uranium	7	0			2-100					
Zinc	9	9	260	76.1		Lognormal	170.6	62.6	187	238.5

Statistical Notes: (Statisical calculations were performed using Washington Department of Ecology's MTCAStat Excel V.5 Macro (Module 2.1), downloaded from their web site.)
Maximum and minimum concentrations are based on detected values only.
Range of reporting limits (RL) are based on results reported as not detected.
Distribution is determined based on the MTCA stat program by analyzing the data through the "W-Test" or "D'Agostino's test". Where data is not lognormally nor normally distributed, the distribution is noted as "Neither".
When approximate distribution is reported as "neither", the maximum concentration is reported as the 95% UCL and is presented in **BOLD** font.
The mean is an arithmetic mean if data are normally distributed or if distribution is indicated as "Neither". The reported mean for lognormally distributed data is a lognormal mean.
Statistical analysis was not performed on data sets where 50% or greater of the results were reported as not detected. Only maximum and minimum concentrations are reported, if applicable.
For these data sets, a calculated median is based on detected values only.

TABLE 7.2.2-1F
STATISTICAL ANALYSIS AND COMPARISON OF SURFACE AND SUBSURFACE TAILINGS METALS CONCENTRATIONS
HOLDEN MINE RI/FS
DAMES & MOORE JOB NO. 17693-005-019

Parameters	Location	SURFACE TAILINGS (TP-2)						STATISTICAL CALCULATIONS TAILINGS PILE 2 (TP-2)										
	Sample ID	502T	HT2-2A	HT2-2B	DMSS-14	DMSS-15	DMSS-16											
	Sample Date	7/95 [c]	6/1/94 [b]	6/1/94 [b]	9/21/97	9/21/97	9/21/97	# of Analyses	# of Detections	Maximum Conc.	Minimum Conc.	Range of RL	Approximate Distribution	Mean	Standard Deviation	Median	UCL (95%)
Total Metals (mg/kg)																		
Aluminum		38000	9750	10900	8,450	17,300	11,000	6	6	38,000	8,450		Neither	15900	11249	10950	**38000**
Arsenic		1.5U	0.5	0.5	*1.4*	*1*	*2.8*	6	5	2.8	0.5	1.5	Lognormal	1.2	0.9	0.9	2.94
Barium		1200	239	275	339	535	286	6	6	1200	239		Lognormal	481	368	312	1057
Beryllium		1 U	0.1	0.11	0.2U	0.1U	0.2	6	3	0.2	0.1	0.1-1				0.11	
Cadmium		0.08 U	0.85	1.3	0.5	0.3	0.4	6	5	1.3	0.3	0.08	Lognormal	0.78	0.45	0.45	10.87
Calcium		11000	1110	1250	1,290J	1,920J	2,200J	6	6	11000	1110		Neither	3128	3880	1605	**11,000**
Chromium		8	23 U	10.7 U	8	15.5	19.1	6	4	19.1	8	10.7-23	Lognormal	11.5	5.2	9.8	19.71
Copper		250	226	261	199	299	161	6	6	299	161		Lognormal	234	48.6	238	287
Iron		54000	60400	68700	71,100	53,400	56,800	6	6	71100	53400		Lognormal	60804	7558	5860	67717
Lead		83	34.1	39	41	51	80	6	6	83	34.1		Neither	55	22	46	**83**
Magnesium		11000	6710	7390	5,340	11,700	6,810	6	6	11700	5340		Lognormal	8216	2572	7100	11168
Manganese		430	230	257	208	385	220	6	6	430	208		Neither	288	95	244	**430**
Mercury			0.23	0.25				2	2	0.25	0.23					0.24	
Molybdenum		8			16	17.3	25.9	4	4	25.9	8		Lognormal	17.4	7.3	16.6	48
Nickel			2.4	2.4	2	3	5	5	5	5	2		Lognormal	3	1.2	2.4	4.7
Potassium		8100	3650	4020	3,810	5,040	3,930	6	6	8100	3650		Neither	4758	1709	3975	**8100**
Selenium			17.9	16.8				2	2	17.9	16.8					17.4	
Silver		1.2	0.66 U	0.61 U	2.2	2.0	2.5	6	4	2.5	1.2	0.61-0.66	Neither	1.4	1	1.6	**2.5**
Sodium		10000	433	479	570	652	551	6	6	10000	433		Neither	2114	3864	560	**10000**
Thallium			0.73	0.74	2U	1U	1U	5	2	0.74	0.73	1-2				0.74	
Uranium		100 U			2U	2U	3U	4	0			2-100					
Zinc		270	216	249	198	163	176	6	6	270	163		Lognormal	213	41.6	207	255

Data Notes:

J - Estimated value.

U - Parameter was analyzed for but not detected above the reporting limit shown.

UJ - Parameter was analyzed for, but not detected. Detection limit is an estimated value.

Grey shading indicates the concentration of analyte was not established, therefore not reported nor analyzed.

Statistical Notes: (Statisical calculations were performed using Washington Department of Ecology's MTCAStat Excel V.5 Macro (Module 2.1), downloaded from their web site.)

Maximum and minimum concentrations are based on detected values only.

Range of reporting limits (RL) are based on results reported as not detected.

Distribution is determined based on the MTCA stat program by analyzing the data through the "W-Test" or "D'Agostino's test". Where data is not lognormally nor normally distributed, the distribution is noted as "Neither".
When approximate distribution is reported as "neither", the maximum concentration is reported as the 95% UCL and is presented in BOLD font.

The mean is an arithmetic mean if data are normally distributed or if distribution is indicated as "Neither". The reported mean for lognormally distributed data is a lognormal mean.

Statistical analysis was not performed on data sets where 50% or greater of the results were reported as not detected. Only maximum and minimum concentrations are reported, if applicable
For these data sets, a calculated median is based on detected values only.

TABLE 7.2.2-1F
STATISTICAL ANALYSIS AND COMPARISON OF SURFACE AND SUBSURFACE TAILINGS METALS CONCENTRATIONS
HOLDEN MINE RI/FS
DAMES & MOORE JOB NO. 17693-005-019

Parameters	Location	SURFACE TAILINGS (TP-3)								STATISTICAL CALCULATIONS FOR TAILINGS PILE 3 (TP-3)									
	Sample ID	360	500T	501T	HT3-2A	HT3-2B	DMSS-17	DMSS-18	DMSS-19										
	Sample Date	7/1/94[a]	7/1/95[c]	7/1/95[c]	6/1/94[b]	6/1/94[d]	9/21/97	9/21/97	9/21/97	# of Analyses	# of Detections	Maximum Conc.	Minimum Conc.	Range of RL	Approximate Distribution	Mean	Standard Deviation	Median	UCL (95%)
Total Metals (mg/kg)																			
Aluminum		44000	44000	43000	6210	7000	10,500	12;800	7,210	8	8	44000	6210		Neither	21840	18200	11650	**44000**
Arsenic		1U	1.5U	1.5U	0.44	0.37	1.7J	2.9J	1.0J	8	5	2.9	0.37	1-1.5	Lognormal	1.1	0.9	0.8	2.2
Barium		172	900	680	220	301	272	397	302	8	8	900	172		Lognormal	409	253	301	687
Beryllium		1 U	1 U	1 U	0.11	0.1	0.2	0.2U	0.2U	8	3	0.2	0.1	0.2-1				0.11	
Cadmium		0.05 U	0.08U	0.08U	1	1	0.3	0.5U	0.5U	8	3	1	0.3	0.05-0.5				1	
Calcium		16000	16000	14000	568	753	2,100J	1,870J	1,090J	8	8	16000	568		Neither	6548	7319	1985	**16,000**
Chromium		24	24	19	11.3 U	50.4 U	18.2	17	11	8	6	24	11	11.3-50.4	Neither	18	6.9	18.6	**24**
Copper		110	110	88	294	355	154	147	154	8	8	355	86		Lognormal	178	96	150	274
Iron		47000	50000	45000	64000	85300	54,300	64,900	73,700	8	8	85300	45000		Lognormal	60697	14102	59150	71894
Lead		75	76	74	41.8	55.9	77	77	70	8	8	77	41.8		Neither	68.3	12.8	74.5	**77**
Magnesium		8800	8900	7700	4040	4180	6,480	8,690	4,730	8	8	8900	4040		Neither	6690	2123	7090	**8900**
Manganese		480	500	390	166	175	210	277	156	8	8	500	156		Lognormal	298	143	243.5	456.2
Mercury					0.27	0.25				2	2	0.27	0.25					0.26	
Molybdenum		20	23	16			24.6	26	30	6	6	30	16		Lognormal	23.4	4.9	23.8	28.7
Nickel		3			0.99	1.8	5	4	3	6	6	5	0.99		Lognormal	3.1	1.4	3	6.6
Potassium		7400	7100	7500	3240	4600	3,730	3,580	3,430	8	8	7500	3430		Neither	5073	1917	4165	**7500**
Selenium					17.1	13.3				2	2	17.1	13.3					15.2	
Silver		0.91	1.1	1	0.65 U	0.58 U	2.3	2.3	2.6	8	6	2.6	0.91	0.58-0.65	Neither	1.4	0.9	1.1	**2.6**
Sodium		14000	14000	13000	497	684	525	550	500	8	8	14000	497		Neither	5470	6795	617	**14000**
Thallium					0.51	0.86	1U	1U	2U	5	2	0.86	0.51	1-2				0.69	
Uranium		100 U	100 U	100 U			2U	3U	2U	6	0			2-100					
Zinc		123	147	78.3	569	767	169	283	305	8	8	767	78.3		Lognormal	316.9	242.5	226	744.6

Data Notes:
J - Estimated value.
U - Parameter was analyzed for but not detected above the reporting limit shown.
UJ - Parameter was analyzed for, but not detected. Detection limit is an estimated value.
Grey shading: indicates the concentration of analyte was not established, therefore not reported nor analyzed.

Statistical Notes: (Statisical calculations were performed using Washington Department of Ecology's MTCAStat Excel V.5 Macro (Module 2.1), downloaded from their web site.)
Maximum and minimum concentrations are based on detected values only.
Range of reporting limits (RL) are based on results reported as not detected.
Distribution is determined based on the MTCA stat program by analyzing the data through the "W-Test" or "D'Agostino's test". Where data is not lognormally nor normally distributed, the distribution is noted as "Neither".
When approximate distribution is reported as "neither", the maximum concentration is reported as the 95% UCL and is presented in **BOLD** font.
The mean is an arithmetic mean if data are normally distributed or if distribution is indicated as "Neither". The reported mean for lognormally distributed data is a lognormal mean.
Statistical analysis was not performed on data sets where 50% or greater of the results were reported as not detected. Only maximum and minimum concentrations are reported, if applicable.
For these data sets, a calculated median is based on detected values only.

TABLE 7.2.2-1F
STATISTICAL ANALYSIS AND COMPARISON OF SURFACE AND SUBSURFACE TAILINGS METALS CONCENTRATIONS
HOLDEN MINE RI/FS
DAMES & MOORE JOB NO. 17693-005-019

Parameters	Location	WIND BLOWN TAILINGS					STATISTICAL CALCULATIONS FOR WINDBLOWN TAILINGS										
	Sample ID	DMSS-20	DMSS-21	DMSS-22	DMSS-23	DMSS-24											
	Sample Date	9/21/97	9/21/97	9/21/97	9/21/97	9/21/97	# of Analyses	# of Detections	Maximum Conc.	Minimum Conc.	Range of RL	Approximate Distribution	Mean	Standard Devation	Median	UCL(95%)
Total Metals (mg/kg)																	
Aluminum		6,510	9,740	20,700	12,900	8,330	5	5	20700	6510		Lognormal	11822	5580	9740	21924
Arsenic		1.9	2.2	2.3	2.0	3.1	5	5	3.1	1.9		Lognormal	2.3	0.47	2.2	2.8
Barium		321	327	79.0	388	380	5	5	388	79		Neither	299	127	327	**388**
Beryllium		0.2U	0.1U	0.2	0.1U	0.1U	5	1	0.2	0.2	0.1-0.2				0.2	
Cadmium		0.5	0.5	0.4	0.6	0.5	5	5	0.6	0.4		Lognormal	0.5	0.07	0.5	0.58
Calcium		1,190	2,140	5,870	3,880	1,790	5	5	5870	1190		Lognormal	3094	1903	2140	9133
Chromium		10	14.7	29.0	18.2	11.8	5	5	29	10		Lognormal	17	7.5	15	30
Copper		107	151	159	332	149	5	5	332	107		Lognormal	181	88	151	319
Iron		65,000	63,500	24,100	40,400	66,200	5	5	66200	24100		Lognormal	53358	18813	63500	98314
Lead		49	52	7	62	59	5	5	62	7		Neither	46	22	52	**62**
Magnesium		3,810	5,840	6,070	6,570	4,860	5	5	6570	3810		Lognormal	5461	1098	5840	6968
Manganese		135	197	292	203	165	5	5	292	135		Lognormal	200	59	197	280
Mercury																
Molybdenum		30	31.7	0.7U	10.7	29.4	5	4	31.7	10.7	0.7	Neither	20.4	14.1	29.4	**31.7**
Nickel		3	6	17	9	4	5	5	17	3		Lognormal	8.1	5.6	6	27.8
Potassium		2,850	2,990	580U	1,340	3,510	5	4	3510	1340	580	Neither	2196	1337	2850	**3510**
Selenium																
Silver		2.8	2.3	0.4U	1.2	2.4	5	4	2.8	1.2	0.4	Neither	1.8	1.1	2.3	**2.8**
Sodium		550	597	1,130	611	774	5	5	1130	550		Lognormal	737	238	611	1044
Thallium		2U	3U	0.7U	2U	3U	5	0			0.7-3					
Uranium		2U	3U	3U	2U	3U	5	0			2-3					
Zinc		246	256	75.3	107	260	5	5	260	75.3		Lognormal	198	90	246	509

Data Source:

(a) Kilburn, et al. 1994. *Geochemical data and sample locality maps for stream-sediment, heavy-mineral-concentrate, mill tailing, water, and precipitate samples collected in and around the Holden mine, Chelan County, Washington.* USGS Open File Report 94-680A Paper Version, 94-680B Diskette version (Data Collected in 1995).
94-680B Diskette version. (Data collected in 1994).
(b) Lambeth, R.H. 1995. Transmittal of laboratory data from samples collected at Holden Mine site by the US Bureau of Mines. (Data collected in 1994).
(c) Kilburn, J.E. & S.J. Sutley 1996. *Characterization of acid mine drainage at the Holden mine, Chelan, Washington.* USGS Open File Report 96-531. (Data collected in 1995).

Statistical Notes: (Statisical calculations were performed using Washington Department of Ecology's MTCAStat Excel V.5 Macro (Module 2.1), downloaded from their web site.)
Maximum and minimum concentrations are based on detected values only.
Range of reporting limits (RL) are based on results reported as not detected.
Distribution is determined based on the MTCA stat program by analyzing the data through the "W-Test" or "D'Agostino's test". Where data is not lognormally nor normally distributed, the distribution is noted as "Neither".
When approximate distribution is reported as "neither", the maximum concentration is reported as the 95% UCL and is presented in BOLD font
The mean is an arithmetic mean if data are normally distributed or if distribution is indicated as "Neither". The reported mean for lognormally distributed data is a lognormal mean.
Statistical analysis was not performed on data sets where 50% or greater of the results were reported as not detected. Only maximum and minimum concentrations are reported, if applicable.
For these data sets, a calculated median is based on detected values only.

TABLE 7.2.2-1F
STATISTICAL ANALYSIS AND COMPARISON OF SURFACE AND SUBSURFACE TAILINGS METALS CONCENTRATIONS
HOLDEN MINE RI/FS
DAMES & MOORE JOB NO. 17693-005-019

Parameters	ample Location	Subsurface Samples from TP-1				Subsurface Samples from TP-2				Subsurface Samples from TP-3						
	Station No.	DMTP1-2	DMTP1-3A	DMTP1-3B	DMTP1-4	TP2-4	DMTP2-1A	DMTP2-1B	·DMTP2-2	DMTP3-1	DMTP3-2	DMTP3-3A	DMTP3-3B	DMTP3-4A	DMTP3-4AX	DMTP3-4B
	Sampling Date	9/25/97	9/25/97	9/25/97	9/25/97	8/23/94[a]	9/29/97	9/29/97	9/29/97	9/29/97	9/29/97	9/29/97	9/29/97	9/30/97	9/30/97	9/30/97
Total Metals (mg/kg)																
Aluminum		6,530	6,620	19,400	7,570	16000	29,700	11,600	19,600	6,840	14,200	10,700	17,800	9,560	10,300	8,660
Arsenic		1.9	3.3	3.3	3.3	0.95	0.6	0.9	1.1	1.3	0.7	0.3	1.1	1.3	1.4	6.0
Barium		851J	301J	180J	320J	480	401J	494J	101J	494J	365J	357J	99.5J	1,180J	1,570J	137J
Beryllium		0.2U	0.1U	1.0U	0.2U	0.2	0.1U	0.1U	0.2	0.2U	0.1U	0.2U	0.1	0.2U	0.3U	0.2U
Cadmium		0.5	0.9	21	0.5	16.2	147	0.7	0.4	0.4	0.4	0.5U	0.3	0.5U	0.5U	0.5U
Calcium		5,430J	7,850J	7,940J	8,020J	6090	11,100J	7,990J	4,110J	1,130J	5,700J	6,320J	4,780J	1,550J	1,620J	2,490J
Chromium		8	5.1	5	6	11.4U	17	10.2	49.9	6	13.7	16	62.0	15	16	18
Copper		525	1,260	12,400	551	774	16,500	160	141	249	244	195	107	159	209	96.7
Iron		87,500	49,800	74,700	69,100	61400	45,700	54,100	26,800	61,400	45,100	62,200	29,500	62,900	81,700	75,900
Lead		114	93	70	83	88.6	40	37	4	89	29	28	4	141	178	23
Magnesium		3,590	3,330	7,610	3,620	8770	18,100	7,890	9,450	4,110	8,730	7,270	8,660	6,950	7,530	5,630
Manganese		124	130	291	141	320	657	250	350	139	282	237	245	179	199	169
Mercury		▨	▨	▨	▨	0.13	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨
Molybdenum		24	32.5	25	24	▨	16	28.6	1.0	24	10.4	10	1.3	23	21	3
Nickel		2U	2	20	2U	8.3	70	1	36	2	4	4	39	3	4	9
Potassium		4,200	2,150	2,760	3,020	3820	6,560	5,540	1,680	3,080	5,620	6,040	1,990	4,900	6,260	5,050
Selenium		▨	▨	▨	▨	15.4	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨
Silver		3.3	4.7	6	4.0	0.65U	6	4.4	0.5	2.8	1.6	1.9	0.5	3.2	3.5	1.3
Sodium		960	900	680	930	783	1,050	1,060	619	540	694	1,050	578	610	700	850
Thallium		3	2U	2U	2U	0.89	3U	2U	0.5U	2U	2U	2U	0.5U	3U	3U	2U
Uranium		2U	2U	3	2U	▨	3U	2U	2U	2U	2U	2U	2U	3U	3U	2U
Zinc		216	74.5	2,350	481	2070	2,750	191	85.0	144	302	96.2	78.7	123	147	78.3

Data Notes:

J - Estimated value.
U - Parameter was analyzed for, but not detected above the reporting limit shown.
UJ - Parameter was analyzed for but not detected. Detection limit is an estimated value.
▨ **Grey Shading** indicates the concentration of analyte was not established, therefore not reported nor analyzed.

Data Source:

(a) Lambeth, R.H. 1995. Transmittal of laboratory data from samples collected at Holden Mine site by the US Bureau of Mines. (Data collected in 1994)

TABLE 7.2.2-1F
STATISTICAL ANALYSIS AND COMPARISON OF SURFACE AND SUBSURFACE TAILINGS METALS CONCENTRATIONS
HOLDEN MINE RI/FS
DAMES & MOORE JOB NO. 17693-005-019

Parameters	STATISTICAL CALCULATIONS FOR SUBSURFACE TAILINGS PILE									
	# of Analyses	# of Detections	Maximum Conc.	Minimum Conc.	Range of RL	Approximate Distribution	Mean	Standard Deviation	Median	UCL (95%)
Total Metals (mg/kg)										
Aluminum	15	15	29700	6530		Lognormal	13046	6503	10700	16771
Arsenic	15	15	6	0.3		Lognormal	1.9	1.5	1.3	3.08
Barium	15	15	1570	99.5		Lognormal	504	414.3	365	863.7
Beryllium	15	3	0.2	0.1	0.1-1.0				0.2	
Cadmium	15	11	147	0.3	0.5-0.5	Neither	12.6	37.7	0.4	147
Calcium	15	15	11100	1130		Normal	5475	2900	55700	6793
Chromium	15	14	62	5	11.4	Neither	17.2	16.5	13.7	62
Copper	15	15	16500	96.7		Neither	2238	5028	244	16500
Iron	15	15	87500	26800		Lognormal	59746	17695	61400	71292
Lead	15	15	178	4		Normal	68	51	70	91
Magnesium	15	15	18100	3330		Lognormal	7458	3623	7530	9542
Manganese	15	15	657	124		Lognormal	247	134	237	315
Mercury	1	1	0.13	0.13					0.13	
Molybdenum	14	14	32.5	1		Normal	17.4	10.5	22	22.4
Nickel	15	13	70	1	2-2	Lognormal	14.5	19.9	4	52.2
Potassium	15	15	6560	1680		Lognormal	4239	1659	4200	5399
Selenium	1	1	15.4	15.4					15.4	
Silver	15	14	6	0.5	0.65	Normal	2.9	1.9	3.2	3.8
Sodium	15	15	1060	540		Lognormal	800	183	783	899
Thallium	15	3	3	0.89	2-3				1.95	
Uranium	14	1	3	3	2-3				3	
Zinc	15	15	2750	74.5		Neither	612.5	935	147	2750

Statistical Notes: (Statisical calculations were performed using Washington Department of Ecology's MTCAStat Excel V.5 Macro (Module 2.1), downloaded from their web site.)
Maximum and minimum concentrations are based on detected values only.
Range of reporting limits (RL) are based on results reported as not detected.
Distribution is determined based on the MTCA stat program by analyzing the data through the "W-Test" or "D'Agostino's test". Where data is not lognormally nor normally distributed, the distribution is noted as "Neither".
When approximate distribution is reported as "neither", the maximum concentration is reported as the 95% UCL and is presented in BOLD font.
The mean is an arithmetic mean if data are normally distributed or if distribution is indicated as "Neither". The reported mean for lognormally distributed data is a lognormal mean.
Statistical analysis was not performed on data sets where 50% or greater of the results were reported as not detected. Only maximum and minimum concentrations are reported, if applicable.
For these data sets, a calculated median is based on detected values only.

TABLE 7.2.2-1G
STATISTICAL ANALYSIS AND COMPARISON OF CHEMICAL DATA FOR STATIONS ALONG PORTAL DRAINAGE
HOLDEN MINE RI/FS
DAMES & MOORE JOB NO. 17693-005-019

Parameters	Location	P-1																		P-2		
	Sample ID	BATTELLE WATER QUALITY MONITORING DATA 1991 [a]								357	USFS 1995		534	605	702	DAMES & MOORE RI DATA				535	606	703
	Sample Date	5/9/91	5/17/91	6/3/91	6/17/91	7/1/91	7/15/91	8/6/91	9/18/91	7/94[b]	6/1/95[c]	9/1/95[c]	7/95[d]	5/96[e]	9/96[f]	5/97	7/97	9/97	5/98	7/95[c]	5/96[e]	9/96[f]
Total Metals (µg/L)																						
Aluminum															2400	13,400	4,850	2,570	22,600			4700
Arsenic																0.3	1U	1U	1U			
Barium															10	12.1	13	10	12			11
Beryllium															10 U	0.3	1U	1U	1U			10 U
Cadmium															10 U	82.2	23	8	170			10 U
Calcium		59046	58695	61285	68580	73610	88632	106150	125615		73000				150000	50,600	70,300	130,000	58,400			150000
Chromium															10 U	1U	5U	5U	5U			10 U
Copper		3780	4086	2867	1746	1498	1048	730	75		1900				160	6,350	912	235	10,400			260
Iron											570				1100	960	540	930	2,030			1800
Lead		62	51	46	50	38	58	52	52		30				50 U	57J	20	8	64			50 U
Magnesium		9768	9909	9074	8888	9000	9502	10200	9450		9600				12000	10,800	8,210	9,820	14,500			12000
Manganese															390	444	287	373	703			380
Mercury																0.00313	0.00024J					
Molybdenum															20 U	0.4	5U	5U	5U			20 U
Nickel															10 U	8J	10U	10U	10U			10 U
Potassium		3510	3285	3529	3834	3704	4254	5505	6250		3500				6300	2,620	4,100	6,300	3,460			6400
Selenium																1U	1U					
Silver																0.2U	0.2U	0.2U	0.2			
Sodium		7392	8081	8373	10190	11212	14818	19345	25700		10000				26000	5,670	12,600	24,600	6,310			26000
Thallium																0.3	1U	1U				
Uranium																4.6	20U	20U				
Zinc		13530	11797	9484	7576	7918	7136	6215	3365		7800				3600	14,900	5,270	3,380	27,800			3600
Dissolved Metals (µg/L)																						
Aluminum										1000			2400	7700	44	13,200	1,460	40U	21,100	2200	6600	43
Arsenic										2 U			1 U	4 U		0.25	1U	1U	1U	1 U	4 U	
Barium										12			12	11	10	23.0J	20	11	12	11	12	11
Beryllium										1 U			0.3 U	0.4 U	10 U	0.34	1U	1U	1U	0.3 U	0.4 U	10 U
Cadmium										21			29	58	10 U	81.2	22	8	160	29	53	10 U
Calcium										72000			94000	42000	160000	50,300	73,200	130,000	57,300	97000	42000	160000
Chromium										1 U			0.9 U	0.5 U	10 U	0.3U	5U	5U	5U	0.9 U	0.5 U	10 U
Copper										570			900	3700	62	5,780	907	77	10,300	910	3500	23
Iron										580			940	230	280	240	280	110	430	430	230	100 U
Lead										21			22 U	35	50 U	48J	19	5U	58	19	31	50 U
Magnesium										7900			8800	7900	11000	10,700	8,430	9,840	14,600	8800	7900	11000
Manganese										350			320	340	420	420	299	374	695	330	310	400
Mercury													0.1 U			0.00257	0.00038J					
Molybdenum										0.6			0.4	0.4 U	20 U	0.05	5U	5U	5U	0.2	0.4 U	20 U
Nickel										4			7.2	5.8	0.01 U	7.7	10U	10U	10U	6.5	5.9	0 01 U
Potassium										2000 U				2700	6200	3,160	4,420	6.150	3,430		2700	6400
Selenium																1.1	1U					
Silver										0.1 U			0.1 U	0.2 U		0.04U	0.2U	0.2U	0.2U	0.1 U	0.2 U	
Sodium										> 5000			> 10000	6300	27000	5,800	13,000	24,600	6,340	> 10000	6300	28000
Thallium										0.1			0.6 U	4 U		0.29	1U	1U		0.6U	4 U	
Uranium										2.7			2.5	3.7		3.95	20U	20U		2.4	3	
Zinc										4800			6000	9600	3600	14,900	5,440	3,280	27,500	6000	8600	3300

Data Notes:
J - Estimated value.
U - Parameter was analyzed for, but not detected above the reporting limit shown.
UJ - Parameter was analyzed for, but not detected. Detection limit is an estimated value.
▨ Grey shading indicates that the data was not available for this parameter

Data Source:
(a) Walters, et al. 1992. *Holden Mine Reclamation Project Final Report.* Pacific Northwest Laboratories,Richland, WA. (Data collected in 1991).
(b) Kilburn, et al. 1994. *Geochemical data and sample locality maps for stream-sediment, heavy-mineral-concentrate, mill tailing, water, and precipitate samples collected in and around the Holden mine, Chelan County, Washington.* USGS Open File Report 94-680A Paper Version, 94-680B Diskette version (Data Collected in 1994).
(c) Anderson, Keith A. (USFS Chelan Ranger District). Compilation of Data for Preliminary Assessment of the Holden Mine Site.
(d) Kilburn, J.E. & S.J. Sutley. 1996. *Characterization of acid mine drainage at the Holden mine, Chelan, Washington*. USGS Open File Report 96-531. (Data collected in 1995).
(e) Kilburn, J.E. & S.J. Sutley 1997. *Analytical results and comparative overview of geochemical studies conducted at the Holden Mine*, spring 1996. USGS Open File Report 97-128 (Data collected in Spring 1996).
(f) Kilburn, J.E. & S.J. Sutley. 1997. Preliminary data (no report attached, data collected in Fall 1996).
(g) Johnson, A., et al. 1997. *Effects of Holden Mine on the Water, Sediments and Benthic Invertebrates of Railroad Creek (Lake Chelan).* Environmental Investigations and Laboratory Services Program. Water Body No. WA-47-1020. Publication No. 97-330 (data collected in Spring and Fall 1996).

TABLE 7.2.2-1G
STATISTICAL ANALYSIS AND COMPARISON OF CHEMICAL DATA FOR STATIONS ALONG PORTAL DRAINAGE
HOLDEN MINE RI/FS
DAMES & MOORE JOB NO. 17693-005-019

Parameters	Location	P-5																			
	Sample ID	BATTELLE/USFS WATER QUALITY MONITORING DATA 1991 [a]								USFS WATER MONITORING DATA 1995 [c]					358	533	ECOLOGY MINE PORTAL DRAINAGE STATION		601	704	706
	Sample Date	5/9/91	5/17/91	6/3/91	6/17/91	7/1/91	7/15/91	8/6/91	9/18/91	6/95	7/95	8/95	8/95	9/95	7/94 [b]	7/95 [d]	6/12/96 [g]	9/10/96 [g]	5/96 [e]	9/96 [f]	9/96 [f]
Total Metals (µg/L)																					
Aluminum																	6650	3970		9400	3000
Arsenic																	0.23	0.02 U			
Barium																				11	11
Beryllium																				10 U	10 U
Cadmium																	35	7.4 U		10 U	10 U
Calcium		48744	52350	61235	68616	71380	88266	107190	125725	73000	95000	110000	110000							150000	14000
Chromium																				10 U	10 U
Copper		3066	3790	2852	1736	1504	1052	715	5.5 U	1900	770	660	410				2040	291		450	160
Iron										640	420	1200	850				591	1370		3500	1100
Lead		62.4 U	45 U	46 U	54 U	38 U	56 U	52 U	52 U	30U	20 U	10 U	10 U				31 U	20 U		50 U	50 U
Magnesium		8124	9010	9113	8948	8924	9458	10060	9440	9600	10000	10000	11000							12000	11000
Manganese																	299	358		390	330
Mercury																	0.0024				
Molybdenum																				20 U	20 U
Nickel																	4.1U			10 U	10 U
Potassium		3366	3169	3551	3632	3522	4092	5300	6615	3500	4400	5300	5300							6300	5600
Selenium																		40 U			
Silver																	0.1 U				
Sodium		6294	7072	8466	9736	10898	15038	19405	24590	10000	19000	21000	22000							26000	23000
Thallium																					
Uranium																					
Zinc		11148	10782	9498	7500	7870	7178	6265	2975	7700	6200	6300	5200				6840	3300		3800	3000
Dissolved Metals (µg/L)																					
Aluminum															940	2200			6300	34	23
Arsenic															2 U	1 U			4 U		
Barium															11	10			14	10	8.6
Beryllium															1 U	0.3 U			0.4 U	10 U	10 U
Cadmium															21	28			50	10 U	10 U
Calcium															73000	99000			36000	150000	11000
Chromium															1 U	0.9 U			0.5 U	10 U	10 U
Copper															580	940			3400	12	11
Iron															370	250			180	100 U	100 U
Lead															22 U	19			28	50 U	50 U
Magnesium															8000	9100			6.3	11000	7700
Manganese															350	330			290	380	270
Mercury																					
Molybdenum															0.5U	0.3			0.4 U	20 U	20 U
Nickel															4U	6.3			7.5	0.01 U	0.01 U
Potassium															2000U				2300	6300	4400
Selenium																					
Silver															1 U	0.1 U			0.2 U		
Sodium															5000 U	> 10000			5500	27000	18000
Thallium															0.1 U	0.6 U			4 U		
Uranium															2.5	2.6			2.6		
Zinc															4900	6200			8000	2900	2200

Data Notes:
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Data Source:
(a) Walters, et al. 1992. *Holden Mine Reclamation Project Final Report.* Pacific Northwest Laboratories, Richland, WA. (Data collected in 1991).
(b) Kilburn, et al. 1994. *Geochemical data and sample locality maps for stream-sediment, heavy-mineral-concentrate, mill tailing, water, and precipitate samples collected in and around the Holden mine, Chelan County, Washington.* USGS Open File Report 94-680A Paper Version, 94-680B Diskette version (Data Collected in 1994).
(c) Anderson, Keith A. (USFS Chelan Ranger District). Compilation of Data for Preliminary Assessment of the Holden Mine Site.
(d) Kilburn, J.E. & S.J. Sutley. 1996. *Characterization of acid mine drainage at the Holden mine, Chelan, Washington.* USGS Open File Report 96-531. (Data collected in 1995).
(e) Kilburn, J.E. & S.J. Sutley. 1997. *Analytical results and comparative overview of geochemical studies conducted at the Holden Mine*, spring 1996.
USGS Open File Report 97-128 (Data collected in Spring 1996).
(f) Kilburn, J.E. & S.J. Sutley. 1997. Preliminary data (no report attached, data collected in Fall 1996).
(g) Johnson, A., et al. 1997. *Effects of Holden Mine on the Water, Sediments and Benthic Invertebrates of Railroad Creek (Lake Chelan).*
Environmental Investigations and Laboratory Services Program. Water Body No. WA-47-1020. Publication No. 97-330 (data collected in Spring and Fall 1996).

TABLE 7.2.2-1G
STATISTICAL ANALYSIS AND COMPARISON OF CHEMICAL DATA FOR STATIONS ALONG PORTAL DRAINAGE
HOLDEN MINE RI/FS
DAMES & MOORE JOB NO. 17693-005-019

Parameters	P-5								STATISTICAL CALCULATIONS FOR PORTAL DRAINAGE									
	DAMES & MOORE RI DATA								# Analyses	# of Detections	Maximum Conc.	Minimum Conc.	Range of RL	Approximate Distribution	Mean	Standard Deviation	Median	UCL (95%)
	5/97	5/97	6/97	6/97	6/97	7/97	9/97	5/98										
Total Metals (µg/L)																		
Aluminum	7,290	6,320	8,270	6,650J	6,500	3,790	2,810	13,600	18	18	22,600	2,400	None	Lognormal	7,155	5,085	6,410	9,884
Arsenic	0.2U	▨	▨	▨	▨	1U	1U	1U	10	2	0.3	0.23	0.02 - 1	NA	NA	NA	0.265	0.3
Barium	14.3	13.3	14.4	13.0J	13	13	10	19	16	16	19	10	None	Lognormal	12.51	2.26	12.55	13.51
Beryllium	0.2U	0.2U	4U	0.2U	4U	1U	1U	1U	16	1	0.3	0.3	0.2 - 10	NA	NA	NA	0.3	0.3
Cadmium	49.7	40.7	45.4	35.8J	36	23	8	80	18	13	170	8	7.4 - 10	Neither	36.7	41.4	29	170
Calcium	30,200	37,000	38,300	48,000J	52,000	71,400	128,000	28,000	37	37	150,000	14,000	None	Lognormal	80,748	36,321	71,380	95,399
Chromium	1U	1U	1U	1U	5U	5U	5U	5U	16	0	NA	NA	1 - 10	NA	NA	NA	NA	NA
Copper	4,040	2,620	3,200	2,270J	2,000	914	237	4,800	39	38	10,400	75	5.5	Lognormal	3,186	2,050	1,504	6,599
Iron	480	440J	830J	500J	520	390	970	2,320	23	23	3,500	390	None	Lognormal	1,036	750	850	1,346
Lead	29J	30	37	29J	30	18	8	36	39	21	64	8	10 - 62	Lognormal	31.2	16.2	27	38.7
Magnesium	8,540	6,400	7,020	7,540J	7,590	8,310	9,630	6,620	37	37	14,500	6,400	None	Lognormal	9,491	1,589	8,458	9953
Manganese	239	229	259	260J	267	291	365	321	18	18	703	229	None	Lognormal	343	108	326	386
Mercury	0.00249	▨	▨	▨	▨	0.00031J	▨	▨	5	5	0.00313	0.00024	None	Neither	0.002	0.001	0.00024	0.00313
Molybdenum	0.2U	▨	▨	▨	▨	5U	5U	10	12	2	10	0.4	0.2 - 20	NA	NA	NA	5.2	10
Nickel	5J	5	6	5J	10U	10U	10U	10U	17	5	8	5	4.1 - 10	NA	NA	NA	5	8
Potassium	2,110	2,480	2,970	3,280J	2,990	4,300	5,810	1,920	37	37	6,615	1,920	None	Lognormal	4,228	1,328	3,704	4,656
Selenium	1U	▨	▨	▨	▨	1U	▨	▨	5	0	NA	NA	1 - 40	NA	NA	NA	NA	NA
Silver	0.2U	0.2UJ	0.2U	0.2U	4U	0.2U	0.2U	0.2U	13	1	0.2	0.2	0.1 - 4	NA	NA	NA	0.2	0.2
Sodium	3,700	5,380	5,180	7,140J	7,800	12,700	24,200	3,310	37	37	26,000	3,310	None	Neither	13,735	7,627	10,898	26,000
Thallium	0.2U	▨	▨	▨	▨	1U	1U	▨	6	1	0.3	0.3	1	NA	NA	NA	0.3	0.3
Uranium	2.4	▨	▨	▨	▨	20U	2U	▨	6	2	4.6	2.4	2 - 20	NA	NA	NA	3.5	4.6
Zinc	8,620	7,050	7,930	6,790J	6,880	5,380	3,230	12,300	39	39	27,800	2,975	None	Lognormal	7,592	4,459	7050	8,849
Dissolved Metals (µg/L)																		
Aluminum	5,840	4,910	7,070	4,860J	4,430	1,360	40U	8,960	24	22	21100	23	40	Neither	4,280	5,001	2,300	21,100
Arsenic	0.15	▨	▨	▨	▨	1U	1U	1U	16	2	0.25	0.15	1 - 4	NA	NA	NA	0.2	0.25
Barium	32.6J	26.4	24.4	26.1J	22	20	10	17	24	24	32.5	8.6	None	Neither	15.71	6.8	12	32.5
Beryllium	0.4U	0.2U	4U	0.2U	4U	1U	1U	1U	24	1	0.34	0.34	0.3 - 10	NA	NA	NA	0.34	0.34
Cadmium	52.5	41.0	47.0	37.0J	36	22	8	70	24	20	160	8	10	Lognormal	40.65	33.64	29	67.7
Calcium	30,500	36,900	38,700	49,100J	53,800	71,900	131,000	28,300	24	24	160000	11000	None	Lognormal	76,645	43,959	64,600	101,940
Chromium	0.2U	1U	1U	1U	5U	5U	5U	5U	24	0	NA	NA	0.2 - 5	NA	NA	NA	NA	NA
Copper	2,340	2,570	3,240	2,360J	2,060	901	28	4,790	24	24	10300	11	None	Neither	2081.7	2406.1	925	10,300
Iron	190	130J	140J	150J	170	180	20U	150	24	20	940	110	20 - 100	Lognormal	271	201	185	439
Lead	27J	28	33	28J	30	17	1U	22	24	16	58	17	1 - 50	Lognormal	30.69	12.45	25	31.34
Magnesium	9,290	6,350	7,160	7,730J	7,530	8,280	9,850	6,650	24	24	14600	6.3	None	Neither	8563.2	2562.5	8355	14,600
Manganese	255	228	261	267J	274	293	372	314	24	24	695	228	None	Neither	339.25	92.21	325	695
Mercury	0.00069	▨	▨	▨	▨	0.00039J	▨	▨	5	4	0.00257	0.00038	0.1	Neither	0.011	0.022	0.00069	0.00257
Molybdenum	0.09	▨	▨	▨	▨	5U	5U	5U	20	6	0.6	0.05	0.4 - 20	NA	NA	NA	0.25	0.6
Nickel	5.0	5	5	5J	10U	10U	10U	10U	24	12	7.7	4	0.01 - 10	Lognormal	56.2	2.4	5	(961)
Potassium	1,750	2,640	2,590	3,420J	2,950	4,020	6,400	1,880	21	19	6400	1750	2000	Lognormal	3,689	1,783	3,160	4,752
Selenium	0.6	▨	▨	▨	▨	1U	▨	▨	4	2	1.1	0.6		Neither	0.68	0.29	0.55	1.1
Silver	0.16	0.2UJ	0.2	0.2U	4U	0.2U	0.2	0.2U	20	3	0.2	0.16	0.10 - 4	NA	NA	NA	0.2	0.2
Sodium *	3,830	5,380	5,390	7,470J	7,770	12,600	24,800	3,290	24	24	28000	2500	None	Neither	10,765	8,854	6,300	28,000
Thallium	0.16	▨	▨	▨	▨	1U	1U	▨	14	3	0.29	0.1	0.6 - 4	NA	NA	NA	0.16	0.29
Uranium	2.04	▨	▨	▨	▨	20U	20U	▨	14	10	3.95	2.04	20	Lognormal	4.8	3.4	2.8	7.2
Zinc	8,820	7,020	7,970	6,960J	6,820	5,330	2,980	12,700	24	24	27500	2200	None	Lognormal	7,263	5,273	6,100	9,256

Data Notes:

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U - Parameter was analyzed for, but not detected above the reporting limit shown.

UJ - Parameter was analyzed for, but not detected. Detection limit is an estimated value.

▨ Grey shading indicates that the data was not available for this parameter

Statistical Notes: (Statistical calculations were performed using Washington Department of Ecology's MTCAStat Excel V.5 Macro (Module 2.1), downloaded from their web site.)

Maximum and minimum concentrations are based on detected values only.

Range of reporting limits (RL) are based on results reported as not detected.

Distribution is determined based on the MTCA stat program by analyzing the data through the "W-Test" or "D'Agostino's test". Where data is not lognormally nor normally distributed, the distribution is noted as "Neither".

When approximate distribution is reported as "neither", the maximum concentration is reported as the 95% UCL and is presented in **BOLD** font.

If UCL is reported in brackets (*UCL value*), this indicates that the calculated result from MTCAStat was reported to be unusually high.

The mean is an arithmetic mean if data are normally distributed or if distribution is indicated as "Neither". The reported mean for lognormally distributed data is a lognormal mean.

Statistical analysis was not performed on data sets where 50% or greater of the results were reported as not detected. Only maximum and minimum concentrations are reported, if applicable.

For these data sets, a calculated median is based on detected values only.

* Values with 'greater than' sign were reported as shown in the applicable report(s) referenced. The actual value was used as an estimate of the lowest concentration in the sample.

TABLE 7.2.2-1H
STATISTICAL ANALYSIS AND COMPARISON OF CHEMICAL DATA FROM GROUNDWATER SEEPAGE
HOLDEN MINE RI/FS
DAMES & MOORE JOB NO. 17693-005-019

Parameters	Location	TAILINGS PILE (TP-1) AREA																								
	Sample ID	364	515	516	518	520	521	523	524	525	527	528	529	536	537	538	623	625	626	627	629	630	654	655	656	657
	Sample Date	7/94^a	7/95^b	7/95^b	7/95^b	7/95^b	7/95^b	7/95^b	7/95^b	7/95^b	7/95^b	7/95^b	7/95^b	7/95^b	7/95^b	7/95^b	5/96^c	5/96^c	5/96^c	5/96^c	5/96^c	5/96^c	5/96^c	5/96^c	5/96^c	5/96^c
Total Metals, (ug/L)																										
Aluminum																										
Arsenic																										
Barium																										
Beryllium																										
Cadmium																										
Calcium																										
Chromium																										
Copper																										
Iron																										
Lead																										
Magnesium																										
Manganese																										
Mercury																										
Molybdenum																										
Nickel																										
Potassium																										
Selenium																										
Silver																										
Sodium																										
Thallium																										
Uranium																										
Zinc																										
Dissolved Metals (ug/L)																										
Aluminum		> 6000	> 10,00	>10000	>10000	2600	>10000	4800	>10000	>10000	>10000	>10000	>10000	>10000	>10000	3800	550	95000	120000	57000	61000	12000	49000	53000	39000	15000
Arsenic		2 U	1 U	1 U	1 U	4.8	1 U	5.4	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	4 U	4 U	4 U	4 U	4 U	4 U	4 U	4 U	4 U	4 U
Barium		13	0.62	4	2.6	11	5.6	9.5	6.1	5.4	0.52	2.1	6	10	10	18	13	3.6	2	8.9	9.8	22	3.2	1	3.4	130
Beryllium		1 U	0.5	0.8	1.2	0.3 U	0.3 U	0.3 U	0.3 U	0.4	0.9	0.8	0.8	0.91	0.3 U	0.3	0.4 U	1.9	2.2	0.8	1	0.4 U	1	0.8	0.5	0.5
Cadmium		6.8	8.1	11	19	2	2	2	13	22	13	22	28	29	17	20	21	6.8	6.6	24	11	14	16	11	12	6.7
Calcium		39000	130000	99000	190000	110000	140000	130000	130000	130000	140000	130000	84000	80000	46000	21000	15000	140000	190000	110000	90000	14000	120000	95000	120000	15000
Chromium		1 U	2	2	6.1	0.9 U	1	0.9 U	2	1	2	2	2	1	0.9 U	0.9 U	0.5 U	7.7	8.4	5.7	3.8	0.5 U	8.6	10	5.4	2
Copper		53	270	410	780	4	59	36	200	140	170	330	300	410	160	1700	1500	490	480	1200	550	500	1100	1300	560	630
Iron		50000	>	>50000	340000	>50000	>50000	>50000	>50000	480000	>50000	390000	110000	160000	110000	650	60	760000	990000	530000	390000	300	800000	950000	1E+06	22000
Lead		2.7	0.3 U	0.3 U	0.3	0.5	4.6	0.6	0.9	0.3 U	0.3 U	0.3 U	0.3 U	1.7	0.4	0.3	2.1	0.6	0.5	1.5	0.4	0.5	0.82	1.9	0.5	0.84
Magnesium		17000	70000	47000	51000	39000	47000	51000	50000	47000	50000	44000	28000	30000	17000	2400	1700	120000	150000	64000	69000	5200	110000	97000	120000	10000
Manganese		1000	5100	3800	3900	3500	4100	4500	4400	2900	3300	2700	1500	1400	780	120	110	6300	7600	3600	3600	250	6600	6000	7200	730
Mercury																										
Molybdenum		0.1 U	0.1 U	0.1 U	0.1 U	0.1	0.1 U	0.2	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U
Nickel		18	100	75	43	12	15	13	15	26	25	28	23	18	13	6.8	20 U	150	170	14	87	12	18	11	14	5.8
Potassium		2000 U															1600	5500	8000	4100	3500	1100	3100	1600	7600	6900
Selenium																										
Silver		0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U
Sodium		4200	9900	8500	9200	6800	8100	7800	8900	>10000	>10000	>10000	9000	7300	4300	1500	1500	15000	19000	9400	12000	2000	17000	14000	17000	2700
Thallium		0.2	0.6 U	0.6 U	0.6 U	0.6 U	0.6 U	0.6 U	0.6 U	0.6 U	0.6 U	0.6 U	0.6 U	0.6 U	0.6 U	0.6 U	4 U	4 U	4 U	4 U	4 U	4 U	4 U	4 U	4 U	4 U
Uranium		1.2	23	14	31	1.1	8.8	1.3	6.7	2	1.8	2.9	2.2	5.8	3.5	1.1	0.7	16	18	7.4	7.2	0.8	4.2	5.7	3.1	2.6
Zinc		3800	7300	7200	4000	1200	1700	1400	2600	4900	5300	6000	4800	6200	3800	1800	2700	9500	11000	3100	7300	2700	2600	3300	4100	1100

Data Notes:

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▨ Grey shading Indicates that the data was not available for this parameter.

Data Source:

(a) Kilburn, et al. 1994. *Geochemical data and sample locality maps for stream-sediment, heavy-mineral-concentrate, mill tailing, water, and precipitate samples collected in and around the Holden mine, Chelan County, Washington.* USGS Open File Report 94-680A Paper Version, 94-680B Diskette version (Data Collected in 1994).

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TABLE 7.2.2-1H
STATISTICAL ANALYSIS AND COMPARISON OF CHEMICAL DATA FROM GROUNDWATER SEEPAGE
HOLDEN MINE RI/FS
DAMES & MOORE JOB NO. 17693-005-019

Parameters	Location	TAILINGS PILE (TP-1) AREA																					STATISTICAL CALCULATIONS FOR TAILINGS PILE (TP-1) AREA			
	Sample ID	710	711	712	713	714	715	716	SP-1			SP-2								SP-2X		SP-10E	SP-19				
	Sample Date	9/96[d]	9/96[d]	9/96[d]	9/96[d]	9/96[d]	9/96[d]	9/96[d]	5/23/97	7/12/97	5/2/98	5/18/97	6/2/97	6/9/97	6/16/97	7/12/97	9/16/97	10/5/97	5/2/98	7/12/97	5/2/98	5/21/97	5/21/97	# Analyses	# of Detections	Maximum Conc.	Minimum Conc.
Total Metals, (ug/L)																											
Aluminum		54000	36000	95000	23000	20000	64000	570																7	7	95000	570
Arsenic																								0	0		
Barium		5.1	9.7	5	9.5	5 U	36	6.7																7	6	36	5
Beryllium		10 U	10 U	10 U	10 U	10 U	10 U	10 U																7	0		
Cadmium		44	22	17	18	36	36	10 U																7	6	44	17
Calcium		300000	260000	250000	340000	330000	410000	15000																7	7	410000	15000
Chromium		10 U	10 U	10 U	10 U	10 U	10 U	10 U																7	0		
Copper		10 U	10 U	160	10 U	10 U	220	10 U																7	2	220	160
Iron		1700000	1600000	1300000	1500000	1600000	1600000	44000																7	7	1700000	44000
Lead		57	76	50 U	50 U	68	50	50 U																7	4	76	50
Magnesium		200000	170000	150000	220000	220000	240000	4900																7	7	240000	4900
Manganese		13000	11000	10000	15000	16000	16000	240																7	7	16000	240
Mercury																								0	0		
Molybdenum		20 U	20 U	20 U	20 U	20 U	20 U	20 U																7	0		
Nickel		10 U	10 U	10 U	10 U	10 U	45	10 U																7	1	45	45
Potassium		15000	16000	9500	20000	19000	30000	1200																7	7	30000	1200
Selenium																								0	0		
Silver																								0	0		
Sodium		27000	23000	23000	21000	22000	31000	1300																7	7	31000	1300
Thallium																								0	0		
Uranium																								0	0		
Zinc		7700	5000	8100	5700	6900	7900	300																7	7	8100	300
Dissolved Metals (ug/L)																											
Aluminum		54,000	36,000	96,000	23,000	20,000	110,000	53	27,100	41,200	30,700	94,600	71,800	70,000J	49,800	115,000	67,900	82,500	100,000	121,000	99,800	9,850	4,640	47	47	121000	53
Arsenic											1U	1.5				5U	5U		5U	5U	5U			32	3	5.4	1.5
Barium		5.4	11	5 U	8.9	5 U	16	5.8	15	13	11	15.2J	19	14J	9	12	5	5	2	10	3	18.4	21.3	47	45	130	0.52
Beryllium		10 U	10 U	10 U	10 U	10 U	10 U	10 U	0.7	5U	2U	1.7	20U	20U	20U	5U	2U	2U	2U	5U	2U	0.2U	0.8U	47	19	2.2	0.3
Cadmium		50	26	21	23	34	43	10 U	22.7	6	7	22.8	15	11J	20U	9	3.9	6	9	10	9	7.0	50.1	47	45	50.1	2
Calcium		300,000	260,000	250,000	340,000	340,000	470,000	16,000	102,000	200,000	140,000	155,000	183,000	188,000J	189,000	241,000	180,000	173,000	232,000	246,000	174,000	5,780	33,600	47	47	470000	5780
Chromium		10 U	10 U	10 U	10 U	10 U	10 U	10 U	10U	20U	10U	5	20U	20U	10U	20U	10U	10U	10U	20U	10U	1U	4U	47	19	10	1
Copper		10 U	10 U	180	10 U	10 U	450	10 U	698	240	321	914	860	660J	224	790	101	181	475	870	474	760	4,180	47	42	4180	4
Iron		1600000	1500000	1300000	1400000	1600000	1500000	44000	542,000	1,260,000	705,000	487,000	956,000J	925,000J	856,000	1,180,000	685,000	515,000	673,000	1,200,000	675,000	14,100	70	47	47	1600000	60
Lead		73	50 U	50 U	50 U	50 U	56	50 U	1U	10U	5U	4U	20U	20U	100U	10U	10U	5U	5U	10U	5U	20J	6J	47	23	73	0.3
Magnesium		180000	150000	140000	200000	210000	270000	4700	53,500	106,000	61,200	96,800	107,000	106,000J	99,000	153,000	94,200	95,100	125,000	155,000	125,000	1,400	3,290	47	47	270000	1400
Manganese		13,000	11,000	9,800	15,000	16,000	19,000	200	3,380	6,310	3,870	6,120	6,280	5,890J	5,220	8,570	5,250	4,980	6,260	8,780	6,280	58.9	247	47	47	19000	58.9
Mercury												0.00244				0.00309				0.00308				3	3	0.00309	0.00244
Molybdenum		20 U	20 U	20 U	20 U	20 U	20 U	20 U			10U	0.8U				20U	10U		10U	20U	10U			36	2	0.2	0.1
Nickel		0.01 U	0.01 U	0.01 U	10	11	54	0.01 U	20	50U	20U	119	60	60J	100	70	100	120	190	50U	200	3	29	47	39	170	3
Potassium		14000	15000	9200	19000	18000	26000	1200	9,870	16,300	11,100	9,040	12,900	13,300J	14,700	9,640	9,840	7,380	9,990	7,620	10,100	3,650	3,190	33	32	26000	1100
Selenium												4				5U				5U				3	1	4	4
Silver									0.2U	0.2U	0.2U	0.8U	4U	4U	20U	0.2U	0.2U	0.2U	0.2U	0.2U	0.2U	0.2U	0.8U	40	0		
Sodium		28000	24000	24000	22000	23000	37000	1700	12,800	20,100	14,400	16,200	19,700	19,900J	21,300	23,300	13,600	13,100	19,800	22,700	19,600	1400	1,670	47	47	37000	1400
Thallium												0.8U				50U	10U			50U				29	1	0.2	0.2
Uranium												10.2				50U	50U			50U				29	26	31	0.7
Zinc		7,800	5,000	8,300	6,000	7,300	8,700	330	3,490	2,590	2,050	5,600	4,570	4,430J	4,700	4,120	5,700	6,120	4,630	3,890	4,620	714	6,170	47	47	11000	330

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Statistical Notes:
Maximum and minimum concentrations are based on detected values only.

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(a) Kilburn, et al. 1994. *Geochemical data and sample locality maps for stream-sediment, heavy-mineral-concentrate, mill tailing, water, and precipitate samples collected in and around the Holden mine, Chelan County, Washington.* USGS Open File Report 94-680A Paper Version, 94-680B Diskette version (Data Collected in 1994).
(b) Kilburn, J.E. & S.J. Sutley. 1996. *Characterization of acid mine drainage at the Holden mine, Chelan, Washington.* USGS Open File Report 96-531. (Data collected in 1995).
(c) Kilburn, J.E. & S.J. Sutley. 1997. *Analytical results and comparative overview of geochemical studies conducted at the Holden Mine*, spring 1996. USGS Open File Report 97-128 (Data collected in Spring 1996).
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(e) Johnson, A., et al. 1997. *Effects of Holden Mine on the Water, Sediments and Benthic Invertebrates of Railroad Creek (Lake Chelan).* Environmental Investigations and Laboratory Services Program. Water Body No. WA-47-1020. Publication No. 97-330 (data collected in Spring and Fall 1996).

TABLE 7.2.2-1H
STATISTICAL ANALYSIS AND COMPARISON OF CHEMICAL DATA FROM GROUNDWATER SEEPAGE
HOLDEN MINE RI/FS
DAMES & MOORE JOB NO. 17693-005-019

Location	TAILINGS PILE (TP-2) AREA																									STATISTICAL CALCULATIONS FOR TAILINGS PILE-2 AREA			
Parameters Sample ID	511	541	542	543	614	615	616	617	ECOLOGY TP#2	717	718	719	720	721	723	724	725	726	728	SP-3			SP-4						
Sample Date	7/95[b]	7/95[b]	7/95[b]	7/95[b]	5/96[c]	5/96[c]	5/96[c]	5/96[c]	9/10/96[e]	9/96[d]	9/96[d]	9/96[d]	9/96[d]	9/96[d]	9/96[d]	9/96[d]	9/96[d]	9/96[d]	9/96[d]	5/20/97	7/12/97	9/16/97	5/20/97	7/12/97	5/2/98	# Analyses	# of Detections	Maximum Conc.	Minimum Conc.
Total Metals, (ug/L)																													
Aluminum									22600	59000	19000	14000	62000	19000	86000	18000	13000	10000	53000							11	11	86000	10000
Arsenic																										0	0		
Barium										26	5.9	6.4	18	28	10	30	36	42	44							10	10	44	5.9
Beryllium										10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U							10.	0		
Cadmium									4	11	10 U	10 U	13	10 U	14	10 U	10 U	10 U	22							11	5	22	4
Calcium										360000	410000	340000	360000	320000	300000	300000	310000	370000	300000							10	10	410000	300000
Chromium										10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U							10	0		
Copper									209	1300	120	58	640	95	140	280	190	160	180							11	11	1300	58
Iron									279000	320000	440000	230000	740000	310000	750000	210000	210000	260000	870000							11	11	870000	210000
Lead									20 U	50 U	50 U	50 U	50 U	50 U	50 U	50 U	50 U	50 U	50 U							11	0		
Magnesium										110000	130000	110000	140000	100000	140000	78000	79000	94000	110000							10	10	140000	78000
Manganese									5030	4900	6700	5200	8000	4900	8800	5200	5200	5200	8000							11	11	8800	4900
Mercury																										0	0		
Molybdenum										20 U	20 U	20 U	20 U	20 U	20 U	20 U	20 U	20 U	20 U							10	0		
Nickel										10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U							10	0		
Potassium										24000	28000	27000	32000	29000	31000	28000	29000	25000	32000							10	10	32000	24000
Selenium									93																	1	1	93	93
Silver																										0	0		
Sodium										16000	16000	14000	20000	15000	19000	12000	12000	14000	18000							10	10	20000	12000
Thallium																										0	0		
Uranium																										0	0		
Zinc									1150	3400	1200	470	2100	730	7700	940	690	1200	3900							11	11	7700	470
Dissolved Metals (ug/L)																													
Aluminum	8400	540	6500	2100	98	25000	18000	7700		56000	19000	13000	59000	19000	88000	17000	12000	10000	51000	33,400	22,500	3,920	19,000	20,100	5,570	24	24	88000	98
Arsenic	1 U	1 U	1 U	1 U	4 U	4 U	4 U	4 U												1.6	1U	2U			1U	12	1	1.6	1.6
Barium	3.5	24	23	26	200	9.9	12	23		19	5 U	5	7.1	20	11	28	32	48	41	14.7	21	23	36.7	30	61	24	23	200	3.5
Beryllium	0.3 U	0.3 U	0.3 U	0.3 U	0.4 U	0.6	0.4	0.4 U		10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	0.6	1U	1U	4U	1U	1U	24	3	0.6	0.4
Cadmium	5.9	2	7.4	4.1	0.8	8.9	16	10 U		11	10 U	10 U	14	10 U	18	10 U	10 U	10 U	24	40.3	6	2.0	7.3	6	1.6	24	17	40.3	0.8
Calcium	130000	24000	120000	47000	2700	130000	120000	90000		380000	410000	350000	380000	330000	300000	310000	320000	300000	300000	137,000	184,000	278,000	114,000	117,000	37,500	24	24	410000	2700
Chromium	0.9 U	0.9 U	0.9 U	0.9 U	0.5 U	2.6	0.8	0.5 U		10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	1	5U	5U	2U	5U	5U	24	3	2.6	0.8
Copper	200	46	310	130	34	1100	740	20		1300	120	57	630	73	110	280	200	150	160	1,280	583	90	670	344	133	24	24	1300	20
Iron	270000	1900	10000	5400	49	170000	140000	59000		290000	430000	230000	740000	290000	800000	210000	210000	210000	880000	154,000	263,000	251,000	74,900	53,000	9,730	24	24	880000	49
Lead	0.3 U	0.3	2.7	1	0.2	0.65	1.2	0.5		50 U	50 U	50 U	50 U	50 U	50 U	50 U	50 U	50 U	50 U	1J	5U	5U	2U	2U	1U	24	8	2.7	0.2
Magnesium	27000	4200	24000	9600	1000 U	44000	28000	18000		100000	130000	100000	140000	92000	130000	74000	74000	73000	100000	47,900	54,400	62,300	36,300	34,100	9,840	24	23	14000	4200
Manganese	2100	180	1000	410	80	2500	2000	940		5000	6700	5200	8000	5000	9000	5200	5200	5200	7900	3,000	3,410	3,850	1,750	1,710	522	24	24	9000	80
Mercury			0.1 U																	0.00193J	0.00072					3	2	0.00193	0.00072
Molybdenum	0.1 U	0.1 U	0.1 U	0.1 U	0.4 U	0.4 U	0.4 U	0.4 U		20 U	20 U	20 U	20 U	20 U	20 U	20 U	20 U	20 U	20 U	0.2UJ	5U	5U			5U	22	0		
Nickel	11	2.4	14	7.5	2	12	9.8	4.8		10	0.01 U	0.01 U	0.01 U	0.01 U	0.01 U	0.01 U	0.01 U	0.01 U	0.01 U	17	10U	10U	13	10	10U	24	12	17	2
Potassium					1100	14000	12000	5000		23000	28000	27000	28000	27000	32000	28000	27000	28000	32000	14,100	17,400	29,300	9,530	13,700	3,550	20	20	32000	1100
Selenium																				1J	2U					2	1	1	1
Silver	0.1 U	0.1 U	0.1 U	0.1 U	0.2 U	0.2 U	0.2 U	0.2 U												0.2U	0.2U	0.2U	4U	0.2U	0.2U	14	0		
Sodium	6700	2000	6500	3000	1000 U	7700	6500	7900		16000	18000	16000	19000	14000	21000	13000	12000	13000	18000	8,610	11,300	11,500	7,310	7,760	2,190	24	23	21000	2000
Thallium	0.6 U	0.6 U	0.6 U	0.6 U	4 U	4 U	4 U	4 U												0.2UJ	5U	5U				11	0		
Uranium	3.2	0.2	1.9	0.5	0.4 U	2.6	3.6	0.5												2.9J	50U	50U				11	8	3.6	0.2
Zinc	1000	120	800	500	77	1300	3000	400		3700	1300	510	2400	760	8000	950	780	960	4100	4,030	1,620	611	904	921	248	24	24	8000	77

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TABLE 7.2.2-1H
STATISTICAL ANALYSIS AND COMPARISON OF CHEMICAL DATA FROM GROUNDWATER SEEPAGE
HOLDEN MINE RI/FS
DAMES & MOORE JOB NO. 17693-005-019

Parameters — Location	TAILINGS PILE (TP-3) AREA																			STATISTICAL CALCULATIONS FOR TAILINGS PILE-3 AREA[4]			
Sample ID	350	506	508	509	539	607	608	609	610	611	ECOLOGY TP#3	SP-17		SP-18		SP-21							
Sample Date	7/94[a]	7/95[b]	7/95[b]	7/95[b]	7/95[b]	5/96[c]	5/96[c]	5/96[c]	5/96[c]	5/96[c]	6/12/96[e]	5/20/97	7/12/97	5/19/97	7/12/97	5/22/97	7/12/97	9/15/97	10/5/97	# Analyses	# of Detections	Maximum Conc.	Minimum Conc.
Total Metals, (ug/L)																							
Aluminum											25700					1,890				2	2	25700	1890
Arsenic											0.35					0.04U				2	1	0.35	0.35
Barium																13.9				1	1	13.9	13.9
Beryllium																0.06				1	1	0.06	0.06
Cadmium											5.5					1.11				2	2	5.5	1.11
Calcium																21,200				1	1	21200	21200
Chromium																0.2U				1	0		
Copper											191					54.0				2	2	191	54
Iron											39900					1,020				2	2	39900	1020
Lead											2					2.1J				2	2	2.1	2
Magnesium																3,490				1	1	3490	3490
Manganese											2140					164				2	2	2140	164
Mercury											0.015					0.1U				2	1	0.015	0.015
Molybdenum																0.34J				1	1	0.34	0.34
Nickel											36					4.5				2	2	36	4.5
Potassium																2,490				1	1	2490	2490
Selenium																0.2UJ				1	0		
Silver											0.1 U					0.17J				2	1	0.17	0.17
Sodium																1,560				1	1	1560	1560
Thallium																0.04UJ				1	0		
Uranium																0.13J				1	1	0.13	0.13
Zinc											522					113				2	2	522	113
Dissolved Metals (ug/L)																							
Aluminum	1500	> 10,000	9000	5300	40	27000	27000	15000	23000	18000		40	70	34,100	38,300	1,500	1,300	1,800	2,410	18	18	38300	40
Arsenic	2 U	1 U	1 U	1 U	1 U	4 U	4 U	4 U	4 U	4 U										10	0		
Barium	58	12	8.8	12	14	54	0.6 U	10	12	16		18.7	23	33.1	21	14.0	22	21	26	18	17	58	8.8
Beryllium	1 U	0.4	0.3	0.3 U	0.3 U	0.4 U	0.4 U	0.9	0.6	0.8		0.04U	1U	0.84	1	0.06	1U	1U	1U	18	8	1	0.06
Cadmium	1 U	15	4.9	2	1 U	3.5	0.7 U	11	9.8	4.6		0.38	0.6	12.3	25	1.06	0.7	1.1	0.8	18	15	25	0.38
Calcium	62000	110000	66000	40000	3600	79000	83000	49000	98000	95000		5,290	4,570	103,000	77,000	22,800	18,000	44,800	42,100	18	18	110000	3600
Chromium	1 U	0.9 U	0.9 U	0.9 U	0.9 U	0.5 U	0.5 U	0.6	0.5 U	0.6		0.2U	5U	0.6	5U	0.2U	5U	5U	5U	18	3	0.6	0.6
Copper	21	890	310	350	9.4	730	2 U	1100	730	300		11.0	8	950	1,220	51.8	34	34	34	18	17	1220	8
Iron	23000	100000	52000	6000	400	2800	3100	16000	42000	81000		60	70	23,900	33,700	1,000	690	1,530	2,370	18	18	100000	60
Lead	1.4	0.6	0.3	0.9	0.3 U	3	0.4	0.6	0.68	1.1		0.2U	1U	1U	2U	0.5J	1U	1U	1U	18	10	3	0.3
Magnesium	8900	15000	13000	7000	390	23000	12000	11000	16000	19000		690	670	17,300	14,200	3,820	2,870	7,630	7,810	18	18	23000	390
Manganese	140	1800	590	300	6.8	1200	3 U	1700	1900	2000		8.94	8	1,810	1,290	174	108	304	348	18	17	2000	6.8
Mercury		0.1	0.1 U	0.1 U												0.1U				4	1	0.1	0.1
Molybdenum	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4										10	1	0.4	0.4
Nickel	4	27	9.7	6.9	0.5	16	1 U	48	34	21		0.7	10U	26.1	40	4.3	10U	10U	10	18	14	48	0.5
Potassium	2000 U					6600	3500	4200	4700	7200		740	1,100	4,140	4,210	2290	2,660	5,030	3,960	14	13	7200	740
Selenium																				0	0		
Silver	0.1 U	0.1	0.1 U	0.1 U	0.1 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U		0.04U	0.2U	0.04U	0.2U	0.2U	0.2U	0.2U	0.2U	18	1	0.1	0.1
Sodium	2900	4300	3700	2700	600	7700	5600	4800	6200	6300		960	850	4,670	3,640	1750	1,470	2,550	2,390	18	18	7700	600
Thallium	0.3	0.6 U	0.6 U	0.6 U	0.6 U	4 U	4 U	4 U	4 U	4 U										10	1	0.3	0.3
Uranium	0.4	1.3	1.1	0.7	0.1 U	1.6	0.4 U	2.8	1.6	1.4										10	8	2.8	0.4
Zinc	130	1200	730	160	30	360	0.8 U	360	660	330		45	77	1,080	2,230	109	109	133	132	18	17	2230	30

Data Notes:
J - Estimated Value.
U - Parameter was analyzed for, but not detected above the reporting limit shown.
UJ - Parameter was analyzed for, but not detected. Detection limit is an estimated value.
▨ Grey shading Indicates that the data was not available for this parameter.

Statistical Notes:
Maximum and minimum concentrations are based on detected values only.

Data Source:
(a) Kilburn, et al. 1994. *Geochemical data and sample locality maps for stream-sediment, heavy-mineral-concentrate, mill tailing, water, and precipitate samples collected in and around the Holden mine, Chelan County, Washington.* USGS Open File Report 94-680A Paper Version, 94-680B Diskette version (Data Collected in 1994).
(b) Kilburn, J.E. & S.J. Sutley. 1996. *Characterization of acid mine drainage at the Holden mine, Chelan, Washington*. USGS Open File Report 96-531. (Data collected in 1995).
(c) Kilburn, J.E. & S.J. Sutley. 1997. *Analytical results and comparative overview of geochemical studies conducted at the Holden Mine*, spring 1996. USGS Open File Report 97-128 (Data collected in Spring 1996).
(d) Kilburn, J.E. & S.J. Sutley. 1997. Preliminary data (no report attached, data collected in Fall 1996).
(e) Johnson, A., et al. 1997. *Effects of Holden Mine on the Water, Sediments and Benthic Invertebrates of Railroad Creek (Lake Chelan).* Environmental Investigations and Laboratory Services Program. Water Body No. WA-47-1020. Publication No. 97-330 (data collected in Spring and Fall 1996).

TABLE 7.2.2-1H
STATISTICAL ANALYSIS AND COMPARISON OF CHEMICAL DATA FROM GROUNDWATER SEEPAGE
HOLDEN MINE RI/FS
DAMES & MOORE JOB NO. 17693-005-019

Parameters	Location	MILL AREA													STATISTICAL CALCULATIONS FOR MILL AREA			
	Sample ID	549 A	549 B	643	646	647	649	651	652	653	SP-7			SP-7X				
	Sample Date	7/95[b]	7/95[b]	5/96[c]	5/96[c]	5/96[c]	5/96[c]	5/96[c]	5/96[c]	5/96[c]	5/21/97	7/12/97	9/19/97	5/21/97	# Analyses	# of Detections	Maximum Conc.	Minimum Conc.
Total Metals, (ug/L)																		
Aluminum																		
Arsenic																		
Barium																		
Beryllium																		
Cadmium																		
Calcium																		
Chromium																		
Copper																		
Iron																		
Lead																		
Magnesium																		
Manganese																		
Mercury																		
Molybdenum																		
Nickel																		
Potassium																		
Selenium																		
Silver																		
Sodium																		
Thallium																		
Uranium																		
Zinc																		
Dissolved Metals (ug/L)																		
Aluminum		> 10,000	> 10,000	280000	260000	760000	2800	32	620000	560000	190	20	1,790	200	13	13	760000	20
Arsenic		1	1	4 U	4 U	4 U	4 U	4 U	4 U	5	0.2U	1U	1U	0.2U	13	3	5	1
Barium		6.4	2.8	4.8	5.6	6.9	12	10	14	10	12.9	27	21	12.5	13	13	27	2.8
Beryllium		2.6	3.2	5.1	4.2	7.2	0.4 U	0.4 U	5.9	4.6	0.2U	1U	1U	0.04	13	8	7.2	0.04
Cadmium		1500	2300	2300	980	3000	79	22	1100	1000	34.0	26	48	35.3	13	13	3000	22
Calcium		160000	130000	270000	300000	400000	22000	6900	300000	320000	15,800	28,700	60,100	15,900	13	13	400000	6900
Chromium		31	120	34	21	100	0.5 U	0.5 U	130	61	1U	5U	5U	1U	13	7	130	21
Copper		> 40,000	> 40,000	270000	240000	650000	9200	540	560000	540000	2,810	1,930	7,560	2,800	13	13	650000	540
Iron		440,000	> 500,000	25000	77000	290000	770	50 U	340000	260000	120	220	710	120	13	12	500000	120
Lead		26	23	5.3	5.1	7.4	6.5	1	54	19	3J	3	13	4J	13	13	54	1
Magnesium		> 100,000	> 100,000	140000	150000	510000	7900	2300	370000	340000	4,810	6,680	11,500	4,860	13	13	510000	2300
Manganese		> 6,000	> 6,000	8300	13000	33000	290	56	14000	13000	116	185	451	144	13	13	33000	56
Mercury											0.00068J	0.00023J		0.00051J	3	3	0.00068	0.00023
Molybdenum		0.1 U	0.1 U	0.4 U	0.4 U	0.4	0.4 U	0.4 U	0.4	0.6	0.2UJ	5U	5U	0.2UJ	13	3	0.6	0.4
Nickel		150	180	260	220	720	11	2	190	190	6	10U	10	7	13	12	720	2
Potassium				490	700	500 U	1300	660	770	690	1,230	2,390	3,200UJ	1,260	11	9	2390	490
Selenium											1UJ	1U		1UJ	3	0		
Silver		1.5	5.7	2.8	0.74	2.7	0.2 U	0.2 U	2.4	2.4	0.2U	0.2U	0.2U	0.13U	13	7	5.7	0.74
Sodium		6000	9200	12000	7800	16000	3000	1400	16000	15000	2,170	3,830	6,470J	2,170	13	13	16000	1400
Thallium		0.6	0.6	4 U	4 U	4 U	4 U	4 U	4 U	4 U	0.2UJ	1U	1U	0.2UJ	13	2	0.6	0.6
Uranium		210	600	110	70	250	0.8	0.4 U	110	96	0.3J	20U	1U	0.33J	13	10	600	0.3
Zinc		81000	140000	160000	92000	610000	9200	3200	110000	86000	4,330	3,470	6,430	4,390	13	13	610000	3200

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▨ Grey shading Indicates that the data was not available for this parameter.

Statistical Notes:
Maximum and minimum concentrations are based on detected values only.

Data Source:

(a) Kilburn, et al. 1994. *Geochemical data and sample locality maps for stream-sediment, heavy-mineral-concentrate, mill tailing, water, and precipitate samples collected in and around the Holden mine, Chelan County, Washington.* USGS Open File Report 94-680A Paper Version, 94-680B Diskette version (Data Collected in 1994).

(b) Kilburn, J.E. & S.J. Sutley. 1996. *Characterization of acid mine drainage at the Holden mine, Chelan, Washington*. USGS Open File Report 96-531. (Data collected in 1995).

(c) Kilburn, J.E. & S.J. Sutley. 1997. *Analytical results and comparative overview of geochemical studies conducted at the Holden Mine*, spring 1996. USGS Open File Report 97-128 (Data collected in Spring 1996).

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TABLE 7.2.2-1H
STATISTICAL ANALYSIS AND COMPARISON OF CHEMICAL DATA FROM GROUNDWATER SEEPAGE
HOLDEN MINE RI/FS
DAMES & MOORE JOB NO. 17693-005-019

Location	MINE INFLUENCED AREA																							
Parameters Sample ID	547	548	622	624	631	632	633	634	637	638	639	640	650	658	SP-6	SP-8	SP-9	SP-9X	SP-10W		SP-11	SP-11X	SP-12	
Sample Date	7/95^b	7/95^b	5/96^c	5/96^c	5/96^c	5/96^c	5/96^c	5/96^c	5/96^c	5/96^c	5/96^c	5/96^c	5/96^c	5/96^c	5/21/97	5/21/97	5/23/97	5/23/97	5/21/97	7/12/97	5/22/97	5/22/97	5/23/97	7/12/97
Total Metals, (ug/L)																								
Aluminum																								
Arsenic																								
Barium																								
Beryllium																								
Cadmium																								
Calcium																								
Chromium																								
Copper																								
Iron																								
Lead																								
Magnesium																								
Manganese																								
Mercury																								
Molybdenum																								
Nickel																								
Potassium																								
Selenium																								
Silver																								
Sodium																								
Thallium																								
Uranium																								
Zinc																								
Dissolved Metals (ug/L)																								
Aluminum	1200	2200	9800	620	24000	34000	65000	4000	160	3100	3400	2800	5000	10000	14,600	9,620	30	20	4,740	3,530	150	150	1,380	1,590
Arsenic	1 U	1	4 U	4 U	4 U	4 U	4 U	4 U	4 U	4 U	4 U	4 U	4 U	4 U							0.3	0.2U		
Barium	22	11	15	12	4.8	4.9	2	15	25	17	16	16	14	20	12.0	22.2	30	29	15.4	27	44.6	45.3	50	27
Beryllium	0.3 U	0.3 U	0.6	0.4 U	0.8	0.8	1.4	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	8U	0.8U	0.8U	0.04U	0.8U	1U	0.04U	0.2U	0.8U	1U
Cadmium	24	62	110	22	5.6	12	5.5	33	9.2	66	68	71	78	22	173	87.8	0.75	0.76	25.7	36	12.8	13.2	14.1	18
Calcium	41000	78000	67000	15000	110000	140000	130000	31000	23000	49000	52000	36000	77000	9500	134,000	56,500	19,000	18,600	27,400	30,600	25,300	24,100	9,610	16,200
Chromium	0.9 U	0.9 U	0.5 U	0.5 U	3.7	3.7	6.8	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	2.5	4U	4U	5U	5U	4U	5U	1U	1U	5U	5U
Copper	2300	3000	8500	1700	320	310	570	1900	410	4600	4900	5000	6000	800	12,700	7,880	3	2	2,210	2,110	460	472	2,000	1,910
Iron	190	20 U	51	50 U	800000	1200000	600000	160	50 U	110	110	180	50 U	15000	30	30	20U	20U	30	30	20U	20U	20U	20U
Lead	7.9	0.6	12	2.1	0.79	0.4	0.6	0.3	0.2 U	5.8	7.2	7.8	0.6	36	15J	13J	0.4U	0.3U	4U	1U	1U	1U	0.2U	1U
Magnesium	4400	9600	7200	1600	74000	130000	78000	4600	2800	7700	8200	7300	12000	2100	15,000	5,380	2,090	2,070	3,870J	4,270	3,180	3,000	1,470	2,920
Manganese	50	320	570	110	5100	8800	5000	200	19	320	330	280	580	130	1,160	419	1U	1U	160	191	37.3	36.3	53	93
Mercury																								
Molybdenum	0.1 U	0.1 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U										
Nickel	10	78	48	11	8.4	15	16	12	3	41	44	17	140	5.6	86	46	10U	10U	11	10	6	5	10U	10U
Potassium			4700	1500	10000	12000	1300	2100	1900	4000	4300	3300	6400	4300	10,500	3,980	1,010	1,020	2,500	3,490	2,410	2,060	1,140	1,840
Selenium																								
Silver	0.1 U	0.1 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	8U	0.8U	0.8U	0.8U	0.8U	0.2U	0.05U	0.2U	0.04U	0.2U
Sodium	5500	5800	4800	1500	12000	16000	14000	3400	4600	5100	4300	3500	5900	1900	4,910	2,440	3,470	3,440	2,760	2,920	3,650	3,410	1,630	3,130
Thallium	0.6 U	0.6 U	4 U	4 U	4 U	4 U	4 U	4 U	4 U	4 U	4 U	4 U	4 U	4 U										
Uranium	0.4	0.7	5.1	0.6	3.2	2.6	4.3	0.4 U	0.4 U	0.4 U	0.4	0.4	0.9	4.8										
Zinc	2700	6500	14000	2800	1200	2400	2400	4300	1500	7500	7800	7800	8900	1400	22,100	11,200	267	267	3,210	4,350	2,340	2,280	2,230	2,720

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Data Source:
(a) Kilburn, et al. 1994. *Geochemical data and sample locality maps for stream-sediment, heavy-mineral-concentrate, mill tailing, water, and precipitate samples collected in and around the Holden mine, Chelan County, Washington.* USGS Open File Report 94-680A Paper Version, 94-680B Diskette version (Data Collected in 1994).
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(d) Kilburn, J.E. & S.J. Sutley. 1997. Preliminary data (no report attached, data collected in Fall 1996).
(e) Johnson, A., et al. 1997. *Effects of Holden Mine on the Water, Sediments and Benthic Invertebrates of Railroad Creek (Lake Chelan).* Environmental Investigations and Laboratory Services Program. Water Body No. WA-47-1020. Publication No. 97-330 (data collected in Spring and Fall 1996).

TABLE 7.2.2-1H
STATISTICAL ANALYSIS AND COMPARISON OF CHEMICAL DATA FROM GROUNDWATER SEEPAGE
HOLDEN MINE RI/FS
DAMES & MOORE JOB NO. 17693-005-019

Location	MINE INFLUENCED AREA																								STATISTICAL CALCULATIONS FOR MINE INFLUENCED AREA			
Parameters Sample ID	SP-15E						SP-15W	SP-16			SP-16X	SP-22	SP-23							SP-23 UP	SP-23 Vent Rd	SP-23B	SP-24	SP-25				
Sample Date	5/22/97	6/2/97	6/9/97	6/16/97	7/12/97	10/5/97	5/22/97	5/22/97	7/12/97	9/16/97	7/12/97	5/23/97	5/23/97	5/26/97	6/2/97	6/9/97	6/16/97	10/5/97	5/2/98	7/11/97	10/5/97	5/23/97	5/23/97	5/23/97	# Analyses	# of Detections	Maximum Conc.	Minimum Conc.
Total Metals, (ug/L)																												
Aluminum																												
Arsenic																												
Barium																												
Beryllium																												
Cadmium																												
Calcium																												
Chromium																												
Copper																												
Iron																												
Lead																												
Magnesium																												
Manganese																												
Mercury																												
Molybdenum																												
Nickel																												
Potassium																												
Selenium																												
Silver																												
Sodium																												
Thallium																												
Uranium																												
Zinc																												
Dissolved Metals (ug/L)																												
Aluminum	1,940	2,240	3,350J	2,560	20U	680	30	2,040	3,490	2,630	3,350	190	7,890	7,940	7,440	6,850J	5,390	4,670	5,620	5,820	4,520	5,250	2,410	890	48	47	65000	20
Arsenic								0.8U	1U	1U	1U								1U						21	2	1	0.3
Barium	18	36.1	34.6J	43	43	36	23	21.6	37	24	37	33	33	40.0	26.5	28.5J	23	27	22	32	20	35	36	42	48	48	50	2
Beryllium	0.09	4U	0.3J	4U	1U	1U	0.04U	0.8U	1U	1U	1U	20U	20U	0.2	4U	0.3J	4U	1U	1U	1U	1U	4U	20U	4U	48	8	1.4	0.09
Cadmium	54.6	55.8	66.9J	74	28	63	9.37	53.5	38	34	38	47.5	38.9	41.8	32.0	27.1J	22	23	34	26	22	28.0	47.7	34.1	48	48	173	0.75
Calcium	47,900	38,300	46,800J	52,900	30,100	51,500	23,000	48,300	44,900	49,800	43,900	58,000	17,000	15,900	11,100	10,300J	7,940	11,200	15,500	10,900	10,500	14,100	45,300	37,400	48	48	140000	7940
Chromium	5U	1U	1U	5U	5U	5U	5U	4U	5U	5U.	5U	5U	5U	1U	1U	1U	5U	5U	5U	5U	5U	5U	5U	5U	48	4	6.8	2.5
Copper	3,560	3,950	4,930J	4,470	899	4,180	206	3,450	3,100	2,110	2,970	2,140	6,850	6,470	6,100	5,940J	4,880	4,920	5,340	5,560	4,520	4,900	3,660	1,880	48	48	12700	2
Iron	80	80J	100J	110	20U	170	20U	60	500	80	450	20U	20U	20U	20U	20U	20U	20U	20U	20U	20U	20U	220	20U	48	24	1200000	30
Lead	6.7U	8	14J	20U	1U	6	1.4U	5J	9	8	10	2.8U	20U	1U	1U	3J	20U	1U	0.22	1U	1U	4U	4.3U	2.2U	48	23	36	0.22
Magnesium	6,330	5,820	7,170J	8,260	5,930	9,040	2,590	6,530	6,500	4,560	6,270	6,880	5,130	4,660	2,660	2,500J	1,630	2,290	3,620	2,540	2,150	3,920	6,240	5,090	48	48	130000	1470
Manganese	247	198	250J	295	148	312	37	253	993	2,030	960	264	248	223	130	115J	79	128	199	114	109	177	270	157	48	46	8800	19
Mercury								0.00056J	0.00093		0.00067														3	3	0.00093	0.00056
Molybdenum								0.8UJ	5U	5U	5U								5U						19	0		
Nickel	20	16	20J	20	10U	20	10U	28	30	20	30	20	20	22	14	12J	10U	10	20	10	10	10	20	10	48	41	140	3
Potassium	3,460	3,910	5,270J	4,760	3,040	3,830	2,120	3,500	4,760	5,230	4,700	3,980	1,160	1,280	1,360	1,120J	840	1,340	1,110	1,420	890	1,000	3,730	2,700	46	46	12000	840
Selenium								4UJ	1U		1U														3	0		
Silver	0.05U	0.2U	0.2U	4U	0.2U	0.2U	0.8U	0.04U	0.2U	0.2U	0.2U	0.04U	0.04U	0.2UJ	0.2U	0.2U	4U	0.2U	0.2U	0.2U	0.2U	0.04U	0.14	0.08	48	2	0.14	0.08
Sodium	2,500	3,010	3,420J	3,940	3,450	3,710	3,380	2,980	4,820	3,350	4,600	3,340	1,600	1,710	1,140	1,240J	1,000	1,360	1,430	1,380	1,330	1,650	3,140	3,300	48	48	16000	1000
Thallium								0.8UJ	1U	1U	1U														18	0		
Uranium								0.8UJ	20U	20U	20U														18	11	5.1	0.4
Zinc	7,970	7,210	8,580J	9,810	3,590	8,960	2,260	7,690	4,920	4,050	4,810	7,350	5,000	5,020	3,400	2,870J	2,250	2,460	4,110	2,610	2,570	3,610	7,560	5,550	48	48	22100	267

Data Notes:
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UJ - Parameter was analyzed for, but not detected. Detection limit is an estimated value.
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Statistical Notes:
Maximum and minimum concentrations are based on detected values only.

Data Source:
(a) Kilburn, et al. 1994. *Geochemical data and sample locality maps for stream-sediment, heavy-mineral-concentrate, mill tailing, water, and precipitate samples collected in and around the Holden mine, Chelan County, Washington.* USGS Open File Report 94-680A Paper Version, 94-680B Diskette version (Data Collected in 1994).
(b) Kilburn, J.E. & S.J. Sutley. 1996. *Characterization of acid mine drainage at the Holden mine, Chelan, Washington.* USGS Open File Report 96-531. (Data collected in 1995).
(c) Kilburn, J.E. & S.J. Sutley. 1997. *Analytical results and comparative overview of geochemical studies conducted at the Holden Mine*, spring 1996. USGS Open File Report 97-128 (Data collected in Spring 1996).
(d) Kilburn, J.E. & S.J. Sutley. 1997. Preliminary data (no report attached, data collected in Fall 1996).
(e) Johnson, A., et al. 1997. *Effects of Holden Mine on the Water, Sediments and Benthic Invertebrates of Railroad Creek (Lake Chelan).* Environmental Investigations and Laboratory Services Program. Water Body No. WA-47-1020. Publication No. 97-330 (data collected in Spring and Fall 1996).

TABLE 7.2.2-1H
STATISTICAL ANALYSIS AND COMPARISON OF CHEMICAL DATA FROM GROUNDWATER SEEPAGE
HOLDEN MINE RI/FS
DAMES & MOORE JOB NO. 17693-005-019

Parameters	NON-MINE INFLUENCED AREAS														
	USGS 1995 b		DAMES & MOORE RI DATA									STATISTICAL CALCULATIONS			
			SP-14 Upper	SP-26		SP-14		SP-14 Lower	SP-13	A-1	SP-27	# Analyses	# of Detections	Maximum Conc.	Minimum Conc.
	515	507	10/3/97	7/11/97	9/16/97	5/23/97	9/18/97	10/3/97	6/2/97	7/11/97	5/7/98				
Total Metals, (ug/L)															
Aluminum						440						1	1	440	440
Arsenic															
Barium						18						1	1	18	18
Beryllium						4U						1	0		
Cadmium						3.46						1	1	3.46	3.46
Calcium						1,830						1	1	1830	1830
Chromium						5U						1	0		
Copper						830						1	1	830	830
Iron						20						1	1	20	20
Lead						6.0						1	1	6	6
Magnesium						300						1	1	300	300
Manganese						9						1	1	9	9
Mercury															
Molybdenum															
Nickel						10U						1	0		
Potassium						500U						1	0		
Selenium															
Silver						0.05J						1	1	0.05	0.05
Sodium						700						1	1	700	700
Thallium															
Uranium															
Zinc						446						1	1	446	446
Dissolved Metals (ug/L)															
Aluminum		1300	70	30	20U	410	160U	900	20U	20U	20U	10	5	1300	30
Arsenic		1 U									1U	2	0		
Barium		47	2	14	3	33	20	51	41	14.4	1U	10	9	51	2
Beryllium		0.3 U	1U	1U	1U	4U	1U	1U	0.8U	0.04U	1U	10	0		
Cadmium		2	0.2U	0.3	0.3	3.46	1.2	12	0.31	2.32	0.2U	10	8	12	0.3
Calcium		13000	700	3,760	4,640	1,800	1,730	5,020	10,400	20,100	4,610	10	10	20100	700
Chromium		0.9 U	5U	5U	5U	5U	5U	5U	5U	0.2U	5U	10	0		
Copper		48	2U	28	22	788	52	1,410	2U	120	2U	10	7	1410	22
Iron		100	20U	20U	20U	20	480	30	330	20U	20U	10	5	480	20
Lead		0.4	1U	1U	1U	4.8U	3	11	0.8U	0.4U J	1U	10	3	11	0.4
Magnesium		1700	130	470	540	290	350	910	1,460	1,910	430	10	9	1910	130
Manganese		370	1U	1U	1U	8	4	43	74	27.8	1	10	6	370	1
Mercury															
Molybdenum		0.1 U									5U	2	0		
Nickel		9.8	10U	10U	10U	10U	10U	10U	10U	1.0	10U	10	2	9.8	1
Potassium			500U	640	790	500U	750UJ	560	1,010	1,770	500U	9	5	1770	560
Selenium															
Silver		0.1 U	0.2U	0.2U	0.2U	0.04U	0.2U	0.2U	1.1U	0.04U	0.2U	10	0		
Sodium		1000	310U	970	1,020	730	590UJ	650	1,950	1,220	1,110	10	8	1950	650
Thallium		0.6 U										1	0		
Uranium		0.2										1	0		
Zinc		170	5	32	22	423	151	1,610	71	257	4U	10	9	1610	5

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TABLE 7.2.2-2
SPECIES OF FEDERAL CONCERN WHICH MAY OCCUR IN THE VICINITY OF HOLDEN MINE, AS INDICATED BY THE U.S. FOREST SERVICE
AUGUST 13, 1997

Common Name	Habitat requirements	Potential to Occur in Project Area
Cascades frog *Rana cascadae*	Small pools and marshy areas adjacent to streams	Possible. Suitable habitat for this species exists in the project area.
Columbia spotted Frog *Rana luteiventris*	Marshy edges of lakes, springs, ponds, or streams	Possible. Suitable habitat exists for this species in the project area.
Tailed frog *Ascaphus truei*	Cold, rocky mountain streams	Possible. Suitable habitat exists for this species in the project area.
Black tern *Ascaphus truei*	Fresh water marshes and lakes	No. There is no suitable habitat for this species in the project area.
Columbian sharp-tailed grouse *Tympanuchus phasianellus columbianus*	Prairie, thickets, forest edges and openings	No. There is no suitable habitat for this species in the project area.
Ferruginous hawk *Buteo regalis*	Plains, prairies	No. There is no suitable habitat for this specie sin the project area.
Harlequin duck *Histrionicus histrionicus*	Mountain streams in summer, rocky coastal waters in winter	Possible. Suitable habitat exists for this species in the project area.
Little willow flycatcher *Empidonax traillii brewsteri*	Stream side, willow thickets	Probable. Suitable habitat exists for this species in the project area.
Loggerhead shrike *Lanius ludovicianus*	Open country with scattered trees and small shrubs, shrub-steppe	Possible. Suitable habitat exists on southern aspects.
Northern goshawk *Accipiter gentilis*	Coniferous and deciduous forests, winters in lowlands	Probable. Suitable habitat exists for this species in the project area.
Olive-sided flycatcher *Contopus borealis*	Conifer forests, burns, slashings (summer)	Probable. Suitable habitat exists for this species in the project area.
Western burrowing owl *Athene cunicularia hypugea*	Shrub-steppe, nonforested plains, and grasslands.	No. There is no suitable habitat for this specie sin the project area.
Western sage grouse *Centrocercus urophasianus phaios*	Sagebrush plains and foothills	No. There is no suitable habitat for this specie sin the project area.
California bighorn sheep *Ovis canadensis californiana*	Alpine meadows and grassy slopes near mountain cliffs	Unlikely. The closest bighorn sheep population is 20 miles to the south.
California wolverine *Gulo Gulo luteus*	Wide ranging, especially in coniferous forest and montane areas	Possible. Wolverine have been observed at the higher elevations of Railroad Creek drainage
Long-eared myotis *Myotis evotis*	Forests	Possible. Suitable habitat exists.
Long-legged myotis *Myotis volans*	Forests, some hibernate in caves in winter	Possible. Suitable habitat exists.
Pacific fisher *Martes pennanti pacifica*	Dense, mature spruce-fir and lowland forests	Possible. Fisher have been observed at the higher elevations of Railroad Creek drainage
Western big-eared bat *Plecotus townsendii pallescens*	Forests, roost in caves, mines, and under bark on trees	Possible. Suitable habitat exists.
Small-footed myotis *Myotis ciliolabrum*	Open, arid areas, roosts in rocky crevices, caves, mines, and old buildings	No. There is no suitable habitat for this species in the project area.
Yuma myotis *Myotis yumanensis*	Open areas in forests	Possible. Suitable habitat exists.
Westslope cutthroat trout *Oncorhynchus (=Salmo) clarki lewisi*	Streams, tributaries, and lakes	Most abundant trout species in Railroad Creek. See Section 4.8.1.4.

TABLE 7.2.2-2 (CONTINUED)
SPECIES OF FEDERAL CONCERN WHICH MAY OCCUR IN THE VICINITY OF HOLDEN MINE, AS INDICATED BY THE U.S. FOREST SERVICE

Common Name	Habitat requirements	Potential to Occur in Project Area
White milk-vetch *Astragalus sinuatus*	Rocky hillsides, associated with big sagebrush	No. There is no suitable habitat for this species in the project area.
Grape-fern *Botrychium paradoxum*	Old, disturbed, gravelly areas, often associated with spruce seedlings.	Possible. Suitable habitat exists.
Clustered lady's slipper *Cypripedium fasciculatum*	Moist to dry and rocky open coniferous forest (Douglas fir and ponderosa pine	Possible. Suitable habitat exists.
Wenatchee larkspur *Delphinium viridescens*	Moist meadows from 2500-5000'	Possible. Suitable habitat exists.
Showy stickseed *Hackelia venusta*	Rocky slopes with ponderosa pine	Possible. Suitable habitat exists.
Chelan rockmat *Petrophyton cinerascens*	Basalt cliffs and bluffs	Possible. Suitable habitat exists.
Seely's silene *Silene seelyi*	Steep talus slopes and rock crevices	Possible. Suitable habitat exists.
Thompson's clover *Trifolium thompsonii*	Open areas on sandy loam and gravelly soils with sagebrush	No. There is no suitable habitat for this species in the project area.

TABLE 7.2.2-3
TOXICITY BENCHMARKS FOR AMPHIBIANS EXPOSED TO CADMIUM, COPPER, LEAD, ZINC, AND MERCURY

	Species	lifestage	Effect	Hardness	ug/L	Reference
Copper	Bufo melanosticus	tadpole	96-h LC50	120-160	320	Khangarol and Ray 1987
	Microhyla omata	tadpole	96-h LC50	97-98	500	Rao and Madhyastha 1987
	Gasterophyrene carolinensis	embryo-larvae	7-day LC50	195	40	Birge et al. 1979
	Rana pipiens	post-hatch	30-d LC50	290	150	Landle and Guttman 1973
	Rana pipiens	adult	48-h LC50		0.00016 %	Kaplan and Yoh 1961
	Xenopus laevis	3-4 week	48-h LC50		1700	deZwart and Sloof 1987
				mean	542	
Zinc	Bufo melanosticus	tadpole	96-h LC50	120-160	19860	Khangarol and Ray 1987
	Microhyla omata	tadpole	96-h LC50	97-98	22410	Rao and Madhyastha 1987
	Gasterophyrene carolinensis	embryo-larvae	7-day LC50	195	10	Birge et al. 1979
	Rana pipiens	tadpole	15-d LC50		155000	Kaplan and Gazenski 1965
	Xenopus laevis	blastula	96-h LC50	100	34500	Dawson et al. 1988
				mean	46356	
Lead	Gasterophyrene carolinensis	Embryo-larvae	7-day LC50	195	40	Birge et al. 1979
	Rana pipiens	adult	96-h LC50		105000	Kaplan et al. 1967
	Xenopus laevis	blastula	6-day NOEC	20	100	Miller and Landesman 1978
				mean	35046	
Cadmium	Bufo melanosticus	tadpole	96-h LC50	120-160	8180	Khangarol and Ray 1987
	Microhyla omata	tadpole	96-h LC50	97-98	1580	Rao and Madhyastha 1987
	Gasterophyrene carolinensis	embryo-larvae	7-day LC50	195	40	Birge et al. 1979
	Xenopus laevis	embryo-larvae	48-h LC50		3200	Canton and Sloof 1982
	Xenopus laevis	3-4 week	48-h LC50		32000	Sloof and Baerselman 1980
	Xenopus laevis	3-4 week	48-h LC50		20200	deZwart and Sloof 1987
	Ambystoma mexicanum	3-4 week	48-h LC50		1300	Sloof and Baerselman 1980
				mean	9500	
Mercury	Gasterophyrene carolinensis	embryo-larvae	7-day LC50	195	1	Birge et al. 1979
	Gasterophyrene carolinensis	embryo-larvae	7-day LC50	195	1300	Birge et al. 1979
	Hyla crysoscelis	embryo-larvae	7-day LC50	195	2400	Birge et al. 1979
	Hyla squirella	embryo-larvae	7-day LC50	195	2400	Birge et al. 1979
	Hyla gratiosa	embryo-larvae	7-day LC50	195	2500	Birge et al. 1979
	Hyla versicolor	embryo-larvae	7-day LC50	195	2600	Birge et al. 1979
	Hyla crucifer	embryo-larvae	7-day LC50	195	2800	Birge et al. 1979
	Rana pipiens	embryo-larvae	7-day LC50	195	7300	Birge et al. 1979
	Rana heckscheri	embryo-larvae	7-day LC50	195	59900	Birge et al. 1979
	Rana grylio	embryo-larvae	7-day LC50	195	67200	Birge et al. 1979
	Acris crepitana	embryo-larvae	7-day LC50	195	10400	Birge et al. 1979
	Bufo fowleri	embryo-larvae	7-day LC50	195	65900	Birge et al. 1979
	Bufo punctatus	embryo-larvae	7-day LC50	195	36800	Birge et al. 1979
	Bufo debilus	embryo-larvae	7-day LC50	195	40000	Birge et al. 1979
	Ambystoma opacum	embryo-larvae	7-day LC50	195	107500	Birge et al. 1979
	Ambystoma mexicanum	embryo-larvae	48-h LC50		40	Sloof and Baerselman 1980
	Xenopus laevis	embryo-larvae	7-day LC50		100	Sloof and Baerselman 1980
	Xenopus laevis	embryo-larvae	48-h LC50		100	deZwart and Sloof 1987
	Microhyla ornata	embryo-larvae	96-h LC50		170	Chate and Mulherkur 1980
				mean	21547.95	

TABLE 7.2.2-4
SUMMARY OF REPRESENTATIVE ROCS

Trophic Level	Aquatic	Terrestrial
Tertiary Consumer	Mink [C]; Osprey [P];	Mink [C]; Red-tailed Hawk [C]
Secondary Consumer	Trout [I]; Dipper [I]	Bat [I]; Shrew [I] Deer Mouse [O]; American Robin
Primary Consumer	Caddisfly [D]	Earthworm [D]; Mule Deer [H]
Primary Producer	Periphyton	*Grasses/Forbs*

[H] = Herbivore; [C] = Carnivore; [P] = Piscivore; [I] = Insectivore;
[V] = Vermivore; [D] = Detritovore; [O] = Omnivore

TABLE 7.2.3-1A
SCREENING OF COCS FOR SURFACE WATER

	NAWQC[1]	UCL Upstream	Max South Bank	UCL Adjacent	UCL Downstream	Eliminated
	µg/L	µg/L	µg/L	µg/L	µg/L	
Al	87	29.5	50	72.9	52.39	X
As	190	0.94	ND	0.49	0.42	X
Ba	NA	24.3	13	31.1	16.2	X
Be	NA	ND	0.04	ND	ND	X
Cd	0.3	0.08	1.14	0.68	0.36	
Cu	2.29	1.1	59.8	41.9	15.82	
Cr	42.6	ND	0.2	0.2	ND	X
Fe	1000	60	40	648	708	X
Pb	0.3	0.9	0.6	0.6	0.5	
Mn	120	3.17	7.68	13.14	14.51	X
Hg	0.0024	ND	ND	0.00053	0.00064	X
Ni	50.2	10.2	1.0	0.9	0.6	X
Ag	NA	ND	0.1	0.07	0.09	X
Zn	20.8	10.7	191	83.75	53.86	

italics - highest value
1 - adjusted to 14.5 mg/L hardness

TABLE 7.2.3-1B
RESULTS OF PEER-REVIEWED BIOASSAYS WITH SALMONID FISHES

Species	Hardness (µg/L)	LC50 (µg/L)	Reference	Species	Hardness (mg/L)	Chronic NOEC (µg/L)	Reference
Cadmium							
Rainbow trout	20	91.0 (48 h)	Calamari et al. 1980	Rainbow trout	31	7.0 (MATC)	Davies et al. 1976
Steelhead	9.2	7.0 (96 h)	Cuismano et al. 1986		28	3.0 (MATC)	Goettl and Davies 1976
	9.2	28.0 (96 h)					
Steelhead	23	1.3 (96 h)	Chapman 1978				
Chinook salmon	23	1.8 (96 h)					
	Mean	7.0				5.0	
Copper							
Rainbow Trout	31-32	22.0-29.0 (96 h)	Howarth and Sprague 1978	Rainbow trout	14	40.0 (21 d)	Grande 1967
Rainbow Trout	30	20.0 (96 h)	Howarth and Sprague 1978		20	40.0 (ILL)	Lloyd and Herbert 1962
Steelhead	22	17.0 (96 h)	Chapman 1978		20	100.0 (ILL)	Liepolt and Herbert 1958
Atlantic Salmon	14	32.0 (48 h)	Sprague and Ramsey 1965	Atlantic Salmon	20	48.0 (ILL)	Sprague 1964
Brown Trout	14	40.0 (10 d)	Grande 1967				
Brook Trout	14	25.0 (96 h)	Zitko et al. 1973				
Chinook Salmon	22	19.0 (96 h)	Chapman 1978				
Cutthroat Trout	26.4	16.0 (96 h)	Chakoumakos et al. 1979				
	Mean	23.0				53.0/2.0*	
Iron	NA	NA		Rainbow trout	28	1,300	Amelung 1981
						1,300	
Lead							
Rainbow trout	28	200.0 (336 h)	Davies et al. 1976	Rainbow trout	28	76.0-14.6 (MATC)	Davies et al. 1976
	28	1,170.0 (96 h)					
Atlantic salmon	11	700.0 (96 h)	Grande and Anderson 1983				
	Mean	547.0				11	
Zinc							
Rainbow trout	30.2	170.0 (96 h)	Bradley and Sprague 1985	Rainbow trout	26	140.0-260.0 (MATC)	Sinely et al. 1974
	31.4	880.0 (96 h)			26	135.0-251.0 (MATC)	Goettl et al. 1973
	10	2,310.0 (96 h)	Everall et al. 1989				
	10	1,410.0 (96 h)					
	10	600.0 (96 h)					
	Mean	782.0				187.0	

* The chronic value for copper is apparently higher than the acute value because toxicity is complete within 96 hours for this metal and because the chronic bioassays were run at slightly higher water hardnesses. While the available data for ILLs are of good quality, an alternative approach was used to estimate the chronic NOEC for copper. McKim et al. (1971) showed that the MATC for brook trout exposed to copper for 22 months ranged between 0.1 and 0.17 of the 96 h LC50. If the lower of these two factors is applied to the geometric mean LC50 calculated above, the chronic NOEC is 2.3 ug copper/L. This agrees well with the hardness corrected chronic value in Table 3-1.

TABLE 7.2.3-2A
SCREENING OF COCS FOR SEDIMENTS AND FLOCCULENT

	ER-L/ LEL	UCL Adjacent	UCL Downstream	Max (RC-9) Flocculent	Eliminated
	mg/kg	mg/kg	mg/kg	mg/kg	
Al	NA	11717	13300	16600	X
As	8.2	11.6	NA	126	
Cd	1.2	4.41	0.9	5	
Cu	34	184	147	982	
Fe	20000	38429	26300	434000	
Pb	46.7	6.68	11	40U	X
Mn	460	308	1200	331	
Hg	0.15	0.02	NA	NA	X
Ni	20.9	23.91	NA	20U	
Ag	1	5.6	NA	11	
Zn	150	136.76	216	481	

TABLE 7.2.3-2B
RESULTS OF PEER-REVIEWED BIOASSAYS WITH BENTHIC MACROINVERTEBRATES

Species	LC50 (mg/L)	Reference	Species	Chronic NOEC (mg/L)	Reference
Cadmium					
Stonefly larvae	18.0 (96 h)		*Tanytarsus dissimilis*	0.004 (10 d)	Anderson et al. 1980
Caddisfly larvae	3.4 (96 h)		*Ephmerella sp.*	0.003 (28 d)	Spehar et al. 1978
Damselfly larvae	8.1 (96 h)				
Ephemerella grandis	2.0 (96 h)				
Ephemerella grandis	28.0 (96 h)				
Mean	7.7			0.003	
Copper					
Ephemerella subvaria	0.32 (96 h)	Warnick and Bell 1969	*Ephemerella grandis*	0.18- 0.2 (14 d)	Nehring 1976
Hydropsyche lateralis	>64 (96 h)	Warnick and Bell 1969	*Pteronarcys californica*	10.0-13.9 (14 d)	
Acroneuria lycorias	8.3 (96 h)				
Damsel fly larvae	4.6 (96 h)	Rehwoldt et al. 1973			
Caddis fly larvae	6.2 (96 h)				
Mean	5.5			1.50	
Lead					
Ephemerella subvaria	16 (7 d)	Warnick and Bell 1969	*Pteronarcys califorica*	>19.2 (14 d)	Nehring 1976
Hydropsyche betteni	32 (7 d)		*Ephemerella grandis*	3.5 (14 d)	
Acroneuria lycorias	64 (96 h)	Warnick and Bell 1969			
Mean	32.0			3.33	
Zinc					
Damsel fly larvae	26.2 (96 h)	Rehwoldt et al. 1973	*Pteronarcys califorica*	13.9 (14 d)	Nehring 1976
Caddis fly larvae	58.1 (96 h)	Rehwoldt et al. 1973	*Ephemerella grandis*	> 9.2 (14 d)	
Mean	39.0			11.31	

TABLE 7.2.3-3A
ELIMINATION OF COCS FOR SOILS, TAILINGS, AND DUST

	Yakima	Background	Worms	Plants	Surface	Subsurface	TP-1	TP-2	TP-3	Dust	Eliminated
	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	
Soils	UCL	UCL			UCL	UCL	UCL	UCL	UCL	UCL	
Al	*33380*	20870	NA	NA	22437	16771	39000	38000	44000	21924	X
As	5.13	11.59	*60*	10	3.4	3.08	5.5	2.94	2.2	2.8	X
Ba	NA	310	NA	NA	380	863.7	860	1057	687	388	X
Be	*1.57*	0.2	NA	NA	0.26	0.01	ND	0.2	0.2	0.2	X
Cd	0.93	5.41	*20*	4	1.54	147	4.51	10.87	1	0.58	
Cu	26.47	57.45	50	*100*	311.3	16500	442	287	274	319	
Fe	38644	24098	NA	NA	26288	71292	67607	67717	71894	98314	X
Pb	11	20.6	500	*50*	61.4	91	118	83	77	62	
Mn	1104.8	*1425*	NA	NA	627	315	470	430	458.2	280	X
Hg	0.05	NA	1.3	34.9	0.08	*0.13*	*0.35*	*0.25*	*0.27*	NA	X
Ni	45.9	22.7	*200*	30	21.1	52.2	4	4.7	6.6	27.8	X
Ag	NA	0.49	NA	2	*0.3*	3.8	3	2.5	2.6	2.8	
Zn	78.71	*253.4*	200	78.7	246	2750	238.5	255	744.6	509	

italics- highest value

1) NAWQC (USEPA 1996). Calculated using mean hardness in Spring and Fall 1997 at site sampling locations (14.65 mg $CaCo_3$/L)
2) Long et al. (1995) with the exceptions of iron and manganese which are from Persaud et al. (1993).
90th percentile from Yakima Basin soils (WSDOE 1994).
90th percentile from Dames & Moore (1998)
Oak Ridge National Laboratory (1997) plant toxicity benchmarks.
Oak Ridge National Laboratory (1997) earthworm toxicity benchmarks.
5) Target Values from the Dutch Department of Soil Protection (1996).
6) Tier II value for the Great Lakes Water Quality Initiative (1995).
7) WDOE. 1997. Creation and analysis of freshwater sediment quality values in Washington State, Olympia, WA.

TABLE 7.2.3-3B
SOIL CONCENTRATIONS OF METALS WHICH ALLOW PLANT GERMINATION AND GROWTH IN THE WILD

Metal	Soil Concentration (mg/kg)
Cadmium	710
Copper	440
Lead	2700
Zinc	24000

TABLE 7.2.3-4A
TOXICITY REFERENCE VALUES (TRVS) AND SAFE FOOD AND WATER CONCENTRATIONS FOR REPRESENTATIVE AVIAN ROCS

Species	Surrogate Species	Body Weight (kg)	Test Species NOAEL (mg/kg/day)	TRV (mg/kg/day)	Reference
Birds					
As	mallard	1.0	5.14 (NOAEL)	5.1	Heinz et al. 1989
Cd	mallard	1.153	20.0 (LOAEL)	4.0*	White and Finley 1978
Cu	chicken	0.534	47 (NOAEL)	47.0	Mehring et al. 1960
Pb	Japanese quail	0.15	11.3 (LOAEL)	2.3*	Vos et al. 1971
Zn	Chicken	1.935	131 (LOAEL)	26.2*	Stahl et al. 1990

* Estimated from LOAEL by dividing by 5 (Lewis et al. 1990)

TABLE 7.2.3-4B
TOXICITY REFERENCE VALUES (TRVS) FOR MAMMALS

Little Brown Bat	**Surrogate Species**	**Body Weight (kg)**	**Endpoint (mg/kg diet)**	**TRV (mg/kg/d)**	**Reference**
Cadmium	rat	0.303	10 (LOAEL)	3.06*	Sutou et al. 1980
Copper	mink	1.0	11.71 (NOAEL)	24.18	Aulerich et al. 1982
Lead	rat	0.35	80 (LOAEL)	25.41*	Azar et al. 1973
Zinc	rat	0.35	320 (LOAEL)	101.65*	Schlicker and Cox 1968
Dusky Shrew	**Surrogate Species**	**Body Weight (kg)**	**Endpoint (mg/kg diet)**	**TRV (mg/kg/d)**	**Reference**
Cadmium	rat	0.303	10 (LOAEL)	10.1	Sutou et al. 1980
Copper	mink	1.0	11.71 (NOAEL)	170.8	Aulerich et al. 1982
Lead	rat	0.35	80 (LOAEL)	16.2	Azar et al. 1973
Zinc	rat	0.35	320 (LOAEL)	323.3	Schlicker and Cox 1968
Mink	**Surrogate Species**	**Body Weight (kg)**	**Endpoint (mg/kg diet)**	**TRV (mg/kg/d)**	**Reference**
Cadmium	Dog	8.3	0.49 (NOAEL)	0.83	Anwar et al. 1961
	Dog	9	9.5 (NOAEL)	16.5	Loeser and Lorke 1077
	Rat	0.303	10.0 (LOAEL)	3.74	Sutou et al. 1980
			Geometric Mean	3.71	
Copper	Mink	1.0	11.7 (NOAEL)	11.7	Aulerich et al. 1982
Lead	Dog	8.3	12.5 (LOAEL)	10.61*	ATSDR 1990
	Rat	0.35	80 (LOAEL)	12.31*	ATSDR 1992
			Geometric Mean	11.43	
Zinc	Rat	0.35	160 (NOAEL)	123.1	Schlicker and Cox 1968
Deer Mouse	**Surrogate Species**	**Body Weight (kg)**	**Endpoint (mg/kg diet)**	**TRV (mg/kg/d)**	**Reference**
Cadmium	rat	0.303	10 (LOAEL)	10.1	Sutou et al. 1980
Copper	mink	1.0	11.71 (NOAEL)	170.8	Aulerich et al. 1982
Lead	rat	0.35	80 (LOAEL)	16.2	Azar et al. 1973
Zinc	rat	0.35	320 (LOAEL)	323.3	Schlicker and Cox 1968
Mule Deer	**Surrogate Species**	**Body Weight (kg)**	**NOAEL (mg/kg diet)**	**TRV (mg/kg/d)**	**Reference**
Cadmium	Calf	14.8	10.3 (NOAEL)	7.26	Powell et al. 1964
	Swine	21.7	12.5 (NOAEL)	9.70	Cousins et al. 1973
	Lamb	47.8	3.0 (NOAEL)	2.83	Doyle et al. 1974
Geometric mean				5.84	
Copper	Swine	92.3	7.7 (NOAEL)	8.58	Kline et al. 1971
Lead	Horse	139.5	6.25 (NOAEL)	7.72	Dollahite et al. 1978
	Calf	55	7.3 (NOAEL)	7.17	Zmudski et al. 1984
Geometric mean				7.44	
Zinc	Horse	100	90 (NOAEL)	102.3	Willoughby et al. 1972
	Swine	47.25	122.4 (NOAEL)	115.3	Hsu et al. 1975
	Calf	110	13.7 (NOAEL)	15.94	Miller et al. 1970
Geometric mean				57.29	

* estimated from LOAEL by dividing by 5 (Lewis et al. 1990) and then scaling to body weight.

TABLE 7.2.3-5
EXAMPLE PREDICTION OF BODY BURDENS OF METALS IN BENTHIC INVERTEBRATES IN RAILROAD CREEK

Metal	CFR Body Burden (mg/kg)	CFR Pore Water (ug/L)	Highest Surface Water (ug/L)	Predicted Body Burden (mg/kg)
Cadmium	8.38	23.2		
	1.2	5.98		
	1.43	1.36		
	2.2	1.49	1.08 (RC-4X)	1.60
	1.76	<0.81		
	0.13 (reference)	<0.81		
Copper	1382	11080		
	122	698		
	181	274		
	266	184		
	48	58.1	79 (RC-4)	65.3
	26	35.2 (reference)		
Lead	67.1	276		
	10.7	120		
	9.93	38.5		
	32.2	35.4		
	3.83	9.4	0.7 (RC-2X)	0.256
	0.54	23.9 (reference)		
Zinc	1665	18900		
	304	1180		
	293	187	185 (RC-4X)	289.9
	453	189		
	359	132		
	212	<70 (reference)		

* Assumed to be equal to the measured Clark Fork body burden.

TABLE 7.2.3-6

TOXICITY REFERENCE VALUES (TRVS) FOR LITTLE BROWN BAT

Metal	Surrogate Species	Body Weight (kg)	Endpoint (mg/kg diet)	TRV (mg/kg/d)	Reference
Arsenic	mouse	0.03	1.26 (LOAEL)	0.22*	Schroeder and Mitchner 1971
Cadmium	rat	0.303	10 (LOAEL)	3.06*	Sutou et al. 1980
Copper	mink	1.0	11.71 (NOAEL)	24.18	Aulerich et al. 1982
Lead	rat	0.35	80 (LOAEL)	25.41*	Azar et al. 1973
Zinc	rat	0.35	320 (LOAEL)	101.65*	Schlicker and Cox 1968

* estimated from LOAEL by dividing by 5 (Lewis et al. 1990) and then scaling to body weight

TABLE 7.2.3-7
DOSES TO AMERICAN DIPPER
HOLDEN MINE RI/FS
DAMES & MOORE JOB NO. 17693-005-019

	UCL-Insects (mg/kg/day)			Max-Water	UCL-Total Dose (mg/kg/day)		
Metal	Upstream	Adjacent to Site	Downstream	(mg/kg/day)	Upstream	Adjacent to Site	Downstream
Cadmium	0.03	0.21	0.26	0.0001	0.03	0.21	0.26
Copper	0.13	2.43	2.75	0.0003	0.13	2.43	2.75
Lead	0.01	0.0002	0.0002	0.0001	0.01	0.0003	0.0003
Zinc	1.70	8.10	7.49	0.0110	1.71	8.11	7.50

TABLE 7.2.3-8
DOSES TO OSPREY CONSUMING TROUT
HOLDEN MINE RI/FS
DAMES & MOORE JOB NO. 17693-005-019

Metal	UCL-Trout (mg/kg/day)				UCL-Water (mg/kg/day)	UCL-Total Dose (mg/kg/day)			
	Upstream	Adjacent to Site	Lucerne	25-Mile Creek		Upstream	Adjacent to Site	Lucerne	25-Mile Creek
Copper	0.29	1.1	0.40	0.29	1.1	0.40	0.25	47	0.0062
Lead	NA	NA	NA	NA	NA	NA	NA	3.9	NA
Mercury	0.0097	0.0047	0.0040	0.0097	0.0047	0.0040	0.0039	0.45	0.022
Selenium	0.24	0.02	0.015	0.24	0.02	0.015	0.17	0.5	0.47
Zinc	2.5	2.1	2.8	2.5	2.1	2.8	1.98	26.2	0.094

TABLE 7.2.3-9
DOSES TO MINK CONSUMING TROUT
HOLDEN MINE RI/FS
DAMES & MOORE JOB NO. 17693-005-019

	UCL-Trout (mg/kg/day)				Max-Water (mg/kg/day)	UCL-Total Dose (mg/kg/day)			
Metal	Upstream	Adjacent to Sight	Lucerne	25-Mile Creek		Upstream	Adjacent to Sight	Lucerne	25-Mile Creek
Copper	0.0800	0.310	0.110	0.0680	0.000250	0.0800	0.310	0.110	0.068
Mercury	0.00270	0.00130	0.00110	0.0011	6.34E-08	0.0027	0.00130	0.00110	0.00110
Selenium	0.0650	0.0550	0.0420	0.0460	ND	0.065	0.0550	0.0420	0.0460
Zinc	0.670	0.570	0.770	0.550	0.00850	0.680	0.570	0.780	0.550

TABLE 7.2.3-10
SOIL : BIOTA UPTAKE ALGORITHMS

Biota	Algorithm	Reference
Plants		Efroymson et al. 1997
Cd	-0.476 + 0.546 x ln[soil]	
Cu	0.699 + 0.394 x ln[soil]	
Pb	-1.328 + 0.561 x ln[soil]	
Zn	1.575 + 0.555 x ln[soil]	
Earthworms		Sample et al. 1998
Cd	2.114 + 0.795 x ln[soil]	
Cu	1.675 + 0.264 x ln[soil]	
Pb	-0.218 + 0.807 x ln[soil]	
Zn	4.449 + 0.328 x ln[soil]	
Insectivores		Sample et al. 1998
Cd	0.815 + 0.9638 x ln[soil]	
Cu	2.1042 + 0.1783 x ln[soil]	
Pb	0.4819 + 0.4869 x ln[soil]	
Zn	4.2479 + 0.1324 x ln[soil]	
Omnivores		Sample et al. 1998
Cd	-1.5383 + 0.566 x ln[soil]	
Cu	1.4592 + 0.2681 x ln[soil]	
Pb	0.5669 + 0.2194 x ln[soil]	
Zn	4.4987 + 0.0745 x ln[soil]	
Herbivores		Sample et al. 1998
Cd	-1.2571 + 0.4723 x ln[soil]	
Cu	2.0423 + 0.06765 x ln[soil]	
Pb	-0.6114 + 0.5181 x ln[soil]	
Zn	4.3632 + 0.0706 x ln[soil]	

TABLE 7.2.3-11
BIOAVAILABILITY OF METALS

Media	Bioavailability(percent)	Reference
Flesh		
Cd	100	Default
Cu	100	Default
Pb	10	Custer et al. 1983
Zn	20	NAS 1989
Soil		
Cd	50.6	Hamel et al. 1998
Cu	7.5	Owen 1964
Pb	6	Davis et al. 1992
Zn	100	Default
Plants		
Cd	100	Default
Cu	100	Default
Pb	100	Default
Zn	100	Default

TABLE 7.2.3-12
DOSES TO MULE DEER
HOLDEN MINE RI/FS
DAMES & MOORE JOB NO. 17693-005-019

Metal	UCL-Plants (mg/kg/day)								UCL-Soil (mg/kg)								UCL-Water (mg/kg/day)	UCL-Total Dose (mg/kg/day)							
	Surface	Subsurface	TP-1	TP-2	TP-3	Dust	Lagoon*	M Yard*	Surface	Subsurface	TP-1	TP-2	TP-3	Dust	Lagoon*	M Yard*		Surface	Subsurface	TP-1	TP-2	TP-3	Dust	Lagoon*	M Yard*
Cadmium	0.0139	0.0128	0.0123	0.0121	0.0120	0.0120	0.192	0.0722	0.000446	0.0426	0.00131	0.00315	0.000290	0.000168	0.0533	0.00625	0.0000473	0.0144	0.0554	0.0137	0.0153	0.0123	0.0122	0.245	0.0785
Copper	0.536	2.563	0.616	0.519	0.510	0.542	2.98	1.34	0.0134	0.708	0.0190	0.0123	0.0118	0.0137	1.03	0.136	0.000166	0.550	3.27	0.635	0.532	0.522	0.555	4.01	1.47
Lead	0.198	0.278	0.347	0.256	0.240	0.199	1.46	2.33	0.00211	0.00312	0.00405	0.00285	0.00264	0.00213	0.0213	0.0367	0.0000592	0.200	0.281	0.352	0.259	0.243	0.201	1.48	2.37
Mercury	0.00777	0.00824	0.00930	0.00892	0.00901												0.0000000421								
Zinc	4.39	2.26	1.56	1.27	1.14	1.07	37.0	12.3	0.0310	0.346	0.0300	0.0321	0.0937	0.0641	2.98	0.408	0.00565	4.43	2.61	1.60	1.31	1.24	1.14	40.0	12.7

* = Maximum Dose

TABLE 7.2.3-13
DOSES TO DEER MICE
HOLDEN MINE RI/FS
DAMES & MOORE JOB NO. 17693-005-019

	UCL-Plants (mg/kg/day)								UCL-Soil (mg/kg/day)								UCL-Water	UCL-Total Dose (mg/kg/day)							
Metal	Surface	Subsurface	TP-1	TP-2	TP-3	Dust	Lagoon*	M Yard*	Surface	Subsurface	TP-1	TP-2	TP-3	Dust	Lagoon*	M Yard*	(mg/kg/day)	Surface	Subsurface	TP-1	TP-2	TP-3	Dust	Lagoon*	M Yard*
Cadmium	0.080	0.074	0.071	0.070	0.069	0.069	1.083	0.408	0.00256	0.245	0.00751	0.0181	0.00167	0.000966	0.300	0.0353	0.000105	0.0826	0.319	0.0785	0.0879	0.0710	0.0700	1.38	0.443
Copper	3.09	14.8	3.55	2.99	2.94	3.12	16.8	7.55	0.0770	4.08	0.109	0.071	0.068	0.079	5.84	0.766	0.000367	3.17	18.9	3.66	3.065	3.01	3.20	22.6	8.31
Lead	1.14	1.60	2.00	1.48	1.38	1.15	8.23	13.2	0.0122	0.018	0.023	0.016	0.015	0.012	0.120	0.207	0.000131	1.15	1.62	2.03	1.49	1.40	1.16	8.35	13.4
Mercury	0.045	0.047	0.054	0.051	0.052	NA	NA	NA	0.000264	0.000429	0.00115	0.000825	0.000890	NA	NA	NA	0.0000000932	0.0450	0.048	0.0547	0.0523	0.0528	NA	NA	NA
Zinc	25.3	13.0	9.00	7.33	6.55	6.15	209	69.3	0.811	9.07	0.787	0.841	2.46	1.68	76.6	10.5	0.0125	26.1	22.1	9.80	8.19	9.01	7.84	286	79.8

* = Maximum Dose

TABLE 7.2.3-14
DOSES TO MINK CONSUMING SMALL MAMMALS
HOLDEN MINE RI/FS
DAMES & MOORE JOB NO. 17693-005-019

	UCL-Insectivores (mg/kg/day)								UCL-Soil (mg/kg/day)								UCL-Water (mg/kg/day)	UCL-Total Dose (mg/kg/day)							
Metal	Surface	Subsurface	TP-1	TP-2	TP-3	Dust	Lagoon*	M Yard*	Surface	Subsurface	TP-1	TP-2	TP-3	Dust	Lagoon*	M Yard*		Surface	Subsurface	TP-1	TP-2	TP-3	Dust	Lagoon*	M Yard*
Cadmium	0.240	19.0	0.660	1.55	0.155	0.092	23.6	3.00	0.00107	0.1022	0.0031	0.0076	0.0007	0.0004	0.128	0.0150	0.0000713	0.236	19.1467	0.666	1.56	0.156	0.0923	23.8	3.01
Copper	0.160	0.320	0.170	0.155	0.153	0.157	3.40	2.37	0.0321	1.70	0.0455	0.0296	0.0282	0.0329	2.48	0.326	0.000249	0.189	2.02	0.213	0.184	0.182	0.191	5.89	2.70
Lead	0.830	1.00	1.10	0.956	0.922	0.830	0.255	0.332	0.00506	0.00750	0.00973	0.00684	0.00635	0.00511	0.0511	0.0882	0.0000891	0.831	1.01	1.14	0.963	0.929	0.835	0.306	0.420
Zinc	2.10	2.80	2.00	2.07	2.38	2.26	3.76	2.89	0.338	3.78	0.328	0.350	1.02	0.699	32.6	4.45	0.00851	2.40	6.62	2.38	2.42	3.41	2.97	36.3	7.35

	UCL-Omnivores (mg/kg/day)								UCL-Soil (mg/kg/day)								UCL-Water (mg/kg/day)	UCL-Total Dose (mg/kg/day)							
Metal	Surface	Subsurface	TP-1	TP-2	TP-3	Dust	Lagoon*	M Yard*	Surface	Subsurface	TP-1	TP-2	TP-3	Dust	Lagoon*	M Yard*		Surface	Subsurface	TP-1	TP-2	TP-3	Dust	Lagoon*	M Yard*
Cadmium	0.019	0.249	0.0346	0.0569	0.0148	0.0108	0.2823	0.0840	0.00107	0.102	0.00314	0.00756	0.000695	0.000403	0.128	0.0150	0.0000713	0.0200	0.351	0.0378	0.0646	0.0155	0.0113	0.410	0.0991
Copper	1.38	3.99	1.51	1.35	1.33	1.39	4.42	2.56	0.0321	1.70	0.0455	0.0296	0.0282	0.0329	2.48	0.326	0.000249	1.41	5.69	1.56	1.38	1.36	1.42	6.90	2.89
Lead	0.030	0.033	0.0345	0.0319	0.0314	0.0300	0.0496	0.0560	0.00506	0.00750	0.00973	0.00684	0.00635	0.00511	0.0511	0.0882	0.0000891	0.0350	0.0402	0.0443	0.0389	0.0378	0.0352	0.101	0.144
Zinc	1.86	2.23	1.86	1.87	2.02	1.97	2.59	2.23	0.338	3.779	0.328	0.350	1.02	0.699	32.5638	4.4518	0.00851	2.21	6.02	2.19	2.23	3.05	2.67	35.2	6.69

	UCL-Herbivores (mg/kg/day)								UCL-Soil (mg/kg/day)								UCL-Water (mg/kg/day)	UCL-Total Dose (mg/kg/day)							
Metal	Surface	Subsurface	TP-1	TP-2	TP-3	Dust	Lagoon*	M Yard*	Surface	Subsurface	TP-1	TP-2	TP-3	Dust	Lagoon*	M Yard*		Surface	Subsurface	TP-1	TP-2	TP-3	Dust	Lagoon*	M Yard*
Cadmium	0.0240	0.206	0.0398	0.0603	0.0195	0.0151	0.229	0.0834	0.00107	0.1022	0.00314	0.00756	0.000695	0.000403	0.128	0.0150	0.0000713	0.0251	0.309	0.0430	0.0679	0.0203	0.0156	0.357	0.0985
Copper	0.780	1.02	0.799	0.776	0.774	0.781	1.05	0.912	0.0321	1.70	0.0455	0.0296	0.0282	0.0329	2.48	0.326	0.000249	0.813	2.72	0.845	0.806	0.802	0.815	3.53	1.24
Lead	0.0315	0.0386	0.0441	0.0368	0.0354	0.0316	0.104	0.138	0.00506	0.00750	0.00973	0.00684	0.00635	0.00511	0.0511	0.0882	0.0000891	0.0366	0.0462	0.0540	0.0437	0.0418	0.0368	0.155	0.227
Zinc	1.59	1.89	1.59	1.60	1.72	1.67	2.20	1.91	0.338	3.78	0.328	0.350	1.02	0.699	32.6	4.45	0.00851	1.94	5.67	1.92	1.95	2.75	2.38	34.8	6.37

	Median Insectivores (mg/kg/day)			
	Food	Soil	Water	Total Dose
Cadmium	0.0330	0.000140	7.13E-05	0.0330

* = Maximum Dose

TABLE 7.2.3-15
DOSES TO DUSKY SHREW
HOLDEN MINE RI/FS
DAMES & MOORE JOB NO. 17693-005-019

Metal	UCL-Worms (mg/kg/day)								UCL Soil (mg/kg/day)								UCL-Water	Total Dose (mg/kg/day)							
	Surface	Subsurface	TP-1	TP-2	TP-3	Dust	Lagoon*	M Yard*	Surface	Subsurface	TP-1	TP-2	TP-3	Dust	Lagoon*	M Yard*	(mg/kg/day)	Surface	Subsurface	TP-1	TP-2	TP-3	Dust	Lagoon*	M Yard*
Cadmium	6.54	245	15.4	30.9	4.64	3.01	293	53.4	0.00873	0.83	0.0256	0.0616	0.0057	0.00329	1.04	0.122	0.0004032	6.55	246	15.4	31.0	4.64	3.01	294	53.5
Copper	13.6	38.8	14.9	13.3	13.2	13.7	42.9	25.1	0.261	13.86	0.371	0.241	0.230	0.268	20.2	2.65	0.00141	13.9	52.7	15.3	13.6	13.4	14.0	63.1	27.7
Lead	1.25	1.72	2.12	1.59	1.50	1.26	8.07	12.5	0.0413	0.0612	0.0793	0.0558	0.0517	0.0417	0.417	0.719	0.000504	1.29	1.78	2.20	1.65	1.55	1.30	8.49	13.3
Mercury	0.219	0.232	0.261	0.251	0.253	N/A	N/A	N/A	0.00000188	0.00000306	0.00000823	0.00000588	0.00000635	N/A	N/A	N/A	0.000000358	0.219	0.232	0.261	0.251	0.253	N/A	N/A	N/A
Zinc	58.3	129	57.7	59.0	83.8	74.0	261	136	2.76	30.80	2.67	2.86	8.34	5.70	265	36.3	0.0482	61.1	160	60.4	61.9	92.2	79.7	526	172

* = Maximum Dose

Metal	Median-Worms (mg/kg/day)						Median-Soil (mg/kg/day)						Median-Water	Median-Total Dose (mg/kg/day)					
	Surface	Subsurface	TP-1	TP-2	TP-3	Dust	Surface	Subsurface	TP-1	TP-2	TP-3	Dust	(mg/kg/day)	Surface	Subsurface	TP-1	TP-2	TP-3	Dust
Cadmium	5.36	1.29	2.24	2.46	4.64	2.67	0.00680	0.00113	0.00227	0.00255	0.00567	0.00283	0.000403	5.37	1.29	2.24	2.46	4.64	2.68
Zinc	51.5	53.3	49.2	55.1	56.7	58.3	1.89	2.09	1.65	2.32	2.53	2.76	0.0482	53.5	55.4	50.9	57.5	59.3	61.1

TABLE 7.2.3-16
DOSES TO RED-TAILED HAWK
HOLDEN MINE RI/FS
DAMES & MOORE JOB NO. 17693-005-019

	UCL-Insectivore (mg/kg/day)								UCL-Water	UCL-Total Dose (mg/kg/day)							
Metals	Surface	Subsurface	TP-1	TP-2	TP-3	Dust	Lagoon*	M Yard*	(mg/kg/day)	Surface	Subsurface	TP-1	TP-2	TP-3	Dust	Lagoon*	M Yard*
Cadmium	0.187	15.14	0.527	1.23	0.123	0.0730	18.80	2.38	0.0000368	0.187	15.1	0.527	1.23	0.123	0.073	18.8	2.38
Copper	1.25	2.53	1.33	1.23	1.22	1.25	2.71	1.88	0.000129	1.25	2.53	1.33	1.23	1.22	1.25	2.71	1.88
Lead	0.0656	0.0795	0.0902	0.0760	0.0733	0.0660	0.202	0.264	0.0000459	0.0657	0.0796	0.0903	0.0761	0.0733	0.0660	0.202	0.264
Zinc	1.63	2.25	1.63	1.64	1.89	1.80	2.99	2.30	0.00439	1.64	2.25	1.63	1.65	1.90	1.80	3.00	2.30

* = Maximum Dose

	UCL-Omnivore (mg/kg/day)								UCL-Water	UCL-Total Dose (mg/kg/day)							
Metals	Surface	Subsurface	TP-1	TP-2	TP-3	Dust	Lagoon*	M Yard*	(mg/kg/day)	Surface	Subsurface	TP-1	TP-2	TP-3	Dust	Lagoon*	M Yard*
Cadmium	0.0150	0.198	0.0275	0.0453	0.0117	0.0086	0.224	0.0668	0.0000368	0.0150	0.198	0.0275	0.0453	0.0118	0.009	0.224	0.0668
Copper	1.10	3.17	1.20	1.07	1.06	1.10	3.51	2.04	0.000129	1.10	3.17	1.20	1.07	1.06	1.10	3.51	2.04
Lead	0.238	0.259	0.274	0.254	0.250	0.238	0.0395	0.0445	0.0000459	0.238	0.259	0.274	0.254	0.250	0.238	0.0395	0.0445
Zinc	7.31	8.75	7.30	7.33	7.94	7.72	2.06	1.77	0.00439	7.32	8.76	7.30	7.34	7.95	7.72	2.06	1.78

* = Maximum Dose

	UCL-Herbivore (mg/kg/day)								UCL-Water	UCL-Total Dose (mg/kg/day)							
Metals	Surface	Subsurface	TP-1	TP-2	TP-3	Dust	Lagoon*	M Yard*	(mg/kg/day)	Surface	Subsurface	TP-1	TP-2	TP-3	Dust	Lagoon*	M Yard*
Cadmium	0.0191	0.164	0.0316	0.0479	0.0155	0.0120	0.182	0.0663	0.0000368	0.0191	0.164	0.0317	0.0480	0.0156	0.0120	0.182	0.0663
Copper	0.620	0.811	0.635	0.617	0.615	0.621	0.832	0.725	0.000129	0.620	0.811	0.635	0.617	0.615	0.621	0.832	0.725
Lead	0.250	0.307	0.351	0.292	0.281	0.251	0.0829	0.110	0.0000459	0.250	0.307	0.351	0.292	0.281	0.251	0.0829	0.110
Zinc	6.32	7.50	6.31	6.34	6.84	6.66	1.75	1.52	0.00439	6.33	7.50	6.31	6.34	6.84	6.66	1.75	1.52

* = Maximum Dose

	Median Insectivore (mg/kg/day)		
	Food	Water	Total Dose
Metal	Subsurface	Subsurface	Subsurface
Cadmium	0.0262	0.0000368	0.0260

TABLE 7.2.3-17
DOSES TO AMERICAN ROBIN
HOLDEN MINE RI/FS
DAMES & MOORE JOB NO. 17693-005-019

Metal	UCL-Worms (mg/kg/day)								UCL-Soil (mg/kg/day)								UCL-Water (mg/kg/day)	UCL-Total Dose (mg/kg/day)							
	Surface	Subsurface	TP-1	TP-2	TP-3	Dust	Lagoon*	M. Yard*	Surface	Subsurface	TP-1	TP-2	TP-3	Dust	Lagoon*	M. Yard*	Railroad Creek	Surface	Subsurface	TP-1	TP-2	TP-3	Dust	Lagoon*	M. Yard*
Cadmium	1.66	62.1	3.89	7.83	1.18	0.76	74.2	13.5	0.00884	0.844	0.0259	0.0624	0.0057	0.0033	1.06	0.124	0.0000920	1.67	62.9	3.92	7.89	1.18	0.765	75.3	13.6
Copper	3.45	9.84	3.78	3.38	3.33	3.47	10.9	6.36	0.265	14.06	0.377	0.245	0.234	0.272	20.54	2.69	0.000322	3.71	23.9	4.16	3.62	3.57	3.74	31.4	9.05
Lead	3.16	4.35	5.36	4.04	3.80	3.19	20.5	31.8	0.0419	0.0621	0.0805	0.0566	0.0525	0.0423	0.423	0.730	0.000115	3.21	4.41	5.44	4.09	3.85	3.23	20.9	32.5
Zinc	14.8	32.6	14.6	14.9	21.2	18.7	34.4	66.1	2.80	31.25	2.71	2.90	8.46	5.78	269.34	36.82	0.0110	17.58	63.9	17.3	17.9	29.7	24.5	600	209

* = Maximum Dose

Metal	Median-Worms (mg/kg/day)						Median-Soil (mg/kg/day)						Median-Water	Median-Total Dose (mg/kg/day)					
	Surface	Subsurface	TP-1	TP-2	TP-3	Dust	Surface	Subsurface	TP-1	TP-2	TP-3	Dust	(mg/kg/day)	Surface	Subsurface	TP-1	TP-2	TP-3	Dust
Cadmium	1.36	0.327	0.567	0.623	1.18	0.677	0.00689	0.00115	0.00230	0.00258	0.00574	0.00287	0.0000920	0.0647	0.0963	0.0430	0.0331	0.0304	0.0627
Lead	1.33	1.38	3.52	2.51	3.70	2.77	0.0143	0.0150	0.0477	0.0314	0.0508	0.0355	0.000115022	1.35	1.40	3.57	2.54	3.75	2.80
Zinc	13.1	13.5	12.5	14.0	14.4	14.8	1.92	2.13	1.67	2.35	2.57	2.80	0.0110	15.0	15.6	14.2	16.3	16.9	17.6

	Cd Concentration (mg/kg)		Doses Using Background Soil (mg/kg/day)				TRV	HQ
	Soil	Worms	Food	Soil	Water	Total Dose	(mg/kg)	
Cadmium-Yakima	0.930	7.82	1.11	0.005337	0.0000920	1.11	4	0.279
Cadmium-Site	5.41	31.7	4.50	0.031048	0.0000920	4.53	4	1.13

TABLE 7.2.3-18
DOSES TO BAT
HOLDEN MINE RI/FS
DAMES & MOORE JOB NO. 17693-005-019

Metals	UCL-Insects (mg/kg/day)			UCL-Water	UCL-Total Dose (mg/kg/day)		
	Upstream	Adjacent to Site	Downstream	(mg/kg/day)	Upstream	Adjacent to Site	Downstream
Cadmium	0.0276	0.211	0.260	0.0000953	0.0277	0.211	0.260
Copper	0.130	2.47	2.79	0.000333	0.130	2.47	2.79
Lead	0.00600	0.000162	0.000162	0.000119	0.00612	0.000281	0.000281
Zinc	1.72	8.21	7.59	0.0114	1.73	8.22	7.60

TABLE 7.2.4-1a
HAZARD QUOTIENTS FOR SALMONIDS IN SOUTHBANK RAILROAD CREEK
HOLDEN MINE RI/FS
DAMES & MOORE JOB NO. 17693-005-019

	UCL Concentration (μg/L)			TRV	HQ		
Metal	Upstream	Adjacent to Site	Downstream	(μg/L)	Upstream	Adjacent to Site	Downstream
Cadmium	0.090	1.14	ND	5.00	0.0180	0.228	NA
Copper	25.2	59.8	1.60	2.30	11.0	26.0	0.696
Lead	0.2	0.600	ND	11.0	0.018	0.055	NA
Zinc	17.5	191	14.0	187	0.094	1.02	0.075

TABLE 7.2.4-1b
HAZARD QUOTIENTS FOR SALMONIDS IN MAINSTREAM RAILROAD CREEK
HOLDEN MINE RI/FS
DAMES & MOORE JOB NO. 17693-005-019

	UCL Concentration (μg/L)			TRV	HQ		
Metal	Upstream	Adjacent to Site	Downstream	(μg/L)	Upstream	Adjacent to Site	Downstream
Cadmium	0.07	0.68	0.36	5.00	0.01	0.14	0.07
Copper	1.06	41.9	15.82	2.30	0.46	18.22	6.88
Lead	0.54	0.6	0.5	11.0	0.05	0.05	0.05
Zinc	7.81	83.75	52.86	187	0.04	0.45	0.28

TABLE 7.2.4-1c
HAZARD QUOTIENTS FOR SALMONIDS IN MEDIAN MAINSTREAM RAILROAD CREEK
HOLDEN MINE RI/FS
DAMES & MOORE JOB NO. 17693-005-019

	Median Concentration (μg/L)		TRV	HQ	
Metal	Adjacent to Site	Downstream	(μg/L)	Adjacent to Site	Downstream
Copper	10.15	3	2.3	4.41	1.30

TABLE 7.2.4-2a
HAZARD QUOTIENTS FOR INSECT NYMPHS IN SOUTHBANK RAILROAD CREEK
HOLDEN MINE RI/FS
DAMES & MOORE JOB NO. 17693-005-019

Metal	UCL Concentration (µg/L)			TRV (µg/L)	HQ		
	Upstream	Adjacent to Site	Downstream		Upstream	Adjacent to Site	Downstream
Cadmium	0.09	1.14	ND	3	0.030	0.38	NA
Copper	25.2	59.8	1.6	1500	0.017	0.04	0.00
Lead	0.2	0.6	ND	3300	0.0001	0.0002	NA
Zinc	17.5	191	14	11310	0.002	0.02	0.001

TABLE 7.2.4-2b
HAZARD QUOTIENTS FOR INSECT NYMPHS IN MAINSTREAM RAILROAD CREEK
HOLDEN MINE RI/FS
DAMES & MOORE JOB NO. 17693-005-019

Metal	UCL Concentration (µg/L)			TRV (µg/L)	HQ		
	Upstream	Adjacent to Site	Downstream		Upstream	Adjacent to Site	Downstream
Cadmium	0.07	0.68	0.36	3	0.023	0.23	0.12
Copper	1.06	41.9	15.82	1500	0.001	0.03	0.01
Lead	0.54	0.6	0.5	3300	0.0002	0.0002	0.0002
Zinc	7.81	83.75	52.86	11310	0.001	0.01	0.005

TABLE 7.2.4-2C
HAZARD QUOTIENTS FOR BENTHIC INVERTEBRATES EXPOSED TO THE HIGHEST METALS CONCENTRATIONS IN SEDIMENTS OF RAILROAD CREEK

Maximum (mg/kg)	ER-M (mg/kg)	Hazard Quotient	ER-L (mg/kg)	Hazard Quotient	FSQV (mg/kg)	Location	Metal	Hazard Quotient
12	70	0.17	8.2	1.46	19	Reference	Arsenic	0.63
2.0	9.6	0.21	1.2	1.67	9.3		Cadmium	0.22
74	270	0.27	34	2.18	340		Copper	0.22
99,000	40,000	2.48	20,000	4.95	NA		Iron	NA
17	218	0.08	46.7	0.36	490		Lead	0.04
1,600	1,100	1.45	460	3.48	1,400		Manganese	1.14
31	51.6	0.60	20.9	1.43	NA		Nickel	NA
0.067	3.7	0.02	1	0.067	3.9		Silver	0.02
180	410	0.44	150	1.20	1,000		Zinc	0.18
13	70	0.19	33	0.39	19	Site	Arsenic	0.68
2.0	9.6	0.21	1.2	1.67	9.3		Cadmium	0.22
240	270	0.89	34	7.06	340		Copper	0.71
150,000	40,000	3.75	20,000	7.50	NA		Iron	NA
66	218	0.30	46.7	1.41	490		Lead	0.13
1,400	1,100	1.27	460	3.04	1,400		Manganese	1.0
30	51.6	0.58	20.9	1.44	NA		Nickel	NA
5.6	3.7	1.51	1	5.6	3.9		Silver	1.44
280	410	0.68	150	1.87	1,000		Zinc	0.28
3.5	70	0.05	33	0.10	19	Downstream	Arsenic	0.18
0.9	9.6	0.09	1.2	0.75	9.3		Cadmium	0.10
150	270	0.56	34	4.41	340		Copper	0.44
71,000	40,000	1.78	20,000	3.55	NA		Iron	NA
25	218	0.11	46.7	0.53	490		Lead	0.05
1,200	1,100	1.09	460	2.61	1,400		Manganese	0.86
32	51.6	0.62	20.9	1.53	NA		Nickel	NA
0.45	3.7	0.12	1	0.45	3.9		Silver	0.12
330	410	0.81	150	2.20	1,000		Zinc	0.33

TABLE 7.2.4-2D
HAZARD QUOTIENTS FOR BENTHIC INVERTEBRATES EXPOSED TO METALS IN FLOCCULENT IN RAILROAD CREEK

Location	Metal	Flocculent (mg/kg)	ER-M	Hazard Quotient	ER-L	Hazard Quotient	FSQV (mg/kg)	Hazard Quotient
RC-2	Arsenic	20.1	70	0.29	8.2	**2.45**	19	**1.06**
	Cadmium	1.3J	9.6	0.14	1.2	**1.08**	9.3	0.14
	Copper	164	270	0.61	34	**4.82**	340	0.48
	Iron	84,400J	40,000	**2.1**	20,000	**4.22**	NA	NA
	Lead	4U	218	0	46.7	0	490	0
	Manganese	53.4J	1,100	0.05	460	0.12	1,400	0.04
	Nickel	2	51.6	0.04	20.9	0.96	NA	NA
	Silver	1.2	0.32	0.32	1.0	**1.2**	3.9	0.31
	Zinc	145J	410	0.35	150	0.97	1,000	0.15
RC-5	Arsenic	47	70	0.67	8.2	**5.73**	19	**2.47**
	Cadmium	4J	9.6	0.42	1.2	**3.33**	9.3	0.43
	Copper	492	270	1.82	34	**14.47**	340	**1.45**
	Iron	125,000	40,000	**3.13**	20,000	**6.25**	NA	NA
	Lead	10U	218	0	46.7	0	490	0
	Manganese	182J	1,100	0.17	460	0.40	1,400	0.13
	Nickel	5U	51.6	0	20.9	0	NA	0
	Silver	2	3.7	0.54	1.0	**2.0**	3.9	0.51
	Zinc	320J	410	0.78	150	**2.13**	1,000	0.32
RC-9	Arsenic	126	70	1.80	8.2	**15.37**	19	**6.63**
	Cadmium	5J	9.6	0.52	1.2	**4.17**	9.3	0.54
	Copper	982	270	**3.64**	34	**28.88**	340	**2.89**
	Iron	434,000	40,000	**10.85**	20,000	**21.70**	NA	NA
	Lead	40U	218	0	46.7	0	490	0
	Manganese	331J	1,100	0.30	460	0.72	1,400	0.24
	Nickel	20U	51.6	0	20.9	0	NA	0
	Silver	11	3.7	**2.97**	1.0	**11.0**	3.9	**2.82**
	Zinc	481J	410	**1.17**	150	**3.21**	1,000	0.48

TABLE 7.2.4-3
HAZARD QUOTIENTS FOR AMERICAN DIPPER
HOLDEN MINE RI/FS
DAMES & MOORE JOB NO. 17693-005-019

Metal	UCL Total Dose (mg/kg/day)			TRV	HQ		
	Upstream	Adjacent to Site	Downstream	(mg/kg/day)	Upstream	Adjacent to Site	Downstream
Cadmium	0.03	0.21	0.26	4	0.0068	0.052	0.064
Copper	0.13	2.43	2.75	47	0.0027	0.052	0.059
Lead	0.01	0.0003	0.0003	11.3	0.00053	2.4E-05	2.4E-05
Zinc	1.7	8.11	7.50	26.2	0.065	0.31	0.29

TABLE 7.2.4-4
HAZARD QUOTIENTS FOR OSPREY
HOLDEN MINE RI/FS
DAMES & MOORE JOB NO. 17693-005-019

Metal	UCL Total Dose (mg/kg/day)				TRV	HQ			
	Upstream	Adjacent to Site	Lucerne	25-Mile	(mg/kg/day)	Upstream	Adjacent to Site	Lucerne	25-Mile
Copper	0.400	0.247	0.006	0.024	47	0.009	0.005	0.001	0.001
Mercury	0.004	0.004	0.022	0.010	0.45	0.009	0.009	0.002	0.002
Selenium	0.015	0.167	0.473	0.040	0.5	0.031	0.335	0.062	0.067
Zinc	2.817	1.989	0.094	0.079	26.2	0.108	0.076	0.022	0.015

TABLE 7.2.4-5
HAZARD QUOTIENTS FOR MINK CONSUMING TROUT
HOLDEN MINE RI/FS
DAMES & MOORE JOB NO. 17693-005-019

Metal	UCL Total Dose (mg/kg/day)				TRV	HQ			
	Upstream	Adjacent to Site	Lucerne	25-Mile	(mg/kg/day)	Upstream	Adjacent to Site	Lucerne	25-Mile
Cadmium	0.080	0.307	0.110	0.068	11.7	0.007	0.026	0.009	0.006
Copper	0.003	0.001	0.001	0.001	0.15	0.018	0.009	0.007	0.007
Lead	0.065	0.055	0.042	0.046	0.153	0.425	0.357	0.277	0.301
Zinc	0.683	0.574	0.782	0.555	123.1	0.006	0.005	0.006	0.005

TABLE 7.2.4-6a
HAZARD QUOTIENTS FOR PLANTS USING SCREENING VALUES
HOLDEN MINE RI/FS
DAMES & MOORE JOB NO. 17693-005-019

	UCL Concentration (mg/kg)								TRV	HQ							
Metal	Surface	Subsurface	TP-1	TP-2	TP-3	Dust	Lagoon*	M. Yard*	(mg/kg)	Surface	Subsurface	TP-1	TP-2	TP-3	Dust	Lagoon*	M. Yard*
Cadmium	1.54	147	4.51	10.87	1	0.58	184	21.6	5.41	0.28	27.17	0.83	2.01	0.18	0.11	34.01	3.99
Copper	311.3	16500	442	287	274	319	24100	3160	100	3.11	165.00	4.42	2.87	2.74	3.19	241.00	31.60
Lead	61.4	91	118	83	77	62	620	1070	50	1.23	1.82	2.36	1.66	1.54	1.24	12.40	21.40
Zinc	246	2750	238.5	255	744.6	509	23700	3240	253.4	0.97	10.85	0.94	1.01	2.94	2.01	93.53	12.79

* = Maximum Concentration

TABLE 7.2.4-6b
HAZARD QUOTIENTS FOR PLANTS USING MEDIAN CONCENTRATIONS
HOLDEN MINE RI/FS
DAMES & MOORE JOB NO. 17693-005-019

	Median Concentration (mg/kg)						TRV	HQ					
Metal	Surface	Subsurface	TP-1	TP-2	TP-3	Dust	(mg/kg)	Surface	Subsurface	TP-1	TP-2	TP-3	Dust
Cadmium	1.2	0.4	0.2	0.45	0.76	0.5	5.41	0.22	0.07	0.04	0.08	0.14	0.09
Copper	150	244	330	238	150	151	100	1.50	2.44	3.30	2.38	1.50	1.51
Lead	21	70	100	46	74.5	52	50	0.42	1.40	2.00	0.92	1.49	1.04
Zinc	169	147	187	207	226	246	253.4	0.67	0.58	0.74	0.82	0.89	0.97

TABLE 7.2.4-6c
HAZARD QUOTIENTS FOR PLANTS USING IN-SITU TOXICITY VALUES
HOLDEN MINE RI/FS
DAMES & MOORE JOB NO. 17693-005-019

	UCL Concentration (mg/kg)								TRV	HQ							
Metal	Surface	Subsurface	TP-1	TP-2	TP-3	Dust	Lagoon*	M. Yard*	(mg/kg)	Surface	Subsurface	TP-1	TP-2	TP-3	Dust	Lagoon*	M. Yard*
Cadmium	1.54	147	4.51	10.87	1	0.58	184	21.6	710	0.00	0.21	0.01	0.02	0.001	0.001	0.26	0.03
Copper	311.3	16500	442	287	274	319	24100	3160	440	0.71	37.50	1.00	0.65	0.62	0.73	54.77	7.18
Lead	61.4	91	118	83	77	62	620	1070	2700	0.02	0.03	0.04	0.03	0.03	0.02	0.23	0.40
Zinc	246	2750	238.5	255	744.6	509	23700	3240	24000	0.01	0.11	0.01	0.01	0.03	0.02	0.99	0.14

* = Maximum Concentration

TABLE 7.2.4-6d
HAZARD QUOTIENTS FOR PLANTS USING MEDIAN CONCENTRATIONS AND IN-SITU DATA
HOLDEN MINE RI/FS
DAMES & MOORE JOB NO. 17693-005-019

	Median Concentration (mg/kg)						TRV	HQ					
Metal	Surface	Subsurface	TP-1	TP-2	TP-3	Dust	(mg/kg)	Surface	Subsurface	TP-1	TP-2	TP-3	Dust
Cadmium	1.2	0.4	0.2	0.45	0.76	0.5	710	0.00	0.00	0.00	0.00	0.001	0.001
Copper	150	244	330	238	150	151	440	0.34	0.55	0.75	0.54	0.34	0.34
Lead	21	70	100	46	74.5	52	2700	0.01	0.03	0.04	0.02	0.03	0.02
Zinc	169	147	187	207	226	246	24000	0.01	0.01	0.01	0.01	0.01	0.01

TABLE 7.2.4-7a
HAZARD QUOTIENTS FOR EARTHWORMS
HOLDEN MINE RI/FS
DAMES & MOORE JOB NO. 17693-005-019

Metal	UCL Concentration (mg/kg)								TRV (mg/kg)	HQ							
	Surface	Subsurface	TP-1	TP-2	TP-3	Dust	Lagoon*	M. Yard*		Surface	Subsurface	TP-1	TP-2	TP-3	Dust	Lagoon*	M. Yard*
Cadmium	1.54	147	4.51	10.87	1	0.58	184	21.6	20	0.08	7.35	0.23	0.54	0.05	0.03	9.20	1.08
Copper	311.3	16500	442	287	274	319	24100	3160	57.45	5.42	287.21	7.69	5.00	4.77	5.55	419.50	55.00
Lead	61.4	91	118	83	77	62	620	1070	500	0.12	0.18	0.24	0.17	0.15	0.12	1.24	2.14
Zinc	246	2750	238.5	255	744.6	509	23700	3240	253.4	0.97	10.85	0.94	1.01	2.94	2.01	93.53	12.79

* = Maximum Concentration

TABLE 7.2.4-7b
HAZARD QUOTIENTS FOR MEDIAN CONCENTRATION EARTHWORMS
HOLDEN MINE RI/FS
DAMES & MOORE JOB NO. 17693-005-019

Metal	Median Concentration (mg/kg)						TRV (mg/kg)	HQ					
	Surface	Subsurface	TP-1	TP-2	TP-3	Dust		Surface	Subsurface	TP-1	TP-2	TP-3	Dust
Cadmium	1.2	0.4	0.2	0.45	0.76	0.5	20	0.06	0.02	0.01	0.02	0.04	0.03
Copper	150	244	330	238	150	151	57.45	2.61	4.25	5.74	4.14	2.61	2.63
Lead	21	70	100	46	74.5	52	500	0.04	0.14	0.20	0.09	0.15	0.10
Zinc	169	147	187	207	226	246	253.4	0.67	0.58	0.74	0.82	0.89	0.97

TABLE 7.2.4-8a
HAZARD QUOTIENTS FOR MULE DEER
HOLDEN MINE RI/FS
DAMES & MOORE JOB NO. 17693-005-019

	UCL Total Dose (mg/kg/day)								TRV	HQ							
Metal	Surface	Subsurface	TP-1	TP-2	TP-3	Dust	Lagoon*	M. Yard*	(mg/kg/day)	Surface	Subsurface	TP-1	TP-2	TP-3	Dust	Lagoon*	M. Yard*
Cadmium	0.014	0.055	0.014	0.015	0.012	0.012	0.245	0.078	5.84	0.002	0.003	0.002	0.002	0.042	0.013	0.042	0.013
Copper	0.550	3.272	0.635	0.532	0.522	0.555	4.011	1.472	8.58	0.074	0.062	0.061	0.065	0.467	0.172	0.467	0.172
Lead	0.200	0.281	0.352	0.259	0.243	0.201	1.478	2.372	7.44	0.047	0.035	0.033	0.027	0.199	0.319	0.199	0.319
Zinc	4.430	2.611	1.598	1.310	1.235	1.136	40.021	12.686	57.29	0.028	0.023	0.022	0.020	0.699	0.221	0.699	0.221

* = Maximum Dose

TABLE 7.2.4-9
HAZARD QUOTIENTS FOR DEER MICE
HOLDEN MINE RI/FS
DAMES & MOORE JOB NO. 17693-005-019

	UCL Total Dose (mg/kg/day)								TRV	HQ							
Metal	Surface	Subsurface	TP-1	TP-2	TP-3	Dust	Lagoon*	M. Yard*	(mg/kg/day)	Surface	Subsurface	TP-1	TP-2	TP-3	Dust	Lagoon*	M. Yard*
Cadmium	0.08	0.32	0.08	0.09	0.07	0.07	1.38	0.44	10.1	0.01	0.03	0.01	0.01	0.01	0.01	0.14	0.04
Copper	3.17	18.85	3.66	3.06	3.01	3.20	22.65	8.31	170.8	0.02	0.11	0.02	0.02	0.02	0.02	0.13	0.05
Lead	1.15	1.62	2.03	1.49	1.40	1.16	8.35	13.39	16.2	0.07	0.10	0.13	0.09	0.09	0.07	0.52	0.83
Zinc	26.14	22.10	9.80	8.19	9.01	7.84	285.74	79.79	323.3	0.08	0.07	0.03	0.03	0.03	0.02	0.88	0.25

* = Maximum Dose

TABLE 7.2.4-10a
HAZARD QUOTIENTS FOR MINK CONSUMING SMALL MAMMALS
HOLDEN MINE RI/FS
DAMES & MOORE JOB NO. 17693-005-019

	UCL Dose (Insectivores, mg/kg)								TRV	HQ							
Metal	Surface	Subsurface	TP-1	TP-2	TP-3	Dust	Lagoon*	M. Yard*	(mg/kg/day)	Surface	Subsurface	TP-1	TP-2	TP-3	Dust	Lagoon*	M. Yard*
Cadmium	0.236	19.147	0.666	1.555	0.156	0.092	23.773	3.015	3.71	0.064	5.161	0.180	0.419	0.042	0.025	6.408	0.813
Copper	0.189	2.019	0.213	0.184	0.182	0.191	5.889	2.696	11.7	0.016	0.173	0.018	0.016	0.016	0.016	0.503	0.230
Lead	0.831	1.008	1.145	0.963	0.929	0.835	0.306	0.420	11.43	0.073	0.088	0.100	0.084	0.081	0.073	0.027	0.037
Zinc	2.402	6.616	2.383	2.424	3.412	2.971	36.335	7.352	123.1	0.020	0.054	0.019	0.020	0.028	0.024	0.295	0.060

* = Maximum Dose

	UCL Dose (Omnivores, mg/kg)								TRV	HQ							
Metal	Surface	Subsurface	TP-1	TP-2	TP-3	Dust	Lagoon*	M. Yard*	(mg/kg/day)	Surface	Subsurface	TP-1	TP-2	TP-3	Dust	Lagoon*	M. Yard*
Cadmium	0.020	0.351	0.038	0.065	0.016	0.011	0.410	0.099	3.71	0.005	0.095	0.010	0.017	0.004	0.003	0.111	0.027
Copper	1.410	5.694	1.559	1.378	1.360	1.420	6.905	2.890	11.7	0.121	0.487	0.133	0.118	0.116	0.121	0.590	0.247
Lead	0.035	0.040	0.044	0.039	0.038	0.035	0.101	0.144	11.43	0.003	0.004	0.004	0.003	0.003	0.003	0.009	0.013
Zinc	2.208	6.015	2.193	2.225	3.053	2.673	35.158	6.690	123.1	0.018	0.049	0.018	0.018	0.025	0.022	0.286	0.054

* = Maximum Dose

	UCL Dose (Herbivores, mg/kg)								TRV	HQ							
Metal	Surface	Subsurface	TP-1	TP-2	TP-3	Dust	Lagoon*	M. Yard*	(mg/kg/day)	Surface	Subsurface	TP-1	TP-2	TP-3	Dust	Lagoon*	M. Yard*
Cadmium	0.025	0.309	0.043	0.068	0.020	0.016	0.357	0.099	3.71	0.007	0.083	0.012	0.018	0.005	0.004	0.096	0.027
Copper	0.813	2.721	0.845	0.806	0.802	0.815	3.530	1.238	11.7	0.069	0.233	0.072	0.069	0.069	0.070	0.302	0.106
Lead	0.037	0.046	0.054	0.044	0.042	0.037	0.155	0.227	11.43	0.003	0.004	0.005	0.004	0.004	0.003	0.014	0.020
Zinc	1.938	5.674	1.924	1.954	2.752	2.383	34.769	6.369	123.1	0.016	0.046	0.016	0.016	0.022	0.019	0.282	0.052

* = Maximum Dose

TABLE 7.2.4-10b
HAZARD QUOTIENTS FOR MINK CONSUMING MEDIAN CONCENTRATION SMALL MAMMALS
HOLDEN MINE RI/FS
DAMES & MOORE JOB NO. 17693-005-019

Metal	Median Dose Subsurface (mg/kg/day)	TRV (mg/kg/day)	HQ Subsurface
Cadmium	0.033	3.71	0.009

TABLE 7.2.4-11a
HAZARD QUOTIENTS FOR RED-TAILED HAWK
HOLDEN MINE RI/FS
DAMES & MOORE JOB NO. 17693-005-019

	UCL Total Dose Insectivore (mg/kg/day)								TRV	HQ							
Metal	Surface	Subsurface	TP-1	TP-2	TP-3	Dust	Lagoon*	M. Yard*	(mg/kg/day)	Surface	Subsurface	TP-1	TP-2	TP-3	Dust	Lagoon*	M. Yard*
Cadmium	0.187	15.139	0.527	1.230	0.123	0.073	18.796	2.384	4	0.047	3.785	0.132	0.308	0.031	0.018	4.699	0.596
Copper	1.246	2.530	1.327	1.228	1.218	1.252	2.707	1.884	47	0.027	0.054	0.028	0.026	0.026	0.027	0.058	0.040
Lead	0.066	0.080	0.090	0.076	0.073	0.066	0.202	0.264	11.3	0.017	0.020	0.023	0.020	0.019	0.017	0.018	0.023
Zinc	1.6	2.2	1.6	1.6	1.9	1.8	3.0	2.3	26.2	0.063	0.086	0.062	0.063	0.072	0.069	0.114	0.088

* = Maximum Dose

	UCL Total Dose Omnivore (mg/kg/day)								TRV	HQ							
Metal	Surface	Subsurface	TP-1	TP-2	TP-3	Dust	Lagoon*	M. Yard*	(mg/kg/day)	Surface	Subsurface	TP-1	TP-2	TP-3	Dust	Lagoon*	M. Yard*
Cadmium	0.015	0.198	0.028	0.045	0.012	0.009	0.224	0.067	4	0.004	0.049	0.007	0.011	0.003	0.002	0.056	0.017
Copper	1.095	3.175	1.203	1.071	1.058	1.102	3.514	2.038	47	0.023	0.068	0.026	0.023	0.023	0.023	0.075	0.043
Lead	0.238	0.259	0.274	0.254	0.250	0.238	0.039	0.044	0.45	0.061	0.066	0.070	0.065	0.064	0.061	0.003	0.004
Zinc	7.3	8.8	7.3	7.3	7.9	7.7	2.1	1.8	26.2	0.279	0.334	0.279	0.280	0.303	0.295	0.078	0.068

* = Maximum Dose

	UCL Total Dose Herbivore (mg/kg/day)								TRV	HQ							
Metal	Surface	Subsurface	TP-1	TP-2	TP-3	Dust	Lagoon*	M. Yard*	(mg/kg/day)	Surface	Subsurface	TP-1	TP-2	TP-3	Dust	Lagoon*	M. Yard*
Cadmium	0.019	0.164	0.032	0.048	0.016	0.012	0.182	0.066		0.005	0.041	0.008	0.012	0.004	0.003	0.046	0.017
Copper	0.620	0.811	0.635	0.617	0.615	0.621	0.832	0.725		0.013	0.017	0.014	0.013	0.013	0.013	0.018	0.015
Lead	0.250	0.307	0.351	0.292	0.281	0.251	0.083	0.110	4	0.109	0.133	0.153	0.127	0.122	0.109	0.007	0.010
Zinc	6.3	7.5	6.3	6.3	6.8	6.7	8.7	7.6	26.2	0.241	0.286	0.241	0.242	0.261	0.254	0.330	0.290

* = Maximum Dose

TABLE 7.2.4-11b
HAZARD QUOTIENTS FOR RED-TAILED HAWKCONSUMING MEDIAN CONCENTRATION INSECTIVORE
HOLDEN MINE RI/FS
DAMES & MOORE JOB NO. 17693-005-019

	edian Doses Insectivores (mg/kg/day	TRV	HQ
Metal	Food Subsurface	(mg/kg/day)	Subsurface
Cadmium	0.026	4	0.0065

TABLE 7.2.4-12a
HAZARD QUOTIENTS FOR DUSKY SHREWS
HOLDEN MINE RI/FS
DAMES & MOORE JOB NO. 17693-005-019

	UCL Total Dose (mg/kg/day)								TRV	HQ							
Metal	Surface	Subsurface	TP-1	TP-2	TP-3	Dust	Lagoon*	M. Yard*	(mg/kg/day)	Surface	Subsurface	TP-1	TP-2	TP-3	Dust	Lagoon*	M. Yard*
Cadmium	6.5	245.9	15.4	31.0	4.6	3.0	294.0	53.5	10.1	0.6	24.3	1.5	3.1	0.5	0.3	29.1	5.3
Copper	13.9	52.7	15.3	13.6	13.4	14.0	63.1	27.7	170.8	0.1	0.3	0.1	0.1	0.1	0.1	0.4	0.2
Lead	1.3	1.8	2.2	1.6	1.6	1.3	8.5	13.3	16.2	0.1	0.1	0.1	0.1	0.1	0.1	0.5	0.8
Zinc	61.1	159.5	60.4	61.9	92.2	79.7	526.3	172.1	323.3	0.2	0.3	0.2	0.2	0.3	0.2	1.6	0.5

* = Maximum Dose

TABLE 7.2.4-12b
HAZARD QUOTIENTS FOR MEDIAN DUSKY SHREWS
HOLDEN MINE RI/FS
DAMES & MOORE JOB NO. 17693-005-019

	Median Total Dose Insectivores (mg/kg/day)			TRV	HQ		
Metal	Subsurface	TP-1	TP-2	(mg/kg/day)	Subsurface	TP-1	TP-2
Cadmium	0.128	0.222	0.244	10.1	0.013	0.02	0.02

TABLE 7.2.4-13a
HAZARD QUOTIENTS FOR ROBIN
HOLDEN MINE RI/FS
DAMES & MOORE JOB NO. 17693-005-019

	UCL Total Dose (mg/kg/day)								TRV	HQ							
Metal	Surface	Subsurface	TP-1	TP-2	TP-3	Dust	Lagoon*	M. Yard*	(mg/kg/day)	Surface	Subsurface	TP-1	TP-2	TP-3	Dust	Lagoon*	M. Yard*
Cadmium	1.67	62.94	3.92	7.89	1.18	0.77	75.29	13.64	4	0.42	15.74	0.98	1.97	0.30	0.19	3.41	18.82
Copper	3.71	23.90	4.16	3.62	3.57	3.74	31.41	9.05	47	0.08	0.51	0.09	0.08	0.08	0.08	0.57	0.29
Lead	3.21	4.41	5.44	4.09	3.85	3.23	20.88	32.50	11.3	0.28	0.39	0.48	0.36	0.34	0.29	2.85	1.87
Zinc	17.58	63.87	17.34	17.85	29.71	24.54	599.77	208.86	26.2	0.67	2.44	0.66	0.68	1.13	0.94	11.59	3.93

* = Maximum Dose

TABLE 7.2.4-13b
HAZARD QUOTIENTS FOR MEDIAN ROBIN
HOLDEN MINE RI/FS
DAMES & MOORE JOB NO. 17693-005-019

	Median Total Dose (mg/kg/day)			TRV	HQ		
Metal	Subsurface	TP-2	TP-3	(mg/kg/day)	Subsurface	TP-2	TP-3
Cadmium	0.096	0.033	0.030	4	0.082	0.16	0.30
Zinc	15.6	16.3	16.9	26.2	0.597	0.62	0.647

TABLE 7.2.4-14
HAZARD QUOTIENTS FOR BATS
HOLDEN MINE RI/FS
DAMES & MOORE JOB NO. 17693-005-019

Metal	Concentration (mg/kg/day)			TRV (mg/kg/day)	HQ		
	Upstream	Adjacent to Site	Downstream		Upstream	Adjacent to Site	Downstream
Cadmium	0.03	0.21	0.26	3.06	0.009	0.07	0.08
Copper	0.13	2.47	2.79	24.18	0.005	0.10	0.12
Lead	NA	NA	NA		NA	NA	NA
Zinc	1.73	8.22	7.60	101.65	0.017	0.08	0.075

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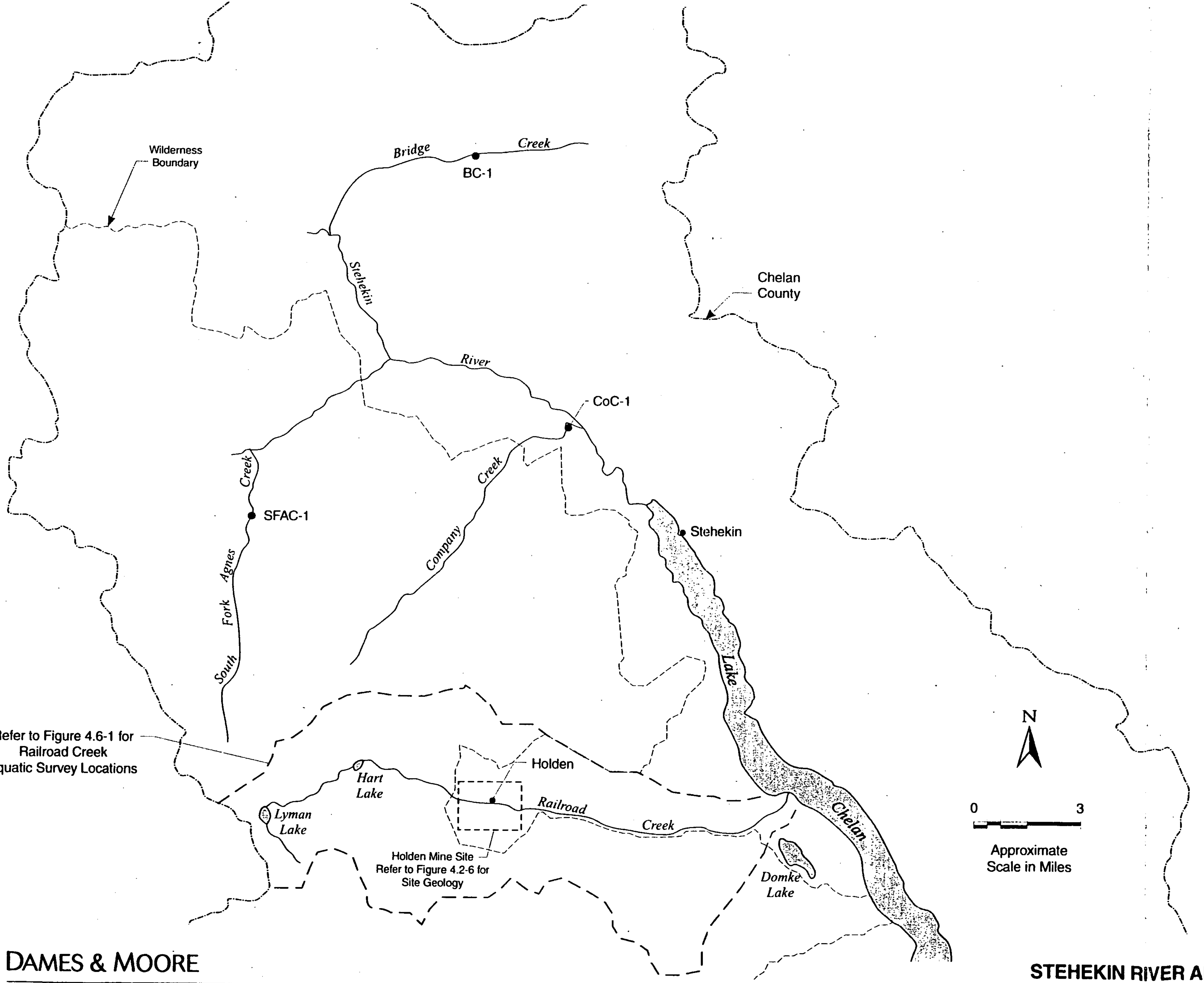

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Figure 7.0-1
STEHEKIN RIVER AND RAILROAD CREEK WATERSHEDS

Job No. 17693-005-019

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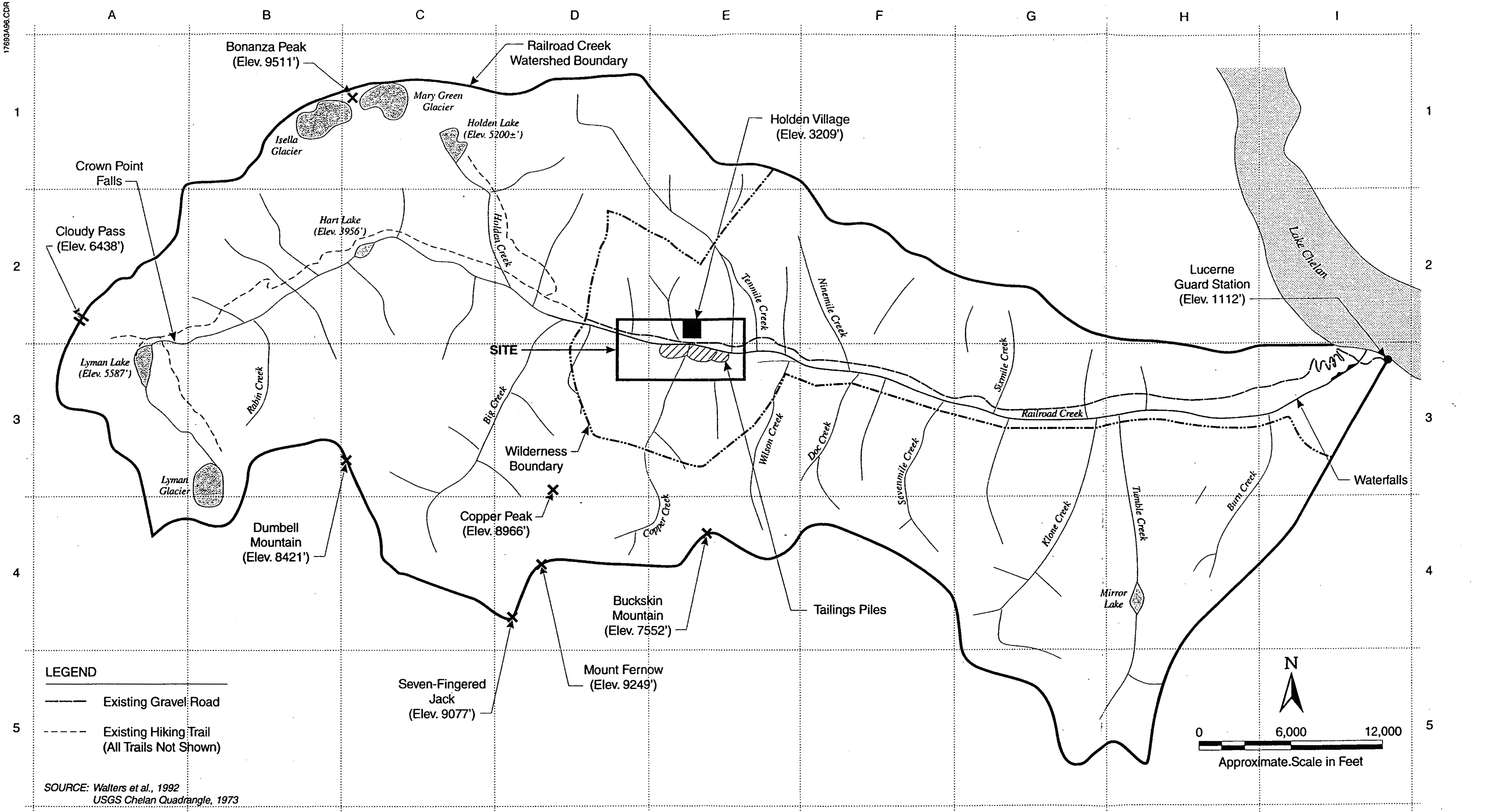
17693A96.CDR



SOURCE: Walters et al., 1992
USGS Chelan Quadrangle, 1973

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Figure 7.0-2

RAILROAD CREEK WATERSHED MAP

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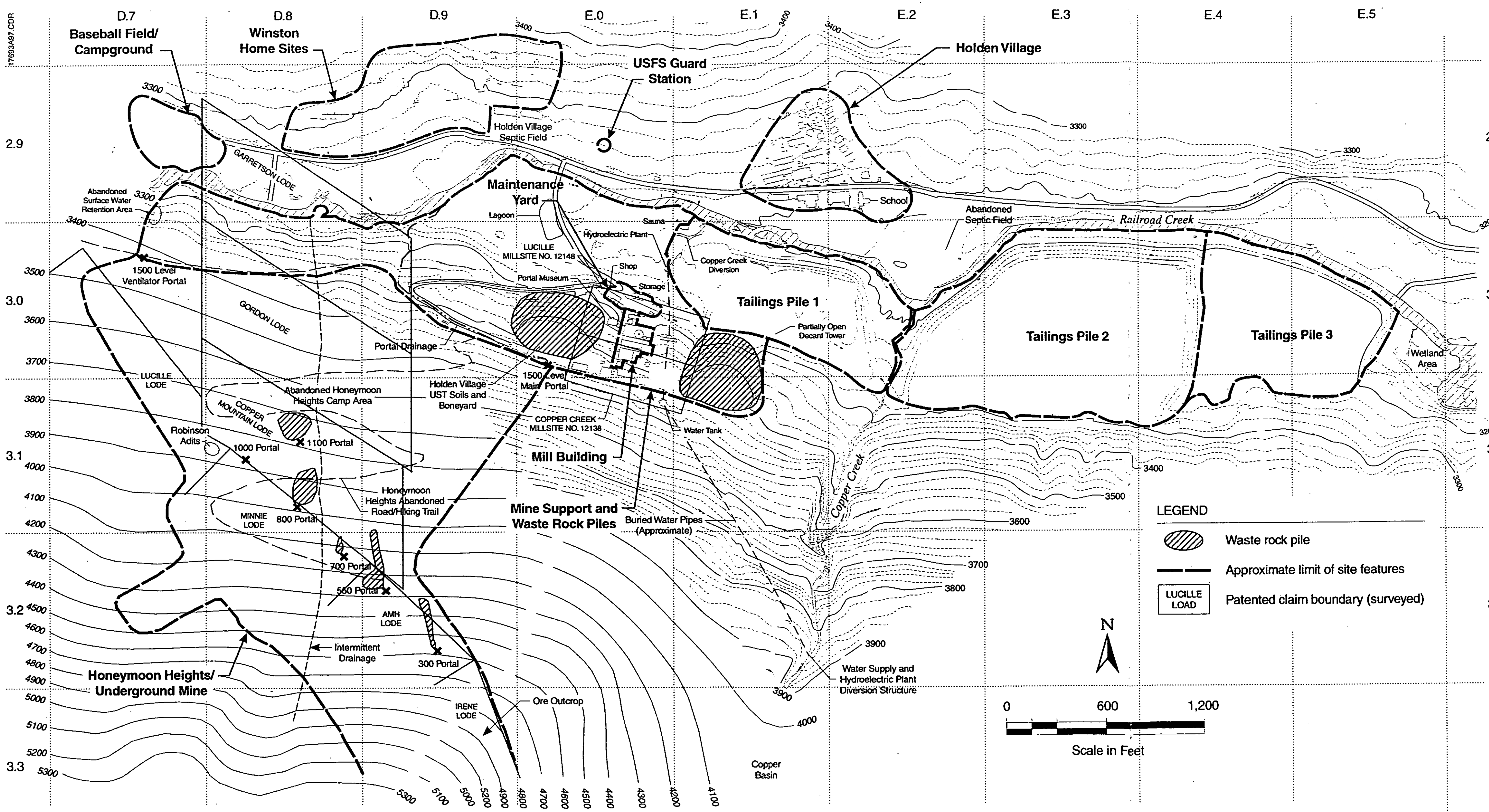

SOURCE: *Base map information from USFS and Washington DNR, DEM CD ROM*

Figure 7.0-3

HOLDEN MINE SITE MAP

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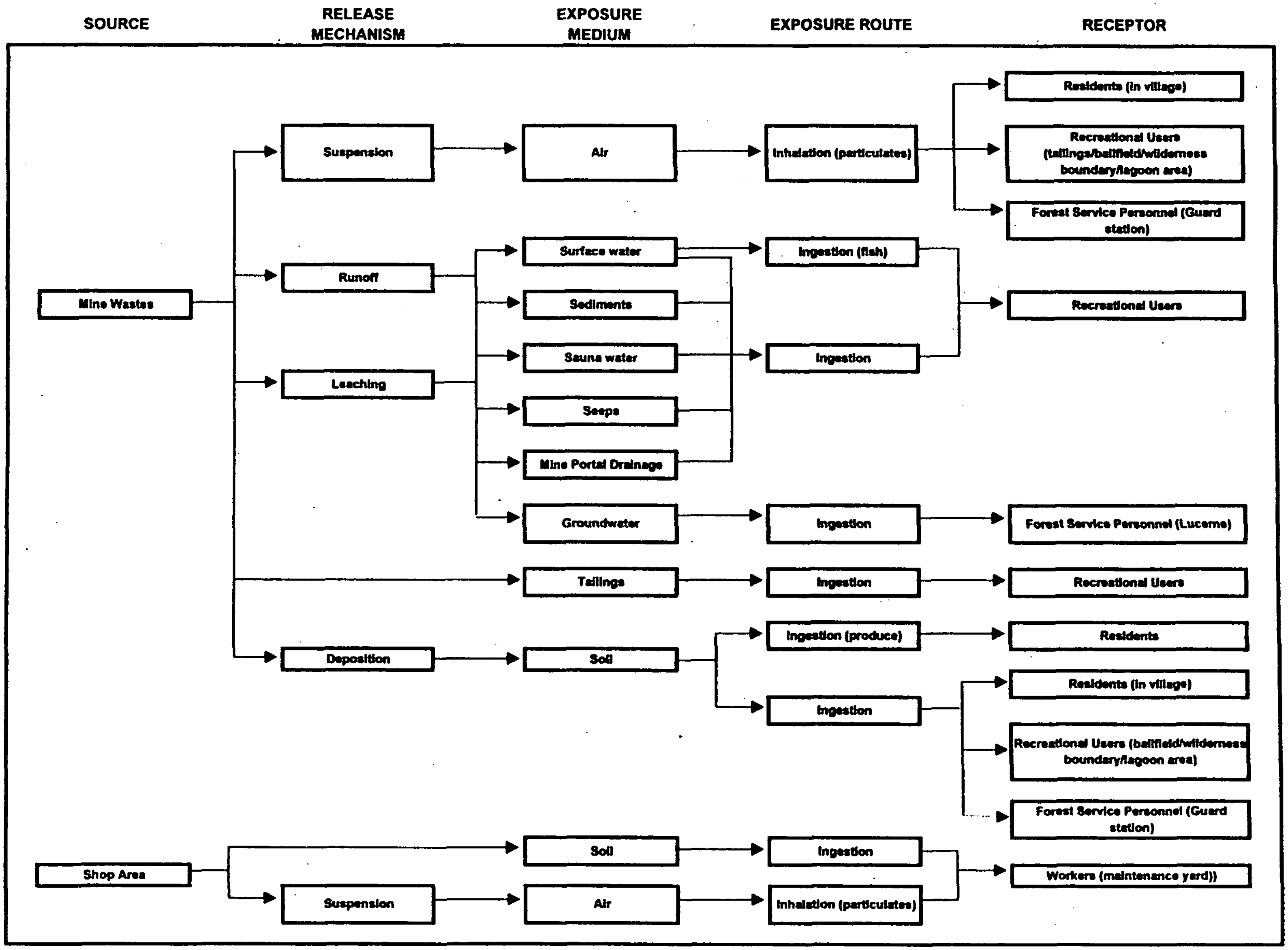

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7/27/99
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Job No. 17693-005-019

FIGURE 7.1-1
PRELIMINARY HUMAN HEALTH EXPOSURE PATHWAY MODEL

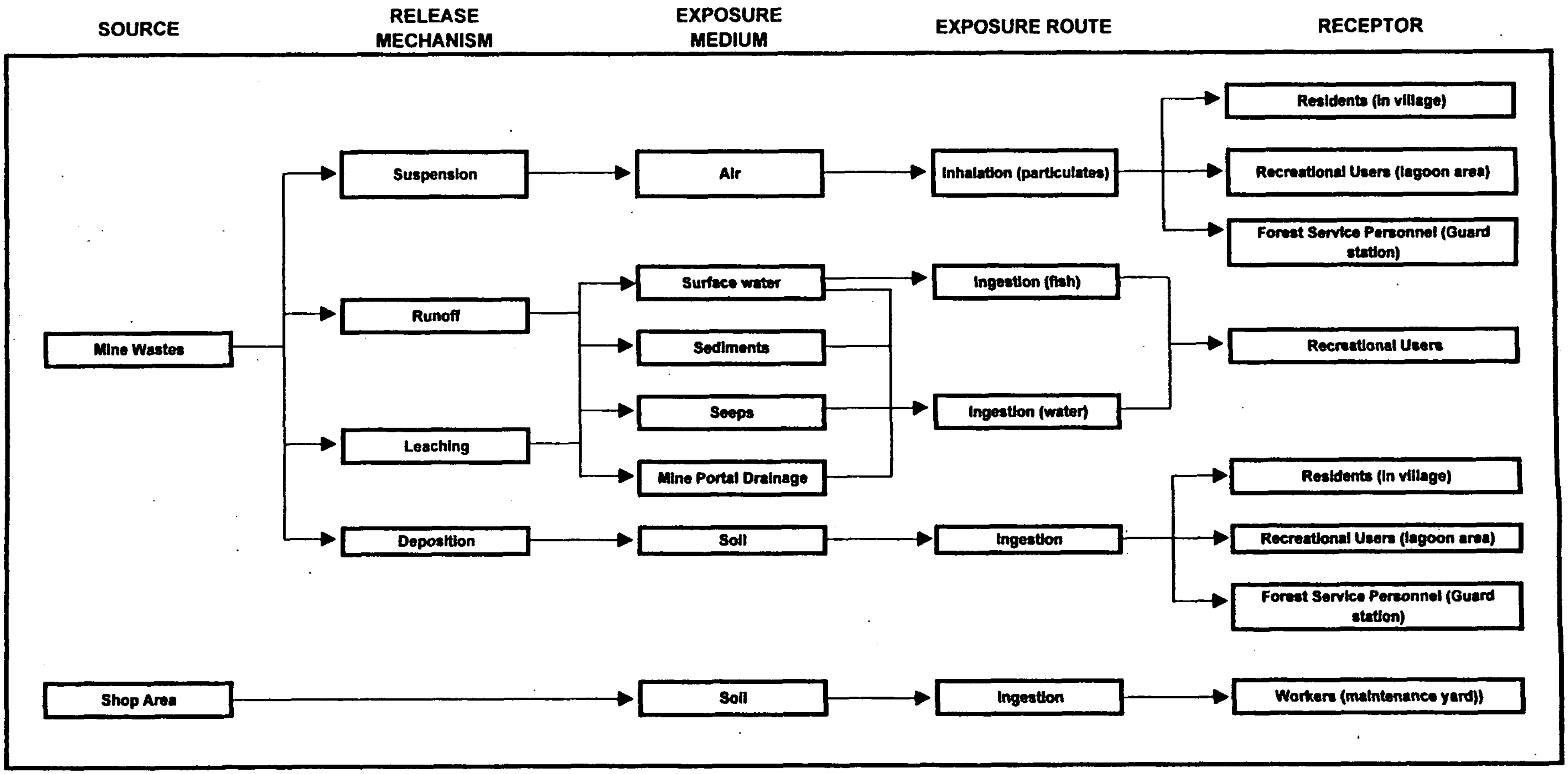
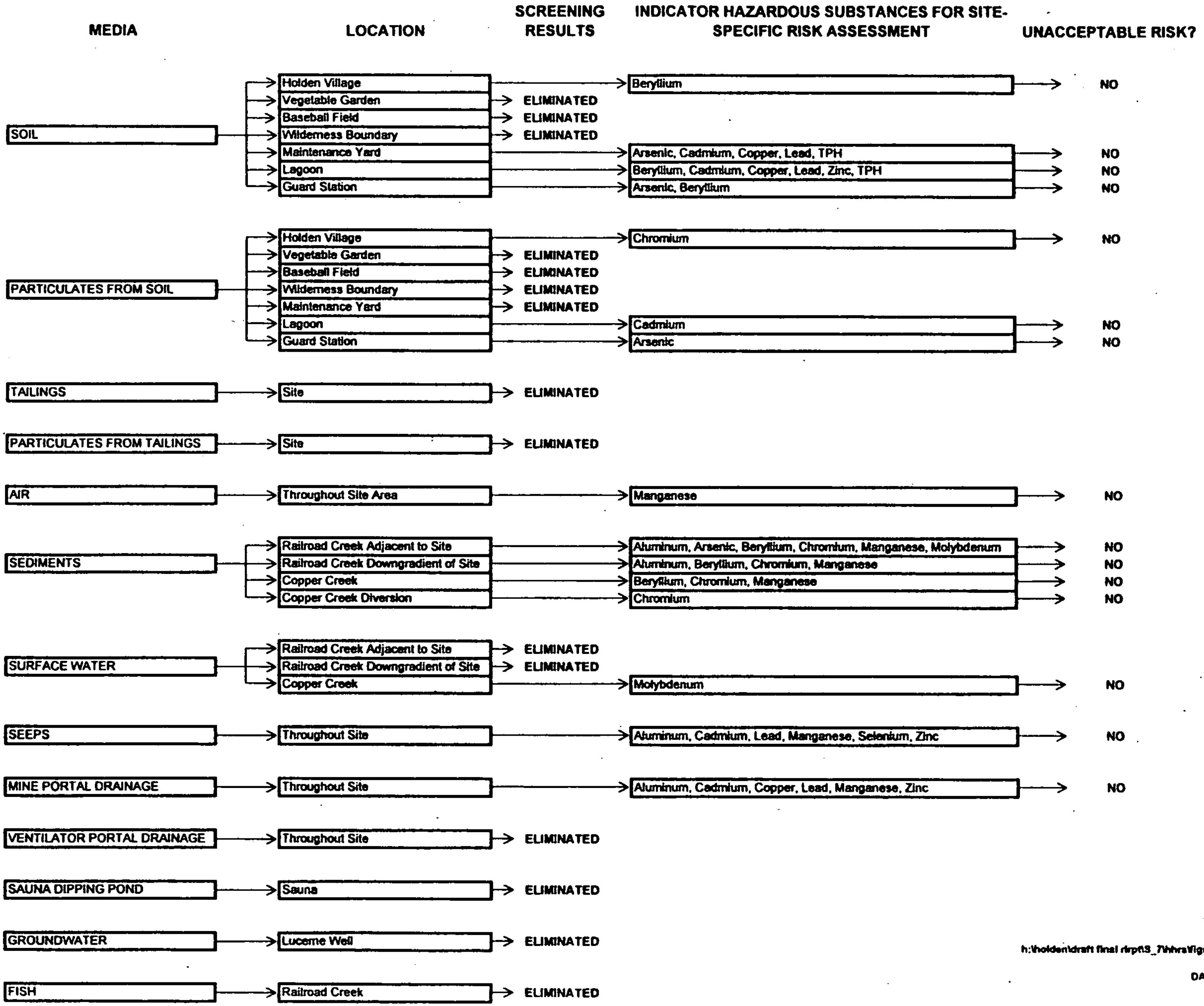


FIGURE 7.1-2
REFINED HUMAN HEALTH EXPOSURE PATHWAY MODEL

FIGURE 7.1-3
FLOW CHART ILLUSTRATING HUMAN HEALTH RISK ASSESSMENT RESULTS



MEDIA	LOCATION	SCREENING RESULTS	INDICATOR HAZARDOUS SUBSTANCES FOR SITE-SPECIFIC RISK ASSESSMENT	UNACCEPTABLE RISK?
SOIL	Holden Village		Beryllium	NO
	Vegetable Garden	ELIMINATED		
	Baseball Field	ELIMINATED		
	Wilderness Boundary	ELIMINATED		
	Maintenance Yard		Arsenic, Cadmium, Copper, Lead, TPH	NO
	Lagoon		Beryllium, Cadmium, Copper, Lead, Zinc, TPH	NO
	Guard Station		Arsenic, Beryllium	NO
PARTICULATES FROM SOIL	Holden Village		Chromium	NO
	Vegetable Garden	ELIMINATED		
	Baseball Field	ELIMINATED		
	Wilderness Boundary	ELIMINATED		
	Maintenance Yard	ELIMINATED		
	Lagoon		Cadmium	NO
	Guard Station		Arsenic	NO
TAILINGS	Site	ELIMINATED		
PARTICULATES FROM TAILINGS	Site	ELIMINATED		
AIR	Throughout Site Area		Manganese	NO
SEDIMENTS	Railroad Creek Adjacent to Site		Aluminum, Arsenic, Beryllium, Chromium, Manganese, Molybdenum	NO
	Railroad Creek Downgradient of Site		Aluminum, Beryllium, Chromium, Manganese	NO
	Copper Creek		Beryllium, Chromium, Manganese	NO
	Copper Creek Diversion		Chromium	NO
SURFACE WATER	Railroad Creek Adjacent to Site	ELIMINATED		
	Railroad Creek Downgradient of Site	ELIMINATED		
	Copper Creek		Molybdenum	NO
SEEPS	Throughout Site		Aluminum, Cadmium, Lead, Manganese, Selenium, Zinc	NO
MINE PORTAL DRAINAGE	Throughout Site		Aluminum, Cadmium, Copper, Lead, Manganese, Zinc	NO
VENTILATOR PORTAL DRAINAGE	Throughout Site	ELIMINATED		
SAUNA DIPPING POND	Sauna	ELIMINATED		
GROUNDWATER	Lucerne Well	ELIMINATED		
FISH	Railroad Creek	ELIMINATED		

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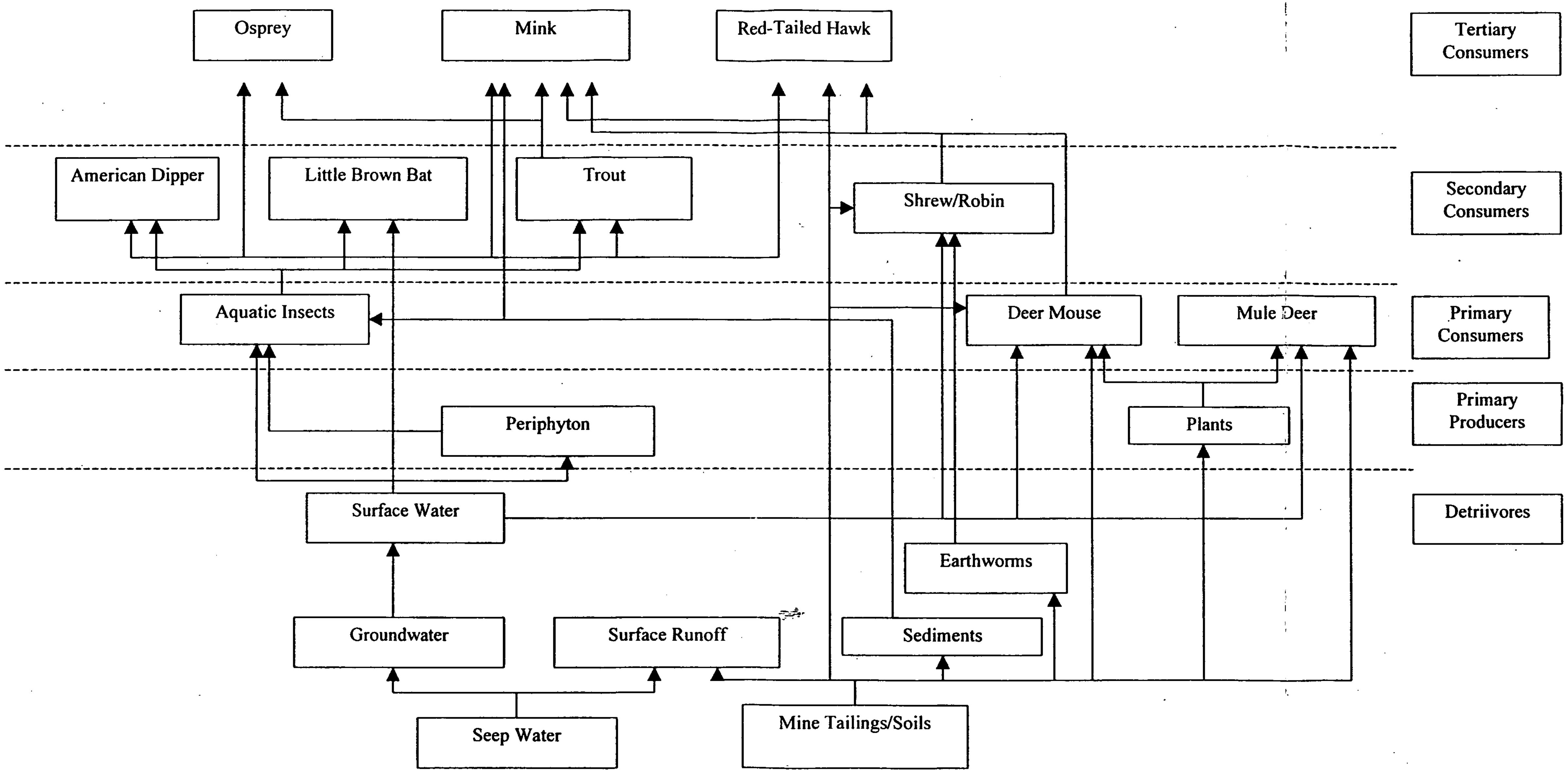
7/27/99
DAMES & MOORE

Figure 7.2-1 Conceptual Site Model



8.0 DISCUSSION AND INTERPRETATION OF FINDINGS

8.1 INTRODUCTION

The geology, surface and subsurface soils, surface water, groundwater, seeps, sediments, air, and ecological conditions of the Holden Mine area and portions of the Railroad Creek watershed, were evaluated during the RI utilizing data collected by Dames & Moore and others. The RI also included evaluation of the presence or absence of asbestos-containing materials in the abandoned mill building, the presence or absence of underground storage tanks and associated possible petroleum hydrocarbons in the Winston Home Sites area, an evaluation of geologic hazards on the Site, an assessment of potential rock and soil sources, and human health and ecological risk assessments. In addition, the RI characterized surface water and ecological conditions in three reference reach locations north of the Railroad Creek watershed in the Stehekin River Watershed (Bridge Creek, Company Creek, and South Fork of Agnes Creek) (Figures 8.1-1 through 8.1-5).

This section presents a summary of the key findings and interpretations of the Site surface and subsurface conditions in terms of the geology; hydrology; hydrogeology; aquatic and terrestrial biota; the nature and extent of contamination in surface and subsurface soils, groundwater, surface water, and sediment; characterization of the transport and fate of contaminants; and the potential for human health and ecological risks associated with the Site. The interpretations of the settings for the aquatic reference reaches outside the Railroad Creek watershed are presented in this section in order to evaluate the comparability of data collected from these areas with the Railroad Creek data.

Due to the complexity of the Site conditions, and to assist in communicating the findings, some redundancy exists between the previous report text and this section of the report; the relevant previous sections of the report are referenced as appropriate.

8.2 INTERPRETATION OF THE SITE SETTING

The Site is located within the Railroad Creek watershed. The Railroad Creek watershed includes the entire watershed area from Lyman Lake to Lake Chelan; and the aquatic reference reaches include one stream segment each in Bridge Creek, South Fork of Agnes Creek, and Company Creek which were sampled for aquatic biota and water quality for comparison to appropriate segments of Railroad Creek. The Site includes the general area within the Railroad Creek valley between the upstream wilderness boundary at surface water sampling station RC-6, to immediately downstream of the eastern end of the tailings piles at seep sampling station SP-21.

Referring to Section 4.0 for a complete discussion of findings, the following section summarizes the most important elements of the setting in terms of the Site and aquatic reference reach areas.

8.2.1 Physiography

8.2.1.1 Site

The Holden Mine is situated in a remote area on the eastern slopes the Cascade Mountains and surrounded on three sides by established wilderness and one side by National Forest System land managed forest land which includes protected natural resources and wildlife habitat (Figures 8.1-1 and 8.1-2). The Site is situated approximately near the center of the Railroad Creek watershed.

The elevation difference between the mouth of Railroad Creek and the westernmost extent of the watershed, as well as the difference between the floor of the valley at the Site and surrounding peaks, is on the order of 4,000 to 6,000 feet. This elevation difference results in wide variations in daily and seasonal temperatures, and the types and amounts of precipitation. The majority of precipitation falls in the form of snow during the months of January through March. Daytime temperatures at the Site are relatively cold during the winter months, often below 32 degrees Fahrenheit, to warm during the summer months, often above 70 degrees Fahrenheit.

The daily temperature variations in the summer months regularly result in down-valley winds during the afternoons, which are normally low to moderate in relative intensity. The north-facing aspect of the Site also reduces the amount of solar gain received during the year when compared to the north side of the valley which receives more sunlight. These factors contribute to the variations in snow melt rates; surface water run on, runoff and infiltration; and the species and densities of vegetation and wildlife. The vegetation types range from lower elevation, predominantly coniferous forests from Lake Chelan to the Site, transitioning to subalpine and alpine sparse vegetation west of the Site to the headwaters at Lyman Lake.

The principal Site surface features in the southwest and western portions of the Site include the underground mine, the Honeymoon Heights area portals and associated waste rock piles, the 1500-level main and ventilator mine portals, the mill building with two associated waste rock piles and mine support area which includes the maintenance yard, lagoon (Figures 8.1-3 and 8.1-4). Three tailings piles are present in the eastern portion of the Site and cover approximately 90 acres. The tailings piles range in height from approximately 50 feet for tailings pile 1, approximately 120 feet for tailings pile 2, and approximately 50 feet for tailings pile 3. Railroad Creek bounds the mine area to the north. Copper Creek enters Railroad Creek between tailings piles 1 and 2.

Holden Village exists north of the abandoned mine and mill areas, immediately north of Railroad Creek. The village includes approximately 50 to 60 year-around residents and approximately 5,000 to 6,000 short-term visitors to Holden Village during the summer months. Other short-term visitors to the Railroad Creek watershed include hikers, backpackers, horse packers, and recreational users who fish the streams and lakes throughout the area. Lucerne, approximately 10 miles to the east of the Site, near the mouth of Railroad Creek on Lake Chelan, includes mostly part-time and several full-time residents.

Aquatic Reference Reaches

The three aquatic reference reach sites were selected for evaluation in the RI and are located to the north of the Railroad Creek watershed within the Stehekin River basin (Figure 8.1-5). The sites are situated on isolated segments of Bridge Creek, North Fork of Agnes Creek, and Company Creek. These reference reach sites were selected because they are situated in areas of similar topographic relief and climatic conditions as observed in the Railroad Creek watershed. The reference reaches are also situated in remote areas of the Wenatchee National Forest or the North Cascades National Park, with only part-time visitors in the form of hikers, backpackers, horse packers, and recreational users who fish the streams and lakes.

8.2.2 Geology

8.2.2.1 Railroad Creek Watershed

The Railroad Creek geology reflects ongoing tectonic mountain building. Based on historic data, Railroad Creek is located in an area of moderate seismicity due to the mountain building processes. The geology of the watershed consists of metamorphic and igneous rocks resulting from the compressive forces associated with the mountain building. The bedrock is exposed at the ground surface throughout the Railroad Creek watershed, but predominantly along the valley walls and ridge lines.

The bedrock was modified into a u-shaped valley by glaciation that occurred within the last 12,000 years (Pleistocene period). Lyman Glacier, located approximately 10 miles to the west of the Site reflects the remnant of the Pleistocene glacier. The glacier removed the bedrock to form a mixture of clay-sized silt, sand, gravel, cobbles, and boulders. The soil was deposited on portions of the floor of the valley and the lower valley walls. The soil mixture was compacted by the glacier into a dense glacial till.

During the most recent recession of the glaciation, the glacial till was covered in places with mixtures of relatively loose sand and gravel with less silt, cobbles, and boulders, as noted at the existing Dan's Camp gravel pit in the lower portion of Railroad Creek. This material is known to be more permeable than the glacial till.. Since the glacial period, Railroad Creek has continued to rework the deposited exposed near the ground surface, in some isolated places removing the glacial deposits to expose the underlying bedrock.

Localized areas throughout the Lake Chelan region contain deposits of economic minerals that have resulted in natural enrichment or mineralization. Areas of mineralized zones in bedrock have been mapped by others throughout the Railroad Creek watershed; the economic metals noted by others as being present in the watershed include those extracted from the Holden Mine (copper, zinc, gold, and silver).

In addition to the Holden Mine, more than 15 other mineral prospects and several smaller mines were developed in the Railroad Creek watershed. Two mines were located approximately 10 miles to the west of the Site, and were reported to have been operated by others early in the 1900s. One prospect was reportedly developed by Howe Sound Company above Holden Lake, northwest of the Site near Martin Ridge at an elevation of approximately 7,500 feet. These workings reportedly included three primary adits, the most extensive being 370 feet in length. A preliminary assessment of the Holden Lake prospect was conducted as part of the RI. In addition, water quality sampling of Holden Creek (which flows from Holden Lake) was completed during the RI. Based on the findings, additional evaluation of the Holden Lake prospect was determined not to be necessary.

8.2.2.2 Site

General

Based on seismic refraction data collected as part of the RI, glacial till covers the bedrock underlying the Site. However, the depth to bedrock near Railroad Creek between tailings piles 2 and 3 was relatively shallow (less than 20 feet), and isolated exposures of bedrock appear to exist immediately downstream of tailings pile 3 in the south bank of the Railroad Creek, and within the lower portion of Copper Creek; the absence of glacial till in the areas is likely due to stream erosion.

The dense glacial till overlying the majority of the bedrock has been mapped by others to be present slightly above the 1100-level mine portal in the Honeymoon Heights area. Borings completed on the Site by others indicate that the glacial till has a relatively low permeability.

The near-surface glacial soils within the valley have apparently been reworked by stream erosion processes by meandering of Railroad Creek across the valley floor at the Site during and since the last glacial advance. The finer grained silt and sand soil within the near-surface glacial till appear to have been generally removed by the alluvial action, resulting in the surficial soils being more permeable than the glacial till soil present at depth.

Railroad Creek has been documented to have been rerouted in 1937 to accommodate the use of the portions of the mine support area near the creek for surface water retention, and to allow for the construction of the tailings piles. The creek was apparently rerouted by constructing a dike consisting of gravel, cobbles, boulders, and occasional wood timbers along the eastern and southern banks of the creek west of the tailing piles. A segment of the previous Railroad Creek stream bed appears to be present beneath the lagoon, north of the maintenance yard and abandoned mill building, and portions of tailings piles 1, 2, and 3. Due to the presence of creek bed material that most likely has a higher permeability than near-surface glacial soils or alluvial materials, the abandoned stream bed appears to act as a preferential pathway for near-surface groundwater movement from the western portion of the Site to Railroad Creek near the confluence with Copper Creek, and beneath tailings piles 2 and 3.

Western Portion of Site

Underground Mine and Honeymoon Heights

The mine levels were developed based on the elevation below the exposure of the ore body above the mine in the Honeymoon Heights area. The exposure of the ore body is considered the "0" level. The 300-level portal is approximately 300 feet below this point, the 550-level is approximately 550 feet below, and so on (Figure 8.2-1).

The two 1500-level portals of the mine are the lowest elevation openings to the surface. The 1500-level main and ventilator portals were apparently timbered through 65 feet and 300 feet of glacial soil, respectively. The thickness of the glacial soil at the ventilator portal is likely less than noted on the underground maps due to the tunnel not being oriented perpendicular to the valley sidewall. The remainder of the mine portals at the 1100, 1000, 800, 700, 550, and 300 levels were either not timber supported or supported only through less than 15 feet of glacial soil and/or weathered bedrock exposed near the surface.

The ore-bearing bedrock within the mine is reported by others to consist principally of copper, zinc, gold, and silver-bearing sulfides within a country rock of primarily schistose rock. Based on a review of historic mine maps, the ore body is approximately 80 feet in width, nearly vertical in orientation, strikes northwest to southeast, and is exposed at the ground surface approximately coincident with the 300-level to 1,000-level mine workings in Honeymoon Heights. Portions of the ore body were removed from within the mine to form openings called "stopes." The stopes range in height from approximately 100 to 600 feet, and approximately 80 feet in width. Select portions of two of the stopes above the 1500-level of the mine appear to have been mapped as being completed to within approximately 50 feet of the ground surface. The potential for subsidence exists in these isolated areas along the strike of the ore body. The areas are generally found between the 300- to 550-level, and the 700- to 1100-level portals.

The bedrock in the mine has been mapped as containing a number of fault and fracture systems. Two primary faults have been mapped within the Holden Mine with measured lateral and vertical movement; no indications of recent movement were noted in literature and/or the field. The presence of the glacial till overlying the bedrock in the lower portion of the valley would appear to decrease the likelihood of groundwater movement from the faults to the near-surface groundwater in the valley alluvial deposits.

The potential for subsidence at the Holden Mine was evaluated as part of the RI. The scope of work included conducting relatively detailed field mapping along exposed portions of the ore body between the 300- and 550-level portals, and the 700- and 1100-levels portals. The results indicate that the bedrock spanning the underground openings is "stable" based on comparisons with historical data; refer to section 4.2.5 for additional discussion.

Mill, Mine Support, and Waste Rock Piles

Referring to Figures 8.1-3 and 8.1-4 for the locations of the mill, mine support, and waste rock piles area, it appears that this portion of the Site is generally underlain by limited man-made fill soils overlying the glacial till soils which have been reworked near the existing ground surface by Railroad Creek.

The waste rock piles are composed of angular rock, including non-mineralized rock removed during initial development of the 1500-level tunnels and other portions of the mine that did not contain sufficient mineralization to warrant processing in the mill. The two piles located next to the abandoned mill are on the order of 120 feet thick and are underlain by apparent glacial till soils; the contact between the waste and glacial till slopes to the north. Water that permeates through the waste rock, therefore, travels along the contact with glacial till materials, forming several intermittent springs or seeps observed near the base of the piles.

The surface of the west waste rock pile is currently being used by Holden Village for the remediation of petroleum hydrocarbon-contaminated soils encountered during the removal of underground storage tanks in the village.

Eastern Portion of Site

Tailings Piles

The tailings materials have been determined to consist generally of silty fine sand to fine sandy silt. The soils were noted by others to consist of higher percentages of sand near the outer boundaries of the piles. The depths of the materials range from approximately 50 feet for tailings piles 1 and 3 to approximately 120 feet for tailings pile 2. The tailings appeared slightly cemented at the surface based on infiltration tests completed by Dames & Moore and others. The permeability of the surfaces of the tailings piles is relatively low, and is discussed further in the groundwater subsection.

Based on the results of borings completed by others, the tailings piles are directly underlain by reworked glacial soils, which have a relatively high permeability. The reworked deposits appear underlain by relatively low permeability glacial till. The northern portions of the tailings piles are also likely underlain by the abandoned Railroad Creek drainage which was relocated at the time of the placement of the tailings piles.

Tailings pile 1 was utilized as a municipal dump and/or sewage lagoon by both Howe Sound and Holden Village; however, no information was discovered regarding the disposal of petroleum products in the dump. The refuse was reportedly placed in a depression in the tailings materials. The placement of municipal waste was discontinued in 1989. The depression was filled with soil and/or tailings materials during the tailings rehabilitation project conducted between 1989 and 1991.

Holden Village, Winston Home Sites, and Baseball Field/Campground Area

The near-surface geology for the area to the north of Railroad Creek, beneath Holden Village, Winston Home Sites, and the Baseball Field/Campground area appears to consist of glacial soil overlain by colluvium originating from the slopes to the north.

8.2.2.3 Tailings Pile Slope Stability

Seismic Potential

The Site is located in an area that is moderately active seismically. The Site has a low to moderate potential to experience an earthquake, which could liquefy the relatively loose alluvium underlying the toes of the tailings piles, based on the analysis of historic seismic data and geologic data. The soils directly beneath the tailings piles have been compacted by the weight of the tailing materials, and are, therefore, less susceptible to liquefaction.

Release Potential

The slopes of the tailings piles facing Railroad Creek were found generally to range in angle between approximately 22 degrees and 58 degrees. The majority of the lower- to mid-slopes for tailings pile 1 range between 22 degrees and 33 degrees, with isolated portions of the upper slopes observed in excess of 60 degrees. The lower slopes of tailings pile 2 were observed to be less than 34 degrees, with the majority of the mid- to upper slopes in excess of 44 degrees. The majority of the lower- to mid-slopes for tailings pile 3 are less than 34 degrees, with the upper slopes ranging from 33 degrees to more than 42 degrees.

Based on engineering analyses of the tailings piles, the slopes of the tailings piles are stable at the present time under static conditions, assuming that the base of the slopes are not eroded by Railroad Creek. However, the "factor of safety" under static conditions was found to be 1.04 (a factor of safety below 1.0 indicates instability, and slopes with factors of safety between 1.0 and 1.25 are considered marginally stable). It was also found that a realistic hypothetical earthquake event with a horizontal peak acceleration of 0.05 gravity (g) and a return period of 40 years would result in a factor of safety of 0.98 for the steepest portions of tailings pile 2 and 1.04 for tailings pile 3 slopes. Tailings pile 1 slopes were not modeled but were generally considered similar to tailings pile 3 slopes, except for isolated steep sections that are similar to tailings pile 2. The factor safety increased with the depth of modeled failures; a slope of approximately 33 degrees was determined to have a factor of safety of 1.25 or greater under seismic conditions and is, therefore, considered stable.

The results of the analyses suggest movement would involve displacement of 1 to 15-foot deep sections of the steepest tailings. The horizontal length of a particular failure zone along the face of the slope could reasonably be expected to range from less than 100 feet to more than several hundred feet. The likelihood of a release is highest for the portion of the tailings piles immediately downstream of the confluence of

Railroad Creek and Copper Creek. The probability of an earthquake occurring sufficient enough to exceed the theoretical threshold for horizontal acceleration to initiate the shallowest movement is relatively moderate to high. However, the deeper hypothetical failure was found to be less likely.

Erosion Potential

Tailings Pile Slopes

Surface erosion of the tailings due to precipitation and wind results in a relatively minor amount of tailings material being transported down slope and down wind. The potential for erosion is highest for the steeper slopes of the tailings piles. The materials transported down slope have the potential for being delivered into Railroad Creek during storm events.

The results of preliminary mapping conducted as part of the RI indicated that the distribution of wind-blown tailings deposited on the ground surface is generally limited to the area between the tailings piles and the confluence of Tenmile Creek and Railroad Creek. The maximum thickness of the deposits was noted to be generally less than several inches immediately north of the Railroad Creek, down wind of the piles. The thickness of the deposits decreased with the distance from the tailings piles, with the thickness near the mapped limits generally less than an inch.

Existing Riprap

The existing riprap was placed along Railroad Creek between 1989 and 1991 with the intent of preventing erosion of the tailings pile slopes by Railroad Creek. The majority of the existing riprap originated from a rock quarry in the eastern portion of the Railroad Creek watershed, near Dan's Camp. An assessment of the existing riprap was conducted as part of the RI.

The results of the assessment indicated that a number of rocks exposed at the surface are in relatively poor condition and eroding relatively rapidly. The riprap of highest quality was observed at the northwest corner of tailings pile 2, immediately downstream of the Copper Creek confluence, at the location where it is most needed to prevent erosion by Railroad Creek. The majority of the remaining riprap was variable in quality and resistance to erosion.

Further erosion of the riprap could reduce its effectiveness for preventing removal of the tailings materials by Railroad Creek during storm events. The implications of the eroding riprap are further discussed below in the Surface Water erosion section.

8.2.2.4 Aquatic Reference Reaches

The geology for the aquatic reference reaches is similar to the Railroad Creek geology, consisting primarily of metamorphic bedrock with igneous intrusives. The bedrock in the main stem of the Stehekin River drainage was scoured by a glacier that carved out the Lake Chelan Basin. The drainages in which the three reference reaches are located were carved by smaller glaciers and overlain by a combination of glacial and alluvial soils, similar to Railroad Creek. Similar to Railroad Creek, the bedrock is generally exposed along the valley walls and ridges, and less often within the stream drainages. The area also contains a number of economic mineral deposits similar to the Railroad Creek drainage, but none as extensive as the Holden mine deposit.

8.2.3 Surface Water

8.2.3.1 Railroad Creek

General

Railroad Creek originates approximately 10 miles west of the Site, from Lyman Glacier. The creek is also fed by precipitation and snow melt. Due to the relatively steep gradient and the presence of relatively low permeability glacial till and/or bedrock near the surface, the creek responds relatively quickly to precipitation events.

A number of tributaries flow into Railroad Creek between the source area and the mouth of the creek at Lake Chelan. Normal flow measurements in the Railroad Creek at the Site vary from a low of approximately 50 to 70 cubic feet per second (cfs) in the late winter months to approximately 500 to 700 cfs between May and July. Record high estimated flows were 3,000 cfs at the Holden, and 3,900 cfs at Lucerne in May 1948.

Even though the total snowfall and snow depths were near record highs in 1997, the discharge flow measurements for Railroad Creek were determined to be within the normal range; however, the period of higher flow measurements lasted longer than for most previous recorded years.

The gradient of Railroad Creek is relatively steep at the headwaters, flattening to less than 1.5 percent at the Site. The gradient remains relatively constant until approximately mile 5-1/2 (from the mouth) where the gradient ranges from 4.3 to 6.9 percent. At the mouth, the gradient decreases to approximately 1.5 percent.

Due to the relatively steep stream gradient, Railroad Creek is generally found to have relatively low volumes of fine-grained sediment within the stream substrate. Areas of observed sediment deposit downstream of the Site include a beaver pond approximately one-half mile downstream of the Site, and a log jam near the confluence of Sevenmile Creek.

Streamflow Monitoring Stations

The nomenclature for the surface water sampling locations in Railroad Creek was developed utilizing a system initially established by the USFS. The sampling station upstream of the Site was initially established by the USFS as RC-1 (Railroad Creek station 1). The sampling station immediately downstream of the Site was designated RC-2, and the station at the mouth of Railroad Creek was noted as RC-3. However, subsequent stations were added during the RI as the need arose for additional data, resulting in a total of eleven Railroad Creek stations (RC-1 through RC-11). This resulted in the nomenclature of the stations not being in numerical order from upstream to downstream. The need to compare the RI data with historical data precluded the ability to renumber the stations.

Streamflow monitoring stations used during the RI are shown on Figures 8.2-2 and 8.2-3. Stations RC-1 (established to be upstream of the mine-affected area), RC-2 (immediately downstream of the tailings piles), and RC-3 (at Lucerne) were continued from previous work conducted by PNL and the USFS. New stations include RC-4 (immediately upstream of the tailings piles), RC-5 (approximately one-half mile downstream of tailings pile 3), RC-6 (established upstream of RC-1 to confirm the upstream limit of the mine-affected area), RC-7 (adjacent to tailings pile 2), RC-8 (established upstream of RC-3 in an attempt to collect data where Railroad Creek flows directly atop bedrock), RC-9 (an aquatics sampling station established upstream of the Copper Creek confluence adjacent to tailings pile 1), RC-10 (approximately three miles downstream of tailings pile 3), and RC-11 (established immediately upstream of the Holden Creek confluence after it was discovered that Howe Sound Company likely conducted limited mineral exploration in the Holden Creek watershed).

Streamflow monitoring stations on Copper Creek include CC-1 upstream of the tailings piles (established by PNL and the USFS), CC-2 near the confluence of Copper Creek and Railroad Creek (also established by PNL and the USFS), and CC-D/CC-D1, which is the Copper Creek diversion (established at the request of the Agencies). CC-D/CC-D1 flow is diverted from Copper Creek upstream of CC-1 and routed through the hydroelectric plant. Flow from CC-D/CC-D1 is also diverted for water use at Holden Village. Flow was also monitored in the portal drainage at stations P-1 (where the drainage flows from the mine portal) and P-5 (upstream of the confluence with Railroad Creek).

Staff gages for measuring water levels are located at stations RC-2, RC-4 and RC-6 in Railroad Creek. Additionally, a continuously recording water level recorder (Troll) was installed in the stilling well at RC-4 on May 24, 1997. The Troll was removed during the winter due to the low water levels and freezing temperatures. A staff gage is also located behind the weir that controls flow out of the hydroelectric plant in the Copper Creek diversion.

Upstream of Site

Less than one mile upstream of the Site, Big Creek enters Railroad Creek from the south and nearly doubles the flow when compared to Railroad Creek above the confluence. Slightly upstream of the Big Creek and Railroad Creek confluence, Holden Creek enters Railroad Creek from the north. Holden Creek drains the Holden Lake basin to the north and provides less than 10 percent of the total flow of Railroad Creek as measured at the nearest downstream station (RC-6).

Adjacent to Site

Due to the difficulty in physically obtaining accurate flow measurements in the field during high flow conditions in the May to June time period, it is not possible to determine whether Railroad Creek is consistently in a gaining condition (water flows into the creek and gains total volume as it flows down valley) or possibly in a losing condition (water is lost to the surrounding soil as the stream flows downstream) for segments of the stream adjacent to the Site.

The portion of Railroad Creek between the portal drainage confluence at P-5 and RC-4 may gain or lose minor amounts of flow during portions of the year. Further downstream, Railroad Creek adjacent to the tailings piles is apparently in a gaining condition during the spring runoff period. However, the portion of the creek adjacent to tailings pile 3 is in a losing condition at least during the fall and probably through the winter months.

Iron-oxide staining and interstitial flocculent were observed on the stream bed for the portion of Railroad Creek from tailings pile 1 to the east end of tailings pile 3. The aquatic sampling location RC-9, upstream of the Copper Creek confluence, was noted to be the transition zone. The creek substrate for the upstream portion of the sampling station did not contain significant staining and/or flocculent. In contrast, the downstream portion of the creek substrate to the east end of tailings pile 3 was predominantly stained and covered with flocculent. The flocculent was observed in suspension during higher stream flows created by snow melt and/or storm events.

The Railroad Creek substrate was also observed to contain ferricrete that is cemented in isolated places. Observations both during the RI and by others document the ferricrete to be limited to portions of the south bank of Railroad Creek near the northwest and northeast corners of tailings pile 1 and the northwest corner of tailings pile 2, generally coincident with the locations of seeps SP-1, 2, and 3, which are further described below.

Downstream of Site

Downstream of the Site, it appears that Railroad Creek is in a net gaining condition throughout the year. Measured streamflows between the Site and the mouth of Railroad Creek generally increases on the order of two to three times. Portions of Railroad Creek between mile 5-1/2 (measured from the mouth) to approximately one-half mile upstream of Lucerne flow directly atop bedrock. Several waterfalls, estimated to be on the order to 50 or more feet in height, exist throughout this segment of Railroad Creek.

The last approximately one-half mile of Railroad Creek near the mouth flows atop alluvial sand and gravel. It is likely that this portion of the creek may be losing a relatively small amount water to these alluvial materials in which the USFS Lucerne guard station water supply well is installed.

The iron-oxide staining and/or flocculent were observed on the creek substrate to slightly east and downstream of the Sevenmile Creek confluence at RC-10. Suspended iron-oxide flocculent was observed in Railroad Creek throughout the stream reach from the Site to the mouth during spring melt and storm events.

Results of Hydrologic Modeling

Streambank Erosion

The results of the hydrologic modeling indicated that the existing riprap height would be marginal in protecting the tailings pile slopes during a 100-year storm event. The area with the highest potential for overtopping by Railroad Creek was the northwest corner of tailings pile 2 immediately downstream of the Copper Creek confluence.

Riprap Size

The results of the modeling indicated that some of the riprap is not of adequate size to prevent removal during a 100-year event. As noted earlier in this section, the existing riprap appears to be actively eroding; therefore, the size of the riprap will decrease over time. Areas with some riprap of marginal size included the majority of tailings pile 1, the eastern half of tailings pile 2, and the majority of tailings pile 3. The size of riprap immediately downstream of the confluence of Railroad Creek and Copper Creek generally appeared adequate. The removal of inadequately sized riprap during a storm event may result in delivery of tailings materials to Railroad Creek.

A 500-year event was not analyzed, with or without fire and landslide upstream scenarios; however, it is assumed that such an event would remove additional riprap and likely result in erosion and the release of tailings materials to Railroad Creek.

8.2.3.2 Copper Creek

The primary tributary to Railroad Creek is Copper Creek which enters Railroad Creek at the Site between tailings piles 1 and 2. Copper Creek provides less than 10 percent of the total flow of Railroad Creek at this location. The source of Copper Creek is the basin to the south of the Site. Due to the relatively steep gradient and irregular substrate, it is difficult to determine whether Copper Creek is losing water adjacent to tailings piles 1 and 2.

Groundwater measurements collected from nearby wells installed in tailings pile 2 infer a losing condition for Copper Creek adjacent to the tailings piles for portions of the year. However, it is reported that much of Copper Creek is diverted to the hydroelectric plant during the winter months to provide electric power for Holden Village. Consequently, the potential for loss of water to the tailings piles is likely limited during this period of time.

8.2.3.3 Copper Creek Diversion

Copper Creek contains a concrete weir approximately one-half mile southeast of the Site. A pipe transports a portion of the Copper Creek water to the Holden Village hydroelectric plant located immediately west of tailings pile 1. The water exits the plant and flows above-ground to Railroad Creek. The drainage, known herein as the Copper Creek Diversion, comes into contact with the western limit of tailings pile 1. A portion of the stream flows through a pond utilized by Holden Village residents and visitors for cooling off after using the sauna facility before it also exits into Railroad Creek.

8.2.3.4 Mine Portal Discharge

1500-Level Main Portal Drainage

After the operations ceased in 1957, the lower workings of the underground mine eventually filled with groundwater. The water now flows out of the lowermost mine opening at the 1500-level portal near the abandoned mill facility. Weekly flow measurements were collected during the RI between May and October 1997. In addition, a data logger was installed in a weir placed at the portal opening in early October, 1997 in order to collect nearly continuous water level readings. The measured flow rates ranged from approximately 0.10 to 0.20 cfs (approximately 45 to 90 gallons per minute) from about September to April, with isolated peak flows as high as 3.5 cfs (approximately 1,570 gallons per minute) during spring melt in May and June of 1997; in comparison, peak flows for May and June of 1998 were measured to be less than approximately 1.8 cfs (approximately 808 gallons per minute).

An analysis of precipitation data collected during the RI when compared to the portal drainage flows for the same period indicates a relatively rapid response (within approximately one to two days) in flow rates in the portal drainage after a precipitation event in spring through early summer. From approximately mid-summer through fall, the influence of precipitation on portal drainage flow rates appears minimal. This suggests that the bedrock is saturated during the spring to early summer months, and unsaturated for most of the remainder of the year.

It is likely that much of the water enters the mine from the ground surface through fractures and/or joints in bedrock. The slopes above the 1100-level mine portal were mapped as being devoid of glacial soil cover, which would limit the percolation of meteoric water into the bedrock, and eventually into the mine. In contrast, the slopes below the 1100-level mine portal are mapped as generally covered with the glacial soil; therefore, both the infiltration of surface water into the bedrock, as well as exfiltration from the underground mine through fractures and joints in the bedrock, is anticipated to be limited below this level of the mine.

8.2.3.5 Surface Water Runon/Runoff Features

General

Surface water run on at the Site occurs primarily in the form of near-surface and overland flow from the slopes to the south during the spring snowmelt period. As the snowmelt proceeds and diminishes, the run on appears to make a transition to being predominantly subsurface flow within the near-surface soils.

Surface water runoff at the Site also varied seasonally. All surface water runoff was noted to eventually flow into Railroad Creek. During the spring snowmelt period, the runoff was noted to be principally in the form of overland flow and seeps (as noted earlier in this report, the term seeps utilized in this RI includes surface expressions of groundwater that are sources of potential metals loading principally from the mill, mine support, Honeymoon Heights, and tailings pile areas into Railroad Creek).

During the May to June spring snowmelt period, one area of overland flow was observed emanating from the lagoon which collects surface water runoff from the mill and waste rock piles. In addition, 26 seeps were observed flowing and/or collecting water during the May-June event. Later in the spring and summer seasons, the surface water runoff decreased significantly when compared to the spring snowmelt period. In September of 1997 and 1998, no indications of overland flow were noted and only three seeps located at the base of the tailing piles were observed flowing.

Western Portion of Site

The principal surface water run on features observed in the mill and mine support area, including the maintenance yard, were a series of seeps (groundwater expressions) that flow overland from the mill building and from near the base of the two waste rock piles during the May-June event. This overland flow discharges into the lagoon which flows directly into Railroad Creek for intermittent periods during the spring snowmelt. However, by September, the seeps were no longer present and the lagoon no longer contained standing water. The decrease in the water level of the lagoon results from a combination of infiltration into the underlying soils and evaporation.

The lagoon is coincident with the mapped location of a pre-existing Railroad Creek channel before the tailings piles were constructed. Consequently, the abandoned stream bed may be acting as a preferential pathway for the draining of the lagoon feature. The pre-existing stream bed was observed on historic Site maps to intersect Railroad Creek near the northwest corner of tailings pile 1, near seeps SP-1 and SP-2.

Intermittent surface water flowing adjacent to two mine waste rock piles in the Honeymoon Heights area (1100 and 800 levels) eventually disappears into talus rock which appears to contain some waste rock. Intermittent seepage from the 1100-level portal also infiltrates into the waste rock pile adjacent to the mine opening. The intermittent drainage from this portion of the Site appears to be coincident with overland flow associated with two seeps adjacent to Railroad Creek, seeps SP-12 and SP-23. In addition, it is possible that some of the Honeymoon Heights intermittent drainage water migrates into the underground mine through fractures and joints in the bedrock. A dye test was completed during the RI to test the hypothesis that discharge from the SP-12 and SP-23 seeps and 1500-level main portal drainage are connected with the Honeymoon Heights intermittent drainage; however, the results were inconclusive.

Eastern Portion of Site

Snow accumulates atop the tailings piles during the winter months and melts during the spring runoff period. A series of the trenches were constructed between 1989 and 1991 up slope and on the surface of the tailings piles with the intent of intercepting surface water run on, and reducing the ponding of water on top of the piles. Most of the water is conveyed in the ditches in the surface of the tailings piles which eventually discharges either to Copper Creek or Railroad Creek. The ditch systems serve to divert water off the tailings piles but do not prevent ponding of water in contact with tailings.

A series of three ditches were constructed on the surface of tailings pile 1. The ditches drain water to the north to Copper Creek Diversion and to the east to Copper Creek. The ditch located in the western portion of the tailings pile also transmits seep water which emanates from the base of the east waste rock pile. One of the ditches present along the southern margin of the tailings pile was observed to be draining into what appears to be an abandoned wood-lined decant tower which was not plugged during the 1989 to 1991 tailings pile rehabilitation.

Tailings piles 2 and 3 also have a system of drainage ditches on the surface of the piles. The ditches divert surface water run on to the east indirectly into Railroad Creek at seep SP-21, east of tailings pile 3. A series of ditches were also observed in a road cut above tailings pile 3; the ditch appears to intercept some of the surface water run on before it comes into contact with the tailings piles. The water that drains to the east from tailings piles 2 and 3 enters a wetland area to the east of tailings pile 3 before eventually discharging to Railroad Creek.

8.2.3.6 Lake Chelan

Lake Chelan is the largest and deepest natural lake in Washington State. The lake is more 50 miles long with an average width of one mile. It is the third deepest lake in the continental United States. The deepest portion of the lake is in the Lucerne Basin, approximately mid-way up the lake and is approximately 453 meters (1,486 feet) deep.

Railroad Creek is the second largest hydrologic source to Lake Chelan, historically contributing approximately 10 percent of the annual input to the basin. The largest is the Stehekin River, at the northern end of the lake. The mouth of the Railroad Creek is situated on the west side of the lake, approximately 15 miles south of the northern end of the lake. Sediments transported by Railroad Creek are deposited in a delta near the mouth of the creek. However, the Stehekin River contributes more sediment to Lake Chelan than does Railroad Creek.

A dam is present at the southernmost end of the lake; the dam raises the water as much as 21 feet above the pre-dam level. During summer, the lake level is approximately 1,100 feet above sea level. When full, the lake has an area of about 52 square miles. The water flows through the dam, over a water falls to the Columbia River. There is no direct pathway for fish to migrate from the Columbia River to Lake Chelan.

8.2.3.7 Aquatic Reference Reaches

The three aquatic reference reach streams are relatively similar to relevant segments of Railroad Creek in terms of hydrologic conditions. However, the reference reach segment selected in Bridge Creek was noted to have deeper pools than Railroad Creek. The selected segment of the South Fork of Agnes Creek was similar in gradient and character as Railroad Creek, but with lower streamflows. The selected segment of Company Creek was situated near the confluence of the Stehekin River.

8.2.4 Groundwater

8.2.4.1 Railroad Creek Watershed

Groundwater within the Railroad Creek valley exists as several relatively isolated occurrences: 1) a shallow occurrence within the near-surface sand and gravel (reworked glacial till), and perched above the less permeable glacial till; 2) a deeper occurrence within the glacial till unit; and 3) within the bedrock.

The permeability of the uppermost occurrence is anticipated to be relatively high; it is anticipated that the majority of near-surface groundwater occurrence is within reworked glacial till unit. Groundwater permeability within the glacial till and bedrock are anticipated to be orders of magnitude lower than the near-surface occurrence, but are difficult to measure due to the random distribution of fractures and/or joints in which water flows, and the relatively low probability of intercepting these fractures during a field testing program (i.e., drilling and monitoring well installation). Groundwater within the glacial till is likely limited to isolated zones of higher permeability sand and gravel. The bedrock groundwater is anticipated to be limited to fractures and joints. The groundwater within the watershed flows eventually into Railroad Creek.

8.2.4.2 Site

General

The groundwater underlying the Site generally exists as the same general three occurrences discussed above for the Railroad Creek watershed. Groundwater and surface water conditions on the Site are considered to be dynamic (refer to Section 4.0 for further details). Surface water infiltrates into the ground surface, travels along surfaces of relatively low permeability soil layers such as glacial till, and either emanates from the base of slopes as springs or seeps, or eventually enters Railroad Creek as diffuse groundwater. Groundwater movement through the bedrock in the mine is anticipated to be significantly greater than the surrounding non-mined bedrock. In addition, isolated groundwater occurrences exist within the tailings piles.

The groundwater levels are highest during spring snowmelt, which is reflected in the relatively frequent occurrences of springs and seeps flowing during that period of time, and by the relatively high portal drainage flow rates. The groundwater levels decline as the source of groundwater recharge, snowmelt and precipitation, decrease over the summer and early fall periods. This is reflected in the reduction in measured Site seeps from a maximum of 26 in the period of the May-June 1997, to three in September 1997, and the reduction in discharge rates from the portal drainage, from a peak of approximately 3.5 cfs to a measured low of approximately 0.1 cfs.

Western Portion of Site

Underground Mine and Honeymoon Heights

The bedrock underlying the Site is likely saturated (the fractures and joints are assumed to be filled with water) during the spring snowmelt period through early summer. Water originating as snowmelt and rainfall likely infiltrates into the upper workings of the mine through the fractures and joints in the bedrock in areas where the bedrock is not covered with glacial till. The 1100-level is generally considered the upper limit of the glacial till unit in the Honeymoon Heights area. A mining engineer who worked at the Site during the period of mine operation reported that water flow into the mine was diffuse, and not focused in the areas of mapped faults. Water was removed from the mine to the surface during operation by utilizing several pumps and trenches in the tunnels. Flows were reportedly higher during the spring snowmelt period.

A small volume of water seepage was observed flowing from 1100-level portal in the Honeymoon Heights area, above the 1500-level portals. Based on the evaluation of the geochemical characteristics described in Section 6, this seepage is assumed to be meteoric water draining through the bedrock near the tunnel opening. The water exits the 1100-level portal and infiltrates into the 1100-level waste rock pile. The groundwater is assumed to intercept the glacial till contact which generally prevents the water from re-entering the bedrock groundwater system and, therefore, the underground mine. The water is assumed to eventually enter Railroad Creek through the reworked glacial materials which are present on the valley floor.

Surface water flow from the intermittent drainage within the avalanche chute immediately east of the 1100- and 800-level mine portals travels downslope on the surface of the exposed bedrock before infiltrating through a mixture of mostly talus debris and minor amounts of waste rock near the base of the slope below the 1100-level mine portal. Groundwater infiltrates the mixture of talus and waste rock and is assumed to travel downslope at the contact with the relatively impermeable glacial till unit within the glacial reworked material. The groundwater is assumed to eventually flow into Railroad Creek; a dye test was conducted during the RI to test this hypothesis; however, the results were inconclusive.

After mining operations ceased in 1957, the underground mine eventually filled with groundwater to the level of the lowermost mine opening at the 1500-level portal (portal drainage). The 1500-level main and ventilator portals were surveyed as part of the RI. The 1500-level ventilator portal was determined to be approximately 20 feet higher in elevation than the 1550-level main portal. The tunnels connect approximately one-half mile back in the mine. The groundwater in the mine is, therefore, assumed to flow out of the 1500-level main portal. The 1500-level ventilator tunnel has a relatively small volume of water flowing from the portal during the spring snowmelt period (less than an estimated 5 gallons per minute). The water observed flowing from the ventilator is assumed to be meteoric water draining through the glacial soil near the tunnel opening.

The 1500-level main portal is partially caved at the entrance, but the caving does not currently impede the flow of groundwater from the mine. It is reported that during the late 1960s, a blockage prevented groundwater discharge from the mine for a period of time. The blockage eventually broke free, resulting in a sudden release of groundwater from the mine.

Mill, Mine Support, and Waste Rock Piles

Sources of groundwater recharge within the glacial/alluvial deposits beneath the western portion of the Site are melt water from the watershed and south of the tailings piles. This component of groundwater recharge appears to decrease after the spring snowmelt period. Infiltration of precipitation and melt water through the surfaces of the waste rock piles adjacent to the mill building likely contributes relatively minor amounts of seasonal water to the near-surface groundwater occurrence beneath the western portion of the Site. Other contributing components to the groundwater occurrence within the glacial/alluvial soil beneath the western portion of the Site include groundwater infiltration from overland flow between the 1500-level main portal and the confluence at RC-4, as well as from the Copper Creek diversion (which is piped to the hydroelectric plant and flows out above ground in a ditch to Railroad Creek) and Copper Creek.

Eastern Portion of Site

Tailings Piles

Groundwater monitoring wells installed by others were completed both within the tailings piles and in native soil underlying the tailings materials. Groundwater levels within the tailings materials were measured in the wells from May-June through September, 1997. The water levels in the wells completed in the tailings materials generally consistent throughout the period, fluctuating a maximum of approximately 2 feet. A total of seven permeability (percolation) tests were completed on the surface of tailings piles 2 and 3 by Dames & Moore and others. These data indicate that the permeability of the tailings is relatively low, with permeability values ranging from 1 x 10^{-3} to 1 x 10^{-5} centimeters per second (cm/sec).

In contrast, the groundwater levels in the wells installed in the native soil underlying the tailings piles tend to fluctuate markedly throughout the May to September sampling period. The water levels in the wells installed near the southern margin of tailings piles 2 and 3 were observed to fluctuate in excess of 30 feet. This compares to a fluctuation of approximately 3 feet in wells installed beneath the tailings materials nearest Railroad Creek, near the northern margin of the tailings piles.

These data strongly suggest that the groundwater within the native reworked deposits during the spring snowmelt period occurs as two primary components: one flowing generally parallel to Railroad Creek near the valley floor within the glacial reworked deposit; and a second component flowing downslope towards Railroad Creek. Using vectors to illustrate the two components, the spring snowmelt period is believed to consist of two relatively equal vectors which are generally perpendicular to each other until the groundwater flow pathways intersect near the valley floor to then flow eastward parallel to Railroad Creek.

Based on the results of both two-dimensional groundwater modeling and surface water flow measurement, the groundwater flow into Railroad Creek during May/June was calculated to be on the order of 5 cfs along tailings piles 1 and 2, and 2.1 cfs along tailings pile 3. In contrast, as the snowmelt and precipitation diminish through the summer months, the vector parallel to Railroad Creek becomes more predominant. The groundwater flow into Railroad Creek during September was calculated to be on the order of 1.0 cfs along tailings piles 1 and 2, and 0.4 cfs along tailings pile 3.

These changes in predominant groundwater components throughout the spring and summer months are also reflected in groundwater levels within the near-surface soils. The spring melt water and precipitation flows from the slopes south and above the tailings piles through the native soil beneath the tailings piles. Since the native soil is of higher permeability than the tailings materials, the water is relatively confined, creating a hydrostatic head pressure in the groundwater beneath a portion of the tailings piles. The pressure likely forces some of the groundwater upward into the tailings materials during the spring months.

However, as the snowmelt diminishes and groundwater flow decreases, the hydrostatic head decreases and eventually diminishes. By September, and for the remainder of the fall and winter months, the groundwater is assumed to generally flow from the tailings materials into the groundwater beneath the piles. Data loggers installed in seven of the groundwater monitoring wells in May-June 1997 will allow further confirmation of this phenomenon during the winter months.

8.2.5 Other Physical Site Features

8.2.5.1 Mine and Honeymoon Heights

The underground mine features were evaluated by reviewing maps completed during and after the mining was conducted. The mine was not entered as part of the RI due to safety considerations. The review of the mine maps indicated the presence of over 56 miles of underground workings. The majority of underground workings below the 1500-level main portal were backfilled with tailings during the operation of the mine. The workings above the main portal level are reported to be open and were not backfilled.

The mine includes 16 primary levels and approximately the same number of secondary levels which are connected by two shafts and a series of inclines. The lowest level in the mine, the 2500 level, is approximately 800 feet below the Railroad Creek valley floor at the Site. The uppermost level of the mine, the 300 level, is approximately 1,400 feet above the valley floor.

The majority of the mine workings were completed in the area generally beneath the 1100- to 300-level portals; the horizontal distance of the majority of the mine workings is approximately 3,000 feet. The north westernmost extent of the underground mine workings is on the 2325-level that was terminated beneath the 1500-level ventilator portal, and is approximately 800 feet below the valley floor. The south easternmost extent of the mine is on the 1500-level that was terminated approximately 13,600 feet from the 1500-level ventilator portal, and is approximately 700 to 800 feet below Copper Creek Basin. No near-surface stopes are noted to exist on the mine and geologic maps below the 1000-level portal. The transverse faults which intersect both of the 1500-level tunnels are noted to be covered with glacial till below the 1100-level mine portal.

8.2.5.2 Mill, Mine Support Area, and Waste Rock Piles

The interior of the mill facility was not evaluated in depth due to safety considerations and because the USGS had completed an assessment earlier. A sample of wall insulation was collected during the RI to assess the presence or absence of asbestos-containing materials (ACMs); no ACMs were found. Some unprocessed ore (less than approximately 20 cubic yards), as well as limited quantities of concentrate, are located in the remains of the mill building.

The maintenance building is located northwest of the mill building. The initial building was constructed by Howe Sound Company and was utilized to maintain vehicles. The building was lost to a fire but was replaced in the 1970s by Holden Village for maintenance of the transport vehicles and other equipment. Petroleum hydrocarbons in the form of fuel products and lubricants are utilized in the operations. A newer maintenance building, which also houses the Holden Village potable water treatment system, was constructed in 1998 to the east of the older maintenance building and to the north of the mill structure.

8.2.5.3 Winston Home Sites Underground Storage Tanks

The assessment of the underground storage tanks (USTs) in the Winston Home Sites area documented the presence of approximately 38 USTs and 2 above-ground storage tanks (ASTs). Test pit excavations completed immediately down slope of eight USTs and the Winston home sites area did not detect petroleum hydrocarbons in soil.

The tanks are not regulated under State of Washington or federal UST regulations because they are less than 1,000 gallons in size and have been used for home-related fuel storage for home heating. It has been reported by individuals who were at Holden Village as volunteers during the 1960s that the majority of fuel product in most, if not all, of the tanks was removed for use in Holden Village.

8.2.5.4 Potential Borrow Source Areas

The borrow source evaluation included the assessment of a rock quarry located in the eastern portion of the Railroad Creek drainage near Dan's Camp. The quarry was utilized as the source for the rip rap placed along the banks of Railroad Creek in 1991. The rock exposed in the quarry was evaluated visually and with rock soundness testing method. The rock was determined not to be of sufficient quality to be utilized in the future as riprap.

An alternative source of rip rap was investigated in a talus slope approximately one mile east of Holden Village near the existing road to Lucerne. This potential source was evaluated by the USFS in 1989 as part of the tailings pile rehabilitation project. The rock was found to be of adequate quality to be used as riprap. This was supported by the findings of Dames & Moore in 1997. The source was reportedly eliminated for consideration by the USFS due to potential dangers associated with rock fall. However, it would appear feasible to remove the rock by incorporating all safety considerations in the design.

A source of granular borrow material was discovered in the slope immediately southeast of tailings pile 3. The amount of material for future site activities, if necessary, will need to be further evaluated during design in order to determine if the source is of sufficient size and quality.

8.2.6 Ecological Conditions

8.2.6.1 Aquatic Biota

The aquatic biota were evaluated by collecting both fish and benthic macroinvertebrates (aquatic insects) from selected reaches of Railroad Creek and control areas, or reference reaches, both in the Railroad Creek watershed and outside the watershed. Five sampling locations were selected within the segment of Railroad Creek adjacent to and downstream of the mine tailings piles. Two sampling stations were established upstream as control or reference sites for comparison to the reaches of Railroad Creek adjacent to and immediately downstream of the mine tailings piles. Three reference stations, Bridge Creek, South Fork of Agnes Creek, and Company Creek, were established in the Stehekin watershed, outside the Railroad Creek watershed, for comparison to reaches of the downstream segment (between RC-5 and RC-10) and the mouth of Railroad Creek (RC-3).

Macroinvertebrate sampling included the collection of eight replicates per site which were applied to seven indices to measure the community health or impairment, including species richness, ratio of scrapers and filtering collectors (types of aquatic insects), ratio of specific benthic insects species (EPT, or Ephemeroptera, Plecoptera, and Trichoptera) to the abundance of certain specific species (Chirononmidae), percent contribution of dominant taxa, an EPT index, a community loss index, and ratio of shredder functional feeding group to the total number of individuals collected. The total number of organisms was also used as an indication of community health or impairment.

The fish surveys were conducted in the Railroad Creek and the reference reaches by utilizing snorkel and electrofishing methods in all but two of the stations. Increasing water levels resulting from a storm event precluded sampling by electrofishing methods at the South Fork of Agnes Creek site. The presence of spawning Kokanee salmon precluded the use of electrofishing methods at the Company Creek sampling location.

The results of the two fish sampling methods were found to be relatively consistent. However, electrofishing methods resulted in higher fish counts at sites where debris and/or bank overhangs were present which reduced visibility for the snorkeling method. The number of fish presented herein is calculated based on the actual number of fish for the sampling station area multiplied to correspond to fish per hectare, or approximately 2-1/2 acres per hectare, an international standard area for fish surveys.

No indications of gross abnormalities or disease were noted in the surveys completed by others (PNL, 1992) and Dames & Moore.

The control areas or reference reach segments of Railroad Creek were selected based on the results of a literature review, interviews with knowledgeable parties, development of key habitat variables, analysis of candidate reaches, and a limited field reconnaissance. Observations made during the aquatic survey allowed for a more thorough assessment of the comparability of the references with the appropriate Railroad Creek stations adjacent to and downstream of the Site to be conducted.

The following presents the results of the RI aquatic biota survey from upstream to downstream in Railroad Creek.

Railroad Creek Reaches

Upstream Stations RC-6 and RC-1

RC-6 was located at the Glacier Peak Wilderness boundary, whereas RC-1 was located approximately 120 meters downstream of RC-6. The sites were selected as references or controls for the segment of Railroad Creek between RC-9 and RC-7, described below. The references for the remainder of the downstream Railroad Creek segments are discussed later in the Stehekin River Watershed Reference Reaches subsection.

The average total number of benthic macroinvertebrates collected in the eight replicate samples at RC-6 and RC-1 were 1006 and 1065 per square meter, respectively. The actual values in the replicate samples ranged from 330 to 1560 per square meter at RC-6, and 650 to 1700 per square meter at RC-1.

The calculated total numbers of fish caught at RC-6 and RC-1 were 64 and 128 per hectare, respectively. The fish caught were a combination of rainbow and rainbow/cutthroat hybrids. The fish length ranged from approximately 70 to 90 millimeters.

Adjacent to Tailings Pile 1 (RC-9)

The portal drainage enters Railroad Creek approximately 1,200 meters upstream from RC-9 and is a source of metals loading to Railroad Creek, primarily cadmium, copper, and zinc. The RC-9 station was established downstream of the Portal Drainage confluence (P-5), near the northeast corner of tailings pile 1, immediately upstream of the confluence of Copper Creek. The station location was selected due to the transition of the presence of iron-oxide staining on the substrate of the creek within the 100-meter length of stream reach.

The average total number of benthic macroinvertebrates collected in the eight replicate samples was 330 per square meter. However, the actual values in the replicate samples ranged from 10 per square meter at within the area of iron-oxide staining and flocculent (suspended iron-oxide precipitate) to 1510 per square meter at in upstream portion of the sampling station without staining.

The species of aquatic insects also changed from the upstream to downstream portions of the sampling station. The number of organisms that feed by collecting detrital materials in the stream substrate were reduced in the area of iron-oxide staining. However, three species of filter feeding insects were found unique to the segments of the RC-9 and RC-7 sampling stations which contained the iron-oxide staining. This is considered significant because filter feeders are generally more affected by contaminants in the water column due to their greater exposure to water. In addition, bioassays were completed by Ecology (Johnson, et al. 1997) utilizing a sensitive filter feeder, cladocerans (*Ceriodaphnia*) and Railroad Creek water collected upstream, immediately downstream of the tailings, approximately three miles downstream of the site, and at the mouth of Railroad Creek; the results indicated no adverse effects.

The total calculated number of fish caught at RC-9 were 114 per hectare. The fish caught were exclusively cutthroat trout. The lengths of fish ranged from approximately 180 to 260 millimeters. The fish were all caught outside the iron-oxide stained area.

Adjacent to Tailings Pile 3 (RC-7)

The RC-7 sampling station was located adjacent to tailings pile 3, upstream of the RC-2 water quality station. The sampling site was situated in an area of iron-oxide staining and flocculent.

The average total number of benthic macroinvertebrates collected in the eight replicate samples was 64 per square meter. The actual values in the replicate samples ranged from 10 per square meter to 140 per square meter. As noted above at the RC-9 station, three species of filter feeding insects were found unique to the RC-7 sampling station.

The calculated number of fish caught at RC-9 were 10 per hectare, and exclusively cutthroat trout. The length was approximately 180 millimeters.

Above Tenmile Creek Confluence (RC-5)

The RC-5 sampling station was located approximately 500 meters downstream of tailings pile 3, immediately upstream of the Tenmile Creek confluence. The amount of iron-oxide staining and flocculent affects was less than observed at RC-7.

The average total number of benthic macroinvertebrates collected in the eight replicate samples was 52 per square meter. The actual values in the replicate samples ranged from 20 per square meter to 150 per square meter.

The total calculated number of fish caught at RC-5 was 20 per hectare, and exclusively cutthroat trout. The fish length ranged from approximately 180 to 215 millimeters.

Sevenmile Creek Confluence (RC-10)

The RC-10 station was located approximately 5 kilometers downstream of tailings pile 3, near the confluence of Sevenmile Creek. Iron-oxide staining was noticeable at this sampling site; however, no indications of a iron-oxide flocculent were noted at the time of sampling.

The average total number of benthic macroinvertebrates collected in the eight replicate samples was 75 per square meter. The actual values in the replicate samples ranged from 20 per square meter to 110 per square meter.

The total calculated number of fish caught at RC-10 was 153 per hectare, and exclusively cutthroat trout. The fish length ranged from approximately 30 to 200 millimeters. The smaller fish were "first of the year" which are normally more sensitive to toxicity than larger fish.

Approximately 100 Meters Upstream of Mouth (RC-3)

The RC-3 station was located approximately 100 meters upstream of the mouth of Railroad Creek.

The average total number of benthic macroinvertebrate populations collected in the eight replicate samples was 381 per square meter. The actual values in the replicate samples ranged from 210 per square meter to 540 per square meter.

The total calculated number of fish caught at RC-3 were 153 per hectare. The species of fish caught included cutthroat trout and sculpin. The length of cutthroat was approximately 110 millimeters. Isolated pockets of gravel potentially suitable as spawning habitat were observed; however, the areas were considered small and marginal for use during spawning.

Even though the RC-3 station provided limited habitat for spawning, Kokanee salmon were observed spawning throughout the reach. Salmon are not allowed to be caught when spawning. Consequently, the number and sizes of salmon in this reach could not be determined for the aquatic survey.

Reference Reaches – Upstream Railroad Creek

RC-1 and RC-6 as References for RC-9 and RC-7

Control areas or reference reach segments of Railroad Creek were selected in order to evaluate the aquatic biota data collected from the segments of Railroad Creek adjacent to and downstream of the site. The selection process was based on ten primary factors, including channel slope, valley width, watershed area size, presence of glaciers, presence of lakes, dominant geology, elevation, drainage network, aspect, and presence of downstream fish barriers. Based on these criteria, it was discovered that the pool of candidate reference streams were situated both upstream of the site within the Railroad Creek watershed and in the North Lake Chelan Basin, north of the Railroad Creek watershed.

It appears that the stream and habitat conditions observed at the RC-6 and RC-1 sampling stations are generally similar to those observed at the RC-9 and RC-7 stations in Railroad Creek, and are, therefore, considered appropriate control or reference reaches. Benthic macroinvertebrate communities appear suppressed within the reach of Railroad Creek that extends adjacent to tailings piles 1, 2, 3, compared to the reference stations based on the 1997 aquatic sampling results. While the density of benthic macroinvertebrates at station RC-7 indicates an affected community, it should be noted that the RC-9 sampling station includes an apparent transition into the influence of tailings pile seepage originating near the south bank of the sampling station. The downstream portion of the station has obvious indication of staining from the tailings pile seeps, while the upstream portion is relatively free of any staining or flocculent-like material on the substrate. Of the eight benthic macroinvertebrate samples collected at this station, four were collected either upstream from the initial staining or near the north bank, while the remaining four were collected within the staining or along the south bank. The density of benthic macroinvertebrates within the samples collected upstream or along the north bank ranged from 260 to 1,510 organisms per m^2, while the density of benthic macroinvertebrates within the staining or along the south bank ranged from 10 to 300 organisms per m^2. The benthic macroinvertebrate results indicate that the communities may be similar to the reference communities, while those immediately downstream of the flocculent are reduced compared to the reference stations.

The 1997 fish survey results at RC-9 and RC-7 varied widely between the two stations (RC-9, 114 trout/hectare and RC-7, 10 trout/hectare); however, the density of trout at RC-9 was within the range of the reference trout densities (64-93 trout/hectare). As indicated by the habitat evaluation scores, station RC-9 had the least desirable habitat (score 77) of all stations sampled, while RC-7 had the third lowest score (94). The reference stations for the reach, RC-6 and RC-1 scored 111 and 105, respectively.

Water quality samples were not collected at RC-9 during the 1997 investigation. The results of samples collected from RC-7 indicate exceedances of water quality criteria for acute toxicity during April (zinc), May (cadmium, copper, and zinc), and July (copper and zinc). Based on the benthic macroinvertebrate sampling results from RC-9, the physical conditions of the substrate within these stations may also adversely influence these communities. Comparison of the individual benthic macroinvertebrate and fish sampling results with the iron-stained and non-iron stained portions of RC-9 indicate that the occurrence of iron flocculent within a portion of the reach has a greater influence on fish and macroinvertebrate populations than dissolved metal concentrations.

Reference Reaches - Stehekin River Watershed

Three stream reaches approximately 100 meters in length were selected within the Stehekin River watershed as references for the other remaining downstream reaches of Railroad Creek. The selection of the reference reaches was difficult due to the relatively unique conditions in Railroad Creek below the Site.

The reference reach aquatic sampling program also included the collection of surface water samples in order to assess potential influences of water quality on the populations of benthic macroinvertebrates and fish.

Bridge Creek and South Fork of Agnes Creek as References for RC-5 and RC-10

During the RI, it was discovered that the segment of Railroad Creek between RC-5 and RC-10 was unique relative to the Railroad Creek upstream reference stations (RC-6 and RC-1), and with respect to gradient (channel slope), watershed area size, and elevation. Consequently, it was decided to attempt to bracket the RC-5 and RC-10 conditions by selecting two reference reaches: one site on the South Fork of Agnes Creek, which was smaller than the relevant stations on Railroad Creek, and one site on Bridge Creek, which was larger than the relevant stations on Railroad Creek.

The Bridge Creek site was located approximately six miles upstream of the confluence of the Stehekin River, at Sixmile Camp. The average total number of benthic macroinvertebrates collected in the eight replicate samples were 997 per square meter. The actual values in the replicate samples ranged from 500 per square meter to 1820 per square meter. The total calculated number of fish caught at the Bridge Creek site were 398 per hectare, predominantly cutthroat trout. The fish length ranged from approximately 10 to 250 millimeters. The majority of the fish at the Bridge Creek site were collected in one pool five to six feet deep.

The South Fork of Agnes Creek site was located immediately downstream of the Swamp Creek confluence. The average total number of benthic macroinvertebrates collected in the eight replicate samples was 1058 per square meter. The actual values in the replicate samples ranged from 490 per square meter to 1580 per square meter. The total calculated number of fish caught at the Bridge Creek site were 67 per hectare, and a predominantly rainbow trout.

The South Fork Agnes Creek and Bridge Creek stations appear generally comparable to the RC-5 and RC-10 stations in Railroad Creek. However, the majority of fish at the Bridge Creek station were caught in a large pool. The presence of the pool had a bearing on the numbers of fish caught. Since similar pools were not present at the South Fork Agnes Creek, RC-5 and RC-10 stations, the fish data from the Bridge Creek station are likely not comparable to these stations.

Benthic macroinvertebrate communities within RC-5a (52 organisms/m^2) and RC-10 (75 organisms/m^2) appear suppressed compared to the respective reference stations BC-1 and SFAC-1 (997 and 1,058 organisms/m^2, respectively) based on the 1997 aquatic sampling results. The substrate throughout both of these stations contains a flocculent material that is readily suspended when disturbed. Surface water samples collected from RC-7 during the 1997 investigation indicate that water quality criteria for acute toxicity were exceeded during April (zinc), May (cadmium, copper and lead), and July (copper and zinc). The reduced density of benthic macroinvertebrates may be the result of water quality conditions at RC-5a; however, although the criteria were never exceeded at RC-10. Benthic macroinvertebrate density at RC-10 is similar to that of RC-5a. The reduced density of benthic macroinvertebrates coincident with the apparent lack of aquatic toxicity at RC-5a suggests that this reduction is more attributed tot he physical presence of flocculent.

Fish survey results indicate reduced numbers at RC-5a (20 trout/ha)) compared to the reference densities of 59 and 384 trout/ha. However, trout density at RC-10 (92 trout/ha) was greater than the density estimated for South Fork Agnes Creek (59 trout/ha). Additionally, four 0+ year class trout (typically the life stage most sensitive to metals toxicity) were collected at RC-10 which may reflect the lack of water quality criteria exceedances. Habitat evaluation scores were slightly higher at the reference stations. Reference stations BC-l and SFAC-1 scored the highest of all aquatic sampling stations at 120 and 113, respectively. The onsite stations RC-5a and RC-10 scored slightly higher than the median score for all stations at 110 and 108, respectively.

Company Creek as a Reference for RC-3

The RC-3 station at the mouth of Railroad Creek was also discovered to be unique relative to the Railroad Creek upstream reference stations (RC-6 and RC-1), primarily with respect to gradient (channel slope), watershed area size, elevation, and its proximity to Lake Chelan (inhabited by a naturally reproducing population of kokanee salmon). The only site, within the pool of candidate reference sites, remotely similar to RC-3 was a site on lower Company Creek. This lower Company Creek site was initially eliminated from the pool of reference sites because only five of the ten parameters were considered comparable to the RC-3 site. However, because no other site was considered more comparable to RC-3 it was subsequently decided that aquatic data would be collected at the lower Company Creek site and analyzed for possible use.

The Company Creek station was situated immediately downstream of the Chelan County PUD hydroelectric plant, and immediately upstream of the confluence of the Stehekin River, which is a spawning ground for Kokanee salmon. The average total number of benthic macroinvertebrates collected in the eight replicate samples was 1266 per square meter. The actual values in the replicate samples ranged from 670 per square meter to 2950 per square meter. The total calculated number of fish caught at the Bridge Creek site was 571 per hectare, predominantly rainbow trout. The fish length ranged from approximately 10 to 250 millimeters. Kokanee salmon were observed but not caught due to the sampling taking place during the spawning period.

Based on the comparison with only one reference station, RC-3 appears to have reduced benthic macroinvertebrate densities. However, the Company Creek reference station was selected primarily to reflect conditions of a stream that was or could be frequented by spawning kokanee. As such, comparisons with the combined reference stations (non-Railroad Creek) provide a better indication of the benthic macroinvertebrate community conditions expected in lower Railroad Creek. Comparing the benthic macroinvertebrate results from RC-3 with the average densities of CC-1, BC-1, and SFAC-l indicates a reduction of approximately 34%. Water quality criteria were exceeded during April and May, leaving relatively suitable conditions during the summer and fall months for colonization of benthic macroinvertebrates.

Fish survey results at RC-3 indicated reduced trout density compared to the reference station (CC-1). RC-3 densities were approximately 25% lower than those estimated for CC-1. The habitat evaluation score at RC-3 was 93, the second lowest score of all aquatic sampling stations, compared to a score of 108 for CC-1 indicating possibly less desirable habitat than CC-1. Surface water samples collected at RC-

3 during the 1997 investigation indicate that water quality criteria for acute toxicity were exceeded during April (zinc) and May (copper and zinc). The relatively lower habitat quality and the presence of dissolved metals (primarily copper and zinc) at RC-3 may contribute to the reduced trout population as compared to CC-1; however, trout populations at RC-3 were greater than the upstream reference reach (RC-6/RC-1) within Railroad Creek.

The Company Creek reference station is not comparable to the RC-3 station on Railroad Creek for a number of reasons. The most significant being the proximity of the creek to the Stehekin River, which is a salmon spawning ground. In contrast, RC-3 is located immediately upstream of Lake Chelan which is a deep water body and not a fish spawning habitat. The stream substrate for Company Creek is also relatively high gradient with numerous large cobbles and boulders which provide excellent trout habitat, and is dissimilar from the RC-3 station. Consequently, the aquatic data collected at the Company Creek station are not considered directly comparable to those of the RC-3 station.

Precipitation Affects on Benthic Macroinvertebrates

It appears that periods of precipitation have an affect on the benthic macroinvertebrates results. The aquatic stations were sampled starting upstream at RC-6 and proceeded downstream to RC-3. After aquatic sampling at RC-10 was conducted, and before sampling at RC-3 was initiated, a storm event occurred which resulted in precipitation and increased stream flows in Railroad Creek. After the sampling was completed at RC-3, a series of additional benthic macroinvertebrate samples was collected at RC-6 within 24 hours of the precipitation event. The influence of precipitation affects on the benthic macroinvertebrates illustrates the variability and lack of precision for the benthic macroinvertebrate population estimating method employed, which is considered the scientific standard. Therefore, the data reflect the natural variability in the benthic macroinvertebrate communities of the Stehekin River drainage.

8.2.6.2 Terrestrial Biota and Wildlife

The RI included an assessment of the terrestrial biota in the area of the Site. For wildlife purposes, the Site and surrounding area was regarded as five sub-areas based on cover type. These sub-areas consisted of the mine tailings, the north-facing slopes and old mine surface workings, the south-facing slopes, the riparian area upstream of the tailings, the riparian area downstream of the tailings, and the tailings themselves.

The vegetation consisted of north-aspect coniferous forest in the area south of the mill and tailings piles, south-aspect coniferous forest and open areas to the north of Holden Village, upstream riparian habitat west of the baseball field and campground, downstream riparian east of tailings pile 3, and the tailings piles with sparse planted and volunteer coniferous trees, deciduous trees and shrubs, and various grasses, forbs, and sedges.

Terrestrial wildlife observed on the Site was generally consistent with the surrounding area. All of the species were either observed and/or assumed to utilize the tailings piles at times.

Potentially federal- and state-listed and candidate species potentially occurring in the vicinity of the Site include the Westslope cutthroat trout which is listed as a Species of Federal Concern. This species of cutthroat trout is found in Railroad Creek. However, the Westslope cutthroat has not been listed as threatened and/or endangered. The peregrine falcon, bald eagle, northern spotted owl, gray wolf, grizzly bear, lynx are listed as Special Status Species and have been observed in the Railroad Creek watershed.

8.3 SITE CONTAMINANT CHARACTERIZATION

8.3.1 Introduction

Site surface and subsurface soil, surface water, groundwater, seeps, sediment, and flocculent were analyzed principally for organic compounds as outlined in the Draft Work Plan, and Sampling and Analysis Plans. Additional select areas and matrices were analyzed for organic compounds. This section summarizes the designation of potential compounds of concern (PCOC). The designation of a matrix as a PCOC indicates that it exceeds a regulatory standard for screening purposes only, but does not necessarily signify that the compound presents risk to human health and the environment. A complete discussion of the results of each sample matrix was previously provided in Section 5.0, and the results of the human health and ecological risk assessment are presented in Section 7.0.

8.3.2 Soil

8.3.2.1 Mine Support Area

Maintenance Yard

Surface Soils

Arsenic, cadmium, copper, iron, lead, and total petroleum hydrocarbons were identified in five soil samples as PCOCs.

Subsurface Soils

Total petroleum hydrocarbons were identified in two subsurface samples as PCOCs.

Lagoon

Surface Soils

Beryllium, iron, and total petroleum hydrocarbons were identified as PCOCs in one soil sample collected in the lagoon.

Subsurface Soils

Cadmium, copper, lead, iron, and total petroleum hydrocarbons were identified as PCOCs in ten subsurface soil samples collected in the lagoon.

8.3.2.2 Tailings Piles

Surface Soils

Iron was identified as a PCOC in nine surface soil samples collected from the tailings piles.

Subsurface Soils

Cadmium, copper, and iron were identified as PCOCs in thirteen subsurface soil samples collected from the tailings piles.

8.3.2.3 Wind-blown Tailings

Iron was identified as a PCOC in five samples collected of wind-blown tailings downwind of the tailings piles.

8.3.2.4 Holden Village

Beryllium and iron were identified as PCOCs in nine surface soil samples collected in Holden Village (included four historical soil samples collected by others).

8.3.2.5 Baseball Field/Campground Area

Iron was identified as a PCOC in one surface soil sample collected in the baseball field.

8.3.2.6 Holden USFS Guard Station

Arsenic was identified as a PCOC in one sample collected and analyzed from the Holden USFS Guard Station.

8.3.3 Surface Water

Surface water samples were collected in April, May/June, July, and September/October in order to characterize water quality during the low flow conditions, the rising limb of the hydrograph, the peak and declining limb of the hydrograph, and low flow conditions which are expected to generally persist between September and March when spring thaw begins. The samples were analyzed for total recoverable and dissolved metals and conventional parameters as discussed in detail in Section 5.0. Three of the Railroad Creek stations were also analyzed for polychlorinated biphenyls (PCBs) and total petroleum hydrocarbons (TPH as gasoline, diesel, and heavier than diesel range).

8.3.3.1 Railroad Creek

Upstream of Site

Data from upstream stations were analyzed statistically and the 90th percentile concentrations were calculated and then compared to water quality criteria. The area background concentrations (as determined by the total data set) for arsenic, beryllium, cadmium, chromium, copper, iron, lead, mercury, nickel, selenium, silver, and zinc were compared to WQC. For those metals requiring hardness correction, background values were compared to the WQC using a minimum hardness of 6.7 ppm. This value was selected as it is representative of the lower hardness values obtained in the RI data and provides the most conservative WQC levels. Hardness concentration in Railroad Creek varied from 6.7 to 31 mg/L dependent upon the station location and sampling event. The lowest hardness values generally occurred in stations upstream of the Holden Mine. The background values were also compared to WQC based on

25 ppm hardness as this is the minimum hardness allowed for WQC under the federal guidance when actual hardness values are below 25 ppm. The WQC and background values are summarized below.

Metal	Background Concentration (µg/L)	WQC (µg/L) (hardness 6.7 ppm)		WQC (µg/L) (hardness 25 ppm)	
		AWQC	CWQC	AWQC	CWQC
Arsenic	0.9	360	190	360	190
Cadmium	0.07	0.20	0.14	0.82	0.37
Chromium	<0.2	60	19	180	57
Copper	1.06	1.3	1.1	4.6	3.5
Lead	0.54	3.1	0.12	14	0.54
Mercury*	0.00066/0.05	2.4	0.012	2.4	0.012
Nickel	0.39	144	16	440	49
Selenium	<0.2	20	5	20	5
Silver	<0.04	0.030	NE	0.32	NE
Zinc	7.81	12	11	35	32

*CWQC is based on total metals (0.00066 µg/L). AWQC is based on dissolved metals (0.05 µg/L).

Based on 6.7 ppm, lead and silver background concentrations (0.54 µg/L and <0.04 µg/L) may exceed the WQC. The lead background value of 0.54 µg/L is likely enhanced due to the suspected laboratory contamination previously discussed. However, if 0.54 µg/L is considered background, the value exceeds the CWQC of 0.12 µg/L if hardness is 6.7 ppm. In the case of silver, the detection limit currently achievable by modification of standard methods is 0.04 µg/L. With a hardness of 6.7 ppm, this detection limit will exceed the AWQC of 0.030 µg/L. The background copper concentration (1.06 µg/L) is only slightly below the WQC at a hardness of 6.7 ppm. Based on a minimum hardness of 25 ppm, the statistically derived background values are below acute and chronic WQC.

For those metals where WQC are not established, data were compared to MTCA Method B cleanup levels. Calculated background values did not exceed MTCA Method B cleanup levels.

Adjacent and Downstream of Site

Listed below are the dissolved metals that were above the AWQC and CWQC during the five sampling events.

Listed below are the dissolved metals that were above the State of Washington AWQC and CWQC, which are based on actual hardness values during the RI sampling events in 1997 and 1998.

Station[1]	April 1997 >AWQC/>CWQC	May/June 1997 >AWQC/>CWQC	July 1997 >AWQC/>CWQC	September/October 1997 >AWQC/>CWQC	May 1998 >AWQC/>CWQC
RC-4	Cu, Zn/ Cu, Zn	Cd, Cu, Zn/Cd, Cu, Pb, Zn	Cu, Zn*/Cu, Pb, Zn*	None/Pb	Cd, Cu, Zn/Cd, Cu, Zn
RC-7	(Fe) Zn/Cd, Zn	Cd, Cu, Zn/Cd, Cu, Pb, Zn	Cu, Zn*/Cu, Pb, Zn*	(Fe) None/Pb	Cd, Cu, Zn/Cd, Cu, Zn
RC-2	(Fe) Zn/Cd, Zn	Cd, Cu, Zn/Cd, Cu, Zn	Cu, Zn*/Cu, Zn*	(Fe) Zn/Zn	Cd, Cu, Zn/Cd, Cu, Zn
RC-5	(Fe) Zn/Cd, Zn	Cd, Cu, Zn/Cd, Cu, Zn	Cu, Zn*/Cu, Zn*	(Fe) Zn/Zn	Cd, Cu, Zn/Cd, Cu, Zn
RC-10	Not Sampled	Not Sampled	Not Sampled	None	Cu, Zn/Cd, Cu, Zn
RC-8	None	Not Sampled	Not Sampled	Cd/Cd, Pb	Not Sampled
RC-3	None/Zn*	Cu, Zn*/Cu, Zn*	None	None	Cu, Zn/Cu, Zn

[1] South bank samples not included

(Fe)- Iron is listed as criteria without reference to chronic or acute status.

Where zinc is marked with an asterisk (Zn*) in the above table, the exceedance of WQC could have been affected by the introduction of zinc during the field filtration process. Therefore, zinc concentrations at RC-3 and zinc concentrations detected in July 1997 should only be considered "apparent" exceedances.

Samples collected from the south banks at RC-4 and RC-2 in 1997 were compared to samples collected across the width of the creek. Concentrations of aluminum, cadmium, copper, manganese, and zinc detected on the south bank of RC-4 during May 1997 were above concentrations detected across the creek width. Concentrations of the other metals in July and September were similar between the bank and creek width samples, with the exception of copper. Data collected from the south bank at RC-2 were similar to data collected from the width of the creek.

The south bank results from RC-4 and RC-2 were compared to state and federal WQC. Metals above WQC in May, June, and July were generally comparable to the metals above WQC in samples collected across the creek width. The September 1997 data compared to state WQC indicate that copper and zinc at RC-4 and zinc at RC-2 are above WQC. The data from RC-4 indicate that copper is also above federal WQC during this timeframe.

In general, concentrations in the upstream stations did not fluctuate with seasonal or stream flow variations. Iron and hardness were inversely proportional to stream flow. Metal concentrations at the adjacent and downstream stations were generally higher that the upstream locations. The widest variation occurred in May. Concentrations were often similar by September. Most metal concentrations increased downstream of RC-1 at RC-4. Concentrations from RC-4 to RC-2 were similar or slightly decreased with the exception of iron, which increased substantially at RC-7. The concentrations of metals decreased from RC-2 down to RC-3.

8.3.3.2 Portal Drainage

The portal drainage reflects overland flow groundwater discharge from the underground mine. Water samples were collected during May/June, July, and September/October 1997, and May 1998 events. The data collected from the portal drainage and the analytical indicate seasonality in exceedances of applicable regulatory thresholds, as tabulated below.

Data collected at P-1 (portal) and P-5 (portal drainage confluence with Railroad Creek) were compared to WQC for surface water (WAC 173-201A) and MTCA Method B cleanup levels for surface water.

Additionally, the data at P-1 were also compared to Washington State ground water criteria (WAC 173-200) and MTCA Method B cleanup levels for groundwater. The following PCOCs were identified at P-1 and P-5.

	Locations	May 1997	July 1997	September 1997	May 1998
Surface Water Criteria	P-1	Be, Cd, Cu, Pb, Zn, pH	Cd, Cu, Pb, Zn, pH	Cd, Cu, Zn	Cd, Cu, Pb, Zn, pH
	P-5	Cd, Cu, Pb, Zn, pH	Cd, Cu, Pb, Zn, pH	Cd, Zn, pH	Cd, Cu, Pb, Zn, pH
Groundwater Criteria	P-1	As, Be, Cd, Cu, Pb, Zn, SO_4, pH	Cd, Cu, Pb, Zn, SO_4, pH	Cd, SO_4, TOS	Cd, Cu, Fe, Pb, Zn, SO_4, TOS, pH

8.3.3.3 Copper Creek Diversion

The Copper Creek diversion reflects water which is diverted from Copper Creek upstream of the Site and flows through the hydroelectric plant. The water was sampled during the April, May/June, July, and September/October events. The results of the analyses indicate that concentrations of cadmium, copper, and zinc were above regulatory thresholds for the spring sampling event only.

8.3.3.4 Copper Creek

Copper Creek, both upstream and adjacent to the tailings piles, was sampled during the May/June, July, and September/October events. No PCOCs were identified for Copper Creek.

8.3.3.5 Lake Chelan

Water quality samples were collected by Ecology in Lake Chelan near the mouth of Railroad Creek in 1989. The samples were analyzed only for arsenic, iron, and zinc. All of the results were noted to be below applicable aquatic life, water quality, and drinking water standards.

8.3.3.6 Aquatic Reference Reaches

Water quality samples were collected during the aquatic biota surveys conducted during the September/October event. The sampling was completed at one site each on Bridge Creek, South Fork of Agnes Creek, and Company Creek. At the South Fork of Agnes Creek station, lead and silver were detected at or slightly above chronic and acute criteria, respectively.

8.3.4 Groundwater

Groundwater samples were collected from selected groundwater monitoring wells installed across the tailings piles and a small portion of the western portion of the Site by others in 1991 and 1994; the western portion of the Site is defined as the general area to the west of the Copper Creek Diversion and southwest of tailings pile 1. Seeps were also sampled across the Site and the data were used to assess groundwater quality. The wells and seeps were sampled during the May/June and September/October 1997events. In addition, selected seeps were again sampled during the May 1998 event.

8.3.4.1 Western Portion of Site

During the May/June 1997 sampling events, the results of the analysis indicated concentrations of cadmium, copper, and zinc above groundwater regulatory threshold (MTCA Method B) for the western portion of the Site. Two seeps sampled below the west waste rock pile (SP-6 and SP-15E) were found to have concentrations of beryllium and manganese slightly above the MTCA groundwater levels, respectively. Seeps SP-11 contained arsenic and SP-10E contained iron above groundwater threshold levels.

The results of the September/October 1997 sampling event detected concentrations of cadmium, copper, and zinc below those measured during the May/June sampling events, but above groundwater MTCA Method B levels.

8.3.4.2 Eastern Portion of Site

During the May/June sampling events, the results of the analyses indicated that concentrations of cadmium, copper, iron, and zinc were above the MTCA Method A or B groundwater levels. The area of the highest groundwater concentrations was found in tailings pile 1. The concentrations in wells and seeps associated with tailings piles 2 and 3 were generally lower than for tailings pile 1. For tailings piles 1 and 2, concentrations of cadmium, copper, arsenic, beryllium, manganese, iron, and zinc were also detected slightly above the groundwater regulatory levels. For tailings pile 3, lead, beryllium, manganese, cadmium, copper, and iron were detected above the groundwater regulatory levels.

In comparison, the results of the September/October sampling detected higher concentrations of iron, and lower concentrations of the other metals found in the May/June sampling event at all tailings piles. Cadmium, copper, arsenic, manganese and iron were detected above the groundwater regulatory criteria for tailings piles 1 and 2. Iron and manganese exceeded groundwater MTCA levels were detected for tailings pile 3 for the September/October event. Iron concentrations were generally much higher in the eastern portion of the Site during the September/October sampling event than during the May/June event.

8.3.4.3 Lucerne USFS Guard Station Well

The water supply well located at the USFS Guard Station in Lucerne was sampled during the September/October event. The results of the analyses indicated concentrations of iron slightly above the secondary MCL (less than 20 percent higher), a non-health based standard.

8.3.5 Sediment

8.3.5.1 Railroad Creek

Sediment in Railroad Creek was observed to consist primarily of relatively large grain size gravel, cobbles, and boulders. The grain size of the stream substrate decreases slightly from the Site to the mouth of Railroad Creek. Stream sediment samples were collected by others in 1994, 1995, and 1996. The results indicate a general increase in iron, zinc, and copper concentrations from upstream of the Site to River Mile 7. However, the metal concentrations were below the Ecology freshwater sediment quality guidance value (FSQV).

8.3.5.2 Lucerne Bar & Stehekin River Bar

Sediment was collected from near the mouth of Railroad Creek at Lucerne Bar and a reference site near the mouth of the Stehekin River, approximately 10 miles north of Lucerne Bar in Lake Chelan. The results indicate concentrations of zinc slightly above FSQVs (approximately 5 percent higher)for one sample out of 12 collected at Lucerne Bar; the sample was collected near the eastern margin of the study area. All others metal concentrations were below FSQVs.

8.3.6 Other Media

8.3.6.1 Ferricrete

Three samples of ferricrete were collected during the RI to characterize the chemistry to assess the formation of the deposits. The samples were collected from the areas near seeps located northwest and northeast of tailings pile. Iron was the dominant metal present, followed by lessor concentrations of aluminum, magnesium, calcium, and copper.

8.3.6.2 Flocculent

Three samples of flocculent were collected during the RI from the substrate in Railroad Creek to assess the formation of the precipitates. The flocculent was similar in metals composition to ferricrete, but generally contained a higher proportion of iron (up to 43 percent higher).

8.3.6.3 Portal Film

Two samples of film or flocculent were collected from the portal drainage substrate. One sample was collected each during the July and September/October 1997 events. Aluminum was the dominant metal in the portal film, followed by iron, calcium, copper, and zinc. Aluminum was approximately twice as high in July when compared to September/October. Zinc and copper were higher by approximately two times in September/October as compared to July.

8.3.6.4 Air

Air samples were collected as part of the pre- and post-construction monitoring associated with the tailings pile rehabilitation project completed at the Site by the USFS between 1989 and 1991. A dust bucket study was completed between 1974 and 1976; however, the dust was not chemically characterized. The post-construction sampling consisted of establishing air monitoring stations both west and east of the Site, as well as on top of the tailings piles. The results indicate that the metals of highest concentrations were aluminum, calcium, magnesium, potassium, and sodium. These data were utilized to evaluate potential risk as discussed in a later subsection.

8.4 CONTAMINANT PATHWAYS AND CHEMICAL LOADING

8.4.1 General

The contaminant pathways were evaluated based on the potential sources of contaminants and chemistry as discussed in the previous subsection. This discussion presents the contaminant pathways for the western and eastern portions of the Site, and Railroad Creek. The western portion of the Site principally includes the mine, Honeymoon Heights, the waste rock piles, mill building, maintenance yard, and lagoon feature. The eastern portion of the Site principally includes the three tailings piles, the Copper Creek diversion, and Copper Creek. The remaining pathway analyzed was Railroad Creek from the Site to Lake Chelan. The detailed results of the transport and fate analyses are presented in Section 6.0. The following discussion is a summary of the findings.

8.4.2 Overview of Site Geochemistry

Consistent geochemical processes are occurring across the Site including iron sulfide mineral oxidation, oxidation of sphalerite and chalcopyrite, and metal attenuation. Specific controls include the release of heavy metals (iron, copper, zinc, cadmium), the release of metals exerting pH control (iron, aluminum), and seep chemistry for different facilities reflecting different rock types (mine vs. tailings). This dictates the difference between water chemistry in the east and west parts of the Site. The underground mine, waste rock piles and mill building area are dominated by the effect of residual zinc and copper mineralization, whereas the tailings piles are dominated by iron sulfides and associated iron alumino-silicates.

Host rock mineralogy is the primary control in water chemistry at the Site. Weathering of these minerals, especially sulfide minerals, dominates Site water chemistry. Non-sulfide mineralogy of the tailings is expected to be dominated by minerals contained in the ore and in diabase dikes whereas the mine wall rocks are dominated by biotite schist.

Secondary mineralization and precipitates produced by weathering processes are visibly evident throughout the Site, including orange brown iron stains (iron oxyhydroxides) on waste rock and tailings, white precipitates (amorphous aluminum hydroxide) in the 1500-level main portal drainage, green stain (copper carbonate) on marble waste rock in the waste rock piles, and efflorescent crusts (metal sulfates) in the mill building and where seepage emerges along the toes of the tailings piles.

The oxidation of sulfide minerals is releasing iron and acid to surface water drainages. Buffering of acidity is occurring by the reaction of waters with alumino-silicates. This limits the solubility of some metals (e.g., iron) but also allows pH to be low enough to solubilize copper. However, since alumino-silicates are abundant, buffering occurs close to the source of acid generation.

Source controls reflect the differences in oxygen availability and water flow. Portions of the underground mine are likely well-oxygenated through the winter months due to airflow induced by temperature differences between the underground mine and the ambient air, and may therefore be actively oxidizing in open stopes above the 1500-level of the mine. Random water flow in fractures dissolves weathering products, some of which are discharged in the 1500-level main portal drainage, and some of which are stored as salts formed by evapo-concentration. Discharge water reflects precipitation of iron in the workings and precipitation of aluminum within the mine and in the portal drainage and Railroad Creek. The tailings piles are only oxygenated near the surface. Chemical processes leading to the release of heavy metals occur primarily in this zone and not at depth. Acid neutralization occurs at depth. Groundwater contains reduced iron which rapidly oxidizes upon emergence in seeps, forming ferricrete and flocculent.

The metal attenuation processes that occur downgradient of sources prior to entering Railroad Creek include precipitation due to pH increase and aeration, efflorescence (causing seasonal formation of salts), co-precipitation of heavy metals (primarily with iron), and adsorption. Precipitation of iron, aluminum, and copper flocculent probably occurs when seeps mix with slightly alkaline Railroad Creek water and groundwater adjacent to Railroad Creek.

Comparison of sulfate and aluminum supports the general conclusion of buffering by alumino-silicates. Aluminum concentrations are lowered by aluminum hydroxide precipitation.

8.4.3 Western Portion of Site

8.4.3.1 Mine to Railroad Creek

Upslope surface water runon in the form of snowmelt and precipitation infiltrates into the soil and bedrock through fractures and joints. Some of the water enters the mine workings, comes into contact with metal salts formed on the walls of the workings, resulting in some of the metals going into solution. The water flows out of the 1500-level main portal, which becomes the portal drainage, and flows into Railroad Creek. Some of the water in the portal drainage infiltrates to shallow groundwater before discharging to Railroad Creek. The shallow groundwater moves to the northeast, eventually discharging to Railroad Creek.

Referring to Figure 8.4-1, the 1500-level main portal drainage as represented by sampling station P-5 at the Railroad Creek confluence, contained exceedances of surface water aquatic life criteria for cadmium, copper, lead, and zinc in the spring and cadmium and zinc in the fall. The 1500-level main portal drainage represents approximately 64 to 67 percent of the loading source of dissolved cadmium, copper, and zinc in the spring, and reduces to less than 20 percent of the cadmium and zinc load to Railroad Creek in September. The 1500-level main portal, therefore, represents the primary point source loading of dissolved cadmium, copper, and zinc from the Site to Railroad Creek.

The groundwater component from the infiltration of overland flow from the 1500-level main portal drainage may be accounted for by seeps SP-9, SP-11, SP-15W, and SP-15E, and/or as a portion of the unaccounted groundwater base flow to Railroad Creek.

8.4.3.2 Honeymoon Heights to Railroad Creek

An intermittent drainage was observed in the Honeymoon Heights area, immediately east of the 1100- and 800-level mine portals and waste rock piles. The source of water is snowmelt and precipitation. The water comes into contact with the waste rock before infiltrating into a mixture of mostly talus with some waste rock near the base of the avalanche chute in which the drainage flows. The water is assumed to enter into Railroad Creek as diffuse groundwater flow, potentially mixing with water flowing from seeps at sampling stations SP-12 and SP-23, located between RC-1 and P-5; however, a dye test completed as part of the RI to test this hypothesis was inconclusive. These seeps flowed during the spring snowmelt and storm event periods only and combined provided approximately 8 percent, 32 percent, and 7 percent of the loading of cadmium, copper, and zinc to Railroad Creek, respectively.

8.4.3.3 Mill Area

1500-Level Waste Rock Piles

Upslope surface water runon in the form of snowmelt and precipitation infiltrates into the waste rock piles situated to the west and east of the abandoned mill building. The water comes into contact with the relatively low grade mineralization in the rock and is assumed to flow down to a layer of relatively low permeability glacial till. The water discharges as seeps near the base of the waste rock piles, where the glacial till contacts the ground surface.

The water from the west waste rock pile (seeps SP-6, SP-15W, and SP-15E) flows overland to the lagoon. During the spring snowmelt period, the lagoon fills with the water and flows intermittently to Railroad Creek; however, the above-mentioned seeps flowing into the lagoon accounted for approximately 4 percent, 6 percent, and 4 percent of the loading of cadmium, copper, and zinc, respectively, to Railroad Creek during May 1997. Later in the summer the water levels in the lagoon drop and eventually completely dissipate. The lagoon is coincident with the abandoned Railroad Creek stream bed. It is possible that the portion of water which does not evaporate infiltrates into the ground surface and flows as groundwater to Railroad Creek, either as diffuse flow and/or through the abandoned streambed, which intercepts Railroad Creek near seeps SP-1 and SP-2.

During the spring snowmelt period, one relatively small seep (SP-8) flows from near the base of the east waste rock pile and flows overland within a ditch across a portion of tailings pile 1 before entering the Copper Creek diversion which flows directly into Railroad Creek. However, seep SP-8 accounts for approximately 1 percent or less of cadmium, copper, and zinc loading to Railroad Creek.

Mill Building

Upslope surface water runon in the form of snowmelt and precipitation also infiltrates into upper foundations of the abandoned mill building, which is not covered with a roof. Surface water passes through the building and eventually flows overland into the lagoon. Unprocessed ore and residual salts in the mill contribute metals to the water as it makes its way through the building remains and rubble. A seep (SP-7) flows from the mill building before exiting a pipe that eventually drains into the lagoon. The seep flows primarily during the spring snow melt period and accounts for less than 2 percent, 4 percent, and 2 percent of the cadmium, copper and zinc loading, respectfully, to Railroad Creek. Seep SP-22 is located to the north of the mill building and may represent metals loading from the mill structure; however, the seep accounts for less than 1 percent of the cadmium, copper, and zinc loading to Railroad Creek.

Maintenance Yard

Surface water, in the form of runon and precipitation, infiltrate into the ground surface in the western portion of the Site. Both surface water runoff and near-surface groundwater flow towards the lagoon. As noted above, the water from the lagoon likely discharges both directly (surface flow) and indirectly (subsurface flow) to Railroad Creek, as well as evaporates. Surface flow from the maintenance drains into the pipe mentioned for the mill building above that eventually drains into the lagoon. Seep SP-22, which is located to the north of both the mill building and maintenance yards, flows during the spring snowmelt period only and accounts for less than 1 percent of cadmium, copper, and zinc loading to Railroad Creek.

8.4.4 Eastern Portion of Site

Groundwater originating upslope and upstream of the Site appears to flow underneath the relatively low permeability tailings materials during the spring snowmelt period, resulting in an increase in hydrostatic pressures and movement of some water up into the tailings piles. As the snowmelt dissipates, the pressures decrease and the flow direction reverses. Low pH water and dissolved iron generated within the tailings are released into the groundwater as it migrates through the tailings materials. The groundwater eventually enters Railroad Creek either as seeps and/or diffuse groundwater flow.

The abandoned Railroad Creek stream bed appears to exist beneath the northern portions of all three tailings piles. However, the majority of the segment of Railroad Creek adjacent to tailings piles 1 and 2 appeared to be in a gaining condition between the April to October period. Therefore, the water in Railroad Creek did not appear to be flowing from the creek and into the tailings materials.

In contrast, the portion of Railroad Creek adjacent to the eastern portion of tailings pile 2 and all of tailings pile 3 may be in a losing condition during the September to April period. During this period of time, water appears to flow from Railroad Creek to beneath the respective portions of the tailings piles, and eventually into the wetland area to the east of tailings pile, and then to drainage noted as seep SP-21 before flowing back into Railroad Creek.

Upslope surface water runon in the form of snowmelt and precipitation flows into the three tailings piles. Surface water is generally collected and diverted into a series of drainage ditches on the surfaces of the piles which were constructed as part of the tailings pile rehabilitation project completed by the USFS. The ditches on tailings pile 1 drain to the northwest to the Copper Creek diversion and to the east to Copper Creek. In addition, one of the ditches is situated immediately adjacent to an apparently abandoned decant tower which was open and receiving surface water; the water entering the decant tower is assumed to flow eventually into Railroad Creek as groundwater.

The ditches constructed across tailings piles 2 and 3 generally flow to the east to Railroad Creek; the surface water flows into the wetland area east of tailings pile 3 before flowing into Railroad Creek by way of the ditch at seep SP-21. A relatively small portion of the water collecting on top of tailings pile 2 also flows directly into Copper Creek. A ditch constructed in a primitive road above tailings pile 3 also diverts some of the upslope surface water around the eastern end of tailings pile 3 to SP-21. The presence of bedrock exposed in the south bank of Railroad Creek near the confluence of seep SP-21 and Railroad Creek suggests that the near-surface ground water occurrence within the glacial deposits becomes surface water at this point. This assumption is based on the absence of the glacial materials at this location and since water flow into the bedrock is anticipated to be negligible.

The drainage ditches do not fully prevent ponding of water on the tailings. Ponded water on the southern border of all three piles results in surface water infiltration into the tailings from spring melt until mid to late summer. Some of the water flowing in the ditches constructed across the piles likely infiltrates into the tailings. However, the permeability of the tailings materials appears to be relatively low.

Based on the transport pathways discussed herein the sources of dissolved metals leading into Railroad Creek from the tailings piles consist of overland flow seeps, and/or diffuse ground water flow into the bottom of the stream bed. The sources of loading for each tailings pile are as follows:

Tailing Pile 1

- Surface water diversion ditches on the surface of tailings pile 1 flow into the Copper Creek diversion and Copper Creek. However, the flow of water on the surface of the tailings pile does not appear to contribute significant loading of dissolved metals to Railroad Creek. Concentrations of cadmium, copper and zinc in the Copper Creek diversion were detected above surface water aquatic life criteria during the spring period only.

- The Copper Creek diversion accounted for approximately 5 percent or less of cadmium and copper, and approximately 3 percent or less of zinc loading to Railroad Creek during the spring and fall sampling events. The majority of the metals loading within this drainage appears to be attributed to seepage from the east waste rock pile (seep SP-8 which flows to become SP-19), and groundwater flow from the west portion of the site. The concentrations of metals within Copper Creek below the drainage ditch confluence were below surface water aquatic life criteria values.
- Two seeps (SP-1 and SP-2) appear to flow year round from near the base of the tailings pile. The seeps appear to represent groundwater exiting from the tailings pile. Each of the two seeps account for approximately 1 percent or less of dissolved cadmium, copper and zinc loading to railroad Creek and approximately 10 to 11 percent of the dissolved iron loading to Railroad Creek during the spring snow melt period. In contrast steeps SP-1 and Sp-2 each account for approximately 0 percent of dissolved cadmium and copper, approximately 1 percent or less dissolved zinc, and approximately 2 percent or less of the dissolved iron loading to Railroad Creek during the fall period.

Tailings Piles 2 and 3

- The surface water diversion ditches on the surface of tailings piles 2 and 3 do not appear to contribute significant loading of dissolved metals to Railroad Creek. Concentration of dissolved cadmium, copper and zinc are above surface water aquatic life criteria at seep SP-21 year round. However, the majority of the metals loading at this location appears to be groundwater in the form of seeps flowing from the east end of tailings pile 3.
- Two seeps (SP-3 and SP-4) appear to flow year round from near the base of tailings piles 2 and 3, respectfully. The seeps appear to represent groundwater exiting from the tailings piles. Each of the two seeps account for approximately 3 percent or less of dissolved cadmium, copper, and zinc loading to Railroad Creek, and 16 to 24 percent of the dissolved iron during the spring snow melt period. In contract, seeps SP-3 and SP-4 account for approximately 0 percent of dissolved cadmium, copper and zinc, and approximately 3 percent or less of the dissolved iron loading into Railroad Creek during the fall period.
- Ground water flow into Railroad Creek from beneath the tailings piles account for less than 15 percent of dissolved cadmium, copper and zinc loading and approximately 35 percent of the dissolved iron loading to Railroad Creek during the spring snow melt period. In contrast, ground water flow into Railroad Creek accounts for the majority of dissolved metals loading to Railroad Creek during the fall period.

8.4.5 Railroad Creek

8.4.5.1 Surface Water

As noted above, the final point of discharge of affected groundwater which originates from both the western and eastern portions of the Site is Railroad Creek.

Copper cadmium and zinc loads to Railroad Creek from measured point sources and other groundwater (baseflow) sources are highest during the spring snowmelt and groundwater discharge period when groundwater levels are highest in the deep wells beneath the tailings, and high flow occurs at the 1500-level portal drainage. During the May round when flows are the highest, the portal drainage is the primary source of loading of cadmium copper and zinc to Railroad Creek. Seeps SP-23 and SP-23B are the two next highest point sources that are estimated to contribute cadmium copper and zinc during May; however, this load drops to zero later in the year as seep SP-23 dries up.

Iron enters Railroad Creek primarily by groundwater associated with the tailings piles. Iron loads are greater in September than May. Iron loads enter Railroad Creek downstream of the load sources (i.e., portal drainage) for cadmium, zinc and copper, which enter the creek as surface flows or seeps.

Additional source areas located at the West and East waste rock piles and the mill area are not significant loading sources to Railroad Creek. Metals loading at SP-21 is insignificant but may account for the unaccounted loads noted in September.

8.4.5.2 Sediment

Railroad Creek was generally found to be relatively sediment poor due to the relatively steep gradient and the occurrence of storm events which transport the natural sediment downstream to Lake Chelan. The natural sediment is being generated by the stream erosion processes of Railroad Creek.

The tailings piles generate iron-oxyhydroxide precipitate which forms due to diffuse groundwater flow from the tailings into the stream substrate. In addition, wind and precipitation-related erosion of the tailings pile slopes results in a relatively minor amount of tailings materials being delivered into Railroad Creek. Both the precipitate and tailings, in addition to the native sediments, are transported downstream both by normal streamflow and higher energy streamflows during storm events.

8.5 RISK CHARACTERIZATION

The following discussion summarizes the findings of the human health and ecological risk assessments. A detailed discussion is presented in Section 7.0 of this report.

8.5.1 Human Health

The combined results of the screening level human health assessment and the site-specific human health risk assessment indicate that the environmental conditions at the Site and Holden Village do not pose an unacceptable risk to potentially exposed populations, i.e., residents, recreational users of the Site, and USFS personnel. An evaluation of the cumulative risks for each potentially exposed population also indicates that cumulative cancer and noncancer risks are below MTCA allowable cumulative risk levels. These conclusions are based upon very conservative screening criteria and site-specific assumptions which, for all practical purposes, overestimate the risk posed by the Site.

8.5.2 Ecological

The results of the Ecological Risk Assessment are summarized below. Hazard quotients are presented for each of the receptors. HQs less than 10 are considered low or no risk, HQs greater than 10 and less than 100 are considered intermediate risk, and HQs greater than 100 are considered high risk.

8.5.2.1 Trout

- An intermediate potential risk for adverse effects (HQ>1 but <100) to trout may be present due to copper concentrations in surface water in Railroad Creek adjacent to the site under both the worst-case and realistic exposure scenarios. A small potential risk for adverse effects downstream of the Site due to copper was identified using the mainstream Railroad Creek water quality data.
- Trout may possibly be at risk due to iron concentrations in surface water adjacent to the site under a worst-case scenario; however, no risk was identified using the median mainstream data.
- The combined results of the ERA and ecological survey suggest that reduced trout population adjacent to the Site near RC-9 to downstream of tailings pile 3 appears to be primarily attributable to the lack of suitable habitat or food items due to the presence of flocculent, although some potential risk for adverse effects due to dissolved metals was identified.
- HQs were less than or equal to 1 for all other metals for trout.

8.5.2.2 Benthic Invertebrates

- A metals toxicity risk to benthic invertebrates under the worst-case and realistic exposure scenarios in surface water of Railroad Creek does not exist.
- A small potential risk of adverse effects may be present for benthic invertebrates due to metal concentrations (copper, iron, manganese, and zinc) in sediment from Railroad Creek adjacent to and downstream of the site (HQs ranged from 1.0 to 3.0). Exceedances of sediment quality guidelines have been shown to be unreliable predictors of toxic conditions. However, bioassays conducted by Ecology (1997) did not show toxicity due to metals concentrations in Railroad Creek sediment.
- An intermediate potential risk of adverse effects to benthic invertebrates may be present due to metal concentrations (arsenic, cadmium, copper, iron, silver, and zinc) in flocculent adjacent to the site in Railroad Creek. It should be noted that the bioavailability and toxicity of metals in flocculent is unknown. Data from other mine sites suggest that flocculent may not be toxic. The benthic macroinvertebrate community assessment conducted during the RI within Railroad Creek, both upstream and downstream of site influences, exhibited a wide range of conditions. The presence of flocculent on and in the substrate in Railroad Creek from the lower portion of station RC-9 to downstream stations (except RC-3) has influenced the substrate by infilling the interstitial spaces and coating the surface of substrate which generally limits the establishment of periphyton. However, three new genera of pollution sensitive organisms are present at RC-7 and RC-9 and are assumed to be present due to the alteration in habitat. The benthic community at station RC-3 indicates recovering conditions. The combined results of the ERA and benthic community evaluation suggest that the reduced benthic community adjacent to the Site near RC-9 to downstream of tailings pile 3 (RC-7) is more attributable to the lack of suitable habitat due to the presence of flocculent, although some potential risk for adverse effects from metal flocculent concentrations was identified.

SOURCE: USGS Topographic Map, State of Washington, Scale 1:500,000, Compiled 1961, Revised 1982

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Figure 8.1-1

LAKE CHELAN WATERSHED MAP

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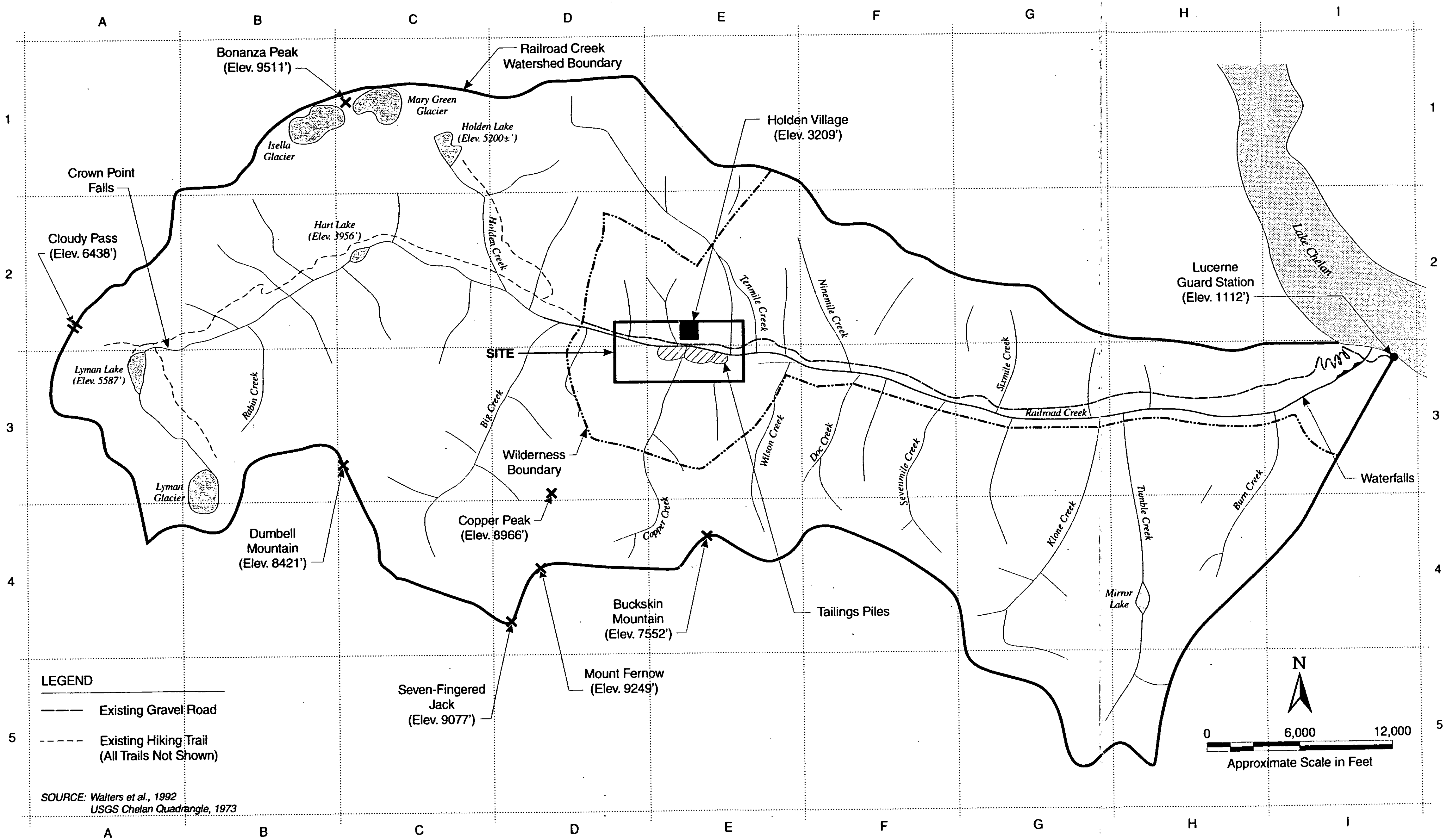
17693A96.CDR



SOURCE: Walters et al., 1992
USGS Chelan Quadrangle, 1973

Figure 8.1-2

RAILROAD CREEK WATERSHED MAP

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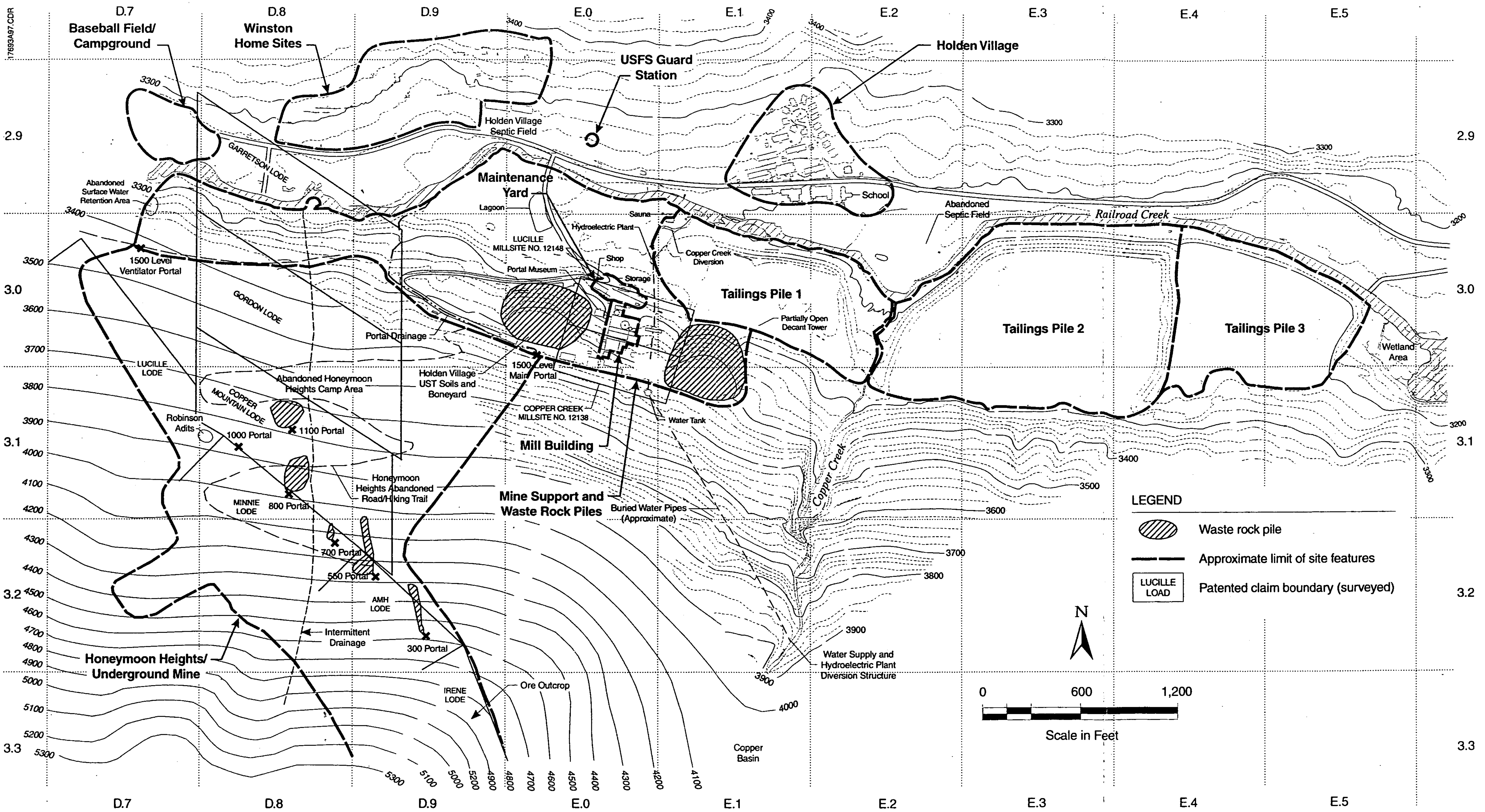

SOURCE: Base map information from USFS and Washington DNR, DEM CD ROM

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Figure 8.1-3

HOLDEN MINE SITE MAP

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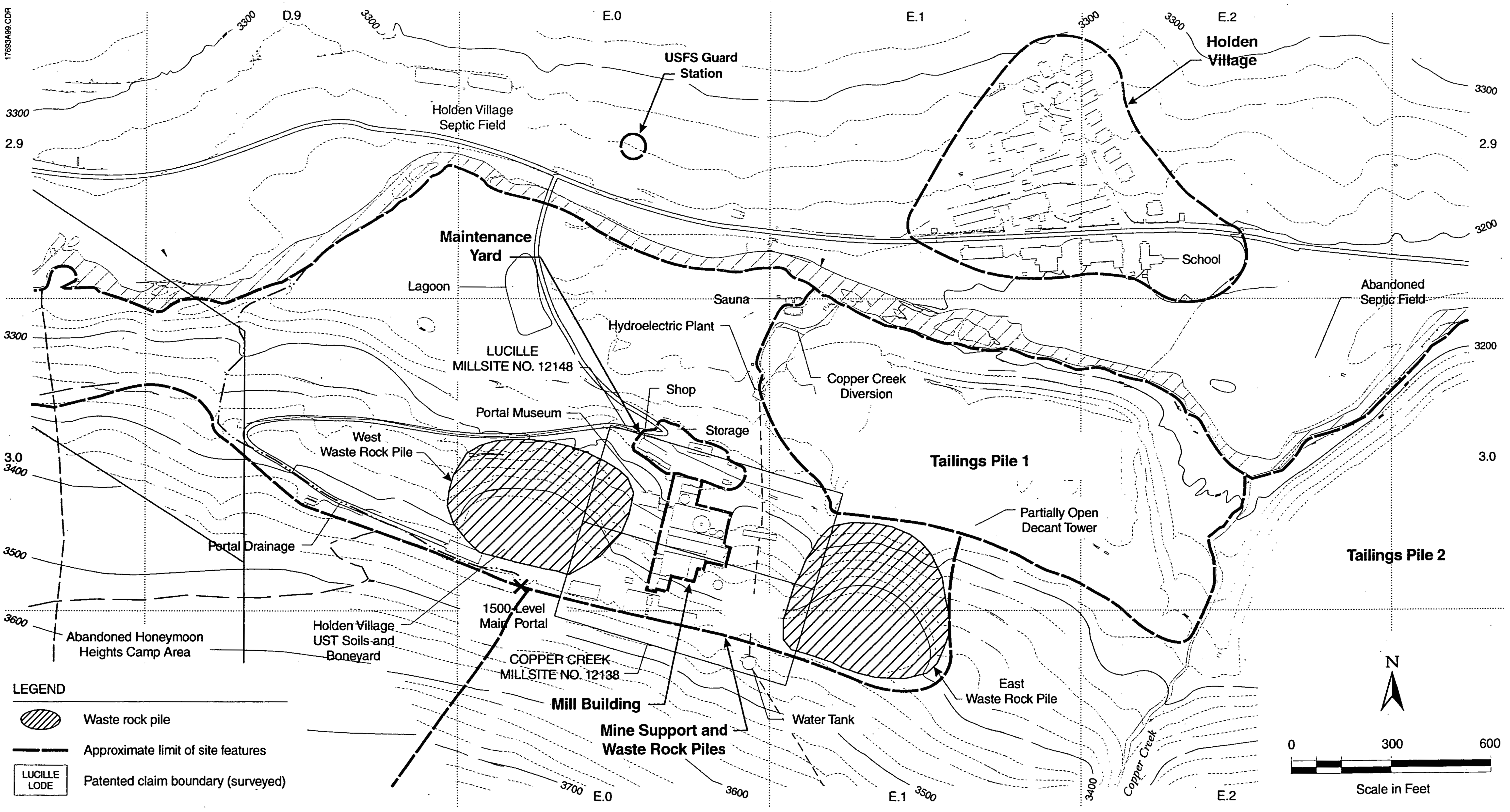

SOURCE: Base map information from USFS and Washington DNR, DEM CD ROM

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Figure 8.1-4

DETAIL OF MINE SUPPORT WASTE ROCK PILES AREA, TAILINGS PILE 1 AND HOLDEN VILLAGE

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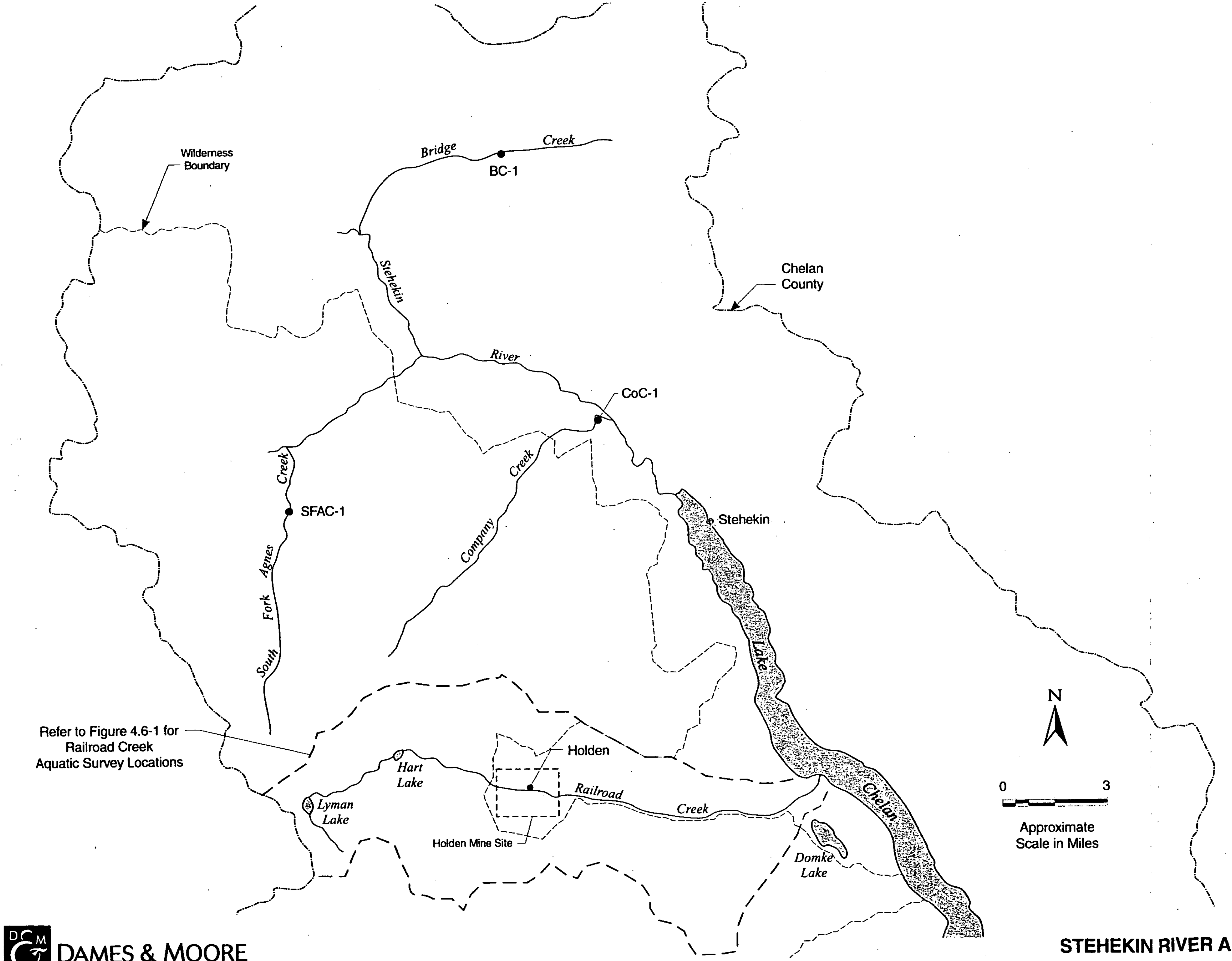

Figure 8.1-5
STEHEKIN RIVER AND RAILROAD CREEK WATERSHEDS

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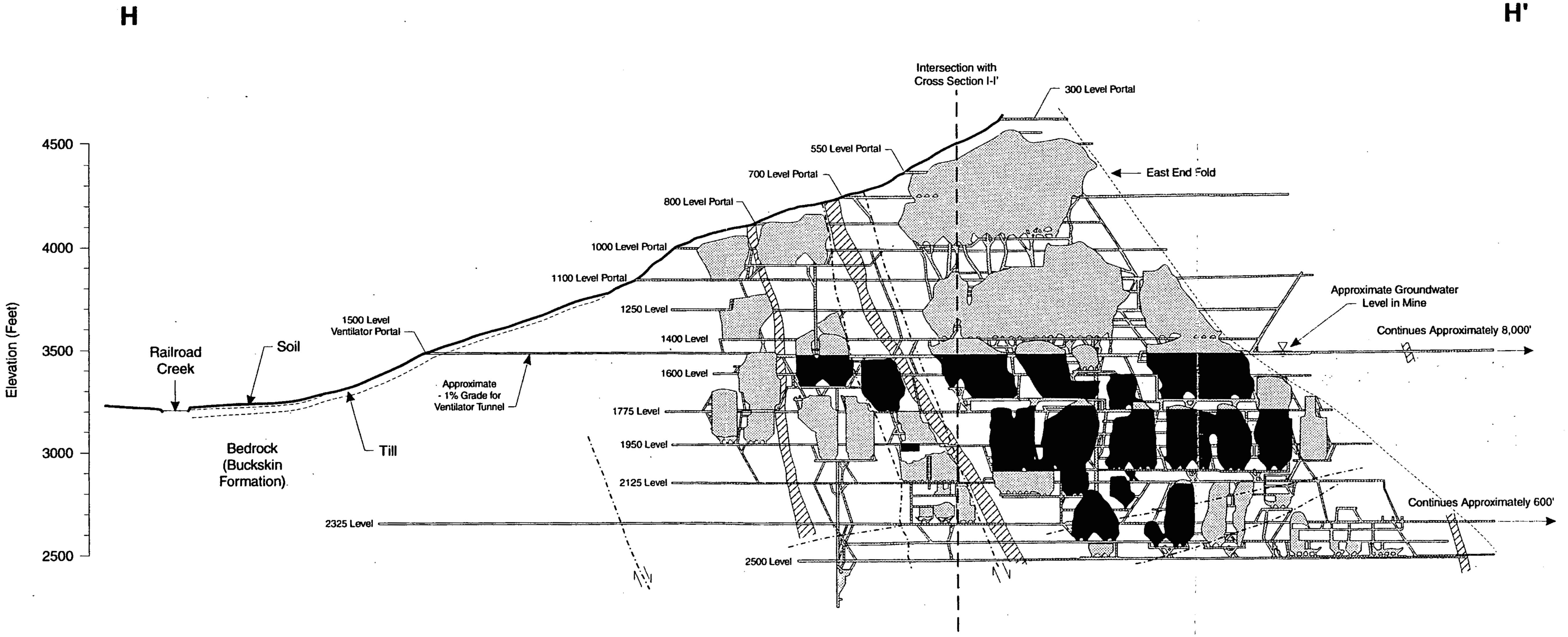
17693805.CDR



NOTE: This cross section is generally parallel to ore body and 1500 level ventilator tunnel

SOURCES: *Northwest Geophysical Associates, 1997, Seismic Line A-A', B-B', Holden Mine Geophysical Investigation.*

Youngberg, E. A., Wilson, T. L., 1952, The Geology of the Holden Mine, Economic Geology, V. 47, No. 1, 1952, pp. 1-12.

W.A.B., 1942, Detailed Surface Geology Map, Howe Sound Co., Chelan Division

F.E., H.B.S., 1938, Geology of 1500 Level, Howe Sound Company Chelan Division

Howe Sound Co, 1957, Holden Mine, East West Section

LEGEND

▒ Open stope

■ Backfilled stope

▨ Dike

-·-·- Transform fault

0 500 1,000

Approximate Horizontal and Vertical Scale in Feet

Figure 8.2-1

HOLDEN MINE SITE
CROSS SECTION OF UNDERGROUND MINE

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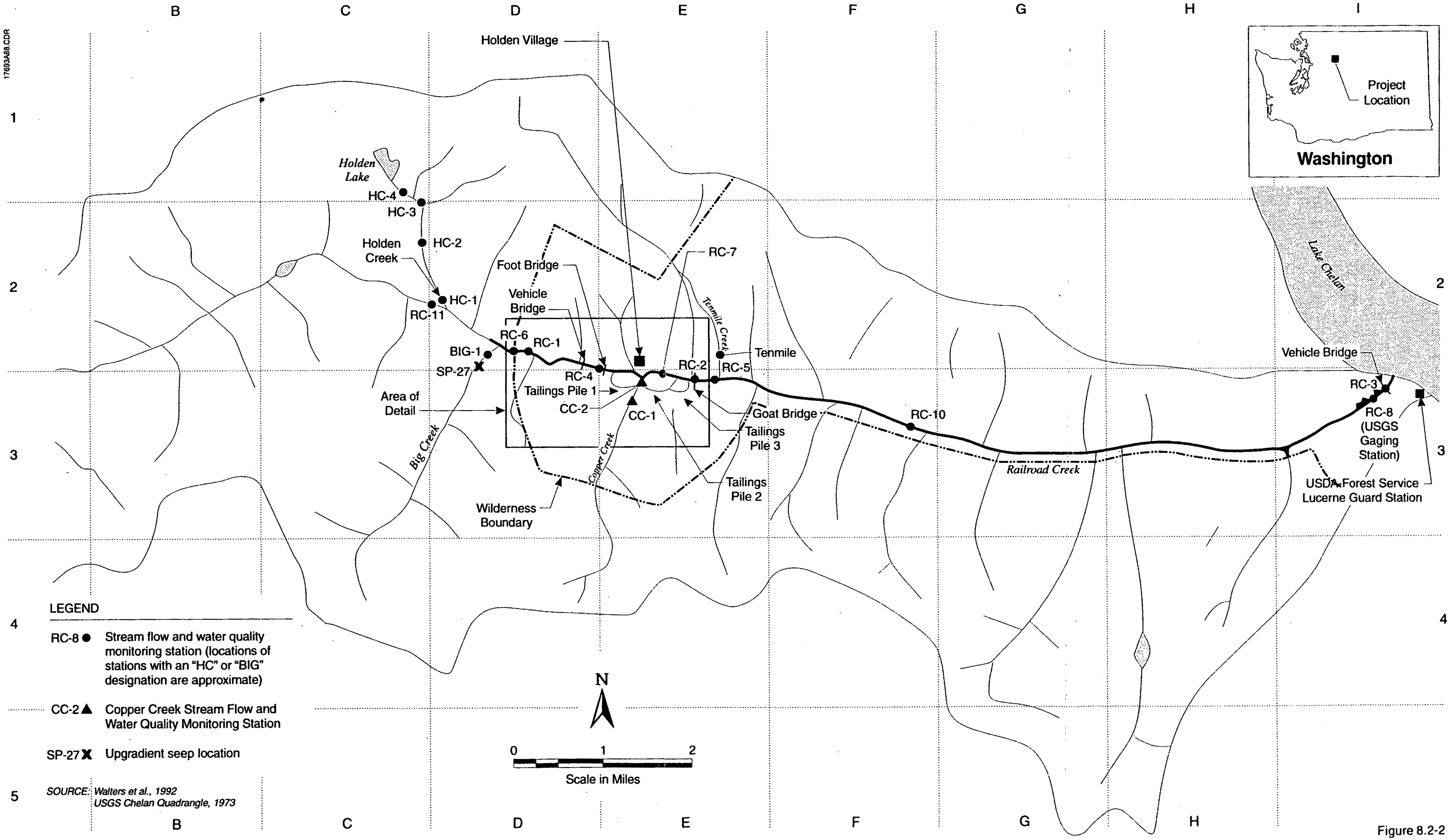

SOURCE: Walters et al., 1992
USGS Chelan Quadrangle, 1973

Figure 8.2-2

**RI HYDROLOGIC INVESTIGATION LOCATIONS
RAILROAD CREEK WATERSHED**

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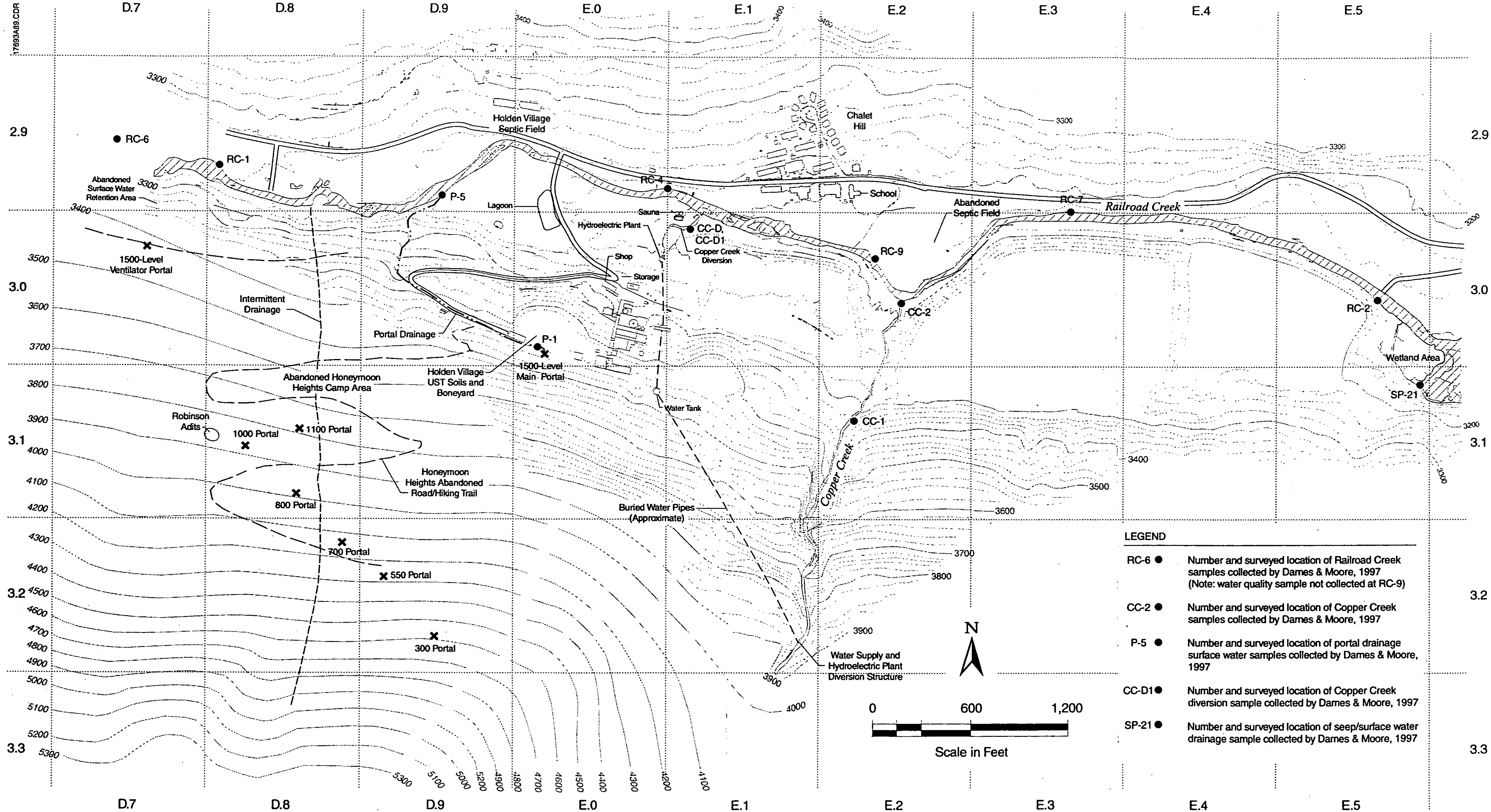

SOURCE: Base map information from USFS and Washington DNR, DEM CD ROM

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Figure 8.2-3

RI HYDROLOGIC INVESTIGATIONS—SITE

Job No. 17693-005-019

Holden Mine RI/FS
Draft Final RI Report

9.0 CONCLUSIONS AND RECOMMENDATIONS

The data collected during the course of the RI are sufficient to define the nature and extent of compounds of concern, the pathways and receptors of concern and to serve as a basis to complete the Feasibility Study. The objectives, conclusions and recommendations and key findings of the RI are summarized in this section. One remaining RI data collection activity has been identified by the Agencies in order to augment or clarify specific findings and conclusions related to sediment. The results will be appended to this document after the field data collection and analyses are completed.

9.1 OBJECTIVES OF THE RI

The RI objectives have been addressed as follows:

- The environmental setting of the Site has been characterized
- The presence, magnitude, nature and extent of potential environmental concerns determined to be associated with historic mining activities have been defined
- The potential pathways and rates of migration of compounds of potential concern on the Site have been characterized
- The potential receptors of compounds of potential concern associated with the historic mining at the Site have been evaluated
- The stream habitat has been characterized
- The analytical data generated from the investigation in terms of applicable, relevant, and appropriate regulations, including both state and federal requirements, have been evaluated
- Relevant data of sufficient quality have been provided so that the FS can evaluate cost-effective remedial alternatives that will address significant environmental concerns identified on the Site.

9.2 CONCLUSIONS

Referring to Figures 9.2-1 through 9.2-5, the RI conclusions are described below:

9.2.1 Host Rock Mineralogy

- The Holden Mine ore deposit is hosted by the Buckskin Schist, which is a quartz amphibole schist sequence with at least two horizons of intermittent marble beds and calcareous schists. The dominant silicates are plagioclase and biotite (aluminum-based). The primary sulfide minerals in the Holden Mine ore deposit include pyrite, pyrrhotite, sphalerite and chalcopyrite.

9.2.2 Site Surface Water/Groundwater Interaction and Movement

The data collected during the RI bracketed both high and low flow conditions in Railroad Creek and component inflows:

- All surface water and groundwater at the Site ultimately discharge to Railroad Creek.
- Spring Conditions - The primary component of surface water and groundwater at the Site and in the vicinity during the spring period (approximately April through July) is snowmelt. The source areas for surface water and groundwater originate upslope of the Site and in the upstream portion of Railroad Creek. Water sources flow into Railroad Creek as overland flow, base groundwater flow through the near-surface glacial sands and gravels, overland flows that infiltrates to groundwater from source areas and as groundwater surface or subsurface expressions that represent springs, seeps, or subsurface flow into the bottom of the streambed. Water enters the mine through fractures and joints. Water discharging from the 1500-level main mine portal represents the bedrock groundwater component observed at the Site. As overland flow discharges from the 1500-level main portal to the confluence of Railroad Creek, water also infiltrates to groundwater which eventually flows to Railroad Creek. The tailings pile materials have relatively low permeability; however, some water infiltrates through the surface of the tailings piles during snowmelt, precipitation events, and ponding on the surface of the piles.
- Remainder of Year - After the spring snowmelt, the amount of water flowing into the Railroad Creek from the valley sidewalls decreases significantly. The discharge from the mine portal also decreases. For the remainder of the year, the majority of water coming into contact with the base of the tailings piles is groundwater that flows generally parallel to Railroad Creek within the glacial sands and gravels; however, base groundwater flow beneath the Site continues to discharge to Railroad Creek.
- A Site-specific water balance conducted for the Site accounted for the component inflow sources to Railroad Creek.

9.2.3 Surface Water Quality in Railroad Creek.

- Seasonal fluctuations in the water quality were observed in Railroad Creek and a direct relationship between streamflow rates and concentrations of dissolved metals in Railroad Creek was observed, (i.e., concentrations of metals increase and decrease with increases/decreases in streamflows).
- Dissolved metal concentrations of copper, cadmium, and/or zinc were periodically above State water quality criteria in Railroad Creek adjacent to the Site from RC-4 to RC-5 between April and July 1997. Dissolved copper and/or zinc concentrations at RC-3 were above State water quality criteria in April and May 1997. Dissolved metal concentrations above State water quality criteria in Railroad Creek decline as streamflow rates decline from spring snow melt to fall. By September, State water quality criteria were slightly exceeded for copper only at RC-4 (south bank) and for zinc only at RC-4 (south bank), RC-2 and RC-5.

9.2.4 Component Inflow Sources and Transport Mechanisms to Railroad Creek and Geochemistry Processes

- Component inflow sources to Railroad Creek were identified and the Site geochemistry was characterized.
- Consistent geochemical processes are occurring across the Site including iron sulfide mineral oxidation, oxidation of sphalerite and chalcopyrite, and metal attenuation. Specific processes include the release of metals (iron, copper, zinc, cadmium), the release of metals exerting pH control (iron, aluminum), and differing seep chemistry for different portions of the site reflecting different rock types (mine vs. tailings). This dictates the difference between water chemistry in the east and west parts of the Site. The underground mine, waste rock piles and mill building area are dominated by the effect of residual zinc and copper mineralization, whereas the tailings piles are dominated by concentrated iron sulfides and associated iron alumino-silicates.
- Host rock mineralogy is the primary factor affecting water chemistry at the Site. Weathering of these minerals, especially sulfide minerals, dominates Site water chemistry. Non-sulfide mineralogy of the tailings is expected to be dominated by minerals contained in the ore and in diabase dikes whereas the mine wall rocks are dominated by biotite schist.
- Secondary mineralization and precipitates produced by weathering processes are visibly evident at the Site, including orange brown iron stains (iron oxyhydroxides) on waste rock and tailings, white precipitates (amorphous aluminum hydroxide) in the 1500-level main portal drainage, green stain (copper carbonate) on marble waste rock in the waste rock piles, and efflorescent crusts (metal sulfates) in the mill building and where seepage emerges along the toes of the tailings piles.
- The differences in oxygen availability and water flow in the Site source areas influence the geochemical characteristics of water quality at the Site. Portions of the underground mine are well-oxygenated through the winter months due to airflow induced by temperature differences between the underground mine and the ambient air. Active oxidation occurs in open stopes above the 1500-level of the mine. Random water flow occurs in fractures and dissolves weathering products, some of which are discharged in the 1500-level main portal drainage, and some of which are stored as salts formed by evapo-concentration. The tailings piles are only oxygenated near the surface; therefore, chemical processes leading to the release of metals occur primarily in this zone and not at depth. Acid neutralization occurs at depth in the tailings piles. Groundwater beneath the tailings piles contains reduced iron which rapidly oxidizes upon emergence in seeps, forming ferricrete and flocculent.
- The metal attenuation processes that occur downgradient of source areas prior to entering Railroad Creek include precipitation due to pH increase and aeration, efflorescence (causing seasonal formation of salts), co-precipitation of heavy metals (primarily with iron), and adsorption. Precipitation of iron, aluminum, and copper flocculent probably occurs when seeps mix with slightly alkaline Railroad Creek water and groundwater adjacent to Railroad Creek.
- Comparison of sulfate and aluminum supports the general conclusion of buffering by alumino-silicates.

- The chemical loading analyses completed during the RI accounted for the overland flow and groundwater loading sources of dissolved metals to Railroad Creek.
- Conclusions associated with the water quality and chemical loading of component inflow sources including the portal drainage, groundwater, the waste rock piles, mill building, Copper Creek diversion and seeps SP-12 and SP-23 are provided below.

9.2.4.1 Portal Drainage

Water quality measured at P-1 (main portal) and P-5 (confluence with Railroad Creek) as overland flow indicates that metals presented in the following table were above regulatory surface and groundwater quality regulatory levels.

	Locations	May 1997	July 1997	September 1997	May 1998
Surface Water Criteria	P-1	Cd, Cu, Pb, Zn, pH	Cd, Cu, Pb, Zn, pH	Cd, Cu, Zn	Cd, Cu, Pb, Zn, pH
	P-5	Cd, Cu, Pb, Zn, pH	Cd, Cu, Pb, Zn, pH	Cd, Zn, pH	Cd, Cu, Pb, Zn, pH
Groundwater Criteria	P-1	As, Be, Cd, Cu, Pb, Zn, SO_4, pH	Cd, Cu, Pb, Zn, SO_4, pH	Cd, SO_4, TDS	Cd, Cu, Fe, Pb, Zn, SO_4, TDS, pH

These dissolved metals concentrations are influenced by seasonal changes in groundwater flow discharging from the main portal. The loading analysis reflects these differences.

- May/June - The portal drainage discharge flows were as high as approximately 3.5 cubic feet per second (cfs) in May 1997 and approximately 1.8 cfs in May 1998, and accounts for more than 65 percent of the load of dissolved cadmium, copper, and zinc to the creek during the spring snowmelt period.
- October/September - Discharge flow rates were measured as low as approximately 0.10 cfs. The drainage accounts for less than 1 percent of the copper load, and approximately one-third of the cadmium and zinc load to Railroad Creek.

The portal drainage overland flow represents the primary source of dissolved copper, cadmium and zinc to Railroad Creek during spring conditions; however during the fall, the concentrations of these metals is greatly reduced.

9.2.4.2 Groundwater

The groundwater geochemistry in the east and west portions of the Site is different due to the different source rock types (mine ore deposit versus tailings) and differences in oxygen availability and water flow. Groundwater data from monitoring wells and expressed as seeps and springs were used to evaluate groundwater quality associated with the Site, particularly for the west side of the Site. Groundwater underlying the Site is not currently being used as drinking water.

West Portion of the Site

The west portion of the site includes the following source areas: underground mine and Honeymoon Heights, portal drainage, west waste rock piles, and the mill building. Groundwater monitoring wells are not present in these areas; therefore, seep water quality was used to evaluate groundwater quality exceedances, source areas and loading to Railroad Creek. Concentrations of cadmium, copper, and zinc were above the MTCA Method B levels in groundwater in the western portal of the site.

Portal Drainage

Groundwater infiltrating from the portal drainage overland flow is a component of the unaccounted load (groundwater) of copper, cadmium and zinc to Railroad Creek.

Waste Rock Piles

Several seeps flow seasonally from near the base of west and east waste rock piles. Two seeps, SP-6 and SP-15W contain concentrations of cadmium, copper, zinc, beryllium and manganese above the MTCA groundwater levels. Seeps SP-6 and SP-15W account from less than 2 percent of the cadmium, copper and zinc loading to Railroad Creek measured at RC-2. Seep SP-11 contained arsenic and SP-10E contained iron above groundwater threshold levels.

Mill Building

One primary seep, SP-7, flows seasonally from the abandoned mill building and contained cadmium, copper and zinc above MTCA groundwater levels. The seep accounts for less than 2 percent of the cadmium, 4 percent of the copper, and 2 percent of the zinc loading to Railroad Creek as measured at RC-2.

Seeps SP-12 and SP-23

Seeps SP-12 and SP-23 are assumed to represent Honeymoon Heights drainage and flow seasonally from the south bank of Railroad Creek to the west of the portal drainage. These seeps contain copper, cadmium, and zinc concentrations above MTCA groundwater levels. The two seeps combined account for approximately 8 percent of the cadmium, 31 percent of the copper, and 7 percent of the zinc loading to Railroad Creek as measured at RC-2.

The loading analysis further demonstrates that overland flow from the 1500-level main portal is the primary source area contributing dissolved cadmium, copper, and zinc concentrations to Railroad Creek. Source areas including the waste rock piles, mill building, Honeymoon Heights drainage, and groundwater infiltrating from the 1500-level main portal overland flow also contribute metals, primarily copper, cadmium and zinc to Railroad Creek, but represent significantly lower load sources as compared to the overland from the 1500-level main portal. Based on the physical characteristics of the west portion of the site, a high likelihood exists that infiltration of overland flow from the 1500-level main portal contributes to dissolved copper, cadmium and zinc to groundwater in the western portion of the site as well as to groundwater beneath the tailings piles.

East Portion of the Site

The east portion of the Site includes the tailings piles and Copper Creek diversion. The groundwater underlying the portion of the Site east of the Copper Creek diversion, including tailings piles 1, 2, and 3. Groundwater bellow the tailings piles contains concentrations of arsenic, cadmium, beryllium, copper, lead, manganese, zinc, and iron above MTCA groundwater levels. Cadmium, copper and zinc were not identified in water within the tailings which indicates that these constituents most likely originate from the western portion of the site.

Groundwater discharge from the tailings piles into Railroad Creek occurs in the form of springs or seeps and diffuse groundwater flow into the creek substrate.

- The tailings piles are the primary source of dissolved and total iron loading to Railroad Creek throughout the year.
- The precipitation of iron results in the cementing of portions of the Railroad Creek streambank, principally at three of the more prominent seep discharges near the northeast corner of tailings pile 1, and the northwest corner of tailings pile 2.
- Most of the dissolved iron from the tailings piles is converted to a fine precipitate or flocculent after it enters the stream.

9.2.5 Sediment Quality

The sediment in Railroad Creek consists mostly of gravel, cobbles, and boulders. The stream gradient is relatively moderate near the Site and steeper upstream and downstream of the Site; however, the gradient appears to be too steep to allow deposition of sediment. The concentrations of metals in Railroad Creek sediments do not indicated the potential for adverse effects based on Ecology guidance values. Sediment samples were collected from both the Lucerne Bar (near the mouth of Railroad Creek in Lake Chelan) and a reference site near the mouth of the Stehekin River. The results indicated concentrations of zinc slightly above FSQVs for only one sample out of 12 collected and analyzed. The remainder of the results were below the FSQVs. These results suggest a low potential for adverse effects in sediment at Lucerne Bar.

9.2.6 Ecological Conditions

The aquatic survey consisted of the sampling of aquatic insects (benthic macroinvertebrates) and fish at eight locations in Railroad Creek (six station adjacent and downstream of the Site, and two upstream reference or control stations) and three locations in reference streams in the Stehekin River watershed which is outside the Railroad Creek watershed. The sampling was completed during the month of September (safety considerations precluded high flow sampling during the spring melt period). The fish survey included the use of both snorkeling and electrofishing methods. The results of the sampling indicated:

- The populations of benthic macroinvertebrates and fish found adjacent to the upstream and westernmost tailings piles, but outside the area of iron-oxide flocculent, were similar to those found upstream of the Site. This area is adjacent to the tailings pile but downstream of the portal drainage and the major sources of dissolved cadmium, copper, and zinc loading into Railroad Creek.
- The comparability of fish data collected from two of the three control stations for the mid to lower portions of Railroad Creek is questionable due to stream habitat dissimilarities. The control site for the mid-Railroad Creek segment (Bridge Creek) included a relatively deep pool in which most fish were caught. The control site for the mouth of Railroad Creek (Company Creek) was dissimilar in size and was located immediately adjacent to a salmon spawning ground.
- Benthic macroinvertebrates and fish populations were reduced in Railroad Creek within the segment of the stream with iron-oxide staining and flocculent on the substrate. This extended from the northeast corner of tailings pile 1 to station RC-5, located approximately one-half mile downstream of tailings pile 3.

- At approximately 3 miles downstream of the Site (sampling station RC-10), benthic macroinvertebrate populations were reduced in comparison to the upstream control stations. Fish populations at this station were within the range of data collected at both the control sites outside the watershed and the upstream control sites. Several young fish, which are generally less resistant to dissolved metals than adult fish, were found at this station.

- Fish populations at the mouth of the creek RC-3 were higher than those at the stations upstream of the Site, but lower than those at the Company Creek control site.

- Benthic macroinvertebrate populations near the mouth of Railroad Creek (RC-3) were reduced in comparison to upstream and control stations but had partially recovered in comparison to stations closer to the Site.

- Of the benthic macroinvertebrate species observed in Railroad Creek, "filter feeders" are present throughout Railroad Creek. Filter feeder insects are generally considered to be more sensitive than other macroinvertebrates to dissolved metals in the water column. Benthic macroinvertebrates that are generally absent downstream of the tailings piles (excluding RC-3 at the mouth) are organisms that require a clean upper stone surface (ex. "scrapers") and organisms that require open interstitial spaces for hiding. Bioassays conducted by Ecology using Cladocerans (*Ceriodaphnia*), a sensitive filter feeder, and Railroad Creek water collected from above and below the tailings piles, at RC-10, and at RC-3 indicated no adverse effects.

- The benthic macroinvertebrate species composition, and the finding that fish and macroinvertebrate populations were not reduced downstream of the major sources of dissolved cadmium, copper and zinc loading to Railroad Creek, indicate that the reductions in fish and macroinvertebrate populations adjacent to and downstream of the tailings piles observed appears to be primarily attributable to the lack of suitable habitat or food sources due to the presence of iron flocculent.

9.2.7 Human Health and Ecological Risk Assessment

The human health and ecological risk assessments analyzed potential risks to human and ecological receptors exposed to the compounds of potential concern within soil, surface water, groundwater, sediments, and air at the Site.

- The human health risk assessment found that the risks were acceptable for both residents and visitors to the Site based on reasonable maximum exposure scenarios.

The ecological risk assessment found that:

9.2.7.1 Trout

- An intermediate potential risk for adverse effects (HQ>1 but <100) to trout may be present due to copper concentrations in surface water in Railroad Creek adjacent to the site under both the worst-case and reasonable exposure scenarios. A small potential risk for adverse effects, downstream of the Site, due to copper was identified using the mainstream Railroad Creek water quality data under both the worst-case and reasonable exposure scenarios.

- Trout may possibly be at risk due to iron concentrations in surface water adjacent to the site under a worst-case scenario; however, no risk was identified using the median mainstream data.

- The combined results of the ERA and ecological survey suggest that reduced trout populations adjacent to the Site near RC-9 to downstream of tailings pile 3 appear to be primarily attributable to the lack of suitable habitat or food items due to the presence of flocculent, although some potential risk for adverse effects due to dissolved metals was noted.
- HQs were less than or equal to 1 for all other metals for trout.

9.2.7.2 Benthic Invertebrates

- A metals toxicity risk to benthic macroinvertebrates under the worst-case and reasonable exposure scenarios in surface water of Railroad Creek does not exist.
- A small potential risk of adverse effects may be present for benthic macroinvertebrates due to metal concentrations (copper, iron, manganese, and zinc) in sediment from Railroad Creek adjacent to and downstream of the site (HQs ranged from 1.0 to 3.0). Exceedances of sediment quality guidelines have been shown to be unreliable predictors of toxic conditions. Bioassays conducted by Ecology (1997) did not show toxicity due to metals concentrations in Railroad Creek sediment.
- An intermediate potential risk of adverse effects to benthic macroinvertebrates may be present due to metal concentrations (arsenic, cadmium, copper, iron, silver, and zinc) in flocculent adjacent to the site in Railroad Creek. It should be noted that the bioavailability and toxicity of metals in flocculent is unknown. Data from other mine sites suggest that flocculent may not be toxic. The benthic macroinvertebrate community assessment conducted during the RI within Railroad Creek, both upstream and downstream of site influences, exhibited a wide range of conditions. The presence of flocculent on and in the substrate in Railroad Creek from the lower portion of station RC-9 to downstream stations (except RC-3) has influenced the substrate by infilling the interstitial spaces and coating the surface of substrate which generally limits the establishment of periphyton. However, three new genera of pollution sensitive organisms are present at RC-7 and RC-9 and are assumed to be present due to the alteration in habitat. The benthic community at station RC-3 indicates recovering conditions. The combined results of the ERA and the Railroad Creek benthic community evaluation indicate that the reduced benthic community adjacent to the Site near RC-9 to downstream of tailings pile 3 (RC-7) is predominately attributable to the lack of suitable habitat due to the presence of flocculent, although some potential risk for adverse effects from metal flocculent concentrations was noted.
- Under a reasonable scenario conditions, there is no risk due to metal toxicity to the birds or mammals associated with aquatic habitat near the site.

9.2.7.3 Terrestrial Exposure Pathway and Receptors of Concern

- Plants may experience toxicity from cadmium, copper, lead, and zinc in Holden Village surface soil and in the surface soils and subsurface soils of tailings piles 1, 2 and 3, the lagoon and the maintenance yard; however, when compared to soil metals concentrations at other mine sites where plants are successfully growing, only copper concentration in subsurface soils, the lagoon, and maintenance yard may present a risk of phytotoxicity.
- Earthworms may be at risk from cadmium, copper, lead and/or zinc in surface and subsurface soils at Holden Village, tailings piles, dust, lagoon and the maintenance yard under the worst-

case scenario; however, suitable earthworm habitat may not exist due to the physical qualities of the substrate at the sample locations.

- Robins could be at risk from cadmium in the subsurface tailings, lagoon and maintenance yard, and from zinc in the subsurface soils, tailings pile 3, the lagoon and the maintenance yard, and from lead in the lagoon and maintenance yard based on the worst-case scenario. However, under the reasonable scenario (median concentration), there was no risk from cadmium or zinc. It is highly likely that the input parameters for the robin overestimate the actual exposure conditions because a risk was also shown for robins feeding on earthworms exposed to background concentrations of cadmium and the exposure assessment does not account for the robins relatively large forage range.
- Under normally expected conditions, there is no risk due to metals toxicity to mammals associated with terrestrial habitat near Holden Mine.

9.2.8 Tailings Pile Slope Stability

The slopes adjacent to Railroad Creek vary in height between 50 and 120 feet, and are relatively steep.

- The tailings pile slopes have the potential to release tailings to the creek during an earthquake event with a recurrence interval of approximately 40 years. The event would likely be limited to a maximum depth of approximately 15 feet and include only those slopes of the tailings piles facing Railroad Creek that are steeper than 34 degrees.
- The rock placed as Railroad Creek streambank protection (riprap) during the Site rehabilitation efforts performed by the USFS is weathering relatively rapidly. The height of the rock placement, as well as the size of the rock, appears marginal to protect the base of the tailings piles during a hypothetical 100-year storm event, and is likely not adequate to protect the base of the tailings piles during a hypothetical 500-year storm event.

9.2.9 Windblown Tailings Material

The erosion of the tailings from the piles has resulted in the deposition of the materials on the ground surface adjacent to and downwind of the Site. The majority of the windblown tailings deposits were found to be less than several millimeters in thickness. Concentrations of all metals analyzed, other than iron, were below the regulatory standard for soil. Based on the results of human health and ecological risk assessment, the potential for adverse effects from the iron concentrations was low.

9.2.10 Riprap and Soil Source Evaluation

An evaluation was completed to identify a source of riprap within the Railroad Creek drainage and sources of granular soil that may be needed for remedial actions. The results of the evaluation confirmed that the rock quality within the existing quarry is relatively poor. However, a potential source of higher quality rock exists nearer the Site as a talus deposit (cobble- to boulder-sized rock at the base of a bedrock outcrop). The riprap source had been eliminated by the USFS during the Site work between 1989 and 1991 due to safety considerations; however, it appears feasible to design measures to mitigate the concerns. A potential source of granular soil was identified near tailings pile 3.

9.2.11 Winston Home Sites Fuel Storage Tanks

The results of the evaluation of the Winston Home Sites identified up to 38 underground storage tanks (USTs) remaining in the area. No indications of petroleum hydrocarbons were noted in soils exposed in backhoe test pits excavations completed adjacent to seven of the tank locations. It was reported that some, if not all, of the tanks were pumped during the 1960s in order to supply fuel for Holden Village. All of the tanks appeared to be less than 1000 gallons in size and, therefore, not regulated as USTs. These tanks have been sufficiently evaluated.

9.3 POTENTIAL ENVIRONMENTAL CONCERNS

The following potential environmental concerns were identified at the Site:

9.3.1 Seasonal Exceedances of Water Quality Criteria

- The discharge of portal drainage water and Site groundwater in the western portion of the site (represented as seeps) into Railroad Creek results in exceedances of water quality criteria for cadmium, copper, lead, and zinc during the spring snowmelt period at the Site in Railroad Creek. Dissolved metal concentrations decreased as streamflow declined. By September, State water quality criteria were exceeded for copper only in a south bank sample and for zinc only at stations adjacent to and immediately downstream of the site.
- Groundwater concentrations of arsenic, beryllium, cadmium, copper, iron and manganese beneath the tailings piles are above the MTCA groundwater levels in the spring. By fall only iron and manganese are above MTCA levels.

9.3.2 Reduction in Benthic Macroinvertebrate and Fish Populations

- Both benthic macroinvertebrate and fish populations are reduced downstream of tailings pile 1 when compared to the control or reference sites. Fish populations remained low in comparison to reference reaches of RC-7, located adjacent to tailings pile 2, and at RC-5, located approximately one-half mile downstream of the Site. Macroinvertebrate counts were lower than reference reach counts from the Site to the mouth of Railroad Creek, but increased with distance from the Site. However, the presence of unique species of filter feeder aquatic insects in the affected reaches of Railroad Creek suggests that the dissolved metals are not the cause of the reduced macroinvertebrate populations. The reduction in benthic macroinvertebrates and fish populations adjacent to the site appears to be principally from physical effects of iron flocculent in the stream. In addition, bioassays completed by Ecology using Cladocerans (*Ceriodaphnia*), a sensitive filter feeder, and water from Railroad Creek above and below the tailings piles, RC-10 and RC-3 indicated no adverse effects.
- The fish populations at the RC-10 sampling station approximately three miles downstream of the Site are within the range of values collected at the control or reference sites. Young fish were observed at this station.

9.3.3 Tailings Pile Slope Stability

- Based on the results of slope stability analyses, the tailings pile slopes facing Railroad Creek are relatively stable under static conditions. However, the tailings could be released to Railroad Creek in the event of a moderate earthquake. Only the slopes steeper than approximately 34 degrees appear to be at risk. The maximum depth of a failure has been estimated to be 15 feet. The failure of a slope would likely result in the delivery of tailings material to Railroad Creek.

- The base of the tailings piles is at increased risk over time of erosion during storm events due to the continued breakdown and insufficient size of some of the rip-rap streambank protection. The erosion of the toes of the piles during a major storm event may result in the delivery of tailings materials to the creek.

9.3.4 Maintenance Yard

- The surface soil within the maintenance yard area exceeds MTCA levels for arsenic, cadmium, copper, iron, lead, and total petroleum hydrocarbons.
- The subsurface soil within the maintenance yard area exceeds current MTCA levels for total petroleum hydrocarbons only.

9.3.5 Lagoon Soils

- The surface soil within the lagoon exceeds levels for total petroleum hydrocarbons; the subsurface soil exceed MTCA levels for cadmium, copper, lead, and total petroleum hydrocarbons.

9.4 RECOMMENDATIONS FOR PHASE III DATA COLLECTION

The following scope of work has been identified by the Agencies as a data need which will require additional sampling and analysis:

9.4.1 Lucerne Bar Sampling

- Additional sediment sampling will be conducted in Lake Chelan near the mouth of Railroad Creek and to the east of the area sampled during the Phase III RI. The objective of the sampling and analysis will be to further characterize the nature and extent of metals concentrations in near-shore sediment. The sampling is scheduled to be completed between August and October 1999.

17693A80.CDR

SOURCE: USGS Topographic Map, State of Washington, Scale 1:500,000, Compiled 1961, Revised 1982

N

0 8 16

Scale in Miles

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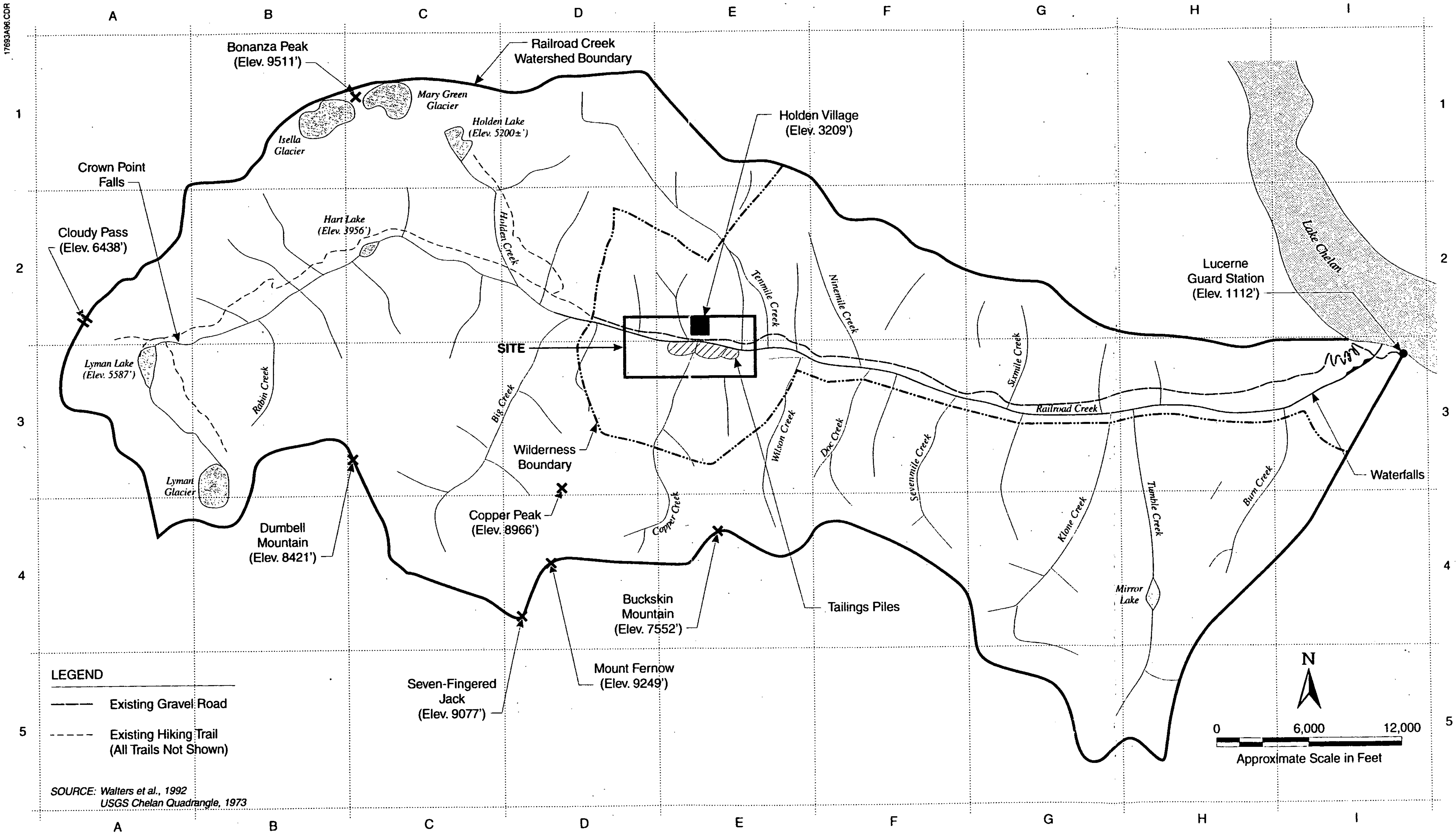
Figure 9.2-1

LAKE CHELAN WATERSHED MAP

Holden Mine RI/FS
Draft Final RI Report

Job No. 17693-005-019



SOURCE: Walters et al., 1992
USGS Chelan Quadrangle, 1973

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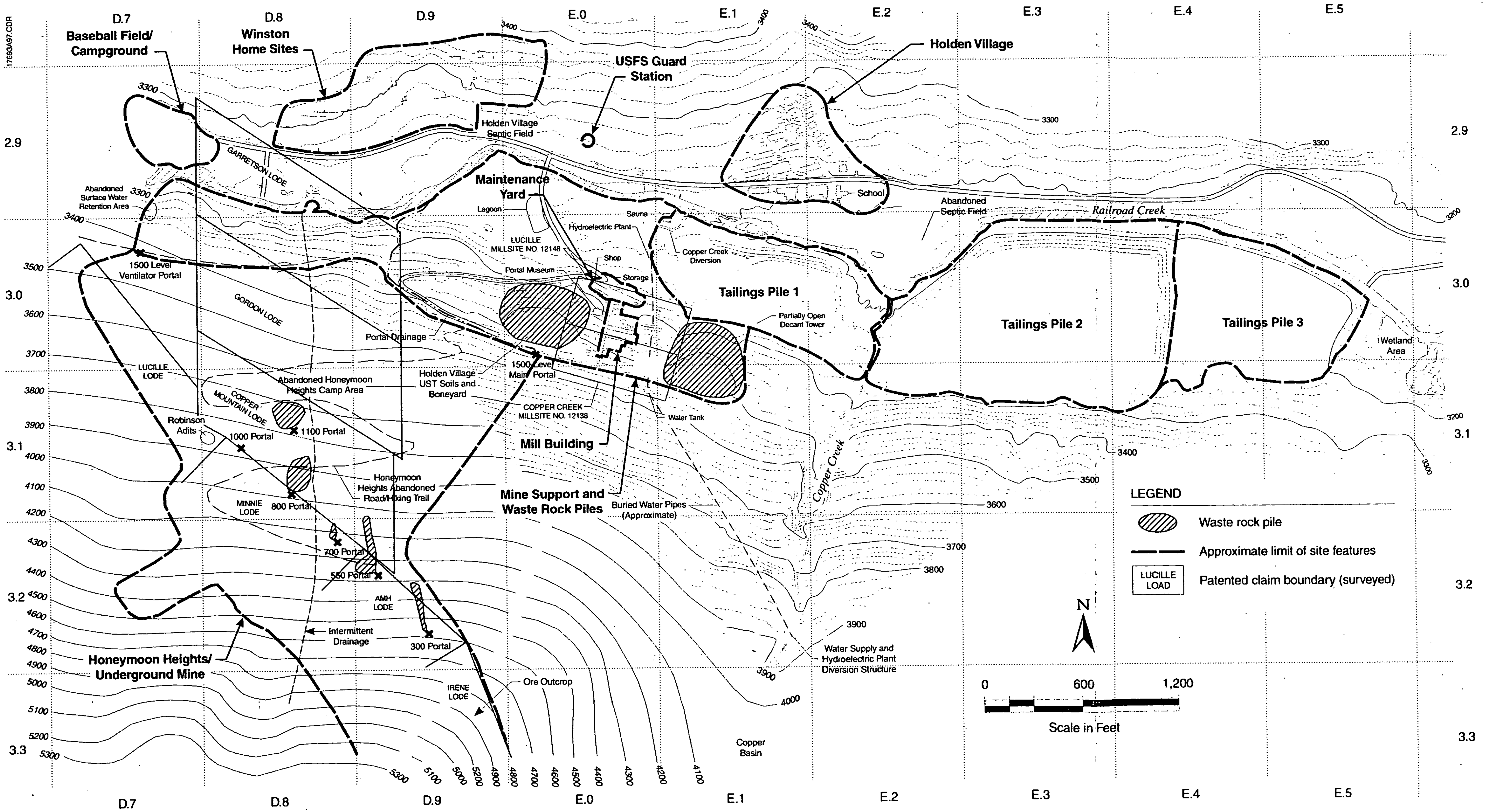
Figure 9.2-2
RAILROAD CREEK WATERSHED MAP

Holden Mine RI/FS
Draft Final RI Report



SOURCE: Base map information from USFS and Washington DNR, DEM CD ROM

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Figure 9.2-3
HOLDEN MINE SITE MAP

Holden Mine RI/FS
Draft Final RI Report

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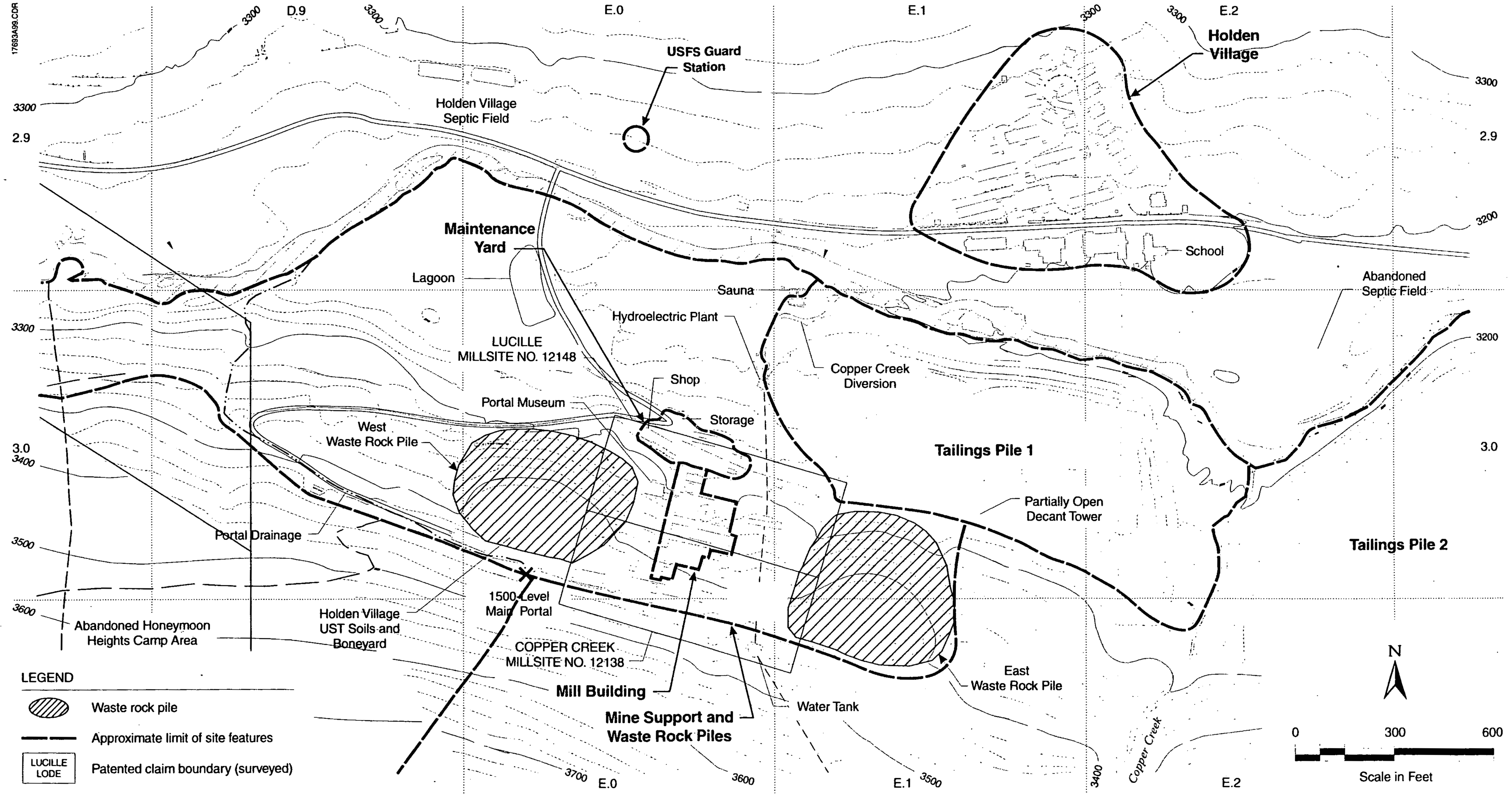

SOURCE: Base map information from USFS and Washington DNR, DEM CD ROM

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Figure 9.2-4
DETAIL OF MINE SUPPORT WASTE ROCK PILES AREA, TAILINGS PILE 1 AND HOLDEN VILLAGE

17693s94.CDR

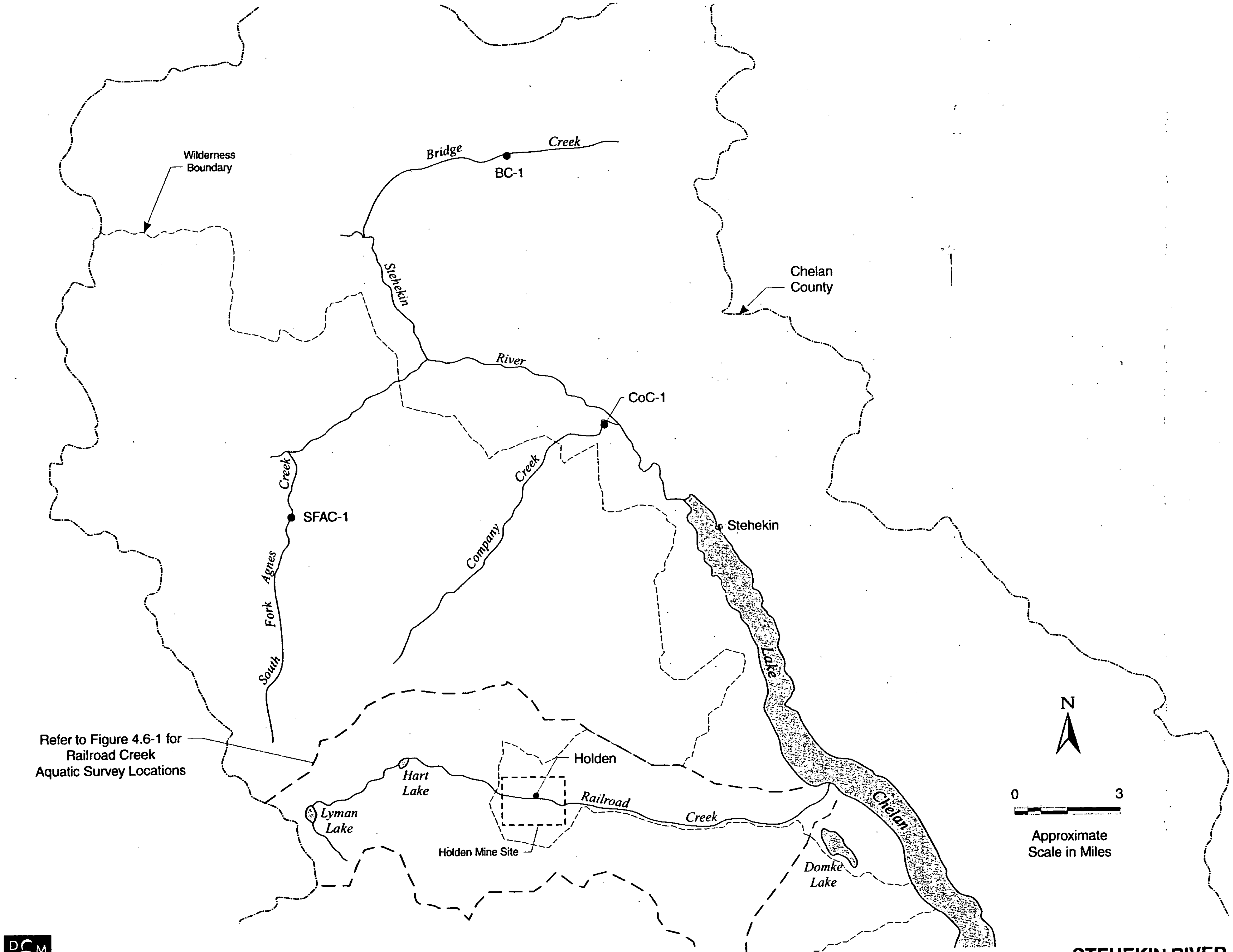

Figure 9.2-5
STEHEKIN RIVER AND RAILROAD CREEK WATERSHEDS

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Draft Final RI Report

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10.0 PROJECT SCHEDULE

The schedule for the future Holden Mine RI/FS deliverables as designated in the RI/FS Statement of Work attached to the Holden Mine Site Administrative Order on Consent are listed below:

PRIMARY DELIVERABLES	DELIVERABLE SCHEDULE
Draft Feasibility Study (FS) Report	Within 90 days of RPM approval of the Final RI Report and Alternatives Development and Screening Technical Memorandum
Final FS Report	Within 60 days of receipt of written RPM comments on the Draft FS Report

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DRAFT FINAL
Remedial Investigation Report
Holden Mine Site

Volume 4 – Appendices

prepared for
Alumet, Inc.

prepared by
Dames & Moore
Seattle, Washington

July 28, 1999

DAMES & MOORE
A DAMES & MOORE GROUP COMPANY

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Seattle, Washington

July 28, 1999

DAMES & MOORE
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MEMORANDUM

Date: June 15, 1998

To: Rik Langendoen, Project Manager

From: Karen Mixon, Project Chemist km

Subject: Summary Data Quality Review
Holden Mine Remedial Investigation Phase III
Equipment Blank, May 1998
Dames & Moore Job #17693-005-019

The summary data quality review of two filter blanks and one bottle blank has been completed. The sample was analyzed at the Analytical Resources, Incorporated (ARI) laboratory in Seattle, Washington for total recoverable and dissolved metals by EPA Methods 6010A and 200.8 modified (including the following metals: aluminum, arsenic, barium, beryllium, cadmium, calcium, chromium, copper, iron, lead, magnesium, manganese, molybdenum, nickel, potassium, silver, sodium, and zinc). The analyses were performed in accordance with the methods specified in EPA Test Methods for Evaluating Solid Waste, SW-846, January 1995. A standard report containing summarized method associated QA/QC data and sample data was provided by the laboratory. The following samples are associated with laboratory work order ARI# W064:

Sample I.D.	ARI Sample #	Analyses Requested
Filter Blank #1	W064A	Dissolved Metals
Filter Blank #2	W064B	Dissolved Metals
#3	W064C	Total Metals

The following comments refer to ARI's performance in meeting quality control specifications described in the EPA documents "EPA Test Methods for Evaluating Solid Waste, SW-846", January 1995 and "USEPA Contract Laboratory Program (CLP) National Functional Guidelines for Inorganic Data Review", February 1994, and the Quality Assurance Project Plan (QAPP) prepared for the Phase III Remedial Investigation dated April 17, 1998.

The sample was prepared in the laboratory using EPA Method 3005A and a modified EPA 200.8 preparation method. Samples were analyzed by ICP (EPA Method 6010A) and ICPMS (EPA Method 200.8 Modified).

1. Holding Time - Acceptable

2. Blanks

Copper (0.3 ug/L), potassium (6 ug/L), and sodium (30 ug/L) were detected in the method blank associated with this sample set. As the concentrations detected were at or near the detection limit, associated sample results less than 5X the concentration in the blank are qualified as not detected and flagged "U" accordingly. Results between 5X and 10X the concentration detected in the method blank are qualified as estimated and flagged "J" accordingly. Results reported as not detected or greater than 10X the concentration detected in the method blank do not require qualification.

After data qualification, the following metals were detected in the filter blanks as noted below:

Analyte	Detection Limit	Filter Blank #1	Filter Blank #2
Aluminum	4 U	8 ug/L	Not Detected
Barium	0.04 ug/L	0.06 ug/L	0.11 ug/L
Cadmium	0.04 ug/L	0.06 ug/L	Not Detected
Manganese	0.04 ug/L	0.05 ug/L	Not Detected

The two filter blanks were collected from the same filter lot. Due to the proximity of the results to the detection limit, the data does not clearly indicate an additive effect from the filters. In addition, the detection limit reported for aluminum is below the project requirements. The filters were considered acceptable for use during the May 1998 sampling event.

3. Laboratory Control Sample – Not Applicable

4. Laboratory Duplicate – Not Applicable

   A laboratory duplicate is not required for field quality control samples.

5. Field Duplicate - Not Applicable

6. Matrix Spike – Not Applicable

   A matrix spike is not required for field quality control samples.

7. Detection Limits - Acceptable

8. Type of Review - Summary

9. Overall Assessment of Data

The usefulness of the data is based on EPA guidance documents listed above. Upon consideration of the information presented above, the data are acceptable except where flagged with data qualifiers that modify the usefulness of the individual values.

Data Qualifiers

U	The analyte was analyzed for, but was not detected above the reported sample quantitation limit.
J	The analyte was positively identified; the associated numerical value is the approximate concentration of the analyte in the sample.
UJ	The analyte was not detected above the reported sample quantitation limit. However, the reported quantitation limit is approximate and may or may not represent the actual limit of quantitation necessary to accurately and precisely measure the analyte in the sample.
R	The sample results are rejected due to serious deficiencies in the ability to analyze the sample and meet quality control criteria. The presence or absence of the analyte cannot be verified.

ANALYTICAL
RESOURCES
INCORPORATED

INORGANICS ANALYSIS DATA SHEET
TOTAL METALS

Sample No: Filter Blank #1

Lab Sample ID: W064A
LIMS ID: 98-7775
Matrix: Water

QC Report No: W064-Dames & Moore
Project: Holden Mine
17693-005-019
Date Sampled:
Date Received: 04/17/98

Data Release Authorized:
Reported: 05/07/98

Prep Meth	Prep Date	Analysis Method	Analysis Date	CAS Number	Analyte	RL	ug/L
200.8	04/18/98	200.8	04/20/98	7429-90-5	Aluminum	4	8
200.8	04/18/98	200.8	04/20/98	7440-38-2	Arsenic	0.04	0.04 U
200.8	04/18/98	200.8	04/20/98	7440-39-3	Barium	0.04	0.06
200.8	04/18/98	200.8	04/20/98	7440-41-7	Beryllium	0.04	0.04 U
200.8	04/18/98	200.8	04/20/98	7440-43-9	Cadmium	0.04	0.06
200.8	04/18/98	200.8	04/20/98	7440-70-2	Calcium	10	10 U
200.8	04/18/98	200.8	04/20/98	7440-47-3	Chromium	0.2	0.2 U
200.8	04/18/98	200.8	04/20/98	7440-50-8	Copper	0.2	0.2 U
200.8	04/18/98	200.8	04/20/98	7439-89-6	Iron	4	4 U
200.8	04/18/98	200.8	04/20/98	7439-92-1	Lead	0.2	0.2 U
200.8	04/18/98	200.8	04/20/98	7439-95-4	Magnesium	4	4 U
200.8	04/18/98	200.8	04/20/98	7439-96-5	Manganese	0.04	0.05
200.8	04/18/98	200.8	04/20/98	7439-98-7	Molybdenum	0.04	0.04 U
200.8	04/18/98	200.8	04/20/98	7440-02-0	Nickel	0.2	0.2 U
200.8	04/18/98	200.8	04/20/98	7440-09-7	Potassium	4	10 U
200.8	04/18/98	200.8	04/20/98	7440-22-4	Silver	0.04	0.04 U
200.8	04/18/98	200.8	04/20/98	7440-23-5	Sodium	20	40 U
200.8	04/18/98	200.8	04/20/98	7440-66-6	Zinc	0.8	0.8 U

Km 4/15/98

U Analyte undetected at given RL

RL Reporting Limit

FORM-I

**ANALYTICAL
RESOURCES
INCORPORATED**

**INORGANICS ANALYSIS DATA SHEET
TOTAL METALS**

Sample No: **Filter Blank #2**

Lab Sample ID: W064B
LIMS ID: 98-7776
Matrix: Water

QC Report No: W064-Dames & Moore
Project: Holden Mine
17693-005-019
Date Sampled:
Date Received: 04/17/98

Data Release Authorized:
Reported: 05/07/98

Prep Meth	Prep Date	Analysis Method	Analysis Date	CAS Number	Analyte	RL	ug/L
200.8	04/18/98	200.8	04/20/98	7429-90-5	Aluminum	4	4 U
200.8	04/18/98	200.8	04/20/98	7440-38-2	Arsenic	0.04	0.04 U
200.8	04/18/98	200.8	04/20/98	7440-39-3	Barium	0.04	0.11
200.8	04/18/98	200.8	04/20/98	7440-41-7	Beryllium	0.04	0.04 U
200.8	04/18/98	200.8	04/20/98	7440-43-9	Cadmium	0.04	0.04 U
200.8	04/18/98	200.8	04/20/98	7440-70-2	Calcium	10	10 U
200.8	04/18/98	200.8	04/20/98	7440-47-3	Chromium	0.2	0.2 U
200.8	04/18/98	200.8	04/20/98	7440-50-8	Copper	0.2	0.3 U
200.8	04/18/98	200.8	04/20/98	7439-89-6	Iron	4	4 U
200.8	04/18/98	200.8	04/20/98	7439-92-1	Lead	0.2	0.2 U
200.8	04/18/98	200.8	04/20/98	7439-95-4	Magnesium	4	4 U
200.8	04/18/98	200.8	04/20/98	7439-96-5	Manganese	0.04	0.04 U
200.8	04/18/98	200.8	04/20/98	7439-98-7	Molybdenum	0.04	0.04 U
200.8	04/18/98	200.8	04/20/98	7440-02-0	Nickel	0.2	0.2 U
200.8	04/18/98	200.8	04/20/98	7440-09-7	Potassium	4	6 U
200.8	04/18/98	200.8	04/20/98	7440-22-4	Silver	0.04	0.04 U
200.8	04/18/98	200.8	04/20/98	7440-23-5	Sodium	20	60 U
200.8	04/18/98	200.8	04/20/98	7440-66-6	Zinc	0.8	0.8 U

KM 6/15/98

U Analyte undetected at given RL

RL Reporting Limit

FORM-I

ANALYTICAL
RESOURCES
INCORPORATED

INORGANICS ANALYSIS DATA SHEET
TOTAL METALS

Sample No: #3

Lab Sample ID: W064C
LIMS ID: 98-7777
Matrix: Water

QC Report No: W064-Dames & Moore
Project: Holden Mine
17693-005-019
Date Sampled:
Date Received: 04/17/98

Data Release Authorized:
Reported: 05/07/98

Prep Meth	Prep Date	Analysis Method	Analysis Date	CAS Number	Analyte	RL	ug/L
200.8	04/18/98	200.8	04/20/98	7429-90-5	Aluminum	4	4 U
200.8	04/18/98	200.8	04/20/98	7440-38-2	Arsenic	0.04	0.04 U
200.8	04/18/98	200.8	04/20/98	7440-39-3	Barium	0.04	0.04 U
200.8	04/18/98	200.8	04/20/98	7440-41-7	Beryllium	0.04	0.04 U
200.8	04/18/98	200.8	04/20/98	7440-43-9	Cadmium	0.04	0.04 U
200.8	04/18/98	200.8	04/20/98	7440-70-2	Calcium	10	10 U
200.8	04/18/98	200.8	04/20/98	7440-47-3	Chromium	0.2	0.2 U
200.8	04/18/98	200.8	04/20/98	7440-50-8	Copper	0.2	0.2 U
200.8	04/18/98	200.8	04/20/98	7439-89-6	Iron	4	4 U
200.8	04/18/98	200.8	04/20/98	7439-92-1	Lead	0.2	0.2 U
200.8	04/18/98	200.8	04/20/98	7439-95-4	Magnesium	4	4 U
200.8	04/18/98	200.8	04/20/98	7439-96-5	Manganese	0.04	0.05
200.8	04/18/98	200.8	04/20/98	7439-98-7	Molybdenum	0.04	0.04 U
200.8	04/18/98	200.8	04/20/98	7440-02-0	Nickel	0.2	0.2 U
200.8	04/18/98	200.8	04/20/98	7440-09-7	Potassium	4	5 U
200.8	04/18/98	200.8	04/20/98	7440-22-4	Silver	0.04	0.04 U
200.8	04/18/98	200.8	04/20/98	7440-23-5	Sodium	20	20 U
200.8	04/18/98	200.8	04/20/98	7440-66-6	Zinc	0.8	0.8 U

Km4/15/98

U Analyte undetected at given RL

RL Reporting Limit

FORM-I

ANALYTICAL
RESOURCES
INCORPORATED

INORGANICS ANALYSIS DATA SHEET
TOTAL METALS

Sample No: Method Blank

Lab Sample ID: W064MB
LIMS ID: 98-7775
Matrix: Water

QC Report No: W064-Dames & Moore
Project: Holden Mine
17693-005-019
Date Sampled: NA
Date Received: NA

Data Release Authorized:
Reported: 05/07/98

Prep Meth	Prep Date	Analysis Method	Analysis Date	CAS Number	Analyte	RL	ug/L	
200.8	04/18/98	200.8	04/20/98	7429-90-5	Aluminum	4	4	U
200.8	04/18/98	200.8	04/20/98	7440-38-2	Arsenic	0.04	0.04	U
200.8	04/18/98	200.8	04/20/98	7440-39-3	Barium	0.04	0.04	U
200.8	04/18/98	200.8	04/20/98	7440-41-7	Beryllium	0.04	0.04	U
200.8	04/18/98	200.8	04/20/98	7440-43-9	Cadmium	0.04	0.04	U
200.8	04/18/98	200.8	04/20/98	7440-70-2	Calcium	10	10	U
200.8	04/18/98	200.8	04/20/98	7440-47-3	Chromium	0.2	0.2	U
200.8	04/18/98	200.8	04/20/98	7440-50-8	Copper	0.2	0.3	
200.8	04/18/98	200.8	04/20/98	7439-89-6	Iron	4	4	U
200.8	04/18/98	200.8	04/20/98	7439-92-1	Lead	0.2	0.2	U
200.8	04/18/98	200.8	04/20/98	7439-95-4	Magnesium	4	4	U
200.8	04/18/98	200.8	04/20/98	7439-96-5	Manganese	0.04	0.04	U
200.8	04/18/98	200.8	04/20/98	7439-98-7	Molybdenum	0.04	0.04	U
200.8	04/18/98	200.8	04/20/98	7440-02-0	Nickel	0.2	0.2	U
200.8	04/18/98	200.8	04/20/98	7440-09-7	Potassium	4	6	
200.8	04/18/98	200.8	04/20/98	7440-22-4	Silver	0.04	0.04	U
200.8	04/18/98	200.8	04/20/98	7440-23-5	Sodium	20	30	
200.8	04/18/98	200.8	04/20/98	7440-66-6	Zinc	0.8	0.8	U

U Analyte undetected at given RL

RL Reporting Limit

FORM-I

98-1115
98-7777

W064

CHAIN-OF-CUSTODY RECORD

WHITE COPY-Original (Accompanies Samples) YELLOW COPY-Collector PINK COPY-Project Manager

Boring or Well Number	Sample Number	Depth	Time	Sample Type	Container Type	Analysis Required: ~~VOA 601/8010~~ metals*	VOA 602/8020	VOA 624/8240/8260	Semi Vol 625/8270	NWTPH-Gx	NWTPH-Dx	NWTPH-Dx-Ext	RCRA 8 Metals	PNA 610/8310	Pest/PCBs 8081	ASBESTOS	FIELD NOTES:	Total Number Of Containers	Laboratory Note Number
Filter Blk	#1			Filter	NA	X											Please label as		
Filter Blk	#2			Filter	NA	X											Filter Blnk #1 or	#2	
	#3			H2O	Bottle	X											Label as Bottle Check		
																	Please fax data		
																	by ~~8AM~~ 5PM 4/21/98		
							On filters,	please	filter	~	1000ml of									
							water	through	the	to	mimic	field situation							

RELINQUISHED BY: (Signature) Karen Mixon DATE/TIME 4/17/98 01:30PM RECEIVED BY: (Signature) 4 Amy Bergen

RELINQUISHED BY: (Signature) DATE/TIME RECEIVED BY: (Signature)

RELINQUISHED BY: (Signature) DATE/TIME RECEIVED BY: (Signature)

ANALYTICAL LABORATORY: ARI

LABORATORY CONTACT: Mark Harris

D&M CONTACT: Karen Mixon PHONE: 728-0744

DAMES & MOORE
AMES & MOORE GROUP COMPANY

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LABORATORY NOTES:

* Aluminum, Arsenic, Barium, Beryllium, Cadmium, Calcium, Chromium, Copper, Iron, magnesium, manganese, molybdenum, Nickel, Potassium, Silver, Sodium, Zinc ; follow surface water analytical plan 6010 / 200.8.

Run lab metal free water through filter, process, and analyze.
~~Run~~ Fill bottle with metal free water, process, and analyze.

JOB NO.: 17693.005 - 019

PROJECT: Holden Mine

LOCATION: Holden Village, WA

LLECTOR: Km DATE OF COLLECTION 4/

MEMORANDUM

Date: June 15, 1998

To: Rik Langendoen, Project Manager

From: Karen Mixon, Project Chemist KM

Subject: Standard Data Quality Review
Holden Mine Remedial Investigation Phase III
Surface Water Data, May 1998
Dames & Moore Job #17693-005-019

The standard data quality review of 17 surface water samples and 3 equipment blanks collected from April 30 to May 5, 1998 has been completed. The samples were analyzed at the Analytical Resources, Incorporated (ARI) laboratory in Seattle, Washington for total recoverable and dissolved metals by EPA Methods 6010A and 200.8 modified (including the following metals: aluminum, arsenic, barium, beryllium, cadmium, calcium, chromium, copper, iron, lead, magnesium, manganese, molybdenum, nickel, potassium, silver, sodium, zinc) and hardness by EPA Method 6010A calculation. In addition, samples were also analyzed for the following: alkalinity by Standard Method 2320, total dissolved solids (TDS) by EPA Method 160.1, total suspended solids (TSS) by EPA Method 160.2, and sulfate by EPA Method 375.2. Select samples were analyzed for total petroleum hydrocarbons (diesel and gasoline range) by Washington State Department of Ecology TPH methods. Samples were analyzed for low-level lead by Frontier Geosciences in Seattle, Washington. The low-level lead results are not included in this report as they were provided separately and validated under separate cover memo. The analyses were performed in accordance with the methods specified in EPA Test Methods for Evaluating Solid Waste, SW-846, January 1995, EPA Methods for Chemical Analysis of Water and Wastes, March 1983, Standard Methods for the Examination of Water and Wastewater, 18th edition, 1992, and Washington State Department of Ecology Total Petroleum Hydrocarbons Methods, April 1992. A validation package containing method associated QA/QC data and summarized sample data was provided by the laboratory. The following samples are associated with laboratory work orders ARI# W219 and W221:

Sample I.D.	ARI Sample #	Analyses Requested
HC-4	W219A/W219R	Dissolved/Total Metals, alkalinity, TDS/TSS, sulfate
HC-3	W219B/W219S	Dissolved/Total Metals, alkalinity, TDS/TSS, sulfate
HC-2	W219C/W219T	Dissolved/Total Metals, alkalinity, TDS/TSS, sulfate
HC-1	W219D/W219U	Dissolved/Total Metals, alkalinity, TDS/TSS, sulfate
RC-11	W219E/W219V	Dissolved/Total Metals, alkalinity, TDS/TSS, sulfate
BIG-1	W219F/W219W	Dissolved/Total Metals, alkalinity, TDS/TSS, sulfate

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Sample I.D.	ARI Sample #	Analyses Requested
CC-1	W219G/W219X	Dissolved/Total Metals, alkalinity, TDS/TSS, sulfate
CC-2	W219H/W219Y	Dissolved/Total Metals, alkalinity, TDS/TSS, sulfate
RC-6	W219I/W219Z	Dissolved/Total Metals, alkalinity, TDS/TSS, sulfate
RC-1	W219J/W219AA	Dissolved/Total Metals, alkalinity, TDS/TSS, sulfate
RC-4	W219K/W219AB	Dissolved/Total Metals, alkalinity, TDS/TSS, sulfate
RC-4X	W219L/W219AC	Dissolved/Total Metals, alkalinity, TDS/TSS, sulfate
RC-7	W219M/W219AD	Dissolved/Total Metals, alkalinity, TDS/TSS, sulfate
RC-5	W219N/W219AE	Dissolved/Total Metals, alkalinity, TDS/TSS, sulfate
RC-10	W219O/W219AF	Dissolved/Total Metals, alkalinity, TDS/TSS, sulfate
RC-3	W219P/W219AG	Dissolved/Total Metals, alkalinity, TDS/TSS, sulfate
RC-2	W219Q/W219AH	Dissolved/Total Metals, alkalinity, TDS/TSS, sulfate, WTPH-G, WTPH-D
EB050298	W221A	Total Metals
EB050398	W221B	Total Metals
EB050598	W221C	Total Metals

The following comments refer to ARI's performance in meeting quality control specifications described in the EPA documents "EPA Test Methods for Evaluating Solid Waste, SW-846", January 1995, "Methods for Chemical Analysis of Water and Wastes", March 1983, "USEPA Contract Laboratory Program (CLP) National Functional Guidelines for Inorganic Data Review", February 1994, and "USEPA Contract Laboratory Program (CLP) National Functional Guidelines for Organic Data Review", February 1994, and Standard Methods for the Examination of Water and Wastewater, 18th Edition, 1992, Washington State Department of Ecology Total Petroleum Hydrocarbons Methods, April 1992, and the Quality Assurance Project Plan (QAPP) prepared for the Phase III Remedial Investigation dated April 17, 1998.

The report is divided into subsections based on type of analyses performed.

Total Recoverable and Dissolved Metals

Sample aliquots for dissolved metals were filtered and preserved in the field. Sample aliquots for total recoverable metals were transferred to preserved containers in the field.

Samples were prepared in the laboratory using EPA Method 3005A and a modified EPA 200.8 preparation method with additional concentration steps where appropriate. Samples were analyzed by ICP (EPA Method 6010A) and ICP MS (EPA Method 200.8 Modified).

1. Holding Time - Acceptable

2. Tunes (ICP MS analysis only) - Acceptable

3. Initial Calibration - Acceptable

4. Continuing Calibration - Acceptable

5. Blanks

Aluminum (30.4 ug/L), calcium (23.3 ug/L), and magnesium (29 ug/L) were detected in the ending continuing calibration blank (CCB) analyzed on May 19, 1998. Samples were not analyzed between the previous CCB and the ending CCB. The detected metals in the ending CCB do not indicate a carryover concern that affects sample results. Data was not qualified based on the CCB.

Aluminum (20 ug/L) and calcium (30 ug/L) were detected in the method blank associated with the total analysis of samples RC-1, RC-4, RC-4X, RC-7, RC-5, RC-10, RC-3, RC-2, HC-4, HC-3, HC-2, HC-1, RC-11, BIG-1, CC-1, CC-2, RC-6, and EB050298, EB050398, and EB050598. As the concentrations detected were at or near the detection limit, sample results in associated samples that are less than 5X the concentration in the blank are qualified as not detected and flagged "U" accordingly. Results between 5X and 10X the concentrations detected in the method blank are qualified as estimated and flagged "J" accordingly. Results reported as not detected or greater than 10X the concentration detected in the method blank do not require qualification.

Barium (0.05 ug/L) and lead (0.4 ug/L) were detected in the method blank associated with the total analysis of RC-1, RC-4, RC-4X, RC-7, RC-5, RC-10, RC-3, RC-2, HC-4, HC-3, HC-2, HC-1, RC-11, BIG-1, CC-1, CC-2, and RC-6. Cadmium (0.11 ug/L) was detected in the method blank associated with the total analysis of RC-1, RC-4, RC-4X, RC-7, RC-5, RC-2, HC-4, HC-3, HC-2, HC-1, RC-11, BIG-1, CC-1, CC-2, and RC-6. Copper (0.3 ug/L) was detected in the method blank associated with the total analysis of RC-4, RC-4X, RC-7, RC-5, RC-10, RC-3, RC-2, HC-4, HC-3, HC-2, HC-1, BIG-1, CC-1, and RC-6. Manganese (0.44 ug/L) was detected in the method blank associated with the total analysis of RC-1, RC-4, RC-4X, RC-7, RC-5, RC-10, RC-3, RC-2, HC-2, CC-2, and RC-6. Sample results for barium, cadmium, copper, and lead were at or near the detection limit. These elements reported in associated samples that are less than 5X the concentration in the blank are qualified as not detected and flagged "U" accordingly. Results between 5X and 10X the concentrations detected in the method blank are qualified as estimated and flagged "J" accordingly. Results reported as not detected or greater than 10X the concentration detected in the method blank do not require qualification.

Manganese detected in the method blank was substantially above the detection limit. Associated samples with results less than 10X the method blank concentration were reprepped and reanalyzed.

Manganese (0.04 ug/L) was detected in the method blank associated with the repreparation for total analysis of samples HC-4, HC-3, HC-1, RC-11, Big-1, and CC-1. As manganese was detected at the detection limit, results reported in associated samples less than 5X the concentration in the blank are qualified as not detected and flagged "U" accordingly. Results between 5X and 10X the concentration detected in the method blank are qualified as estimated and flagged "J" accordingly. Results reported as not detected or greater than 10X the concentration detected in the method blank do not require qualification.

Manganese (0.05 ug/L) was detected in the method blank associated with the dissolved analysis of RC-1, RC-4, RC-4X, RC-7, RC-5, RC-10, RC-3, RC-2, HC-4, HC-3, HC-2, HC-1, RC-11, BIG-1, CC-1, CC-2, and RC-6 and the total analysis of EB050298, EB050398, and EB050598. Manganese results were not detected or were greater than 10X the method blank concentration in all samples with the exception of BIG-1. The result was less than 5X the method blank concentration and qualified as not detected and flagged "U" accordingly.

Analytes of concern were detected in the equipment blanks as noted below.

Analyte	Detection Limit	EB050298	EB050398	EB050598
Barium	0.04	0.04	0.05	0.12
Copper	0.2	Not Detected	Not Detected	0.4
Lead	0.2	0.4	Not Detected	0.3
Sodium	50	50	50	Not Detected

Each of the equipment blanks is associated to samples as follows:

EB050298 – Tubing used for filtration of portal, ventilator portal, and seep samples.
EB050398 – Decon of nozzles and adaptors associated with surface water sampling. Note that the additional equipment used for surface water sampling is generally dedicated to each individual station.
EB050598 – Ending decontamination blank for all sampling equipment used in the May 1998 sampling event.

Due to the low level detection of the metals shown, the proximity of the results to the detection limits of the method, and the associated samples for each equipment blank, the data does not clearly show an additive effect related to the decontamination of equipment. Data were not qualified based on the equipment blank results.

6. Internal Standards (ICP MS analysis only) - Acceptable

7. ICP Interference Check (ICP analysis only) - Acceptable

8. Laboratory Control Sample - Acceptable

9. Laboratory Duplicate Sample

The laboratory duplicate performed on HC-3 (dissolved) was acceptable (within 20%) for all elements except lead. The lead results were not detected and 0.8 ug/L. As the difference is greater than the CRDL, associated sample results for lead reported greater than the detection limit are qualified as estimated and flagged "J". Associated samples include dissolved analysis of HC-4, HC-3, HC-2, HC-1, RC-11, BIG-1, CC-1, CC-2, RC-6, RC-1, RC-4, RC-4X, RC-7, RC-5, RC-10, RC-3, RC-2, EB050298, EB050398, and EB050598.

10. Field Duplicate - Acceptable

    Sample RC-4X is the field duplicate of RC-4.

11. Matrix Spike - Acceptable

12. ICP Serial Dilution (ICP analysis only) - Acceptable

13. Detection Limits - Acceptable

14. Type of Review - Standard

15. Overall Assessment of Data

The usefulness of the data is based on EPA guidance documents listed above. Upon consideration of the information presented above, the data are acceptable except where flagged with data qualifiers that modify the usefulness of the individual values.

Conventional Analyses

Samples were analyzed for total dissolved solids (TDS), total suspended solids (TSS), alkalinity, and sulfate by EPA or other methods identified in the introduction of this report. In addition, hardness was determined by calculation from dissolved metals analysis and reviewed for correctness.

1. Hold Time - Acceptable

2. Initial Calibration - Acceptable

   Applicable for alkalinity and sulfate.

3. Continuing Calibration - Acceptable

   Applicable for alkalinity and sulfate.

4. Blanks - Acceptable

5. Laboratory Control Sample - Acceptable

Applicable for alkalinity. A standard reference material (SRM) was used to evaluate sulfate. Results were acceptable.

6. Laboratory Sample Duplicate - Acceptable

7. Field Duplicate - Acceptable

   Sample RC-4X is the field duplicate of sample RC-4.

8. Matrix Spike (MS) - Acceptable

   Applicable for sulfate.

9. Detection Limits - Acceptable

The detection limit for TSS reported for sample HC-4 was 2.2 mg/L which is above the QAPP requirement of 1.0 mg/L. The increased detection limit was due to the use of reduced sample volume as this sample was used for the laboratory duplicate analysis. Data usability is not affected.

10. Type of Review - Standard

11. Overall Assessment of Data

The usefulness of the data is based on the EPA guidance documents listed above. Upon consideration of the information presented above, data are considered acceptable except where flagged with data qualifiers that modify the usefulness of the individual values.

Organic Analyses

Select samples (as noted in the report introduction) were analyzed for TPH (gasoline range), and TPH (diesel extended range) per the Ecology methods previously referenced.

1. Hold Time - Acceptable

2. Initial Calibration - Acceptable

3. Continuing Calibration - Acceptable

4. Blanks - Acceptable

5. Surrogate Recoveries - Acceptable

6. Laboratory Duplicate

A lab duplicate was not performed for WTPH-G or WTPH-D extended as required by the method. Data was not qualified based on the omission of a laboratory duplicate.

7. Matrix Spike/Matrix Spike Duplicate (MS/MSD)

A MS/MSD was not performed. A MS/MSD is not required per the method.

8. Laboratory Control Sample/Blank Spike (LCS/BS) - Acceptable

9. Field Duplicate - Not applicable

10. Target Compound Identification - Acceptable

11. Detection Limits - Acceptable

12. Type of Review - Standard

13. Overall Assessment of Data

The usefulness of the data is based on the EPA guidance documents listed above. Upon consideration of the information presented above, data are considered acceptable except where flagged with data qualifiers that modify the usefulness of the individual values.

Data Qualifiers

U	The analyte was analyzed for, but was not detected above the reported sample quantitation limit.
J	The analyte was positively identified; the associated numerical value is the approximate concentration of the analyte in the sample.
UJ	The analyte was not detected above the reported sample quantitation limit. However, the reported quantitation limit is approximate and may or may not represent the actual limit of quantitation necessary to accurately and precisely measure the analyte in the sample.
R	The sample results are rejected due to serious deficiencies in the ability to analyze the sample and meet quality control criteria. The presence or absence of the analyte cannot be verified.

ANALYTICAL
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INORGANICS ANALYSIS DATA SHEET
TOTAL METALS

Sample No: HC-4

Lab Sample ID: W219R
LIMS ID: 98-9036
Matrix: Water

QC Report No: W219-Dames & Moore
Project: Holden Mine
17693-005-019
Date Sampled: 04/30/98
Date Received: 05/05/98

Data Release Authorized:
Reported: 06/10/98

Prep Meth	Prep Date	Analysis Method	Analysis Date	CAS Number	Analyte	RL	ug/L
3005	05/15/98	6010	05/18/98	7429-90-5	Aluminum	20	50 U
200.8	05/18/98	200.8	05/19/98	7440-38-2	Arsenic	0.04	1.33
200.8	05/18/98	200.8	05/19/98	7440-39-3	Barium	0.04	6.82
200.8	05/18/98	200.8	05/19/98	7440-41-7	Beryllium	0.04	0.04 U
200.8	05/18/98	200.8	05/19/98	7440-43-9	Cadmium	0.04	0.06 U
3005	05/15/98	6010	05/18/98	7440-70-2	Calcium	20	4,150
200.8	05/18/98	200.8	05/19/98	7440-47-3	Chromium	0.2	0.2 U
200.8	05/18/98	200.8	05/19/98	7440-50-8	Copper	0.2	0.9 U
3005	05/15/98	6010	05/18/98	7439-89-6	Iron	20	100
200.8	05/18/98	200.8	05/19/98	7439-92-1	Lead	0.2	0.3 U
3005	05/15/98	6010	05/18/98	7439-95-4	Magnesium	20	260
200.8	06/04/98	200.8	06/04/98	7439-96-5	Manganese	0.04	2.87
200.8	05/18/98	200.8	05/19/98	7439-98-7	Molybdenum	0.04	0.69
200.8	05/18/98	200.8	05/19/98	7440-02-0	Nickel	0.2	0.2 U
3005	05/15/98	6010	05/18/98	7440-09-7	Potassium	500	500 U
200.8	05/18/98	200.8	05/19/98	7440-22-4	Silver	0.04	0.04 U
3005	05/15/98	6010	05/18/98	7440-23-5	Sodium	50	640
3005	05/15/98	6010	05/18/98	7440-66-6	Zinc	4	4

Calculated Hardness (mg-CaCO3/L): 11

Km 6/15/98

U Analyte undetected at given RL

RL Reporting Limit

FORM-I

6/11/98

ANALYTICAL RESOURCES INCORPORATED

INORGANICS ANALYSIS DATA SHEET
TOTAL METALS

Sample No: HC-4
QC Report No: W219-Dames & Moore
Project: Holden Mine
17693-005-019
Date Received: 05/05/98

Lab Sample ID: W219R
LIMS ID: 98-9036
Matrix: Water

Data Release Authorized:
Reported: 05/21/98

MATRIX SPIKE QUALITY CONTROL REPORT

Analyte	Sample ug/L	Spike ug/L	Spike Added	% Recovery	Q
Aluminum	51	2150	2000	105%	
Arsenic	1.33	6.46	5.00	103%	
Barium	6.82	12.2	5.00	108%	
Beryllium	0.04 U	4.64	5.00	92.8%	
Cadmium	0.06	5.19	5.00	103%	
Calcium	4150	14800	10000	106%	
Chromium	0.2 U	4.9	5.0	98.0%	
Copper	0.9	6.4	5.0	110%	
Iron	97	1110	1000	101%	
Lead	0.3	5.7	5.0	108%	
Magnesium	257	10800	10000	105%	
Manganese	3.00	7.64	5.00	92.8%	
Molybdenum	0.69	5.88	5.00	104%	
Nickel	0.2 U	5.6	5.0	112%	
Potassium	500 U	10400	10000	104%	
Silver	0.04 U	4.87	5.00	97.4%	
Sodium	641	10700	10000	101%	
Zinc	4	515	500	102%	

'Q' codes:
N = control limit not met
H = %R not applicable, sample concentration too high
* = RPD control limit not met
NA = Not applicable - analyte not spiked

Control Limits:
Percent Recovery: 75-125%
RPD: +/-20%

FORM-V

ANALYTICAL
RESOURCES
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INORGANICS ANALYSIS DATA SHEET
TOTAL METALS

Sample No: HC-3

Lab Sample ID: W219S
LIMS ID: 98-9037
Matrix: Water

QC Report No: W219-Dames & Moore
Project: Holden Mine
17693-005-019
Date Sampled: 04/30/98
Date Received: 05/05/98

Data Release Authorized:
Reported: 06/10/98

Prep Meth	Prep Date	Analysis Method	Analysis Date	CAS Number	Analyte	RL	ug/L
3005	05/15/98	6010	05/19/98	7429-90-5	Aluminum	20	70 U
200.8	05/18/98	200.8	05/19/98	7440-38-2	Arsenic	0.04	0.78
200.8	05/18/98	200.8	05/19/98	7440-39-3	Barium	0.04	5.76
200.8	05/18/98	200.8	05/19/98	7440-41-7	Beryllium	0.04	0.04 U
200.8	05/18/98	200.8	05/19/98	7440-43-9	Cadmium	0.04	0.07 U
3005	05/15/98	6010	05/19/98	7440-70-2	Calcium	20	5,010
200.8	05/18/98	200.8	05/19/98	7440-47-3	Chromium	0.2	0.2 U
200.8	05/18/98	200.8	05/19/98	7440-50-8	Copper	0.2	1.0 U
3005	05/15/98	6010	05/19/98	7439-89-6	Iron	20	100
200.8	05/18/98	200.8	05/19/98	7439-92-1	Lead	0.2	0.4 U
3005	05/15/98	6010	05/19/98	7439-95-4	Magnesium	20	580
200.8	06/03/98	200.8	06/04/98	7439-96-5	Manganese	0.04	3.95
200.8	05/18/98	200.8	05/19/98	7439-98-7	Molybdenum	0.04	0.45
200.8	05/18/98	200.8	05/19/98	7440-02-0	Nickel	0.2	0.2 U
3005	05/15/98	6010	05/19/98	7440-09-7	Potassium	500	600
200.8	05/18/98	200.8	05/19/98	7440-22-4	Silver	0.04	0.04 U
3005	05/15/98	6010	05/19/98	7440-23-5	Sodium	50	880
3005	05/15/98	6010	05/19/98	7440-66-6	Zinc	4	4 U

Calculated Hardness (mg-CaCO3/L): 15

Km 4/15/98

U Analyte undetected at given RL

RL Reporting Limit

FORM-I

MD 6/11/98

ANALYTICAL
RESOURCES
INCORPORATED

INORGANICS ANALYSIS DATA SHEET
TOTAL METALS

Sample No: HC-3
Lab Sample ID: W219S
QC Report No: W219-Dames & Moore
LIMS ID: 98-9037
Project: Holden Mine
17693-005-019
Matrix: Water
Date Received: 05/05/98
Data Release Authorized:
Reported: 05/21/98

MATRIX DUPLICATE QUALITY CONTROL REPORT

Analyte	Sample ug/L	Duplicate ug/L	RPD	Control Limit	Q
Aluminum	70	90	25.0%	+/- 20	L
Arsenic	0.78	0.78	0.0%	+/- 20 %	
Barium	5.76	5.81	0.9%	+/- 20 %	
Beryllium	0.04 U	0.04 U	0.0%	+/- 0.04	L
Cadmium	0.07	0.05	33.3%	+/- 0.04	L
Calcium	5010	5100	1.8%	+/- 20 %	
Chromium	0.2 U	0.2 U	0.0%	+/- 0.2	L
Copper	1.0	1.1	9.5%	+/- 20 %	
Iron	100	120	18.2%	+/- 20	L
Lead	0.4	0.3	28.6%	+/- 0.2	L
Magnesium	580	600	3.4%	+/- 20 %	
Manganese	3.98	4.24	6.3%	+/- 20 %	
Molybdenum	0.45	0.46	2.2%	+/- 20 %	
Nickel	0.2 U	0.2 U	0.0%	+/- 0.2	L
Potassium	600	510	16.2%	+/- 500	L
Silver	0.04 U	0.04 U	0.0%	+/- 0.04	L
Sodium	880	900	2.2%	+/- 20 %	
Zinc	4 U	4 U	0.0%	+/- 4	L

'Q' codes:
* = control limit not met
L = RPD not valid, alternate limit = detection limit

FORM-VI

ANALYTICAL
RESOURCES
INCORPORATED

INORGANICS ANALYSIS DATA SHEET
TOTAL METALS

Sample No: HC-2

Lab Sample ID: W219T
LIMS ID: 98-9038
Matrix: Water

QC Report No: W219-Dames & Moore
Project: Holden Mine
17693-005-019
Date Sampled: 04/30/98
Date Received: 05/05/98

Data Release Authorized
Reported: 05/21/98

Prep Meth	Prep Date	Analysis Method	Analysis Date	CAS Number	Analyte	RL	ug/L	
3005	05/15/98	6010	05/18/98	7429-90-5	Aluminum	20	240	
200.8	05/18/98	200.8	05/19/98	7440-38-2	Arsenic	0.04	0.65	
200.8	05/18/98	200.8	05/19/98	7440-39-3	Barium	0.04	6.17	
200.8	05/18/98	200.8	05/19/98	7440-41-7	Beryllium	0.04	0.04	U
200.8	05/18/98	200.8	05/19/98	7440-43-9	Cadmium	0.04	0.07	U
3005	05/15/98	6010	05/18/98	7440-70-2	Calcium	20	5,690	
200.8	05/18/98	200.8	05/19/98	7440-47-3	Chromium	0.2	0.3	
200.8	05/18/98	200.8	05/19/98	7440-50-8	Copper	0.2	1.6	J
3005	05/15/98	6010	05/18/98	7439-89-6	Iron	20	230	
200.8	05/18/98	200.8	05/19/98	7439-92-1	Lead	0.2	0.4	U
3005	05/15/98	6010	05/18/98	7439-95-4	Magnesium	20	670	
200.8	05/18/98	200.8	05/19/98	7439-96-5	Manganese	0.04	6.80	
200.8	05/18/98	200.8	05/19/98	7439-98-7	Molybdenum	0.04	0.53	
200.8	05/18/98	200.8	05/19/98	7440-02-0	Nickel	0.2	0.5	
3005	05/15/98	6010	05/18/98	7440-09-7	Potassium	500	500	U
200.8	05/18/98	200.8	05/19/98	7440-22-4	Silver	0.04	0.04	U
3005	05/15/98	6010	05/18/98	7440-23-5	Sodium	50	880	
3005	05/15/98	6010	05/18/98	7440-66-6	Zinc	4	5	

Calculated Hardness (mg-CaCO3/L): 17

Km 6/4/98

U Analyte undetected at given RL

RL Reporting Limit

FORM-I

ANALYTICAL
RESOURCES
INCORPORATED

INORGANICS ANALYSIS DATA SHEET
TOTAL METALS

Sample No: HC-1

Lab Sample ID: W219U
LIMS ID: 98-9039
Matrix: Water

QC Report No: W219-Dames & Moore
Project: Holden Mine
17693-005-019
Date Sampled: 05/01/98
Date Received: 05/05/98

Data Release Authorized:
Reported: 06/10/98

Prep Meth	Prep Date	Analysis Method	Analysis Date	CAS Number	Analyte	RL	ug/L
3005	05/15/98	6010	05/18/98	7429-90-5	Aluminum	20	80 U
200.8	05/18/98	200.8	05/19/98	7440-38-2	Arsenic	0.04	0.52
200.8	05/18/98	200.8	05/19/98	7440-39-3	Barium	0.04	5.04
200.8	05/18/98	200.8	05/19/98	7440-41-7	Beryllium	0.04	0.04 U
200.8	05/18/98	200.8	05/19/98	7440-43-9	Cadmium	0.04	0.04 U
3005	05/15/98	6010	05/18/98	7440-70-2	Calcium	20	5,180
200.8	05/18/98	200.8	05/19/98	7440-47-3	Chromium	0.2	0.2 U
200.8	05/18/98	200.8	05/19/98	7440-50-8	Copper	0.2	1.2 U
3005	05/15/98	6010	05/18/98	7439-89-6	Iron	20	70
200.8	05/18/98	200.8	05/19/98	7439-92-1	Lead	0.2	0.2 U
3005	05/15/98	6010	05/18/98	7439-95-4	Magnesium	20	560
200.8	06/03/98	200.8	06/04/98	7439-96-5	Manganese	0.04	2.69
200.8	05/18/98	200.8	05/19/98	7439-98-7	Molybdenum	0.04	0.50
200.8	05/18/98	200.8	05/19/98	7440-02-0	Nickel	0.2	0.2 U
3005	05/15/98	6010	05/18/98	7440-09-7	Potassium	500	500 U
200.8	05/18/98	200.8	05/19/98	7440-22-4	Silver	0.04	0.04 U
3005	05/15/98	6010	05/18/98	7440-23-5	Sodium	50	850
3005	05/15/98	6010	05/18/98	7440-66-6	Zinc	4	5

Calculated Hardness (mg-CaCO3/L): 15

Km 6/15/98

U Analyte undetected at given RL

RL Reporting Limit

FORM-I

RL

6/11/98

ANALYTICAL
RESOURCES
INCORPORATED

INORGANICS ANALYSIS DATA SHEET
TOTAL METALS

Sample No: RC-11

Lab Sample ID: W219V
LIMS ID: 98-9040
Matrix: Water

QC Report No: W219-Dames & Moore
Project: Holden Mine
17693-005-019
Date Sampled: 05/01/98
Date Received: 05/05/98

Data Release Authorized:
Reported: 06/10/98

Prep Meth	Prep Date	Analysis Method	Analysis Date	CAS Number	Analyte	RL	ug/L
3005	05/15/98	6010	05/18/98	7429-90-5	Aluminum	20	70 U
200.8	05/18/98	200.8	05/19/98	7440-38-2	Arsenic	0.04	1.12
200.8	05/18/98	200.8	05/19/98	7440-39-3	Barium	0.04	4.14
200.8	05/18/98	200.8	05/19/98	7440-41-7	Beryllium	0.04	0.04 U
200.8	05/18/98	200.8	05/19/98	7440-43-9	Cadmium	0.04	0.04 U
3005	05/15/98	6010	05/18/98	7440-70-2	Calcium	20	2,410
200.8	05/18/98	200.8	05/19/98	7440-47-3	Chromium	0.2	0.2 U
200.8	06/03/98	200.8	06/04/98	7440-50-8	Copper	0.2	1.0
3005	05/15/98	6010	05/18/98	7439-89-6	Iron	20	90
200.8	05/18/98	200.8	05/19/98	7439-92-1	Lead	0.2	0.2 U
3005	05/15/98	6010	05/18/98	7439-95-4	Magnesium	20	240
200.8	06/03/98	200.8	06/04/98	7439-96-5	Manganese	0.04	3.83
200.8	05/18/98	200.8	05/19/98	7439-98-7	Molybdenum	0.04	0.65
200.8	05/18/98	200.8	05/19/98	7440-02-0	Nickel	0.2	0.3
3005	05/15/98	6010	05/18/98	7440-09-7	Potassium	500	500 U
200.8	05/18/98	200.8	05/19/98	7440-22-4	Silver	0.04	0.04 U
3005	05/15/98	6010	05/18/98	7440-23-5	Sodium	50	670
3005	05/15/98	6010	05/18/98	7440-66-6	Zinc	4	4 U

Calculated Hardness (mg-$CaCO_3$/L): 7

KM 6/15/98

U Analyte undetected at given RL

RL Reporting Limit

FORM-I

6/11/98

ANALYTICAL
RESOURCES
INCORPORATED

INORGANICS ANALYSIS DATA SHEET
TOTAL METALS

Sample No: RC-11
QC Report No: W219-Dames & Moore
Project: Holden Mine
17693-005-019
Date Received: 05/05/98

Lab Sample ID: W219V
LIMS ID: 98-9040
Matrix: Water

Data Release Authorized:
Reported: 06/10/98

MATRIX DUPLICATE QUALITY CONTROL REPORT

Analyte	Sample ug/L	Duplicate ug/L	RPD	Control Limit	Q
Copper	1.0	0.9	10.5%	+/- 0.2	L
Manganese	3.83	3.77	1.6%	+/- 20 %	

'Q' codes:
* = control limit not met
L = RPD not valid, alternate limit = detection limit

FORM-VI

ANALYTICAL
RESOURCES
INCORPORATED

INORGANICS ANALYSIS DATA SHEET
TOTAL METALS

Sample No: RC-11
Lab Sample ID: W219V
QC Report No: W219-Dames & Moore
LIMS ID: 98-9040
Project: Holden Mine
17693-005-019
Matrix: Water
Date Received: 05/05/98

Data Release Authorized:
Reported: 06/10/98

MATRIX SPIKE QUALITY CONTROL REPORT

Analyte	Sample ug/L	Spike ug/L	Spike Added	% Recovery	Q
Copper	1.0	6.1	5.0	102%	
Manganese	3.83	8.61	5.00	95.6%	

'Q' codes:
N = control limit not met
H = %R not applicable, sample concentration too high
* = RPD control limit not met
NA = Not applicable - analyte not spiked

Control Limits: Percent Recovery: 75-125%
RPD: +/-20%

FORM-V

ANALYTICAL RESOURCES INCORPORATED

INORGANICS ANALYSIS DATA SHEET
TOTAL METALS

Sample No: BIG-1

Lab Sample ID: W219W
LIMS ID: 98-9041
Matrix: Water

QC Report No: W219-Dames & Moore
Project: Holden Mine
17693-005-019
Date Sampled: 05/02/98
Date Received: 05/05/98

Data Release Authorized:
Reported: 06/10/98

Prep Meth	Prep Date	Analysis Method	Analysis Date	CAS Number	Analyte	RL	ug/L
3005	05/15/98	6010	05/18/98	7429-90-5	Aluminum	20	30 U
200.8	05/18/98	200.8	05/19/98	7440-38-2	Arsenic	0.04	0.33
200.8	05/18/98	200.8	05/19/98	7440-39-3	Barium	0.04	7.09
200.8	05/18/98	200.8	05/19/98	7440-41-7	Beryllium	0.04	0.04 U
200.8	05/18/98	200.8	05/19/98	7440-43-9	Cadmium	0.04	0.04 U
3005	05/15/98	6010	05/18/98	7440-70-2	Calcium	20	7,050
200.8	05/18/98	200.8	05/19/98	7440-47-3	Chromium	0.2	0.2 U
200.8	05/18/98	200.8	05/19/98	7440-50-8	Copper	0.2	0.5 U
3005	05/15/98	6010	05/18/98	7439-89-6	Iron	20	20 U
200.8	05/18/98	200.8	05/19/98	7439-92-1	Lead	0.2	0.2 U
3005	05/15/98	6010	05/18/98	7439-95-4	Magnesium	20	360
200.8	06/03/98	200.8	06/04/98	7439-96-5	Manganese	0.04	0.73
200.8	05/18/98	200.8	05/19/98	7439-98-7	Molybdenum	0.04	0.35
200.8	05/18/98	200.8	05/19/98	7440-02-0	Nickel	0.2	0.2 U
3005	05/15/98	6010	05/18/98	7440-09-7	Potassium	500	500 U
200.8	05/18/98	200.8	05/19/98	7440-22-4	Silver	0.04	0.04 U
3005	05/15/98	6010	05/18/98	7440-23-5	Sodium	50	660
3005	05/15/98	6010	05/18/98	7440-66-6	Zinc	4	4 U

Calculated Hardness (mg-CaCO3/L): 19

Km 6/15/98

U Analyte undetected at given RL

RL Reporting Limit

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6/11/98

ANALYTICAL RESOURCES INCORPORATED

INORGANICS ANALYSIS DATA SHEET
TOTAL METALS

Sample No: CC-1

Lab Sample ID: W219X
LIMS ID: 98-9042
Matrix: Water

QC Report No: W219-Dames & Moore
Project: Holden Mine
17693-005-019
Date Sampled: 05/02/98
Date Received: 05/05/98

Data Release Authorized:
Reported: 06/10/98

Prep Meth	Prep Date	Analysis Method	Analysis Date	CAS Number	Analyte	RL	ug/L	
3005	05/15/98	6010	05/18/98	7429-90-5	Aluminum	20	100	J
200.8	05/18/98	200.8	05/19/98	7440-38-2	Arsenic	0.04	0.04	U
200.8	05/18/98	200.8	05/19/98	7440-39-3	Barium	0.04	5.64	
200.8	05/18/98	200.8	05/19/98	7440-41-7	Beryllium	0.04	0.04	U
200.8	05/18/98	200.8	05/19/98	7440-43-9	Cadmium	0.04	0.04	U
3005	05/15/98	6010	05/18/98	7440-70-2	Calcium	20	3,980	
200.8	05/18/98	200.8	05/19/98	7440-47-3	Chromium	0.2	0.3	
200.8	05/18/98	200.8	05/19/98	7440-50-8	Copper	0.2	0.6	U
3005	05/15/98	6010	05/18/98	7439-89-6	Iron	20	100	
200.8	05/18/98	200.8	05/19/98	7439-92-1	Lead	0.2	0.2	U
3005	05/15/98	6010	05/18/98	7439-95-4	Magnesium	20	490	
200.8	06/03/98	200.8	06/04/98	7439-96-5	Manganese	0.04	2.96	
200.8	05/18/98	200.8	05/19/98	7439-98-7	Molybdenum	0.04	0.49	
200.8	05/18/98	200.8	05/19/98	7440-02-0	Nickel	0.2	0.4	
3005	05/15/98	6010	05/18/98	7440-09-7	Potassium	500	500	U
200.8	05/18/98	200.8	05/19/98	7440-22-4	Silver	0.04	0.04	U
3005	05/15/98	6010	05/18/98	7440-23-5	Sodium	50	640	
3005	05/15/98	6010	05/18/98	7440-66-6	Zinc	4	5	

Calculated Hardness (mg-CaCO3/L): 12

Km 4/15/99

U Analyte undetected at given RL

RL Reporting Limit

FORM-I

7799

ANALYTICAL
RESOURCES
INCORPORATED

INORGANICS ANALYSIS DATA SHEET
TOTAL METALS

Sample No: CC-2

Lab Sample ID: W219Y
LIMS ID: 98-9043
Matrix: Water

QC Report No: W219-Dames & Moore
Project: Holden Mine
17693-005-019
Date Sampled: 05/02/98
Date Received: 05/05/98

Data Release Authorized:
Reported: 06/10/98

Prep Meth	Prep Date	Analysis Method	Analysis Date	CAS Number	Analyte	RL	ug/L
3005	05/15/98	6010	05/18/98	7429-90-5	Aluminum	20	170 J
200.8	05/18/98	200.8	05/19/98	7440-38-2	Arsenic	0.04	0.04 U
200.8	05/18/98	200.8	05/19/98	7440-39-3	Barium	0.04	6.31
200.8	05/18/98	200.8	05/19/98	7440-41-7	Beryllium	0.04	0.04 U
200.8	05/18/98	200.8	05/19/98	7440-43-9	Cadmium	0.04	0.04 U
3005	05/15/98	6010	05/18/98	7440-70-2	Calcium	20	4,060
200.8	05/18/98	200.8	05/19/98	7440-47-3	Chromium	0.2	0.4
200.8	06/03/98	200.8	06/04/98	7440-50-8	Copper	0.2	1.0
3005	05/15/98	6010	05/18/98	7439-89-6	Iron	20	170
200.8	05/18/98	200.8	05/19/98	7439-92-1	Lead	0.2	0.3 U
3005	05/15/98	6010	05/18/98	7439-95-4	Magnesium	20	520
200.8	05/18/98	200.8	05/19/98	7439-96-5	Manganese	0.04	4.91
200.8	05/18/98	200.8	05/19/98	7439-98-7	Molybdenum	0.04	0.48
200.8	05/18/98	200.8	05/19/98	7440-02-0	Nickel	0.2	0.7
3005	05/15/98	6010	05/18/98	7440-09-7	Potassium	500	500 U
200.8	05/18/98	200.8	05/19/98	7440-22-4	Silver	0.04	0.04 U
3005	05/15/98	6010	05/18/98	7440-23-5	Sodium	50	660
3005	05/15/98	6010	05/18/98	7440-66-6	Zinc	4	4 U

Calculated Hardness (mg-CaCO3/L): 12

Km 6/15/98

U Analyte undetected at given RL

RL Reporting Limit

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RL

MG 6/11/98

ANALYTICAL
RESOURCES
INCORPORATED

INORGANICS ANALYSIS DATA SHEET
TOTAL METALS

Sample No: RC-6

Lab Sample ID: W219Z
LIMS ID: 98-9044
Matrix: Water

QC Report No: W219-Dames & Moore
Project: Holden Mine
17693-005-019
Date Sampled: 05/03/98
Date Received: 05/05/98

Data Release Authorized:
Reported: 05/21/98

Prep Meth	Prep Date	Analysis Method	Analysis Date	CAS Number	Analyte	RL	ug/L
3005	05/15/98	6010	05/18/98	7429-90-5	Aluminum	20	150 J
200.8	05/18/98	200.8	05/19/98	7440-38-2	Arsenic	0.04	1.07
200.8	05/18/98	200.8	05/19/98	7440-39-3	Barium	0.04	5.10
200.8	05/18/98	200.8	05/19/98	7440-41-7	Beryllium	0.04	0.04 U
200.8	05/18/98	200.8	05/19/98	7440-43-9	Cadmium	0.04	0.04 U
3005	05/15/98	6010	05/18/98	7440-70-2	Calcium	20	3,800
200.8	05/18/98	200.8	05/19/98	7440-47-3	Chromium	0.2	0.2 U
200.8	05/18/98	200.8	05/19/98	7440-50-8	Copper	0.2	1.8 J
3005	05/15/98	6010	05/18/98	7439-89-6	Iron	20	180
200.8	05/18/98	200.8	05/19/98	7439-92-1	Lead	0.2	0.5 U
3005	05/15/98	6010	05/18/98	7439-95-4	Magnesium	20	360
200.8	05/18/98	200.8	05/19/98	7439-96-5	Manganese	0.04	6.52
200.8	05/18/98	200.8	05/19/98	7439-98-7	Molybdenum	0.04	0.53
200.8	05/18/98	200.8	05/19/98	7440-02-0	Nickel	0.2	0.3
3005	05/15/98	6010	05/18/98	7440-09-7	Potassium	500	500 U
200.8	05/18/98	200.8	05/19/98	7440-22-4	Silver	0.04	0.04 U
3005	05/15/98	6010	05/18/98	7440-23-5	Sodium	50	690
3005	05/15/98	6010	05/18/98	7440-66-6	Zinc	4	4 U

Calculated Hardness (mg-CaCO3/L): 11

Km 6/4/98

U Analyte undetected at given RL

RL Reporting Limit

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**ANALYTICAL
RESOURCES
INCORPORATED**

INORGANICS ANALYSIS DATA SHEET
TOTAL METALS

Sample No: RC-1

Lab Sample ID: W219AA
LIMS ID: 98-9045
Matrix: Water

QC Report No: W219-Dames & Moore
Project: Holden Mine
17693-005-019
Date Sampled: 05/03/98
Date Received: 05/05/98

Data Release Authorized:
Reported: 06/10/98

Prep Meth	Prep Date	Analysis Method	Analysis Date	CAS Number	Analyte	RL	ug/L
3005	05/15/98	6010	05/18/98	7429-90-5	Aluminum	20	100 J
200.8	05/18/98	200.8	05/19/98	7440-38-2	Arsenic	0.04	0.86
200.8	05/18/98	200.8	05/19/98	7440-39-3	Barium	0.04	-4.91
200.8	05/18/98	200.8	05/19/98	7440-41-7	Beryllium	0.04	0.04 U
200.8	05/18/98	200.8	05/19/98	7440-43-9	Cadmium	0.04	0.04 U
3005	05/15/98	6010	05/18/98	7440-70-2	Calcium	20	3,860
200.8	05/18/98	200.8	05/19/98	7440-47-3	Chromium	0.2	0.2 U
200.8	06/03/98	200.8	06/04/98	7440-50-8	Copper	0.2	1.1
3005	05/15/98	6010	05/18/98	7439-89-6	Iron	20	110
200.8	05/18/98	200.8	05/19/98	7439-92-1	Lead	0.2	0.2 U
3005	05/15/98	6010	05/18/98	7439-95-4	Magnesium	20	360
200.8	05/18/98	200.8	05/19/98	7439-96-5	Manganese	0.04	4.45
200.8	05/18/98	200.8	05/19/98	7439-98-7	Molybdenum	0.04	0.52
200.8	05/18/98	200.8	05/19/98	7440-02-0	Nickel	0.2	0.3
3005	05/15/98	6010	05/18/98	7440-09-7	Potassium	500	500 U
200.8	05/18/98	200.8	05/19/98	7440-22-4	Silver	0.04	0.04 U
3005	05/15/98	6010	05/18/98	7440-23-5	Sodium	50	730
3005	05/15/98	6010	05/18/98	7440-66-6	Zinc	4	4 U

Calculated Hardness (mg-CaCO3/L): 11

KM 6/15/98

U Analyte undetected at given RL

RL Reporting Limit

FORM-I

TMB 6/11/98

ANALYTICAL
RESOURCES
INCORPORATED

INORGANICS ANALYSIS DATA SHEET
TOTAL METALS

Sample No: RC-4

Lab Sample ID: W219AB
LIMS ID: 98-9046
Matrix: Water

QC Report No: W219-Dames & Moore
Project: Holden Mine
17693-005-019
Date Sampled: 05/03/98
Date Received: 05/05/98

Data Release Authorized:
Reported: 05/21/98

Prep Meth	Prep Date	Analysis Method	Analysis Date	CAS Number	Analyte	RL	ug/L
3005	05/15/98	6010	05/18/98	7429-90-5	Aluminum	20	200 J
200.8	05/18/98	200.8	05/19/98	7440-38-2	Arsenic	0.04	0.93
200.8	05/18/98	200.8	05/19/98	7440-39-3	Barium	0.04	5.48
200.8	05/18/98	200.8	05/19/98	7440-41-7	Beryllium	0.04	0.04 U
200.8	05/18/98	200.8	05/19/98	7440-43-9	Cadmium	0.04	0.73 J
3005	05/15/98	6010	05/18/98	7440-70-2	Calcium	20	4,370
200.8	05/18/98	200.8	05/19/98	7440-47-3	Chromium	0.2	0.2 U
200.8	05/18/98	200.8	05/19/98	7440-50-8	Copper	0.2	56.7
3005	05/15/98	6010	05/18/98	7439-89-6	Iron	20	140
200.8	05/18/98	200.8	05/19/98	7439-92-1	Lead	0.2	0.4 U
3005	05/15/98	6010	05/18/98	7439-95-4	Magnesium	20	450
200.8	05/18/98	200.8	05/19/98	7439-96-5	Manganese	0.04	8.22
200.8	05/18/98	200.8	05/19/98	7439-98-7	Molybdenum	0.04	0.52
200.8	05/18/98	200.8	05/19/98	7440-02-0	Nickel	0.2	0.5
3005	05/15/98	6010	05/18/98	7440-09-7	Potassium	500	500 U
200.8	05/18/98	200.8	05/19/98	7440-22-4	Silver	0.04	0.04 U
3005	05/15/98	6010	05/18/98	7440-23-5	Sodium	50	780
3005	05/15/98	6010	05/18/98	7440-66-6	Zinc	4	115

Calculated Hardness (mg-CaCO3/L): 13

Km 6/4/98

U Analyte undetected at given RL

RL Reporting Limit

FORM-I

ANALYTICAL
RESOURCES
INCORPORATED

INORGANICS ANALYSIS DATA SHEET
TOTAL METALS

Sample No: RC-4X

Lab Sample ID: W219AC
LIMS ID: 98-9047
Matrix: Water

QC Report No: W219-Dames & Moore
Project: Holden Mine
17693-005-019
Date Sampled: 05/03/98
Date Received: 05/05/98

Data Release Authorized:
Reported: 05/21/98

Prep Meth	Prep Date	Analysis Method	Analysis Date	CAS Number	Analyte	RL	ug/L
3005	05/15/98	6010	05/18/98	7429-90-5	Aluminum	20	160 J
200.8	05/18/98	200.8	05/19/98	7440-38-2	Arsenic	0.04	0.85
200.8	05/18/98	200.8	05/19/98	7440-39-3	Barium	0.04	5.32
200.8	05/18/98	200.8	05/19/98	7440-41-7	Beryllium	0.04	0.04 U
200.8	05/18/98	200.8	05/19/98	7440-43-9	Cadmium	0.04	0.75 J
3005	05/15/98	6010	05/18/98	7440-70-2	Calcium	20	4,310
200.8	05/18/98	200.8	05/19/98	7440-47-3	Chromium	0.2	0.2 U
200.8	05/18/98	200.8	05/19/98	7440-50-8	Copper	0.2	58.6
3005	05/15/98	6010	05/18/98	7439-89-6	Iron	20	100
200.8	05/18/98	200.8	05/19/98	7439-92-1	Lead	0.2	0.6 U
3005	05/15/98	6010	05/18/98	7439-95-4	Magnesium	20	450
200.8	05/18/98	200.8	05/19/98	7439-96-5	Manganese	0.04	7.53
200.8	05/18/98	200.8	05/19/98	7439-98-7	Molybdenum	0.04	0.53
200.8	05/18/98	200.8	05/19/98	7440-02-0	Nickel	0.2	0.5
3005	05/15/98	6010	05/18/98	7440-09-7	Potassium	500	500 U
200.8	05/18/98	200.8	05/19/98	7440-22-4	Silver	0.04	0.04 U
3005	05/15/98	6010	05/18/98	7440-23-5	Sodium	50	740
3005	05/15/98	6010	05/18/98	7440-66-6	Zinc	4	114

Calculated Hardness (mg-CaCO3/L): 13

km 6/4/98

U Analyte undetected at given RL

RL Reporting Limit

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ANALYTICAL
RESOURCES
INCORPORATED

INORGANICS ANALYSIS DATA SHEET
TOTAL METALS

Sample No: RC-7

Lab Sample ID: W219AD
LIMS ID: 98-9048
Matrix: Water

QC Report No: W219-Dames & Moore
Project: Holden Mine
17693-005-019
Date Sampled: 05/03/98
Date Received: 05/05/98

Data Release Authorized:
Reported: 05/21/98

Prep Meth	Prep Date	Analysis Method	Analysis Date	CAS Number	Analyte	RL	ug/L	
3005	05/15/98	6010	05/18/98	7429-90-5	Aluminum	20	220	
200.8	05/18/98	200.8	05/19/98	7440-38-2	Arsenic	0.04	0.76	
200.8	05/18/98	200.8	05/19/98	7440-39-3	Barium	0.04	5.48	
200.8	05/18/98	200.8	05/19/98	7440-41-7	Beryllium	0.04	0.04	U
200.8	05/18/98	200.8	05/19/98	7440-43-9	Cadmium	0.04	0.75	J
3005	05/15/98	6010	05/18/98	7440-70-2	Calcium	20	4,670	
200.8	05/18/98	200.8	05/19/98	7440-47-3	Chromium	0.2	0.2	U
200.8	05/18/98	200.8	05/19/98	7440-50-8	Copper	0.2	52.8	
3005	05/15/98	6010	05/18/98	7439-89-6	Iron	20	590	
200.8	05/18/98	200.8	05/19/98	7439-92-1	Lead	0.2	0.5	U
3005	05/15/98	6010	05/18/98	7439-95-4	Magnesium	20	550	
200.8	05/18/98	200.8	05/19/98	7439-96-5	Manganese	0.04	11.8	
200.8	05/18/98	200.8	05/19/98	7439-98-7	Molybdenum	0.04	0.52	
200.8	05/18/98	200.8	05/19/98	7440-02-0	Nickel	0.2	0.6	
3005	05/15/98	6010	05/18/98	7440-09-7	Potassium	500	500	U
200.8	05/18/98	200.8	05/19/98	7440-22-4	Silver	0.04	0.04	U
3005	05/15/98	6010	05/18/98	7440-23-5	Sodium	50	770	
3005	05/15/98	6010	05/18/98	7440-66-6	Zinc	4	119	

Calculated Hardness (mg-CaCO3/L): 14

Km 4/4/98

U Analyte undetected at given RL

RL Reporting Limit

FORM-I

ANALYTICAL
RESOURCES
INCORPORATED

INORGANICS ANALYSIS DATA SHEET
TOTAL METALS

Sample No: RC-5

Lab Sample ID: W219AE
LIMS ID: 98-9049
Matrix: Water

QC Report No: W219-Dames & Moore
Project: Holden Mine
17693-005-019
Date Sampled: 05/04/98
Date Received: 05/05/98

Data Release Authorized:
Reported: 05/21/98

Prep Meth	Prep Date	Analysis Method	Analysis Date	CAS Number	Analyte	RL	ug/L
3005	05/15/98	6010	05/18/98	7429-90-5	Aluminum	20	250
200.8	05/18/98	200.8	05/19/98	7440-38-2	Arsenic	0.04	0.76
200.8	05/18/98	200.8	05/19/98	7440-39-3	Barium	0.04	6.22
200.8	05/18/98	200.8	05/19/98	7440-41-7	Beryllium	0.04	0.04 U
200.8	05/18/98	200.8	05/19/98	7440-43-9	Cadmium	0.04	0.66 J
3005	05/15/98	6010	05/18/98	7440-70-2	Calcium	20	5,210
200.8	05/18/98	200.8	05/19/98	7440-47-3	Chromium	0.2	0.2 U
200.8	05/18/98	200.8	05/19/98	7440-50-8	Copper	0.2	43.5
3005	05/15/98	6010	05/18/98	7439-89-6	Iron	20	650
200.8	05/18/98	200.8	05/19/98	7439-92-1	Lead	0.2	0.5 U
3005	05/15/98	6010	05/18/98	7439-95-4	Magnesium	20	660
200.8	05/18/98	200.8	05/19/98	7439-96-5	Manganese	0.04	15.0
200.8	05/18/98	200.8	05/19/98	7439-98-7	Molybdenum	0.04	0.52
200.8	05/18/98	200.8	05/19/98	7440-02-0	Nickel	0.2	0.6
3005	05/15/98	6010	05/18/98	7440-09-7	Potassium	500	500 U
200.8	05/18/98	200.8	05/19/98	7440-22-4	Silver	0.04	0.04 U
3005	05/15/98	6010	05/18/98	7440-23-5	Sodium	50	820
3005	05/15/98	6010	05/18/98	7440-66-6	Zinc	4	101

Calculated Hardness (mg-CaCO3/L): 16

Km 6/4/98

U Analyte undetected at given RL

RL Reporting Limit

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ANALYTICAL
RESOURCES
INCORPORATED

INORGANICS ANALYSIS DATA SHEET
TOTAL METALS

Sample No: RC-10

Lab Sample ID: W219AF
LIMS ID: 98-9050
Matrix: Water

QC Report No: W219-Dames & Moore
Project: Holden Mine
17693-005-019
Date Sampled: 05/04/98
Date Received: 05/05/98

Data Release Authorized
Reported: 06/10/98

Prep Meth	Prep Date	Analysis Method	Analysis Date	CAS Number	Analyte	RL	ug/L	
3005	05/15/98	6010	05/18/98	7429-90-5	Aluminum	20	300	
200.8	05/18/98	200.8	05/19/98	7440-38-2	Arsenic	0.04	0.72	
200.8	05/18/98	200.8	05/19/98	7440-39-3	Barium	0.04	6.74	
200.8	05/18/98	200.8	05/19/98	7440-41-7	Beryllium	0.04	0.04	U
200.8	06/03/98	200.8	06/04/98	7440-43-9	Cadmium	0.04	0.45	
3005	05/15/98	6010	05/18/98	7440-70-2	Calcium	20	5,730	
200.8	05/18/98	200.8	05/19/98	7440-47-3	Chromium	0.2	0.2	
200.8	05/18/98	200.8	05/19/98	7440-50-8	Copper	0.2	30.3	
3005	05/15/98	6010	05/18/98	7439-89-6	Iron	20	790	
200.8	05/18/98	200.8	05/19/98	7439-92-1	Lead	0.2	0.6	U
3005	05/15/98	6010	05/18/98	7439-95-4	Magnesium	20	720	
200.8	05/18/98	200.8	05/19/98	7439-96-5	Manganese	0.04	13.4	
200.8	05/18/98	200.8	05/19/98	7439-98-7	Molybdenum	0.04	0.55	
200.8	05/18/98	200.8	05/19/98	7440-02-0	Nickel	0.2	0.6	
3005	05/15/98	6010	05/18/98	7440-09-7	Potassium	500	500	U
200.8	05/18/98	200.8	05/19/98	7440-22-4	Silver	0.04	0.04	U
3005	05/15/98	6010	05/18/98	7440-23-5	Sodium	50	850	
3005	05/15/98	6010	05/18/98	7440-66-6	Zinc	4	75	

Calculated Hardness (mg-CaCO3/L): 17

Km 6/15/98

U Analyte undetected at given RL

RL Reporting Limit

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ANALYTICAL
RESOURCES
INCORPORATED

INORGANICS ANALYSIS DATA SHEET
TOTAL METALS

Sample No: RC-3

Lab Sample ID: W219AG
LIMS ID: 98-9051
Matrix: Water

QC Report No: W219-Dames & Moore
Project: Holden Mine
17693-005-019
Date Sampled: 05/05/98
Date Received: 05/05/98

Data Release Authorized:
Reported: 06/10/98

Prep Meth	Prep Date	Analysis Method	Analysis Date	CAS Number	Analyte	RL	ug/L
3005	05/15/98	6010	05/18/98	7429-90-5	Aluminum	20	250
200.8	05/18/98	200.8	05/19/98	7440-38-2	Arsenic	0.04	0.50
200.8	05/18/98	200.8	05/19/98	7440-39-3	Barium	0.04	7.07
200.8	05/18/98	200.8	05/19/98	7440-41-7	Beryllium	0.04	0.04 U
200.8	06/03/98	200.8	06/04/98	7440-43-9	Cadmium	0.04	0.37
3005	05/15/98	6010	05/18/98	7440-70-2	Calcium	20	5,520
200.8	05/18/98	200.8	05/19/98	7440-47-3	Chromium	0.2	0.2
200.8	05/18/98	200.8	05/19/98	7440-50-8	Copper	0.2	19.7
3005	05/15/98	6010	05/18/98	7439-89-6	Iron	20	580
200.8	05/18/98	200.8	05/19/98	7439-92-1	Lead	0.2	0.6 U
3005	05/15/98	6010	05/18/98	7439-95-4	Magnesium	20	700
200.8	05/18/98	200.8	05/19/98	7439-96-5	Manganese	0.04	10.7
200.8	05/18/98	200.8	05/19/98	7439-98-7	Molybdenum	0.04	0.55
200.8	05/18/98	200.8	05/19/98	7440-02-0	Nickel	0.2	0.5
3005	05/15/98	6010	05/18/98	7440-09-7	Potassium	500	530
200.8	05/18/98	200.8	05/19/98	7440-22-4	Silver	0.04	0.04 U
3005	05/15/98	6010	05/18/98	7440-23-5	Sodium	50	930
3005	05/15/98	6010	05/18/98	7440-66-6	Zinc	4	56

Calculated Hardness (mg-CaCO3/L): 17

Km 4/15/98

U Analyte undetected at given RL

RL Reporting Limit

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RL

6/11/98

ANALYTICAL
RESOURCES
INCORPORATED

INORGANICS ANALYSIS DATA SHEET
TOTAL METALS

Sample No: RC-2

Lab Sample ID: W219AH
LIMS ID: 98-9052
Matrix: Water

QC Report No: W219-Dames & Moore
Project: Holden Mine
17693-005-019
Date Sampled: 05/03/98
Date Received: 05/05/98

Data Release Authorized:
Reported: 05/21/98

Prep Meth	Prep Date	Analysis Method	Analysis Date	CAS Number	Analyte	RL	ug/L	
3005	05/15/98	6010	05/18/98	7429-90-5	Aluminum	20	250	
200.8	05/18/98	200.8	05/19/98	7440-38-2	Arsenic	0.04	0.83	
200.8	05/18/98	200.8	05/19/98	7440-39-3	Barium	0.04	5.75	
200.8	05/18/98	200.8	05/19/98	7440-41-7	Beryllium	0.04	0.04	U
200.8	05/18/98	200.8	05/19/98	7440-43-9	Cadmium	0.04	0.77	J
3005	05/15/98	6010	05/18/98	7440-70-2	Calcium	20	4,700	
200.8	05/18/98	200.8	05/19/98	7440-47-3	Chromium	0.2	0.2	
200.8	05/18/98	200.8	05/19/98	7440-50-8	Copper	0.2	52.3	
3005	05/15/98	6010	05/18/98	7439-89-6	Iron	20	630	
200.8	05/18/98	200.8	05/19/98	7439-92-1	Lead	0.2	0.6	U
3005	05/15/98	6010	05/18/98	7439-95-4	Magnesium	20	570	
200.8	05/18/98	200.8	05/19/98	7439-96-5	Manganese	0.04	12.7	
200.8	05/18/98	200.8	05/19/98	7439-98-7	Molybdenum	0.04	0.53	
200.8	05/18/98	200.8	05/19/98	7440-02-0	Nickel	0.2	0.6	
3005	05/15/98	6010	05/18/98	7440-09-7	Potassium	500	500	U
200.8	05/18/98	200.8	05/19/98	7440-22-4	Silver	0.04	0.04	U
3005	05/15/98	6010	05/18/98	7440-23-5	Sodium	50	790	
3005	05/15/98	6010	05/18/98	7440-66-6	Zinc	4	116	

Calculated Hardness (mg-CaCO3/L): 14

km 6/4/98

U Analyte undetected at given RL

RL Reporting Limit

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ANALYTICAL
RESOURCES
INCORPORATED

INORGANICS ANALYSIS DATA SHEET
DISSOLVED METALS

Sample No: HC-4

Lab Sample ID: W219A
LIMS ID: 98-9019
Matrix: Water

QC Report No: W219-Dames & Moore
Project: Holden Mine
17693-005-019
Date Sampled: 04/30/98
Date Received: 05/05/98

Data Release Authorized:
Reported: 05/21/98

Prep Meth	Prep Date	Analysis Method	Analysis Date	CAS Number	Analyte	RL	ug/L	
3005	05/15/98	6010	05/18/98	7429-90-5	Aluminum	20	20	U
200.8	05/15/98	200.8	05/18/98	7440-38-2	Arsenic	0.04	1.00	
200.8	05/15/98	200.8	05/18/98	7440-39-3	Barium	0.04	6.19	
200.8	05/15/98	200.8	05/18/98	7440-41-7	Beryllium	0.04	0.04	U
200.8	05/15/98	200.8	05/18/98	7440-43-9	Cadmium	0.04	0.06	
3005	05/15/98	6010	05/18/98	7440-70-2	Calcium	20	3,990	
200.8	05/15/98	200.8	05/18/98	7440-47-3	Chromium	0.2	0.2	U
200.8	05/15/98	200.8	05/18/98	7440-50-8	Copper	0.2	0.5	
3005	05/15/98	6010	05/18/98	7439-89-6	Iron	20	30	
200.8	05/15/98	200.8	05/18/98	7439-92-1	Lead	0.2	0.2	J
3005	05/15/98	6010	05/18/98	7439-95-4	Magnesium	20	230	
200.8	05/15/98	200.8	05/18/98	7439-96-5	Manganese	0.04	1.05	
200.8	05/15/98	200.8	05/18/98	7439-98-7	Molybdenum	0.04	0.64	
200.8	05/15/98	200.8	05/18/98	7440-02-0	Nickel	0.2	0.2	U
3005	05/15/98	6010	05/18/98	7440-09-7	Potassium	500	500	U
200.8	05/15/98	200.8	05/18/98	7440-22-4	Silver	0.04	0.04	U
3005	05/15/98	6010	05/18/98	7440-23-5	Sodium	50	610	
3005	05/15/98	6010	05/18/98	7440-66-6	Zinc	4	4	U

Calculated Dissolved Hardness (mg-CaCO3/L): 11

km 4/4/99

U Analyte undetected at given RL

RL Reporting Limit

FORM-I

ANALYTICAL
RESOURCES
INCORPORATED

INORGANICS ANALYSIS DATA SHEET
DISSOLVED METALS

Sample No: HC-4
Lab Sample ID: W219A
QC Report No: W219-Dames & Moore
LIMS ID: 98-9019
Project: Holden Mine
Matrix: Water
17693-005-019
Date Received: 05/05/98
Data Release Authorized:
Reported: 05/21/98

MATRIX SPIKE QUALITY CONTROL REPORT

Analyte	Sample ug/L		Spike ug/L	Spike Added	% Recovery	Q
Aluminum	20	U	2060	2000	103%	
Arsenic	1.00		5.93	5.00	98.6%	
Barium	6.19		10.8	5.00	92.2%	
Beryllium	0.04	U	4.65	5.00	93.0%	
Cadmium	0.06		4.91	5.00	97.0%	
Calcium	3990		14300	10000	103%	
Chromium	0.2	U	4.8	5.0	96.0%	
Copper	0.5		5.6	5.0	102%	
Iron	29		1020	1000	99.1%	
Lead	0.2		5.4	5.0	104%	
Magnesium	230		10300	10000	101%	
Manganese	1.05		5.80	5.00	95.0%	
Molybdenum	0.64		5.13	5.00	89.8%	
Nickel	0.2	U	5.2	5.0	104%	
Potassium	500	U	10000	10000	100%	
Silver	0.04	U	4.85	5.00	97.0%	
Sodium	612		10400	10000	97.9%	
Zinc	4	U	514	500	103%	

'Q' codes:
N = control limit not met
H = %R not applicable, sample concentration too high
* = RPD control limit not met
NA = Not applicable - analyte not spiked

Control Limits: Percent Recovery: 75-125%
RPD: +/-20%

ANALYTICAL
RESOURCES
INCORPORATED

INORGANICS ANALYSIS DATA SHEET
DISSOLVED METALS

Sample No: HC-3

Lab Sample ID: W219B
LIMS ID: 98-9020
Matrix: Water

QC Report No: W219-Dames & Moore
Project: Holden Mine
17693-005-019
Date Sampled: 04/30/98
Date Received: 05/05/98

Data Release Authorized:
Reported: 05/21/98

Prep Meth	Prep Date	Analysis Method	Analysis Date	CAS Number	Analyte	RL	ug/L
3005	05/15/98	6010	05/18/98	7429-90-5	Aluminum	20	20
200.8	05/15/98	200.8	05/18/98	7440-38-2	Arsenic	0.04	0.61
200.8	05/15/98	200.8	05/18/98	7440-39-3	Barium	0.04	4.88
200.8	05/15/98	200.8	05/18/98	7440-41-7	Beryllium	0.04	0.04 U
200.8	05/15/98	200.8	05/18/98	7440-43-9	Cadmium	0.04	0.04 U
3005	05/15/98	6010	05/18/98	7440-70-2	Calcium	20	5,030
200.8	05/15/98	200.8	05/18/98	7440-47-3	Chromium	0.2	0.2 U
200.8	05/15/98	200.8	05/18/98	7440-50-8	Copper	0.2	0.6
3005	05/15/98	6010	05/18/98	7439-89-6	Iron	20	20
200.8	05/15/98	200.8	05/18/98	7439-92-1	Lead	0.2	0.2 U
3005	05/15/98	6010	05/18/98	7439-95-4	Magnesium	20	570
200.8	05/15/98	200.8	05/18/98	7439-96-5	Manganese	0.04	1.32
200.8	05/15/98	200.8	05/18/98	7439-98-7	Molybdenum	0.04	0.43
200.8	05/15/98	200.8	05/18/98	7440-02-0	Nickel	0.2	0.2 U
3005	05/15/98	6010	05/18/98	7440-09-7	Potassium	500	500 U
200.8	05/15/98	200.8	05/18/98	7440-22-4	Silver	0.04	0.04 U
3005	05/15/98	6010	05/18/98	7440-23-5	Sodium	50	880
3005	05/15/98	6010	05/18/98	7440-66-6	Zinc	4	4 U

Calculated Dissolved Hardness (mg-CaCO3/L): 15

U Analyte undetected at given RL

RL Reporting Limit

FORM-I

ANALYTICAL
RESOURCES
INCORPORATED

INORGANICS ANALYSIS DATA SHEET
DISSOLVED METALS

Sample No: HC-3

Lab Sample ID: W219B
QC Report No: W219-Dames & Moore
LIMS ID: 98-9020
Project: Holden Mine
Matrix: Water
17693-005-019
Date Received: 05/05/98

Data Release Authorized
Reported: 05/21/98

MATRIX DUPLICATE QUALITY CONTROL REPORT

Analyte	Sample ug/L	Duplicate ug/L	RPD	Control Limit	Q
Aluminum	20	20 U	0.0%	+/- 20	L
Arsenic	0.61	0.62	1.6%	+/- 20 %	
Barium	4.88	4.91	0.6%	+/- 20 %	
Beryllium	0.04 U	0.04 U	0.0%	+/- 0.04	L
Cadmium	0.04 U	0.04 U	0.0%	+/- 0.04	L
Calcium	5030	4990	0.8%	+/- 20 %	
Chromium	0.2 U	0.2 U	0.0%	+/- 0.2	L
Copper	0.6	0.5	18.2%	+/- 0.2	L
Iron	20	20 U	0.0%	+/- 20	L
Lead	0.2 U	0.8	120%	+/- 0.2	L*
Magnesium	570	550	3.6%	+/- 20 %	
Manganese	1.32	1.34	1.5%	+/- 20 %	
Molybdenum	0.43	0.44	2.3%	+/- 20 %	
Nickel	0.2 U	0.2 U	0.0%	+/- 0.2	L
Potassium	500 U	500 U	0.0%	+/- 500	L
Silver	0.04 U	0.04 U	0.0%	+/- 0.04	L
Sodium	880	860	2.3%	+/- 20 %	
Zinc	4 U	4 U	0.0%	+/- 4	L

'Q' codes:
* = control limit not met
L = RPD not valid, alternate limit = detection limit

FORM-VI

ANALYTICAL
RESOURCES
INCORPORATED

INORGANICS ANALYSIS DATA SHEET
DISSOLVED METALS

Sample No: HC-2

Lab Sample ID: W219C
LIMS ID: 98-9021
Matrix: Water

QC Report No: W219-Dames & Moore
Project: Holden Mine
17693-005-019
Date Sampled: 04/30/98
Date Received: 05/05/98

Data Release Authorized:
Reported: 05/21/98

Prep Meth	Prep Date	Analysis Method	Analysis Date	CAS Number	Analyte	RL	ug/L
3005	05/15/98	6010	05/18/98	7429-90-5	Aluminum	20	30
200.8	05/15/98	200.8	05/18/98	7440-38-2	Arsenic	0.04	0.45
200.8	05/15/98	200.8	05/18/98	7440-39-3	Barium	0.04	4.56
200.8	05/15/98	200.8	05/18/98	7440-41-7	Beryllium	0.04	0.04 U
200.8	05/15/98	200.8	05/18/98	7440-43-9	Cadmium	0.04	0.05
3005	05/15/98	6010	05/18/98	7440-70-2	Calcium	20	5,340
200.8	05/15/98	200.8	05/18/98	7440-47-3	Chromium	0.2	0.2 U
200.8	05/15/98	200.8	05/18/98	7440-50-8	Copper	0.2	0.7
3005	05/15/98	6010	05/18/98	7439-89-6	Iron	20	20 U
200.8	05/15/98	200.8	05/18/98	7439-92-1	Lead	0.2	0.3 J
3005	05/15/98	6010	05/18/98	7439-95-4	Magnesium	20	580
200.8	05/15/98	200.8	05/18/98	7439-96-5	Manganese	0.04	2.91
200.8	05/15/98	200.8	05/18/98	7439-98-7	Molybdenum	0.04	0.49
200.8	05/15/98	200.8	05/18/98	7440-02-0	Nickel	0.2	0.2
3005	05/15/98	6010	05/18/98	7440-09-7	Potassium	500	500 U
200.8	05/15/98	200.8	05/18/98	7440-22-4	Silver	0.04	0.04 U
3005	05/15/98	6010	05/18/98	7440-23-5	Sodium	50	820
3005	05/15/98	6010	05/18/98	7440-66-6	Zinc	4	4 U

Calculated Dissolved Hardness (mg-CaCO3/L): 16

Km 4/4/98

U Analyte undetected at given RL

RL Reporting Limit

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RESOURCES
INCORPORATED

INORGANICS ANALYSIS DATA SHEET
DISSOLVED METALS

Sample No: HC-1

Lab Sample ID: W219D
LIMS ID: 98-9022
Matrix: Water

QC Report No: W219-Dames & Moore
Project: Holden Mine
17693-005-019
Date Sampled: 05/01/98
Date Received: 05/05/98

Data Release Authorized:
Reported: 05/21/98

Prep Meth	Prep Date	Analysis Method	Analysis Date	CAS Number	Analyte	RL	ug/L	
3005	05/15/98	6010	05/18/98	7429-90-5	Aluminum	20	50	
200.8	05/15/98	200.8	05/18/98	7440-38-2	Arsenic	0.04	0.39	
200.8	05/15/98	200.8	05/18/98	7440-39-3	Barium	0.04	4.27	
200.8	05/15/98	200.8	05/18/98	7440-41-7	Beryllium	0.04	0.04	U
200.8	05/15/98	200.8	05/18/98	7440-43-9	Cadmium	0.04	0.04	U
3005	05/15/98	6010	05/18/98	7440-70-2	Calcium	20	4,980	
200.8	05/15/98	200.8	05/18/98	7440-47-3	Chromium	0.2	0.2	U
200.8	05/15/98	200.8	05/18/98	7440-50-8	Copper	0.2	0.6	
3005	05/15/98	6010	05/18/98	7439-89-6	Iron	20	20	U
200.8	05/15/98	200.8	05/18/98	7439-92-1	Lead	0.2	0.2	U
3005	05/15/98	6010	05/18/98	7439-95-4	Magnesium	20	520	
200.8	05/15/98	200.8	05/18/98	7439-96-5	Manganese	0.04	0.78	
200.8	05/15/98	200.8	05/18/98	7439-98-7	Molybdenum	0.04	0.46	
200.8	05/15/98	200.8	05/18/98	7440-02-0	Nickel	0.2	0.2	U
3005	05/15/98	6010	05/18/98	7440-09-7	Potassium	500	500	U
200.8	05/15/98	200.8	05/18/98	7440-22-4	Silver	0.04	0.04	U
3005	05/15/98	6010	05/18/98	7440-23-5	Sodium	50	850	
3005	05/15/98	6010	05/18/98	7440-66-6	Zinc	4	4	U

Calculated Dissolved Hardness (mg-CaCO3/L): 15

U Analyte undetected at given RL

RL Reporting Limit

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ANALYTICAL
RESOURCES
INCORPORATED

INORGANICS ANALYSIS DATA SHEET
DISSOLVED METALS

Sample No: RC-11

Lab Sample ID: W219E
LIMS ID: 98-9023
Matrix: Water

QC Report No: W219-Dames & Moore
Project: Holden Mine
17693-005-019
Date Sampled: 05/01/98
Date Received: 05/05/98

Data Release Authorized:
Reported: 05/21/98

Prep Meth	Prep Date	Analysis Method	Analysis Date	CAS Number	Analyte	RL	ug/L	
3005	05/15/98	6010	05/18/98	7429-90-5	Aluminum	20	30	
200.8	05/15/98	200.8	05/18/98	7440-38-2	Arsenic	0.04	0.73	
200.8	05/15/98	200.8	05/18/98	7440-39-3	Barium	0.04	3.61	
200.8	05/15/98	200.8	05/18/98	7440-41-7	Beryllium	0.04	0.04	U
200.8	05/15/98	200.8	05/18/98	7440-43-9	Cadmium	0.04	0.04	U
3005	05/15/98	6010	05/18/98	7440-70-2	Calcium	20	2,310	
200.8	05/15/98	200.8	05/18/98	7440-47-3	Chromium	0.2	0.2	U
200.8	05/15/98	200.8	05/18/98	7440-50-8	Copper	0.2	0.7	
3005	05/15/98	6010	05/18/98	7439-89-6	Iron	20	30	
200.8	05/15/98	200.8	05/18/98	7439-92-1	Lead	0.2	0.5	J
3005	05/15/98	6010	05/18/98	7439-95-4	Magnesium	20	230	
200.8	05/15/98	200.8	05/18/98	7439-96-5	Manganese	0.04	2.88	
200.8	05/15/98	200.8	05/18/98	7439-98-7	Molybdenum	0.04	0.59	
200.8	05/15/98	200.8	05/18/98	7440-02-0	Nickel	0.2	0.3	
3005	05/15/98	6010	05/18/98	7440-09-7	Potassium	500	500	U
200.8	05/15/98	200.8	05/18/98	7440-22-4	Silver	0.04	0.04	U
3005	05/15/98	6010	05/18/98	7440-23-5	Sodium	50	630	
3005	05/15/98	6010	05/18/98	7440-66-6	Zinc	4	4	U

Calculated Dissolved Hardness (mg-CaCO3/L): 7

Km 4/4/99

U Analyte undetected at given RL

RL Reporting Limit

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INCORPORATED

INORGANICS ANALYSIS DATA SHEET
DISSOLVED METALS

Sample No: BIG-1

Lab Sample ID: W219F
LIMS ID: 98-9024
Matrix: Water

QC Report No: W219-Dames & Moore
Project: Holden Mine
17693-005-019
Date Sampled: 05/02/98
Date Received: 05/05/98

Data Release Authorized:
Reported: 05/21/98

Prep Meth	Prep Date	Analysis Method	Analysis Date	CAS Number	Analyte	RL	ug/L	
3005	05/15/98	6010	05/18/98	7429-90-5	Aluminum	20	30	
200.8	05/15/98	200.8	05/18/98	7440-38-2	Arsenic	0.04	0.29	
200.8	05/15/98	200.8	05/18/98	7440-39-3	Barium	0.04	6.51	
200.8	05/15/98	200.8	05/18/98	7440-41-7	Beryllium	0.04	0.04	U
200.8	05/15/98	200.8	05/18/98	7440-43-9	Cadmium	0.04	0.04	U
3005	05/15/98	6010	05/18/98	7440-70-2	Calcium	20	6,730	
200.8	05/15/98	200.8	05/18/98	7440-47-3	Chromium	0.2	0.2	U
200.8	05/15/98	200.8	05/18/98	7440-50-8	Copper	0.2	0.3	
3005	05/15/98	6010	05/18/98	7439-89-6	Iron	20	20	U
200.8	05/15/98	200.8	05/18/98	7439-92-1	Lead	0.2	0.2	U
3005	05/15/98	6010	05/18/98	7439-95-4	Magnesium	20	350	
200.8	05/15/98	200.8	05/18/98	7439-96-5	Manganese	0.04	0.29	U
200.8	05/15/98	200.8	05/18/98	7439-98-7	Molybdenum	0.04	0.33	
200.8	05/15/98	200.8	05/18/98	7440-02-0	Nickel	0.2	0.2	U
3005	05/15/98	6010	05/18/98	7440-09-7	Potassium	500	500	U
200.8	05/15/98	200.8	05/18/98	7440-22-4	Silver	0.04	0.04	U
3005	05/15/98	6010	05/18/98	7440-23-5	Sodium	50	640	
3005	05/15/98	6010	05/18/98	7440-66-6	Zinc	4	4	U

Calculated Dissolved Hardness (mg-CaCO3/L): 18

Km 6/15/98

U Analyte undetected at given RL

RL Reporting Limit

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INCORPORATED

INORGANICS ANALYSIS DATA SHEET
DISSOLVED METALS

Sample No: CC-1

Lab Sample ID: W219G
LIMS ID: 98-9025
Matrix: Water

QC Report No: W219-Dames & Moore
Project: Holden Mine
17693-005-019
Date Sampled: 05/02/98
Date Received: 05/05/98

Data Release Authorized:
Reported: 05/21/98

Prep Meth	Prep Date	Analysis Method	Analysis Date	CAS Number	Analyte	RL	ug/L
3005	05/15/98	6010	05/18/98	7429-90-5	Aluminum	20	20 U
200.8	05/15/98	200.8	05/18/98	7440-38-2	Arsenic	0.04	0.04 U
200.8	05/15/98	200.8	05/18/98	7440-39-3	Barium	0.04	4.96
200.8	05/15/98	200.8	05/18/98	7440-41-7	Beryllium	0.04	0.04 U
200.8	05/15/98	200.8	05/18/98	7440-43-9	Cadmium	0.04	0.04 U
3005	05/15/98	6010	05/18/98	7440-70-2	Calcium	20	3,790
200.8	05/15/98	200.8	05/18/98	7440-47-3	Chromium	0.2	0.2 U
200.8	05/15/98	200.8	05/18/98	7440-50-8	Copper	0.2	0.5
3005	05/15/98	6010	05/18/98	7439-89-6	Iron	20	20 U
200.8	05/15/98	200.8	05/18/98	7439-92-1	Lead	0.2	0.2 U
3005	05/15/98	6010	05/18/98	7439-95-4	Magnesium	20	430
200.8	05/15/98	200.8	05/18/98	7439-96-5	Manganese	0.04	0.82
200.8	05/15/98	200.8	05/18/98	7439-98-7	Molybdenum	0.04	0.48
200.8	05/15/98	200.8	05/18/98	7440-02-0	Nickel	0.2	0.3
3005	05/15/98	6010	05/18/98	7440-09-7	Potassium	500	500 U
200.8	05/15/98	200.8	05/18/98	7440-22-4	Silver	0.04	0.04 U
3005	05/15/98	6010	05/18/98	7440-23-5	Sodium	50	600
3005	05/15/98	6010	05/18/98	7440-66-6	Zinc	4	4 U

Calculated Dissolved Hardness (mg-CaCO3/L): 11

U Analyte undetected at given RL

RL Reporting Limit

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INCORPORATED

INORGANICS ANALYSIS DATA SHEET
DISSOLVED METALS

Sample No: CC-2

Lab Sample ID: W219H
LIMS ID: 98-9026
Matrix: Water

QC Report No: W219-Dames & Moore
Project: Holden Mine
17693-005-019
Date Sampled: 05/02/98
Date Received: 05/05/98

Data Release Authorized:
Reported: 05/21/98

Prep Meth	Prep Date	Analysis Method	Analysis Date	CAS Number	Analyte	RL	ug/L
3005	05/15/98	6010	05/18/98	7429-90-5	Aluminum	20	20 U
200.8	05/15/98	200.8	05/18/98	7440-38-2	Arsenic	0.04	0.04 U
200.8	05/15/98	200.8	05/18/98	7440-39-3	Barium	0.04	5.05
200.8	05/15/98	200.8	05/18/98	7440-41-7	Beryllium	0.04	0.04 U
200.8	05/15/98	200.8	05/18/98	7440-43-9	Cadmium	0.04	0.04 U
3005	05/15/98	6010	05/18/98	7440-70-2	Calcium	20	3,850
200.8	05/15/98	200.8	05/18/98	7440-47-3	Chromium	0.2	0.2 U
200.8	05/15/98	200.8	05/18/98	7440-50-8	Copper	0.2	0.4
3005	05/15/98	6010	05/18/98	7439-89-6	Iron	20	20 U
200.8	05/15/98	200.8	05/18/98	7439-92-1	Lead	0.2	0.3 J
3005	05/15/98	6010	05/18/98	7439-95-4	Magnesium	20	460
200.8	05/15/98	200.8	05/18/98	7439-96-5	Manganese	0.04	0.72
200.8	05/15/98	200.8	05/18/98	7439-98-7	Molybdenum	0.04	0.47
200.8	05/15/98	200.8	05/18/98	7440-02-0	Nickel	0.2	0.3
3005	05/15/98	6010	05/18/98	7440-09-7	Potassium	500	530
200.8	05/15/98	200.8	05/18/98	7440-22-4	Silver	0.04	0.04 U
3005	05/15/98	6010	05/18/98	7440-23-5	Sodium	50	620
3005	05/15/98	6010	05/18/98	7440-66-6	Zinc	4	4 U

Calculated Dissolved Hardness (mg-CaCO3/L): 12

Km 4/4/98

U Analyte undetected at given RL

RL Reporting Limit

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INORGANICS ANALYSIS DATA SHEET
DISSOLVED METALS

Sample No: RC-6

Lab Sample ID: W219I
LIMS ID: 98-9027
Matrix: Water

QC Report No: W219-Dames & Moore
Project: Holden Mine
17693-005-019
Date Sampled: 05/03/98
Date Received: 05/05/98

Data Release Authorized:
Reported: 05/21/98

Prep Meth	Prep Date	Analysis Method	Analysis Date	CAS Number	Analyte	RL	ug/L
3005	05/15/98	6010	05/18/98	7429-90-5	Aluminum	20	40
200.8	05/15/98	200.8	05/18/98	7440-38-2	Arsenic	0.04	0.54
200.8	05/15/98	200.8	05/18/98	7440-39-3	Barium	0.04	4.14
200.8	05/15/98	200.8	05/18/98	7440-41-7	Beryllium	0.04	0.04 U
200.8	05/15/98	200.8	05/18/98	7440-43-9	Cadmium	0.04	0.08
3005	05/15/98	6010	05/18/98	7440-70-2	Calcium	20	3,630
200.8	05/15/98	200.8	05/18/98	7440-47-3	Chromium	0.2	0.2 U
200.8	05/15/98	200.8	05/18/98	7440-50-8	Copper	0.2	0.6
3005	05/15/98	6010	05/18/98	7439-89-6	Iron	20	30
200.8	05/15/98	200.8	05/18/98	7439-92-1	Lead	0.2	0.3 J
3005	05/15/98	6010	05/18/98	7439-95-4	Magnesium	20	320
200.8	05/15/98	200.8	05/18/98	7439-96-5	Manganese	0.04	2.08
200.8	05/15/98	200.8	05/18/98	7439-98-7	Molybdenum	0.04	0.48
200.8	05/15/98	200.8	05/18/98	7440-02-0	Nickel	0.2	0.2 U
3005	05/15/98	6010	05/18/98	7440-09-7	Potassium	500	500 U
200.8	05/15/98	200.8	05/18/98	7440-22-4	Silver	0.04	0.04 U
3005	05/15/98	6010	05/18/98	7440-23-5	Sodium	50	700
3005	05/15/98	6010	05/18/98	7440-66-6	Zinc	4	4 U

Calculated Dissolved Hardness (mg-CaCO3/L): 10

km 4/4/98

U Analyte undetected at given RL

RL Reporting Limit

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ANALYTICAL
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INORGANICS ANALYSIS DATA SHEET
DISSOLVED METALS

Sample No: RC-1

Lab Sample ID: W219J
LIMS ID: 98-9028
Matrix: Water

QC Report No: W219-Dames & Moore
Project: Holden Mine
17693-005-019
Date Sampled: 05/03/98
Date Received: 05/05/98

Data Release Authorized:
Reported: 05/21/98

Prep Meth	Prep Date	Analysis Method	Analysis Date	CAS Number	Analyte	RL	ug/L
3005	05/15/98	6010	05/18/98	7429-90-5	Aluminum	20	30
200.8	05/15/98	200.8	05/18/98	7440-38-2	Arsenic	0.04	0.53
200.8	05/15/98	200.8	05/18/98	7440-39-3	Barium	0.04	4.38
200.8	05/15/98	200.8	05/18/98	7440-41-7	Beryllium	0.04	0.04 U
200.8	05/15/98	200.8	05/18/98	7440-43-9	Cadmium	0.04	0.04 U
3005	05/15/98	6010	05/18/98	7440-70-2	Calcium	20	3,730
200.8	05/15/98	200.8	05/18/98	7440-47-3	Chromium	0.2	0.2 U
200.8	05/15/98	200.8	05/18/98	7440-50-8	Copper	0.2	0.8
3005	05/15/98	6010	05/18/98	7439-89-6	Iron	20	20
200.8	05/15/98	200.8	05/18/98	7439-92-1	Lead	0.2	0.2 U
3005	05/15/98	6010	05/18/98	7439-95-4	Magnesium	20	330
200.8	05/15/98	200.8	05/18/98	7439-96-5	Manganese	0.04	2.00
200.8	05/15/98	200.8	05/18/98	7439-98-7	Molybdenum	0.04	0.49
200.8	05/15/98	200.8	05/18/98	7440-02-0	Nickel	0.2	0.2 U
3005	05/15/98	6010	05/18/98	7440-09-7	Potassium	500	500 U
200.8	05/15/98	200.8	05/18/98	7440-22-4	Silver	0.04	0.04 U
3005	05/15/98	6010	05/18/98	7440-23-5	Sodium	50	690
3005	05/15/98	6010	05/18/98	7440-66-6	Zinc	4	4 U

Calculated Dissolved Hardness (mg-CaCO3/L): 11

U	Analyte undetected at given RL
RL	Reporting Limit

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**ANALYTICAL
RESOURCES
INCORPORATED**

INORGANICS ANALYSIS DATA SHEET
DISSOLVED METALS

Sample No: RC-4

Lab Sample ID: W219K
LIMS ID: 98-9029
Matrix: Water

QC Report No: W219-Dames & Moore
Project: Holden Mine
17693-005-019
Date Sampled: 05/03/98
Date Received: 05/05/98

Data Release Authorized:
Reported: 05/21/98

Prep Meth	Prep Date	Analysis Method	Analysis Date	CAS Number	Analyte	RL	ug/L	
3005	05/15/98	6010	05/18/98	7429-90-5	Aluminum	20	60	
200.8	05/15/98	200.8	05/18/98	7440-38-2	Arsenic	0.04	0.46	
200.8	05/15/98	200.8	05/18/98	7440-39-3	Barium	0.04	4.69	
200.8	05/15/98	200.8	05/18/98	7440-41-7	Beryllium	0.04	0.04	U
200.8	05/15/98	200.8	05/18/98	7440-43-9	Cadmium	0.04	0.66	
3005	05/15/98	6010	05/18/98	7440-70-2	Calcium	20	4,250	
200.8	05/15/98	200.8	05/18/98	7440-47-3	Chromium	0.2	0.2	U
200.8	05/15/98	200.8	05/18/98	7440-50-8	Copper	0.2	41.7	
3005	05/15/98	6010	05/18/98	7439-89-6	Iron	20	20	U
200.8	05/15/98	200.8	05/18/98	7439-92-1	Lead	0.2	0.3	J
3005	05/15/98	6010	05/18/98	7439-95-4	Magnesium	20	420	
200.8	05/15/98	200.8	05/18/98	7439-96-5	Manganese	0.04	4.83	
200.8	05/15/98	200.8	05/18/98	7439-98-7	Molybdenum	0.04	0.49	
200.8	05/15/98	200.8	05/18/98	7440-02-0	Nickel	0.2	0.5	
3005	05/15/98	6010	05/18/98	7440-09-7	Potassium	500	500	U
200.8	05/15/98	200.8	05/18/98	7440-22-4	Silver	0.04	0.04	U
3005	05/15/98	6010	05/18/98	7440-23-5	Sodium	50	740	
3005	05/15/98	6010	05/18/98	7440-66-6	Zinc	4	114	

Calculated Dissolved Hardness (mg-CaCO3/L): 12

km 6/4/98

U Analyte undetected at given RL

RL Reporting Limit

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ANALYTICAL
RESOURCES
INCORPORATED

INORGANICS ANALYSIS DATA SHEET
DISSOLVED METALS

Sample No: RC-4X

Lab Sample ID: W219L
LIMS ID: 98-9030
Matrix: Water

QC Report No: W219-Dames & Moore
Project: Holden Mine
17693-005-019
Date Sampled: 05/03/98
Date Received: 05/05/98

Data Release Authorized:
Reported: 05/21/98

Prep Meth	Prep Date	Analysis Method	Analysis Date	CAS Number	Analyte	RL	ug/L
3005	05/15/98	6010	05/18/98	7429-90-5	Aluminum	20	70
200.8	05/15/98	200.8	05/18/98	7440-38-2	Arsenic	0.04	0.45
200.8	05/15/98	200.8	05/18/98	7440-39-3	Barium	0.04	4.60
200.8	05/15/98	200.8	05/18/98	7440-41-7	Beryllium	0.04	0.04 U
200.8	05/15/98	200.8	05/18/98	7440-43-9	Cadmium	0.04	0.67
3005	05/15/98	6010	05/18/98	7440-70-2	Calcium	20	4,240
200.8	05/15/98	200.8	05/18/98	7440-47-3	Chromium	0.2	0.2 U
200.8	05/15/98	200.8	05/18/98	7440-50-8	Copper	0.2	41.9
3005	05/15/98	6010	05/18/98	7439-89-6	Iron	20	20 U
200.8	05/15/98	200.8	05/18/98	7439-92-1	Lead	0.2	0.2 J
3005	05/15/98	6010	05/18/98	7439-95-4	Magnesium	20	420
200.8	05/15/98	200.8	05/18/98	7439-96-5	Manganese	0.04	4.94
200.8	05/15/98	200.8	05/18/98	7439-98-7	Molybdenum	0.04	0.61
200.8	05/15/98	200.8	05/18/98	7440-02-0	Nickel	0.2	0.5
3005	05/15/98	6010	05/18/98	7440-09-7	Potassium	500	500 U
200.8	05/15/98	200.8	05/18/98	7440-22-4	Silver	0.04	0.04 U
3005	05/15/98	6010	05/18/98	7440-23-5	Sodium	50	750
3005	05/15/98	6010	05/18/98	7440-66-6	Zinc	4	116

Calculated Dissolved Hardness (mg-CaCO3/L): 12

Km 4/4/98

U Analyte undetected at given RL

RL Reporting Limit

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ANALYTICAL
RESOURCES
INCORPORATED

INORGANICS ANALYSIS DATA SHEET
DISSOLVED METALS

Sample No: RC-7

Lab Sample ID: W219M
LIMS ID: 98-9031
Matrix: Water

QC Report No: W219-Dames & Moore
Project: Holden Mine
17693-005-019
Date Sampled: 05/03/98
Date Received: 05/05/98

Data Release Authorized:
Reported: 05/21/98

Prep Meth	Prep Date	Analysis Method	Analysis Date	CAS Number	Analyte	RL	ug/L	
3005	05/15/98	6010	05/18/98	7429-90-5	Aluminum	20	90	
200.8	05/15/98	200.8	05/18/98	7440-38-2	Arsenic	0.04	0.36	
200.8	05/15/98	200.8	05/18/98	7440-39-3	Barium	0.04	4.88	
200.8	05/15/98	200.8	05/18/98	7440-41-7	Beryllium	0.04	0.04	U
200.8	05/15/98	200.8	05/18/98	7440-43-9	Cadmium	0.04	0.67	
3005	05/15/98	6010	05/18/98	7440-70-2	Calcium	20	4,520	
200.8	05/15/98	200.8	05/18/98	7440-47-3	Chromium	0.2	0.2	U
200.8	05/15/98	200.8	05/18/98	7440-50-8	Copper	0.2	37.5	
3005	05/15/98	6010	05/18/98	7439-89-6	Iron	20	380	
200.8	05/15/98	200.8	05/18/98	7439-92-1	Lead	0.2	0.4	J
3005	05/15/98	6010	05/18/98	7439-95-4	Magnesium	20	510	
200.8	05/15/98	200.8	05/18/98	7439-96-5	Manganese	0.04	9.60	
200.8	05/15/98	200.8	05/18/98	7439-98-7	Molybdenum	0.04	0.48	
200.8	05/15/98	200.8	05/18/98	7440-02-0	Nickel	0.2	0.4	
3005	05/15/98	6010	05/18/98	7440-09-7	Potassium	500	500	U
200.8	05/15/98	200.8	05/18/98	7440-22-4	Silver	0.04	0.04	U
3005	05/15/98	6010	05/18/98	7440-23-5	Sodium	50	760	
3005	05/15/98	6010	05/18/98	7440-66-6	Zinc	4	115	

Calculated Dissolved Hardness (mg-$CaCO_3$/L): 13

Km 4/4/99

U Analyte undetected at given RL

RL Reporting Limit

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ANALYTICAL
RESOURCES
INCORPORATED

INORGANICS ANALYSIS DATA SHEET
DISSOLVED METALS

Sample No: RC-5

Lab Sample ID: W219N
LIMS ID: 98-9032
Matrix: Water

QC Report No: W219-Dames & Moore
Project: Holden Mine
17693-005-019
Date Sampled: 05/04/98
Date Received: 05/05/98

Data Release Authorized:
Reported: 05/21/98

Prep Meth	Prep Date	Analysis Method	Analysis Date	CAS Number	Analyte	RL	ug/L
3005	05/15/98	6010	05/18/98	7429-90-5	Aluminum	20	90
200.8	05/15/98	200.8	05/18/98	7440-38-2	Arsenic	0.04	0.28
200.8	05/15/98	200.8	05/18/98	7440-39-3	Barium	0.04	5.40
200.8	05/15/98	200.8	05/18/98	7440-41-7	Beryllium	0.04	0.04 U
200.8	05/15/98	200.8	05/18/98	7440-43-9	Cadmium	0.04	0.58
3005	05/15/98	6010	05/18/98	7440-70-2	Calcium	20	5,040
200.8	05/15/98	200.8	05/18/98	7440-47-3	Chromium	0.2	0.2 U
200.8	05/15/98	200.8	05/18/98	7440-50-8	Copper	0.2	26.9
3005	05/15/98	6010	05/18/98	7439-89-6	Iron	20	300
200.8	05/15/98	200.8	05/18/98	7439-92-1	Lead	0.2	0.4 J
3005	05/15/98	6010	05/18/98	7439-95-4	Magnesium	20	620
200.8	05/15/98	200.8	05/18/98	7439-96-5	Manganese	0.04	12.0
200.8	05/15/98	200.8	05/18/98	7439-98-7	Molybdenum	0.04	0.45
200.8	05/15/98	200.8	05/18/98	7440-02-0	Nickel	0.2	0.4
3005	05/15/98	6010	05/18/98	7440-09-7	Potassium	500	500 U
200.8	05/15/98	200.8	05/18/98	7440-22-4	Silver	0.04	0.04 U
3005	05/15/98	6010	05/18/98	7440-23-5	Sodium	50	780
3005	05/15/98	6010	05/18/98	7440-66-6	Zinc	4	98

Calculated Dissolved Hardness (mg-CaCO3/L): 15

KM. 4/9/99

U Analyte undetected at given RL

RL Reporting Limit

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ANALYTICAL
RESOURCES
INCORPORATED

INORGANICS ANALYSIS DATA SHEET
DISSOLVED METALS

Sample No: RC-10

Lab Sample ID: W2190
LIMS ID: 98-9033
Matrix: Water

QC Report No: W219-Dames & Moore
Project: Holden Mine
17693-005-019
Date Sampled: 05/04/98
Date Received: 05/05/98

Data Release Authorized:
Reported: 05/21/98

Prep Meth	Prep Date	Analysis Method	Analysis Date	CAS Number	Analyte	RL	ug/L	
3005	05/15/98	6010	05/18/98	7429-90-5	Aluminum	20	80	
200.8	05/15/98	200.8	05/18/98	7440-38-2	Arsenic	0.04	0.26	
200.8	05/15/98	200.8	05/18/98	7440-39-3	Barium	0.04	5.51	
200.8	05/15/98	200.8	05/18/98	7440-41-7	Beryllium	0.04	0.04	U
200.8	05/15/98	200.8	05/18/98	7440-43-9	Cadmium	0.04	0.40	
3005	05/15/98	6010	05/18/98	7440-70-2	Calcium	20	5,410	
200.8	05/15/98	200.8	05/18/98	7440-47-3	Chromium	0.2	0.2	U
200.8	05/15/98	200.8	05/18/98	7440-50-8	Copper	0.2	18.5	
3005	05/15/98	6010	05/18/98	7439-89-6	Iron	20	220	
200.8	05/15/98	200.8	05/18/98	7439-92-1	Lead	0.2	0.3	J
3005	05/15/98	6010	05/18/98	7439-95-4	Magnesium	20	640	
200.8	05/15/98	200.8	05/18/98	7439-96-5	Manganese	0.04	9.29	
200.8	05/15/98	200.8	05/18/98	7439-98-7	Molybdenum	0.04	0.43	
200.8	05/15/98	200.8	05/18/98	7440-02-0	Nickel	0.2	0.5	
3005	05/15/98	6010	05/18/98	7440-09-7	Potassium	500	500	U
200.8	05/15/98	200.8	05/18/98	7440-22-4	Silver	0.04	0.04	U
3005	05/15/98	6010	05/18/98	7440-23-5	Sodium	50	810	
3005	05/15/98	6010	05/18/98	7440-66-6	Zinc	4	69	

Calculated Dissolved Hardness (mg-CaCO3/L): 16

KM 4/4/98

U Analyte undetected at given RL

RL Reporting Limit

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ANALYTICAL
RESOURCES
INCORPORATED

INORGANICS ANALYSIS DATA SHEET
DISSOLVED METALS

Sample No: RC-3

Lab Sample ID: W219P
LIMS ID: 98-9034
Matrix: Water

QC Report No: W219-Dames & Moore
Project: Holden Mine
17693-005-019
Date Sampled: 05/05/98
Date Received: 05/05/98

Data Release Authorized:
Reported: 05/21/98

Prep Meth	Prep Date	Analysis Method	Analysis Date	CAS Number	Analyte	RL	ug/L
3005	05/15/98	6010	05/18/98	7429-90-5	Aluminum	20	70
200.8	05/15/98	200.8	05/18/98	7440-38-2	Arsenic	0.04	0.20
200.8	05/15/98	200.8	05/18/98	7440-39-3	Barium	0.04	5.80
200.8	05/15/98	200.8	05/18/98	7440-41-7	Beryllium	0.04	0.04 U
200.8	05/15/98	200.8	05/18/98	7440-43-9	Cadmium	0.04	0.26
3005	05/15/98	6010	05/18/98	7440-70-2	Calcium	20	5,250
200.8	05/15/98	200.8	05/18/98	7440-47-3	Chromium	0.2	0.2 U
200.8	05/15/98	200.8	05/18/98	7440-50-8	Copper	0.2	12.6
3005	05/15/98	6010	05/18/98	7439-89-6	Iron	20	170
200.8	05/15/98	200.8	05/18/98	7439-92-1	Lead	0.2	0.3 J
3005	05/15/98	6010	05/18/98	7439-95-4	Magnesium	20	620
200.8	05/15/98	200.8	05/18/98	7439-96-5	Manganese	0.04	6.48
200.8	05/15/98	200.8	05/18/98	7439-98-7	Molybdenum	0.04	0.51
200.8	05/15/98	200.8	05/18/98	7440-02-0	Nickel	0.2	0.3
3005	05/15/98	6010	05/18/98	7440-09-7	Potassium	500	500 U
200.8	05/15/98	200.8	05/18/98	7440-22-4	Silver	0.04	0.04 U
3005	05/15/98	6010	05/18/98	7440-23-5	Sodium	50	870
3005	05/15/98	6010	05/18/98	7440-66-6	Zinc	4	45

Calculated Dissolved Hardness (mg-CaCO3/L): 16

km 4/4/98

U Analyte undetected at given RL

RL Reporting Limit

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ANALYTICAL
RESOURCES
INCORPORATED

INORGANICS ANALYSIS DATA SHEET
DISSOLVED METALS

Sample No: RC-2

Lab Sample ID: W219Q
LIMS ID: 98-9035
Matrix: Water

QC Report No: W219-Dames & Moore
Project: Holden Mine
17693-005-019
Date Sampled: 05/03/98
Date Received: 05/05/98

Data Release Authorized:
Reported: 05/21/98

Prep Meth	Prep Date	Analysis Method	Analysis Date	CAS Number	Analyte	RL	ug/L	
3005	05/15/98	6010	05/18/98	7429-90-5	Aluminum	20	100	
200.8	05/15/98	200.8	05/18/98	7440-38-2	Arsenic	0.04	0.35	
200.8	05/15/98	200.8	05/18/98	7440-39-3	Barium	0.04	5.02	
200.8	05/15/98	200.8	05/18/98	7440-41-7	Beryllium	0.04	0.04	U
200.8	05/15/98	200.8	05/18/98	7440-43-9	Cadmium	0.04	0.68	
3005	05/15/98	6010	05/18/98	7440-70-2	Calcium	20	4,680	
200.8	05/15/98	200.8	05/18/98	7440-47-3	Chromium	0.2	0.2	U
200.8	05/15/98	200.8	05/18/98	7440-50-8	Copper	0.2	35.7	
3005	05/15/98	6010	05/18/98	7439-89-6	Iron	20	350	
200.8	05/15/98	200.8	05/18/98	7439-92-1	Lead	0.2	0.4	J
3005	05/15/98	6010	05/18/98	7439-95-4	Magnesium	20	550	
200.8	05/15/98	200.8	05/18/98	7439-96-5	Manganese	0.04	9.90	
200.8	05/15/98	200.8	05/18/98	7439-98-7	Molybdenum	0.04	0.48	
200.8	05/15/98	200.8	05/18/98	7440-02-0	Nickel	0.2	0.4	
3005	05/15/98	6010	05/18/98	7440-09-7	Potassium	500	500	U
200.8	05/15/98	200.8	05/18/98	7440-22-4	Silver	0.04	0.04	U
3005	05/15/98	6010	05/18/98	7440-23-5	Sodium	50	800	
3005	05/15/98	6010	05/18/98	7440-66-6	Zinc	4	113	

Calculated Dissolved Hardness (mg-CaCO3/L): 14

Km 4/4/98

U Analyte undetected at given RL

RL Reporting Limit

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ANALYTICAL
RESOURCES
INCORPORATED

INORGANICS ANALYSIS DATA SHEET
TOTAL METALS

Sample No: EB050298

Lab Sample ID: W221A
LIMS ID: 98-9058
Matrix: Water

QC Report No: W221-Dames & Moore
Project: Holden Mine
17693-005-019
Date Sampled: 05/02/98
Date Received: 05/05/98

Data Release Authorized:
Reported: 05/21/98

Prep Meth	Prep Date	Analysis Method	Analysis Date	CAS Number	Analyte	RL	ug/L	
3005	05/15/98	6010	05/18/98	7429-90-5	Aluminum	20	20	U
200.8	05/15/98	200.8	05/18/98	7440-38-2	Arsenic	0.04	0.04	U
200.8	05/15/98	200.8	05/18/98	7440-39-3	Barium	0.04	0.04	
200.8	05/15/98	200.8	05/18/98	7440-41-7	Beryllium	0.04	0.04	U
200.8	05/15/98	200.8	05/18/98	7440-43-9	Cadmium	0.04	0.04	U
3005	05/15/98	6010	05/18/98	7440-70-2	Calcium	20	30	U
200.8	05/15/98	200.8	05/18/98	7440-47-3	Chromium	0.2	0.2	U
200.8	05/15/98	200.8	05/18/98	7440-50-8	Copper	0.2	0.2	U
3005	05/15/98	6010	05/18/98	7439-89-6	Iron	20	20	U
200.8	05/15/98	200.8	05/18/98	7439-92-1	Lead	0.2	0.4	J
3005	05/15/98	6010	05/18/98	7439-95-4	Magnesium	20	20	U
200.8	05/15/98	200.8	05/18/98	7439-96-5	Manganese	0.04	0.04	U
200.8	05/15/98	200.8	05/18/98	7439-98-7	Molybdenum	0.04	0.04	U
200.8	05/15/98	200.8	05/18/98	7440-02-0	Nickel	0.2	0.2	U
3005	05/15/98	6010	05/18/98	7440-09-7	Potassium	500	500	U
200.8	05/15/98	200.8	05/18/98	7440-22-4	Silver	0.04	0.04	U
3005	05/15/98	6010	05/18/98	7440-23-5	Sodium	50	50	
3005	05/15/98	6010	05/18/98	7440-66-6	Zinc	4	4	U

Km 6/4/98

U Analyte undetected at given RL

RL Reporting Limit

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ANALYTICAL
RESOURCES
INCORPORATED

INORGANICS ANALYSIS DATA SHEET
TOTAL METALS

Sample No: EB050398

Lab Sample ID: W221B
LIMS ID: 98-9059
Matrix: Water

QC Report No: W221-Dames & Moore
Project: Holden Mine
17693-005-019
Date Sampled: 05/03/98
Date Received: 05/05/98

Data Release Authorized:
Reported: 05/21/98

Prep Meth	Prep Date	Analysis Method	Analysis Date	CAS Number	Analyte	RL	ug/L
3005	05/15/98	6010	05/18/98	7429-90-5	Aluminum	20	20 U
200.8	05/15/98	200.8	05/18/98	7440-38-2	Arsenic	0.04	0.04 U
200.8	05/15/98	200.8	05/18/98	7440-39-3	Barium	0.04	0.05
200.8	05/15/98	200.8	05/18/98	7440-41-7	Beryllium	0.04	0.04 U
200.8	05/15/98	200.8	05/18/98	7440-43-9	Cadmium	0.04	0.04 U
3005	05/15/98	6010	05/18/98	7440-70-2	Calcium	20	30 U
200.8	05/15/98	200.8	05/18/98	7440-47-3	Chromium	0.2	0.2 U
200.8	05/15/98	200.8	05/18/98	7440-50-8	Copper	0.2	0.2 U
3005	05/15/98	6010	05/18/98	7439-89-6	Iron	20	20 U
200.8	05/15/98	200.8	05/18/98	7439-92-1	Lead	0.2	0.2 U
3005	05/15/98	6010	05/18/98	7439-95-4	Magnesium	20	20 U
200.8	05/15/98	200.8	05/18/98	7439-96-5	Manganese	0.04	0.06 U
200.8	05/15/98	200.8	05/18/98	7439-98-7	Molybdenum	0.04	0.04 U
200.8	05/15/98	200.8	05/18/98	7440-02-0	Nickel	0.2	0.2 U
3005	05/15/98	6010	05/18/98	7440-09-7	Potassium	500	500 U
200.8	05/15/98	200.8	05/18/98	7440-22-4	Silver	0.04	0.04 U
3005	05/15/98	6010	05/18/98	7440-23-5	Sodium	50	50
3005	05/15/98	6010	05/18/98	7440-66-6	Zinc	4	4 U

Km 6/4/98

U Analyte undetected at given RL

RL Reporting Limit

FORM-I

ANALYTICAL
RESOURCES
INCORPORATED

INORGANICS ANALYSIS DATA SHEET
TOTAL METALS

Sample No: EB050598

Lab Sample ID: W221C
LIMS ID: 98-9060
Matrix: Water

QC Report No: W221-Dames & Moore
Project: Holden Mine
17693-005-019
Date Sampled: 05/05/98
Date Received: 05/05/98

Data Release Authorized:
Reported: 05/21/98

Prep Meth	Prep Date	Analysis Method	Analysis Date	CAS Number	Analyte	RL	ug/L
3005	05/15/98	6010	05/18/98	7429-90-5	Aluminum	20	20 U
200.8	05/15/98	200.8	05/18/98	7440-38-2	Arsenic	0.04	0.04 U
200.8	05/15/98	200.8	05/18/98	7440-39-3	Barium	0.04	0.12
200.8	05/15/98	200.8	05/18/98	7440-41-7	Beryllium	0.04	0.04 U
200.8	05/15/98	200.8	05/18/98	7440-43-9	Cadmium	0.04	0.04 U
3005	05/15/98	6010	05/18/98	7440-70-2	Calcium	20	40 U
200.8	05/15/98	200.8	05/18/98	7440-47-3	Chromium	0.2	0.2 U
200.8	05/15/98	200.8	05/18/98	7440-50-8	Copper	0.2	0.4
3005	05/15/98	6010	05/18/98	7439-89-6	Iron	20	20 U
200.8	05/15/98	200.8	05/18/98	7439-92-1	Lead	0.2	0.3 J
3005	05/15/98	6010	05/18/98	7439-95-4	Magnesium	20	20 U
200.8	05/15/98	200.8	05/18/98	7439-96-5	Manganese	0.04	0.24 U
200.8	05/15/98	200.8	05/18/98	7439-98-7	Molybdenum	0.04	0.04 U
200.8	05/15/98	200.8	05/18/98	7440-02-0	Nickel	0.2	0.2 U
3005	05/15/98	6010	05/18/98	7440-09-7	Potassium	500	500 U
200.8	05/15/98	200.8	05/18/98	7440-22-4	Silver	0.04	0.04 U
3005	05/15/98	6010	05/18/98	7440-23-5	Sodium	50	50 U
3005	05/15/98	6010	05/18/98	7440-66-6	Zinc	4	4 U

km 4/4/98

U Analyte undetected at given RL

RL Reporting Limit

FORM-I

ANALYTICAL
RESOURCES
INCORPORATED

INORGANICS ANALYSIS DATA SHEET
TOTAL METALS

Sample No: Method Blank

Lab Sample ID: W219MB
LIMS ID: 98-9036
Matrix: Water

QC Report No: W219-Dames & Moore
Project: Holden Mine
17693-005-019
Date Sampled: NA
Date Received: NA

Data Release Authorized:
Reported: 05/21/98

Prep Meth	Prep Date	Analysis Method	Analysis Date	CAS Number	Analyte	RL	ug/L
3005	05/15/98	6010	05/18/98	7429-90-5	Aluminum	20	20
200.8	05/18/98	200.8	05/19/98	7440-38-2	Arsenic	0.04	0.04 U
200.8	05/18/98	200.8	05/19/98	7440-39-3	Barium	0.04	0.05
200.8	05/18/98	200.8	05/19/98	7440-41-7	Beryllium	0.04	0.04 U
200.8	05/18/98	200.8	05/19/98	7440-43-9	Cadmium	0.04	0.11
3005	05/15/98	6010	05/18/98	7440-70-2	Calcium	20	30
200.8	05/18/98	200.8	05/19/98	7440-47-3	Chromium	0.2	0.2 U
200.8	05/18/98	200.8	05/19/98	7440-50-8	Copper	0.2	0.3
3005	05/15/98	6010	05/18/98	7439-89-6	Iron	20	20 U
200.8	05/18/98	200.8	05/19/98	7439-92-1	Lead	0.2	0.4
3005	05/15/98	6010	05/18/98	7439-95-4	Magnesium	20	20 U
200.8	05/18/98	200.8	05/19/98	7439-96-5	Manganese	0.04	0.44
200.8	05/18/98	200.8	05/19/98	7439-98-7	Molybdenum	0.04	0.04 U
200.8	05/18/98	200.8	05/19/98	7440-02-0	Nickel	0.2	0.2 U
3005	05/15/98	6010	05/18/98	7440-09-7	Potassium	500	500 U
200.8	05/18/98	200.8	05/19/98	7440-22-4	Silver	0.04	0.04 U
3005	05/15/98	6010	05/18/98	7440-23-5	Sodium	50	50 U
3005	05/15/98	6010	05/18/98	7440-66-6	Zinc	4	4 U

U Analyte undetected at given RL

RL Reporting Limit

FORM-I

INORGANICS ANALYSIS DATA SHEET
DISSOLVED METALS

Sample No: Method Blank

Lab Sample ID: W219MB
LIMS ID: 98-9019
Matrix: Water

QC Report No: W219-Dames & Moore
Project: Holden Mine
17693-005-019
Date Sampled: NA
Date Received: NA

Data Release Authorized
Reported: 05/21/98

Prep Meth	Prep Date	Analysis Method	Analysis Date	CAS Number	Analyte	RL	ug/L
3005	05/15/98	6010	05/18/98	7429-90-5	Aluminum	20	20 U
200.8	05/15/98	200.8	05/18/98	7440-38-2	Arsenic	0.04	0.04 U
200.8	05/15/98	200.8	05/18/98	7440-39-3	Barium	0.04	0.04 U
200.8	05/15/98	200.8	05/18/98	7440-41-7	Beryllium	0.04	0.04 U
200.8	05/15/98	200.8	05/18/98	7440-43-9	Cadmium	0.04	0.04 U
3005	05/15/98	6010	05/18/98	7440-70-2	Calcium	20	20 U
200.8	05/15/98	200.8	05/18/98	7440-47-3	Chromium	0.2	0.2 U
200.8	05/15/98	200.8	05/18/98	7440-50-8	Copper	0.2	0.2 U
3005	05/15/98	6010	05/18/98	7439-89-6	Iron	20	20 U
200.8	05/15/98	200.8	05/18/98	7439-92-1	Lead	0.2	0.2 U
3005	05/15/98	6010	05/18/98	7439-95-4	Magnesium	20	20 U
200.8	05/15/98	200.8	05/18/98	7439-96-5	Manganese	0.04	0.05
200.8	05/15/98	200.8	05/18/98	7439-98-7	Molybdenum	0.04	0.04 U
200.8	05/15/98	200.8	05/18/98	7440-02-0	Nickel	0.2	0.2 U
3005	05/15/98	6010	05/18/98	7440-09-7	Potassium	500	500 U
200.8	05/15/98	200.8	05/18/98	7440-22-4	Silver	0.04	0.04 U
3005	05/15/98	6010	05/18/98	7440-23-5	Sodium	50	50 U
3005	05/15/98	6010	05/18/98	7440-66-6	Zinc	4	4 U

U Analyte undetected at given RL

RL Reporting Limit

FORM-I

ANALYTICAL
RESOURCES
INCORPORATED

INORGANICS ANALYSIS DATA SHEET

Sample No: STD REFERENCE
I.V. Lots 869-6 and 889-1

Lab Sample ID: W219LCS
LIMS ID: 98-9019
Matrix: Water

QC Report No: W219-Dames & Moore
Project: Holden Mine
17693-005-019
Date Sampled: NA
Date Received: NA

Data Release Authorized:
Reported: 05/21/98

Analyte	STD Value	Value Found	Recovery
Aluminum	2000	2050	102%
Calcium	2000	2070	104%
Iron	2000	1990	99.5%
Magnesium	2000	1980	99.0%
Potassium	20000	20000	100%
Sodium	2000	2000	100%
Zinc	1000	1000	100%

Recovery Limits 80-120

Values reported in parts per billion (ug/L)

I.V. Lot 869-6 used for GFA. I.V. Lot 889-1 used for ICP.

FORM-III-R

INORGANICS ANALYSIS DATA SHEET

Sample No: STD REFERENCE
I.V. Lots 869-6 and 889-1

Lab Sample ID: W219LCS
LIMS ID: 98-9036
Matrix: Water

QC Report No: W219-Dames & Moore
Project: Holden Mine
17693-005-019
Date Sampled: NA
Date Received: NA

Data Release Authorized:
Reported: 05/21/98

Analyte	STD Value	Value Found	Recovery
Aluminum	2000	2040	102%
Calcium	2000	2090	104%
Iron	2000	1960	98.0%
Magnesium	2000	2000	100%
Potassium	20000	20000	100%
Sodium	2000	1970	98.5%
Zinc	1000	970	97.0%

Recovery Limits 80-120

Values reported in parts per billion (ug/L)

I.V. Lot 869-6 used for GFA. I.V. Lot 889-1 used for ICP.

FORM-III-R

ANALYTICAL
RESOURCES
INCORPORATED

Final Report
Laboratory Analysis of Conventional Parameters

Sample No: RC-7

Lab Sample ID: W219M
LIMS ID: 98-9031
Matrix: Water

QC Report No: W219-Dames & Moore
Project: Holden Mine
17693-005-019
Date Sampled: 05/03/98
Date Received: 05/05/98

Data Release Authorized:
Reported: 05/27/98 Dr. M.A. Perkins

Analyte	Analysis Date & Batch	Method	RL	Units	Result
Alkalinity	05/14/98 051498#1	SM 2320	1.0	mg/L CaCO3	8.1
Total Dissolved Solids	05/07/98 050798#1	EPA 160.1	5.0	mg/L	23
Total Suspended Solids	05/07/98 050798#1	EPA 160.2	1.0	mg/L	1.7
Sulfate	05/13/98 051398#1	EPA 375.2	2.5	mg/L	4.8

RL Analytical reporting limit
U Undetected at reported detection limit

Report for W219 received 05/05/98

ANALYTICAL
RESOURCES
INCORPORATED

Final Report
Laboratory Analysis of Conventional Parameters

Sample No: RC-5

Lab Sample ID: W219N
LIMS ID: 98-9032
Matrix: Water

QC Report No: W219-Dames & Moore
Project: Holden Mine
17693-005-019
Date Sampled: 05/04/98
Date Received: 05/05/98

Data Release Authorized:
Reported: 05/27/98 Dr. M.A. Perkins

Analyte	Analysis Date & Batch	Method	RL	Units	Result
Alkalinity	05/14/98 051498#1	SM 2320	1.0	mg/L CaCO3	8.1
Total Dissolved Solids	05/07/98 050798#1	EPA 160.1	5.0	mg/L	20
Total Suspended Solids	05/07/98 050798#1	EPA 160.2	1.0	mg/L	2.5
Sulfate	05/13/98 051398#1	EPA 375.2	2.5	mg/L	5.6

RL Analytical reporting limit
U Undetected at reported detection limit

Report for W219 received 05/05/98

ANALYTICAL
RESOURCES
INCORPORATED

Final Report
Laboratory Analysis of Conventional Parameters

Sample No: RC-10

Lab Sample ID: W2190
LIMS ID: 98-9033
Matrix: Water

QC Report No: W219-Dames & Moore
Project: Holden Mine
17693-005-019
Date Sampled: 05/04/98
Date Received: 05/05/98

Data Release Authorized:
Reported: 05/27/98 Dr. M.A. Perkins

Analyte	Analysis Date & Batch	Method	RL	Units	Result
Alkalinity	05/14/98 051498#1	SM 2320	1.0	mg/L CaCO3	11
Total Dissolved Solids	05/07/98 050798#1	EPA 160.1	5.0	mg/L	25
Total Suspended Solids	05/07/98 050798#1	EPA 160.2	1.0	mg/L	3.8
Sulfate	05/14/98 051498#2	EPA 375.2	2.5	mg/L	5.5

RL Analytical reporting limit
U Undetected at reported detection limit

Report for W219 received 05/05/98

ANALYTICAL
RESOURCES
INCORPORATED

Final Report
Laboratory Analysis of Conventional Parameters

Sample No: RC-3

Lab Sample ID: W219P
LIMS ID: 98-9034
Matrix: Water

Data Release Authorized:
Reported: 05/27/98 Dr. M.A. Perkins

QC Report No: W219-Dames & Moore
Project: Holden Mine
17693-005-019
Date Sampled: 05/05/98
Date Received: 05/05/98

Analyte	Analysis Date & Batch	Method	RL	Units	Result
Alkalinity	05/14/98 051498#1	SM 2320	1.0	mg/L CaCO3	12
Total Dissolved Solids	05/07/98 050798#1	EPA 160.1	5.0	mg/L	29
Total Suspended Solids	05/07/98 050798#1	EPA 160.2	1.0	mg/L	4.3
Sulfate	05/14/98 051498#2	EPA 375.2	2.5	mg/L	5.3

RL	Analytical reporting limit
U	Undetected at reported detection limit

Report for W219 received 05/05/98

ANALYTICAL
RESOURCES
INCORPORATED

Final Report
Laboratory Analysis of Conventional Parameters

Sample No: RC-2

Lab Sample ID: W219Q
LIMS ID: 98-9035
Matrix: Water

QC Report No: W219-Dames & Moore
Project: Holden Mine
17693-005-019
Date Sampled: 05/03/98
Date Received: 05/05/98

Data Release Authorized:
Reported: 05/27/98 Dr. M.A. Perkins

Analyte	Analysis Date & Batch	Method	RL	Units	Result
Alkalinity	05/14/98 051498#1	SM 2320	1.0	mg/L CaCO3	8.4
Total Dissolved Solids	05/07/98 050798#1	EPA 160.1	5.0	mg/L	23
Total Suspended Solids	05/07/98 050798#1	EPA 160.2	1.0	mg/L	3.1
Sulfate	05/14/98 051498#2	EPA 375.2	2.5	mg/L	6.2

RL	Analytical reporting limit
U	Undetected at reported detection limit

Report for W219 received 05/05/98

ANALYTICAL
RESOURCES
INCORPORATED

QA Report - Method Blank Analysis

QC Report No: W219-Dames & Moore
Matrix: Water
Project: Holden Mine
17693-005-019
Date Received: NA

Data Release Authorized:
Reported: 05/27/98 Dr. M.A. Perkins

METHOD BLANK RESULTS
CONVENTIONALS

Analysis Date & Batch	Constituent	Units		Result	
05/07/98 050798#1	Total Dissolved Solids	mg/L	<	10	U
05/07/98 050798#1	Total Suspended Solids	mg/L	<	1.0	U
05/13/98 051398#1	Sulfate	mg/L	<	2.5	U
05/14/98 051498#2	Sulfate	mg/L	<	2.5	U

ANALYTICAL
RESOURCES
INCORPORATED

QA Report - Replicate Analysis

QC Report No: W219-Dames & Moore
Project: Holden Mine
17693-005-019
Date Received: 05/05/98

Matrix: Water

Data Release Authorized:
Reported: 05/27/98 Dr. M.A. Perkins

DUPLICATE ANALYSIS RESULTS
CONVENTIONALS

Constituent	Units	Sample Value	Duplicate Value	RPD
ARI ID: 98-9019, W219 A	**Client Sample ID: HC-4**			
Alkalinity	mg/L CaCO3	11	10	9.5%
Total Dissolved Solids	mg/L	11	12	8.7%
Total Suspended Solids	mg/L	< 2.2 U	< 2.2 U	NA
ARI ID: 98-9033, W219 O	**Client Sample ID: RC-10**			
Sulfate	mg/L	5.5	6.7	19.7%

QA Report - Matrix Spike/Matrix Spike Duplicate Analysis

QC Report No: W219-Dames & Moore
Matrix: Water
Project: Holden Mine
17693-005-019
Date Received: 05/05/98

Data Release Authorized:
Reported: 05/27/98 Dr. M.A. Perkins

MATRIX SPIKE QA/QC REPORT
CONVENTIONALS

Constituent	Units	Sample Value	Spike Value	Spike Added	Recovery
ARI ID: 98-9033, W219 O	**Client Sample ID: RC-10**				
Sulfate	mg/L	5.5	25.7	20.0	101%

MS/MSD Recovery Limits: 75 - 125 %

ANALYTICAL
RESOURCES
INCORPORATED

QA Report - Laboratory Control Samples

QC Report No: W219-Dames & Moore
Project: Holden Mine
17693-005-019
Date Received: NA

Data Release Authorized:
Reported: 05/27/98 Dr. M.A. Perkins

LABORATORY CONTROL SAMPLES
CONVENTIONALS

Constituent	Units	Measured Value	True Value	Recovery
Laboratory Control Sample				
Alkalinity	mg/L CaCO3	121	118	103%
Date analyzed: 05/14/98	Batch ID: 051498#1			

ANALYTICAL
RESOURCES
INCORPORATED

QA Report - Standard Reference Material Analysis

QC Report No: W219-Dames & Moore
Project: Holden Mine
17693-005-019
Date Received: NA

Data Release Authorized:
Reported: 05/27/98 Dr. M.A. Perkins

STANDARD REFERENCE MATERIAL ANALYSIS
CONVENTIONALS

Constituent	Units	Value	True Value	Recovery
SPEX#13-22AS				
Sulfate	mg/L	24.8	25.0	99.2%
Date analyzed: 05/13/98	Batch ID: 051398#1			
SPEX#13-22AS				
Sulfate	mg/L	25.7	25.0	103%
Date analyzed: 05/14/98	Batch ID: 051498#2			

TOTAL GASOLINE RANGE HYDROCARBONS
WTPHg Range Toluene to C12 by GC/FID

QC Report No: W219-Dames & Moore
Matrix: Water
Project: Holden Mine
17693-005-019
Data Release Authorized: CH
Date Received: 05/05/98
Reported: 05/12/98 5/12/98

Lab ID	Client Sample ID	Date Analyzed	Dilution Factor	Gas Range	Gas ID	Surr A Rec	Surr B Rec
W219-0511MB	Method Blank	05/11/98	1:1	0.25 U	NO	99.3%	95.1%
98-9035-W219Q	RC-2	05/11/98	1:1	0.25 U	NO	98.1%	101%

Surrogate A is Trifluorotoluene.
Surrogate B is Bromobenzene.
Values reported in ppm (mg/L).
Quantitation on total peaks in the gasoline range from Toluene to C12.

Data Qualifiers

U	Compound not detected at the given detection limit.
X	Value detected above linear range of instrument. Dilution required.
J	Indicates an estimated value below the calculated detection limit.
S	No value reported due to saturation of the detector. Dilution required.
D	Indicates the surrogate was not detected because of dilution of the extract.
NR	Indicates no recovery due to matrix interference.

FORM-1 TPH-g

ANALYTICAL
RESOURCES
INCORPORATED

TOTAL GASOLINE RANGE HYDROCARBONS
WTPHg Range Toluene to C12 by GC/FID

Lab Sample ID: W219SB
LIMS ID: 98-9035
Matrix: Water

QC Report No: W219-Dames & Moore
Project: Holden Mine
17693-005-019

Data Release Authorized: CH
Reported: 05/12/98 5/12/98

LABORATORY CONTROL SAMPLE RECOVERY REPORT
Analyzed 05/11/98

CONSTITUENT	SPIKE FOUND	SPIKE ADDED	% RECOVERY
LABORATORY CONTROL SAMPLE			
Gasoline Range Hydrocarbons	2.85	2.5	114%

TPHg Surrogate Recovery

Trifluorotoluene	111%
Bromobenzene	NR

Values reported in parts per million (mg/L)

TPHg SPIKE CONTROL LIMITS

Percent Recovery	50-150%
Duplicate RPD	<50%

Advisory QA Limits

TOTAL DIESEL RANGE HYDROCARBONS
WA TPHd Range C12 to C24 by GC/FID
and Motor Oil

ANALYTICAL
RESOURCES
INCORPORATED

Lab ID: 98-9035
Matrix: Water

QC Report No: W219-Dames & Moore
Project: Holden Mine
17693-005-019
Date Received: 05/05/98

Data Release Authorized: C/A
5/14/98
Reported: 05/14/98

Lab ID	Sample ID	Date Extracted	Date Analyzed	Dilution Factor	Diesel Range	*HC ID	Motor Oil Range	Surr Rec
W219MB	Method Blank	05/08/98	05/12/98	1:1	0.25 U	---	0.50 U	99.0%
W219Q	RC-2	05/08/98	05/12/98	1:1	0.25 U	---	0.50 U	102%

Surrogate is Methyl-Arachidate.

* ID indicates, in the opinion of the analyst, the petroleum product with the best pattern match. 'NO' indicates that there was not a good match for any of the requested products.
Values reported in ppm (mg/L)
Diesel quantitation on total peaks in the range from C12 to C24.
Motor Oil quantitation on total peaks in the range from C24 to C38.

Data Qualifiers

U	Compound not detected at the given detection limit.
J	Indicates an estimated value below the calculated detection limit.
S	No value reported due to saturation of the detector. Dilution required.
D	Indicates the surrogate was not detected because of dilution of the extract.
E	Indicates a value above the linear range of the detector. Dilution required.
NR	Indicates no recovery due to matrix interference.
B	Indicates compound also detected in the method blank.

ANALYTICAL
RESOURCES
INCORPORATED

TOTAL DIESEL RANGE HYDROCARBONS
WA TPHd Range C12 to C24 by GC/FID

Lab Sample ID: W219SB
LIMS ID: 98-9035
Matrix: Water

QC Report No: W219-Dames & Moore
Project: Holden Mine
17693-005-019

Data Release Authorized: c/t
5/14/98
Reported: 05/14/98

LABORATORY CONTROL SAMPLE RECOVERY REPORT
Extracted: 05/08/98
Analyzed 05/12/98

CONSTITUENT	SPIKE FOUND	SPIKE ADDED	% RECOVERY
Diesel Range Hydrocarbons	2.25	2.50	90.0%

TPHd Surrogate Recovery

Methylarachidate	93.0%

Values reported in parts per million (mg/L)

Surface Water Samples

Page 1 of 1

CHAIN-OF-CUSTODY RECORD

WHITE COPY-Original (Accompanies Samples) YELLOW COPY-Collector PINK COPY-Project Manager

Boring or Well Number	Sample Number	Date Collected ~~Depth~~	Time	Sample Type	Container Type	Analysis Required Total Rec metals ~~VOA 601/8010~~	Diss metals ~~VOA 602/8020~~	TDS; TSS ~~VOA-624/8240/8260~~	Sulfate ~~Semi-Vol 625/8270~~	Alkalinity ~~NWTPH-Gx~~	Hardness ~~NWTPH-Dx~~	NWTPH-Dx-Ext	RCRA 8 Metals	PNA 610/8310	Pest/PCBs 8081	ASBESTOS	FIELD NOTES:	Total Number Of Containers	Laboratory Note Number
	HC-4	4-30-98	1245	H_2O		X	X	X	X	X	X						ARI cooler 1	4	
	HC-3	4-30-98	1325	H_2O		X	X	X	X	X	X						↓	4	
	HC-2	4-30-98	1425	H_2O		X	X	X	X	X	X							4	
	HC-1	5-1-98	1100	H_2O		X	X	X	X	X	X						ARI cooler 1	4	
	~~RC~~																		
	RC-11	5-1-98	1210	H_2O		X	X	X	X	X	X						ARI cooler 2	4	
	BIG-1	5-2-98	1050	H_2O		X	X	X	X	X	X						ARI cooler 2	4	
	CC-1	5-2-98	1420	H_2O		X	X	X	X	X	X						ARI cooler 3	4	
	CC-2	5/2/98	1450	H_2O		X	X	X	X	X	X						ARI cooler 4	4	
	RC-6	5/3/98	1020	H_2O		X	X	X	X	X	X						ARI cooler 5	4	
	RC-1	5/3/98	1050	H_2O		X	X	X	X	X	X						ARI cooler 5	4	
	RC-4	5/3/98	1130	H_2O		X	X	X	X	X	X						ARI cooler 6	54	
	RC-4X	5/3/98	1140	H_2O		X	X	X	X	X	X						ARI cooler 6	45	
	RC-7	5/3/98	1420	H_2O		X	X	X	X	X	X						ARI cooler 6	4	

RELINQUISHED BY: (Signature)	DATE/TIME	RECEIVED BY: (Signature)
	5/5/98 2150	

ANALYTICAL LABORATORY: ARI

LABORATORY CONTACT: Mark Harris

D&M CONTACT: Karen Mixon PHONE:

LABORATORY NOTES:

Cooler Temps -
#2 - 2.0 #1 - 3.0
4 - 2.0 8 - 3.0
5 - 1.0 7 - 1.0
3 - 1.0
1/8 - 3.0

98-9019 to
98-~~9035~~ 9052
W719

JOB NO.: 17693-005-019

PROJECT: Holden Mine

LOCATION: Holden, WA

~~COLLECTOR~~: ~~DATE OF COLLECTION~~:

DAMES & MOORE
A DAMES & MOORE GROUP COMPANY

500 Market Place Tower
2025 First Avenue
Seattle, Washington 98121
Phone (206) 728-0744
Fax (206) 727-3350

CHAIN-OF-CUSTODY RECORD

WHITE COPY-Original (Accompanies Samples) YELLOW COPY-Collector PINK COPY-Project Manager

Boring or Well Number	Sample Number	Date Collected ~~Depth~~	Time	Sample Type	Container Type	Analysis Required: Total Re. Metals ~~VOA 601/8010~~	Dissolved metals ~~VOA 602/8020~~	TDS/TSS ~~VOA 624/8240/8260~~	Sulfate ~~Semi Vol 625/8270~~	alkalinity ~~NWTPH-Gx~~	Hardness ~~NWTPH-Dx~~	WTPH-G ~~NWTPH-Dx Ext~~	WTPH-D (extended) ~~RCRA 8 Metals~~	PNA 610/8310	Pest/PCBs 8081	ASBESTOS	FIELD NOTES:	Total Number Of Containers	Laboratory Note Number
	RC-2	5/3/98	1535	H_2O		X	X	X	X	X	X	X	X				cooler 7	~~4~~9	
	RC-5	5/4/98	1310	H_2O		X	X	X	X	X	X						cooler #7	4	
	RC-10	5/4/98	1110	H_2O		X	X	X	X	X	X						cooler #7	4	
	RC-3	5/5/98	1140	H_2O		X	X	X	X	X	X						cooler #8	4	

RELINQUISHED BY: (Signature)	DATE/TIME	RECEIVED BY: (Signature)
	5/5/98 2130	
RELINQUISHED BY: (Signature)	DATE/TIME	RECEIVED BY: (Signature)
RELINQUISHED BY: (Signature)	DATE/TIME	RECEIVED BY: (Signature)

ANALYTICAL LABORATORY: ART

LABORATORY CONTACT: Mark Harris

D&M CONTACT: Karen Mixon PHONE: 728-0744 ext 253

LABORATORY NOTES:

JOB NO.: 17693-005-019

PROJECT: Holden Mine

LOCATION: Holden, WA

~~COLLECTOR:~~

~~DATE OF COLLECTION~~

DAMES & MOORE
DAMES & MOORE GROUP COMPANY

500 Market Place Tower
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Seattle, Washington 98121
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Equipment blanks

page 1 of 1

CHAIN-OF-CUSTODY RECORD

WHITE COPY-Original (Accompanies Samples) YELLOW COPY-Collector PINK COPY-Project Manager

Boring or Well Number	Sample Number	Date Collected ~~Depth~~	Time	Sample Type	Container Type	Analysis Required: Total Rec Metals ~~VOA 601/8010~~	VOA 602/8020	VOA 624/8240/8260	Semi Vol 625/8270	NWTPH-Gx	NWTPH-Dx	NWTPH-Dx-Ext	RCRA 8 Metals	PNA 610/8310	Pest/PCBs 8081	ASBESTOS	FIELD NOTES:	Total Number Of Containers	Laboratory Note Number
	EB050298	5/2/98	1640	H2O		X											cooler #4	1	
	EB050398	5/3/98	0730	H2O		X											cooler #6	1	
	~~E05~~																		
	EB050598	5/5/98	1030	H2O		X											cooler #8	1	
																	W221		
																	98-9058 –		
																	98-9060		

RELINQUISHED BY: (Signature)	DATE/TIME	RECEIVED BY: (Signature)
	5/5/98 2130	
RELINQUISHED BY: (Signature)	DATE/TIME	RECEIVED BY: (Signature)
RELINQUISHED BY: (Signature)	DATE/TIME	RECEIVED BY: (Signature)

ANALYTICAL LABORATORY: ARI

LABORATORY CONTACT: Mark Harris

D&M CONTACT: Karen Mixon PHONE: 206-728-0744

LABORATORY NOTES:

JOB NO.: 17693-005-019

PROJECT: Holden Mine

LOCATION: Holden, WA

~~COLLECTOR:~~ ~~DATE OF COLLECTION~~

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500 Market Place Tower
2025 First Avenue
Seattle, Washington 98121
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ANALYTICAL
RESOURCES
INCORPORATED

Final Report
Laboratory Analysis of Conventional Parameters

Sample No: RC-10

Lab Sample ID: W2190
LIMS ID: 98-9033
Matrix: Water

QC Report No: W219-Dames & Moore
Project: Holden Mine
17693-005-019
Date Sampled: 05/04/98
Date Received: 05/05/98

Data Release Authorized:
Reported: 05/27/98 Dr. M.A. Perkins

Analyte	Analysis Date & Batch	Method	RL	Units	Result
Alkalinity	05/14/98 051498#1	SM 2320	1.0	mg/L CaCO3	11
Total Dissolved Solids	05/07/98 050798#1	EPA 160.1	5.0	mg/L	25
Total Suspended Solids	05/07/98 050798#1	EPA 160.2	1.0	mg/L	3.8
Sulfate	05/14/98 051498#2	EPA 375.2	2.5	mg/L	5.5

RL Analytical reporting limit
U Undetected at reported detection limit

Report for W219 received 05/05/98

ANALYTICAL
RESOURCES
INCORPORATED

Final Report
Laboratory Analysis of Conventional Parameters

Sample No: RC-3

Lab Sample ID: W219P
LIMS ID: 98-9034
Matrix: Water

Data Release Authorized:
Reported: 05/27/98 Dr. M.A. Perkins

QC Report No: W219-Dames & Moore
Project: Holden Mine
17693-005-019
Date Sampled: 05/05/98
Date Received: 05/05/98

Analyte	Analysis Date & Batch	Method	RL	Units	Result
Alkalinity	05/14/98 051498#1	SM 2320	1.0	mg/L CaCO3	12
Total Dissolved Solids	05/07/98 050798#1	EPA 160.1	5.0	mg/L	29
Total Suspended Solids	05/07/98 050798#1	EPA 160.2	1.0	mg/L	4.3
Sulfate	05/14/98 051498#2	EPA 375.2	2.5	mg/L	5.3

RL	Analytical reporting limit
U	Undetected at reported detection limit

Report for W219 received 05/05/98

ANALYTICAL
RESOURCES
INCORPORATED

Final Report
Laboratory Analysis of Conventional Parameters

Sample No: RC-2

Lab Sample ID: W219Q
LIMS ID: 98-9035
Matrix: Water

Data Release Authorized:
Reported: 05/27/98 Dr. M.A. Perkins

QC Report No: W219-Dames & Moore
Project: Holden Mine
17693-005-019
Date Sampled: 05/03/98
Date Received: 05/05/98

Analyte	Analysis Date & Batch	Method	RL	Units	Result
Alkalinity	05/14/98 051498#1	SM 2320	1.0	mg/L CaCO3	8.4
Total Dissolved Solids	05/07/98 050798#1	EPA 160.1	5.0	mg/L	23
Total Suspended Solids	05/07/98 050798#1	EPA 160.2	1.0	mg/L	3.1
Sulfate	05/14/98 051498#2	EPA 375.2	2.5	mg/L	6.2

RL	Analytical reporting limit
U	Undetected at reported detection limit

Report for W219 received 05/05/98

ANALYTICAL
RESOURCES
INCORPORATED

QA Report - Method Blank Analysis

QC Report No: W219-Dames & Moore
Project: Holden Mine
17693-005-019
Date Received: NA

Matrix: Water

Data Release Authorized:
Reported: 05/27/98 Dr. M.A. Perkins

METHOD BLANK RESULTS
CONVENTIONALS

Analysis Date & Batch	Constituent	Units	Result		
05/07/98 050798#1	Total Dissolved Solids	mg/L	<	10	U
05/07/98 050798#1	Total Suspended Solids	mg/L	<	1.0	U
05/13/98 051398#1	Sulfate	mg/L	<	2.5	U
05/14/98 051498#2	Sulfate	mg/L	<	2.5	U

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ANALYTICAL
RESOURCES
INCORPORATED

QA Report - Replicate Analysis

QC Report No: W219-Dames & Moore
Project: Holden Mine
17693-005-019
Date Received: 05/05/98

Matrix: Water

Data Release Authorized:
Reported: 05/27/98 Dr. M.A. Perkins

DUPLICATE ANALYSIS RESULTS
CONVENTIONALS

Constituent	Units	Sample Value	Duplicate Value	RPD
ARI ID: 98-9019, W219 A	**Client Sample ID: HC-4**			
Alkalinity	mg/L CaCO3	11	10	9.5%
Total Dissolved Solids	mg/L	11	12	8.7%
Total Suspended Solids	mg/L	< 2.2 U	< 2.2 U	NA
ARI ID: 98-9033, W219 O	**Client Sample ID: RC-10**			
Sulfate	mg/L	5.5	6.7	19.7%

ANALYTICAL
RESOURCES
INCORPORATED

QA Report - Matrix Spike/Matrix Spike Duplicate Analysis

QC Report No: W219-Dames & Moore
Matrix: Water
Project: Holden Mine
17693-005-019
Date Received: 05/05/98

Data Release Authorized:
Reported: 05/27/98 Dr. M.A. Perkins

MATRIX SPIKE QA/QC REPORT
CONVENTIONALS

Constituent	Units	Sample Value	Spike Value	Spike Added	Recovery
ARI ID: 98-9033, W219 O Client Sample ID: RC-10					
Sulfate	mg/L	5.5	25.7	20.0	101%

MS/MSD Recovery Limits: 75 - 125 %

QA Report - Laboratory Control Samples

QC Report No: W219-Dames & Moore
Project: Holden Mine
17693-005-019
Date Received: NA

Data Release Authorized:
Reported: 05/27/98 Dr. M.A. Perkins

LABORATORY CONTROL SAMPLES
CONVENTIONALS

Constituent	Units	Measured Value	True Value	Recovery
Laboratory Control Sample				
Alkalinity	mg/L CaCO3	121	118	103%

Date analyzed: 05/14/98 Batch ID: 051498#1

ANALYTICAL
RESOURCES
INCORPORATED

QA Report - Standard Reference Material Analysis

QC Report No: W219-Dames & Moore
Project: Holden Mine
17693-005-019
Date Received: NA

Data Release Authorized:
Reported: 05/27/98 Dr. M.A. Perkins

STANDARD REFERENCE MATERIAL ANALYSIS
CONVENTIONALS

Constituent	Units	Value	True Value	Recovery
SPEX#13-22AS				
Sulfate	mg/L	24.8	25.0	99.2%
Date analyzed: 05/13/98 Batch ID: 051398#1				
SPEX#13-22AS				
Sulfate	mg/L	25.7	25.0	103%
Date analyzed: 05/14/98 Batch ID: 051498#2				

ANALYTICAL
RESOURCES
INCORPORATED

TOTAL GASOLINE RANGE HYDROCARBONS
WTPHg Range Toluene to C12 by GC/FID

QC Report No: W219-Dames & Moore
Project: Holden Mine
17693-005-019
Date Received: 05/05/98

Matrix: Water

Data Release Authorized:
Reported: 05/12/98 5/12/98

Lab ID	Client Sample ID	Date Analyzed	Dilution Factor	Gas Range	Gas ID	Surr A Rec	Surr B Rec
W219-0511MB	Method Blank	05/11/98	1:1	0.25 U	NO	99.3%	95.1%
98-9035-W219Q	RC-2	05/11/98	1:1	0.25 U	NO	98.1%	101%

Surrogate A is Trifluorotoluene.
Surrogate B is Bromobenzene.
Values reported in ppm (mg/L).
Quantitation on total peaks in the gasoline range from Toluene to C12.

Data Qualifiers

U	Compound not detected at the given detection limit.
X	Value detected above linear range of instrument. Dilution required.
J	Indicates an estimated value below the calculated detection limit.
S	No value reported due to saturation of the detector. Dilution required.
D	Indicates the surrogate was not detected because of dilution of the extract.
NR	Indicates no recovery due to matrix interference.

FORM-1 TPH-g

ANALYTICAL
RESOURCES
INCORPORATED

TOTAL GASOLINE RANGE HYDROCARBONS
WTPHg Range Toluene to C12 by GC/FID

Lab Sample ID: W219SB
LIMS ID: 98-9035
Matrix: Water

QC Report No: W219-Dames & Moore
Project: Holden Mine
17693-005-019

Data Release Authorized: cu
Reported: 05/12/98 5/12/98

LABORATORY CONTROL SAMPLE RECOVERY REPORT
Analyzed 05/11/98

CONSTITUENT	SPIKE FOUND	SPIKE ADDED	% RECOVERY
LABORATORY CONTROL SAMPLE			
Gasoline Range Hydrocarbons	2.85	2.5	114%

TPHg Surrogate Recovery

Trifluorotoluene	111%
Bromobenzene	NR

Values reported in parts per million (mg/L)

TPHg SPIKE CONTROL LIMITS

Percent Recovery	50-150%
Duplicate RPD	<50%

Advisory QA Limits

TOTAL DIESEL RANGE HYDROCARBONS
WA TPHd Range C12 to C24 by GC/FID and Motor Oil

ANALYTICAL RESOURCES INCORPORATED

Lab ID: 98-9035
Matrix: Water

QC Report No: W219-Dames & Moore
Project: Holden Mine
17693-005-019
Date Received: 05/05/98

Data Release Authorized: c/4
5/17/98
Reported: 05/14/98

Lab ID	Sample ID	Date Extracted	Date Analyzed	Dilution Factor	Diesel Range	*HC ID	Motor Oil Range	Surr Rec
W219MB	Method Blank	05/08/98	05/12/98	1:1	0.25 U	---	0.50 U	99.0%
W219Q	RC-2	05/08/98	05/12/98	1:1	0.25 U	---	0.50 U	102%

Surrogate is Methyl-Arachidate.

* ID indicates, in the opinion of the analyst, the petroleum product with the best pattern match. 'NO' indicates that there was not a good match for any of the requested products.
Values reported in ppm (mg/L)
Diesel quantitation on total peaks in the range from C12 to C24.
Motor Oil quantitation on total peaks in the range from C24 to C38.

Data Qualifiers

U	Compound not detected at the given detection limit.
J	Indicates an estimated value below the calculated detection limit.
S	No value reported due to saturation of the detector. Dilution required.
D	Indicates the surrogate was not detected because of dilution of the extract.
E	Indicates a value above the linear range of the detector. Dilution required.
NR	Indicates no recovery due to matrix interference.
B	Indicates compound also detected in the method blank.

FORM-1 WA TPHD

ANALYTICAL
RESOURCES
INCORPORATED

TOTAL DIESEL RANGE HYDROCARBONS
WA TPHd Range C12 to C24 by GC/FID

Lab Sample ID: W219SB
LIMS ID: 98-9035
Matrix: Water

QC Report No: W219-Dames & Moore
Project: Holden Mine
17693-005-019

Data Release Authorized: 5/14/98
Reported: 05/14/98

LABORATORY CONTROL SAMPLE RECOVERY REPORT
Extracted: 05/08/98
Analyzed 05/12/98

CONSTITUENT	**SPIKE FOUND**	**SPIKE ADDED**	**% RECOVERY**
Diesel Range Hydrocarbons	2.25	2.50	90.0%

<u>TPHd Surrogate Recovery</u>

Methylarachidate	93.0%

Values reported in parts per million (mg/L)

Surface Water Samples

Page 1 of 2

CHAIN-OF-CUSTODY RECORD

WHITE COPY-Original (Accompanies Samples) YELLOW COPY-Collector PINK COPY-Project Manager

Boring or Well Number	Sample Number	Date Collected ~~Depth~~	Time	Sample Type	Container Type	Analysis Required: Total Rec metals ~~VOA 601/8010~~	Diss metals ~~VOA 602/8020~~	TDS; TSS ~~VOA-624/8240/8260~~	Sulfate Semi-Vol 625/8270	Alkalinity ~~NWTPH-Gx~~	Hardness ~~NWTPH-Dx~~	NWTPH-Dx-Ext	RCRA 8 Metals	PNA 610/8310	Pest/PCBs 8081	ASBESTOS	FIELD NOTES:	Total Number Of Containers	Laboratory Note Number
	HC-4	4-30-98	1245	H_2O		X	X	X	X	X	X						ARI cooler 1	4	
	HC-3	4-30-98	1325	H_2O		X	X	X	X	X	X							4	
	HC-2	4-30-98	1425	H_2O		X	X	X	X	X	X						↓	4	
	HC-1	5-1-98	1100	H_2O		X	X	X	X	X	X						ARI cooler 1	4	
	~~RC~~																		
	RC-11	5-1-98	1210	H_2O		X	X	X	X	X	X						ARI cooler 2	4	
	BIG-1	5-2-98	1050	H_2O		X	X	X	X	X	X						ARI cooler 2	4	
	CC-1	5-2-98	1420	H_2O		X	X	X	X	X	X						ARI cooler 3	4	
	CC-2	5/2/98	1450	H_2O		X	X	X	X	X	X						ARI cooler 4	4	
	RC-6	5/3/98	1020	H_2O		X	X	X	X	X	X						ARI cooler 5	4	
	RC-1	5/3/98	1050	H_2O		X	X	X	X	X	X						ARI cooler 5	4	
	RC-4	5/3/98	1130	H_2O		X	X	X	X	X	X						ARI cooler 6	~~5~~4	
	RC-4X	5/3/98	1140	H_2O		X	X	X	X	X	X						ARI cooler 6	~~4~~5	
	RC-7	5/3/98	1420	H_2O		X	X	X	X	X	X						ARI cooler 6	4	

RELINQUISHED BY: (Signature) Karen Mixon DATE/TIME 5/5/98 2150 RECEIVED BY: (Signature)

RELINQUISHED BY: (Signature) DATE/TIME RECEIVED BY: (Signature)

RELINQUISHED BY: (Signature) DATE/TIME RECEIVED BY: (Signature)

ANALYTICAL LABORATORY: ARI

LABORATORY CONTACT: Mark Harris

D&M CONTACT: Karen Mixon PHONE:

LABORATORY NOTES:

Cooler Temps -

#2 - 2.0 #1 - 3.0

4 - 2.0 8 - 3.0

5 - 1.0 7 - 1.0

3 - 1.0

1/8 - 3.0

98-9019 to

98-~~9035~~ 9052

W719

JOB NO.: 17693-005-019

PROJECT: Holden mine

LOCATION: Holden, WA

~~COLLECTOR:~~

~~DATE OF COLLECTION:~~

DAMES & MOORE

A DAMES & MOORE GROUP COMPANY

500 Market Place Tower
2025 First Avenue
Seattle, Washington 98121
Phone (206) 728-0744
Fax (206) 727-3350

CHAIN-OF-CUSTODY RECORD

WHITE COPY-Original (Accompanies Samples) YELLOW COPY-Collector PINK COPY-Project Manager

Boring or Well Number	Sample Number	Date Collected ~~Depth~~	Time	Sample Type	Container Type	Analysis Required Total Re. Metals ~~VOA 601/8010~~	Dissolved metals ~~VOA 602/8020~~	TDS/TSS ~~VOA 624/8240/8260~~	Sulfate ~~Semi Vol 625/8270~~	alkalinity ~~NWTPH-Gx~~	Hardness ~~NWTPH-Dx~~	WTPH-G ~~NWTPH-Dx-Ext~~	WTPH-D (extend) ~~RCRA 8 Metals~~	PNA 610/8310	Pest/PCBs 8081	ASBESTOS	FIELD NOTES:	Total Number Of Containers	Laboratory Note Number
	RC-2	5/3/98	1535	H2O		X	X	X	X	X	X	X	X				cooler 7	~~4~~ 9	
	RC-5	5/4/98	1310	H2O		X	X	X	X	X	X						cooler #7	4	
	RC-10	5/4/98	1110	H2O		X	X	X	X	X	X						cooler #7	4	
	RC-3	5/5/98	1140	H2O		X	X	X	X	X	X						cooler #8	4	

RELINQUISHED BY: (Signature)	DATE/TIME	RECEIVED BY: (Signature)
	5/5/98 2130	
RELINQUISHED BY: (Signature)	DATE/TIME	RECEIVED BY: (Signature)
RELINQUISHED BY: (Signature)	DATE/TIME	RECEIVED BY: (Signature)

LABORATORY NOTES:

ANALYTICAL LABORATORY: ART

LABORATORY CONTACT: Mark Harris

D&M CONTACT: Karen Mixon PHONE: 728-0744 ext 253

JOB NO.: 17693-005-019

PROJECT: Holden Mine

LOCATION: Holden, WA

~~COLLECTOR:~~ ~~DATE OF COLLECTION~~ /

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Equipment Blanks

page 1 of 1

CHAIN-OF-CUSTODY RECORD

WHITE COPY-Original (Accompanies Samples) YELLOW COPY-Collector PINK COPY-Project Manager

Boring or Well Number	Sample Number	Date Collected ~~Depth~~	Time	Sample Type	Container Type	Analysis Required: Total Re-Metals ~~VOA 601/8010~~	VOA 602/8020	VOA 624/8240/8260	Semi Vol 625/8270	NWTPH-Gx	NWTPH-Dx	NWTPH-Dx-Ext	RCRA 8 Metals	PNA 610/8310	Pest/PCBs 8081	ASBESTOS	FIELD NOTES:	Total Number Of Containers	Laboratory Note Number
	EB050298	5/2/98	1640	H_2O		X											cooler #4	1	
	EB050398	5/3/98	0730	H_2O		X											cooler #6	1	
	~~E005~~																		
	EB050598	5/5/98	1030	H_2O		X											cooler #8	1	
																	W221		
																	98-9058 —		
																	98-9060		

RELINQUISHED BY: (Signature)	DATE/TIME	RECEIVED BY: (Signature)
	5/5/98 2130	
RELINQUISHED BY: (Signature)	DATE/TIME	RECEIVED BY: (Signature)
RELINQUISHED BY: (Signature)	DATE/TIME	RECEIVED BY: (Signature)

ANALYTICAL LABORATORY: ARI

LABORATORY CONTACT: Mark Harris

D&M CONTACT: Karen Mason PHONE: 206-728-0744

LABORATORY NOTES:

JOB NO.: 17693-005-019

PROJECT: Holden Mine

LOCATION: Holden, WA

~~COLLECTOR:~~ ~~DATE OF COLLECTION~~

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MEMORANDUM

Date: June 8, 1998

To: Rik Langendoen, Project Manager

From: Karen Mixon, Project Chemist KM

Subject: Data Quality Review
Holden Mine Remedial Investigation Phase III
Seep and Portal Data, May 1998
Dames & Moore Job #17693-005-019

The data quality review of 7 seep samples, 2 portal drainage samples, and one ventilator portal sample collected from May 1 to May 7, 1998 has been completed. The samples were analyzed at the Analytical Resources, Incorporated (ARI) laboratory in Seattle, Washington for total recoverable and dissolved metals by EPA Methods 6010A, 7000 series, and 200.8 modified (including the following metals: aluminum, arsenic, barium, beryllium, cadmium, calcium, chromium, copper, iron, lead, magnesium, manganese, molybdenum, nickel, potassium, silver, sodium, and zinc) and hardness by EPA Method 6010A calculation. In addition, samples were also analyzed for the following: alkalinity by Standard Method 2320, total dissolved solids (TDS) by EPA Method 160.1, total suspended solids (TSS) by EPA Method 160.2, and sulfate by EPA Method 375.2. The analyses were performed in accordance with the methods specified in EPA Test Methods for Evaluating Solid Waste, SW-846, January 1995, EPA Methods for Chemical Analysis of Water and Wastes, March 1983, and Standard Methods for the Examination of Water and Wastewater, 18th edition, 1992. A validation package containing method associated QA/QC data and summarized sample data was provided by the laboratory. The following samples are associated with laboratory work orders ARI# W222 and W264:

Sample I.D.	ARI Sample #	Analyses Requested
P-1	W222A/W222J	Dissolved/Total Metals, alkalinity, TDS/TSS, sulfate
P-5	W222B/W222K	Dissolved/Total Metals, alkalinity, TDS/TSS, sulfate
VP-1	W222C/W222A (LIMS 98-9623) W222C (LIMS 98-9625)	Dissolved/Total Metals, alkalinity, TDS/TSS, sulfate
SP-23	W222D	Dissolved Metals, alkalinity, TDS/TSS, sulfate
SP-2	W222E	Dissolved Metals, alkalinity, TDS/TSS, sulfate
SP-2X	W222F	Dissolved Metals, alkalinity, TDS/TSS, sulfate
SP-1	W222G	Dissolved Metals, alkalinity, TDS/TSS, sulfate

Sample I.D.	ARI Sample #	Analyses Requested
CC-D1	W222H/W222B (LIMS 98-9624)	Dissolved Metals, alkalinity, TDS/TSS, sulfate
SP-4	W222I	Dissolved Metals, alkalinity, TDS/TSS, sulfate
SP-27	W264A	Dissolved Metals, alkalinity, TDS/TSS, sulfate

The following comments refer to ARI's performance in meeting quality control specifications described in the EPA documents "EPA Test Methods for Evaluating Solid Waste, SW-846", January 1995, "Methods for Chemical Analysis of Water and Wastes", March 1983, and "USEPA Contract Laboratory Program (CLP) National Functional Guidelines for Inorganic Data Review", February 1994, and Standard Methods for the Examination of Water and Wastewater, 18th Edition, 1992, and the Quality Assurance Project Plan (QAPP) prepared for the Phase III Remedial Investigation dated April 17, 1998.

The report is divided into subsections based on type of analyses performed.

Total Recoverable and Dissolved Metals

Sample aliquots for dissolved metals were filtered and preserved in the field. Sample aliquots for total recoverable metals were transferred to preserved containers in the field.

Samples were prepared in the laboratory using EPA Method 3005A, EPA 7000 series methods, and a modified EPA 200.8 preparation method. Samples were analyzed by ICP (EPA Method 6010A), GFAA (EPA Methods 7060, 7131, 7421, 7761), and ICP MS (EPA Method 200.8 Modified).

1. Holding Time - Acceptable
2. Tunes (ICP MS analysis only) - Acceptable
3. Initial Calibration - Acceptable
4. Continuing Calibration - Acceptable
5. Blanks

Lead (-1.0 ug/L) was detected in the continuing calibration blank (CCB) and ending CCB (-1.3 ug/L) analyzed on May 24, 1998. Samples analyzed and associated with these CCBs include P-1 (dissolved), P-5 (dissolved), SP-23, and P-5 (total). As lead in all of these samples was not detected or exceeded the concentration detected in the CCB, the impact of the CCB is considered minimal. Data were not qualified.

Aluminum (30 ug/L) was detected in the method blank associated with the analysis of samples P-5 (dissolved), SP-23, SP-2, SP-2X, SP-4, SP-1, and SP-27. Sample results for all samples were greater than 10X the method blank concentration with the exception of SP-27. The result for SP-27 is less than 5X the method blank concentration and is qualified as not detected and flagged "U" accordingly.

Cadmium (0.3 ug/L) was detected in the method blank associated with P-1 (total) and P-5 (total). As the concentration detected in the blank was at or near the detection limit, sample results in associated samples that are less than 5X the concentration in the blank are qualified as not detected and flagged "U" accordingly. Results between 5X and 10X the concentration detected in the method blank are qualified as estimated and flagged "J" accordingly. Results reported as not detected or greater than 10X the concentration detected in the method blank do not require qualification.

Aluminum (20 ug/L) and lead (0.3 ug/L) were detected in the method blank associated with the analysis of samples VP-1 (total and dissolved) and CC-D1. As the concentrations detected were at or near the detection limit, sample results in associated samples that are less than 5X the concentration in the blank are qualified as not detected and flagged "U" accordingly. Results between 5X and 10X the concentrations detected in the method blank are qualified as estimated and flagged "J" accordingly. Results reported as not detected or greater than 10X the concentration detected in the method blank do not require qualification.

6. Internal Standards (ICP MS analysis only) - Acceptable

7. ICP Interference Check (ICP analysis only) - Acceptable

8. Laboratory Control Sample - Acceptable

9. Laboratory Duplicate Sample - Acceptable

10. Field Duplicate - Acceptable

    Sample SP-2X is the field duplicate of SP-2.

11. Matrix Spike – Acceptable

12. Graphite Furnace Atomic Absorption (GFAA) QC – Acceptable

13. ICP Serial Dilution (ICP analysis only) – Acceptable

14. Detection Limits

    The detection limits for beryllium, chromium, and molybdenum were 2X the QAPP limits for samples SP-1, SP-2, and SP-2X due to necessary sample dilutions related to other analytes. The detection limit for lead was also raised 5X due to sample dilution. The detection limit for arsenic was raised 5X for samples SP-2 and SP-2X. The detection limit for nickel was raised 2X for sample SP-1. These metals were not considered compounds of concern at the Site; data usability was not affected.

15. Type of Review

    A summary review was performed on ICP and ICP MS data. A standard review was performed on the GFAA data.

16. Overall Assessment of Data

The usefulness of the data is based on EPA guidance documents listed above. Upon consideration of the information presented above, the data are acceptable except where flagged with data qualifiers that modify the usefulness of the individual values.

Conventional Analyses

Samples were analyzed for total dissolved solids (TDS), total suspended solids (TSS), alkalinity, and sulfate by EPA or other methods identified in the introduction of this report. In addition, hardness was determined by calculation from dissolved metals analysis and reviewed for correctness.

1. Hold Time - Acceptable

2. Initial Calibration - Acceptable

   Applicable for alkalinity and sulfate.

3. Continuing Calibration - Acceptable

   Applicable for alkalinity and sulfate.

4. Blanks - Acceptable

5. Laboratory Control Sample - Acceptable

   Applicable for alkalinity. A standard reference material (SRM) was used to evaluate sulfate. Results were acceptable.

6. Laboratory Sample Duplicate - Acceptable

7. Field Duplicate - Acceptable

   Sample SP-2X is the field duplicate of sample SP-2.

8. Matrix Spike (MS) - Acceptable

   Applicable for sulfate.

9. Detection Limits - Acceptable

   The detection limit reported for sample HC-4 was 2.2 mg/L which is above the QAPP requirement of 1.0 mg/L. The increased detection limit was due to the use of reduced sample volume as this sample was used for the laboratory duplicate analysis.

10. Type of Review - Summary

11. Overall Assessment of Data

The usefulness of the data is based on the EPA guidance documents listed above. Upon consideration of the information presented above, data are considered acceptable except where flagged with data qualifiers that modify the usefulness of the individual values.

Data Qualifiers

U	The analyte was analyzed for, but was not detected above the reported sample quantitation limit.
J	The analyte was positively identified; the associated numerical value is the approximate concentration of the analyte in the sample.
UJ	The analyte was not detected above the reported sample quantitation limit. However, the reported quantitation limit is approximate and may or may not represent the actual limit of quantitation necessary to accurately and precisely measure the analyte in the sample.
R	The sample results are rejected due to serious deficiencies in the ability to analyze the sample and meet quality control criteria. The presence or absence of the analyte cannot be verified.

ANALYTICAL
RESOURCES
INCORPORATED

INORGANICS ANALYSIS DATA SHEET
DISSOLVED METALS

Sample No: P-1

Lab Sample ID: W222A
LIMS ID: 98-9063
Matrix: Water

QC Report No: W222-Dames & Moore
Project: Holden Mine
17693-005-019
Date Sampled: 05/01/98
Date Received: 05/05/98

Data Release Authorized:
Reported: 05/28/98

Prep Meth	Prep Date	Analysis Method	Analysis Date	CAS Number	Analyte	RL	ug/L
3005	05/26/98	6010	05/27/98	7429-90-5	Aluminum	20	21,100
7060	05/23/98	7060	05/26/98	7440-38-2	Arsenic	1	1 U
3005	05/26/98	6010	05/27/98	7440-39-3	Barium	1	12
3005	05/26/98	6010	05/27/98	7440-41-7	Beryllium	1	1 U
3020	05/23/98	7131	05/24/98	7440-43-9	Cadmium	20	160
3005	05/26/98	6010	05/27/98	7440-70-2	Calcium	20	57,300
3005	05/26/98	6010	05/27/98	7440-47-3	Chromium	5	5 U
3005	05/26/98	6010	05/27/98	7440-50-8	Copper	2	10,300
3005	05/26/98	6010	05/27/98	7439-89-6	Iron	20	430
3020	05/23/98	7421	05/24/98	7439-92-1	Lead	5	58
3005	05/26/98	6010	05/27/98	7439-95-4	Magnesium	20	14,600
3005	05/26/98	6010	05/27/98	7439-96-5	Manganese	1	695
3005	05/26/98	6010	05/27/98	7439-98-7	Molybdenum	5	5 U
3005	05/26/98	6010	05/27/98	7440-02-0	Nickel	10	10 U
3005	05/26/98	6010	05/27/98	7440-09-7	Potassium	500	3,430
3020	05/23/98	7761	05/26/98	7440-22-4	Silver	0.2	0.2 U
3005	05/26/98	6010	05/27/98	7440-23-5	Sodium	50	6,340
3005	05/26/98	6010	05/27/98	7440-66-6	Zinc	4	27,500

Calculated Dissolved Hardness (mg-CaCO3/L): 200

U Analyte undetected at given RL

RL Reporting Limit

FORM-I

ANALYTICAL RESOURCES INCORPORATED

INORGANICS ANALYSIS DATA SHEET
DISSOLVED METALS

Sample No: P-1
Lab Sample ID: W222A
QC Report No: W222-Dames & Moore
LIMS ID: 98-9063
Project: Holden Mine
17693-005-019
Matrix: Water
Date Received: 05/05/98

Data Release Authorized
Reported: 05/28/98

MATRIX SPIKE QUALITY CONTROL REPORT

Analyte	Sample ug/L		Spike ug/L	Spike Added	% Recovery	Q
Aluminum	21100		23100	2000	100%	H
Arsenic	1	U	41	40	102%	
Barium	12		1990	2000	98.9%	
Beryllium	1	U	50	50	100%	
Cadmium	161		167	5	120%	H
Calcium	57300		67400	10000	101%	H
Chromium	5	U	205	200	102%	
Copper	10300		20600	10000	103%	
Iron	426		1440	1000	101%	
Lead	58		78	20	100%	
Magnesium	14600		24900	10000	103%	
Manganese	695		1200	500	101%	
Molybdenum	5	U	258	250	103%	
Nickel	10	U	520	500	104%	
Potassium	3430		13800	10000	104%	
Silver	0.2	U	20.8	20.0	104%	
Sodium	6340		16500	10000	102%	
Zinc	27500		37000	10000	95.0%	

'Q' codes:
N = control limit not met
H = %R not applicable, sample concentration too high
* = RPD control limit not met
NA = Not applicable - analyte not spiked

Control Limits:
Percent Recovery: 75-125%
RPD: +/-20%

FORM-V

INORGANICS ANALYSIS DATA SHEET
DISSOLVED METALS

Sample No: P-5

Lab Sample ID: W222B
LIMS ID: 98-9064
Matrix: Water

QC Report No: W222-Dames & Moore
Project: Holden Mine
17693-005-019
Date Sampled: 05/01/98
Date Received: 05/05/98

Data Release Authorized:
Reported: 05/28/98

Prep Meth.	Prep Date	Analysis Method	Analysis Date	CAS Number	Analyte	RL	ug/L
3005	05/23/98	6010	05/24/98	7429-90-5	Aluminum	20	8,960
7060	05/23/98	7060	05/26/98	7440-38-2	Arsenic	1	1 U
3005	05/23/98	6010	05/24/98	7440-39-3	Barium	1	17
3005	05/23/98	6010	05/24/98	7440-41-7	Beryllium	1	1 U
3020	05/23/98	7131	05/24/98	7440-43-9	Cadmium	10	70
3005	05/23/98	6010	05/24/98	7440-70-2	Calcium	20	28,300
3005	05/23/98	6010	05/24/98	7440-47-3	Chromium	5	5 U
3005	05/23/98	6010	05/24/98	7440-50-8	Copper	2	4,790
3005	05/23/98	6010	05/24/98	7439-89-6	Iron	20	150
3020	05/23/98	7421	05/24/98	7439-92-1	Lead	2	22
3005	05/23/98	6010	05/24/98	7439-95-4	Magnesium	20	6,650
3005	05/23/98	6010	05/24/98	7439-96-5	Manganese	1	314
3005	05/23/98	6010	05/24/98	7439-98-7	Molybdenum	5	5 U
3005	05/23/98	6010	05/24/98	7440-02-0	Nickel	10	10 U
3005	05/23/98	6010	05/24/98	7440-09-7	Potassium	500	1,880
3020	05/23/98	7761	05/26/98	7440-22-4	Silver	0.2	0.2 U
3005	05/23/98	6010	05/24/98	7440-23-5	Sodium	50	3,290
3005	05/23/98	6010	05/24/98	7440-66-6	Zinc	4	12,700

Calculated Dissolved Hardness (mg-CaCO3/L): 98

U Analyte undetected at given RL

RL Reporting Limit

ANALYTICAL RESOURCES INCORPORATED

INORGANICS ANALYSIS DATA SHEET
DISSOLVED METALS

Sample No: P-5
QC Report No: W222-Dames & Moore
Project: Holden Mine
17693-005-019
Date Received: 05/05/98

Lab Sample ID: W222B
LIMS ID: 98-9064
Matrix: Water

Data Release Authorized
Reported: 05/28/98

MATRIX DUPLICATE QUALITY CONTROL REPORT

Analyte	Sample ug/L	Duplicate ug/L	RPD	Control Limit	Q
Aluminum	8960	8850	1.2%	+/- 20 %	
Arsenic	1 U	1 U	0.0%	+/- 1	L
Barium	17	15	12.5%	+/- 20 %	
Beryllium	1 U	1 U	0.0%	+/- 1	L
Cadmium	70	70	0.0%	+/- 20 %	
Calcium	28300	28000	1.1%	+/- 20 %	
Chromium	5 U	5 U	0.0%	+/- 5	L
Copper	4790	4730	1.3%	+/- 20 %	
Iron	150	160	6.5%	+/- 20 %	
Lead	22	22	0.0%	+/- 20 %	
Magnesium	6650	6590	0.9%	+/- 20 %	
Manganese	314	311	1.0%	+/- 20 %	
Molybdenum	5 U	5 U	0.0%	+/- 5	L
Nickel	10 U	10 U	0.0%	+/- 10	L
Potassium	1880	2100	11.1%	+/- 500	L
Silver	0.2 U	0.2 U	0.0%	+/- 0.2	L
Sodium	3290	3260	0.9%	+/- 20 %	
Zinc	12700	12500	1.6%	+/- 20 %	

'Q' codes:
* = control limit not met
L = RPD not valid, alternate limit = detection limit

FORM-VI

**ANALYTICAL
RESOURCES
INCORPORATED**

INORGANICS ANALYSIS DATA SHEET
DISSOLVED METALS

Sample No: SP-23

Lab Sample ID: W222D
LIMS ID: 98-9066
Matrix: Water

QC Report No: W222-Dames & Moore
Project: Holden Mine
17693-005-019
Date Sampled: 05/02/98
Date Received: 05/05/98

Data Release Authorized:
Reported: 05/28/98

Prep Meth	Prep Date	Analysis Method	Analysis Date	CAS Number	Analyte	RL	ug/L	
3005	05/23/98	6010	05/24/98	7429-90-5	Aluminum	20	5,620	
7060	05/23/98	7060	05/26/98	7440-38-2	Arsenic	1	1	U
3005	05/23/98	6010	05/24/98	7440-39-3	Barium	1	22	
3005	05/23/98	6010	05/24/98	7440-41-7	Beryllium	1	1	U
3020	05/23/98	7131	05/24/98	7440-43-9	Cadmium	4	34	
3005	05/23/98	6010	05/24/98	7440-70-2	Calcium	20	15,500	
3005	05/23/98	6010	05/24/98	7440-47-3	Chromium	5	5	U
3005	05/23/98	6010	05/24/98	7440-50-8	Copper	2	5,340	
3005	05/23/98	6010	05/24/98	7439-89-6	Iron	20	20	U
3020	05/23/98	7421	05/24/98	7439-92-1	Lead	1	1	U
3005	05/23/98	6010	05/24/98	7439-95-4	Magnesium	20	3,620	
3005	05/23/98	6010	05/24/98	7439-96-5	Manganese	1	199	
3005	05/23/98	6010	05/24/98	7439-98-7	Molybdenum	5	5	U
3005	05/23/98	6010	05/24/98	7440-02-0	Nickel	10	20	
3005	05/23/98	6010	05/24/98	7440-09-7	Potassium	500	1,110	
3020	05/23/98	7761	05/26/98	7440-22-4	Silver	0.2	0.2	U
3005	05/23/98	6010	05/24/98	7440-23-5	Sodium	50	1,430	
3005	05/23/98	6010	05/24/98	7440-66-6	Zinc	4	4,110	

Calculated Dissolved Hardness (mg-CaCO3/L): 54

U Analyte undetected at given RL

RL Reporting Limit

FORM-I

INORGANICS ANALYSIS DATA SHEET
DISSOLVED METALS

Sample No: SP-2

Lab Sample ID: W222E
LIMS ID: 98-9067
Matrix: Water

QC Report No: W222-Dames & Moore
Project: Holden Mine
17693-005-019
Date Sampled: 05/02/98
Date Received: 05/05/98

Data Release Authorized:
Reported: 05/28/98

Prep Meth	Prep Date	Analysis Method	Analysis Date	CAS Number	Analyte	RL	ug/L	
3005	05/23/98	6010	05/24/98	7429-90-5	Aluminum	40	100,000	
7060	05/23/98	7060	05/24/98	7440-38-2	Arsenic	5	5	U
3005	05/23/98	6010	05/24/98	7440-39-3	Barium	2	2	
3005	05/23/98	6010	05/24/98	7440-41-7	Beryllium	2	2	U
3020	05/23/98	7131	05/24/98	7440-43-9	Cadmium	1	9	
3005	05/23/98	6010	05/24/98	7440-70-2	Calcium	40	232,000	
3005	05/23/98	6010	05/24/98	7440-47-3	Chromium	10	10	U
3005	05/23/98	6010	05/24/98	7440-50-8	Copper	4	475	
3005	05/23/98	6010	05/24/98	7439-89-6	Iron	40	673,000	
3020	05/23/98	7421	05/26/98	7439-92-1	Lead	5	5	U
3005	05/23/98	6010	05/24/98	7439-95-4	Magnesium	40	125,000	
3005	05/23/98	6010	05/24/98	7439-96-5	Manganese	2	6,260	
3005	05/23/98	6010	05/24/98	7439-98-7	Molybdenum	10	10	U
3005	05/23/98	6010	05/24/98	7440-02-0	Nickel	20	190	
3005	05/23/98	6010	05/24/98	7440-09-7	Potassium	1,000	9,990	
3020	05/23/98	7761	05/26/98	7440-22-4	Silver	0.2	0.2	U
3005	05/23/98	6010	05/24/98	7440-23-5	Sodium	100	19,800	
3005	05/23/98	6010	05/24/98	7440-66-6	Zinc	8	4,630	

Calculated Dissolved Hardness (mg-CaCO3/L): 1100

U Analyte undetected at given RL

RL Reporting Limit

ANALYTICAL
RESOURCES
INCORPORATED

INORGANICS ANALYSIS DATA SHEET
DISSOLVED METALS

Sample No: SP-2X

Lab Sample ID: W222F
LIMS ID: 98-9068
Matrix: Water

QC Report No: W222-Dames & Moore
Project: Holden Mine
17693-005-019
Date Sampled: 05/02/98
Date Received: 05/05/98

Data Release Authorized:
Reported: 05/28/98

Prep Meth	Prep Date	Analysis Method	Analysis Date	CAS Number	Analyte	RL	ug/L
3005	05/23/98	6010	05/24/98	7429-90-5	Aluminum	40	99,800
7060	05/23/98	7060	05/24/98	7440-38-2	Arsenic	5	5 U
3005	05/23/98	6010	05/24/98	7440-39-3	Barium	2	3
3005	05/23/98	6010	05/24/98	7440-41-7	Beryllium	2	2 U
3020	05/23/98	7131	05/24/98	7440-43-9	Cadmium	1	9
3005	05/23/98	6010	05/24/98	7440-70-2	Calcium	40	174,000
3005	05/23/98	6010	05/24/98	7440-47-3	Chromium	10	10 U
3005	05/23/98	6010	05/24/98	7440-50-8	Copper	4	474
3005	05/23/98	6010	05/24/98	7439-89-6	Iron	40	675,000
3020	05/23/98	7421	05/26/98	7439-92-1	Lead	5	5 U
3005	05/23/98	6010	05/24/98	7439-95-4	Magnesium	40	125,000
3005	05/23/98	6010	05/24/98	7439-96-5	Manganese	2	6,280
3005	05/23/98	6010	05/24/98	7439-98-7	Molybdenum	10	10 U
3005	05/23/98	6010	05/24/98	7440-02-0	Nickel	20	200
3005	05/23/98	6010	05/24/98	7440-09-7	Potassium	1,000	10,100
3020	05/23/98	7761	05/26/98	7440-22-4	Silver	0.2	0.2 U
3005	05/23/98	6010	05/24/98	7440-23-5	Sodium	100	19,600
3005	05/23/98	6010	05/24/98	7440-66-6	Zinc	8	4,620

Calculated Dissolved Hardness (mg-$CaCO_3$/L): 950

U Analyte undetected at given RL

RL Reporting Limit

FORM-I

ANALYTICAL
RESOURCES
INCORPORATED

INORGANICS ANALYSIS DATA SHEET
DISSOLVED METALS

Sample No: SP-1

Lab Sample ID: W222G
LIMS ID: 98-9069
Matrix: Water

QC Report No: W222-Dames & Moore
Project: Holden Mine
17693-005-019
Date Sampled: 05/02/98
Date Received: 05/05/98

Data Release Authorized:
Reported: 05/28/98

Prep Meth	Prep Date	Analysis Method	Analysis Date	CAS Number	Analyte	RL	ug/L
3005	05/23/98	6010	05/24/98	7429-90-5	Aluminum	40	30,700
7060	05/23/98	7060	05/26/98	7440-38-2	Arsenic	1	1 U
3005	05/23/98	6010	05/24/98	7440-39-3	Barium	2	11
3005	05/23/98	6010	05/24/98	7440-41-7	Beryllium	2	2 U
3020	05/23/98	7131	05/24/98	7440-43-9	Cadmium	1	7
3005	05/23/98	6010	05/24/98	7440-70-2	Calcium	40	140,000
3005	05/23/98	6010	05/24/98	7440-47-3	Chromium	10	10 U
3005	05/23/98	6010	05/24/98	7440-50-8	Copper	4	321
3005	05/23/98	6010	05/24/98	7439-89-6	Iron	40	705,000
3020	05/23/98	7421	05/26/98	7439-92-1	Lead	5	5 U
3005	05/23/98	6010	05/24/98	7439-95-4	Magnesium	40	61,200
3005	05/23/98	6010	05/24/98	7439-96-5	Manganese	2	3,870
3005	05/23/98	6010	05/24/98	7439-98-7	Molybdenum	10	10 U
3005	05/23/98	6010	05/24/98	7440-02-0	Nickel	20	20 U
3005	05/23/98	6010	05/24/98	7440-09-7	Potassium	1,000	11,100
3020	05/23/98	7761	05/26/98	7440-22-4	Silver	0.2	0.2 U
3005	05/23/98	6010	05/24/98	7440-23-5	Sodium	100	14,400
3005	05/23/98	6010	05/24/98	7440-66-6	Zinc	8	2,050

Calculated Dissolved Hardness (mg-CaCO3/L): 600

U Analyte undetected at given RL

RL Reporting Limit

FORM-I

**ANALYTICAL
RESOURCES
INCORPORATED**

**INORGANICS ANALYSIS DATA SHEET
DISSOLVED METALS**

Sample No: SP-4

Lab Sample ID: W222I
LIMS ID: 98-9071
Matrix: Water

QC Report No: W222-Dames & Moore
Project: Holden Mine
17693-005-019
Date Sampled: 05/02/98
Date Received: 05/05/98

Data Release Authorized:
Reported: 05/28/98

Prep Meth	Prep Date	Analysis Method	Analysis Date	CAS Number	Analyte	RL	ug/L
3005	05/23/98	6010	05/24/98	7429-90-5	Aluminum	20	5,570
7060	05/23/98	7060	05/26/98	7440-38-2	Arsenic	1	1 U
3005	05/23/98	6010	05/24/98	7440-39-3	Barium	1	61
3005	05/23/98	6010	05/24/98	7440-41-7	Beryllium	1	1 U
3020	05/23/98	7131	05/27/98	7440-43-9	Cadmium	0.2	1.6
3005	05/23/98	6010	05/24/98	7440-70-2	Calcium	20	37,500
3005	05/23/98	6010	05/24/98	7440-47-3	Chromium	5	5 U
3005	05/23/98	6010	05/24/98	7440-50-8	Copper	2	133
3005	05/23/98	6010	05/24/98	7439-89-6	Iron	20	9,730
3020	05/23/98	7421	05/24/98	7439-92-1	Lead	1	1 U
3005	05/23/98	6010	05/24/98	7439-95-4	Magnesium	20	9,840
3005	05/23/98	6010	05/24/98	7439-96-5	Manganese	1	522
3005	05/23/98	6010	05/24/98	7439-98-7	Molybdenum	5	5 U
3005	05/23/98	6010	05/24/98	7440-02-0	Nickel	10	10 U
3005	05/23/98	6010	05/24/98	7440-09-7	Potassium	500	3,550
3020	05/23/98	7761	05/26/98	7440-22-4	Silver	0.2	0.2 U
3005	05/23/98	6010	05/24/98	7440-23-5	Sodium	50	2,190
3005	05/23/98	6010	05/24/98	7440-66-6	Zinc	4	248

Calculated Dissolved Hardness (mg-CaCO3/L): 130

U Analyte undetected at given RL

RL Reporting Limit

FORM-I

ANALYTICAL
RESOURCES
INCORPORATED

INORGANICS ANALYSIS DATA SHEET
TOTAL METALS

Sample No: P-1

Lab Sample ID: W222J
LIMS ID: 98-9072
Matrix: Water

QC Report No: W222-Dames & Moore
Project: Holden Mine
17693-005-019
Date Sampled: 05/01/98
Date Received: 05/05/98

Data Release Authorized:
Reported: 05/28/98

Prep Meth	Prep Date	Analysis Method	Analysis Date	CAS Number	Analyte	RL	ug/L
3005	05/26/98	6010	05/27/98	7429-90-5	Aluminum	20	22,600
7060	05/23/98	7060	05/26/98	7440-38-2	Arsenic	1	1 U
3005	05/26/98	6010	05/27/98	7440-39-3	Barium	1	12
3005	05/26/98	6010	05/27/98	7440-41-7	Beryllium	1	1 U
3020	05/23/98	7131	05/24/98	7440-43-9	Cadmium	20	170
3005	05/26/98	6010	05/27/98	7440-70-2	Calcium	20	58,400
3005	05/26/98	6010	05/27/98	7440-47-3	Chromium	5	5 U
3005	05/26/98	6010	05/27/98	7440-50-8	Copper	2	10,400
3005	05/26/98	6010	05/27/98	7439-89-6	Iron	20	2,030
3020	05/23/98	7421	05/24/98	7439-92-1	Lead	5	64
3005	05/26/98	6010	05/27/98	7439-95-4	Magnesium	20	14,500
3005	05/26/98	6010	05/27/98	7439-96-5	Manganese	1	703
3005	05/26/98	6010	05/27/98	7439-98-7	Molybdenum	5	5 U
3005	05/26/98	6010	05/27/98	7440-02-0	Nickel	10	10 U
3005	05/26/98	6010	05/27/98	7440-09-7	Potassium	500	3,460
3020	05/23/98	7761	05/26/98	7440-22-4	Silver	0.2	0.2
3005	05/26/98	6010	05/27/98	7440-23-5	Sodium	50	6,310
3005	05/26/98	6010	05/27/98	7440-66-6	Zinc	4	27,800

Calculated Hardness (mg-CaCO3/L): 210

U Analyte undetected at given RL

RL Reporting Limit

FORM-I

INORGANICS ANALYSIS DATA SHEET
TOTAL METALS

Sample No: P-1
Lab Sample ID: W222J
QC Report No: W222-Dames & Moore
LIMS ID: 98-9072
Project: Holden Mine
17693-005-019
Matrix: Water
Date Received: 05/05/98

Data Release Authorized
Reported: 05/28/98

MATRIX SPIKE QUALITY CONTROL REPORT

Analyte	Sample ug/L		Spike ug/L	Spike Added	% Recovery	Q
Aluminum	22600		24500	2000	95.0%	H
Arsenic	1	U	40	40	100%	
Barium	12		2020	2000	100%	
Beryllium	1	U	51	50	102%	
Cadmium	168		172	5	80.0%	H
Calcium	58400		68200	10000	98.0%	H
Chromium	5	U	206	200	103%	
Copper	10400		20700	10000	103%	
Iron	2030		3030	1000	100%	
Lead	64		82	20	90.0%	
Magnesium	14500		24900	10000	104%	
Manganese	703		1210	500	101%	
Molybdenum	5	U	260	250	104%	
Nickel	10	U	528	500	106%	
Potassium	3460		13600	10000	101%	
Silver	0.2		21.3	20.0	106%	
Sodium	6310		16500	10000	102%	
Zinc	27800		37200	10000	94.0%	

'Q' codes:
N = control limit not met
H = %R not applicable, sample concentration too high
* = RPD control limit not met
NA = Not applicable - analyte not spiked

Control Limits:
Percent Recovery: 75-125%
RPD: +/-20%

FORM-V

ANALYTICAL
RESOURCES
INCORPORATED

INORGANICS ANALYSIS DATA SHEET
TOTAL METALS

Sample No: P-5

Lab Sample ID: W222K
LIMS ID: 98-9073
Matrix: Water

QC Report No: W222-Dames & Moore
Project: Holden Mine
17693-005-019
Date Sampled: 05/01/98
Date Received: 05/05/98

Data Release Authorized:
Reported: 05/28/98

Prep Meth	Prep Date	Analysis Method	Analysis Date	CAS Number	Analyte	RL	ug/L
3005	05/23/98	6010	05/24/98	7429-90-5	Aluminum	20	13,600
7060	05/23/98	7060	05/26/98	7440-38-2	Arsenic	1	1 U
3005	05/23/98	6010	05/24/98	7440-39-3	Barium	1	19
3005	05/23/98	6010	05/24/98	7440-41-7	Beryllium	1	1 U
3020	05/23/98	7131	05/24/98	7440-43-9	Cadmium	10	80
3005	05/23/98	6010	05/24/98	7440-70-2	Calcium	20	28,000
3005	05/23/98	6010	05/24/98	7440-47-3	Chromium	5	5 U
3005	05/23/98	6010	05/24/98	7440-50-8	Copper	2	4,800
3005	05/23/98	6010	05/24/98	7439-89-6	Iron	20	2,320
3020	05/23/98	7421	05/24/98	7439-92-1	Lead	2	36
3005	05/23/98	6010	05/24/98	7439-95-4	Magnesium	20	6,620
3005	05/23/98	6010	05/24/98	7439-96-5	Manganese	1	321
3005	05/23/98	6010	05/24/98	7439-98-7	Molybdenum	5	10
3005	05/23/98	6010	05/24/98	7440-02-0	Nickel	10	10 U
3005	05/23/98	6010	05/24/98	7440-09-7	Potassium	500	1,920
3020	05/23/98	7761	05/26/98	7440-22-4	Silver	0.2	0.2 U
3005	05/23/98	6010	05/24/98	7440-23-5	Sodium	50	3,310
3005	05/23/98	6010	05/24/98	7440-66-6	Zinc	4	12,300

Calculated Hardness (mg-CaCO3/L): 97

U Analyte undetected at given RL

RL Reporting Limit

ANALYTICAL
RESOURCES
INCORPORATED

INORGANICS ANALYSIS DATA SHEET
TOTAL METALS

Sample No: P-5
QC Report No: W222-Dames & Moore
Project: Holden Mine
17693-005-019
Date Received: 05/05/98

Lab Sample ID: W222K
LIMS ID: 98-9073
Matrix: Water

Data Release Authorized
Reported: 05/28/98

MATRIX DUPLICATE QUALITY CONTROL REPORT

Analyte	Sample ug/L	Duplicate ug/L	RPD	Control Limit	Q
Aluminum	13600	13700	0.7%	+/- 20 %	
Arsenic	1 U	1 U	0.0%	+/- 1	L
Barium	19	19	0.0%	+/- 20 %	
Beryllium	1 U	1 U	0.0%	+/- 1	L
Cadmium	80	80	0.0%	+/- 20 %	
Calcium	28000	28000	0.0%	+/- 20 %	
Chromium	5 U	5 U	0.0%	+/- 5	L
Copper	4800	4810	0.2%	+/- 20 %	
Iron	2320	2360	1.7%	+/- 20 %	
Lead	36	35	2.8%	+/- 20 %	
Magnesium	6620	6640	0.3%	+/- 20 %	
Manganese	321	322	0.3%	+/- 20 %	
Molybdenum	10	5 U	66.7%	+/- 5	L
Nickel	10 U	10 U	0.0%	+/- 10	L
Potassium	1920	1880	2.1%	+/- 500	L
Silver	0.2 U	0.2 U	0.0%	+/- 0.2	L
Sodium	3310	3330	0.6%	+/- 20 %	
Zinc	12300	12400	0.8%	+/- 20 %	

'Q' codes:
* = control limit not met
L = RPD not valid, alternate limit = detection limit

FORM-VI

ANALYTICAL
RESOURCES
INCORPORATED

INORGANICS ANALYSIS DATA SHEET
DISSOLVED METALS

Sample No: SP-27

Lab Sample ID: W264A
LIMS ID: 98-9387
Matrix: Water

QC Report No: W264-Dames & Moore
Project: Holden Mine
17693 005 019
Date Sampled: 05/07/98
Date Received: 05/08/98

Data Release Authorized:
Reported: 05/28/98

Prep Meth	Prep Date	Analysis Method	Analysis Date	CAS Number	Analyte	RL	ug/L
3005	05/23/98	6010	05/24/98	7429-90-5	Aluminum	20	20 U
7060	05/23/98	7060	05/26/98	7440-38-2	Arsenic	1	1 U
3005	05/23/98	6010	05/24/98	7440-39-3	Barium	1	1 U
3005	05/23/98	6010	05/24/98	7440-41-7	Beryllium	1	1 U
3020	05/23/98	7131	05/27/98	7440-43-9	Cadmium	0.2	0.2 U
3005	05/23/98	6010	05/24/98	7440-70-2	Calcium	20	4,610
3005	05/23/98	6010	05/24/98	7440-47-3	Chromium	5	5 U
3005	05/23/98	6010	05/24/98	7440-50-8	Copper	2	2 U
3005	05/23/98	6010	05/24/98	7439-89-6	Iron	20	20 U
3020	05/23/98	7421	05/26/98	7439-92-1	Lead	1	1 U
3005	05/23/98	6010	05/24/98	7439-95-4	Magnesium	20	430
3005	05/23/98	6010	05/24/98	7439-96-5	Manganese	1	1
3005	05/23/98	6010	05/24/98	7439-98-7	Molybdenum	5	5 U
3005	05/23/98	6010	05/24/98	7440-02-0	Nickel	10	10 U
3005	05/23/98	6010	05/24/98	7440-09-7	Potassium	500	500 U
3020	05/23/98	7761	05/26/98	7440-22-4	Silver	0.2	0.2 U
3005	05/23/98	6010	05/24/98	7440-23-5	Sodium	50	1,110
3005	05/23/98	6010	05/24/98	7440-66-6	Zinc	4	4 U

Calculated Dissolved Hardness (mg-CaCO3/L): 13

Km 6/4/98

U Analyte undetected at given RL

RL Reporting Limit

FORM-I

ANALYTICAL
RESOURCES
INCORPORATED

INORGANICS ANALYSIS DATA SHEET
DISSOLVED METALS

Sample No: Method Blank

Lab Sample ID: W222MB
LIMS ID: 98-9064
Matrix: Water

QC Report No: W222-Dames & Moore
Project: Holden Mine
17693-005-019
Date Sampled: NA
Date Received: NA

Data Release Authorized:
Reported: 05/28/98

Prep Meth	Prep Date	Analysis Method	Analysis Date	CAS Number	Analyte	RL	ug/L	
3005	05/23/98	6010	05/24/98	7429-90-5	Aluminum	20	30	
7060	05/23/98	7060	05/24/98	7440-38-2	Arsenic	1	1	U
3005	05/23/98	6010	05/24/98	7440-39-3	Barium	1	1	U
3005	05/23/98	6010	05/24/98	7440-41-7	Beryllium	1	1	U
3020	05/23/98	7131	05/24/98	7440-43-9	Cadmium	0.2	0.2	U
3005	05/23/98	6010	05/24/98	7440-70-2	Calcium	20	20	U
3005	05/23/98	6010	05/24/98	7440-47-3	Chromium	5	5	U
3005	05/23/98	6010	05/24/98	7440-50-8	Copper	2	2	U
3005	05/23/98	6010	05/24/98	7439-89-6	Iron	20	20	U
3020	05/23/98	7421	05/24/98	7439-92-1	Lead	1	1	U
3005	05/23/98	6010	05/24/98	7439-95-4	Magnesium	20	20	U
3005	05/23/98	6010	05/24/98	7439-96-5	Manganese	1	1	U
3005	05/23/98	6010	05/24/98	7439-98-7	Molybdenum	5	5	U
3005	05/23/98	6010	05/24/98	7440-02-0	Nickel	10	10	U
3005	05/23/98	6010	05/24/98	7440-09-7	Potassium	500	500	U
3020	05/23/98	7761	05/26/98	7440-22-4	Silver	0.2	0.2	U
3005	05/23/98	6010	05/24/98	7440-23-5	Sodium	50	50	U
3005	05/23/98	6010	05/24/98	7440-66-6	Zinc	4	4	U

U Analyte undetected at given RL

RL Reporting Limit

FORM-I

ANALYTICAL RESOURCES INCORPORATED

INORGANICS ANALYSIS DATA SHEET
DISSOLVED METALS

Sample No: Method Blank

Lab Sample ID: W222MB
LIMS ID: 98-9069
Matrix: Water

QC Report No: W222-Dames & Moore
Project: Holden Mine
17693-005-019
Date Sampled: NA
Date Received: NA

Data Release Authorized:
Reported: 05/28/98

Prep Meth	Prep Date	Analysis Method	Analysis Date	CAS Number	Analyte	RL	ug/L
3005	05/26/98	6010	05/27/98	7429-90-5	Aluminum	20	20 U
3005	05/26/98	6010	05/27/98	7440-39-3	Barium	1	1 U
3005	05/26/98	6010	05/27/98	7440-41-7	Beryllium	1	1 U
3005	05/26/98	6010	05/27/98	7440-70-2	Calcium	20	20 U
3005	05/26/98	6010	05/27/98	7440-47-3	Chromium	5	5 U
3005	05/26/98	6010	05/27/98	7440-50-8	Copper	2	2 U
3005	05/26/98	6010	05/27/98	7439-89-6	Iron	20	20 U
3005	05/26/98	6010	05/27/98	7439-95-4	Magnesium	20	20 U
3005	05/26/98	6010	05/27/98	7439-96-5	Manganese	1	1 U
3005	05/26/98	6010	05/27/98	7439-98-7	Molybdenum	5	5 U
3005	05/26/98	6010	05/27/98	7440-02-0	Nickel	10	10 U
3005	05/26/98	6010	05/27/98	7440-09-7	Potassium	500	500 U
3005	05/26/98	6010	05/27/98	7440-23-5	Sodium	50	50 U
3005	05/26/98	6010	05/27/98	7440-66-6	Zinc	4	4 U

U Analyte undetected at given RL

RL Reporting Limit

FORM-I

**ANALYTICAL
RESOURCES
INCORPORATED**

INORGANICS ANALYSIS DATA SHEET
TOTAL METALS

Sample No: Method Blank

Lab Sample ID: W222MB
LIMS ID: 98-9073
Matrix: Water

QC Report No: W222-Dames & Moore
Project: Holden Mine
17693-005-019
Date Sampled: NA
Date Received: NA

Data Release Authorized:
Reported: 05/28/98

Prep Meth	Prep Date	Analysis Method	Analysis Date	CAS Number	Analyte	RL	ug/L
3005	05/23/98	6010	05/22/98	7429-90-5	Aluminum	20	20 U
7060	05/23/98	7060	05/24/98	7440-38-2	Arsenic	1	1 U
3005	05/23/98	6010	05/22/98	7440-39-3	Barium	1	1 U
3005	05/23/98	6010	05/22/98	7440-41-7	Beryllium	1	1 U
3020	05/23/98	7131	05/24/98	7440-43-9	Cadmium	0.2	0.3
3005	05/23/98	6010	05/22/98	7440-70-2	Calcium	20	20 U
3005	05/23/98	6010	05/22/98	7440-47-3	Chromium	5	5 U
3005	05/23/98	6010	05/22/98	7440-50-8	Copper	2	2 U
3005	05/23/98	6010	05/22/98	7439-89-6	Iron	20	20 U
3020	05/23/98	7421	05/24/98	7439-92-1	Lead	1	1 U
3005	05/23/98	6010	05/22/98	7439-95-4	Magnesium	20	20 U
3005	05/23/98	6010	05/22/98	7439-96-5	Manganese	1	1 U
3005	05/23/98	6010	05/22/98	7439-98-7	Molybdenum	5	5 U
3005	05/23/98	6010	05/22/98	7440-02-0	Nickel	10	10 U
3005	05/23/98	6010	05/22/98	7440-09-7	Potassium	500	500 U
3020	05/23/98	7761	05/26/98	7440-22-4	Silver	0.2	0.2 U
3005	05/23/98	6010	05/22/98	7440-23-5	Sodium	50	50 U
3005	05/23/98	6010	05/22/98	7440-66-6	Zinc	4	4 U

U Analyte undetected at given RL

RL Reporting Limit

FORM-I

**ANALYTICAL
RESOURCES
INCORPORATED**

INORGANICS ANALYSIS DATA SHEET

Sample No: STD REFERENCE
I.V. Lots 869-6 and 867-12

Lab Sample ID: W222LCS
LIMS ID: 98-9064
Matrix: Water

QC Report No: W222-Dames & Moore
Project: Holden Mine
17693-005-019
Date Sampled: NA
Date Received: NA

Data Release Authorized:
Reported: 05/28/98

Analyte	STD Value	Value Found	Recovery
Aluminum	2000	2030	102%
Arsenic	100	102	102%
Barium	1000	960	96.0%
Beryllium	1000	933	93.3%
Cadmium	10.0	10.4	104%
Calcium	2000	2100	105%
Chromium	1000	1000	100%
Copper	1000	978	97.8%
Iron	2000	2000	100%
Lead	100	98.0	98.0%
Magnesium	2000	1990	99.5%
Manganese	1000	991	99.1%
Molybdenum	1000	1010	101%
Nickel	1000	1000	100%
Potassium	20000	19400	97.0%
Silver	20.0	20.2	101%
Sodium	2000	1940	97.0%
Zinc	1000	992	99.2%

Recovery Limits 80-120

Values reported in parts per billion (ug/L)

I.V. Lot 869-6 used for GFA. I.V. Lot 867-12 used for ICP.

FORM-III-R

ANALYTICAL
RESOURCES
INCORPORATED

INORGANICS ANALYSIS DATA SHEET

Sample No: STD REFERENCE
I.V. Lots 869-6 and 867-12

Lab Sample ID: W222LCS
LIMS ID: 98-9069
Matrix: Water

QC Report No: W222-Dames & Moore
Project: Holden Mine
17693-005-019
Date Sampled: NA
Date Received: NA

Data Release Authorized
Reported: 05/28/98

Analyte	STD Value	Value Found	Recovery
Aluminum	2000	2070	104%
Barium	1000	991	99.1%
Beryllium	1000	964	96.4%
Calcium	2000	2130	106%
Chromium	1000	1020	102%
Copper	1000	1010	101%
Iron	2000	2040	102%
Magnesium	2000	2030	102%
Manganese	1000	1010	101%
Molybdenum	1000	1020	102%
Nickel	1000	1020	102%
Potassium	20000	20100	100%
Sodium	2000	2090	104%
Zinc	1000	999	99.9%

Recovery Limits 80-120

Values reported in parts per billion (ug/L)

I.V. Lot 869-6 used for GFA. I.V. Lot 867-12 used for ICP.

FORM-III-R

ANALYTICAL
RESOURCES
INCORPORATED

INORGANICS ANALYSIS DATA SHEET

Sample No: STD REFERENCE
I.V. Lots 869-6 and 867-12

Lab Sample ID: W222LCS
LIMS ID: 98-9073
Matrix: Water

QC Report No: W222-Dames & Moore
Project: Holden Mine
17693-005-019
Date Sampled: NA
Date Received: NA

Data Release Authorized:
Reported: 05/28/98

Analyte	STD Value	Value Found	Recovery
Aluminum	2000	2050	102%
Arsenic	100	92.5	92.5%
Barium	1000	960	96.0%
Beryllium	1000	936	93.6%
Cadmium	10.0	10.4	104%
Calcium	2000	2100	105%
Chromium	1000	1000	100%
Copper	1000	980	98.0%
Iron	2000	2000	100%
Lead	100	100	100%
Magnesium	2000	2010	100%
Manganese	1000	991	99.1%
Molybdenum	1000	1010	101%
Nickel	1000	1010	101%
Potassium	20000	19700	98.5%
Silver	20.0	20.5	102%
Sodium	2000	1950	97.5%
Zinc	1000	998	99.8%

Recovery Limits 80-120

Values reported in parts per billion (ug/L)

I.V. Lot 869-6 used for GFA. I.V. Lot 867-12 used for ICP.

FORM-III-R

ANALYTICAL
RESOURCES
INCORPORATED

INORGANICS ANALYSIS DATA SHEET
DISSOLVED METALS

Sample No: VP-1

Lab Sample ID: W222A
LIMS ID: 98-9623
Matrix: Water

QC Report No: W222-Dames & Moore
Project: Holden Mine
17693-005-019
Date Sampled: 05/02/98
Date Received: 05/05/98

Data Release Authorized:
Reported: 06/01/98

Prep Meth	Prep Date	Analysis Method	Analysis Date	CAS Number	Analyte	RL	ug/L	
3005	05/21/98	6010	05/24/98	7429-90-5	Aluminum	20	50	U
200.8	05/20/98	200.8	05/26/98	7440-38-2	Arsenic	0.04	0.05	
200.8	05/20/98	200.8	05/26/98	7440-39-3	Barium	0.04	1.15	
200.8	05/20/98	200.8	05/26/98	7440-41-7	Beryllium	0.04	0.04	U
200.8	05/20/98	200.8	05/26/98	7440-43-9	Cadmium	0.04	0.04	
3005	05/21/98	6010	05/24/98	7440-70-2	Calcium	20	4,120	
200.8	05/20/98	200.8	05/26/98	7440-47-3	Chromium	0.2	0.2	U
200.8	05/20/98	200.8	05/26/98	7440-50-8	Copper	0.2	0.7	
3005	05/21/98	6010	05/24/98	7439-89-6	Iron	20	20	U
200.8	05/20/98	200.8	05/26/98	7439-92-1	Lead	0.2	0.6	U
3005	05/21/98	6010	05/24/98	7439-95-4	Magnesium	20	530	
200.8	05/20/98	200.8	05/26/98	7439-96-5	Manganese	0.04	0.81	
200.8	05/20/98	200.8	05/26/98	7439-98-7	Molybdenum	0.04	0.25	
200.8	05/20/98	200.8	05/26/98	7440-02-0	Nickel	0.2	0.2	U
3005	05/21/98	6010	05/24/98	7440-09-7	Potassium	500	500	U
200.8	05/20/98	200.8	05/26/98	7440-22-4	Silver	0.04	0.04	U
3005	05/21/98	6010	05/24/98	7440-23-5	Sodium	50	950	
3005	05/21/98	6010	05/24/98	7440-66-6	Zinc	4	4	U

Calculated Dissolved Hardness (mg-$CaCO_3$/L): 12

Km 6/4/98

U Analyte undetected at given RL

RL Reporting Limit

FORM-I

ANALYTICAL
RESOURCES
INCORPORATED

INORGANICS ANALYSIS DATA SHEET
DISSOLVED METALS

Sample No: CC-D1

Lab Sample ID: W222B
LIMS ID: 98-9624
Matrix: Water

QC Report No: W222-Dames & Moore
Project: Holden Mine
17693-005-019
Date Sampled: 05/02/98
Date Received: 05/05/98

Data Release Authorized:
Reported: 06/01/98

Prep Meth	Prep Date	Analysis Method	Analysis Date	CAS Number	Analyte	RL	ug/L
3005	05/21/98	6010	05/24/98	7429-90-5	Aluminum	20	60 U
200.8	05/20/98	200.8	05/26/98	7440-38-2	Arsenic	0.04	0.04 U
200.8	05/20/98	200.8	05/26/98	7440-39-3	Barium	0.04	6.78
200.8	05/20/98	200.8	05/26/98	7440-41-7	Beryllium	0.04	0.04 U
200.8	05/20/98	200.8	05/26/98	7440-43-9	Cadmium	0.04	2.57
3005	05/21/98	6010	05/24/98	7440-70-2	Calcium	20	5,770
200.8	05/20/98	200.8	05/26/98	7440-47-3	Chromium	0.2	0.2 U
200.8	05/20/98	200.8	05/26/98	7440-50-8	Copper	2	155
3005	05/21/98	6010	05/24/98	7439-89-6	Iron	20	20 U
200.8	05/20/98	200.8	05/26/98	7439-92-1	Lead	0.2	0.2 U
3005	05/21/98	6010	05/24/98	7439-95-4	Magnesium	20	660
200.8	05/20/98	200.8	05/26/98	7439-96-5	Manganese	0.04	15.5
200.8	05/20/98	200.8	05/26/98	7439-98-7	Molybdenum	0.04	0.38
200.8	05/20/98	200.8	05/26/98	7440-02-0	Nickel	0.2	2.0
3005	05/21/98	6010	05/24/98	7440-09-7	Potassium	500	610
200.8	05/20/98	200.8	05/26/98	7440-22-4	Silver	0.04	0.04 U
3005	05/21/98	6010	05/24/98	7440-23-5	Sodium	50	690
3005	05/21/98	6010	05/24/98	7440-66-6	Zinc	4	372

Calculated Dissolved Hardness (mg-CaCO3/L): 17

Km 6/4/98

U Analyte undetected at given RL

RL Reporting Limit

FORM-I

ANALYTICAL
RESOURCES
INCORPORATED

INORGANICS ANALYSIS DATA SHEET
TOTAL METALS

Sample No: VP-1

Lab Sample ID: W222C
LIMS ID: 98-9625
Matrix: Water

QC Report No: W222-Dames & Moore
Project: Holden Mine
17693-005-019
Date Sampled: 05/01/98
Date Received: 05/05/98

Data Release Authorized:
Reported: 06/01/98

Prep Meth	Prep Date	Analysis Method	Analysis Date	CAS Number	Analyte	RL	ug/L
3005	05/21/98	6010	05/24/98	7429-90-5	Aluminum	20	4,400
200.8	05/20/98	200.8	05/26/98	7440-38-2	Arsenic	0.04	0.64
200.8	05/20/98	200.8	05/26/98	7440-39-3	Barium	0.04	27.6
200.8	05/20/98	200.8	05/26/98	7440-41-7	Beryllium	0.04	0.04 U
200.8	05/20/98	200.8	05/26/98	7440-43-9	Cadmium	0.04	0.09
3005	05/21/98	6010	05/24/98	7440-70-2	Calcium	20	5,400
200.8	05/20/98	200.8	05/26/98	7440-47-3	Chromium	0.4	3.0
200.8	05/20/98	200.8	05/26/98	7440-50-8	Copper	0.2	9.6
3005	05/21/98	6010	05/24/98	7439-89-6	Iron	20	3,510
200.8	05/20/98	200.8	05/26/98	7439-92-1	Lead	0.2	2.9
3005	05/21/98	6010	05/24/98	7439-95-4	Magnesium	20	1,870
200.8	05/20/98	200.8	05/26/98	7439-96-5	Manganese	0.08	40.6
200.8	05/20/98	200.8	05/26/98	7439-98-7	Molybdenum	0.04	0.26
200.8	05/20/98	200.8	05/26/98	7440-02-0	Nickel	0.2	3.3
3005	05/21/98	6010	05/24/98	7440-09-7	Potassium	500	870
200.8	05/20/98	200.8	05/26/98	7440-22-4	Silver	0.04	0.04 U
3005	05/21/98	6010	05/24/98	7440-23-5	Sodium	50	1,360
3005	05/21/98	6010	05/24/98	7440-66-6	Zinc	4	13

Calculated Hardness (mg-CaCO3/L): 21

U Analyte undetected at given RL

RL Reporting Limit

FORM-I

ANALYTICAL RESOURCES INCORPORATED

INORGANICS ANALYSIS DATA SHEET
DISSOLVED METALS

Sample No: Method Blank

Lab Sample ID: W222MB
LIMS ID: 98-9623
Matrix: Water

QC Report No: W222-Dames & Moore
Project: Holden Mine
17693-005-019
Date Sampled: NA
Date Received: NA

Data Release Authorized
Reported: 06/01/98

Prep Meth	Prep Date	Analysis Method	Analysis Date	CAS Number	Analyte	RL	ug/L
3005	05/21/98	6010	05/24/98	7429-90-5	Aluminum	20	20
200.8	05/20/98	200.8	05/26/98	7440-38-2	Arsenic	0.04	0.04 U
200.8	05/20/98	200.8	05/26/98	7440-39-3	Barium	0.04	0.04 U
200.8	05/20/98	200.8	05/26/98	7440-41-7	Beryllium	0.04	0.04 U
200.8	05/20/98	200.8	05/26/98	7440-43-9	Cadmium	0.04	0.04 U
3005	05/21/98	6010	05/24/98	7440-70-2	Calcium	20	20 U
200.8	05/20/98	200.8	05/26/98	7440-47-3	Chromium	0.2	0.2 U
200.8	05/20/98	200.8	05/26/98	7440-50-8	Copper	0.2	0.2 U
3005	05/21/98	6010	05/24/98	7439-89-6	Iron	20	20 U
200.8	05/20/98	200.8	05/26/98	7439-92-1	Lead	0.2	0.3
3005	05/21/98	6010	05/24/98	7439-95-4	Magnesium	20	20 U
200.8	05/20/98	200.8	05/26/98	7439-96-5	Manganese	0.04	0.04 U
200.8	05/20/98	200.8	05/26/98	7439-98-7	Molybdenum	0.04	0.04 U
200.8	05/20/98	200.8	05/26/98	7440-02-0	Nickel	0.2	0.2 U
3005	05/21/98	6010	05/24/98	7440-09-7	Potassium	500	500 U
200.8	05/20/98	200.8	05/26/98	7440-22-4	Silver	0.04	0.04 U
3005	05/21/98	6010	05/24/98	7440-23-5	Sodium	50	50 U
3005	05/21/98	6010	05/24/98	7440-66-6	Zinc	4	4 U

U Analyte undetected at given RL

RL Reporting Limit

FORM-I

ANALYTICAL
RESOURCES
INCORPORATED

METALS ANALYSIS DATA SHEET
DISSOLVED METALS

Sample No: VP-1
Lab Sample ID: W222LCS
QC Report No: W222-Dames & Moore
LIMS ID: 98-9623
Project: Holden Mine
17693-005-019
Matrix: Water
Date Received: 05/05/98

Data Release Authorized
Reported: 06/01/98

BLANK SPIKE QUALITY CONTROL REPORT

Analyte	Spike ug/L	Spike Added	% Recovery	Q
Arsenic	4.59	5.00	91.8%	
Barium	4.97	5.00	99.4%	
Beryllium	4.46	5.00	89.2%	
Cadmium	4.74	5.00	94.8%	
Chromium	5.1	5.0	102%	
Copper	5.2	5.0	104%	
Lead	5.1	5.0	102%	
Manganese	5.10	5.00	102%	
Molybdenum	5.04	5.00	101%	
Nickel	5.2	5.0	104%	
Silver	4.85	5.00	97.0%	

'Q' codes: N = control limit not met

Control Limits: 80-120%

FORM-VII

ANALYTICAL
RESOURCES
INCORPORATED

INORGANICS ANALYSIS DATA SHEET

Sample No: STD REFERENCE
I.V. Lots 869-6 and 889-1

Lab Sample ID: W222LCS
LIMS ID: 98-9623
Matrix: Water

QC Report No: W222-Dames & Moore
Project: Holden Mine
17693-005-019
Date Sampled: NA
Date Received: NA

Data Release Authorized:
Reported: 05/28/98

Analyte	STD Value	Value Found	Recovery
Aluminum	2000	2050	102%
Calcium	2000	2120	106%
Iron	2000	2010	100%
Magnesium	2000	2000	100%
Potassium	20000	19900	99.5%
Sodium	2000	1960	98.0%
Zinc	1000	996	99.6%

Recovery Limits 80-120

Values reported in parts per billion (ug/L)

I.V. Lot 869-6 used for GFA. I.V. Lot 889-1 used for ICP.

Final Report
Laboratory Analysis of Conventional Parameters

Sample No: P-1

Lab Sample ID: W222A
LIMS ID: 98-9063
Matrix: Water

QC Report No: W222-Dames & Moore
Project: Holden Mine
17693-005-019
Date Sampled: 05/01/98
Date Received: 05/05/98

Data Release Authorized:
Reported: 05/27/98 Dr. M.A. Perkins

Analyte	Analysis Date & Batch	Method	RL	Units		Result
Alkalinity	05/14/98 051498#1	SM 2320	1.0	mg/L CaCO3	<	1.0 U
Total Dissolved Solids	05/07/98 050798#1	EPA 160.1	10	mg/L		540
Total Suspended Solids	05/07/98 050798#1	EPA 160.2	2.2	mg/L		9.1
Sulfate	05/14/98 051498#2	EPA 375.2	75	mg/L		310

RL	Analytical reporting limit
U	Undetected at reported detection limit

Report for W222 received 05/05/98

ANALYTICAL
RESOURCES
INCORPORATED

Final Report
Laboratory Analysis of Conventional Parameters

Sample No: P-5

Lab Sample ID: W222B
LIMS ID: 98-9064
Matrix: Water

Data Release Authorized:
Reported: 05/27/98 Dr. M.A. Perkins

QC Report No: W222-Dames & Moore
Project: Holden Mine
17693-005-019
Date Sampled: 05/01/98
Date Received: 05/05/98

Analyte	Analysis Date & Batch	Method	RL	Units	Result
Alkalinity	05/14/98 051498#1	SM 2320	1.0	mg/L CaCO3	< 1.0 U
Total Dissolved Solids	05/07/98 050798#1	EPA 160.1	10	mg/L	260
Total Suspended Solids	05/07/98 050798#1	EPA 160.2	2.0	mg/L	39
Sulfate	05/14/98 051498#2	EPA 375.2	25	mg/L	140

RL	Analytical reporting limit
U	Undetected at reported detection limit

Report for W222 received 05/05/98

ANALYTICAL
RESOURCES
INCORPORATED

Final Report
Laboratory Analysis of Conventional Parameters

Sample No: VP-1

Lab Sample ID: W222C
LIMS ID: 98-9065
Matrix: Water

QC Report No: W222-Dames & Moore
Project: Holden Mine
17693-005-019
Date Sampled: 05/02/98
Date Received: 05/05/98

Data Release Authorized:
Reported: 05/27/98 Dr. M.A. Perkins

Analyte	Analysis Date & Batch	Method	RL	Units	Result
Alkalinity	05/14/98 051498#1	SM 2320	1.0	mg/L CaCO3	12
Total Dissolved Solids	05/07/98 050798#1	EPA 160.1	10	mg/L	< 10 U
Total Suspended Solids	05/07/98 050798#1	EPA 160.2	1.2	mg/L	69
Sulfate	05/14/98 051498#2	EPA 375.2	2.5	mg/L	3.5

RL Analytical reporting limit
U Undetected at reported detection limit

Report for W222 received 05/05/98

ANALYTICAL
RESOURCES
INCORPORATED

Final Report
Laboratory Analysis of Conventional Parameters

Sample No: SP-23

Lab Sample ID: W222D
LIMS ID: 98-9066
Matrix: Water

Data Release Authorized:
Reported: 05/27/98 Dr. M.A. Perkins

QC Report No: W222-Dames & Moore
Project: Holden Mine
17693-005-019
Date Sampled: 05/02/98
Date Received: 05/05/98

Analyte	Analysis Date & Batch	Method	RL	Units		Result
Alkalinity	05/14/98 051498#1	SM 2320	1.0	mg/L CaCO3	<	1.0 U
Total Dissolved Solids	05/07/98 050798#1	EPA 160.1	10	mg/L		160
Total Suspended Solids	05/07/98 050798#1	EPA 160.2	1.0	mg/L		1.5
Sulfate	05/14/98 051498#2	EPA 375.2	5.0	mg/L		88

RL Analytical reporting limit
U Undetected at reported detection limit

Report for W222 received 05/05/98

ANALYTICAL
RESOURCES
INCORPORATED

Final Report
Laboratory Analysis of Conventional Parameters

Sample No: SP-2

Lab Sample ID: W222E
LIMS ID: 98-9067
Matrix: Water

QC Report No: W222-Dames & Moore
Project: Holden Mine
17693-005-019
Date Sampled: 05/02/98
Date Received: 05/05/98

Data Release Authorized:
Reported: 05/27/98 Dr. M.A. Perkins

Analyte	Analysis Date & Batch	Method	RL	Units	Result
Alkalinity	05/14/98 051498#1	SM 2320	1.0	mg/L CaCO3	< 1.0 U
Total Dissolved Solids	05/07/98 050798#1	EPA 160.1	50	mg/L	4,400
Total Suspended Solids	05/07/98 050798#1	EPA 160.2	1.0	mg/L	9.1
Sulfate	05/14/98 051498#2	EPA 375.2	120	mg/L	2,700

RL	Analytical reporting limit
U	Undetected at reported detection limit

Report for W222 received 05/05/98

ANALYTICAL
RESOURCES
INCORPORATED

Final Report
Laboratory Analysis of Conventional Parameters

Sample No: SP-2X

Lab Sample ID: W222F
LIMS ID: 98-9068
Matrix: Water

Data Release Authorized:
Reported: 05/27/98 Dr. M.A. Perkins

QC Report No: W222-Dames & Moore
Project: Holden Mine
17693-005-019
Date Sampled: 05/02/98
Date Received: 05/05/98

Analyte	Analysis Date & Batch	Method	RL	Units	Result
Alkalinity	05/14/98 051498#1	SM 2320	1.0	mg/L CaCO3	< 1.0 U
Total Dissolved Solids	05/07/98 050798#1	EPA 160.1	50	mg/L	4,400
Total Suspended Solids	05/07/98 050798#1	EPA 160.2	1.0	mg/L	6.1
Sulfate	05/14/98 051498#2	EPA 375.2	120	mg/L	2,800

RL	Analytical reporting limit
U	Undetected at reported detection limit

Report for W222 received 05/05/98

ANALYTICAL
RESOURCES
INCORPORATED

Final Report
Laboratory Analysis of Conventional Parameters

Sample No: SP-1

Lab Sample ID: W222G
LIMS ID: 98-9069
Matrix: Water

QC Report No: W222-Dames & Moore
Project: Holden Mine
17693-005-019
Date Sampled: 05/02/98
Date Received: 05/05/98

Data Release Authorized:
Reported: 05/27/98 Dr. M.A. Perkins

Analyte	Analysis Date & Batch	Method	RL	Units		Result
Alkalinity	05/14/98 051498#1	SM 2320	1.0	mg/L CaCO3	<	1.0 U
Total Dissolved Solids	05/07/98 050798#1	EPA 160.1	50	mg/L		3,200
Total Suspended Solids	05/07/98 050798#1	EPA 160.2	1.0	mg/L		2.2
Sulfate	05/14/98 051498#2	EPA 375.2	120	mg/L		2,000

RL	Analytical reporting limit
U	Undetected at reported detection limit

Report for W222 received 05/05/98

ANALYTICAL
RESOURCES
INCORPORATED

Final Report
Laboratory Analysis of Conventional Parameters

Sample No: CC-D1

Lab Sample ID: W222H
LIMS ID: 98-9070
Matrix: Water

Data Release Authorized:
Reported: 05/27/98 Dr. M.A. Perkins

QC Report No: W222-Dames & Moore
Project: Holden Mine
17693-005-019
Date Sampled: 05/02/98
Date Received: 05/05/98

Analyte	**Analysis Date & Batch**	**Method**	**RL**	**Units**	**Result**
Alkalinity	05/14/98 051498#1	SM 2320	1.0	mg/L CaCO3	6.8
Total Dissolved Solids	05/07/98 050798#1	EPA 160.1	10	mg/L	24
Total Suspended Solids	05/07/98 050798#1	EPA 160.2	1.0	mg/L	7.0
Sulfate	05/14/98 051498#2	EPA 375.2	25	mg/L	56

RL Analytical reporting limit
U Undetected at reported detection limit

Report for W222 received 05/05/98

ANALYTICAL
RESOURCES
INCORPORATED

Final Report
Laboratory Analysis of Conventional Parameters

Sample No: SP-4

Lab Sample ID: W222I
LIMS ID: 98-9071
Matrix: Water

QC Report No: W222-Dames & Moore
Project: Holden Mine
17693-005-019
Date Sampled: 05/02/98
Date Received: 05/05/98

Data Release Authorized:
Reported: 05/27/98 Dr. M.A. Perkins

Analyte	Analysis Date & Batch	Method	RL	Units	Result
Alkalinity	05/14/98 051498#1	SM 2320	1.0	mg/L CaCO3	< 1.0 U
Total Dissolved Solids	05/07/98 050798#1	EPA 160.1	10	mg/L	280
Total Suspended Solids	05/07/98 050798#1	EPA 160.2	1.0	mg/L	< 1.0 U
Sulfate	05/14/98 051498#2	EPA 375.2	50	mg/L	190

RL Analytical reporting limit
U Undetected at reported detection limit

Report for W222 received 05/05/98

ANALYTICAL
RESOURCES
INCORPORATED

QA Report - Method Blank Analysis

QC Report No: W222-Dames & Moore
Matrix: Water
Project: Holden Mine
17693-005-019
Date Received: NA

Data Release Authorized:
Reported: 05/27/98 Dr. M.A. Perkins

METHOD BLANK RESULTS
CONVENTIONALS

Analysis Date & Batch	Constituent	Units	Result		
05/07/98 050798#1	Total Dissolved Solids	mg/L	<	10	U
05/07/98 050798#1	Total Suspended Solids	mg/L	<	1.0	U
05/14/98 051498#2	Sulfate	mg/L	<	2.5	U

ANALYTICAL
RESOURCES
INCORPORATED

QA Report - Replicate Analysis

QC Report No: W222-Dames & Moore
Matrix: Water
Project: Holden Mine
17693-005-019
Date Received: 05/05/98

Data Release Authorized:
Reported: 05/27/98 Dr. M.A. Perkins

DUPLICATE ANALYSIS RESULTS
CONVENTIONALS

Constituent	Units	Sample Value	Duplicate Value	RPD
ARI ID: 98-9063, W222 A	**Client Sample ID: P-1**			
Total Dissolved Solids	mg/L	540	560	3.6%
Total Suspended Solids	mg/L	9.1	9.8	7.4%
Sulfate	mg/L	310	320	3.2%
ARI ID: 98-9065, W222 C	**Client Sample ID: VP-1**			
Alkalinity	mg/L $CaCO_3$	12	12	0.0%

ANALYTICAL
RESOURCES
INCORPORATED

QA Report - Matrix Spike/Matrix Spike Duplicate Analysis

QC Report No: W222-Dames & Moore
Project: Holden Mine
17693-005-019
Date Received: 05/05/98

Matrix: Water

Data Release Authorized:
Reported: 05/27/98 Dr. M.A. Perkins

MATRIX SPIKE QA/QC REPORT
CONVENTIONALS

Constituent	Units	Sample Value	Spike Value	Spike Added	Recovery
ARI ID: 98-9063, W222 A	Client Sample ID: P-1				
Sulfate	mg/L	312	902	600	98.3%

MS/MSD Recovery Limits: 75 - 125 %

QA Report - Laboratory Control Samples

QC Report No: W222-Dames & Moore
Project: Holden Mine
17693-005-019
Date Received: NA

Data Release Authorized:
Reported: 05/27/98 Dr. M.A. Perkins

LABORATORY CONTROL SAMPLES
CONVENTIONALS

Constituent	Units	Measured Value	True Value	Recovery
Laboratory Control Sample				
Alkalinity	mg/L CaCO3	120	118	102%

Date analyzed: 05/14/98 Batch ID: 051498#1

ANALYTICAL
RESOURCES
INCORPORATED

QA Report - Standard Reference Material Analysis

QC Report No: W222-Dames & Moore
Project: Holden Mine
17693-005-019
Date Received: NA

Data Release Authorized:
Reported: 05/27/98 Dr. M.A. Perkins

STANDARD REFERENCE MATERIAL ANALYSIS
CONVENTIONALS

Constituent	Units	Value	True Value	Recovery
SPEX #13-22AS				
Sulfate	mg/L	25.7	25.0	103%

Date analyzed: 05/14/98 Batch ID: 051498#2

ANALYTICAL
RESOURCES
INCORPORATED

Final Report
Laboratory Analysis of Conventional Parameters

Sample No: SP-27

Lab Sample ID: W264A
LIMS ID: 98-9387
Matrix: Water

Data Release Authorized:
Reported: 06/01/98 Dr. M.A. Perkins

QC Report No: W264-Dames & Moore
Project: Holden Mine
17693 005 019
Date Sampled: 05/07/98
Date Received: 05/08/98

Analyte	Analysis Date & Batch	Method	RL	Units	Result
Alkalinity	05/14/98 051498#1	SM 2320	1.0	mg/L CaCO3	14
Total Dissolved Solids	05/11/98 051198#1	EPA 160.1	10	mg/L	350
Total Suspended Solids	05/11/98 051198#1	EPA 160.2	2.2	mg/L	< 2.2 U
Sulfate	05/13/98 051398#1	EPA 375.2	2.5	mg/L	2.6

RL Analytical reporting limit
U Undetected at reported detection limit

Report for W264 received 05/08/98

ANALYTICAL
RESOURCES
INCORPORATED

QA Report - Replicate Analysis

QC Report No: W264-Dames & Moore
Project: Holden Mine
17693 005 019
Date Received: 05/08/98

Matrix: Water

Data Release Authorized:
Reported: 06/01/98 Dr. M.A. Perkins

DUPLICATE ANALYSIS RESULTS
CONVENTIONALS

Constituent	Units	Sample Value	Duplicate Value	RPD
ARI ID: 98-9387, W264 A	Client Sample ID: SP-27			
Total Dissolved Solids	mg/L	350	350	0.0%
Total Suspended Solids	mg/L	< 2.2 U	< 2.2 U	NA
Sulfate	mg/L	2.6	< 2.5 U	NA

ANALYTICAL
RESOURCES
INCORPORATED

QA Report - Matrix Spike/Matrix Spike Duplicate Analysis

QC Report No: W264-Dames & Moore
Project: Holden Mine
17693 005 019
Date Received: 05/08/98

Matrix: Water

Data Release Authorized:
Reported: 06/01/98 Dr. M.A. Perkins

MATRIX SPIKE QA/QC REPORT
CONVENTIONALS

Constituent	Units	Sample Value	Spike Value	Spike Added	Recovery
ARI ID: 98-9387, W264 A Client Sample ID: SP-27					
Sulfate	mg/L	2.6	18.7	20.0	80.5%

MS/MSD Recovery Limits: 75 - 125 %

ANALYTICAL
RESOURCES
INCORPORATED

QA Report - Laboratory Control Samples

QC Report No: W264-Dames & Moore
Project: Holden Mine
17693 005 019
Date Received: NA

Data Release Authorized:
Reported: 06/01/98 Dr. M.A. Perkins

LABORATORY CONTROL SAMPLES
CONVENTIONALS

Constituent	Units	Measured Value	True Value	Recovery
Laboratory Control Sample				
Alkalinity	mg/L $CaCO_3$	121	118	103%

Date analyzed: 05/14/98 Batch ID: 051498#1

ANALYTICAL
RESOURCES
INCORPORATED

QA Report - Standard Reference Material Analysis

QC Report No: W264-Dames & Moore
Project: Holden Mine
17693 005 019
Date Received: NA

Data Release Authorized:
Reported: 06/01/98 Dr. M.A. Perkins

STANDARD REFERENCE MATERIAL ANALYSIS
CONVENTIONALS

Constituent	Units	Value	True Value	Recovery
SPEX#13-22AS				
Sulfate	mg/L	24.8	25.0	99.2%

Date analyzed: 05/13/98 Batch ID: 051398#1

ANALYTICAL
RESOURCES
INCORPORATED

QA Report - Method Blank Analysis

QC Report No: W264-Dames & Moore
Project: Holden Mine
17693 005 019
Date Received: NA

Matrix: Water

Data Release Authorized:
Reported: 06/01/98 Dr. M.A. Perkins

METHOD BLANK RESULTS
CONVENTIONALS

Analysis Date & Batch	Constituent	Units	Result
05/11/98 051198#1	Total Dissolved Solids	mg/L	< 10 U
05/11/98 051198#1	Total Suspended Solids	mg/L	< 1.0 U
05/13/98 051398#1	Sulfate	mg/L	< 2.5 U

Portal + Seep Samples

Page 1 of 1

CHAIN-OF-CUSTODY RECORD

WHITE COPY-Original (Accompanies Samples) YELLOW COPY-Collector PINK COPY-Project Manager

Boring or Well Number	Sample Number	Date Collected ~~Depth~~	Time	Sample Type	Container Type	Analysis Required: Total Rec Metals ~~VOA 601/8010~~	Diss Metals ~~VOA 602/8020~~	TDS/TSS ~~VOA 624/8240/8260~~	Sulfate ~~Semi-Vol 625/8270~~	Alkalinity ~~NWTPH-Gx~~	Hardness ~~NWTPH-Dx~~	NWTPH-Dx-Ext	RCRA 8 Metals	PNA 610/8310	Pest/PCBs 8081	ASBESTOS	FIELD NOTES:	Total Number Of Containers	Laboratory Note Number
	P-1	5/1/98	1520			X	X	X	X	X	X						ARI cooler 2	4	
	P-5	5/1/98	1550			X	X	X	X	X	X						ARI cooler ~~2~~ 3	4	
	VP-1	5/2/98	1005			X	X	X	X	X	X						ARI cooler ~~2~~ 3	4	
	SP-23	5/2/98	1042		same →		X	X	X	X	X						ARI cooler 3	3	
	SP-2	5/2/98	1315				X	X	X	X	X						ARI cooler 4	3	
	SP-2X	5/2/98	1320				X	X	X	X	X						ARI cooler 4	3	
	SP-1	5/2/98	1415				X	X	X	X	X						ARI cooler 4	3	
	CC-D1	5/2/98	1430				X	X	X	X	X						ARI cooler 5	3	
	SP-4	5/2/98	1555				X	X	X	X	X						ARI cooler 5	3	
																	W222		
																	98-9063 to		
																	98-9074		

RELINQUISHED BY: (Signature)	DATE/TIME	RECEIVED BY: (Signature)
	5/5/98 2130	

LABORATORY NOTES:

ANALYTICAL LABORATORY: ARI

LABORATORY CONTACT: Mark Harris

D&M CONTACT: Karen Mixon PHONE: 206-728-0744

JOB NO.: 17693-005-019

PROJECT: Holden Mine

LOCATION: Holden, WA

~~COLLECTOR:~~

~~DATE OF COLLECTION:~~

DAMES & MOORE
A DAMES & MOORE GROUP COMPANY

500 Market Place Tower
2025 First Avenue
Seattle, Washington 98121
Phone (206) 728-0744
Fax (206) 727-3350

SEEP SAMPLE
* MARK HARRIS, SAMPLE MAY CONTAIN 5 FOLD CONCENTRATION

CHAIN-OF-CUSTODY RECORD

WHITE COPY-Original (Accompanies Samples) YELLOW COPY-Collector PINK COPY-Project Manager

Boring or Well Number	Sample Number	Depth	Time	Sample Type	Container Type	Analysis Required ~~VOA 601/8010~~ DISSOLVED METALS	~~VOA 602/8020~~ TDS/TSS	~~VOA 624/8240/8260~~ SULFATE	~~Semi Vol 625/8270~~ ALKALINITY	~~NWTPH-Gx~~ HARDNESS	NWTPH-Dx	NWTPH-Dx-Ext	RCRA 8 Metals	PNA 610/8310	Pest/PCBs 8081	ASBESTOS	FIELD NOTES:	Total Number Of Containers	Laboratory Note Number
SP-27	–	–	12:00	WATER		X	X	X	X	X								3	
																	98-9387		
																	W264		

RELINQUISHED BY: (Signature)	DATE/TIME	RECEIVED BY: (Signature)
	5/8/98 13:26	Amy Bergam 5/8/98 1340

LABORATORY NOTES:

ANALYTICAL LABORATORY: ARI
LABORATORY CONTACT: MARK HARRIS
D&M CONTACT: KAREN MIXON PHONE:

JOB NO.: 17693 005 019
PROJECT: HOLDEN MINE
LOCATION: HOLDEN, WA
COLLECTOR:
DATE OF COLLECTION 5/ /98

DAMES & MOORE
DAMES & MOORE GROUP COMPANY

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Fax (206) 727-3350

MEMORANDUM

Date: June 8, 1998

To: Rik Langendoen, Project Manager

From: Karen Mixon, Project Chemist KM

Subject: Summary Data Quality Review
Holden Mine Remedial Investigation Phase III
Equipment Blank, May 1998
Dames & Moore Job #17693-005-019

The summary data quality review of one equipment blank collected on May 5, 1998 has been completed. The sample was analyzed at the Analytical Resources, Incorporated (ARI) laboratory in Seattle, Washington for total recoverable metals by EPA Methods 6010A and 200.8 modified (including the following metals: aluminum, arsenic, barium, beryllium, cadmium, calcium, chromium, copper, iron, lead, magnesium, manganese, molybdenum, nickel, potassium, silver, sodium, and zinc). The analyses were performed in accordance with the methods specified in EPA Test Methods for Evaluating Solid Waste, SW-846, January 1995. A validation package containing method associated QA/QC data and summarized sample data was provided by the laboratory. The following sample is associated with laboratory work order ARI# W263:

Sample I.D.	ARI Sample #	Analyses Requested
EB-05-PM	W263A	Total Metals

The following comments refer to ARI's performance in meeting quality control specifications described in the EPA documents "EPA Test Methods for Evaluating Solid Waste, SW-846", January 1995 and "USEPA Contract Laboratory Program (CLP) National Functional Guidelines for Inorganic Data Review", February 1994, and the Quality Assurance Project Plan (QAPP) prepared for the Phase III Remedial Investigation dated April 17, 1998.

The sample was prepared in the laboratory using EPA Method 3005A and a modified EPA 200.8 preparation method. Samples were analyzed by ICP (EPA Method 6010A) and ICPMS (EPA Method 200.8 Modified).

1. Holding Time - Acceptable
2. Tunes (ICP MS analysis only) - Acceptable
3. Initial Calibration - Acceptable
4. Continuing Calibration - Acceptable
5. Blanks

Aluminum (20 ug/L), barium (0.04 ug/L), calcium (50 ug/L), lead (0.3 ug/L), and manganese (0.07 ug/L) were detected in the method blank associated with sample EB-05-PM. As the concentrations detected were at or near the detection limit, sample results in EB-05-PM that are less than 5X the concentration in the blank are qualified as not detected and flagged "U" accordingly. Results between 5X and 10X the concentrations detected in the method blank are qualified as estimated and flagged "J" accordingly. Results reported as not detected or greater than 10X the concentration detected in the method blank do not require qualification.

The following metals were detected in the equipment blank (EB-05-PM): copper (0.4 ug/L), iron (30 ug/L), and zinc (6 ug/L). Aluminum (30 ug/L), barium (0.08 ug/L), calcium (70 ug/L), lead (0.3 ug/L), and manganese (0.15 ug/L) were also detected in the equipment blank but qualified as not detected based on the method blank results. The equipment blank is associated with the equipment used for collection of seep and portal samples during the May sampling event. Copper, iron, and zinc in seep and portal samples were not detected or detected at concentrations greater than 10X the equipment blank with the exception of dissolved copper (0.7 ug/L) in sample VP-1. However, the total copper concentration for VP-1 (9.6 ug/L) was greater than 10X the equipment blank. The low-level detection of copper, iron, and zinc in the equipment blank combined with the high concentrations of these metals detected in associated samples indicate that the sampling equipment for the seep/portal samples did not measurably affect the data. Associated data were not qualified based on equipment blank results.

6. Internal Standards (ICP MS analysis only) - Acceptable

7. ICP Interference Check (ICP analysis only) - Acceptable

8. Laboratory Control Sample - Acceptable

9. Laboratory Duplicate Sample – Not Applicable

   A laboratory duplicate is not required for equipment blanks.

10. Field Duplicate - Not Applicable

11. Matrix Spike – Not Applicable

    A matrix spike is not required for equipment blanks.

12. ICP Serial Dilution (ICP analysis only) - Acceptable

13. Detection Limits - Acceptable

14. Type of Review - Summary

15. Overall Assessment of Data

    The usefulness of the data is based on EPA guidance documents listed above. Upon consideration of the information presented above, the data are acceptable except where flagged with data qualifiers that modify the usefulness of the individual values.

<u>Data Qualifiers</u>

U The analyte was analyzed for, but was not detected above the reported sample quantitation limit.

J The analyte was positively identified; the associated numerical value is the approximate concentration of the analyte in the sample.

UJ	The analyte was not detected above the reported sample quantitation limit. However, the reported quantitation limit is approximate and may or may not represent the actual limit of quantitation necessary to accurately and precisely measure the analyte in the sample.
R	The sample results are rejected due to serious deficiencies in the ability to analyze the sample and meet quality control criteria. The presence or absence of the analyte cannot be verified.

ANALYTICAL
RESOURCES
INCORPORATED

INORGANICS ANALYSIS DATA SHEET
TOTAL METALS

Sample No: EB-05-PM

Lab Sample ID: W263A
LIMS ID: 98-9386
Matrix: Water

QC Report No: W263-Dames & Moore
Project: Holden Mine
17693 005 019
Date Sampled: 05/05/98
Date Received: 05/08/98

Data Release Authorized:
Reported: 05/21/98

Prep Meth	Prep Date	Analysis Method	Analysis Date	CAS Number	Analyte	RL	ug/L
3005	05/14/98	6010	05/19/98	7429-90-5	Aluminum	20	30 U
200.8	05/14/98	200.8	05/18/98	7440-38-2	Arsenic	0.04	0.04 U
200.8	05/14/98	200.8	05/18/98	7440-39-3	Barium	0.04	0.08 U
200.8	05/14/98	200.8	05/18/98	7440-41-7	Beryllium	0.04	0.04 U
200.8	05/14/98	200.8	05/18/98	7440-43-9	Cadmium	0.04	0.04 U
3005	05/14/98	6010	05/19/98	7440-70-2	Calcium	20	70 U
200.8	05/14/98	200.8	05/18/98	7440-47-3	Chromium	0.2	0.2 U
200.8	05/14/98	200.8	05/18/98	7440-50-8	Copper	0.2	0.4
3005	05/14/98	6010	05/19/98	7439-89-6	Iron	20	30
200.8	05/14/98	200.8	05/18/98	7439-92-1	Lead	0.2	0.3 U
3005	05/14/98	6010	05/19/98	7439-95-4	Magnesium	20	20 U
200.8	05/14/98	200.8	05/18/98	7439-96-5	Manganese	0.04	0.15 U
200.8	05/14/98	200.8	05/18/98	7439-98-7	Molybdenum	0.04	0.04 U
200.8	05/14/98	200.8	05/18/98	7440-02-0	Nickel	0.2	0.2 U
3005	05/14/98	6010	05/19/98	7440-09-7	Potassium	500	500 U
200.8	05/14/98	200.8	05/18/98	7440-22-4	Silver	0.04	0.04 U
3005	05/14/98	6010	05/19/98	7440-23-5	Sodium	50	50 U
3005	05/14/98	6010	05/19/98	7440-66-6	Zinc	4	6

km 6/4/98

U Analyte undetected at given RL

RL Reporting Limit

FORM-I

ANALYTICAL
RESOURCES
INCORPORATED

INORGANICS ANALYSIS DATA SHEET
TOTAL METALS

Sample No: Method Blank

Lab Sample ID: W263MB
LIMS ID: 98-9386
Matrix: Water

QC Report No: W263-Dames & Moore
Project: Holden Mine
17693 005 019
Date Sampled: NA
Date Received: NA

Data Release Authorized:
Reported: 05/21/98

Prep Meth	Prep Date	Analysis Method	Analysis Date	CAS Number	Analyte	RL	ug/L
3005	05/14/98	6010	05/19/98	7429-90-5	Aluminum	20	20
200.8	05/14/98	200.8	05/18/98	7440-38-2	Arsenic	0.04	0.04 U
200.8	05/14/98	200.8	05/18/98	7440-39-3	Barium	0.04	0.04
200.8	05/14/98	200.8	05/18/98	7440-41-7	Beryllium	0.04	0.04 U
200.8	05/14/98	200.8	05/18/98	7440-43-9	Cadmium	0.04	0.04 U
3005	05/14/98	6010	05/19/98	7440-70-2	Calcium	20	50
200.8	05/14/98	200.8	05/18/98	7440-47-3	Chromium	0.2	0.2 U
200.8	05/14/98	200.8	05/18/98	7440-50-8	Copper	0.2	0.2 U
3005	05/14/98	6010	05/19/98	7439-89-6	Iron	20	20 U
200.8	05/14/98	200.8	05/18/98	7439-92-1	Lead	0.2	0.3
3005	05/14/98	6010	05/19/98	7439-95-4	Magnesium	20	20 U
200.8	05/14/98	200.8	05/18/98	7439-96-5	Manganese	0.04	0.07
200.8	05/14/98	200.8	05/18/98	7439-98-7	Molybdenum	0.04	0.04 U
200.8	05/14/98	200.8	05/18/98	7440-02-0	Nickel	0.2	0.2 U
3005	05/14/98	6010	05/19/98	7440-09-7	Potassium	500	500 U
200.8	05/14/98	200.8	05/18/98	7440-22-4	Silver	0.04	0.04 U
3005	05/14/98	6010	05/19/98	7440-23-5	Sodium	50	50 U
3005	05/14/98	6010	05/19/98	7440-66-6	Zinc	4	4 U

U	Analyte undetected at given RL
RL	Reporting Limit

FORM-I

ANALYTICAL
RESOURCES
INCORPORATED

METALS ANALYSIS DATA SHEET
TOTAL METALS

Lab Sample ID: W263LCS
LIMS ID: 98-9386
Matrix: Water

Data Release Authorized:
Reported: 05/21/98

Sample No: EB-05-PM
QC Report No: W263-Dames & Moore
Project: Holden Mine
17693 005 019
Date Received: 05/08/98

BLANK SPIKE QUALITY CONTROL REPORT

Analyte	Spike ug/L	Spike Added	% Recovery	Q
Arsenic	4.70	5.00	94.0%	
Barium	4.97	5.00	99.4%	
Beryllium	4.60	5.00	92.0%	
Cadmium	4.76	5.00	95.2%	
Chromium	5.20	5.00	104%	
Copper	5.30	5.00	106%	
Lead	5.20	5.00	104%	
Manganese	5.23	5.00	105%	
Molybdenum	4.83	5.00	96.6%	
Nickel	5.20	5.00	104%	
Silver	4.74	5.00	94.8%	

'Q' codes: N = control limit not met

Control Limits: 80-120%

FORM-VII

ANALYTICAL
RESOURCES
INCORPORATED

INORGANICS ANALYSIS DATA SHEET

Sample No: STD REFERENCE
I.V. Lots 869-6 and 889-1

Lab Sample ID: W263LCS
LIMS ID: 98-9386
Matrix: Water

QC Report No: W263-Dames & Moore
Project: Holden Mine
17693 005 019
Date Sampled: NA
Date Received: NA

Data Release Authorized:
Reported: 05/21/98

Analyte	STD Value	Value Found	Recovery
Aluminum	2000	2070	104%
Calcium	2000	2110	106%
Iron	2000	2030	102%
Magnesium	2000	2020	101%
Potassium	20000	20400	102%
Sodium	2000	2030	102%
Zinc	1000	1010	101%

Recovery Limits 80-120

Values reported in parts per billion (ug/L)

I.V. Lot 869-6 used for GFA. I.V. Lot 889-1 used for ICP.

FORM-III-R

EQUIPMENT BLANK

+.0

CHAIN-OF-CUSTODY RECORD

WHITE COPY-Original (Accompanies Samples) YELLOW COPY-Collector PINK COPY-Project Manager

Boring or Well Number	Sample Number	Depth	Time	Sample Type	Container Type	Analysis Required: ~~VOA 601/8010~~ TOTAL METALS	VOA 602/8020	VOA 624/8240/8260	Semi Vol 625/8270	NWTPH-Gx	NWTPH-Dx	NWTPH-Dx-Ext	RCRA 8 Metals	PNA 610/8310	Pest/PCBs 8081	ASBESTOS	FIELD NOTES:	Total Number Of Containers	Laboratory Note Number
	EB-05-PM		16:55	WATER		X												1	
																	98-9386		
																	W263		

RELINQUISHED BY: (Signature) DATE/TIME 5/8/98 15:26 RECEIVED BY: (Signature) 5/8/98 1730

RELINQUISHED BY: (Signature) DATE/TIME RECEIVED BY: (Signature)

RELINQUISHED BY: (Signature) DATE/TIME RECEIVED BY: (Signature)

LABORATORY NOTES:

ANALYTICAL LABORATORY: ARI

LABORATORY CONTACT: MARK HARRIS

D&M CONTACT: KAREN MIXON PHONE:

JOB NO.: 17693 005 019

PROJECT: HOLDEN MINE

LOCATION: HOLDEN, WA

COLLECTOR: DATE OF COLLECTION /98

DAMES & MOORE
A DAMES & MOORE GROUP COMPANY

500 Market Place Tower
2025 First Avenue
Seattle, Washington 98121
Phone (206) 728-0744
Fax (206) 727-3350

MEMORANDUM

Date: June 15, 1998

To: Rik Langendoen, Project Manager

From: Karen Mixon, Project Chemist KM

Subject: Standard Data Quality Review
Holden Mine Remedial Investigation Phase III
Low Level Lead Data, May 1998
Dames & Moore Job #17693-005-019

The standard data quality review of 36 water samples collected April 30 through May 5, 1998 has been completed. The samples were submitted to Frontier Geosciences laboratory in Seattle, Washington. The samples were analyzed for low level lead by draft EPA Method 1638 modified. The analyses were performed in accordance with the method specified. A validatable package containing method associated QA/QC data and summarized sample data was provided by the laboratory. The following samples were analyzed and reported by Frontier Geosciences. The samples were identified by the field identification.

Sample I.D.	Analyses Requested
HC-4	Dissolved/Total Metals
HC-3	Dissolved/Total Metals
HC-2	Dissolved/Total Metals
HC-1	Dissolved/Total Metals
RC-11	Total Metals
BIG-1	Dissolved/Total Metals
CC-1	Dissolved/Total Metals
CC-2	Dissolved/Total Metals
RC-6	Dissolved/Total Metals
RC-1	Dissolved/Total Metals
RC-4	Dissolved/Total Metals
RC-4X	Dissolved/Total Metals
RC-7	Dissolved/Total Metals
RC-5	Dissolved/Total Metals
RC-10	Dissolved/Total Metals
RC-3	Dissolved/Total Metals
RC-2	Dissolved/Total Metals

Sample I.D.	Analyses Requested
VP-1	Dissolved/Total Metals
SP-23	Dissolved Metals

The following comments refer to Frontier Geosciences' performance in meeting quality control specifications described in the EPA documents "Draft Method 1638", and "USEPA Contract Laboratory Program (CLP) National Functional Guidelines for Inorganic Data Review", February 1994, and the Quality Assurance Project Plan (QAPP) prepared for the Phase III Remedial Investigation dated April 17, 1997.

Sample aliquots for dissolved metals were filtered in the field. Samples were collected in precleaned containers provided by Frontier. The samples were preserved immediately upon receipt by the laboratory.

Samples were prepared in the laboratory using EPA Method 1638 modified as documented by Frontier Geosciences.

1. Holding Time - Acceptable

2. Tunes – Acceptable

3. Initial Calibration - Acceptable

4. Continuing Calibration - Acceptable

5. Blanks - Acceptable

   Blank subtraction is outlined in the method. The reagent blank was properly analyzed and results were averaged per the method for the purpose of blank subtraction related to sample calculation.

6. Internal Standards – Acceptable

7. Laboratory Control Sample - Acceptable

8. Laboratory Duplicate Sample - Acceptable

9. Field Duplicate - Acceptable

   A field duplicate for RC-4 was submitted and labeled RC-4X.

10. Matrix Spike/Matrix Spike Duplicate (MS/MSD) - Acceptable

    A MS/MSD was performed on the total fraction of sample RC-4 and RC-10.

11. Detection Limits - Acceptable

12. Type of Review - Standard

13. Overall Assessment of Data

The usefulness of the data is based on EPA guidance documents listed above. Upon consideration of the information presented above, the data are acceptable except where flagged with data qualifiers that modify the usefulness of the individual values.

Data Qualifiers

U	The analyte was analyzed for, but was not detected above the reported sample quantitation limit.
J	The analyte was positively identified; the associated numerical value is the approximate concentration of the analyte in the sample.
UJ	The analyte was not detected above the reported sample quantitation limit. However, the reported quantitation limit is approximate and may or may not represent the actual limit of quantitation necessary to accurately and precisely measure the analyte in the sample.
R	The sample results are rejected due to serious deficiencies in the ability to analyze the sample and meet quality control criteria. The presence or absence of the analyte cannot be verified.

Sample Results for Dames and Moore

Reported by Frontier Geosciences Inc.

Sample ID	Total Pb (μg/L)	Diss. Pb (μg/L)	Date Digested	Date Analyzed
CC-1	0.060	ND	5/6/98	5/8/98
CC-2	0.054	ND	5/6/98	5/8/98
RC-6	0.124	ND	5/6/98	5/8/98
RC-1	0.103	ND	5/6/98	5/8/98
RC-4	0.276	0.088	5/6/98	5/8/98
RC-4X	0.279	0.085	5/6/98	5/8/98
HC-4	0.069	ND	5/6/98	5/8/98
HC-3	0.067	ND	5/6/98	5/8/98
HC-2	0.129	ND	5/6/98	5/8/98
HC-1	0.054	0.018	5/6/98	5/8/98
BIG-1	ND	ND	5/6/98	5/8/98
RC-10	0.201	0.082	5/6/98	5/8/98
RC-5	0.249	0.106	5/6/98	5/8/98
RC-3	0.159	0.053	5/6/98	5/8/98
RC-7	0.295	0.126	5/6/98	5/8/98
RC-2	0.284	0.107	5/6/98	5/8/98
VP-1	1.66	0.015	5/6/98	5/8/98
SP-23	-	0.220	5/6/98	5/8/98
RC-11	0.139	-	5/6/98	5/8/98
RL	0.011	0.011		

ND = Lead concentration in sample found to be less than the RL.

Matrix: Waters

Date Received: 5/6/98

QC Summary for Dames and Moore

Reported by Frontier Geosciences Inc.

Blanks:	[Pb] (µg/L)
PBW1	0.002
PBW2	0.004
PBW3	0.006
PBW4	0.000
PBW5	0.007
PBW6	0.002
Mean PBW	0.004
Std Dev	0.003
Est MDL	0.008
Reporting Limit	0.011

SRMs:	[Pb] (µg/L)
Identity	NIST 1643d
Certified Value	18.15
LCSW1	18.19
% Rec.	100.2
LCSW2	18.06
% Rec.	99.5
RPD	0.7

Matrix QC:	[Pb] (µg/L)		[Pb] (µg/L)
Sample QCed	RC-4	Sample QCed	RC-10
Sample Conc.	0.276	Sample Conc.	0.201
MD Conc.	0.278	MD Conc.	0.200
RPD	0.7	RPD	0.4
Spiking Level	1.000	Spiking Level	1.000
MS Conc.	1.312	MS Conc.	1.204
% Rec.	103.5	% Rec.	100.3
MSD Conc.	1.377	MSD Conc.	1.208
% Rec.	110.0	% Rec.	100.7
RPD	4.8	RPD	0.3

note Samples were field filtered when dissolved is noted but not preserved. Samples marked as total are not preserved.

Frontier Geosciences Inc.
414 Pontius Avenue North
Seattle, WA 98109
(206) 622-6960 fax (206) 622-6870
info@frontier.wa.com

Chain-of-Custody (COC)

Frontier Client: Dames + Moore
Client Contact: Karen Mixon
Address: 500 market Place Tower
2025 1st Ave
Seattle, WA 98121
Phone #: 206-728-0744
Fax #: 206-727-3350
Project Name: Holden Mine
Contract/PO #: 17693-005-019

teed TAT: standard
Confirmation of Sample Arrival at Lab ____ (Y/N)
QA Level: Standard ☐ High ☑ Low ☐

	Sample ID	Matrix	Date/Time Sampled	Collected By	Preservation	Analysis Required/Comments	
506	*CC-1 Dissolved	H2O	5/2/98, 1420	D+M	none	low level lead	Frontier code #1
492	*CC-2 Dissolved	H2O	5/2/98, 1450	D+M	none	low level lead	↓
583	*RC-6 Total	H2O	5/3/98, 1020	D+M	none	low level lead	cooler #2
13	*RC-6 Dissolved	H2O	5/3/98, 1020				cooler #2
515	*RC-1 Total	H2O	5/3/98, 1050				cooler #2
578	*RC-1 Dissolved	H2O	5/3/98, 1050				cooler #2
23	*RC-4 Total	H2O	5/3/98, 1130				cooler #2
512	*RC-4 Dissolved	H2O	5/3/98, 1130				cooler #2
55	*RC-4X Total	H2O	5/3/98, 1140				cooler #2
11	*RC-4X Dissolved	H2O	5/3/98, 1140				cooler #2
35	*RC-7 Total	H2O	5/3/98, 1420				cooler #2
473	*RC-7 Dissolved	H2O	5/3/98, 1420				cooler #2
5/6 40	TM 4570 *RC-2 Total	H2O	5/3/98, 1535				cooler #2
23	*RC-2 Dissolved	H2O	5/3/98, 1535	↓	↓	↓	cooler #2

hed by (signature): Karen Mixon
ne: Karen L. Mixon
: Dames + Moore
5/6/98 Time: 1030

Received by (signature): Chris Tuilaepa Date: 5/6/98 Time: 1:00pm
Print Name: ____
Cooler Temp.: ____
Company: FGS
Blue Ice/[✓ Ice]:
Condition of Samples upon arrival: Cold / Water

on of unused sample (circle one) [✓ Frontier Dispose]/Return to Client/Ship to 3rd party (discuss with Frontier project manager)

confirm before disposing (60 days from report sendout)

eosciences Inc. COC Form, Version IV, 1/15/98

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note: Sample ID is marked on outside bag and is [illegible] correct, we had difficulty reading scratched n[illegible] on bottles so bottle # noted is what was hand m[illegible] on bags

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Frontier Geosciences Inc.
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(206) 622-6960 fax (206) 622-6870
info@frontier.wa.com

Chain-of-Custody (COC)

Frontier Client Dames + Moore
Client Contact Kren Mixon
Address 500 Market Place Tower
2025 1st Ave
Seattle, WA 98121

Phone # 206-728-0744
Fax # 206-727-3350
Project Name Holden Mine
Contract/PO # ______

eed TAT Standard Confirmation of Sample Arrival at Lab ____ (Y/N) QA Level: Standard ☐ High ☑ Low ☐

	Sample ID	Matrix	Date/Time Sampled	Collected By	Preservation	Analysis Required/Comments
509	HC-4 . Total	H_2O	4/30/98, 1245	D+M	none	low level Lead Frontier cooler #1
507	HC-4 , Dissolved	H_2O	4/30/98 1245	D+M	none	
33	HC-3 Total	H_2O	4/30/98 1325	D+M	none	
83	HC-3 Dissolved	H_2O	4/30/98, 1325	D+M	none	
18	HC-2 Total	H_2O	4/30/98, 1425	D+M	none	
2	HC-2 Dissolved	H_2O	4/30/98, 1425	D+M	none	
21	HC-1 Total	H_2O	5/1/98, 1100	D+M	none	
51	HC-1 Dissolved	H_2O	5/1/98, 1100	D+M	none	Frontier cooler #1
16	RC-11 Total	H_2O	5/1/98, 1210	D+M	none	
577	BIG-1 Total	H_2O	5/2/98, 1050	D+M	none	
62	BIG-1 Dissolved	H_2O	5/2/98, 1050	D+M	none	
15	VP-1 TOTAL	H_2O	5/2/98, 1005	D+M	none	
5	VP-1 Dissolved	H_2O	5/2/98, 1005	D+M	none	
7	SP-23 Dissolved	H_2O	5/2/98 1042	D+M	none	
0	CC-1 TOTAL	H_2O	5/2/98, 1420	D+M	none	
8	CC-2 TOTAL	H_2O	5/2/98 1450	D+M	none	↓ ↓

ed by (signature):
e: Kren L Mixon
Dames + Moore
5/4/98 Time: 1030

Received by (signature): Chris Tuilaepa Date: 5/6/98 Time: 1:pm
Print Name: ______ Cooler Temp.: ______
Company: FGS Blue Ice/[✓ Ice] ______
Condition of Samples upon arrival: Cold / Water

n of unused sample (circle one) [✓ Frontier Dispose]/Return to Client/Ship to 3rd party (discuss with Frontier project manager)

confirming before disposing (waiting from report sendout)

sciences Inc. COC Form, Version IV, 1/15/98

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Chain-of-Custody (COC)

Frontier Client: Dames + Moore
Client Contact: Karen Mixon
Address: 500 Market Place Tower
2025 1st Ave
Seattle, WA 98121

Phone #: 206-728-0744
Fax #: 206-727-3350
Project Name: Holden Mine
Contract/PO #:

nteed TAT ____________ Confirmation of Sample Arrival at Lab ____ (Y/N) QA Level: Standard ☐ High ☐ Low ☐

#	Sample ID	Matrix	Date/Time Sampled	Collected By	Preservation	Analysis Required/Comments
TM712	*RC-10 Total	H2O	5/4/98 - 1110	Dames + Moore	none	low level lead cooler #2
TM594	*RC-10 Dissolved	H2O	5/4/98 - 1110	↓	↓	↓ ↓
TM503	*RC-5 Total	H2O	5/4/98 - 1310	↓	↓	↓ ↓
TM4569	*RC-5 Dissolved	H2O	5/4/98 - 1310	↓	↓	↓ ↓
TM4471	*RC-3 Total	H2O	5/5/98 - 1140	↓	↓	↓ ↓
TM4472	~~AOT~~ RC-3 Diss.	H2O	5/5/98 - 11:40	↓	↓	↓ ↓ mlg 5/6/98
	~~OA listing~~					

ished by (signature):
ame: Karen L. Mixon
ny: Dames + Moore
5/6/98 Time: 1030

Received by (signature): Chris Tulaepa Date: 5/6/98 Time: 1pm
Print Name:
Company: FGS
Cooler Temp.:
Blue Ice/[✓ Ice]:
Condition of Samples upon arrival: Cold / Water

ition of unused sample (circle one) [✓ Frontier Dispose]/Return to Client/Ship to 3rd party (discuss with Frontier project manager)

confirm before disposing (60 days from report sendout).

Geosciences Inc. COC Form, Version IV, 1/15/98

Page 3 of 3

MEMORANDUM

Date: June 25, 1998

To: Rik Langendoen, Project Manager

From: Karen Mixon, Project Chemist KM

Subject: Summary Data Quality Review
Holden Mine Remedial Investigation Phase III
Ventilator Portal Sample, June 1998
Dames & Moore Job #17693-005-019

The summary data quality review of one sample collected on June 14, 1998 has been completed. The sample was analyzed at the Analytical Resources, Incorporated (ARI) laboratory in Seattle, Washington for total recoverable and dissolved metals by EPA Methods 6010A and 200.8 modified (including the following metals: aluminum, arsenic, barium, beryllium, cadmium, calcium, chromium, copper, iron, lead, magnesium, manganese, molybdenum, nickel, potassium, silver, sodium, and zinc). The analyses were performed in accordance with the methods specified in EPA Test Methods for Evaluating Solid Waste, SW-846, January 1995. A validation package containing method associated QA/QC data and summarized sample data was provided by the laboratory. The following sample is associated with laboratory work order ARI# W676:

Sample I.D.	ARI Sample #	Analyses Requested
VP-1	W676A	Dissolved Metals
VP-1	W676B	Total Metals

The following comments refer to ARI's performance in meeting quality control specifications described in the EPA documents "EPA Test Methods for Evaluating Solid Waste, SW-846", January 1995 and "USEPA Contract Laboratory Program (CLP) National Functional Guidelines for Inorganic Data Review", February 1994, and the Quality Assurance Project Plan (QAPP) prepared for the Phase III Remedial Investigation dated April 17, 1998.

The sample was prepared in the laboratory using EPA Method 3005A and a modified EPA 200.8 preparation method. Samples were analyzed by ICP (EPA Method 6010A) and ICPMS (EPA Method 200.8 Modified).

1. Holding Time - Acceptable
2. Tunes (ICP MS analysis only) - Acceptable
3. Initial Calibration - Acceptable
4. Continuing Calibration - Acceptable
5. Blanks

Copper (0.2 ug/L), manganese (0.04 ug/L), and sodium (60 ug/L) were detected in the method blank associated with sample VP-1 (total and dissolved analyses). As the concentrations detected were at or near the detection limit, sample results in VP-1 (total and dissolved) that are less than 5X the concentration in the blank are qualified as not detected and flagged "U" accordingly. Results between 5X and 10X the concentrations detected in the method blank are qualified as estimated and flagged "J" accordingly. Results reported as not detected or greater than 10X the concentration detected in the method blank do not require qualification.

6. Internal Standards (ICP MS analysis only) - Acceptable

7. ICP Interference Check (ICP analysis only) - Acceptable

8. Laboratory Control Sample - Acceptable

9. Laboratory Duplicate Sample – Not Applicable

   A laboratory duplicate was not performed due to the limited number of samples.

10. Field Duplicate - Not Applicable

11. Matrix Spike – Not Applicable

   A matrix spike was not performed due to the limited number of samples.

12. ICP Serial Dilution (ICP analysis only) - Acceptable

13. Detection Limits - Acceptable

14. Type of Review - Summary

15. Overall Assessment of Data

   The usefulness of the data is based on EPA guidance documents listed above. Upon consideration of the information presented above, the data are acceptable except where flagged with data qualifiers that modify the usefulness of the individual values.

   The result for dissolved zinc is reported as 411 ug/L; however, the zinc concentration reported for the total fraction is 4 ug/L. The ICP raw data was reviewed for calculations and no errors were identified. The laboratory analyzed a serial dilution on the dissolved fraction, reanalyzed dissolved fraction directly from the original sample container, and reviewed calculations. No errors were identified and the reanalyses of the dilutions and additional sample resulted in concentrations similar to 411 ug/L. This result appears to be an anomaly and should be considered as such during data evaluation and use.

Data Qualifiers

U	The analyte was analyzed for, but was not detected above the reported sample quantitation limit.
J	The analyte was positively identified; the associated numerical value is the approximate concentration of the analyte in the sample.
UJ	The analyte was not detected above the reported sample quantitation limit. However, the reported quantitation limit is approximate and may or may not represent the actual limit of quantitation necessary to accurately and precisely measure the analyte in the sample.

R	The sample results are rejected due to serious deficiencies in the ability to analyze the sample and meet quality control criteria. The presence or absence of the analyte cannot be verified.

ANALYTICAL
RESOURCES
INCORPORATED

INORGANICS ANALYSIS DATA SHEET
TOTAL METALS

Sample No: VP-1

Lab Sample ID: W676B
LIMS ID: 98-12170
Matrix: Water

QC Report No: W676-Dames & Moore
Project:
Holden Mine
Date Sampled: 06/15/98
Date Received: 06/15/98

Data Release Authorized:
Reported: 06/22/98

Prep Meth	Prep Date	Analysis Method	Analysis Date	CAS Number	Analyte	RL	ug/L
3005	06/17/98	6010	06/18/98	7429-90-5	Aluminum	20	90
200.8	06/17/98	200.8	06/18/98	7440-38-2	Arsenic	0.04	0.07
200.8	06/17/98	200.8	06/18/98	7440-39-3	Barium	0.04	2.41
200.8	06/17/98	200.8	06/18/98	7440-41-7	Beryllium	0.04	0.04 U
200.8	06/17/98	200.8	06/18/98	7440-43-9	Cadmium	0.04	0.04 U
3005	06/17/98	6010	06/18/98	7440-70-2	Calcium	20	4,810
200.8	06/17/98	200.8	06/18/98	7440-47-3	Chromium	0.2	0.2 U
200.8	06/17/98	200.8	06/18/98	7440-50-8	Copper	0.2	1.1 J
3005	06/17/98	6010	06/18/98	7439-89-6	Iron	20	80
200.8	06/17/98	200.8	06/18/98	7439-92-1	Lead	0.2	0.5
3005	06/17/98	6010	06/18/98	7439-95-4	Magnesium	20	680
200.8	06/17/98	200.8	06/18/98	7439-96-5	Manganese	0.04	1.48
200.8	06/17/98	200.8	06/18/98	7439-98-7	Molybdenum	0.04	0.30
200.8	06/17/98	200.8	06/18/98	7440-02-0	Nickel	0.2	0.2
3005	06/17/98	6010	06/18/98	7440-09-7	Potassium	500	890
200.8	06/17/98	200.8	06/18/98	7440-22-4	Silver	0.04	0.04 U
3005	06/17/98	6010	06/18/98	7440-23-5	Sodium	50	1,040
3005	06/17/98	6010	06/18/98	7440-66-6	Zinc	4	4

Km 6/25/98

U Analyte undetected at given RL

RL Reporting Limit

FORM-I

ANALYTICAL
RESOURCES
INCORPORATED

INORGANICS ANALYSIS DATA SHEET
DISSOLVED METALS

Sample No: VP-1

Lab Sample ID: W676A
LIMS ID: 98-12169
Matrix: Water

QC Report No: W676-Dames & Moore
Project: Holden Mine
Date Sampled: 06/15/98
Date Received: 06/15/98

Data Release Authorized:
Reported: 06/22/98

Prep Meth	Prep Date	Analysis Method	Analysis Date	CAS Number	Analyte	RL	ug/L
3005	06/17/98	6010	06/18/98	7429-90-5	Aluminum	20	20
200.8	06/17/98	200.8	06/18/98	7440-38-2	Arsenic	0.04	0.07
200.8	06/17/98	200.8	06/18/98	7440-39-3	Barium	0.04	2.09
200.8	06/17/98	200.8	06/18/98	7440-41-7	Beryllium	0.04	0.04 U
200.8	06/17/98	200.8	06/18/98	7440-43-9	Cadmium	0.04	0.04 U
3005	06/17/98	6010	06/18/98	7440-70-2	Calcium	20	4,820
200.8	06/17/98	200.8	06/18/98	7440-47-3	Chromium	0.2	0.2 U
200.8	06/17/98	200.8	06/18/98	7440-50-8	Copper	0.2	0.9 U
3005	06/17/98	6010	06/18/98	7439-89-6	Iron	20	30
200.8	06/17/98	200.8	06/18/98	7439-92-1	Lead	0.2	0.3
3005	06/17/98	6010	06/18/98	7439-95-4	Magnesium	20	670
200.8	06/17/98	200.8	06/18/98	7439-96-5	Manganese	0.04	1.04
200.8	06/17/98	200.8	06/18/98	7439-98-7	Molybdenum	0.04	0.32
200.8	06/17/98	200.8	06/18/98	7440-02-0	Nickel	0.2	0.2
3005	06/17/98	6010	06/18/98	7440-09-7	Potassium	500	800
200.8	06/17/98	200.8	06/18/98	7440-22-4	Silver	0.04	0.04 U
3005	06/17/98	6010	06/18/98	7440-23-5	Sodium	50	1,050
3005	06/17/98	6010	06/18/98	7440-66-6	Zinc	4	411 *

Calculated Dissolved Hardness (mg-CaCO3/L): 15

* Result is anomalous.

Km 4/25/98

U Analyte undetected at given RL

RL Reporting Limit

FORM-I

ANALYTICAL
RESOURCES
INCORPORATED

INORGANICS ANALYSIS DATA SHEET
TOTAL METALS

Sample No: Method Blank

Lab Sample ID: W676MB
LIMS ID: 98-12170
Matrix: Water

QC Report No: W676-Dames & Moore
Project: Holden Mine
Date Sampled: NA
Date Received: NA

Data Release Authorized:
Reported: 06/22/98

Prep Meth	Prep Date	Analysis Method	Analysis Date	CAS Number	Analyte	RL	ug/L
3005	06/17/98	6010	06/18/98	7429-90-5	Aluminum	20	20 U
200.8	06/17/98	200.8	06/18/98	7440-38-2	Arsenic	0.04	0.04 U
200.8	06/17/98	200.8	06/18/98	7440-39-3	Barium	0.04	0.04 U
200.8	06/17/98	200.8	06/18/98	7440-41-7	Beryllium	0.04	0.04 U
200.8	06/17/98	200.8	06/18/98	7440-43-9	Cadmium	0.04	0.04 U
3005	06/17/98	6010	06/18/98	7440-70-2	Calcium	20	20 U
200.8	06/17/98	200.8	06/18/98	7440-47-3	Chromium	0.2	0.2 U
200.8	06/17/98	200.8	06/18/98	7440-50-8	Copper	0.2	0.2
3005	06/17/98	6010	06/18/98	7439-89-6	Iron	20	20 U
200.8	06/17/98	200.8	06/18/98	7439-92-1	Lead	0.2	0.2 U
3005	06/17/98	6010	06/18/98	7439-95-4	Magnesium	20	20 U
200.8	06/17/98	200.8	06/18/98	7439-96-5	Manganese	0.04	0.04
200.8	06/17/98	200.8	06/18/98	7439-98-7	Molybdenum	0.04	0.04 U
200.8	06/17/98	200.8	06/18/98	7440-02-0	Nickel	0.2	0.2 U
3005	06/17/98	6010	06/18/98	7440-09-7	Potassium	500	500 U
200.8	06/17/98	200.8	06/18/98	7440-22-4	Silver	0.04	0.04 U
3005	06/17/98	6010	06/18/98	7440-23-5	Sodium	50	60
3005	06/17/98	6010	06/18/98	7440-66-6	Zinc	4	4 U

U Analyte undetected at given RL

RL Reporting Limit

FORM-I

ANALYTICAL
RESOURCES
INCORPORATED

INORGANICS ANALYSIS DATA SHEET

Sample No: STD REFERENCE
I.V. Lots 869-6 and 889-1

Lab Sample ID: W676LCS
LIMS ID: 98-12170
Matrix: Water

QC Report No: W676-Dames & Moore
Project:
Holden Mine
Date Sampled: NA
Date Received: NA

Data Release Authorized:
Reported: 06/22/98

Analyte	STD Value	Value Found	Recovery
Aluminum	2000	2090	104%
Calcium	2000	2190	110%
Iron	2000	2100	105%
Magnesium	2000	2060	103%
Potassium	20000	21000	105%
Sodium	2000	2020	101%
Zinc	1000	1030	103%

Recovery Limits 80-120

Values reported in parts per billion (ug/L)

I.V. Lot 869-6 used for GFA. I.V. Lot 889-1 used for ICP.

FORM-III-R

ANALYTICAL
RESOURCES
INCORPORATED

INORGANICS ANALYSIS DATA SHEET
TOTAL METALS

Lab Sample ID: W676LCS
LIMS ID: 98-12170
Matrix: Water

QC Report No: W676-Dames & Moore
Project: Holden Mine

Data Release Authorized:
Reported: 06/22/98

BLANK SPIKE QUALITY CONTROL REPORT

Analyte	Spike mg/L	Spike Added	% Recovery	Q
Arsenic	0.0046	0.0050	93.8%	
Barium	0.0051	0.0050	103%	
Beryllium	0.0046	0.0050	92.4%	
Cadmium	0.0047	0.0050	95.4%	
Chromium	0.0051	0.0050	102%	
Copper	0.0055	0.0050	110%	
Lead	0.0052	0.0050	104%	
Manganese	0.0052	0.0050	104%	
Molybdenum	0.0051	0.0050	102%	
Nickel	0.0054	0.0050	108%	
Silver	0.0048	0.0050	96.0%	

'Q' codes: N = control limit not met

Control Limits: 80-120%

FORM-VII

98-1216
98-12170 WG76

CHAIN-OF-CUSTODY RECORD

WHITE COPY-Original (Accompanies Samples) YELLOW COPY-Collector PINK COPY-Project Manag

Boring or Well Number	Sample Number	Depth	Time	Sample Type	Container Type	Analysis Required: DISSOLVED METAL ~~VOA 601/8010~~	VOA 602/8020	VOA 624/8240/8260	Semi Vol 625/8270	NWTPH-Gx	NWTPH-Dx	NWTPH-Dx-Ext	RCRA 8 Metals	PNA 610/8310	Pest/PCBs 8081	ASBESTOS	FIELD NOTES:	Total Number Of Containers	Laboratory
	VP-1		0825	WATER		X												2	

RELINQUISHED BY: (Signature)	DATE/TIME	RECEIVED BY: (Signature)
	6/15/98 1350	

LABORATORY NOTES:
ANALYZE FOR: ALUMINUM, ARSENIC, BARIUM, BERYLLIUM, CADMIUM, CALCIUM, CHROMIUM, COPPER, IRON, LEAD, MAGNESIUM, MANGANESE, MOLYBDENUM, NICKEL, POTASSIUM, SILVER, SODIUM, ZINC

RESULTS BY 6/19/98

ANALYTICAL LABORATORY: ARI
LABORATORY CONTACT: MARK HARRIS
D&M CONTACT: KAREN MIXON PHONE: 206 727 3369 x253

JOB NO.: 17693-005-019
PROJECT: HOLDEN MINE
LOCATION: HOLDEN, WA
COLLECTOR: S.A.D. COBURLY DATE OF COLLECTION 6/14/98

DAMES & MOORE
A DAMES & MOORE GROUP COMPANY

500 Market Place Tower
2025 First Avenue
Seattle, Washington 98121
Phone (206) 728-0744
Fax (206) 727-3350

MEMORANDUM

Date: December 11, 1998

To: Rik Langendoen, Project Manager

From: Karen Mixon, QA/QC Manager

Subject: Standard Data Quality Review
Holden Mine Remedial Investigation Phase III
Sediment Data, Fall 1998
Dames & Moore Job #17693-005-019

The standard data quality review of 18 sediment samples and 2 equipment blanks collected from October 15 through October 16, 1998 has been completed. The samples were analyzed at the Analytical Resources, Incorporated (ARI) laboratory in Seattle, Washington for metals by EPA Methods 6010A and 200.8 modified (including the following metals: aluminum, arsenic, cadmium, copper, iron, lead, manganese, and zinc), pH by EPA Method 150.1, total solids by EPA Method 160.3, total volatile solids (TVS) by EPA Method 160.4, total organic carbon (TOC) by Plumb, 1981, and acid volatile sulfides (AVS) by EPA method dated 1991. The analyses were performed in accordance with the methods specified in EPA Test Methods for Evaluating Solid Waste, SW-846, January 1995, EPA Methods for Chemical Analysis of Water and Wastes, March 1983, EPA method "Determination of Acid Volatile Sulfides and Simultaneously Extractable Metals in Sediment", April 1991, and Plumb, 1981. Grain size analyses were subcontracted by ARI to Rosa Environmental & Geotechnical Laboratory, LLC (REG) located in Seattle, Washington. The grain size analyses were performed in accordance with Puget Sound Estuary Program (PSEP) guidelines. The laboratory provided a validation package containing method associated QA/QC data as well as sample data. The following samples are associated with laboratory work order ARI# Y931:

Sample I.D.	ARI Sample #
STE-SED-101698-1	Y931A
STE-SED-101698-2	Y931B
STE-SED-101698-3A	Y931C
STE-SED-101698-3B	Y931D
STE-SED-101698-3C	Y931E
STE-SED-101698-4	Y931F
LUC-SED-101698-2-2	Y931G
LUC-SED-101698-1-2	Y931H
LUC-SED-101598-3.5-2	Y931I
LUC-SED-101598-3-1A	Y931J
LUC-SED-101598-1-1	Y931K
LUC-SED-101598-3-2	Y931L
LUC-SED-101598-3.5-1	Y931M
LUC-SED-101598-3-1C	Y931N
LUC-SED-101598-3-1B	Y931O
LUC-SED-101598-5-2	Y931P
LUC-SED-101598-2-1	Y931Q
LUC-SED-101598-5-1	Y931R
Rinse 10/15/98	Y931S
Rinse 10/16/98	Y931T

The sample matrix is sediment with the exception of samples Rinse 10/15/98 and Rinse 10/16/98 which are equipment blank samples (water).

The following comments refer to ARI's performance in meeting quality control specifications described in the EPA documents "EPA Test Methods for Evaluating Solid Waste, SW-846", January 1995, "Methods for Chemical Analysis of Water and Wastes", March 1983, and "USEPA Contract Laboratory Program (CLP) National Functional Guidelines for Inorganic Data Review", February 1994. AVS, TOC, and grain size data were evaluated using guidance referenced in methods published in the following sources: "Determination of Acid Volatile Sulfides and Simultaneously Extractable Metals in Sediment", EPA, April 1991, PSEP guidelines, and Plumb 1981. Data were also reviewed in reference to the Quality Assurance Project Plan (QAPP) prepared for the Phase III Remedial Investigation referenced in addendum (August 28, 1998) to the Sampling and Analysis Plan.

The report is divided into subsections based on type of analyses performed.

Metals

Samples were prepared in the laboratory using EPA Methods 3010, 3050, and 200.8 as appropriate. Samples were analyzed by ICP (EPA Method 6010A) and ICP MS (EPA Method 200.8 Modified) methods.

1. Holding Time - Acceptable
2. Tunes (ICP MS analysis only) - Acceptable
3. Initial Calibration - Acceptable
4. Continuing Calibration - Acceptable
5. Blanks

Aluminum (21.3 ug/L) was detected in the continuing calibration blank (CCB) analyzed prior to samples STE-SED-101698-4, LUC-SED-101698-2-2, LUC-SED-101698-1-2, LUC-SED-101598-3.5-2, LUC-SED-101598-3-1A, LUC-SED-101598-1-1, LUC-SED-101598-3-2, LUC-SED-101598-3.5-1, LUC-SED-101598-3-1C, and LUC-SED-101598-3-1B. As the concentration of aluminum in the samples was several orders of magnitude above the CCB concentration, the data were not affected. Data qualifiers were not assigned.

Aluminum (7 mg/kg) was detected in the method blank associated with the sediment samples in this sample group. The concentration of aluminum detected in the samples was greater than 10X the concentration detected in the method blank. Data were not qualified.

Aluminum (0.03 mg/L) was detected in the method blank associated with samples Rinse 10/15/98 and Rinse 10/16/98. The following metals were detected in the rinsate blanks:

Rinse 10/15/98		Rinse 10/16/98	
Aluminum	0.17 mg/L	Aluminum	0.10 mg/L
Manganese	0.0003 mg/L	Iron	0.03 mg/L
Zinc	0.203 mg/L	Manganese	0.0006 mg/L
		Zinc	0.007 mg/L

The aluminum results were qualified as not detected in the rinsate samples due to CCB results. The concentration of manganese, iron, and zinc in the associated sediment samples were orders of magnitude higher than the rinsate blanks. The sample data were not affected. Data were not qualified.

6. Internal Standards (ICP MS analysis only) – Acceptable

7. ICP Interference Check (ICP analysis only) - Acceptable

8. Laboratory Control Sample (LCS) – Acceptable

A standard reference material (SRM) was analyzed in lieu of a typical LCS. Lead recovery (124%) in the SRM associated with this sample set was above the typical LCS control limits of 80 to 120%. However, the recovery was within the advisory range published by the supplier. Data were not qualified based on the LCS recoveries.

9. Laboratory Duplicate Sample - Acceptable

10. Field Duplicate

Field replicates were collected and labeled LUC-SED-101598-1A, -1B, and -1C. Data were comparable for all analyses. It is noted that the relative percent difference for cadmium was 53%. Data qualifiers were not assigned based on the field replicate results.

11. Matrix Spike

A matrix spike was performed on sediment sample STE-SED-101698-1. Aluminum (210%) and iron (511%) recoveries were outside of the control limits (75-125%). The concentration of aluminum and iron in the original sample exceeded the spiking concentration by greater than 4X. Data qualification was not required.

12. ICP Serial Dilution (ICP analysis only) - Acceptable

13. Detection Limits - Acceptable

14. Type of Review - Standard

15. Overall Assessment of Data

The usefulness of the data is based on EPA guidance documents listed above. Upon consideration of the information presented above, the data are acceptable except where flagged with data qualifiers that modify the usefulness of the individual values.

Conventional Analyses

Samples were analyzed for pH, total solids, total volatile solids (TVS), acid volatile sulfides (AVS), total organic carbon (TOC), and grain size by EPA or other appropriate methodology identified in the introduction to this report.

1. Hold Time

The analysis for pH in the sediment samples was performed 14 days after sample collection. As pH generally should be analyzed as soon as possible after sample collection, the data is qualified as estimated and flagged "J" accordingly.

2. Initial Calibration – Acceptable

   Applicable to AVS and TOC analyses only.

3. Continuing Calibration – Acceptable

   Applicable to AVS and TOC analyses only.

4. Blanks - Acceptable

5. Laboratory Control Sample (LCS) – Acceptable

   Applicable to pH, AVS, and TOC analyses only.

6. Laboratory Sample Duplicate – Acceptable

   Per PSEP guidelines for grain size analysis, one sample was analyzed in triplicate.

7. Field Duplicate – Acceptable

Field replicates were collected and labeled LUC-SED-101598-1A, -1B, and –1C. Results indicate that total solids are similar. TOC, TVS, AVS, and pH results indicate variability. The results did not indicate variability related specifically to a sample but variability by analytical method from sample to sample. It appears that the variability is not due to sampling technique but specifically to individual sample content. Data were not qualified based on field replicate results.

8. Matrix Spike (MS) – Acceptable

   Applicable to AVS and TOC analyses only.

9. Detection Limits – Acceptable

10. Type of Review – Summary

11. Overall Assessment of Data

The usefulness of the data is based on EPA guidance documents listed above. Upon consideration of the information presented above, the data are acceptable except where flagged with data qualifiers that modify the usefulness of the individual values.

Data Qualifiers

U The analyte was analyzed for, but was not detected above the reported sample quantitation limit.

J The analyte was positively identified; the associated numerical value is the approximate concentration of the analyte in the sample.

UJ The analyte was not detected above the reported sample quantitation limit. However, the reported quantitation limit is approximate and may or may not represent the actual limit of quantitation necessary to accurately and precisely measure the analyte in the sample..

R The sample results are rejected due to serious deficiencies in the ability to analyze the sample and meet quality control criteria. The presence or absence of the analyte cannot be verified.

ANALYTICAL
RESOURCES
INCORPORATED

INORGANICS ANALYSIS DATA SHEET
TOTAL METALS

Sample No: STE-SED-101698-1

Lab Sample ID: Y931A
LIMS ID: 98-21651
Matrix: Sediment

QC Report No: Y931-Dames & Moore
Project: Holden Mine
17693-005-019
Date Sampled: 10/16/98
Date Received: 10/19/98

Data Release Authorized:
Reported: 11/04/98

Percent Total Solids: 58.7%

Prep Meth	Prep Date	Analysis Method	Analysis Date	CAS Number	Analyte	RL	mg/kg-dry
3050	10/23/98	6010	10/29/98	7429-90-5	Aluminum	3	12,500
3050	10/23/98	200.8	10/30/98	7440-38-2	Arsenic	0.3	21.1
3050	10/23/98	200.8	10/30/98	7440-43-9	Cadmium	0.3	0.4
3050	10/23/98	200.8	10/30/98	7440-50-8	Copper	2	24
3050	10/23/98	6010	10/29/98	7439-89-6	Iron	3	23,700
3050	10/23/98	200.8	10/30/98	7439-92-1	Lead	2	8
3050	10/23/98	6010	10/29/98	7439-96-5	Manganese	0.2	255
3050	10/23/98	6010	10/29/98	7440-66-6	Zinc	0.7	112

U Analyte undetected at given RL

RL Reporting Limit

FORM-I

ANALYTICAL
RESOURCES
INCORPORATED

INORGANICS ANALYSIS DATA SHEET
TOTAL METALS

Sample No: STE-SED-101698-2

Lab Sample ID: Y931B
LIMS ID: 98-21652
Matrix: Sediment

QC Report No: Y931-Dames & Moore
Project: Holden Mine
17693-005-019
Date Sampled: 10/16/98
Date Received: 10/19/98

Data Release Authorized:
Reported: 11/04/98

Percent Total Solids: 59.8%

Prep Meth	Prep Date	Analysis Method	Analysis Date	CAS Number	Analyte	RL	mg/kg-dry
3050	10/23/98	6010	10/29/98	7429-90-5	Aluminum	3	12,600
3050	10/23/98	200.8	10/30/98	7440-38-2	Arsenic	0.3	8.9
3050	10/23/98	200.8	10/30/98	7440-43-9	Cadmium	0.3	0.3 U
3050	10/23/98	200.8	10/30/98	7440-50-8	Copper	2	21
3050	10/23/98	6010	10/29/98	7439-89-6	Iron	3	18,800
3050	10/23/98	200.8	10/30/98	7439-92-1	Lead	2	6
3050	10/23/98	6010	10/29/98	7439-96-5	Manganese	0.2	212
3050	10/23/98	6010	10/29/98	7440-66-6	Zinc	0.7	68.7

U Analyte undetected at given RL

RL Reporting Limit

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ANALYTICAL
RESOURCES
INCORPORATED

INORGANICS ANALYSIS DATA SHEET **Sample No: STE-SED-101698-3A**
TOTAL METALS

Lab Sample ID: Y931C
LIMS ID: 98-21653
Matrix: Sediment

QC Report No: Y931-Dames & Moore
Project: Holden Mine
17693-005-019
Date Sampled: 10/16/98
Date Received: 10/19/98

Data Release Authorized:
Reported: 11/04/98

Percent Total Solids: 39.2%

Prep Meth	Prep Date	Analysis Method	Analysis Date	CAS Number	Analyte	RL	mg/kg-dry
3050	10/23/98	6010	10/29/98	7429-90-5	Aluminum	5	16,300
3050	10/23/98	200.8	10/30/98	7440-38-2	Arsenic	0.5	13.5
3050	10/23/98	200.8	10/30/98	7440-43-9	Cadmium	0.5	0.5
3050	10/23/98	200.8	10/30/98	7440-50-8	Copper	2	40
3050	10/23/98	6010	10/29/98	7439-89-6	Iron	5	26,300
3050	10/23/98	200.8	10/30/98	7439-92-1	Lead	2	11
3050	10/23/98	6010	10/29/98	7439-96-5	Manganese	0.3	339
3050	10/23/98	6010	10/29/98	7440-66-6	Zinc	1	93

U Analyte undetected at given RL

RL Reporting Limit

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**ANALYTICAL
RESOURCES
INCORPORATED**

**INORGANICS ANALYSIS DATA SHEET
TOTAL METALS**

Sample No: STE-SED-101698-3B

Lab Sample ID: Y931D
LIMS ID: 98-21654
Matrix: Sediment

QC Report No: Y931-Dames & Moore
Project: Holden Mine
17693-005-019
Date Sampled: 10/16/98
Date Received: 10/19/98

Data Release Authorized:
Reported: 11/04/98

Percent Total Solids: 43.8%

Prep Meth	Prep Date	Analysis Method	Analysis Date	CAS Number	Analyte	RL	mg/kg-dry
3050	10/23/98	6010	10/29/98	7429-90-5	Aluminum	4	17,400
3050	10/23/98	200.8	10/30/98	7440-38-2	Arsenic	0.5	12.4
3050	10/23/98	200.8	10/30/98	7440-43-9	Cadmium	0.5	0.5 U
3050	10/23/98	200.8	10/30/98	7440-50-8	Copper	2	39
3050	10/23/98	6010	10/29/98	7439-89-6	Iron	4	25,400
3050	10/23/98	200.8	10/30/98	7439-92-1	Lead	2	12
3050	10/23/98	6010	10/29/98	7439-96-5	Manganese	0.2	342
3050	10/23/98	6010	10/29/98	7440-66-6	Zinc	0.9	93.5

U	Analyte undetected at given RL
RL	Reporting Limit

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INORGANICS ANALYSIS DATA SHEET
TOTAL METALS

Sample No: STE-SED-101698-3C

Lab Sample ID: Y931E
LIMS ID: 98-21655
Matrix: Sediment

QC Report No: Y931-Dames & Moore
Project: Holden Mine
17693-005-019
Date Sampled: 10/16/98
Date Received: 10/19/98

Data Release Authorized:
Reported: 11/04/98

Percent Total Solids: 34.9%

Prep Meth	Prep Date	Analysis Method	Analysis Date	CAS Number	Analyte	RL	mg/kg-dry
3050	10/23/98	6010	10/29/98	7429-90-5	Aluminum	6	20,000
3050	10/23/98	200.8	10/30/98	7440-38-2	Arsenic	0.6	14.6
3050	10/23/98	200.8	10/30/98	7440-43-9	Cadmium	0.6	0.6 U
3050	10/23/98	200.8	10/30/98	7440-50-8	Copper	3	48
3050	10/23/98	6010	10/29/98	7439-89-6	Iron	6	30,100
3050	10/23/98	200.8	10/30/98	7439-92-1	Lead	3	14
3050	10/23/98	6010	10/29/98	7439-96-5	Manganese	0.3	404
3050	10/23/98	6010	10/29/98	7440-66-6	Zinc	1	113

U Analyte undetected at given RL

RL Reporting Limit

ANALYTICAL
RESOURCES
INCORPORATED

INORGANICS ANALYSIS DATA SHEET
TOTAL METALS

Sample No: STE-SED-101698-4

Lab Sample ID: Y931F
LIMS ID: 98-21656
Matrix: Sediment

QC Report No: Y931-Dames & Moore
Project: Holden Mine
17693-005-019
Date Sampled: 10/16/98
Date Received: 10/19/98

Data Release Authorized:
Reported: 11/04/98

Percent Total Solids: 45.5%

Prep Meth	Prep Date	Analysis Method	Analysis Date	CAS Number	Analyte	RL	mg/kg-dry
3050	10/23/98	6010	10/29/98	7429-90-5	Aluminum	4	18,100
3050	10/23/98	200.8	10/30/98	7440-38-2	Arsenic	0.4	14.4
3050	10/23/98	200.8	10/30/98	7440-43-9	Cadmium	0.4	0.4 U
3050	10/23/98	200.8	10/30/98	7440-50-8	Copper	2	40
3050	10/23/98	6010	10/29/98	7439-89-6	Iron	4	28,900
3050	10/23/98	200.8	10/30/98	7439-92-1	Lead	2	10
3050	10/23/98	6010	10/29/98	7439-96-5	Manganese	0.2	353
3050	10/23/98	6010	10/29/98	7440-66-6	Zinc	0.8	106

U Analyte undetected at given RL

RL Reporting Limit

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INORGANICS ANALYSIS DATA SHEET
TOTAL METALS

Sample No: LUC-SED-101698-2-2

Lab Sample ID: Y931G
LIMS ID: 98-21657
Matrix: Sediment

QC Report No: Y931-Dames & Moore
Project: Holden Mine
17693-005-019
Date Sampled: 10/16/98
Date Received: 10/19/98

Data Release Authorized:
Reported: 11/04/98

Percent Total Solids: 51.1%

Prep Meth	Prep Date	Analysis Method	Analysis Date	CAS Number	Analyte	RL	mg/kg-dry
3050	10/23/98	6010	10/29/98	7429-90-5	Aluminum	4	13,500
3050	10/23/98	200.8	10/30/98	7440-38-2	Arsenic	0.4	6.3
3050	10/23/98	200.8	10/30/98	7440-43-9	Cadmium	0.4	0.9
3050	10/23/98	200.8	10/30/98	7440-50-8	Copper	2	109
3050	10/23/98	6010	10/29/98	7439-89-6	Iron	4	24,200
3050	10/23/98	200.8	10/30/98	7439-92-1	Lead	2	7
3050	10/23/98	6010	10/29/98	7439-96-5	Manganese	0.2	250
3050	10/23/98	6010	10/29/98	7440-66-6	Zinc	0.7	226

U Analyte undetected at given RL

RL Reporting Limit

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INORGANICS ANALYSIS DATA SHEET
TOTAL METALS

Sample No: LUC-SED-101698-1-2

Lab Sample ID: Y931H
LIMS ID: 98-21658
Matrix: Sediment

QC Report No: Y931-Dames & Moore
Project: Holden Mine
17693-005-019
Date Sampled: 10/16/98
Date Received: 10/19/98

Data Release Authorized:
Reported: 11/04/98

Percent Total Solids: 40.1%

Prep Meth	Prep Date	Analysis Method	Analysis Date	CAS Number	Analyte	RL	mg/kg-dry
3050	10/23/98	6010	10/29/98	7429-90-5	Aluminum	5	16,500
3050	10/23/98	200.8	10/30/98	7440-38-2	Arsenic	0.5	11.0
3050	10/23/98	200.8	10/30/98	7440-43-9	Cadmium	0.5	1.9
3050	10/23/98	200.8	10/30/98	7440-50-8	Copper	2	191
3050	10/23/98	6010	10/29/98	7439-89-6	Iron	5	29,300
3050	10/23/98	200.8	10/30/98	7439-92-1	Lead	2	12
3050	10/23/98	6010	10/29/98	7439-96-5	Manganese	0.2	308
3050	10/23/98	6010	10/29/98	7440-66-6	Zinc	0.9	318

U Analyte undetected at given RL

RL Reporting Limit

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RESOURCES
INCORPORATED

INORGANICS ANALYSIS DATA SHEET
TOTAL METALS

Sample No: LUC-SED-101598-3.5-2

Lab Sample ID: Y931I
LIMS ID: 98-21659
Matrix: Sediment

QC Report No: Y931-Dames & Moore
Project: Holden Mine
17693-005-019
Date Sampled: 10/15/98
Date Received: 10/19/98

Data Release Authorized:
Reported: 11/04/98

Percent Total Solids: 39.4%

Prep Meth	Prep Date	Analysis Method	Analysis Date	CAS Number	Analyte	RL	mg/kg-dry
3050	10/23/98	6010	10/29/98	7429-90-5	Aluminum	5	16,200
3050	10/23/98	200.8	10/30/98	7440-38-2	Arsenic	0.5	9.4
3050	10/23/98	200.8	10/30/98	7440-43-9	Cadmium	0.5	2.0
3050	10/23/98	200.8	10/30/98	7440-50-8	Copper	2	219
3050	10/23/98	6010	10/29/98	7439-89-6	Iron	5	28,300
3050	10/23/98	200.8	10/30/98	7439-92-1	Lead	2	14
3050	10/23/98	6010	10/29/98	7439-96-5	Manganese	0.3	282
3050	10/23/98	6010	10/29/98	7440-66-6	Zinc	1	365

U Analyte undetected at given RL

RL Reporting Limit

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RESOURCES
INCORPORATED

INORGANICS ANALYSIS DATA SHEET
TOTAL METALS

Sample No: LUC-SED-101598-3-1A

Lab Sample ID: Y931J
LIMS ID: 98-21660
Matrix: Sediment

QC Report No: Y931-Dames & Moore
Project: Holden Mine
17693-005-019
Date Sampled: 10/15/98
Date Received: 10/19/98

Data Release Authorized:
Reported: 11/04/98

Percent Total Solids: 43.1%

Prep Meth	Prep Date	Analysis Method	Analysis Date	CAS Number	Analyte	RL	mg/kg-dry
3050	10/23/98	6010	10/29/98	7429-90-5	Aluminum	5	14,600
3050	10/23/98	200.8	10/30/98	7440-38-2	Arsenic	0.5	6.6
3050	10/23/98	200.8	10/30/98	7440-43-9	Cadmium	0.5	0.9
3050	10/23/98	200.8	10/30/98	7440-50-8	Copper	2	106
3050	10/23/98	6010	10/29/98	7439-89-6	Iron	5	28,400
3050	10/23/98	200.8	10/30/98	7439-92-1	Lead	2	7
3050	10/23/98	6010	10/29/98	7439-96-5	Manganese	0.2	287
3050	10/23/98	6010	10/29/98	7440-66-6	Zinc	0.9	285

U Analyte undetected at given RL

RL Reporting Limit

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RESOURCES
INCORPORATED

INORGANICS ANALYSIS DATA SHEET
TOTAL METALS

Sample No: LUC-SED-101598-1-1

Lab Sample ID: Y931K
LIMS ID: 98-21661
Matrix: Sediment

QC Report No: Y931-Dames & Moore
Project: Holden Mine
17693-005-019
Date Sampled: 10/15/98
Date Received: 10/19/98

Data Release Authorized:
Reported: 11/04/98

Percent Total Solids: 74.3%

Prep Meth	Prep Date	Analysis Method	Analysis Date	CAS Number	Analyte	RL	mg/kg-dry
3050	10/23/98	6010	10/29/98	7429-90-5	Aluminum	3	11,400
3050	10/23/98	200.8	10/30/98	7440-38-2	Arsenic	0.3	4.6
3050	10/23/98	200.8	10/30/98	7440-43-9	Cadmium	0.3	0.6
3050	10/23/98	200.8	10/30/98	7440-50-8	Copper	1	67
3050	10/23/98	6010	10/29/98	7439-89-6	Iron	3	20,800
3050	10/23/98	200.8	10/30/98	7439-92-1	Lead	1	5
3050	10/23/98	6010	10/29/98	7439-96-5	Manganese	0.1	270
3050	10/23/98	6010	10/29/98	7440-66-6	Zinc	0.5	173

U Analyte undetected at given RL

RL Reporting Limit

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INORGANICS ANALYSIS DATA SHEET
TOTAL METALS

Sample No: LUC-SED-101598-3-2

Lab Sample ID: Y931L
LIMS ID: 98-21662
Matrix: Sediment

QC Report No: Y931-Dames & Moore
Project: Holden Mine
17693-005-019
Date Sampled: 10/15/98
Date Received: 10/19/98

Data Release Authorized:
Reported: 11/04/98

Percent Total Solids: 32.1%

Prep Meth	Prep Date	Analysis Method	Analysis Date	CAS Number	Analyte	RL	mg/kg-dry
3050	10/23/98	6010	10/29/98	7429-90-5	Aluminum	6	18,400
3050	10/23/98	200.8	10/30/98	7440-38-2	Arsenic	0.6	7.7
3050	10/23/98	200.8	10/30/98	7440-43-9	Cadmium	0.6	1.4
3050	10/23/98	200.8	10/30/98	7440-50-8	Copper	3	171
3050	10/23/98	6010	10/29/98	7439-89-6	Iron	6	33,200
3050	10/23/98	200.8	10/30/98	7439-92-1	Lead	3	9
3050	10/23/98	6010	10/29/98	7439-96-5	Manganese	0.3	355
3050	10/23/98	6010	10/29/98	7440-66-6	Zinc	1	334

U	Analyte undetected at given RL
RL	Reporting Limit

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ANALYTICAL
RESOURCES
INCORPORATED

INORGANICS ANALYSIS DATA SHEET
TOTAL METALS

Sample No: LUC-SED-101598-3.5-1

Lab Sample ID: Y931M
LIMS ID: 98-21663
Matrix: Sediment

QC Report No: Y931-Dames & Moore
Project: Holden Mine
17693-005-019
Date Sampled: 10/15/98
Date Received: 10/19/98

Data Release Authorized:
Reported: 11/04/98

Percent Total Solids: 49.1%

Prep Meth	Prep Date	Analysis Method	Analysis Date	CAS Number	Analyte	RL	mg/kg-dry
3050	10/23/98	6010	10/29/98	7429-90-5	Aluminum	4	12,100
3050	10/23/98	200.8	10/30/98	7440-38-2	Arsenic	0.4	6.6
3050	10/23/98	200.8	10/30/98	7440-43-9	Cadmium	0.4	1.3
3050	10/23/98	200.8	10/30/98	7440-50-8	Copper	2	140
3050	10/23/98	6010	10/29/98	7439-89-6	Iron	4	20,700
3050	10/23/98	200.8	10/30/98	7439-92-1	Lead	2	8
3050	10/23/98	6010	10/29/98	7439-96-5	Manganese	0.2	207
3050	10/23/98	6010	10/29/98	7440-66-6	Zinc	0.8	297

U	Analyte undetected at given RL
RL	Reporting Limit

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ANALYTICAL
RESOURCES
INCORPORATED

INORGANICS ANALYSIS DATA SHEET
TOTAL METALS

Sample No: LUC-SED-101598-3-1C

Lab Sample ID: Y931N
LIMS ID: 98-21664
Matrix: Sediment

QC Report No: Y931-Dames & Moore
Project: Holden Mine
17693-005-019
Date Sampled: 10/15/98
Date Received: 10/19/98

Data Release Authorized:
Reported: 11/04/98

Percent Total Solids: 45.7%

Prep Meth	Prep Date	Analysis Method	Analysis Date	CAS Number	Analyte	RL	mg/kg-dry
3050	10/23/98	6010	10/29/98	7429-90-5	Aluminum	4	14,600
3050	10/23/98	200.8	10/30/98	7440-38-2	Arsenic	0.4	7.6
3050	10/23/98	200.8	10/30/98	7440-43-9	Cadmium	0.4	1.1
3050	10/23/98	200.8	10/30/98	7440-50-8	Copper	2	121
3050	10/23/98	6010	10/29/98	7439-89-6	Iron	4	27,000
3050	10/23/98	200.8	10/30/98	7439-92-1	Lead	2	7
3050	10/23/98	6010	10/29/98	7439-96-5	Manganese	0.2	283
3050	10/23/98	6010	10/29/98	7440-66-6	Zinc	0.8	297

U	Analyte undetected at given RL
RL	Reporting Limit

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ANALYTICAL
RESOURCES
INCORPORATED

INORGANICS ANALYSIS DATA SHEET
TOTAL METALS

Sample No: LUC-SED-101598-3-1B

Lab Sample ID: Y9310
LIMS ID: 98-21665
Matrix: Sediment

QC Report No: Y931-Dames & Moore
Project: Holden Mine
17693-005-019
Date Sampled: 10/15/98
Date Received: 10/19/98

Data Release Authorized:
Reported: 11/04/98

Percent Total Solids: 33.3%

Prep Meth	Prep Date	Analysis Method	Analysis Date	CAS Number	Analyte	RL	mg/kg-dry
3050	10/23/98	6010	10/29/98	7429-90-5	Aluminum	6	13,800
3050	10/23/98	200.8	10/30/98	7440-38-2	Arsenic	0.6	9.8
3050	10/23/98	200.8	10/30/98	7440-43-9	Cadmium	0.6	2.3
3050	10/23/98	200.8	10/30/98	7440-50-8	Copper	3	165
3050	10/23/98	6010	10/29/98	7439-89-6	Iron	6	26,100
3050	10/23/98	200.8	10/30/98	7439-92-1	Lead	3	9
3050	10/23/98	6010	10/29/98	7439-96-5	Manganese	0.3	264
3050	10/23/98	6010	10/29/98	7440-66-6	Zinc	1	352

U Analyte undetected at given RL

RL Reporting Limit

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ANALYTICAL
RESOURCES
INCORPORATED

INORGANICS ANALYSIS DATA SHEET
TOTAL METALS

Sample No: LUC-SED-101598-5-2

Lab Sample ID: Y931P
LIMS ID: 98-21666
Matrix: Sediment

QC Report No: Y931-Dames & Moore
Project: Holden Mine
17693-005-019
Date Sampled: 10/15/98
Date Received: 10/19/98

Data Release Authorized:
Reported: 11/04/98

Percent Total Solids: 50.3%

Prep Meth	Prep Date	Analysis Method	Analysis Date	CAS Number	Analyte	RL	mg/kg-dry
3050	10/23/98	6010	10/29/98	7429-90-5	Aluminum	4	15,000
3050	10/23/98	200.8	10/30/98	7440-38-2	Arsenic	0.4	9.0
3050	10/23/98	200.8	10/30/98	7440-43-9	Cadmium	0.4	1.2
3050	10/23/98	200.8	10/30/98	7440-50-8	Copper	2	153
3050	10/23/98	6010	10/29/98	7439-89-6	Iron	4	27,800
3050	10/23/98	200.8	10/30/98	7439-92-1	Lead	2	11
3050	10/23/98	6010	10/29/98	7439-96-5	Manganese	0.2	271
3050	10/23/98	6010	10/29/98	7440-66-6	Zinc	0.7	288

U Analyte undetected at given RL

RL Reporting Limit

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ANALYTICAL
RESOURCES
INCORPORATED

INORGANICS ANALYSIS DATA SHEET
TOTAL METALS

Sample No: LUC-SED-101598-2-1

Lab Sample ID: Y931Q
LIMS ID: 98-21667
Matrix: Sediment

QC Report No: Y931-Dames & Moore
Project: Holden Mine
17693-005-019
Date Sampled: 10/15/98
Date Received: 10/19/98

Data Release Authorized:
Reported: 11/04/98

Percent Total Solids: 75.4%

Prep Meth	Prep Date	Analysis Method	Analysis Date	CAS Number	Analyte	RL	mg/kg-dry
3050	10/23/98	6010	10/29/98	7429-90-5	Aluminum	3	9,390
3050	10/23/98	200.8	10/30/98	7440-38-2	Arsenic	0.2	3.1
3050	10/23/98	200.8	10/30/98	7440-43-9	Cadmium	0.2	0.4
3050	10/23/98	200.8	10/30/98	7440-50-8	Copper	1	46
3050	10/23/98	6010	10/29/98	7439-89-6	Iron	3	15,400
3050	10/23/98	200.8	10/30/98	7439-92-1	Lead	1	4
3050	10/23/98	6010	10/29/98	7439-96-5	Manganese	0.1	215
3050	10/23/98	6010	10/29/98	7440-66-6	Zinc	0.5	131

U Analyte undetected at given RL

RL Reporting Limit

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ANALYTICAL
RESOURCES
INCORPORATED

INORGANICS ANALYSIS DATA SHEET
TOTAL METALS

Sample No: LUC-SED-101598-5-1

Lab Sample ID: Y931R
LIMS ID: 98-21668
Matrix: Sediment

QC Report No: Y931-Dames & Moore
Project: Holden Mine
17693-005-019
Date Sampled: 10/15/98
Date Received: 10/19/98

Data Release Authorized:
Reported: 11/04/98

Percent Total Solids: 43.1%

Prep Meth	Prep Date	Analysis Method	Analysis Date	CAS Number	Analyte	RL	mg/kg-dry
3050	10/23/98	6010	10/29/98	7429-90-5	Aluminum	5	16,100
3050	10/23/98	200.8	10/30/98	7440-38-2	Arsenic	0.5	18.8
3050	10/23/98	200.8	10/30/98	7440-43-9	Cadmium	0.5	1.3
3050	10/23/98	200.8	10/30/98	7440-50-8	Copper	2	170
3050	10/23/98	6010	10/29/98	7439-89-6	Iron	5	52,800
3050	10/23/98	200.8	10/30/98	7439-92-1	Lead	2	16
3050	10/23/98	6010	10/29/98	7439-96-5	Manganese	0.2	408
3050	10/23/98	6010	10/29/98	7440-66-6	Zinc	0.9	426

U Analyte undetected at given RL

RL Reporting Limit

FORM-I

INORGANICS ANALYSIS DATA SHEET
TOTAL METALS

Sample No: Method Blank

Lab Sample ID: Y931MB
LIMS ID: 98-21651
Matrix: Sediment

QC Report No: Y931-Dames & Moore
Project: Holden Mine
17693-005-019
Date Sampled: NA
Date Received: NA

Data Release Authorized:
Reported: 11/04/98

Percent Total Solids: NA

Prep Meth	Prep Date	Analysis Method	Analysis Date	CAS Number	Analyte	RL	mg/kg-dry
3050	10/23/98	6010	10/29/98	7429-90-5	Aluminum	2	7
3050	10/23/98	200.8	10/30/98	7440-38-2	Arsenic	0.2	0.2 U
3050	10/23/98	200.8	10/30/98	7440-43-9	Cadmium	0.2	0.2 U
3050	10/23/98	200.8	10/30/98	7440-50-8	Copper	1	1 U
3050	10/23/98	6010	10/29/98	7439-89-6	Iron	2	2 U
3050	10/23/98	200.8	10/30/98	7439-92-1	Lead	1	1 U
3050	10/23/98	6010	10/29/98	7439-96-5	Manganese	0.1	0.1 U
3050	10/23/98	6010	10/29/98	7440-66-6	Zinc	0.4	0.4 U

U Analyte undetected at given RL

RL Reporting Limit

FORM-I

INORGANICS ANALYSIS DATA SHEET

Sample No: STD REFERENCE
ERA Lot 233

Lab Sample ID: Y931-SRM
LIMS ID: 98-21651
Matrix: Sediment

QC Report No: Y931-Dames & Moore
Project: Holden Mine
17693-005-019
Date Sampled: NA
Date Received: NA

Data Release Authorized:
Reported: 11/04/98

Analyte	**mg/kg-dry**	**Certified Value**	**Advisory Range**
Aluminum	4640	3980	2100-5860
Arsenic	114	108	80.1-136
Cadmium	119	114	68.6-159
Copper	79.5	68.9	56.4-81.3
Iron	7350	7300	2920-11700
Lead	55.1	44.3	33.7-54.9
Manganese	128	128	93.7-162
Zinc	83.7	85.6	66.2-105

FORM-VII

ANALYTICAL
RESOURCES
INCORPORATED

INORGANIC ANALYSIS DATA SHEET
TOTAL METALS

Sample No: STE-SED-101698-1
QC Report No: Y931-Dames & Moore
Project: Holden Mine
17693-005-019
Date Received: 10/19/98

Lab Sample ID: Y931A
LIMS ID: 98-21651
Matrix: Sediment

Data Release Authorized:
Reported: 11/04/98

MATRIX DUPLICATE QUALITY CONTROL REPORT

Analyte	Analysis Method	Sample mg/kg-dry	Duplicate mg/kg-dry	RPD	Control Limit	Q
Aluminum	6010	12500	12500	0.0%	+/- 20 %	
Arsenic	200.8	21.1	19.1	10.0%	+/- 20 %	
Cadmium	200.8	0.4	0.4	0.0%	+/- 0.3	L
Copper	200.8	24	23	4.3%	+/- 20 %	
Iron	6010	23700	24600	3.7%	+/- 20 %	
Lead	200.8	8	8	0.0%	+/- 20 %	
Manganese	6010	255	260	1.9%	+/- 20 %	
Zinc	6010	112	110	1.8%	+/- 20 %	

'Q' codes:
* = control limit not met
L = RPD not valid, alternate limit = detection limit

ANALYTICAL
RESOURCES
INCORPORATED

INORGANICS ANALYSIS DATA SHEET
TOTAL METALS

Lab Sample ID: Y931A
LIMS ID: 98-21651
Matrix: Sediment

Data Release Authorized:
Reported: 11/04/98

Sample No: STE-SED-101698-1
QC Report No: Y931-Dames & Moore
Project: Holden Mine
17693-005-019
Date Received: 10/19/98

MATRIX SPIKE QUALITY CONTROL REPORT

Analyte	Analysis Method	Sample mg/kg-dry	Spike mg/kg-dry	Spike Added	% Recovery	Q
Aluminum	6010	12500	13900	667	210%	H
Arsenic	200.8	21.1	59.8	39.8	97.2%	
Cadmium	200.8	0.4	40.1	39.8	99.7%	
Copper	200.8	24	61	40	92.5%	
Iron	6010	23700	25400	333	511%	H
Lead	200.8	8	47	40	97.5%	
Manganese	6010	255	422	167	100%	
Zinc	6010	112	265	167	91.6%	

'Q' codes:
N = control limit not met
H = %R not applicable, sample concentration too high
* = RPD control limit not met
NA = Not applicable - analyte not spiked

Control Limits:
Percent Recovery: 75-125%
RPD: +/-20%

FORM-V

ANALYTICAL
RESOURCES
INCORPORATED

INORGANICS ANALYSIS DATA SHEET
TOTAL METALS

Sample No: Rinse 10/15/98

Lab Sample ID: Y931S
LIMS ID: 98-21669
Matrix: Water

QC Report No: Y931-Dames & Moore
Project: Holden Mine
17693-005-019
Date Sampled: 10/19/98
Date Received: 10/19/98

Data Release Authorized:
Reported: 11/09/98

Prep Meth	Prep Date	Analysis Method	Analysis Date	CAS Number	Analyte	RL	mg/L	
3010	10/22/98	6010	10/29/98	7429-90-5	Aluminum	0.02	0.17	
200.8	10/22/98	200.8	10/30/98	7440-38-2	Arsenic	0.0002	0.0002	U
200.8	10/22/98	200.8	10/30/98	7440-43-9	Cadmium	0.0002	0.0002	U
200.8	10/22/98	200.8	10/30/98	7440-50-8	Copper	0.001	0.001	U
3010	10/22/98	6010	10/29/98	7439-89-6	Iron	0.02	0.02	U
200.8	10/22/98	200.8	10/30/98	7439-92-1	Lead	0.001	0.001	U
200.8	10/22/98	200.8	10/30/98	7439-96-5	Manganese	0.0002	0.0003	
3010	10/22/98	6010	10/29/98	7440-66-6	Zinc	0.004	0.203	

U	Analyte undetected at given RL
RL	Reporting Limit

FORM-I

ANALYTICAL
RESOURCES
INCORPORATED

INORGANICS ANALYSIS DATA SHEET
TOTAL METALS

Sample No: Rinse 10/16/98

Lab Sample ID: Y931T
LIMS ID: 98-21670
Matrix: Water

QC Report No: Y931-Dames & Moore
Project: Holden Mine
17693-005-019
Date Sampled: 10/19/98
Date Received: 10/19/98

Data Release Authorized
Reported: 11/09/98

Prep Meth	Prep Date	Analysis Method	Analysis Date	CAS Number	Analyte	RL	mg/L
3010	10/22/98	6010	10/29/98	7429-90-5	Aluminum	0.02	0.10
200.8	10/22/98	200.8	10/30/98	7440-38-2	Arsenic	0.0002	0.0002 U
200.8	10/22/98	200.8	10/30/98	7440-43-9	Cadmium	0.0002	0.0002 U
200.8	10/22/98	200.8	10/30/98	7440-50-8	Copper	0.001	0.001 U
3010	10/22/98	6010	10/29/98	7439-89-6	Iron	0.02	0.03
200.8	10/22/98	200.8	10/30/98	7439-92-1	Lead	0.001	0.001 U
200.8	10/22/98	200.8	10/30/98	7439-96-5	Manganese	0.0002	0.0006
3010	10/22/98	6010	10/29/98	7440-66-6	Zinc	0.004	0.007

U Analyte undetected at given RL

RL Reporting Limit

FORM-I

ANALYTICAL
RESOURCES
INCORPORATED

INORGANICS ANALYSIS DATA SHEET
TOTAL METALS

Sample No: Method Blank

Lab Sample ID: Y931MB
LIMS ID: 98-21669
Matrix: Water

QC Report No: Y931-Dames & Moore
Project: Holden Mine
17693-005-019
Date Sampled: NA
Date Received: NA

Data Release Authorized:
Reported: 11/09/98

Prep Meth	Prep Date	Analysis Method	Analysis Date	CAS Number	Analyte	RL	mg/L	
3010	10/22/98	6010	10/29/98	7429-90-5	Aluminum	0.02	0.03	
200.8	10/22/98	200.8	10/30/98	7440-38-2	Arsenic	0.0002	0.0002	U
200.8	10/22/98	200.8	10/30/98	7440-43-9	Cadmium	0.0002	0.0002	U
200.8	10/22/98	200.8	10/30/98	7440-50-8	Copper	0.001	0.001	U
3010	10/22/98	6010	10/29/98	7439-89-6	Iron	0.02	0.02	U
200.8	10/22/98	200.8	10/30/98	7439-92-1	Lead	0.001	0.001	U
200.8	10/22/98	200.8	10/30/98	7439-96-5	Manganese	0.0002	0.0002	U
3010	10/22/98	6010	10/29/98	7440-66-6	Zinc	0.004	0.004	U

U Analyte undetected at given RL

RL Reporting Limit

FORM-I

INORGANICS ANALYSIS DATA SHEET
TOTAL METALS

ANALYTICAL
RESOURCES
INCORPORATED

Lab Sample ID: Y931LCS
LIMS ID: 98-21669
Matrix: Water

QC Report No: Y931-Dames & Moore
Project: Holden Mine
17693-005-019

Data Release Authorized:
Reported: 11/09/98

BLANK SPIKE QUALITY CONTROL REPORT

Analyte	Spike mg/L	Spike Added	% Recovery	Q
Aluminum	2.01	2.00	100%	
Arsenic	0.0251	0.0250	100%	
Cadmium	0.0254	0.0250	102%	
Copper	0.028	0.025	112%	
Iron	1.00	1.00	100%	
Lead	0.025	0.025	100%	
Manganese	0.0263	0.0250	105%	
Zinc	0.488	0.500	97.6%	

'Q' codes: N = control limit not met

Control Limits: 80-120%

FORM-VII

ANALYTICAL
RESOURCES
INCORPORATED

Final Report
Laboratory Analysis of Conventional Parameters

Sample No: STE-SED-101698-1

Lab Sample ID: Y931A
LIMS ID: 98-21651
Matrix: Sediment

QC Report No: Y931-Dames & Moore
Project: Holden Mine
17693-005-019
Date Sampled: 10/16/98
Date Received: 10/19/98

Data Release Authorized:
Reported: 11/04/98 Dr. M.A. Perkins

Analyte	Analysis Date/Batch	Method	Dilution Factor	RL	Units	Result
pH	10/29/98 102998#1	EPA 150.1 SM 4500 H			std units	5.8 J
Total Solids	10/27/98 102798#1	EPA 160.3 SM 2540 B		0.01	Percent	60.3
Total Volatile Solids	10/27/98 102798#1	EPA 160.4 SM 2540 E		1.0	mg/kg	38,000
Acid Volatile Sulfide	10/21/98 102198#1	EPA 1991		0.85	mg/kg	2.9
Total Organic Carbon	10/27/98 102798#1	Plumb,1981		0.0050	Percent	1.6

pH determined on 1:1 soil:D.I. water extracts.

KM 12/11/98

RL	Analytical reporting limit
U	Undetected at reported detection limit
B	Analyte found in method blank above detection

Report for Y931 received 10/19/98

ANALYTICAL
RESOURCES
INCORPORATED

Final Report
Laboratory Analysis of Conventional Parameters

Sample No: STE-SED-101698-2

Lab Sample ID: Y931B
LIMS ID: 98-21652
Matrix: Sediment

QC Report No: Y931-Dames & Moore
Project: Holden Mine
17693-005-019
Date Sampled: 10/16/98
Date Received: 10/19/98

Data Release Authorized:
Reported: 11/04/98 Dr. M.A. Perkins

Analyte	Analysis Date/Batch	Method	Dilution Factor	RL	Units	Result
pH	10/29/98 102998#1	EPA 150.1 SM 4500 H			std units	5.5 J
Total Solids	10/27/98 102798#1	EPA 160.3 SM 2540 B		0.01	Percent	62.5
Total Volatile Solids	10/27/98 102798#1	EPA 160.4 SM 2540 E		1.0	mg/kg	54,000
Acid Volatile Sulfide	10/21/98 102198#1	EPA 1991		0.94	mg/kg	4.0
Total Organic Carbon	10/27/98 102798#1	Plumb,1981		0.0050	Percent	1.9

pH determined on 1:1 soil:D.I. water extracts.

KM 12/1/98

RL Analytical reporting limit
U Undetected at reported detection limit
B Analyte found in method blank above detection

Report for Y931 received 10/19/98

ANALYTICAL
RESOURCES
INCORPORATED

Final Report
Laboratory Analysis of Conventional Parameters

Sample No: STE-SED-101698-3A

Lab Sample ID: Y931C
LIMS ID: 98-21653
Matrix: Sediment

Data Release Authorized:
Reported: 11/04/98 Dr. M.A. Perkins

QC Report No: Y931-Dames & Moore
Project: Holden Mine
17693-005-019
Date Sampled: 10/16/98
Date Received: 10/19/98

Analyte	Analysis Date/Batch	Method	Dilution Factor	RL	Units	Result
pH	10/29/98 102998#1	EPA 150.1 SM 4500 H			std units	5.6 J
Total Solids	10/27/98 102798#1	EPA 160.3 SM 2540 B		0.01	Percent	40.8
Total Volatile Solids	10/27/98 102798#1	EPA 160.4 SM 2540 E		1.0	mg/kg	140,000
Acid Volatile Sulfide	10/21/98 102198#1	EPA 1991		1.3	mg/kg	< 1.3 U
Total Organic Carbon	10/27/98 102798#1	Plumb,1981		0.0050	Percent	3.8

pH determined on 1:1 soil:D.I. water extracts.

Km 12/11/98

RL Analytical reporting limit
U Undetected at reported detection limit
B Analyte found in method blank above detection

Report for Y931 received 10/19/98

ANALYTICAL
RESOURCES
INCORPORATED

Final Report
Laboratory Analysis of Conventional Parameters

Sample No: STE-SED-101698-3B

Lab Sample ID: Y931D
LIMS ID: 98-21654
Matrix: Sediment

QC Report No: Y931-Dames & Moore
Project: Holden Mine
17693-005-019
Date Sampled: 10/16/98
Date Received: 10/19/98

Data Release Authorized:
Reported: 11/04/98 Dr. M.A. Perkins

Analyte	Analysis Date/Batch	Method	Dilution Factor	RL	Units	Result
pH	10/29/98 102998#1	EPA 150.1 SM 4500 H			std units	5.6 J
Total Solids	10/27/98 102798#1	EPA 160.3 SM 2540 B		0.01	Percent	36.5
Total Volatile Solids	10/27/98 102798#1	EPA 160.4 SM 2540 E		1.0	mg/kg	190,000
Acid Volatile Sulfide	10/21/98 102198#1	EPA 1991		1.5	mg/kg	< 1.5 U
Total Organic Carbon	10/27/98 102798#1	Plumb,1981		0.0050	Percent	4.2

pH determined on 1:1 soil:D.I. water extracts.

KM 14/11/98

RL	Analytical reporting limit
U	Undetected at reported detection limit
B	Analyte found in method blank above detection

Report for Y931 received 10/19/98

ANALYTICAL
RESOURCES
INCORPORATED

Final Report
Laboratory Analysis of Conventional Parameters

Sample No: STE-SED-101698-3C

Lab Sample ID: Y931E
LIMS ID: 98-21655
Matrix: Sediment

QC Report No: Y931-Dames & Moore
Project: Holden Mine
17693-005-019
Date Sampled: 10/16/98
Date Received: 10/19/98

Data Release Authorized:
Reported: 11/04/98 Dr. M.A. Perkins

Analyte	**Analysis Date/Batch**	**Method**	**Dilution Factor**	**RL**	**Units**	**Result**
pH	10/29/98 102998#1	EPA 150.1 SM 4500 H			std units	5.8 J
Total Solids	10/27/98 102798#1	EPA 160.3 SM 2540 B		0.01	Percent	40.2
Total Volatile Solids	10/27/98 102798#1	EPA 160.4 SM 2540 E		1.0	mg/kg	150,000
Acid Volatile Sulfide	10/21/98 102198#1	EPA 1991		1.4	mg/kg	< 1.4 U
Total Organic Carbon	10/27/98 102798#1	Plumb,1981	2.2	0.011	Percent	3.3

pH determined on 1:1 soil:D.I. water extracts.

Km 12/11/98

RL Analytical reporting limit
U Undetected at reported detection limit
B Analyte found in method blank above detection

Report for Y931 received 10/19/98

ANALYTICAL
RESOURCES
INCORPORATED

Final Report
Laboratory Analysis of Conventional Parameters

Sample No: STE-SED-101698-4

Lab Sample ID: Y931F
LIMS ID: 98-21656
Matrix: Sediment

Data Release Authorized:
Reported: 11/04/98 Dr. M.A. Perkins

QC Report No: Y931-Dames & Moore
Project: Holden Mine
17693-005-019
Date Sampled: 10/16/98
Date Received: 10/19/98

Analyte	Analysis Date/Batch	Method	Dilution Factor	RL	Units	Result
pH	10/29/98 102998#1	EPA 150.1 SM 4500 H			std units	5.5 J
Total Solids	10/27/98 102798#1	EPA 160.3 SM 2540 B		0.01	Percent	47.4
Total Volatile Solids	10/27/98 102798#1	EPA 160.4 SM 2540 E		1.0	mg/kg	100,000
Acid Volatile Sulfide	10/21/98 102198#1	EPA 1991		1.1	mg/kg	3.5
Total Organic Carbon	10/27/98 102798#1	Plumb,1981		0.0050	Percent	3.1

pH determined on 1:1 soil:D.I. water extracts.

km 12/1/98

RL	Analytical reporting limit
U	Undetected at reported detection limit
B	Analyte found in method blank above detection

Report for Y931 received 10/19/98

ANALYTICAL
RESOURCES
INCORPORATED

Final Report
Laboratory Analysis of Conventional Parameters

Sample No: LUC-SED-101698-2-2

Lab Sample ID: Y931G
LIMS ID: 98-21657
Matrix: Sediment

QC Report No: Y931-Dames & Moore
Project: Holden Mine
17693-005-019
Date Sampled: 10/16/98
Date Received: 10/19/98

Data Release Authorized: MAP
Reported: 11/04/98 Dr. M.A. Perkins

Analyte	Analysis Date/Batch	Method	Dilution Factor	RL	Units	Result
pH	10/29/98 102998#1	EPA 150.1 SM 4500 H			std units	5.0 J
Total Solids	10/27/98 102798#1	EPA 160.3 SM 2540 B		0.01	Percent	49.8
Total Volatile Solids	10/27/98 102798#1	EPA 160.4 SM 2540 E		1.0	mg/kg	130,000
Acid Volatile Sulfide	10/21/98 102198#1	EPA 1991		1.0	mg/kg	10
Total Organic Carbon	10/27/98 102798#1	Plumb,1981	4.7	0.023	Percent	10

pH determined on 1:1 soil:D.I. water extracts.

KM 12/11/98

RL	Analytical reporting limit
U	Undetected at reported detection limit
B	Analyte found in method blank above detection

Report for Y931 received 10/19/98

ANALYTICAL
RESOURCES
INCORPORATED

Final Report
Laboratory Analysis of Conventional Parameters

Sample No: LUC-SED-101698-1-2

Lab Sample ID: Y931H
LIMS ID: 98-21658
Matrix: Sediment

QC Report No: Y931-Dames & Moore
Project: Holden Mine
17693-005-019
Date Sampled: 10/16/98
Date Received: 10/19/98

Data Release Authorized:
Reported: 11/04/98 Dr. M.A. Perkins

Analyte	Analysis Date/Batch	Method	Dilution Factor	RL	Units	Result
pH	10/29/98 102998#1	EPA 150.1 SM 4500 H			std units	5.3 J
Total Solids	10/27/98 102798#1	EPA 160.3 SM 2540 B		0.01	Percent	44.3
Total Volatile Solids	10/27/98 102798#1	EPA 160.4 SM 2540 E		1.0	mg/kg	140,000
Acid Volatile Sulfide	10/21/98 102198#1	EPA 1991		1.3	mg/kg	14
Total Organic Carbon	10/27/98 102798#1	Plumb,1981	3.8	0.019	Percent	5.9

pH determined on 1:1 soil:D.I. water extracts.

Km 12/11/98

RL	Analytical reporting limit
U	Undetected at reported detection limit
B	Analyte found in method blank above detection

Report for Y931 received 10/19/98

ANALYTICAL
RESOURCES
INCORPORATED

Final Report
Laboratory Analysis of Conventional Parameters

Sample No: LUC-SED-101598-3.5-2

Lab Sample ID: Y931I
LIMS ID: 98-21659
Matrix: Sediment

QC Report No: Y931-Dames & Moore
Project: Holden Mine
17693-005-019
Date Sampled: 10/15/98
Date Received: 10/19/98

Data Release Authorized:
Reported: 11/04/98 Dr. M.A. Perkins

Analyte	Analysis Date/Batch	Method	Dilution Factor	RL	Units	Result
pH	10/29/98 102998#1	EPA 150.1 SM 4500 H			std units	5.7 J
Total Solids	10/27/98 102798#1	EPA 160.3 SM 2540 B		0.01	Percent	41.0
Total Volatile Solids	10/27/98 102798#1	EPA 160.4 SM 2540 E		1.0	mg/kg	110,000
Acid Volatile Sulfide	10/21/98 102198#1	EPA 1991	10	15	mg/kg	96
Total Organic Carbon	10/27/98 102798#1	Plumb,1981	2.2	0.011	Percent	5.2

pH determined on 1:1 soil:D.I. water extracts.

km 12/11/98

RL	Analytical reporting limit
U	Undetected at reported detection limit
B	Analyte found in method blank above detection

Report for Y931 received 10/19/98

ANALYTICAL
RESOURCES
INCORPORATED

Final Report
Laboratory Analysis of Conventional Parameters

Sample No: LUC-SED-101598-3-1A

Lab Sample ID: Y931J	QC Report No: Y931-Dames & Moore
LIMS ID: 98-21660	Project: Holden Mine
Matrix: Sediment	17693-005-019
	Date Sampled: 10/15/98
Data Release Authorized:	Date Received: 10/19/98
Reported: 11/04/98 Dr. M.A. Perkins	

Analyte	Analysis Date/Batch	Method	Dilution Factor	RL	Units	Result
pH	10/29/98 102998#1	EPA 150.1 SM 4500 H			std units	5.8 J
Total Solids	10/27/98 102798#1	EPA 160.3 SM 2540 B		0.01	Percent	44.4
Total Volatile Solids	10/27/98 102798#1	EPA 160.4 SM 2540 E		1.0	mg/kg	120,000
Acid Volatile Sulfide	10/21/98 102198#1	EPA 1991	10	13	mg/kg	120
Total Organic Carbon	10/27/98 102798#1	Plumb,1981	3.0	0.015	Percent	7.9

pH determined on 1:1 soil:D.I. water extracts.

Km 12/11/98

RL	Analytical reporting limit
U	Undetected at reported detection limit
B	Analyte found in method blank above detection

Report for Y931 received 10/19/98

ANALYTICAL
RESOURCES
INCORPORATED

Final Report
Laboratory Analysis of Conventional Parameters

Sample No: LUC-SED-101598-1-1

Lab Sample ID: Y931K
LIMS ID: 98-21661
Matrix: Sediment

QC Report No: Y931-Dames & Moore
Project: Holden Mine
17693-005-019
Date Sampled: 10/15/98
Date Received: 10/19/98

Data Release Authorized:
Reported: 11/04/98 Dr. M.A. Perkins

Analyte	Analysis Date/Batch	Method	Dilution Factor	RL	Units	Result
pH	10/29/98 102998#1	EPA 150.1 SM 4500 H			std units	6.0 J
Total Solids	10/27/98 102798#1	EPA 160.3 SM 2540 B		0.01	Percent	75.2
Total Volatile Solids	10/27/98 102798#1	EPA 160.4 SM 2540 E		1.0	mg/kg	11,000
Acid Volatile Sulfide	10/21/98 102198#1	EPA 1991		0.66	mg/kg	< 0.7 U
Total Organic Carbon	10/27/98 102798#1	Plumb,1981		0.0050	Percent	0.30

pH determined on 1:1 soil:D.I. water extracts.

Km 12/11/98

RL	Analytical reporting limit
U	Undetected at reported detection limit
B	Analyte found in method blank above detection

Report for Y931 received 10/19/98

**ANALYTICAL
RESOURCES
INCORPORATED**

Final Report
Laboratory Analysis of Conventional Parameters

Sample No: LUC-SED-101598-3-2

Lab Sample ID: Y931L
LIMS ID: 98-21662
Matrix: Sediment

Data Release Authorized:
Reported: 11/04/98 Dr. M.A. Perkins

QC Report No: Y931-Dames & Moore
Project: Holden Mine
17693-005-019
Date Sampled: 10/15/98
Date Received: 10/19/98

Analyte	Analysis Date/Batch	Method	Dilution Factor	RL	Units	Result
pH	10/29/98 102998#1	EPA 150.1 SM 4500 H			std units	5.4 J
Total Solids	10/27/98 102798#1	EPA 160.3 SM 2540 B		0.01	Percent	40.6
Total Volatile Solids	10/27/98 102798#1	EPA 160.4 SM 2540 E		1.0	mg/kg	150,000
Acid Volatile Sulfide	10/21/98 102198#1	EPA 1991	5.0	6.2	mg/kg	48
Total Organic Carbon	10/27/98 102798#1	Plumb,1981	8.0	0.040	Percent	14

pH determined on 1:1 soil:D.I. water extracts.

KM 12/1/98

RL	Analytical reporting limit
U	Undetected at reported detection limit
B	Analyte found in method blank above detection

Report for Y931 received 10/19/98

ANALYTICAL
RESOURCES
INCORPORATED

Final Report
Laboratory Analysis of Conventional Parameters

Sample No: LUC-SED-101598-3.5-1

Lab Sample ID: Y931M
LIMS ID: 98-21663
Matrix: Sediment

QC Report No: Y931-Dames & Moore
Project: Holden Mine
17693-005-019
Date Sampled: 10/15/98
Date Received: 10/19/98

Data Release Authorized:
Reported: 11/04/98 Dr. M.A. Perkins

Analyte	Analysis Date/Batch	Method	Dilution Factor	RL	Units	Result
pH	10/29/98 102998#1	EPA 150.1 SM 4500 H			std units	5.5 J
Total Solids	10/27/98 102798#1	EPA 160.3 SM 2540 B		0.01	Percent	55.8
Total Volatile Solids	10/27/98 102798#1	EPA 160.4 SM 2540 E		1.0	mg/kg	66,000
Acid Volatile Sulfide	10/21/98 102198#1	EPA 1991	2.0	1.9	mg/kg	24
Total Organic Carbon	10/27/98 102798#1	Plumb,1981	3.4	0.017	Percent	6.2

pH determined on 1:1 soil:D.I. water extracts.

Km 12/11/98

RL	Analytical reporting limit
U	Undetected at reported detection limit
B	Analyte found in method blank above detection

Report for Y931 received 10/19/98

Final Report
Laboratory Analysis of Conventional Parameters

Sample No: LUC-SED-101598-3-1C

Lab Sample ID: Y931N
LIMS ID: 98-21664
Matrix: Sediment

Data Release Authorized: MP
Reported: 11/04/98 Dr. M.A. Perkins

QC Report No: Y931-Dames & Moore
Project: Holden Mine
17693-005-019
Date Sampled: 10/15/98
Date Received: 10/19/98

Analyte	Analysis Date/Batch	Method	Dilution Factor	RL	Units	Result
pH	10/29/98 102998#1	EPA 150.1 SM 4500 H			std units	5.3 J
Total Solids	10/27/98 102798#1	EPA 160.3 SM 2540 B		0.01	Percent	46.9
Total Volatile Solids	10/27/98 102798#1	EPA 160.4 SM 2540 E		1.0	mg/kg	130,000
Acid Volatile Sulfide	10/21/98 102198#1	EPA 1991		1.1	mg/kg	< 1.1 U
Total Organic Carbon	10/27/98 102798#1	Plumb,1981	4.0	0.020	Percent	11

pH determined on 1:1 soil:D.I. water extracts.

Km 12/4/98

RL	Analytical reporting limit
U	Undetected at reported detection limit
B	Analyte found in method blank above detection

Report for Y931 received 10/19/98

ANALYTICAL
RESOURCES
INCORPORATED

Final Report
Laboratory Analysis of Conventional Parameters

Sample No: LUC-SED-101598-3-1B

Lab Sample ID: Y9310
LIMS ID: 98-21665
Matrix: Sediment

QC Report No: Y931-Dames & Moore
Project: Holden Mine
17693-005-019
Date Sampled: 10/15/98
Date Received: 10/19/98

Data Release Authorized:
Reported: 11/04/98 Dr. M.A. Perkins

Analyte	Analysis Date/Batch	Method	Dilution Factor	RL	Units	Result
pH	10/29/98 102998#1	EPA 150.1 SM 4500 H			std units	4.7 J
Total Solids	10/27/98 102798#1	EPA 160.3 SM 2540 B		0.01	Percent	35.8
Total Volatile Solids	10/27/98 102798#1	EPA 160.4 SM 2540 E		1.0	mg/kg	220,000
Acid Volatile Sulfide	10/21/98 102198#1	EPA 1991		1.7	mg/kg	9.4
Total Organic Carbon	10/27/98 102798#1	Plumb,1981	8.4	0.042	Percent	15

Km 12/11/98

pH determined on 1:1 soil:D.I. water extracts.

RL Analytical reporting limit
U Undetected at reported detection limit
B Analyte found in method blank above detection

Report for Y931 received 10/19/98

ANALYTICAL
RESOURCES
INCORPORATED

Final Report
Laboratory Analysis of Conventional Parameters

Sample No: LUC-SED-101598-5-2

Lab Sample ID: Y931P
LIMS ID: 98-21666
Matrix: Sediment

QC Report No: Y931-Dames & Moore
Project: Holden Mine
17693-005-019
Date Sampled: 10/15/98
Date Received: 10/19/98

Data Release Authorized:
Reported: 11/04/98 Dr. M.A. Perkins

Analyte	Analysis Date/Batch	Method	Dilution Factor	RL	Units	Result
pH	10/29/98 102998#1	EPA 150.1 SM 4500 H			std units	5.7 J
Total Solids	10/27/98 102798#1	EPA 160.3 SM 2540 B		0.01	Percent	52.5
Total Volatile Solids	10/27/98 102798#1	EPA 160.4 SM 2540 E		1.0	mg/kg	67,000
Acid Volatile Sulfide	10/21/98 102198#1	EPA 1991		1.1	mg/kg	3.3
Total Organic Carbon	10/27/98 102798#1	Plumb,1981		0.0050	Percent	1.9

pH determined on 1:1 soil:D.I. water extracts.

KM 12/11/98

RL Analytical reporting limit
U Undetected at reported detection limit
B Analyte found in method blank above detection

Report for Y931 received 10/19/98

ANALYTICAL
RESOURCES
INCORPORATED

Final Report
Laboratory Analysis of Conventional Parameters

Sample No: LUC-SED-101598-2-1

Lab Sample ID: Y931Q
LIMS ID: 98-21667
Matrix: Sediment

Data Release Authorized:
Reported: 11/04/98 Dr. M.A. Perkins

QC Report No: Y931-Dames & Moore
Project: Holden Mine
17693-005-019
Date Sampled: 10/15/98
Date Received: 10/19/98

Analyte	Analysis Date/Batch	Method	Dilution Factor	RL	Units	Result
pH	10/29/98 102998#1	EPA 150.1 SM 4500 H			std units	6.2 J
Total Solids	10/27/98 102798#1	EPA 160.3 SM 2540 B		0.01	Percent	78.4
Total Volatile Solids	10/27/98 102798#1	EPA 160.4 SM 2540 E		1.0	mg/kg	7,800
Acid Volatile Sulfide	10/21/98 102198#1	EPA 1991		0.66	mg/kg	< 0.7 U
Total Organic Carbon	10/27/98 102798#1	Plumb,1981		0.0050	Percent	0.38

pH determined on 1:1 soil:D.I. water extracts.

KM 12/11/98

RL Analytical reporting limit
U Undetected at reported detection limit
B Analyte found in method blank above detection

Report for Y931 received 10/19/98

ANALYTICAL
RESOURCES
INCORPORATED

Final Report
Laboratory Analysis of Conventional Parameters

Sample No: LUC-SED-101598-5-1

Lab Sample ID: Y931R
LIMS ID: 98-21668
Matrix: Sediment

QC Report No: Y931-Dames & Moore
Project: Holden Mine
17693-005-019
Date Sampled: 10/15/98
Date Received: 10/19/98

Data Release Authorized:
Reported: 11/04/98 Dr. M.A. Perkins

Analyte	Analysis Date/Batch	Method	Dilution Factor	RL	Units	Result
pH	10/29/98 102998#1	EPA 150.1 SM 4500 H			std units	5.8 J
Total Solids	10/27/98 102798#1	EPA 160.3 SM 2540 B		0.01	Percent	45.5
Total Volatile Solids	10/27/98 102798#1	EPA 160.4 SM 2540 E		1.0	mg/kg	95,000
Acid Volatile Sulfide	10/21/98 102198#1	EPA 1991	10	12	mg/kg	91
Total Organic Carbon	10/27/98 102798#1	Plumb,1981		0.0050	Percent	2.5

pH determined on 1:1 soil:D.I. water extracts.

Km 12/4/98

RL	Analytical reporting limit
U	Undetected at reported detection limit
B	Analyte found in method blank above detection

Report for Y931 received 10/19/98

ANALYTICAL
RESOURCES
INCORPORATED

QA Report - Method Blank Analysis

QC Report No: Y931-Dames & Moore
Project: Holden Mine
17693-005-019
Date Received: NA

Matrix: Sediment

Data Release Authorized:
Reported: 11/04/98 Dr. M.A. Perkins

METHOD BLANK RESULTS
CONVENTIONALS

Analysis Date & Batch	Constituent	Units	Result
Method Blank 10/21/98 102198#1	Acid Volatile Sulfide	mg/L	< 0.050 U
Method Blank 10/27/98 102798#1	Total Organic Carbon	Percent	<0.0050 U
Method Blank 10/27/98 102798#1	Total Solids	mg residue	< 1.00 U
Method Blank 10/27/98 102798#1	Total Volatile Solids	mg residue	< 1.0 U

ANALYTICAL
RESOURCES
INCORPORATED

QA Report - Replicate Analysis

QC Report No: Y931-Dames & Moore
Project: Holden Mine
17693-005-019
Date Received: 10/19/98

Matrix: Sediment

Data Release Authorized:
Reported: 11/04/98 Dr. M.A. Perkins

REPLICATE ANALYSIS RESULTS
CONVENTIONALS

Constituent	Units	Sample Value	Replicate Value(s)	RPD/RSD
ARI ID: 98-21651, Y931 A	**Client Sample ID: STE-SED-101698-1**			
Acid Volatile Sulfide	mg/kg	2.9	3.3 3.2	RSD: 6.6%
Total Organic Carbon	Percent	1.6	1.7	RPD: 6.1%
ARI ID: 98-21652, Y931 B	**Client Sample ID: STE-SED-101698-2**			
pH	std units	5.5	5.5	RPD: 0.0%
ARI ID: 98-21653, Y931 C	**Client Sample ID: STE-SED-101698-3A**			
Total Solids	Percent	40.8	41.0 41.6	RSD: 1.0%
Total Volatile Solids	mg/kg	140,000	150,000 130,000	RSD: 7.1%

QA Report - Matrix Spike/Matrix Spike Duplicate Analysis

Matrix: Sediment

QC Report No: Y931-Dames & Moore
Project: Holden Mine
17693-005-019
Date Received: 10/19/98

Data Release Authorized:
Reported: 11/04/98 Dr. M.A. Perkins

MATRIX SPIKE QA/QC REPORT
CONVENTIONALS

Constituent	Units	Sample Value	Spike Value	Spike Added	Recovery
ARI ID: 98-21651, Y931 A	Client Sample ID: STE-SED-101698-1				
Acid Volatile Sulfide	mg/kg	2.9	98.0	109	86.9%
Total Organic Carbon	Percent	1.63	4.77	2.67	118%

MS/MSD Recovery Limits: 75 - 125 %

ANALYTICAL
RESOURCES
INCORPORATED

QA Report - Laboratory Control Samples

QC Report No: Y931-Dames & Moore
Project: Holden Mine
17693-005-019
Date Received: NA

Data Release Authorized:
Reported: 11/04/98 Dr. M.A. Perkins

LABORATORY CONTROL SAMPLES
CONVENTIONALS

Constituent	Units	Measured Value	True Value	Recovery
Laboratory Control Sample				
Acid Volatile Sulfide	mg/L	5.07	6.19	81.9%
Date analyzed: 10/21/98 Batch ID: 102198#1				
Laboratory Control Sample				
Total Organic Carbon	Percent	0.525	0.500	105%
Date analyzed: 10/27/98 Batch ID: 102798#1				
pH Calibration Standard				
pH	std units	7.01	7.00	100%
Date analyzed: 10/29/98 Batch ID: 102998#1				

ANALYTICAL
RESOURCES
INCORPORATED

QA Report - Standard Reference Material Analysis

QC Report No: Y931-Dames & Moore
Project: Holden Mine
17693-005-019
Date Received: NA

Data Release Authorized:
Reported: 11/04/98 Dr. M.A. Perkins

STANDARD REFERENCE MATERIAL ANALYSIS
CONVENTIONALS

Constituent	Units	Value	True Value	Recovery
NBS #2704				
Total Organic Carbon	Percent	3.52	3.35	105%

Date analyzed: 10/27/98 Batch ID: 102798#1

REG Lab WMBE
Rosa Environmental & Geotechnical Laboratory, LLC

400 Ninth Avenue N., Suite B
Seattle, WA 98109-5187
(206) 287-9122

Client: Dames & Moore	REGL Project No.: 1000-121
Client Project No.: 17693-005-019	Sample Batch No.: 1000-121-01

Case Narrative

1. The samples were received on October 19, 1998 and were in good condition.
2. There were eighteen samples for PSEP grain size analysis. A triplicate was run on one sample.
3. The samples were set-up for testing on October 21, 1998. The analysis was complete on October 27, 1998.
4. PSEP methodology requires that there be between 5 and 25 g in the pipette portion of the analysis. The method also requires that all weights be measured to the nearest 0.1 mg, which limits the size of the test portion to 205 g. In most cases, a test portion that would meet the 5 g limit is too large to weigh on the analytical balance. Many of the samples reported in this set contained less than the 5 g limit. The analysis was run anyway and the data has been flagged (noted in italics/shading in the summary table). Because of the lack of fines in these samples, the amount retained in many of the individual size fractions was less than the detection limit. These samples have been reported as "NA" in the table, and were shown in the plots as "0.0."
5. Each bench sheet lists a simple sieve by sieve visual observation of the amount of organic material contained in each sample. All but one sample have similar organic characteristics; generally, organic material accounts for all weights from the #120 sieve and larger. The exception is sample LUC-SED-101598-1-1 which contained only 2 pine needles in the #18 sieve. Also, most samples contained small shiny flecks (mica?).

Approved by: Date: 11/2/98
Title: Laboratory Manager

Rosa Environmental and Geotechnical Laboratory, LLC

QA SUMMARY

PROJECT:	Dames & Moore	Project No.:	17693-005-019
REGL Triplicate Sample ID:	98-1476	Batch No.:	1000-121
Client Triplicate Sample ID:	STE-SED-101698-2	Page:	1 of 1

Relative Standard Deviation, By Phi Size

Sample ID	-3	-2	-1	0	1	2	3	4	5	6	7	8	9	10
STE-SED-101698-2	100.0	98.1	97.5	95.9	86.7	42.4	31.4	20.5	8.1	3.4	1.4	0.6	0.1	0.1
STE-SED-101698-2(2)	100.0	97.5	95.2	93.8	84.4	40.8	30.0	18.8	8.3	3.3	1.2	0.6	0.2	0.2
STE-SED-101698-2(3)	100.0	98.4	96.8	95.2	84.8	40.7	29.8	19.1	8.4	3.3	1.2	0.6	0.2	0.2
AVE	NA	97.99	96.48	94.98	85.31	41.29	30.41	19.48	8.28	3.35	1.29	0.58	0.15	0.16
STDEV	NA	0.47	1.16	1.09	1.21	0.94	0.90	0.90	0.19	0.09	0.14	0.01	0.04	0.03
%RSD	NA	0.48	1.21	1.15	1.42	2.29	2.95	4.62	2.29	2.66	10.50	2.27	23.76	16.27

The Triplicate Applies To The Following Samples

REGL ID	Client ID	Date Sampled	Date Extracted	Date Complete	QA*
981475	STE-SED-101698-1	10/16/98	10/21/98	10/27/98	1.01
981476	STE-SED-101698-2	10/16/98	10/21/98	10/27/98	1.03
981476	STE-SED-101698-2(2)	10/16/98	10/21/98	10/27/98	1.01
981476	STE-SED-101698-2(3)	10/16/98	10/21/98	10/27/98	1.01
981477	STE-SED-101698-3A	10/16/98	10/21/98	10/27/98	1.00
981478	STE-SED-101698-3B	10/16/98	10/21/98	10/27/98	1.01
981479	STE-SED-101698-3C	10/16/98	10/21/98	10/27/98	1.01
981480	STE-SED-101698-4	10/16/98	10/21/98	10/27/98	1.02
981481	LUC-SED-101698-2-2	10/16/98	10/21/98	10/27/98	1.00
981482	LUC-SED-101698-1-2	10/16/98	10/21/98	10/27/98	1.02
981483	LUC-SED-101598-3-5-2	10/15/98	10/21/98	10/27/98	1.00
981484	LUC-SED-101598-3-1A	10/15/98	10/21/98	10/27/98	1.05
981485	LUC-SED-101598-1-1	10/15/98	10/21/98	10/27/98	1.02
981486	LUC-SED-101598-3-2	10/15/98	10/21/98	10/27/98	1.01
981487	LUC-SED-101598-3-5-1	10/15/98	10/21/98	10/27/98	1.02
981488	LUC-SED-101598-3-1C	10/15/98	10/21/98	10/27/98	1.00
981489	LUC-SED-101598-3-1B	10/15/98	10/21/98	10/27/98	1.03
981490	LUC-SED-101598-5-2	10/15/98	10/21/98	10/27/98	1.02
981491	LUC-SED-101598-2-1	10/15/98	10/21/98	10/27/98	1.02
981492	LUC-SED-101598-5-1	10/15/98	10/21/98	10/27/98	1.01

* QA limits = 95-105%

Notes to the Testing:

1. Plus 10 organic material listed on laboratory bench sheets.

Rosa Environmental Geo[illegible]nical Laboratory, LLC

Dames and Moore, Inc.
Project No.: 17693-005-019

Table 1. Apparent Grain Size Distribution Summary
Percent Finer Than Indicated Size

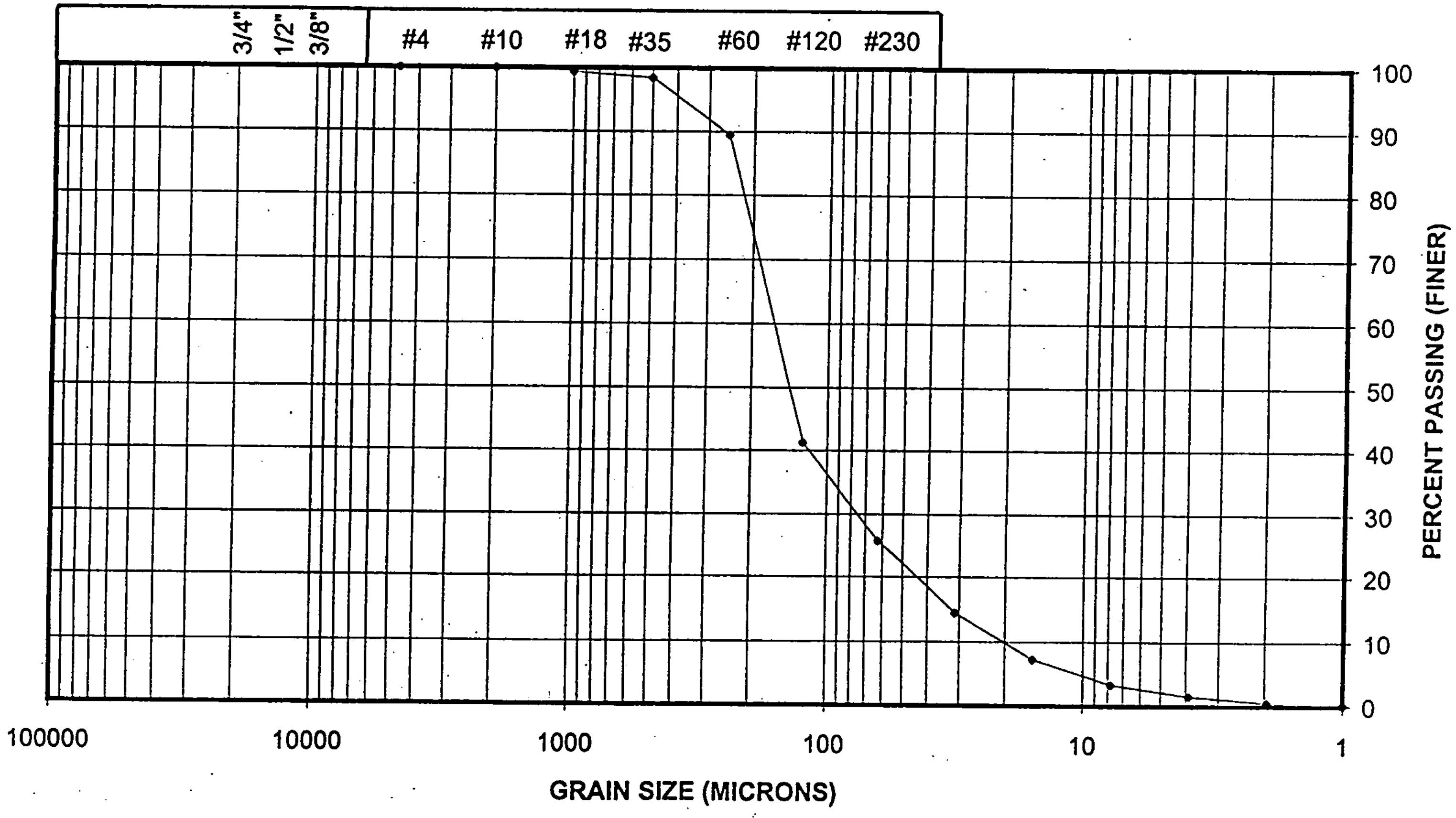
Sample No.	Gravel			Very Coarse Sand	Coarse Sand	Medium Sand	Fine Sand	Very Fine Sand	Silt				Clay	
Phi Size	-3	-2	-1	0	1	2	3	4	5	6	7	8	9	10
Sieve Size (microns)	3/8"	#4	#10 (2000)	#18 (1000)	#35 (500)	#60 (250)	#120 (125)	#230 (62)	31.00	15.60	7.80	3.90	2.00	1.00
STE-SED-101698-1	-	100.0	99.9	99.4	98.5	89.5	41.3	25.8	14.6	7.3	3.3	1.5	0.5	0.2
STE-SED-101698-2	100.0	98.1	97.5	95.9	86.7	42.4	31.4	20.5	8.1	3.4	1.4	0.6	0.1	0.1
STE-SED-101698-2(2)	100.0	97.5	95.2	93.8	84.4	40.8	30.0	18.8	8.3	3.3	1.2	0.6	0.2	0.2
STE-SED-101698-2(3)	100.0	98.4	96.8	95.2	84.8	40.7	29.8	19.1	8.4	3.3	1.2	0.6	0.2	0.2
STE-SED-101698-3A	*100.0*	*99.9*	*97.5*	*92.1*	*86.7*	*81.8*	*52.4*	*19.5*	*8.0*	*3.5*	*1.5*	*0.5*	*0.1*	*0.1*
STE-SED-101698-3B	*100.0*	*99.4*	*98.0*	*95.5*	*92.5*	*88.7*	*65.9*	*27.6*	*9.1*	*4.3*	*2.0*	*1.0*	*0.3*	*0.0*
STE-SED-101698-3C		*100.0*	*99.2*	*95.9*	*91.4*	*86.6*	*68.0*	*25.9*	*9.1*	*3.9*	*2.0*	*0.7*	*0.1*	*0.1*
STE-SED-101698-4	100.0	99.5	97.7	94.7	91.5	87.1	66.0	28.9	9.3	4.0	1.9	0.8	0.3	0.2
LUC-SED-101698-2-2	*100.0*	*99.3*	*96.1*	*91.2*	*81.8*	*64.0*	*14.5*	*6.1*	*1.4*	*0.5*	*0.1*	*NA*	*NA*	*NA*
LUC-SED-101698-1-2	*100.0*	*99.2*	*96.6*	*92.1*	*87.8*	*70.4*	*27.8*	*9.2*	*3.8*	*1.7*	*0.7*	*0.2*	*NA*	*NA*
LUC-SED-101598-1-1		*100.0*	*99.8*	*99.5*	*93.5*	*59.0*	*12.8*	*3.3*	*0.4*	*0.1*	*NA*	*NA*	*NA*	*NA*
LUC-SED-101598-2-1		*100.0*	*96.1*	*86.8*	*58.0*	*15.0*	*3.2*	*2.0*	*0.0*	*NA*	*NA*	*NA*	*NA*	*NA*
LUC-SED-101598-3-1A		*100.0*	*98.0*	*94.3*	*86.6*	*52.3*	*15.0*	*6.3*	*1.0*	*0.5*	*0.1*	*NA*	*NA*	*NA*
LUC-SED-101598-3-1B	*100.0*	*98.7*	*96.2*	*88.4*	*81.4*	*58.8*	*19.8*	*7.6*	*3.1*	*1.7*	*0.7*	*NA*	*NA*	*NA*
LUC-SED-101598-3-1C	*100.0*	*99.0*	*95.6*	*89.2*	*79.3*	*43.2*	*11.1*	*2.3*	*1.1*	*0.6*	*0.1*	*NA*	*NA*	*NA*
LUC-SED-101598-3-2	*100.0*	*96.7*	*93.0*	*86.8*	*80.7*	*56.4*	*10.8*	*2.3*	*0.4*	*0.0*	*NA*	*NA*	*NA*	*NA*
LUC-SED-101598-3-5-1	*100.0*	*99.6*	*98.4*	*95.8*	*90.1*	*67.8*	*22.6*	*6.1*	*2.4*	*1.4*	*0.7*	*0.3*	*NA*	*NA*
LUC-SED-101598-3-5-2	*100.0*	*99.9*	*99.0*	*96.5*	*92.8*	*80.4*	*40.2*	*18.2*	*6.7*	*3.9*	*2.5*	*1.2*	*0.3*	*0.0*
LUC-SED-101598-5-1		*100.0*	*98.8*	*98.0*	*80.2*	*68.2*	*46.6*	*11.5*	*4.3*	*2.2*	*1.3*	*0.7*	*0.0*	*0.0*
LUC-SED-101598-5-2		*100.0*	*99.2*	*97.1*	*90.0*	*75.6*	*38.3*	*12.2*	*6.0*	*3.0*	*2.0*	*1.2*	*0.5*	*0.4*

Notes to the Testing:
1. Apparent grain size distributions according to PSEP protocols.
2. Samples in italics/shaded contain less than 5 grams in the pipette portion of the analysis.
NA= less than detection limits for this size fraction.

ROSA ENVIRONMENTAL & GEOTECHNICAL LABORATORY

PSEP APPARENT GRAIN SIZE DISTRIBUTION

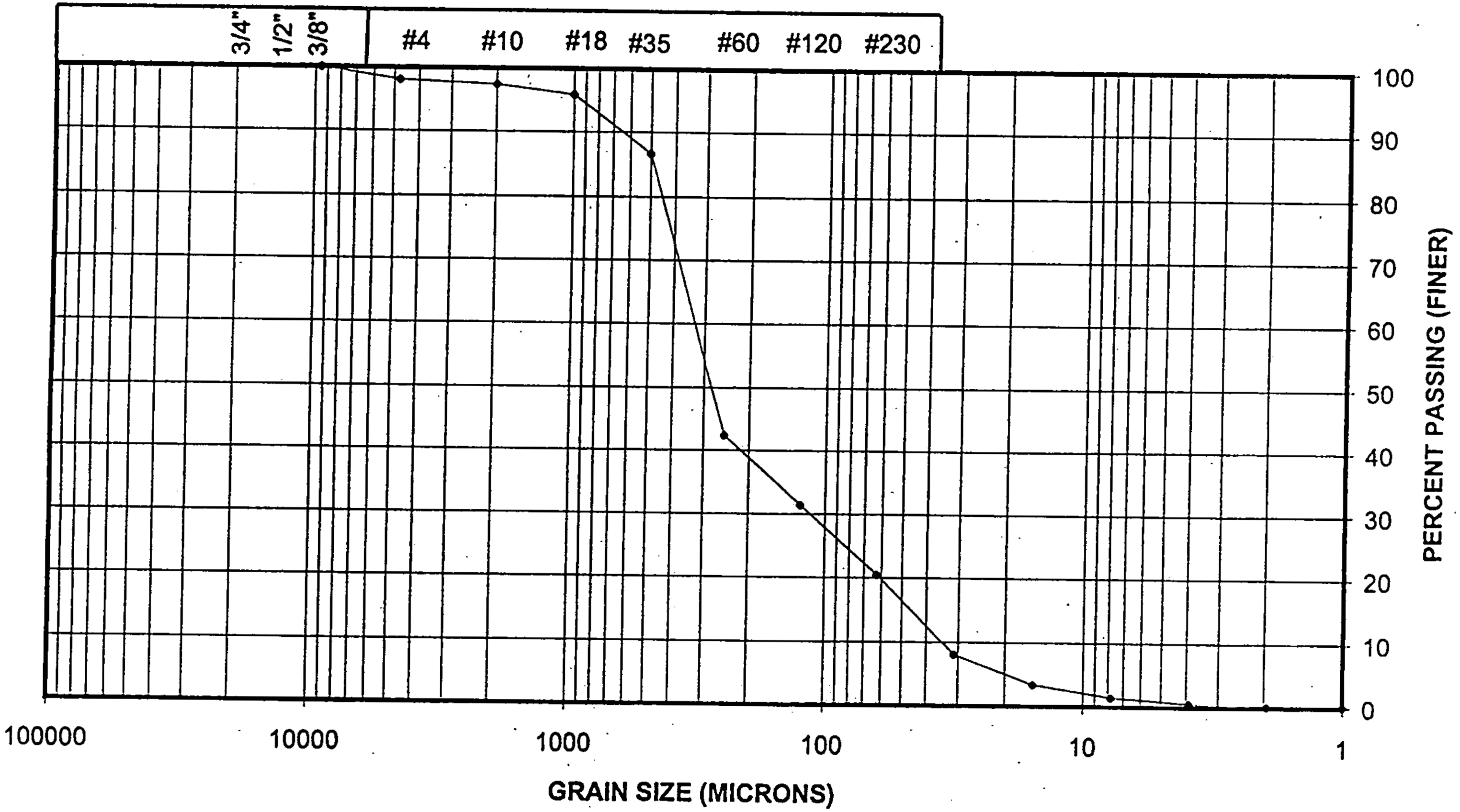
Project: Dames & Moore
Sample No. STE-SED-101698-1



ROSA ENVIRONMENTAL & GEOTECHNICAL LABORATORY

PSEP APPARENT GRAIN SIZE DISTRIBUTION

Project: Dames & Moore
Sample No. STE-SED-101698-2

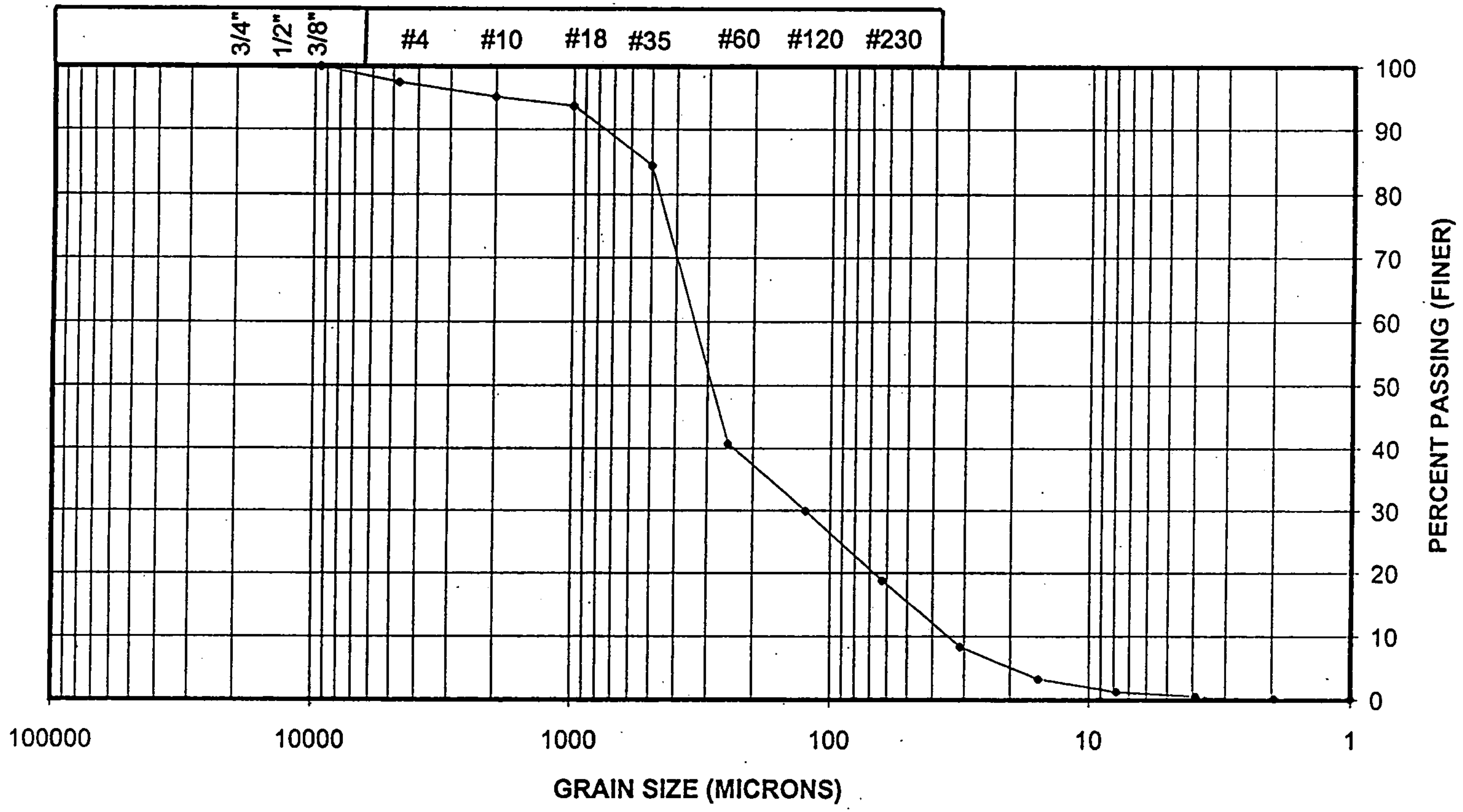


1000-121

ROSA ENVIRONMENTAL & GEOTECHNICAL LABORATORY

PSEP APPARENT GRAIN SIZE DISTRIBUTION

Project: Dames & Moore
Sample No. STE-SED-101698-2(2)

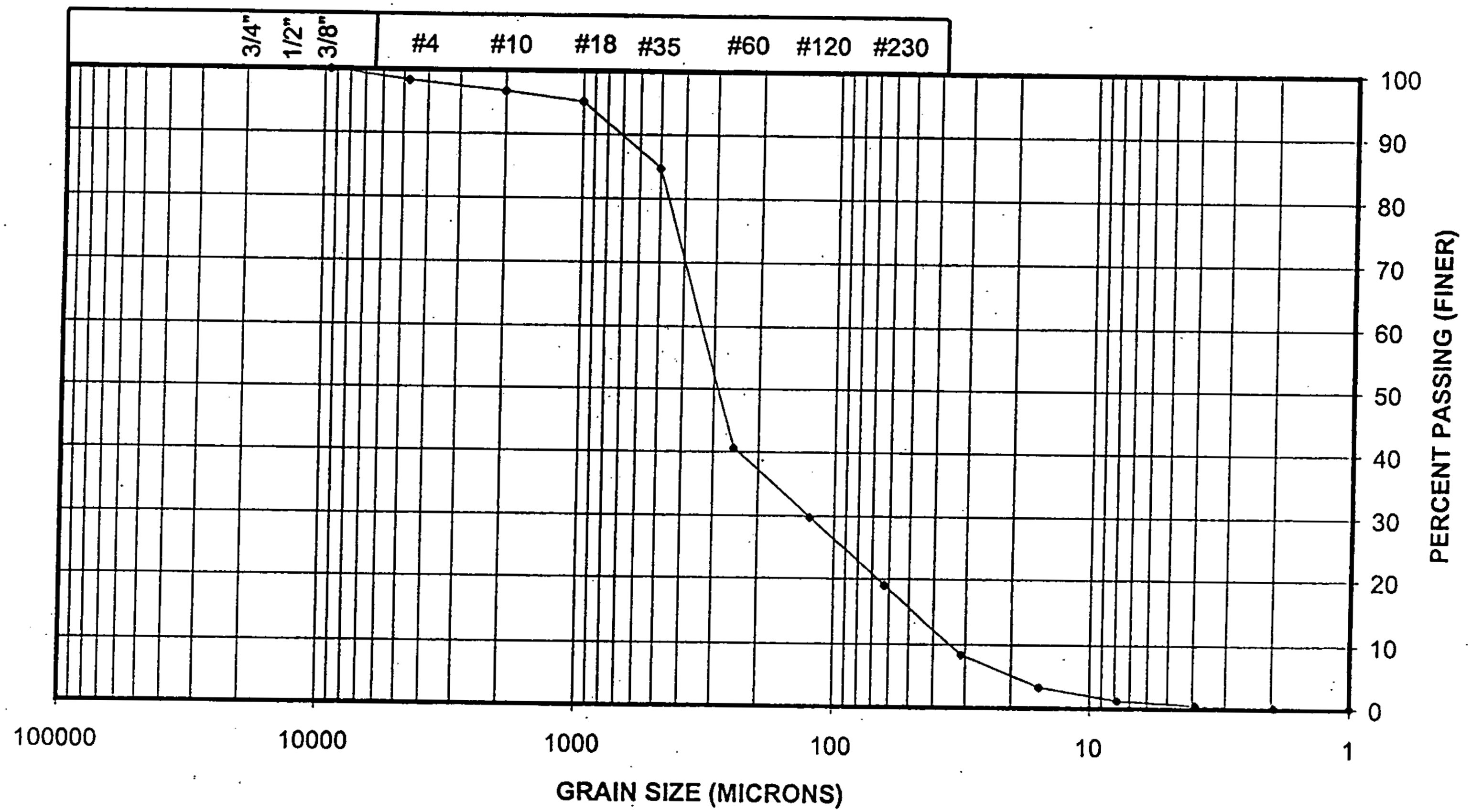


1000-121

ROSA ENVIRONMENTAL & GEOTECHNICAL LABORATORY

PSEP APPARENT GRAIN SIZE DISTRIBUTION

Project: Dames & Moore
Sample No. STE-SED-101698-2(3)

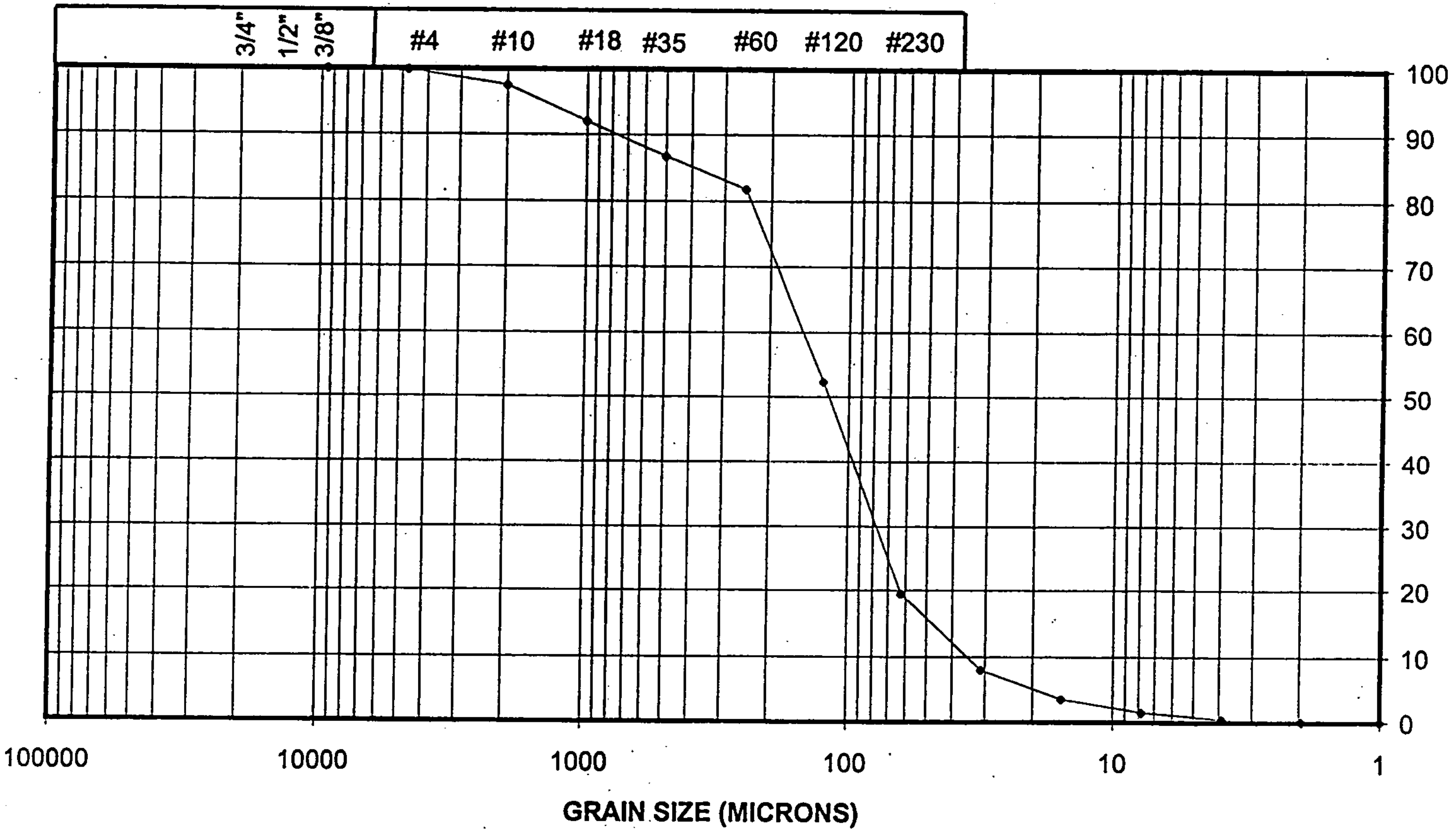


1000-121

ROSA ENVIRONMENTAL & GEOTECHNICAL LABORATORY

PSEP APPARENT GRAIN SIZE DISTRIBUTION

Project: Dames & Moore
Sample No. STE-SED-101698-3A

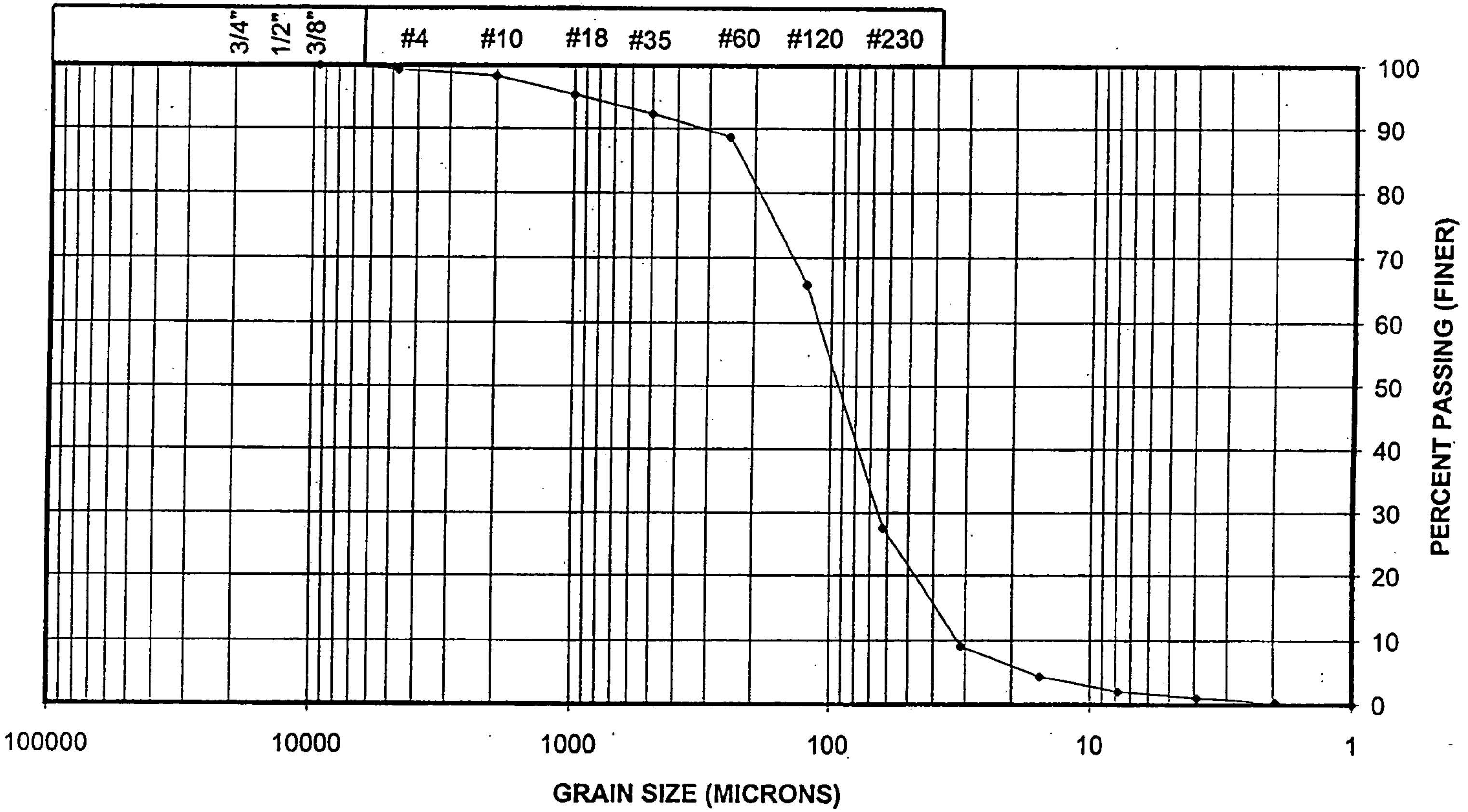


1000-121

ROSA ENVIRONMENTAL & GEOTECHNICAL LABORATORY

PSEP APPARENT GRAIN SIZE DISTRIBUTION

Project: Dames & Moore
Sample No. STE-SED-101698-3B

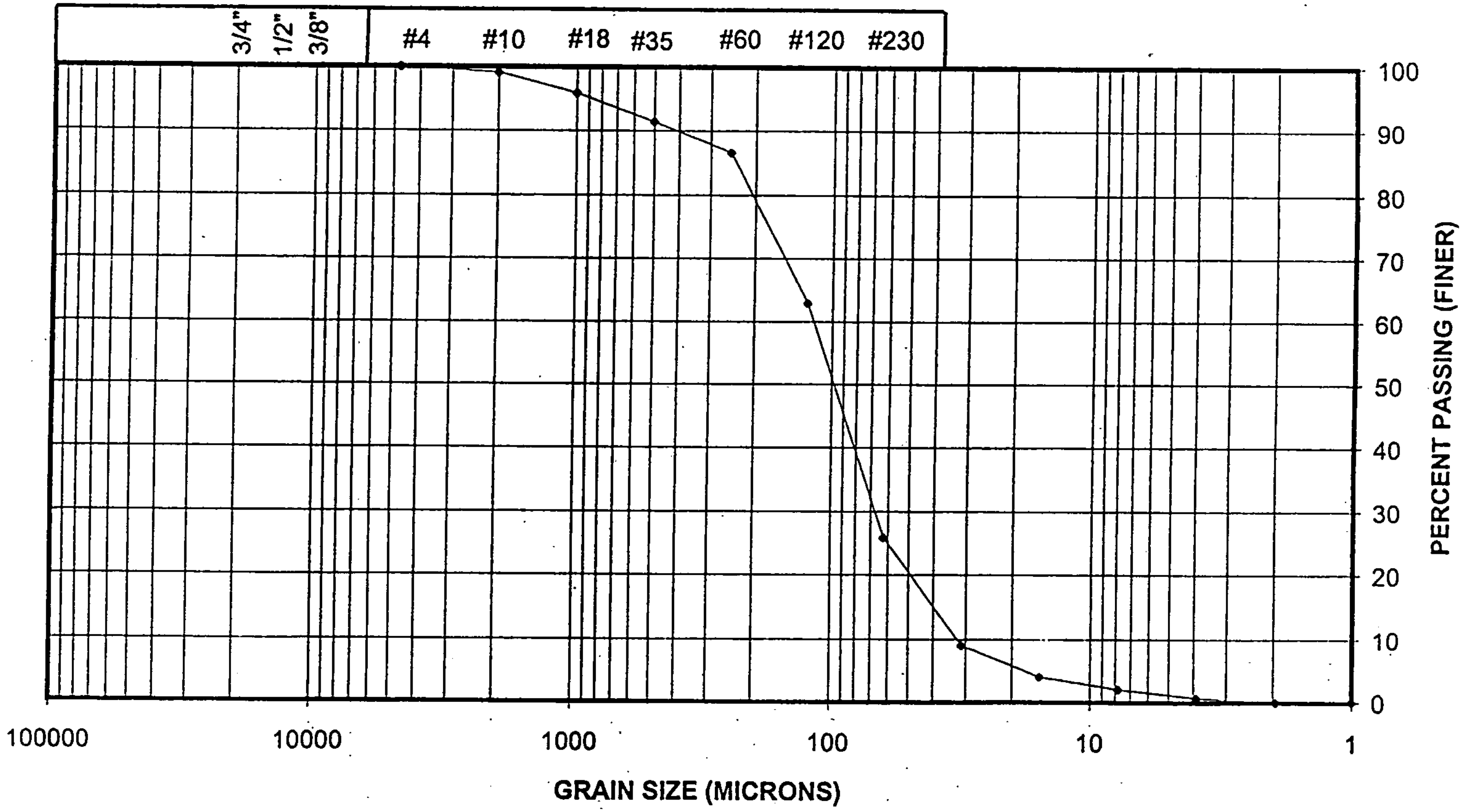


1000-121

ROSA ENVIRONMENTAL & GEOTECHNICAL LABORATORY

PSEP APPARENT GRAIN SIZE DISTRIBUTION

Project: Dames & Moore
Sample No. STE-SED-101698-3C

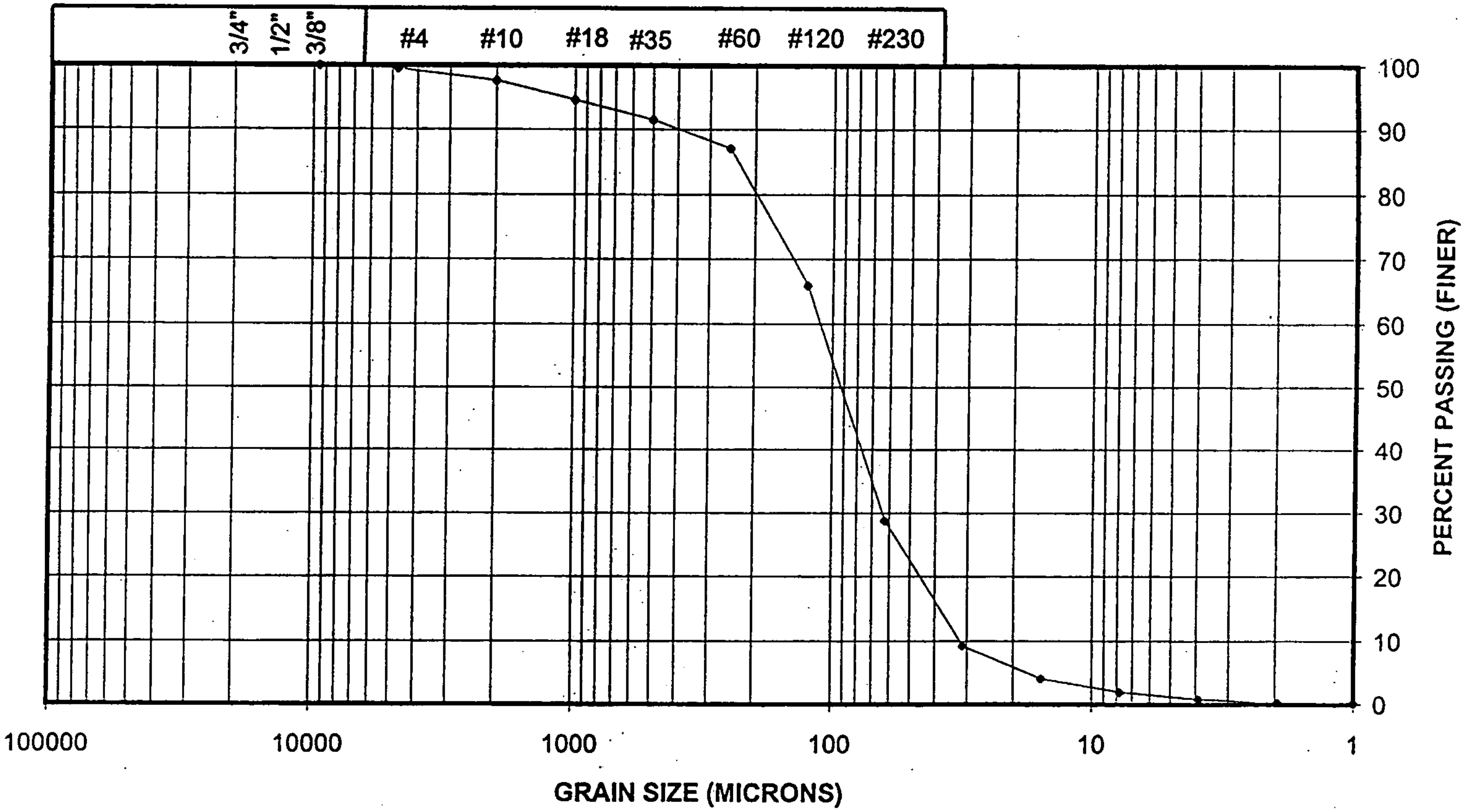


1000-121

ROSA ENVIRONMENTAL & GEOTECHNICAL LABORATORY

PSEP APPARENT GRAIN SIZE DISTRIBUTION

Project: Dames & Moore
Sample No. STE-SED-101698-4

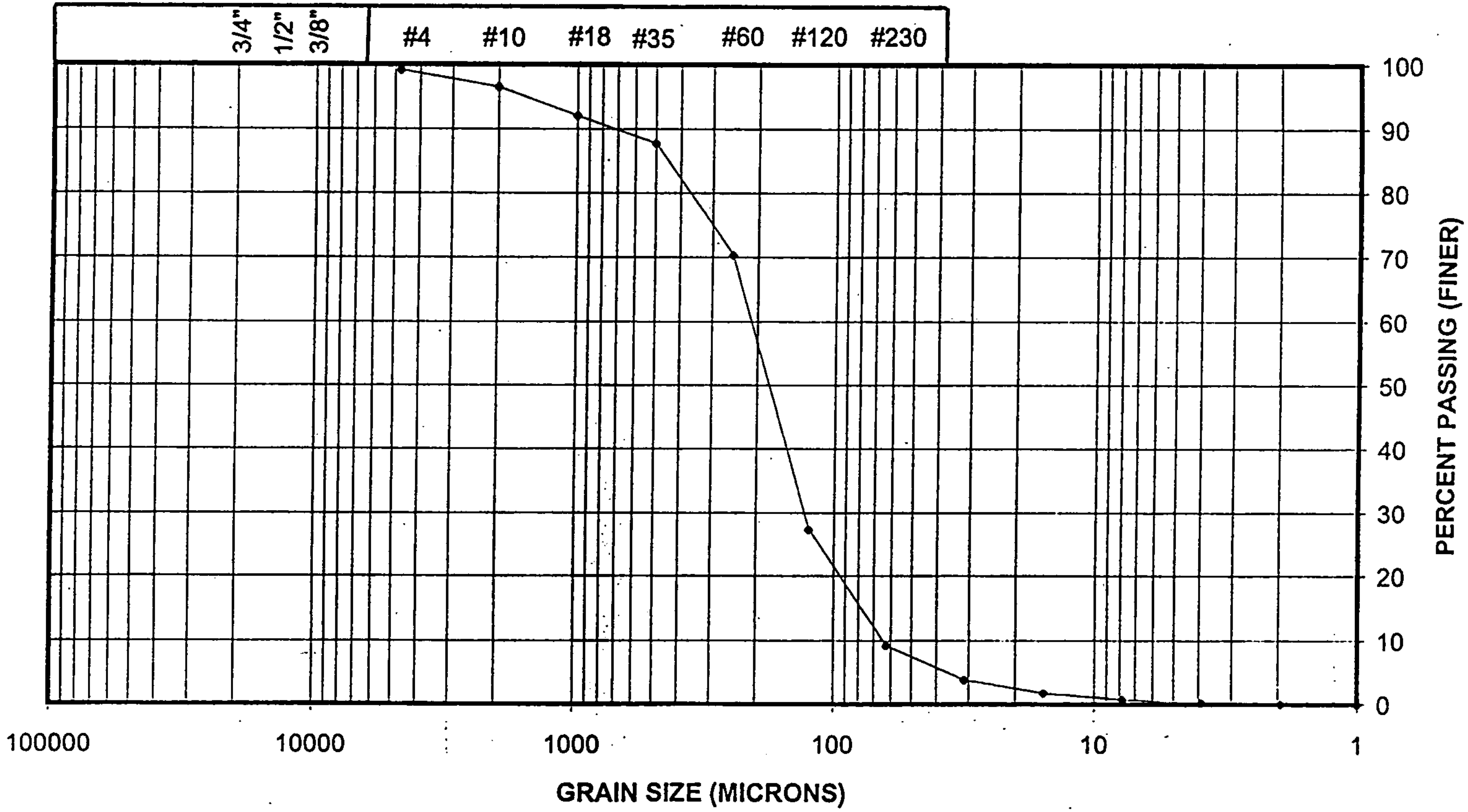


1000-121

ROSA ENVIRONMENTAL & GEOTECHNICAL LABORATORY

PSEP APPARENT GRAIN SIZE DISTRIBUTION

Project: Dames & Moore
Sample No. LUC-SED-101698-1-2

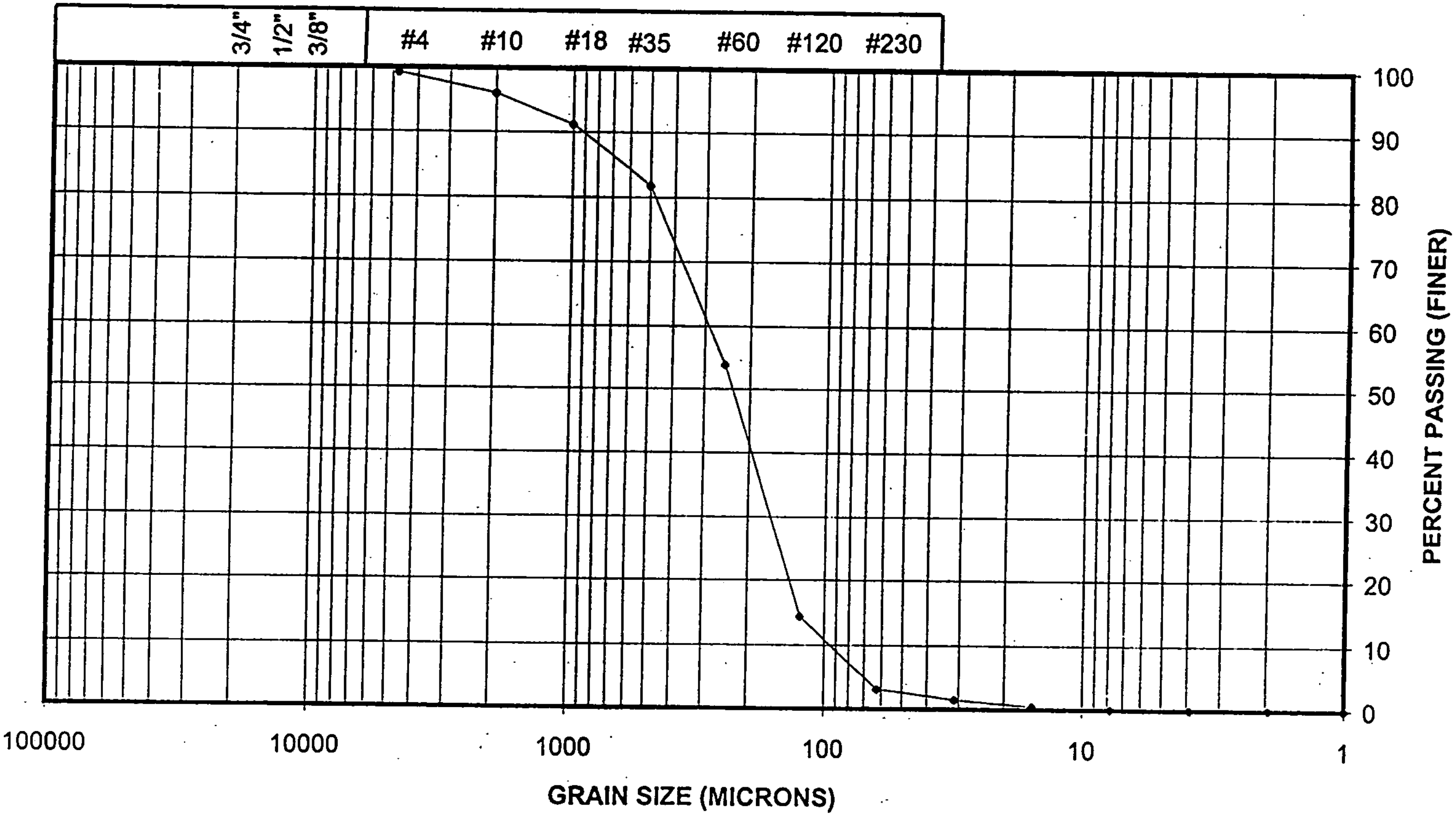


1000-121

ROSA ENVIRONMENTAL & GEOTECHNICAL LABORATORY

PSEP APPARENT GRAIN SIZE DISTRIBUTION

Project: Dames & Moore
Sample No. LUC-SED-101698-2-2

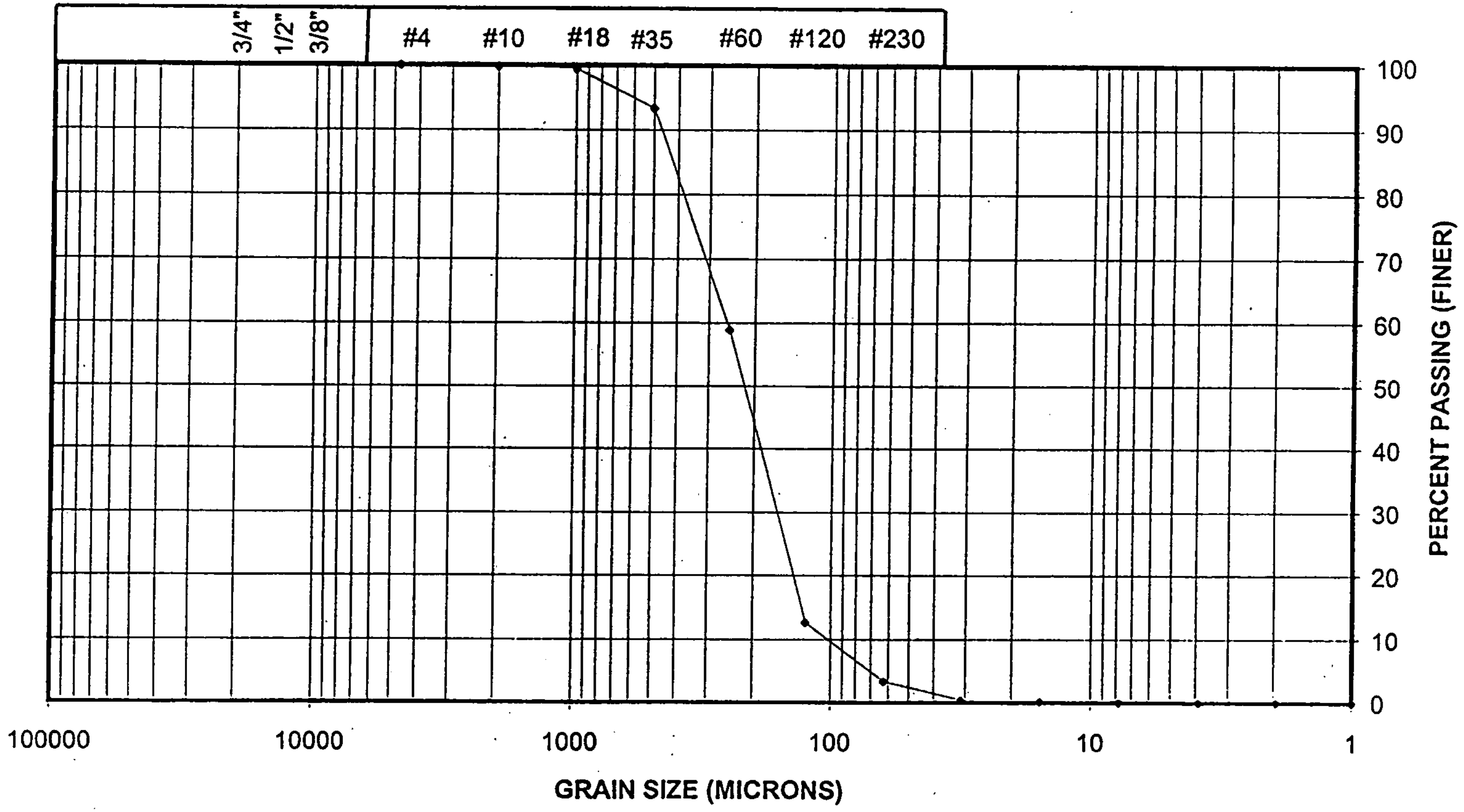


1000-121

ROSA ENVIRONMENTAL & GEOTECHNICAL LABORATORY

PSEP APPARENT GRAIN SIZE DISTRIBUTION

Project: Dames & Moore
Sample No. LUC-SED-101598-1-1

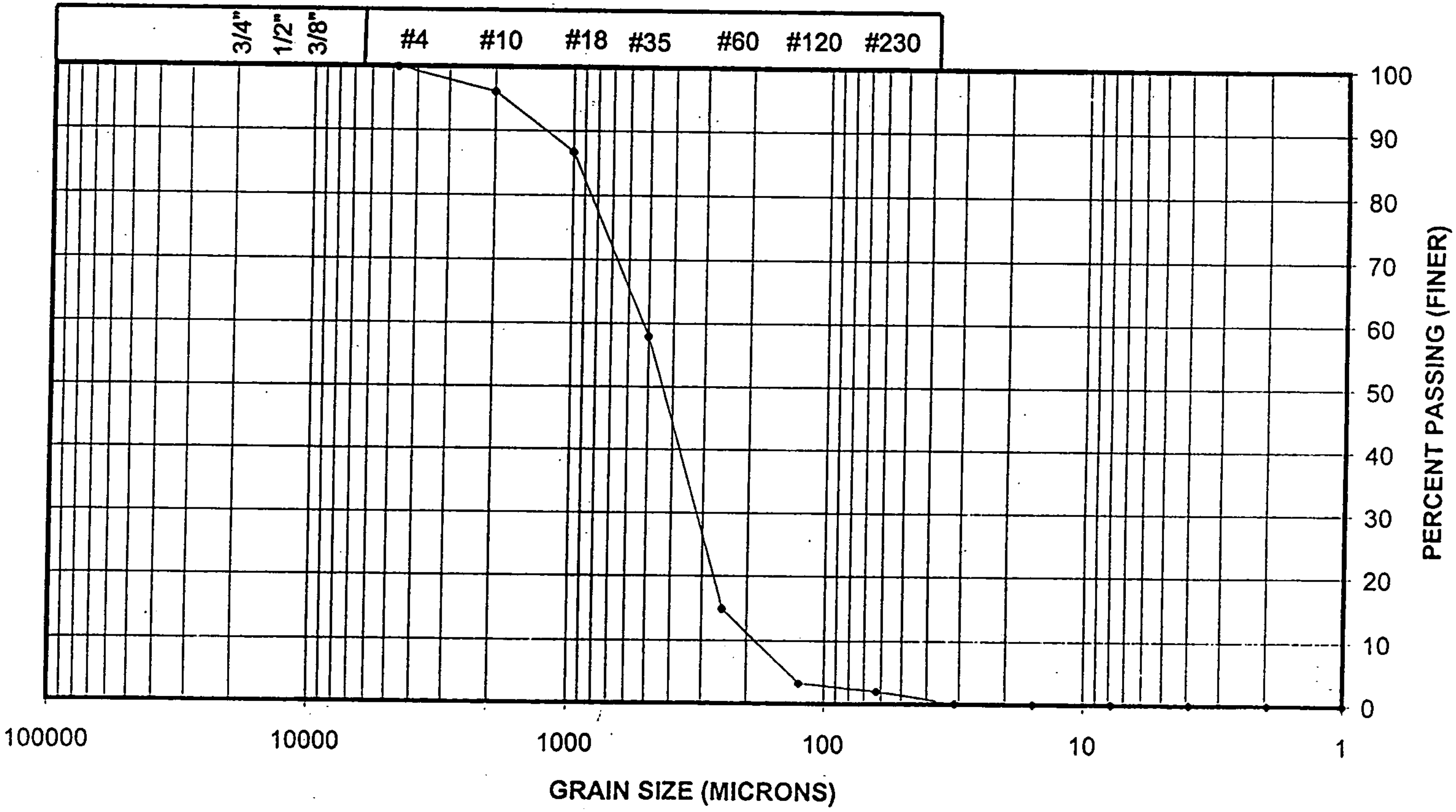


1000-121

ROSA ENVIRONMENTAL & GEOTECHNICAL LABORATORY

PSEP APPARENT GRAIN SIZE DISTRIBUTION

Project: Dames & Moore
Sample No. LUC-SED-101598-2-1

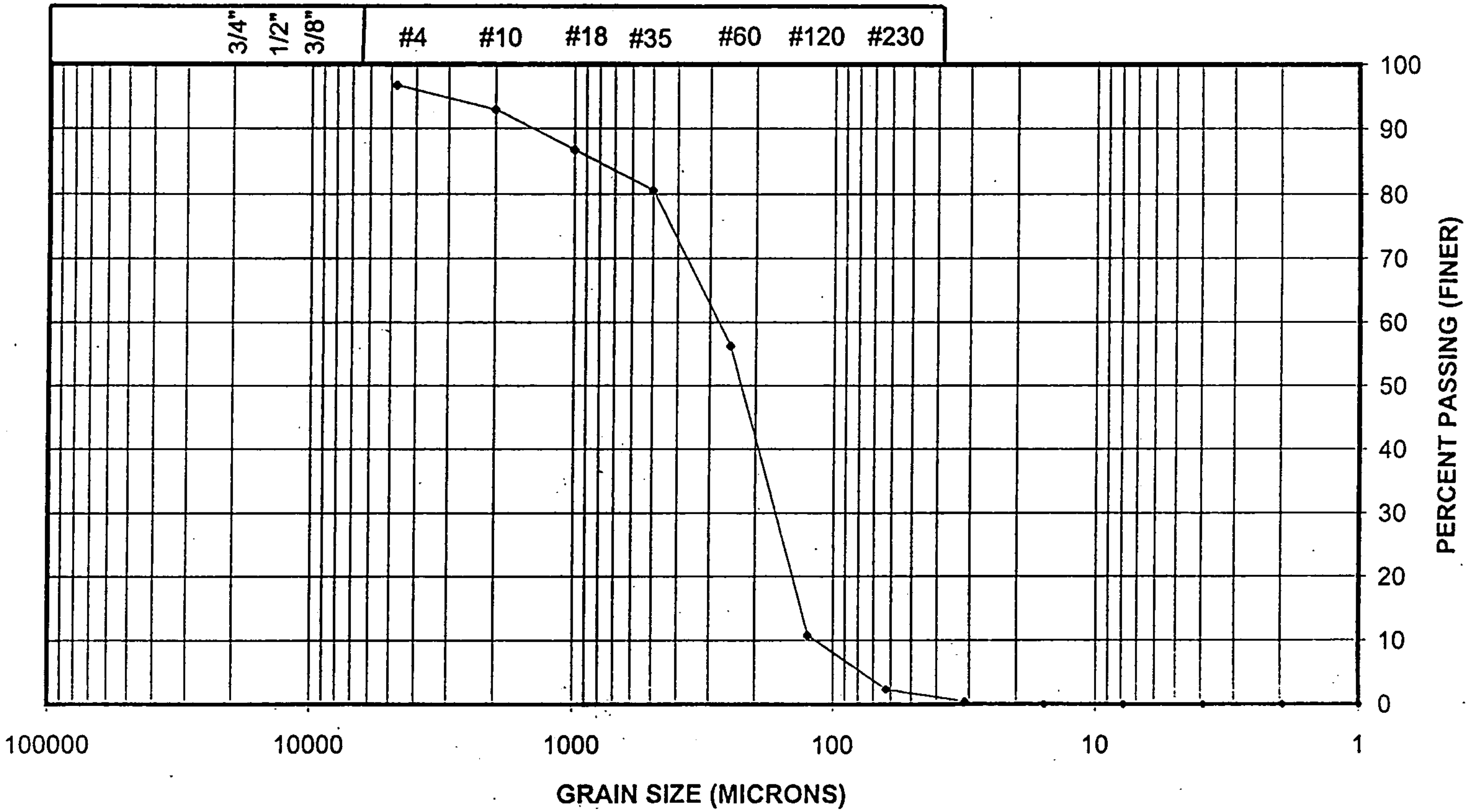


1000-121

ROSA ENVIRONMENTAL & GEOTECHNICAL LABORATORY

PSEP APPARENT GRAIN SIZE DISTRIBUTION

Project: Dames & Moore
Sample No. LUC-SED-101598-3-2

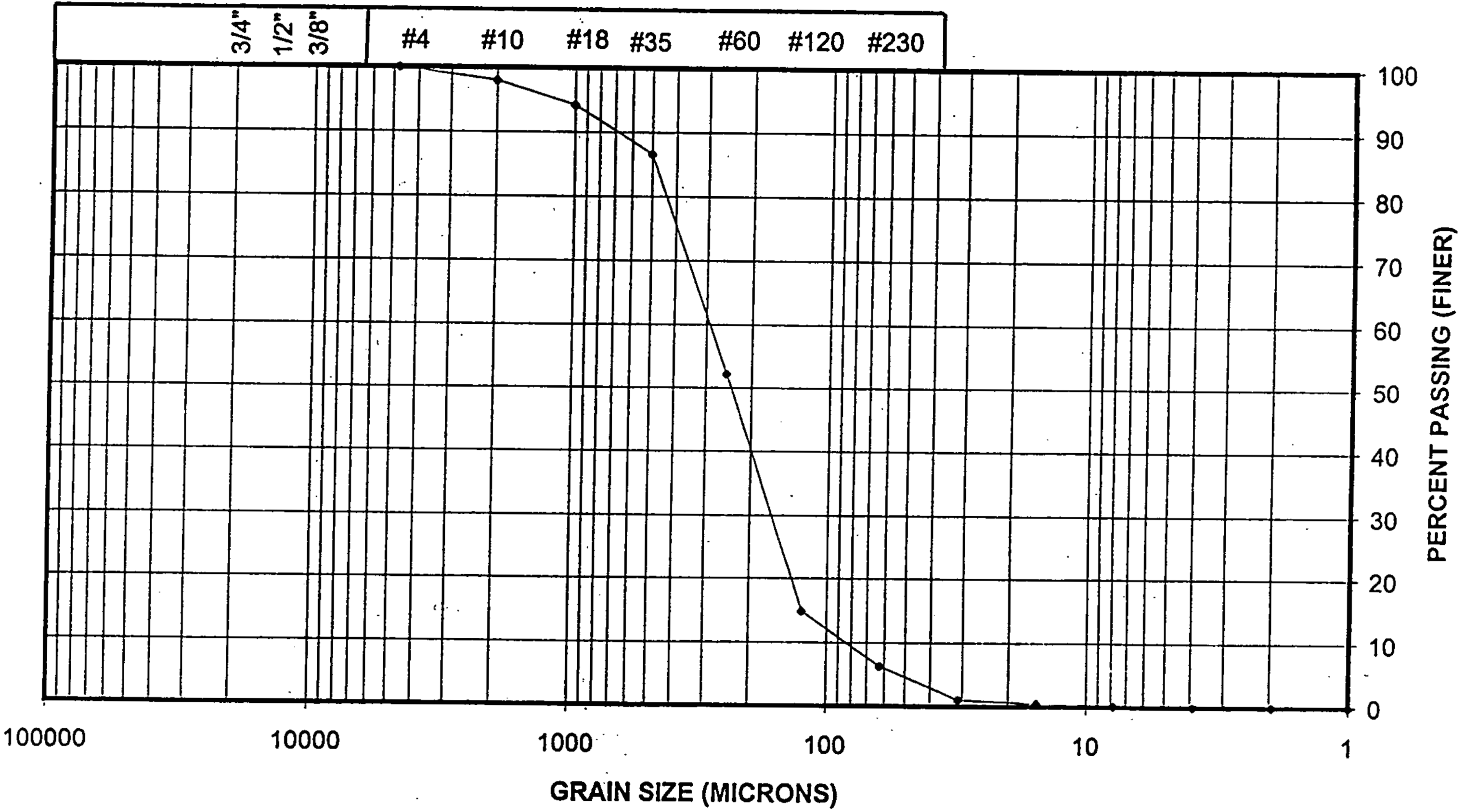


1000-121

ROSA ENVIRONMENTAL & GEOTECHNICAL LABORATORY

PSEP APPARENT GRAIN SIZE DISTRIBUTION

Project: Dames & Moore
Sample No. LUC-SED-101598-3-1A

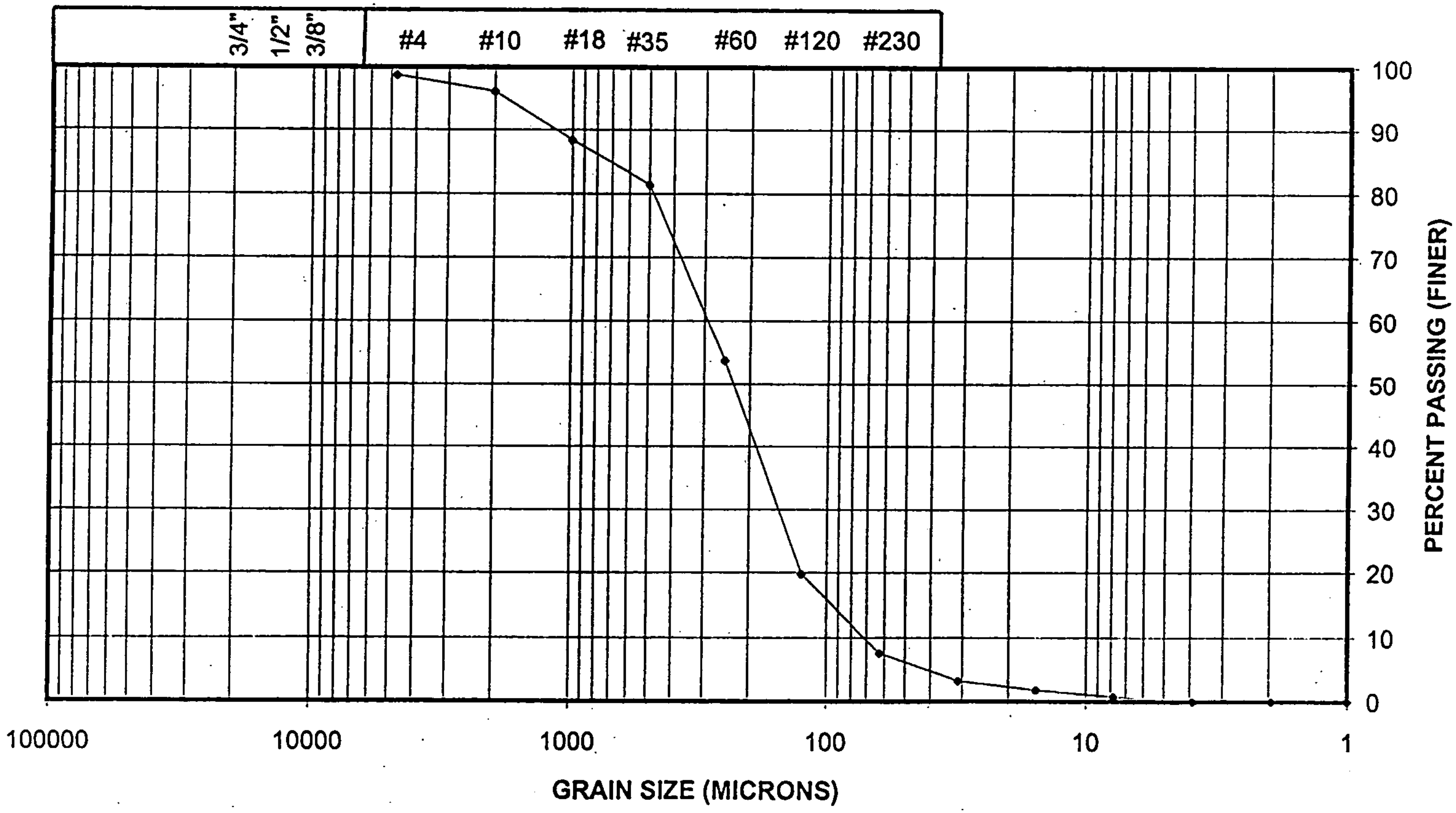


1000-121

ROSA ENVIRONMENTAL & GEOTECHNICAL LABORATORY

PSEP APPARENT GRAIN SIZE DISTRIBUTION

Project: Dames & Moore
Sample No. LUC-SED-101598-3-1B

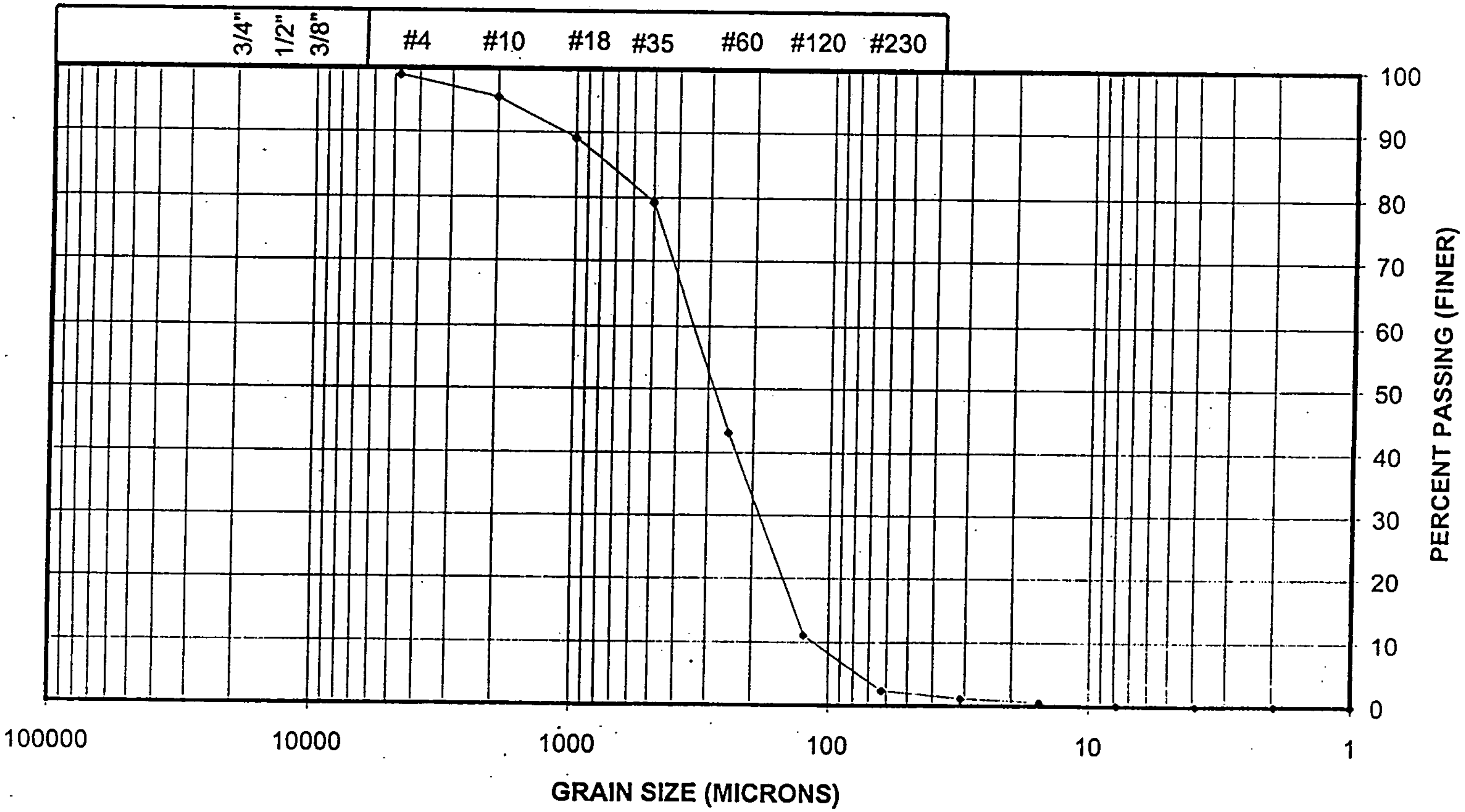


1000-121

ROSA ENVIRONMENTAL & GEOTECHNICAL LABORATORY

PSEP APPARENT GRAIN SIZE DISTRIBUTION

Project: Dames & Moore
Sample No. LUC-SED-101598-3-1C

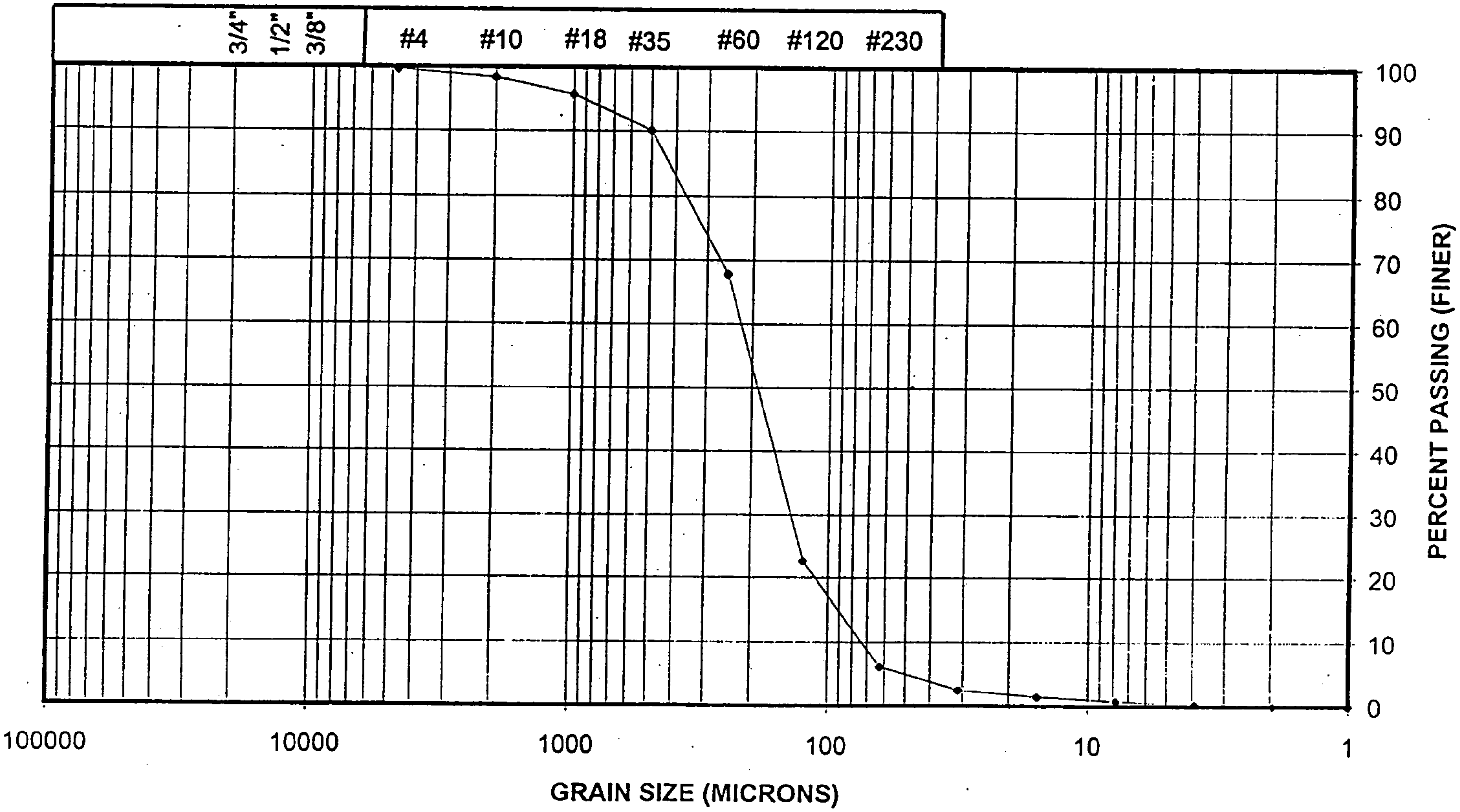


1000-121

ROSA ENVIRONMENTAL & GEOTECHNICAL LABORATORY

PSEP APPARENT GRAIN SIZE DISTRIBUTION

Project: Dames & Moore
Sample No. LUC-SED-101598-3-5-1

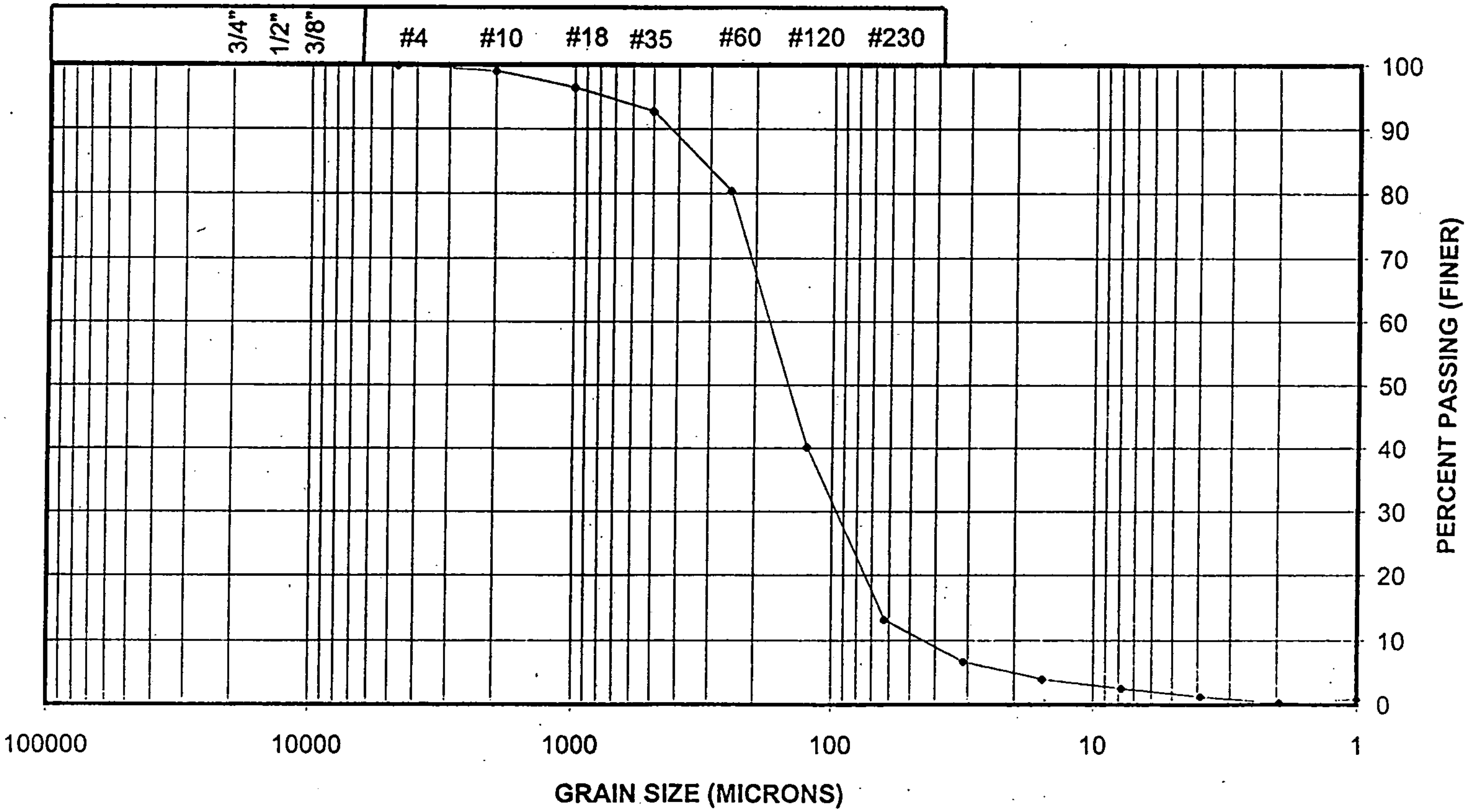


1000-121

ROSA ENVIRONMENTAL & GEOTECHNICAL LABORATORY

PSEP APPARENT GRAIN SIZE DISTRIBUTION

Project: Dames & Moore
Sample No. LUC-SED-101598-3-5-2

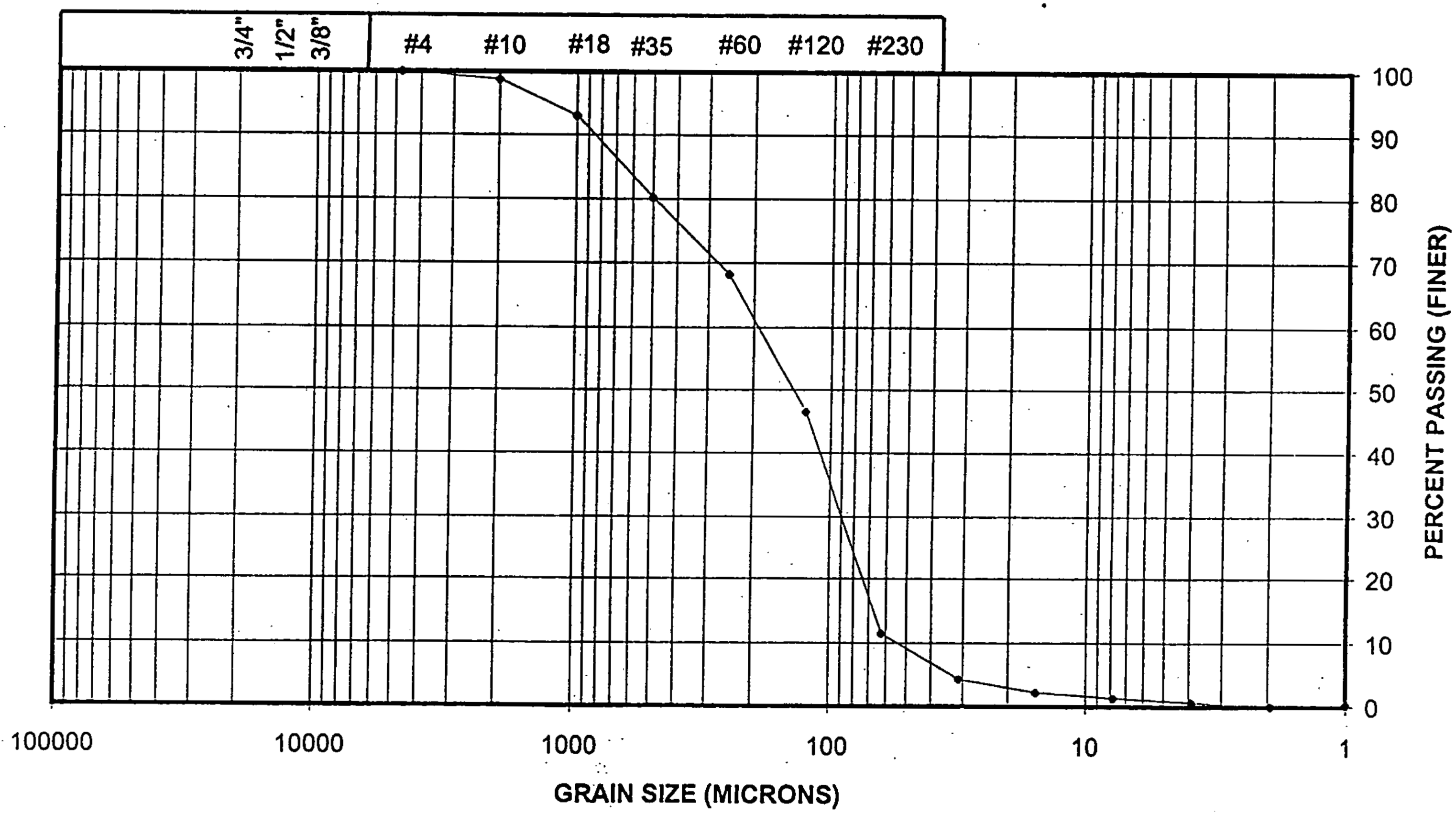


1000-121

ROSA ENVIRONMENTAL & GEOTECHNICAL LABORATORY

PSEP APPARENT GRAIN SIZE DISTRIBUTION

Project: Dames & Moore
Sample No. LUC-SED-101598-5-1

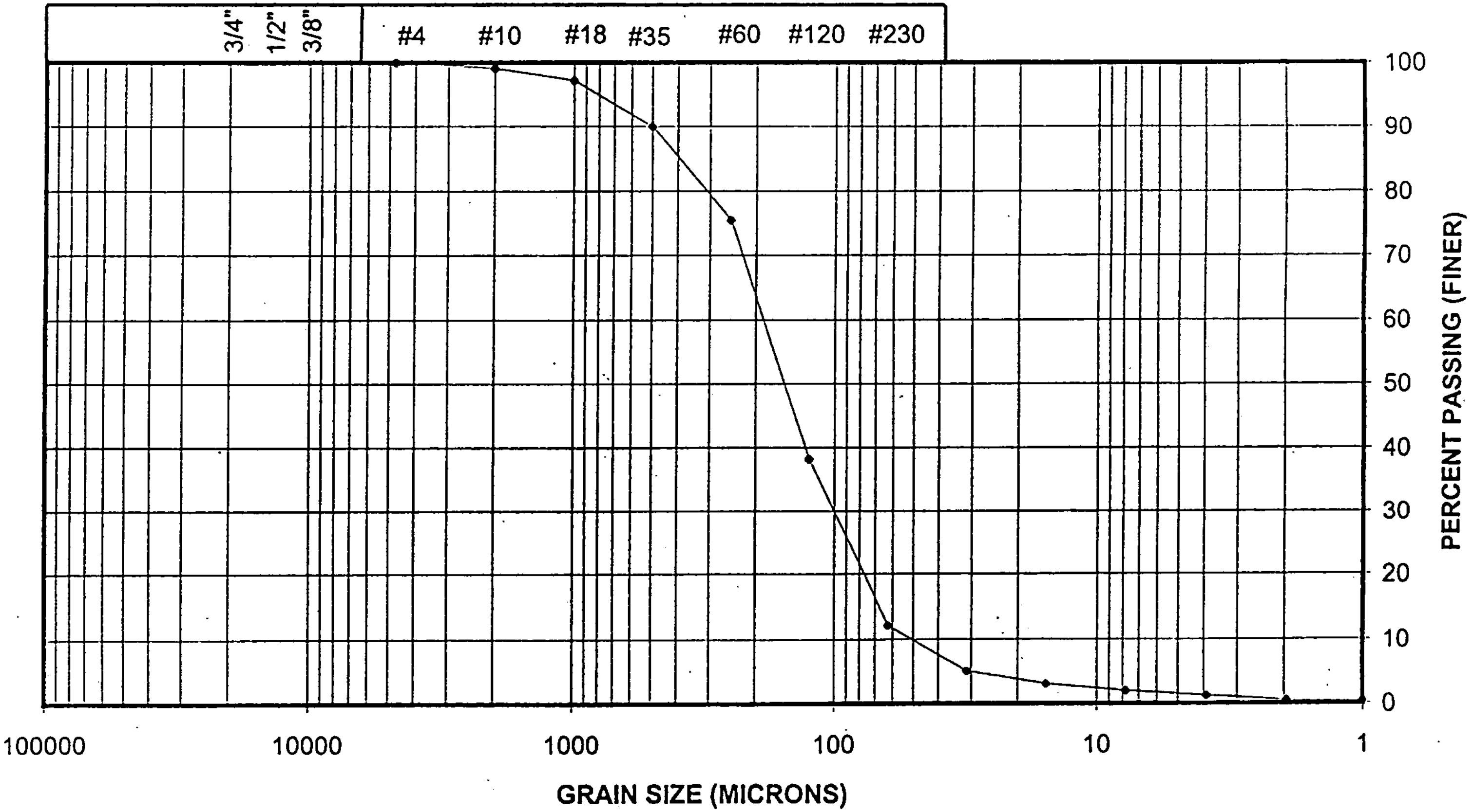


1000-121

ROSA ENVIRONMENTAL & GEOTECHNICAL LABORATORY

PSEP APPARENT GRAIN SIZE DISTRIBUTION

Project: Dames & Moore
Sample No. LUC-SED-101598-5-2



1000-121

Field Sample / Chain of Custody Record

Parametrix, Inc. · 5808 Lake Washington Blvd. · Kirkland, Washington 98033-7350 · 206-822-8880 · Fax 206-889-8808

Project Name: Holden Mine
Project Number: 1768-005-019
Client: Dames+moore
Samplers: P Stoltz
Recorder: P. Stoltz

Matrix				# of Containers and Preservatives							Sample Number	Date				Analysis Required
Water	Tissue	Sediment	Other	Unpreserved	HCl	H2S04	HNO3	NAOH	NAOH and Zinc Acetate	Other		Month	Day	Year PS 10/19/98	Time	
X							X				Rinse 10/15/98	10	19	~~830~~ 98	0830	Metals - Rinsate Blank
X							X				Rinse 10/16/98	10	19	~~0830~~ 1998 PS 10/19/98	0830	Metals - Rinsate Blank
																(HNO3)
Total Containers:																

Chain of Custody Record (Please Print)

Relinquished By: (Name)	Date:	Time:	Received By: (Name)	Date:	Time:
Peter Stoltz	10/19/98	0:840	Amy Bergin	10/19/98	845

Shipping Information

Cooler#: N/A
Airbill #:
___ of ___ Coolers on this Airbill

White Copy: Laboratory · Yellow Copy: Return to Parametrix Inc. · Pink Copy: Parametrix Inc.

Field Sample / Chain of Custody Record

4931 1D 7.5, 7.0 98-21651 to 98-21669

Parametrix, Inc. · 5808 Lake Washington Blvd. · Kirkland, Washington 98033-7350 · 206-822-8880 · Fax 206-889-8808

Project Name: Holden mine	**Project Number:** 17693-005-019	**Client:** Dames + Moore, Inc	
Samplers: Pete Stoltz, Kevin Smith, Bill Peters		**Recorder:** Bill Peters	

Matrix: Water	Matrix: Tissue	Matrix: Sediment	Matrix: Other	# of Containers and Preservatives: Unpreserved	HCl	H2S04	HNO3	NAOH	NAOH and Zinc Acetate	Other	Sample Number	Date: Month	Day	Year	Time	Analysis Required
											LUC-SED-101598-5-1					← 1540 WEBP 10/16/98
		✓		✓							Luc-Sed.101598-~~3.5-2~~ WEBP 10/15/98 7.5-1	10	15	98	~~1604~~	Grain size
		✓		✓							Luc-Sed-101598-3.5-1	10	15	98	1531	Metals + TOC + AVS - pH
		✓		✓							Luc-Sed-101598-1-1	10	15	98	1355	
		✓		✓							Luc-Sed-101598-5-2	10	15	98	1548	
		✓		✓							LUC-Sed-101598-3-2	10	15	98	1619	
		✓		✓							LUC-Sed-101598-3.5-2	10	15	98	1604	
		✓		✓							LUC-Sed-101598-3-1C	10	15	98	1523	
		✓		✓							LUC-Sed-101598-3-1B	10	15	98	1512	
		✓		✓							LUC-Sed-101598-3-1A	10	15	98	~~1426~~ 1441	WEBP 10/15/98 Grain size — Time 1441
		✓		✓							LUC-Sed-101598-2-1	10	15	98	1426	metals + TOC + AVS + pH
		✓		✓							LUC-Sed-101598-3-1A	10	15	98	1447	metals + TOC + AVS + pH
											LUC-Sed-101598-5-1	10	15	98	1540	metals + TOC + AVS + pH

Total Containers 12

Chain of Custody Record (Please Print)

Relinquished By: (Name)	Date:	Time:	Received By: (Name)	Date:	Time:
SI/ Placed in cooler on ice	10/15/98	1630	Samples in custody of Samplers	10/15/98	1630
	10/19/96	0826	Amy Bergin	10/19/96	8:30

Shipping Information

Cooler#:

Airbill #:

____ of ____ Coolers this Airbill

Field Sample / Chain of Custody Record

415

Parametrix, Inc. · 6808 Lake Washington Blvd. · Kirkland, Washington 98033-7350 · 206-[illegible]22-8880 · Fax 206-889-8808

Project Name: Holden Mine
Project Number: 1769-005-019
Client: Dames + Moore
Samplers: P. Stoltz, K. Smith, B. Peters (PMX) R. Langendoen (Dames + Moore)
Recorder: P. Stoltz

Matrix				# of Containers and Preservatives							Sample Number	Date				Analysis Required
Water	Tissue	Sediment	Other	Unpreserved	HCl	H2S04	HNO3	NAOH	NAOH and Zinc Acetate	Other		Month	Day	Year	Time	
		X		1							STE-SED-101698-1	10	16	98	1200	Metals, TOC, AVS, pH
		X		1							STE-SED-101698-2	10	16	98	1223	↓
		X		1							STE-SED-101698-3A	10	16	98	1236	
		X		1							STE-SED-101698-3B	10	16	98	1240	
		X		1							STE-SED-101698-3C	10	16	98	1247	
		X		1							STE-SED-101698-4	10	16	98	1258	

Total Containers: 6

Chain of Custody Record (Please Print)

Relinquished By: (Name)	Date:	Time:	Received By: (Name)	Date:	Time:
Peter Stoltz	10/16/98	1300	Samples in custody of samplers	10/16/98	1300
	10/19/98	0826	Amy Begin	10/19/98	8:30

Shipping Information

Cooler#: N/A

Airbill #:

___ of ___ Coolers on this Airbill

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~~314~~ 415

Field Sample / Chain of Custody Record

Parametrix, Inc. • 5808 Lake Washington Blvd. • Kirkland, Washington 98033-7350 • 206-822-8880 • Fax 206-889-8808

Project Name: Holden Mine
Project Number: 17693-005-019
Client: Dames + Moore, Inc
Samplers: Pete Stoltz, Kevin Smith, Bill Peters
Recorder: Bill Peters

Matrix				# of Containers and Preservatives							Sample Number	Date				Analysis Required
Water	Tissue	Sediment	Other	Unpreserved	HCl	H2S04	HNO3	NAOH	NAOH and Zinc Acetate	Other		Month	Day	Year	Time	WE BP 10/15/98
		✓		✓						-	LUC-SED-101598-2-1	10	15	98	1426	~~Tox~~ - Grain size
		✓		✓						-	LUC-SED-101598-3.5-1	10	15	98	1531	Grain size
		✓		✓						-	LUC-SED-101598-1-1	10	15	98	1355	Grain size
		✓		✓						-	LUC-SED-101598-5-2	10	15	98	1548	↓
		✓		✓						-	LUC-SED-101598-3-2	10	15	98	1019	
		✓		✓						-	LUC-SED-101598-3.5-2	10	15	98	1604	
		✓		✓						-	LUC-SED-101598-3-1C	10	15	98	1523	
		✓		✓						-	LUC-SED-101599-3-1B	10	15	98	1512	Grain size
											~~LUC-SED-101599-~~ WE BP 10/15/98					

Total Containers: 8

Chain of Custody Record (Please Print)

Relinquished By: (Name)	Date:	Time:	Received By: (Name)	Date:	Time:
Bill Peters Samples intact Placed in cooler w/ice	10/15/98	1630	samples in custody of samplers	10/15/98	1630
	10/19/98	08:26	Amy Bergin	10/19/98	8:30

Shipping Information

Cooler#:

Airbill #:

____ of ____ Cooler his Airbill

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Field Sar / Chain of Custody Record

8H 315

Parametrix, Inc. · 5808 Lake Washington Blvd. · Kirkland, Washington 98033-7350 · 206-822-8880 · Fax 206-889-8808

Project Name: Holden Mine
Project Number: 769-005-019
Client: Dames + Moore, Inc.
Samplers: P. Stoltz, B. Peters, K. Smith (PMX), R. Langendoen (Dames + Moore)
Recorder: P. Stoltz

Matrix				# of Containers and Preservatives							Sample Number	Date				Analysis Required
Water	Tissue	Sediment	Other	Unpreserved	HCl	H2S04	HNO3	NAOH	NAOH and Zinc Acetate	Other		Month	Day	Year	Time	
		X		1							STE-SED-101698-1	10	16	98	1200	Grain Size
		X		1							STE-SED-101698-2	10	16	98	1223	
		X		1							STE-SED-101698-3A	10	16	98	1236	
		X		1							STE-SED-101698-3B	10	16	98	1240	time on jar reads 1247
		X		1							STE-SED-101698-3C	10	16	98	1247	
		X		1							STE-SED-101698-4	10	16	98	1258	
											~~STE-SED-101698-~~	~~10~~	~~16~~	~~98~~		PS 10/16/98
											UIC-SED-1016-98-2-2	10	16	98	1013	grainsize, metals, etc.
											UIC-sed-1016-98-1-1	10	16	98	951	" "
Total Containers:				6							+ two samples not listed on COC.					

Chain of Custody Record (Please Print)

Relinquished By: (Name)	Date:	Time:	Received By: (Name)	Date:	Time:
Peter Stoltz	10/16/98	1300	Samples in custody of samplers	10/16/98	1300
	10/19/98	0826	Amy Burgh	10/19/98	8:20

Shipping Information

Cooler#: N/A
Airbill #:
___ of ___ Coolers on this Airbill

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MEMORANDUM

Date: July 2,1999

To: Rik Langendoen, Project Manager

From: Karen Mixon, QA/QC Manager KM

Subject: Summary Data Quality Review
Holden Mine Remedial Investigation Phase III
Sediment Data, Fall 1998
Dames & Moore Job #17693-005-019

The summary data quality review of one sediment sample collected on October 15, 1998 has been completed. A reanalysis of this sample was requested by Dames & Moore to confirm original sample results. The sample was analyzed at the Analytical Resources, Incorporated (ARI) laboratory in Seattle, Washington for metals by EPA Methods 6010A and 200.8 modified (including the following metals: aluminum, arsenic, cadmium, copper, iron, lead, manganese, and zinc). The analyses were performed in accordance with the methods specified in EPA Test Methods for Evaluating Solid Waste, SW-846, January 1995. The laboratory provided a validation package containing method associated QA/QC data as well as sample data. The following sample is associated with laboratory work order ARI# AB35:

Sample I.D.	ARI Sample #
LUC-SED-101598-5-1	AB35A

The following comments refer to ARI's performance in meeting quality control specifications described in the EPA documents "EPA Test Methods for Evaluating Solid Waste, SW-846", January 1995, and "USEPA Contract Laboratory Program (CLP) National Functional Guidelines for Inorganic Data Review", February 1994. Data were also reviewed in reference to the Quality Assurance Project Plan (QAPP) prepared for the Phase III Remedial Investigation referenced in addendum (August 28, 1998) to the Sampling and Analysis Plan.

1. Holding Time - Acceptable
2. Tunes (ICP MS analysis only) - Acceptable
3. Initial Calibration - Acceptable
4. Continuing Calibration - Acceptable
5. Blanks - Acceptable
6. Internal Standards (ICP MS analysis only) – Acceptable
7. ICP Interference Check (ICP analysis only) - Acceptable
8. Laboratory Control Sample (LCS) – Acceptable

   A standard reference material (SRM) was analyzed in lieu of a typical LCS.

9. Laboratory Duplicate Sample – Not Applicable

A laboratory duplicate was not performed as only one sample analysis was performed. Data were not qualified.

10. Field Duplicate – Not Applicable

11. Matrix Spike

A matrix spike was not performed as only one sample analysis was performed. Data were not qualified.

12. ICP Serial Dilution (ICP analysis only) - Acceptable

13. Detection Limits - Acceptable

14. Type of Review - Summary

15. Overall Assessment of Data

The usefulness of the data is based on EPA guidance documents listed above. Upon consideration of the information presented above, the data are acceptable except where flagged with data qualifiers that modify the usefulness of the individual values.

Data Qualifiers:

U The analyte was analyzed for, but was not detected above the reported sample quantitation limit.

J The analyte was positively identified; the associated numerical value is the approximate concentration of the analyte in the sample.

UJ The analyte was not detected above the reported sample quantitation limit. However, the reported quantitation limit is approximate and may or may not represent the actual limit of quantitation necessary to accurately and precisely measure the analyte in the sample.

R The sample results are rejected due to serious deficiencies in the ability to analyze the sample and meet quality control criteria. The presence or absence of the analyte cannot be verified.

**ANALYTICAL
RESOURCES
INCORPORATED**

**INORGANICS ANALYSIS DATA SHEET
TOTAL METALS**

Sample No: LUC-SED-101598-5-1

Lab Sample ID: AB35A
LIMS ID: 99-3080
Matrix: Soil

QC Report No: AB35-Dames & Moore
Project: Holden Mine
17693-005-079
Date Sampled: 10/15/98
Date Received: 10/16/99

Data Release Authorized:
Reported: 03/19/99

Percent Total Solids: 45.3%

Prep Meth	Prep Date	Analysis Method	Analysis Date	CAS Number	Analyte	RL	mg/kg-dry
3050	03/15/99	6010	03/16/99	7429-90-5	Aluminum	4	17,800
3050	03/15/99	200.8	03/17/99	7440-38-2	Arsenic	0.4	17.5
3050	03/15/99	200.8	03/17/99	7440-43-9	Cadmium	0.4	1.6
3050	03/15/99	200.8	03/17/99	7440-50-8	Copper	1	161
3050	03/15/99	6010	03/16/99	7439-89-6	Iron	4	53,700
3050	03/15/99	200.8	03/17/99	7439-92-1	Lead	2	19
3050	03/15/99	6010	03/16/99	7439-96-5	Manganese	0.2	401
3050	03/15/99	6010	03/16/99	7440-66-6	Zinc	0.8	432

U Analyte undetected at given RL

RL Reporting Limit

FORM-I

ANALYTICAL
RESOURCES
INCORPORATED

INORGANICS ANALYSIS DATA SHEET
TOTAL METALS

Sample No: Method Blank

Lab Sample ID: AB35MB
LIMS ID: 99-3080
Matrix: Soil

QC Report No: AB35-Dames & Moore
Project: Holden Mine
17693-005-079
Date Sampled: NA
Date Received: NA

Data Release Authorized:
Reported: 03/19/99

Percent Total Solids: NA

Prep Meth	**Prep Date**	**Analysis Method**	**Analysis Date**	**CAS Number**	**Analyte**	**RL**	**mg/kg-dry**
3050	03/15/99	6010	03/16/99	7429-90-5	Aluminum	2	2 U
3050	03/15/99	200.8	03/17/99	7440-38-2	Arsenic	0.2	0.2 U
3050	03/15/99	200.8	03/17/99	7440-43-9	Cadmium	0.2	0.2 U
3050	03/15/99	200.8	03/17/99	7440-50-8	Copper	0.5	0.5 U
3050	03/15/99	6010	03/16/99	7439-89-6	Iron	2	2 U
3050	03/15/99	200.8	03/17/99	7439-92-1	Lead	1	1 U
3050	03/15/99	6010	03/16/99	7439-96-5	Manganese	0.1	0.1 U
3050	03/15/99	6010	03/16/99	7440-66-6	Zinc	0.4	0.4 U

U Analyte undetected at given RL

RL Reporting Limit

FORM-I

ANALYTICAL
RESOURCES
INCORPORATED

INORGANICS ANALYSIS DATA SHEET

Sample No: STD REFERENCE
ERA Lot 239

Lab Sample ID: AB35-SRM
LIMS ID: 99-3080
Matrix: Sediment

QC Report No: AB35-Dames & Moore
Project: Holden Mine
17693-005-079
Date Sampled: NA
Date Received: NA

Data Release Authorized:
Reported: 03/19/99

Analyte	**mg/kg-dry**	**Certified Value**	**Advisory Range**
Aluminum	6680	5720	3760-7690
Arsenic	161	189	118-260
Cadmium	107	141	105-177
Copper	86.0	99.8	70.9-129
Iron	9020	9080	4830-13300
Lead	64.1	84.4	57.1-112
Manganese	281	261	204-319
Zinc	201	190	144-236

FORM-VII

MEMORANDUM

Date: December 8, 1998

To: Rik Langendoen, Project Manager

From: Karen Mixon, QA/QC Manager KM

Subject: Summary Data Quality Review
Holden Mine Remedial Investigation Phase III
Background Soil Data, Fall 1998
Dames & Moore Job #17693-005-019

The summary data quality review of 20 soil samples collected from October 12 through 17, 1998 has been completed. The samples were analyzed at the Analytical Resources, Incorporated (ARI) laboratory in Seattle, Washington for metals by EPA Methods 6010A, 7000 series, and 200.8 modified (including the following metals: aluminum, arsenic, barium, beryllium, cadmium, calcium, chromium, copper, iron, lead, magnesium, manganese, molybdenum, nickel, potassium, silver, sodium, thallium, uranium, and zinc). The analyses were performed in accordance with the methods specified in EPA Test Methods for Evaluating Solid Waste, SW-846, January 1995. A validation package containing method associated QA/QC data and sample data was provided by the laboratory. The following samples are associated with laboratory work order ARI# Y962:

Sample I.D.	ARI Sample #
DMBG-10	Y962A
DMBG-10X	Y962B
DMBG-6	Y962C
DMBG-5	Y962D
DMBG-7	Y962E
DMBG-4	Y962F
DMBG-3	Y962G
DMBG-8	Y962H
DMBG-2	Y962I
DMBG-1	Y962J
DMBG-9	Y962K
DMBG-16	Y962L
DMBG-17	Y962M
DMBG-18	Y962N
DMBG-19	Y962O
DMBG-15	Y962P
DMBG-14	Y962Q
DMBG-13	Y962R
DMBG-12	Y962S
DMBG-11	Y962T

The following comments refer to ARI's performance in meeting quality control specifications described in the EPA documents "EPA Test Methods for Evaluating Solid Waste, SW-846", January 1995, and "USEPA Contract Laboratory Program (CLP) National Functional Guidelines for Inorganic Data Review", February 1994, and the Quality Assurance Project Plan (QAPP) prepared for the Phase III Remedial Investigation referenced in an addendum (August 28, 1998) to the Phase III Sampling and Analysis Plan.

Samples were prepared in the laboratory using EPA Methods 3050, 7060, 7841, and 200.8 as appropriate. Samples were analyzed by ICP (EPA Method 6010A), GFAA (EPA 7000 series), and ICP MS (EPA Method 200.8 Modified).

1. Holding Time - Acceptable

2. Tunes (ICP MS analysis only) - Acceptable

3. Initial Calibration - Acceptable

4. Continuing Calibration - Acceptable

5. Blanks

Barium (1.1 ug/L) was detected in the continuing calibration blank (CCB) analyzed prior to samples DMBG-1, DMBG-2, DMBG-3, DMBG-4, DMBG-5, DMBG-7, DMBG-8, and DMBG-9. This CCB was analyzed after samples DMBG-10, DMBG-10X, and DMBG-6. Aluminum (21.3 ug/L) was detected in the CCB analyzed after samples DMBG-1, DMBG-2, DMBG-3, DMBG-4, DMBG-5, DMBG-7, DMBG-8, and DMBG-9. Aluminum (23.4 ug/L), calcium (39.2 ug/L), copper (3.2 ug/L), magnesium (29.9 ug/L) and zinc (5.6 ug/L) were detected in the ending CCB associated with samples DMBG-1, DMBG-2, DMBG-3, DMBG-4, DMBG-5, DMBG-6, DMBG-7, DMBG-8, DMBG-9, DMBG-10, and DMBG-10X. As the concentrations of metals detected in the CCBs were substantially lower (minimum of 10X) than the concentration of metals detected in the associated samples, data were not qualified.

Calcium (25.8 ug/L to 44.2 ug/L) was detected in the CCBs associated with samples DMBG-11, DMBG-12, DMBG-13, DMBG-14, DMBG-15, DMBG-16, DMBG-17, DMBG-18, and DMBG-19. Aluminum (25.6 ug/L) and manganese (1.8 ug/L) were detected in the CCB analyzed prior to samples DMBG-14, DMBG-15, DMBG-16, and DMBG-19. As the aluminum, calcium, and manganese concentrations detected in the CCBs were substantially lower (minimum of 10X) than the concentration of metals detected in the associated samples, data were not qualified.

Aluminum (4 mg/kg), barium (0.1 mg/kg), calcium (3 mg/kg), sodium (18 mg/kg), and zinc (0.5 mg/kg) were detected in the method blank associated with samples DMBG-10, DMBG-10X, DMBG-6, DMBG-5, DMBG-7, DMBG-4, DMBG-3, DMBG-8, DMBG-2, DMBG-1, and DMBG-9. Concentrations of these metals in the samples were greater than 10X the concentrations detected in the method blank. Data were not qualified.

Calcium (7 mg/kg) was detected in the method blank associated with samples DMBG-11, DMBG-12, DMBG-13, DMBG-14, DMBG-15, DMBG-16, DMBG-17, DMBG-18, and DMBG-19. Sample results for calcium reported in associated samples were greater than 10X the method blank concentration. Data were not qualified.

6. Internal Standards (ICP MS analysis only) - Acceptable

7. ICP Interference Check (ICP analysis only) - Acceptable

8. Laboratory Control Sample (LCS) – Acceptable

A standard reference material (SRM) was analyzed in lieu of a typical LCS. Aluminum recovery (127%) in the SRM associated with samples DMBG-1, DMBG-2, DMBG-3, DMBG-4, DMBG-5, DMBG-6, DMBG-7, DMBG-8, DMBG-9, DMBG-10, and DMBG-10X was above the typical LCS control limits of 80 to 120%. However, the recovery was within the advisory range published by the supplier. Calcium recovery (52.6%) in the SRM associated with samples DMBG-11, DMBG-12, DMBG-13, DMBG-14, DMBG-15, DMBG-16, DMBG-17, DMBG-18, and DMBG-19 was below the typical LCS control limits of 80 to 120%. However, the recovery was within the advisory range published by the supplier. Uranium was inadvertently omitted from SRM or LCS analysis.

Data qualifiers were not assigned to aluminum or calcium results as the recoveries from the SRM were within published advisory ranges. Uranium results were not qualified as the associated matrix spike results were acceptable.

9. Laboratory Duplicate Sample

A laboratory duplicate was performed on sample DMBG-10. The relative percent difference for chromium was 26.6 %, above the method criteria of 20%. Chromium results reported above the detection limit in associated samples are qualified as estimated and flagged "J" accordingly. Results reported as not detected do not require qualification. Associated samples include DMBG-1, DMBG-2, DMBG-3, DMBG-4, DMBG-5, DMBG-6, DMBG-7, DMBG-8, DMBG-9, DMBG-10, and DMBG-10X.

A laboratory duplicate was performed on sample DMBG-16. The relative percent difference for manganese was 20.8%, slightly above the method criteria of 20%. Manganese results reported above the detection limit in associated samples are qualified as estimated and flagged "J" accordingly. Results reported as not detected do not require qualification. Associated samples include DMBG-11, DMBG-12, DMBG-13, DMBG-14, DMBG-15, DMBG-16, DMBG-17, DMBG-18, and DMBG-19.

10. Field Duplicate - Acceptable

A field duplicate for DMBG-10 was submitted and labeled DMBG-10X. Duplicate results were comparable to the original sample results.

11. Matrix Spike

A matrix spike was performed on sample DMBG-10. The recovery for iron (47.4%) was outside of the control limits (75-125%). The concentration of iron (10,400 mg/kg) in the sample exceeded the spiking concentration by greater than 4X. Data qualification was not required.

A matrix spike was performed on sample DMBG-16. The recovery for aluminum (199%), iron (181%), and manganese (137%) were outside of the method control limits (75-125%). The concentration of aluminum (11,200 mg/kg), iron (10,500 mg/kg), and manganese (1,160 mg/kg) in the sample exceeded the spiking concentration by greater than 4X. Data qualification was not required.

12. Graphite Furnace Atomic Absorption QC – Acceptable

13. ICP Serial Dilution (ICP analysis only) - Acceptable

14. Detection Limits - Acceptable

15. Type of Review - Summary

16. Overall Assessment of Data

The usefulness of the data is based on EPA guidance documents listed above. Upon consideration of the information presented above, the data are acceptable except where flagged with data qualifiers that modify the usefulness of the individual values.

Data Qualifiers

U	The analyte was analyzed for, but was not detected above the reported sample quantitation limit.
J	The analyte was positively identified; the associated numerical value is the approximate concentration of the analyte in the sample.
UJ	The analyte was not detected above the reported sample quantitation limit. However, the reported quantitation limit is approximate and may or may not represent the actual limit of quantitation necessary to accurately and precisely measure the analyte in the sample.
R	The sample results are rejected due to serious deficiencies in the ability to analyze the sample and meet quality control criteria. The presence or absence of the analyte cannot be verified.

ANALYTICAL
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INORGANICS ANALYSIS DATA SHEET
TOTAL METALS

Sample No: DMBG-10

Lab Sample ID: Y962A
LIMS ID: 98-21900
Matrix: Soil

QC Report No: Y962-Dames & Moore
Project: Holden Mine
17693-005-019
Date Sampled: 10/12/98
Date Received: 10/19/98

Data Release Authorized
Reported: 11/04/98

Percent Total Solids: 94.2%

Prep Meth	Prep Date	Analysis Method	Analysis Date	CAS Number	Analyte	RL	mg/kg-dry
3050	10/26/98	6010	10/30/98	7429-90-5	Aluminum	2	11,000
3050	10/26/98	7060	10/30/98	7440-38-2	Arsenic	0.2	0.7
3050	10/26/98	6010	10/30/98	7440-39-3	Barium	0.1	68.8
3050	10/26/98	6010	10/30/98	7440-41-7	Beryllium	0.1	0.2
3050	10/26/98	6010	10/30/98	7440-43-9	Cadmium	0.2	0.2 U
3050	10/26/98	6010	10/30/98	7440-70-2	Calcium	2	2,190
3050	10/26/98	6010	10/30/98	7440-47-3	Chromium	0.5	6.2 J
3050	10/26/98	6010	10/30/98	7440-50-8	Copper	0.2	11.0
3050	10/26/98	6010	10/30/98	7439-89-6	Iron	2	10,400
3050	10/26/98	6010	10/30/98	7439-92-1	Lead	2	3
3050	10/26/98	6010	10/30/98	7439-95-4	Magnesium	2	1,190
3050	10/26/98	6010	10/30/98	7439-96-5	Manganese	0.1	383
3050	10/26/98	6010	10/30/98	7439-98-7	Molybdenum	0.5	0.5 U
3050	10/26/98	6010	10/30/98	7440-02-0	Nickel	1	5
3050	10/26/98	6010	10/30/98	7440-09-7	Potassium	50	480
3050	10/26/98	6010	10/30/98	7440-22-4	Silver	0.3	0.3 U
3050	10/26/98	6010	10/30/98	7440-23-5	Sodium	5	517
3050	10/26/98	7841	10/30/98	7440-28-0	Thallium	0.1	0.1 U
3050	10/26/98	200.8	11/02/98	7440-61-1	Uranium	0.2	0.2 U
3050	10/26/98	6010	10/30/98	7440-66-6	Zinc	0.4	32.5

Km 12/4/98

U Analyte undetected at given RL

RL Reporting Limit

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ANALYTICAL
RESOURCES
INCORPORATED

INORGANICS ANALYSIS DATA SHEET
TOTAL METALS

Sample No: DMBG-10x

Lab Sample ID: Y962B
LIMS ID: 98-21901
Matrix: Soil

QC Report No: Y962-Dames & Moore
Project: Holden Mine
17693-005-019
Date Sampled: 10/12/98
Date Received: 10/19/98

Data Release Authorized:
Reported: 11/04/98

Percent Total Solids: 94.3%

Prep Meth	Prep Date	Analysis Method	Analysis Date	CAS Number	Analyte	RL	mg/kg-dry
3050	10/26/98	6010	10/30/98	7429-90-5	Aluminum	2	10,000
3050	10/26/98	7060	10/30/98	7440-38-2	Arsenic	0.2	0.8
3050	10/26/98	6010	10/30/98	7440-39-3	Barium	0.1	76.0
3050	10/26/98	6010	10/30/98	7440-41-7	Beryllium	0.1	0.2
3050	10/26/98	6010	10/30/98	7440-43-9	Cadmium	0.2	0.2
3050	10/26/98	6010	10/30/98	7440-70-2	Calcium	2	2,330
3050	10/26/98	6010	10/30/98	7440-47-3	Chromium	0.5	5.8 J
3050	10/26/98	6010	10/30/98	7440-50-8	Copper	0.2	11.1
3050	10/26/98	6010	10/30/98	7439-89-6	Iron	2	10,500
3050	10/26/98	6010	10/30/98	7439-92-1	Lead	2	4
3050	10/26/98	6010	10/30/98	7439-95-4	Magnesium	2	1,240
3050	10/26/98	6010	10/30/98	7439-96-5	Manganese	0.1	344
3050	10/26/98	6010	10/30/98	7439-98-7	Molybdenum	0.5	0.5 U
3050	10/26/98	6010	10/30/98	7440-02-0	Nickel	1	5
3050	10/26/98	6010	10/30/98	7440-09-7	Potassium	50	480
3050	10/26/98	6010	10/30/98	7440-22-4	Silver	0.3	0.3 U
3050	10/26/98	6010	10/30/98	7440-23-5	Sodium	5	528
3050	10/26/98	7841	10/30/98	7440-28-0	Thallium	0.1	0.1 U
3050	10/26/98	200.8	11/02/98	7440-61-1	Uranium	0.2	0.2 U
3050	10/26/98	6010	10/30/98	7440-66-6	Zinc	0.4	34.8

km 12/9/98

U Analyte undetected at given RL

RL Reporting Limit

FORM-I

ANALYTICAL
RESOURCES
INCORPORATED

INORGANICS ANALYSIS DATA SHEET
TOTAL METALS

Sample No: DMBG-6

Lab Sample ID: Y962C
LIMS ID: 98-21902
Matrix: Soil

QC Report No: Y962-Dames & Moore
Project: Holden Mine
17693-005-019
Date Sampled: 10/13/98
Date Received: 10/19/98

Data Release Authorized:
Reported: 11/04/98

Percent Total Solids: 70.6%

Prep Meth	Prep Date	Analysis Method	Analysis Date	CAS Number	Analyte	RL	mg/kg-dry
3050	10/26/98	6010	10/30/98	7429-90-5	Aluminum	3	3,430
3050	10/26/98	7060	10/30/98	7440-38-2	Arsenic	0.1	0.5
3050	10/26/98	6010	10/30/98	7440-39-3	Barium	0.1	26.1
3050	10/26/98	6010	10/30/98	7440-41-7	Beryllium	0.1	0.1 U
3050	10/26/98	6010	10/30/98	7440-43-9	Cadmium	0.3	0.3 U
3050	10/26/98	6010	10/30/98	7440-70-2	Calcium	3	894
3050	10/26/98	6010	10/30/98	7440-47-3	Chromium	0.7	4.2 J
3050	10/26/98	6010	10/30/98	7440-50-8	Copper	0.3	7.7
3050	10/26/98	6010	10/30/98	7439-89-6	Iron	3	5,510
3050	10/26/98	6010	10/30/98	7439-92-1	Lead	3	4
3050	10/26/98	6010	10/30/98	7439-95-4	Magnesium	3	197
3050	10/26/98	6010	10/30/98	7439-96-5	Manganese	0.1	343
3050	10/26/98	6010	10/30/98	7439-98-7	Molybdenum	0.7	0.7 U
3050	10/26/98	6010	10/30/98	7440-02-0	Nickel	1	4
3050	10/26/98	6010	10/30/98	7440-09-7	Potassium	70	310
3050	10/26/98	6010	10/30/98	7440-22-4	Silver	0.4	0.5
3050	10/26/98	6010	10/30/98	7440-23-5	Sodium	7	336
3050	10/26/98	7841	10/30/98	7440-28-0	Thallium	0.1	0.1 U
3050	10/26/98	200.8	11/02/98	7440-61-1	Uranium	0.3	0.3 U
3050	10/26/98	6010	10/30/98	7440-66-6	Zinc	0.5	19.5

Km 12/9/98

U Analyte undetected at given RL

RL Reporting Limit

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ANALYTICAL
RESOURCES
INCORPORATED

INORGANICS ANALYSIS DATA SHEET
TOTAL METALS

Sample No: DMBG-5

Lab Sample ID: Y962D
LIMS ID: 98-21903
Matrix: Soil

QC Report No: Y962-Dames & Moore
Project: Holden Mine
17693-005-019
Date Sampled: 10/13/98
Date Received: 10/19/98

Data Release Authorized:
Reported: 11/04/98

Percent Total Solids: 69.7%

Prep Meth	Prep Date	Analysis Method	Analysis Date	CAS Number	Analyte	RL	mg/kg-dry	
3050	10/26/98	6010	10/30/98	7429-90-5	Aluminum	3	14,900	
3050	10/26/98	7060	10/29/98	7440-38-2	Arsenic	0.7	12.3	
3050	10/26/98	6010	10/30/98	7440-39-3	Barium	0.1	29.5	
3050	10/26/98	6010	10/30/98	7440-41-7	Beryllium	0.1	0.2	
3050	10/26/98	6010	10/30/98	7440-43-9	Cadmium	0.3	0.3	
3050	10/26/98	6010	10/30/98	7440-70-2	Calcium	3	2,630	
3050	10/26/98	6010	10/30/98	7440-47-3	Chromium	0.7	5.0	J
3050	10/26/98	6010	10/30/98	7440-50-8	Copper	0.3	8.8	
3050	10/26/98	6010	10/30/98	7439-89-6	Iron	3	12,900	
3050	10/26/98	6010	10/30/98	7439-92-1	Lead	3	17	
3050	10/26/98	6010	10/30/98	7439-95-4	Magnesium	3	1,190	
3050	10/26/98	6010	10/30/98	7439-96-5	Manganese	0.1	244	
3050	10/26/98	6010	10/30/98	7439-98-7	Molybdenum	0.7	0.7	
3050	10/26/98	6010	10/30/98	7440-02-0	Nickel	1	4	
3050	10/26/98	6010	10/30/98	7440-09-7	Potassium	70	280	
3050	10/26/98	6010	10/30/98	7440-22-4	Silver	0.4	0.4	U
3050	10/26/98	6010	10/30/98	7440-23-5	Sodium	7	607	
3050	10/26/98	7841	10/30/98	7440-28-0	Thallium	0.1	0.1	U
3050	10/26/98	200.8	11/02/98	7440-61-1	Uranium	0.3	1.0	
3050	10/26/98	6010	10/30/98	7440-66-6	Zinc	0.5	38.5	

km 12/9/98

U Analyte undetected at given RL

RL Reporting Limit

FORM-I

ANALYTICAL
RESOURCES
INCORPORATED

INORGANICS ANALYSIS DATA SHEET
TOTAL METALS

Sample No: DMBG-7

Lab Sample ID: Y962E
LIMS ID: 98-21904
Matrix: Soil

QC Report No: Y962-Dames & Moore
Project: Holden Mine
17693-005-019
Date Sampled: 10/13/98
Date Received: 10/19/98

Data Release Authorized:
Reported: 11/04/98

Percent Total Solids: 63.2%

Prep Meth	Prep Date	Analysis Method	Analysis Date	CAS Number	Analyte	RL	mg/kg-dry	
3050	10/26/98	6010	10/30/98	7429-90-5	Aluminum	3	13,700	
3050	10/26/98	7060	10/30/98	7440-38-2	Arsenic	6	98	
3050	10/26/98	6010	10/30/98	7440-39-3	Barium	0.2	94.7	
3050	10/26/98	6010	10/30/98	7440-41-7	Beryllium	0.2	0.2	
3050	10/26/98	6010	10/30/98	7440-43-9	Cadmium	0.3	2.7	
3050	10/26/98	6010	10/30/98	7440-70-2	Calcium	3	5,480	
3050	10/26/98	6010	10/30/98	7440-47-3	Chromium	0.8	5.0	J
3050	10/26/98	6010	10/30/98	7440-50-8	Copper	0.3	39.3	
3050	10/26/98	6010	10/30/98	7439-89-6	Iron	3	15,900	
3050	10/26/98	6010	10/30/98	7439-92-1	Lead	3	56	
3050	10/26/98	6010	10/30/98	7439-95-4	Magnesium	3	3,070	
3050	10/26/98	6010	10/30/98	7439-96-5	Manganese	0.2	577	
3050	10/26/98	6010	10/30/98	7439-98-7	Molybdenum	0.8	2.1	
3050	10/26/98	6010	10/30/98	7440-02-0	Nickel	2	5	
3050	10/26/98	6010	10/30/98	7440-09-7	Potassium	80	1,150	
3050	10/26/98	6010	10/30/98	7440-22-4	Silver	0.5	0.5	
3050	10/26/98	6010	10/30/98	7440-23-5	Sodium	8	622	
3050	10/26/98	7841	10/30/98	7440-28-0	Thallium	0.2	0.2	U
3050	10/26/98	200.8	11/02/98	7440-61-1	Uranium	0.3	2.0	
3050	10/26/98	6010	10/30/98	7440-66-6	Zinc	0.6	134	

Km 12/9/98

U Analyte undetected at given RL

RL Reporting Limit

FORM-I

ANALYTICAL
RESOURCES
INCORPORATED

INORGANICS ANALYSIS DATA SHEET
TOTAL METALS

Sample No: DMBG-4

Lab Sample ID: Y962F
LIMS ID: 98-21905
Matrix: Soil

QC Report No: Y962-Dames & Moore
Project: Holden Mine
17693-005-019
Date Sampled: 10/13/98
Date Received: 10/19/98

Data Release Authorized:
Reported: 11/04/98

Percent Total Solids: 70.2%

Prep Meth	Prep Date	Analysis Method	Analysis Date	CAS Number	Analyte	RL	mg/kg-dry
3050	10/26/98	6010	10/30/98	7429-90-5	Aluminum	3	11,000
3050	10/26/98	7060	10/29/98	7440-38-2	Arsenic	0.7	5.2
3050	10/26/98	6010	10/30/98	7440-39-3	Barium	0.1	205
3050	10/26/98	6010	10/30/98	7440-41-7	Beryllium	0.1	0.1
3050	10/26/98	6010	10/30/98	7440-43-9	Cadmium	0.3	1.8
3050	10/26/98	6010	10/30/98	7440-70-2	Calcium	3	10,400
3050	10/26/98	6010	10/30/98	7440-47-3	Chromium	0.7	9.9 J
3050	10/26/98	6010	10/30/98	7440-50-8	Copper	0.3	27.5
3050	10/26/98	6010	10/30/98	7439-89-6	Iron	3	11,600
3050	10/26/98	6010	10/30/98	7439-92-1	Lead	3	13
3050	10/26/98	6010	10/30/98	7439-95-4	Magnesium	3	4,780
3050	10/26/98	6010	10/30/98	7439-96-5	Manganese	0.1	448
3050	10/26/98	6010	10/30/98	7439-98-7	Molybdenum	0.7	0.7 U
3050	10/26/98	6010	10/30/98	7440-02-0	Nickel	1	8
3050	10/26/98	6010	10/30/98	7440-09-7	Potassium	70	560
3050	10/26/98	6010	10/30/98	7440-22-4	Silver	0.4	0.4 U
3050	10/26/98	6010	10/30/98	7440-23-5	Sodium	7	428
3050	10/26/98	7841	10/30/98	7440-28-0	Thallium	0.1	0.1 U
3050	10/26/98	200.8	11/02/98	7440-61-1	Uranium	0.3	0.3 U
3050	10/26/98	6010	10/30/98	7440-66-6	Zinc	0.5	90.9

Km 12/9/98

U Analyte undetected at given RL

RL Reporting Limit

FORM-I

ANALYTICAL
RESOURCES
INCORPORATED

INORGANICS ANALYSIS DATA SHEET
TOTAL METALS

Sample No: DMBG-3

Lab Sample ID: Y962G
LIMS ID: 98-21906
Matrix: Soil

QC Report No: Y962-Dames & Moore
Project: Holden Mine
17693-005-019
Date Sampled: 10/13/98
Date Received: 10/19/98

Data Release Authorized
Reported: 11/04/98

Percent Total Solids: 76.5%

Prep Meth	Prep Date	Analysis Method	Analysis Date	CAS Number	Analyte	RL	mg/kg-dry	
3050	10/26/98	6010	10/30/98	7429-90-5	Aluminum	3	7,010	
3050	10/26/98	7060	10/29/98	7440-38-2	Arsenic	0.6	3.3	
3050	10/26/98	6010	10/30/98	7440-39-3	Barium	0.1	194	
3050	10/26/98	6010	10/30/98	7440-41-7	Beryllium	0.1	0.1	
3050	10/26/98	6010	10/30/98	7440-43-9	Cadmium	0.3	4.1	
3050	10/26/98	6010	10/30/98	7440-70-2	Calcium	3	7,460	
3050	10/26/98	6010	10/30/98	7440-47-3	Chromium	0.6	5.6	J
3050	10/26/98	6010	10/30/98	7440-50-8	Copper	0.3	6.2	
3050	10/26/98	6010	10/30/98	7439-89-6	Iron	3	8,230	
3050	10/26/98	6010	10/30/98	7439-92-1	Lead	3	21	
3050	10/26/98	6010	10/30/98	7439-95-4	Magnesium	3	998	
3050	10/26/98	6010	10/30/98	7439-96-5	Manganese	0.1	1,340	
3050	10/26/98	6010	10/30/98	7439-98-7	Molybdenum	0.6	0.7	
3050	10/26/98	6010	10/30/98	7440-02-0	Nickel	1	6	
3050	10/26/98	6010	10/30/98	7440-09-7	Potassium	60	430	
3050	10/26/98	6010	10/30/98	7440-22-4	Silver	0.4	0.4	U
3050	10/26/98	6010	10/30/98	7440-23-5	Sodium	6	641	
3050	10/26/98	7841	10/30/98	7440-28-0	Thallium	0.1	0.1	U
3050	10/26/98	200.8	11/02/98	7440-61-1	Uranium	0.3	0.3	U
3050	10/26/98	6010	10/30/98	7440-66-6	Zinc	0.5	139	

Km 12/9/98

U	Analyte undetected at given RL
RL	Reporting Limit

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ANALYTICAL
RESOURCES
INCORPORATED

INORGANICS ANALYSIS DATA SHEET
TOTAL METALS

Sample No: DMBG-8

Lab Sample ID: Y962H
LIMS ID: 98-21907
Matrix: Soil

QC Report No: Y962-Dames & Moore
Project: Holden Mine
17693-005-019
Date Sampled: 10/13/98
Date Received: 10/19/98

Data Release Authorized:
Reported: 11/04/98

Percent Total Solids: 67.7%

Prep Meth	Prep Date	Analysis Method	Analysis Date	CAS Number	Analyte	RL	mg/kg-dry	
3050	10/26/98	6010	10/30/98	7429-90-5	Aluminum	3	11,300	
3050	10/26/98	7060	10/30/98	7440-38-2	Arsenic	0.3	1.2	
3050	10/26/98	6010	10/30/98	7440-39-3	Barium	0.1	117	
3050	10/26/98	6010	10/30/98	7440-41-7	Beryllium	0.1	0.1	U
3050	10/26/98	6010	10/30/98	7440-43-9	Cadmium	0.3	0.8	
3050	10/26/98	6010	10/30/98	7440-70-2	Calcium	3	10,900	
3050	10/26/98	6010	10/30/98	7440-47-3	Chromium	0.7	9.3	J
3050	10/26/98	6010	10/30/98	7440-50-8	Copper	0.3	21.7	
3050	10/26/98	6010	10/30/98	7439-89-6	Iron	3	15,400	
3050	10/26/98	6010	10/30/98	7439-92-1	Lead	3	6	
3050	10/26/98	6010	10/30/98	7439-95-4	Magnesium	3	5,760	
3050	10/26/98	6010	10/30/98	7439-96-5	Manganese	0.1	279	
3050	10/26/98	6010	10/30/98	7439-98-7	Molybdenum	0.7	0.9	
3050	10/26/98	6010	10/30/98	7440-02-0	Nickel	1	6	
3050	10/26/98	6010	10/30/98	7440-09-7	Potassium	70	850	
3050	10/26/98	6010	10/30/98	7440-22-4	Silver	0.4	0.4	U
3050	10/26/98	6010	10/30/98	7440-23-5	Sodium	7	235	
3050	10/26/98	7841	10/30/98	7440-28-0	Thallium	0.1	0.1	U
3050	10/26/98	200.8	11/02/98	7440-61-1	Uranium	0.3	0.3	U
3050	10/26/98	6010	10/30/98	7440-66-6	Zinc	0.6	42.2	

km 12/9/98

U Analyte undetected at given RL

RL Reporting Limit

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ANALYTICAL
RESOURCES
INCORPORATED

INORGANICS ANALYSIS DATA SHEET
TOTAL METALS

Sample No: DMBG-2

Lab Sample ID: Y962I
LIMS ID: 98-21908
Matrix: Soil

QC Report No: Y962-Dames & Moore
Project: Holden Mine
17693-005-019
Date Sampled: 10/15/98
Date Received: 10/19/98

Data Release Authorized:
Reported: 11/04/98

Percent Total Solids: 85.2%

Prep Meth	Prep Date	Analysis Method	Analysis Date	CAS Number	Analyte	RL	mg/kg-dry	
3050	10/26/98	6010	10/30/98	7429-90-5	Aluminum	2	18,800	
3050	10/26/98	7060	10/29/98	7440-38-2	Arsenic	0.6	3.7	
3050	10/26/98	6010	10/30/98	7440-39-3	Barium	0.1	120	
3050	10/26/98	6010	10/30/98	7440-41-7	Beryllium	0.1	0.2	
3050	10/26/98	6010	10/30/98	7440-43-9	Cadmium	0.2	0.8	
3050	10/26/98	6010	10/30/98	7440-70-2	Calcium	2	2,380	
3050	10/26/98	6010	10/30/98	7440-47-3	Chromium	0.6	18.9	J
3050	10/26/98	6010	10/30/98	7440-50-8	Copper	0.2	36.2	
3050	10/26/98	6010	10/30/98	7439-89-6	Iron	2	36,300	
3050	10/26/98	6010	10/30/98	7439-92-1	Lead	2	10	
3050	10/26/98	6010	10/30/98	7439-95-4	Magnesium	2	7,640	
3050	10/26/98	6010	10/30/98	7439-96-5	Manganese	0.1	433	
3050	10/26/98	6010	10/30/98	7439-98-7	Molybdenum	0.6	0.7	
3050	10/26/98	6010	10/30/98	7440-02-0	Nickel	1	9	
3050	10/26/98	6010	10/30/98	7440-09-7	Potassium	60	770	
3050	10/26/98	6010	10/30/98	7440-22-4	Silver	0.3	0.4	
3050	10/26/98	6010	10/30/98	7440-23-5	Sodium	6	306	
3050	10/26/98	7841	10/30/98	7440-28-0	Thallium	0.1	0.1	
3050	10/26/98	200.8	11/02/98	7440-61-1	Uranium	0.2	0.2	U
3050	10/26/98	6010	10/30/98	7440-66-6	Zinc	0.5	75.8	

Km 12/9/98

U Analyte undetected at given RL

RL Reporting Limit

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INORGANICS ANALYSIS DATA SHEET
TOTAL METALS

Sample No: DMBG-1

Lab Sample ID: Y962J
LIMS ID: 98-21909
Matrix: Soil

QC Report No: Y962-Dames & Moore
Project: Holden Mine
17693-005-019
Date Sampled: 10/15/98
Date Received: 10/19/98

Data Release Authorized:
Reported: 11/04/98

Percent Total Solids: 87.7%

Prep Meth	Prep Date	Analysis Method	Analysis Date	CAS Number	Analyte	RL	mg/kg-dry	
3050	10/26/98	6010	10/30/98	7429-90-5	Aluminum	2	16,800	
3050	10/26/98	7060	10/30/98	7440-38-2	Arsenic	0.2	0.6	
3050	10/26/98	6010	10/30/98	7440-39-3	Barium	0.1	48.4	
3050	10/26/98	6010	10/30/98	7440-41-7	Beryllium	0.1	0.2	
3050	10/26/98	6010	10/30/98	7440-43-9	Cadmium	0.2	0.8	
3050	10/26/98	6010	10/30/98	7440-70-2	Calcium	2	2,380	
3050	10/26/98	6010	10/30/98	7440-47-3	Chromium	0.5	7.5	J
3050	10/26/98	6010	10/30/98	7440-50-8	Copper	0.2	13.3	
3050	10/26/98	6010	10/30/98	7439-89-6	Iron	2	11,900	
3050	10/26/98	6010	10/30/98	7439-92-1	Lead	2	4	
3050	10/26/98	6010	10/30/98	7439-95-4	Magnesium	2	1,740	
3050	10/26/98	6010	10/30/98	7439-96-5	Manganese	0.1	309	
3050	10/26/98	6010	10/30/98	7439-98-7	Molybdenum	0.5	0.5	U
3050	10/26/98	6010	10/30/98	7440-02-0	Nickel	1	7	
3050	10/26/98	6010	10/30/98	7440-09-7	Potassium	50	600	
3050	10/26/98	6010	10/30/98	7440-22-4	Silver	0.3	0.3	U
3050	10/26/98	6010	10/30/98	7440-23-5	Sodium	5	595	
3050	10/26/98	7841	10/30/98	7440-28-0	Thallium	0.1	0.1	U
3050	10/26/98	200.8	11/02/98	7440-61-1	Uranium	0.2	1.3	
3050	10/26/98	6010	10/30/98	7440-66-6	Zinc	0.4	110	

Km 12/9/98

U Analyte undetected at given RL

RL Reporting Limit

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INORGANICS ANALYSIS DATA SHEET
TOTAL METALS

Sample No: DMBG-9

Lab Sample ID: Y962K
LIMS ID: 98-21910
Matrix: Soil

QC Report No: Y962-Dames & Moore
Project: Holden Mine
17693-005-019
Date Sampled: 10/15/98
Date Received: 10/19/98

Data Release Authorized
Reported: 11/04/98

Percent Total Solids: 93.2%

Prep Meth	Prep Date	Analysis Method	Analysis Date	CAS Number	Analyte	RL	mg/kg-dry	
3050	10/26/98	6010	10/30/98	7429-90-5	Aluminum	2	22,100	
3050	10/26/98	7060	10/30/98	7440-38-2	Arsenic	1	4	
3050	10/26/98	6010	10/30/98	7440-39-3	Barium	0.1	76.3	
3050	10/26/98	6010	10/30/98	7440-41-7	Beryllium	0.1	0.2	
3050	10/26/98	6010	10/30/98	7440-43-9	Cadmium	0.2	0.5	
3050	10/26/98	6010	10/30/98	7440-70-2	Calcium	2	3,880	
3050	10/26/98	6010	10/30/98	7440-47-3	Chromium	0.5	16.0	J
3050	10/26/98	6010	10/30/98	7440-50-8	Copper	0.2	42.2	
3050	10/26/98	6010	10/30/98	7439-89-6	Iron	2	24,500	
3050	10/26/98	6010	10/30/98	7439-92-1	Lead	2	6	
3050	10/26/98	6010	10/30/98	7439-95-4	Magnesium	2	7,580	
3050	10/26/98	6010	10/30/98	7439-96-5	Manganese	0.1	297	
3050	10/26/98	6010	10/30/98	7439-98-7	Molybdenum	0.5	0.5	U
3050	10/26/98	6010	10/30/98	7440-02-0	Nickel	1	12	
3050	10/26/98	6010	10/30/98	7440-09-7	Potassium	50	560	
3050	10/26/98	6010	10/30/98	7440-22-4	Silver	0.3	0.3	
3050	10/26/98	6010	10/30/98	7440-23-5	Sodium	5	563	
3050	10/26/98	7841	10/30/98	7440-28-0	Thallium	0.1	0.1	U
3050	10/26/98	200.8	11/02/98	7440-61-1	Uranium	0.2	0.2	U
3050	10/26/98	6010	10/30/98	7440-66-6	Zinc	0.4	105	

KM 12/9/98

U Analyte undetected at given RL

RL Reporting Limit

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RESOURCES
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INORGANICS ANALYSIS DATA SHEET
TOTAL METALS

Sample No: Method Blank

Lab Sample ID: Y962MB
LIMS ID: 98-21900
Matrix: Soil

QC Report No: Y962-Dames & Moore
Project: Holden Mine
17693-005-019
Date Sampled: NA
Date Received: NA

Data Release Authorized:
Reported: 11/04/98

Percent Total Solids: NA

Prep Meth	Prep Date	Analysis Method	Analysis Date	CAS Number	Analyte	RL	mg/kg-dry
3050	10/26/98	6010	10/30/98	7429-90-5	Aluminum	2	4
3050	10/26/98	7060	10/29/98	7440-38-2	Arsenic	0.1	0.1 U
3050	10/26/98	6010	10/30/98	7440-39-3	Barium	0.1	0.1
3050	10/26/98	6010	10/30/98	7440-41-7	Beryllium	0.1	0.1 U
3050	10/26/98	6010	10/30/98	7440-43-9	Cadmium	0.2	0.2 U
3050	10/26/98	6010	10/30/98	7440-70-2	Calcium	2	3
3050	10/26/98	6010	10/30/98	7440-47-3	Chromium	0.5	0.5 U
3050	10/26/98	6010	10/30/98	7440-50-8	Copper	0.2	0.2 U
3050	10/26/98	6010	10/30/98	7439-89-6	Iron	2	2 U
3050	10/26/98	6010	10/30/98	7439-92-1	Lead	2	2 U
3050	10/26/98	6010	10/30/98	7439-95-4	Magnesium	2	2 U
3050	10/26/98	6010	10/30/98	7439-96-5	Manganese	0.1	0.1 U
3050	10/26/98	6010	10/30/98	7439-98-7	Molybdenum	0.5	0.5 U
3050	10/26/98	6010	10/30/98	7440-02-0	Nickel	1	1 U
3050	10/26/98	6010	10/30/98	7440-09-7	Potassium	50	50 U
3050	10/26/98	6010	10/30/98	7440-22-4	Silver	0.3	0.3 U
3050	10/26/98	6010	10/30/98	7440-23-5	Sodium	5	18
3050	10/26/98	7841	10/30/98	7440-28-0	Thallium	0.1	0.1 U
3050	10/26/98	200.8	11/02/98	7440-61-1	Uranium	0.2	0.2 U
3050	10/26/98	6010	10/30/98	7440-66-6	Zinc	0.4	0.5

U Analyte undetected at given RL

RL Reporting Limit

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ANALYTICAL
RESOURCES
INCORPORATED

INORGANICS ANALYSIS DATA SHEET

Sample No: STD REFERENCE
ERA Lot 233

Lab Sample ID: Y962-SRM
LIMS ID: 98-21900
Matrix: Sediment

QC Report No: Y962-Dames & Moore
Project: Holden Mine
17693-005-019
Date Sampled: NA
Date Received: NA

Data Release Authorized:
Reported: 11/04/98

Analyte	mg/kg-dry	Certified Value	Advisory Range
Aluminum	5040	3980	2100-5860
Arsenic	108	108	80.1-136
Barium	60.0	59.7	45.2-74.2
Beryllium	49.7	47.6	33.7-61.4
Cadmium	107	114	68.6-159
Calcium	1790	1770	1290-2250
Chromium	42.8	42.2	32.4-52.1
Copper	69.9	68.9	56.4-81.3
Iron	7800	7300	2920-11700
Lead	45.4	44.3	33.7-54.9
Magnesium	1970	1880	1360-2400
Manganese	126	128	93.7-162
Molybdenum	60.8	61.1	44.1-78.1
Nickel	74.3	71.8	55.7-88.0
Potassium	2700	2400	1830-2970
Silver	57.1	59.7	30.6-88.8
Sodium	265	280	168-391
Thallium	74.7	77.8	44.5-111
Zinc	87.2	85.6	66.2-105

FORM-VII

ANALYTICAL
RESOURCES
INCORPORATED

INORGANIC ANALYSIS DATA SHEET
TOTAL METALS

Sample No: DMBG-10
Lab Sample ID: Y962A
QC Report No: Y962-Dames & Moore
LIMS ID: 98-21900
Project: Holden Mine
17693-005-019
Matrix: Soil
Date Received: 10/19/98

Data Release Authorized:
Reported: 11/04/98

MATRIX DUPLICATE QUALITY CONTROL REPORT

Analyte	Analysis Method	Sample mg/kg-dry	Duplicate mg/kg-dry	RPD	Control Limit	Q
Aluminum	6010	11000	10700	2.8%	+/- 20 %	
Arsenic	7060	0.7	0.7	0.0%	+/- 0.2	L
Barium	6010	68.8	70.7	2.7%	+/- 20 %	
Beryllium	6010	0.2	0.2	0.0%	+/- 0.1	L
Cadmium	6010	0.2 U	0.2 U	0.0%	+/- 0.2	L
Calcium	6010	2190	1990	9.6%	+/- 20 %	
Chromium	6010	6.2	8.1	26.6%	+/- 20 %	*
Copper	6010	11.0	11.4	3.6%	+/- 20 %	
Iron	6010	10400	10900	4.7%	+/- 20 %	
Lead	6010	3	4	28.6%	+/- 2	L
Magnesium	6010	1190	1170	1.7%	+/- 20 %	
Manganese	6010	383	387	1.0%	+/- 20 %	
Molybdenum	6010	0.5 U	0.5 U	0.0%	+/- 0.5	L
Nickel	6010	5	6	18.2%	+/- 20 %	
Potassium	6010	480	500	4.1%	+/- 20 %	
Silver	6010	0.3 U	0.3 U	0.0%	+/- 0.3	L
Sodium	6010	517	439	16.3%	+/- 20 %	
Thallium	7841	0.1 U	0.1 U	0.0%	+/- 0.1	L
Uranium	200.8	0.2 U	0.2 U	0.0%	+/- 0.2	L
Zinc	6010	32.5	32.9	1.2%	+/- 20 %	

'Q' codes:
* = control limit not met
L = RPD not valid, alternate limit = detection limit

FORM-VI

ANALYTICAL
RESOURCES
INCORPORATED

INORGANICS ANALYSIS DATA SHEET
TOTAL METALS

Sample No: DMBG-10
QC Report No: Y962-Dames & Moore
Project: Holden Mine
17693-005-019
Date Received: 10/19/98

Lab Sample ID: Y962A
LIMS ID: 98-21900
Matrix: Soil

Data Release Authorized:
Reported: 11/09/98

MATRIX SPIKE QUALITY CONTROL REPORT

Analyte	Analysis Method	Sample mg/kg-dry	Spike mg/kg-dry	Spike Added	% Recovery	Q
Aluminum	6010	11000	11400	423	94.6%	H
Arsenic	7060	0.7	36.1	34.6	102%	
Barium	6010	68.8	466	423	93.9%	
Beryllium	6010	0.2	10.5	10.6	97.2%	
Cadmium	6010	0.2 U	9.6	10.6	90.6%	
Calcium	6010	2190	4260	2110	98.1%	
Chromium	6010	6.2	50.1	42.3	104%	
Copper	6010	11.0	62.0	52.8	96.6%	
Iron	6010	10400	10500	211	47.4%	H
Lead	6010	3	105	106	96.2%	
Magnesium	6010	1190	3250	2110	97.6%	
Manganese	6010	383	481	106	92.5%	
Molybdenum	6010	0.5 U	26.4	26.4	100%	
Nickel	6010	5	109	106	98.1%	
Potassium	6010	480	2540	2110	97.6%	
Silver	6010	0.3 U	10.2	10.6	96.2%	
Sodium	6010	517	2530	2110	95.4%	
Thallium	7841	0.1 U	39.2	36.7	107%	
Uranium	200.8	0.2 U	28.4	26.2	108%	
Zinc	6010	32.5	132	106	93.9%	

'Q' codes:
N = control limit not met
H = %R not applicable, sample concentration too high
* = RPD control limit not met
NA = Not applicable - analyte not spiked

Control Limits:
Percent Recovery: 75-125%
RPD: +/-20%

FORM-V

ANALYTICAL
RESOURCES
INCORPORATED

INORGANICS ANALYSIS DATA SHEET
TOTAL METALS

Sample No: DMBG-16

Lab Sample ID: Y962L
LIMS ID: 98-21911
Matrix: Soil

QC Report No: Y962-Dames & Moore
Project: Holden Mine
17693-005-019
Date Sampled: 10/17/98
Date Received: 10/19/98

Data Release Authorized:
Reported: 11/13/98

Percent Total Solids: 70.9%

Prep Meth	Prep Date	Analysis Method	Analysis Date	CAS Number	Analyte	RL	mg/kg-dry	
3050	11/02/98	6010	11/04/98	7429-90-5	Aluminum	3	11,200	
3050	11/02/98	7060	11/04/98	7440-38-2	Arsenic	0.7	0.8	
3050	11/02/98	6010	11/04/98	7440-39-3	Barium	0.1	250	
3050	11/02/98	6010	11/04/98	7440-41-7	Beryllium	0.1	0.2	
3050	11/02/98	6010	11/04/98	7440-43-9	Cadmium	0.3	17.4	
3050	11/02/98	6010	11/04/98	7440-70-2	Calcium	3	11,000	
3050	11/02/98	6010	11/04/98	7440-47-3	Chromium	0.7	8.4	
3050	11/02/98	6010	11/04/98	7440-50-8	Copper	0.3	24.8	
3050	11/02/98	6010	11/04/98	7439-89-6	Iron	3	10,500	
3050	11/02/98	6010	11/04/98	7439-92-1	Lead	3	7	
3050	11/02/98	6010	11/04/98	7439-95-4	Magnesium	3	2,220	
3050	11/02/98	6010	11/04/98	7439-96-5	Manganese	0.1	1,160	J
3050	11/02/98	6010	11/04/98	7439-98-7	Molybdenum	0.7	0.9	
3050	11/02/98	6010	11/04/98	7440-02-0	Nickel	1	12	
3050	11/02/98	6010	11/04/98	7440-09-7	Potassium	70	1,160	
3050	11/02/98	6010	11/04/98	7440-22-4	Silver	0.4	0.4	U
3050	11/02/98	6010	11/04/98	7440-23-5	Sodium	7	557	
3050	11/02/98	7841	11/06/98	7440-28-0	Thallium	0.7	0.7	U
3050	11/02/98	200.8	11/10/98	7440-61-1	Uranium	0.3	0.3	
3050	11/02/98	6010	11/04/98	7440-66-6	Zinc	0.6	298	

Km 12/9/98

U Analyte undetected at given RL

RL Reporting Limit

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ANALYTICAL
RESOURCES
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INORGANICS ANALYSIS DATA SHEET
TOTAL METALS

Sample No: DMBG-17

Lab Sample ID: Y962M
LIMS ID: 98-21912
Matrix: Soil

QC Report No: Y962-Dames & Moore
Project: Holden Mine
17693-005-019
Date Sampled: 10/17/98
Date Received: 10/19/98

Data Release Authorized:
Reported: 11/13/98

Percent Total Solids: 91.1%

Prep Meth	Prep Date	Analysis Method	Analysis Date	CAS Number	Analyte	RL	mg/kg-dry	
3050	11/02/98	6010	11/04/98	7429-90-5	Aluminum	2	16,200	
3050	11/02/98	7060	11/04/98	7440-38-2	Arsenic	0.5	1.2	
3050	11/02/98	6010	11/04/98	7440-39-3	Barium	0.1	526	
3050	11/02/98	6010	11/04/98	7440-41-7	Beryllium	0.1	0.2	
3050	11/02/98	6010	11/04/98	7440-43-9	Cadmium	0.2	3.6	
3050	11/02/98	6010	11/04/98	7440-70-2	Calcium	2	12,200	
3050	11/02/98	6010	11/04/98	7440-47-3	Chromium	0.5	39.2	
3050	11/02/98	6010	11/04/98	7440-50-8	Copper	0.2	65.0	
3050	11/02/98	6010	11/04/98	7439-89-6	Iron	2	22,300	
3050	11/02/98	6010	11/04/98	7439-92-1	Lead	2	7	
3050	11/02/98	6010	11/04/98	7439-95-4	Magnesium	2	8,530	
3050	11/02/98	6010	11/04/98	7439-96-5	Manganese	0.1	2,970	J
3050	11/02/98	6010	11/04/98	7439-98-7	Molybdenum	0.5	1.2	
3050	11/02/98	6010	11/04/98	7440-02-0	Nickel	1	23	
3050	11/02/98	6010	11/04/98	7440-09-7	Potassium	50	1,080	
3050	11/02/98	6010	11/04/98	7440-22-4	Silver	0.3	0.3	U
3050	11/02/98	6010	11/04/98	7440-23-5	Sodium	5	439	
3050	11/02/98	7841	11/06/98	7440-28-0	Thallium	0.5	0.5	U
3050	11/02/98	200.8	11/10/98	7440-61-1	Uranium	0.2	0.2	
3050	11/02/98	6010	11/04/98	7440-66-6	Zinc	0.4	215	

KM 12/9/98

U	Analyte undetected at given RL
RL	Reporting Limit

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ANALYTICAL
RESOURCES
INCORPORATED

INORGANICS ANALYSIS DATA SHEET
TOTAL METALS

Sample No: DMBG-18

Lab Sample ID: Y962N
LIMS ID: 98-21913
Matrix: Soil

QC Report No: Y962-Dames & Moore
Project: Holden Mine
17693-005-019
Date Sampled: 10/17/98
Date Received: 10/19/98

Data Release Authorized:
Reported: 11/13/98

Percent Total Solids: 90.1%

Prep Meth	Prep Date	Analysis Method	Analysis Date	CAS Number	Analyte	RL	mg/kg-dry	
3050	11/02/98	6010	11/04/98	7429-90-5	Aluminum	2	9,310	
3050	11/02/98	7060	11/04/98	7440-38-2	Arsenic	0.5	1.3	
3050	11/02/98	6010	11/04/98	7440-39-3	Barium	0.1	237	
3050	11/02/98	6010	11/04/98	7440-41-7	Beryllium	0.1	0.2	
3050	11/02/98	6010	11/04/98	7440-43-9	Cadmium	0.2	0.5	
3050	11/02/98	6010	11/04/98	7440-70-2	Calcium	2	12,300	
3050	11/02/98	6010	11/04/98	7440-47-3	Chromium	0.5	8.0	
3050	11/02/98	6010	11/04/98	7440-50-8	Copper	0.2	30.2	
3050	11/02/98	6010	11/04/98	7439-89-6	Iron	2	9,290	
3050	11/02/98	6010	11/04/98	7439-92-1	Lead	2	6	
3050	11/02/98	6010	11/04/98	7439-95-4	Magnesium	2	2,160	
3050	11/02/98	6010	11/04/98	7439-96-5	Manganese	0.1	702	J
3050	11/02/98	6010	11/04/98	7439-98-7	Molybdenum	0.5	0.8	
3050	11/02/98	6010	11/04/98	7440-02-0	Nickel	1	5	
3050	11/02/98	6010	11/04/98	7440-09-7	Potassium	50	610	
3050	11/02/98	6010	11/04/98	7440-22-4	Silver	0.3	0.3	U
3050	11/02/98	6010	11/04/98	7440-23-5	Sodium	5	510	
3050	11/02/98	7841	11/06/98	7440-28-0	Thallium	0.5	0.5	U
3050	11/02/98	200.8	11/10/98	7440-61-1	Uranium	0.2	0.3	
3050	11/02/98	6010	11/04/98	7440-66-6	Zinc	0.4	57.3	

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U Analyte undetected at given RL

RL Reporting Limit

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INORGANICS ANALYSIS DATA SHEET
TOTAL METALS

Sample No: DMBG-19

Lab Sample ID: Y9620
LIMS ID: 98-21914
Matrix: Soil

QC Report No: Y962-Dames & Moore
Project: Holden Mine
17693-005-019
Date Sampled: 10/17/98
Date Received: 10/19/98

Data Release Authorized:
Reported: 11/13/98

Percent Total Solids: 88.1%

Prep Meth	Prep Date	Analysis Method	Analysis Date	CAS Number	Analyte	RL	mg/kg-dry
3050	11/02/98	6010	11/04/98	7429-90-5	Aluminum	2	17,100
3050	11/02/98	7060	11/04/98	7440-38-2	Arsenic	0.6	0.9
3050	11/02/98	6010	11/04/98	7440-39-3	Barium	0.1	350
3050	11/02/98	6010	11/04/98	7440-41-7	Beryllium	0.1	0.1
3050	11/02/98	6010	11/04/98	7440-43-9	Cadmium	0.2	0.7
3050	11/02/98	6010	11/04/98	7440-70-2	Calcium	2	10,500
3050	11/02/98	6010	11/04/98	7440-47-3	Chromium	0.5	41.5
3050	11/02/98	6010	11/04/98	7440-50-8	Copper	0.2	62.6
3050	11/02/98	6010	11/04/98	7439-89-6	Iron	2	23,900
3050	11/02/98	6010	11/04/98	7439-92-1	Lead	2	7
3050	11/02/98	6010	11/04/98	7439-95-4	Magnesium	2	9,750
3050	11/02/98	6010	11/04/98	7439-96-5	Manganese	0.1	1,030 J
3050	11/02/98	6010	11/04/98	7439-98-7	Molybdenum	0.5	0.5 U
3050	11/02/98	6010	11/04/98	7440-02-0	Nickel	1	23
3050	11/02/98	6010	11/04/98	7440-09-7	Potassium	50	2,020
3050	11/02/98	6010	11/04/98	7440-22-4	Silver	0.3	0.3 U
3050	11/02/98	6010	11/04/98	7440-23-5	Sodium	5	499
3050	11/02/98	7841	11/06/98	7440-28-0	Thallium	0.6	0.6 U
3050	11/02/98	200.8	11/10/98	7440-61-1	Uranium	0.2	0.6
3050	11/02/98	6010	11/04/98	7440-66-6	Zinc	0.4	94.1

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U Analyte undetected at given RL

RL Reporting Limit

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INORGANICS ANALYSIS DATA SHEET
TOTAL METALS

Sample No: DMBG-15

Lab Sample ID: Y962P
LIMS ID: 98-21915
Matrix: Soil

QC Report No: Y962-Dames & Moore
Project: Holden Mine
17693-005-019
Date Sampled: 10/17/98
Date Received: 10/19/98

Data Release Authorized:
Reported: 11/13/98

Percent Total Solids: 85.0%

Prep Meth	Prep Date	Analysis Method	Analysis Date	CAS Number	Analyte	RL	mg/kg-dry
3050	11/02/98	6010	11/04/98	7429-90-5	Aluminum	2	21,700
3050	11/02/98	7060	11/04/98	7440-38-2	Arsenic	0.6	2.0
3050	11/02/98	6010	11/04/98	7440-39-3	Barium	0.1	127
3050	11/02/98	6010	11/04/98	7440-41-7	Beryllium	0.1	0.3
3050	11/02/98	6010	11/04/98	7440-43-9	Cadmium	0.2	3.8
3050	11/02/98	6010	11/04/98	7440-70-2	Calcium	2	11,600
3050	11/02/98	6010	11/04/98	7440-47-3	Chromium	0.6	12.5
3050	11/02/98	6010	11/04/98	7440-50-8	Copper	0.2	59.5
3050	11/02/98	6010	11/04/98	7439-89-6	Iron	2	17,800
3050	11/02/98	6010	11/04/98	7439-92-1	Lead	2	10
3050	11/02/98	6010	11/04/98	7439-95-4	Magnesium	2	5,440
3050	11/02/98	6010	11/04/98	7439-96-5	Manganese	0.1	534 J
3050	11/02/98	6010	11/04/98	7439-98-7	Molybdenum	0.6	0.9
3050	11/02/98	6010	11/04/98	7440-02-0	Nickel	1	20
3050	11/02/98	6010	11/04/98	7440-09-7	Potassium	60	1,010
3050	11/02/98	6010	11/04/98	7440-22-4	Silver	0.3	0.3 U
3050	11/02/98	6010	11/04/98	7440-23-5	Sodium	6	605
3050	11/02/98	7841	11/06/98	7440-28-0	Thallium	0.6	0.6 U
3050	11/02/98	200.8	11/10/98	7440-61-1	Uranium	0.2	0.5
3050	11/02/98	6010	11/04/98	7440-66-6	Zinc	0.5	518

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U Analyte undetected at given RL

RL Reporting Limit

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INORGANICS ANALYSIS DATA SHEET
TOTAL METALS

Sample No: DMBG-14

Lab Sample ID: Y962Q
LIMS ID: 98-21916
Matrix: Soil

QC Report No: Y962-Dames & Moore
Project: Holden Mine
17693-005-019
Date Sampled: 10/17/98
Date Received: 10/19/98

Data Release Authorized:
Reported: 11/13/98

Percent Total Solids: 92.7%

Prep Meth	Prep Date	Analysis Method	Analysis Date	CAS Number	Analyte	RL	mg/kg-dry
3050	11/02/98	6010	11/04/98	7429-90-5	Aluminum	2	12,300
3050	11/02/98	7060	11/04/98	7440-38-2	Arsenic	0.5	1.8
3050	11/02/98	6010	11/04/98	7440-39-3	Barium	0.1	85.8
3050	11/02/98	6010	11/04/98	7440-41-7	Beryllium	0.1	0.1
3050	11/02/98	6010	11/04/98	7440-43-9	Cadmium	0.2	0.6
3050	11/02/98	6010	11/04/98	7440-70-2	Calcium	2	3,550
3050	11/02/98	6010	11/04/98	7440-47-3	Chromium	0.5	8.1
3050	11/02/98	6010	11/04/98	7440-50-8	Copper	0.2	17.0
3050	11/02/98	6010	11/04/98	7439-89-6	Iron	2	12,400
3050	11/02/98	6010	11/04/98	7439-92-1	Lead	2	5
3050	11/02/98	6010	11/04/98	7439-95-4	Magnesium	2	2,580
3050	11/02/98	6010	11/04/98	7439-96-5	Manganese	0.1	436 J
3050	11/02/98	6010	11/04/98	7439-98-7	Molybdenum	0.5	0.5 U
3050	11/02/98	6010	11/04/98	7440-02-0	Nickel	1	6
3050	11/02/98	6010	11/04/98	7440-09-7	Potassium	50	500
3050	11/02/98	6010	11/04/98	7440-22-4	Silver	0.3	0.3 U
3050	11/02/98	6010	11/04/98	7440-23-5	Sodium	5	725
3050	11/02/98	7841	11/06/98	7440-28-0	Thallium	0.5	0.5 U
3050	11/02/98	200.8	11/10/98	7440-61-1	Uranium	0.2	0.2 U
3050	11/02/98	6010	11/04/98	7440-66-6	Zinc	0.4	93.4

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U Analyte undetected at given RL

RL Reporting Limit

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RESOURCES
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INORGANICS ANALYSIS DATA SHEET
TOTAL METALS

Sample No: DMBG-13

Lab Sample ID: Y962R
LIMS ID: 98-21917
Matrix: Soil

QC Report No: Y962-Dames & Moore
Project: Holden Mine
17693-005-019
Date Sampled: 10/17/98
Date Received: 10/19/98

Data Release Authorized:
Reported: 11/13/98

Percent Total Solids: 86.8%

Prep Meth	Prep Date	Analysis Method	Analysis Date	CAS Number	Analyte	RL	mg/kg-dry
3050	11/02/98	6010	11/04/98	7429-90-5	Aluminum	2	16,800
3050	11/02/98	7060	11/04/98	7440-38-2	Arsenic	0.6	1.2
3050	11/02/98	6010	11/04/98	7440-39-3	Barium	0.1	40.2
3050	11/02/98	6010	11/04/98	7440-41-7	Beryllium	0.1	0.2
3050	11/02/98	6010	11/04/98	7440-43-9	Cadmium	0.2	0.2 U
3050	11/02/98	6010	11/04/98	7440-70-2	Calcium	2	2,410
3050	11/02/98	6010	11/04/98	7440-47-3	Chromium	0.6	7.6
3050	11/02/98	6010	11/04/98	7440-50-8	Copper	0.2	6.8
3050	11/02/98	6010	11/04/98	7439-89-6	Iron	2	10,600
3050	11/02/98	6010	11/04/98	7439-92-1	Lead	2	4
3050	11/02/98	6010	11/04/98	7439-95-4	Magnesium	2	628
3050	11/02/98	6010	11/04/98	7439-96-5	Manganese	0.1	97.1 J
3050	11/02/98	6010	11/04/98	7439-98-7	Molybdenum	0.6	0.6 U
3050	11/02/98	6010	11/04/98	7440-02-0	Nickel	1	6
3050	11/02/98	6010	11/04/98	7440-09-7	Potassium	60	270
3050	11/02/98	6010	11/04/98	7440-22-4	Silver	0.3	0.3 U
3050	11/02/98	6010	11/04/98	7440-23-5	Sodium	6	724
3050	11/02/98	7841	11/06/98	7440-28-0	Thallium	0.6	0.6
3050	11/02/98	200.8	11/10/98	7440-61-1	Uranium	0.2	0.3
3050	11/02/98	6010	11/04/98	7440-66-6	Zinc	0.4	22.3

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U Analyte undetected at given RL

RL Reporting Limit

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ANALYTICAL
RESOURCES
INCORPORATED

INORGANICS ANALYSIS DATA SHEET
TOTAL METALS

Sample No: DMBG-12

Lab Sample ID: Y962S
LIMS ID: 98-21918
Matrix: Soil

QC Report No: Y962-Dames & Moore
Project: Holden Mine
17693-005-019
Date Sampled: 10/17/98
Date Received: 10/19/98

Data Release Authorized:
Reported: 11/13/98

Percent Total Solids: 85.0%

Prep Meth	Prep Date	Analysis Method	Analysis Date	CAS Number	Analyte	RL	mg/kg-dry	
3050	11/02/98	6010	11/04/98	7429-90-5	Aluminum	2	15,900	
3050	11/02/98	7060	11/04/98	7440-38-2	Arsenic	0.6	0.9	
3050	11/02/98	6010	11/04/98	7440-39-3	Barium	0.1	31.1	
3050	11/02/98	6010	11/04/98	7440-41-7	Beryllium	0.1	0.2	
3050	11/02/98	6010	11/04/98	7440-43-9	Cadmium	0.2	0.2	U
3050	11/02/98	6010	11/04/98	7440-70-2	Calcium	2	2,500	
3050	11/02/98	6010	11/04/98	7440-47-3	Chromium	0.6	6.5	
3050	11/02/98	6010	11/04/98	7440-50-8	Copper	0.2	7.2	
3050	11/02/98	6010	11/04/98	7439-89-6	Iron	2	10,500	
3050	11/02/98	6010	11/04/98	7439-92-1	Lead	2	3	
3050	11/02/98	6010	11/04/98	7439-95-4	Magnesium	2	1,290	
3050	11/02/98	6010	11/04/98	7439-96-5	Manganese	0.1	79.4	J
3050	11/02/98	6010	11/04/98	7439-98-7	Molybdenum	0.6	0.6	U
3050	11/02/98	6010	11/04/98	7440-02-0	Nickel	1	7	
3050	11/02/98	6010	11/04/98	7440-09-7	Potassium	60	360	
3050	11/02/98	6010	11/04/98	7440-22-4	Silver	0.3	0.3	U
3050	11/02/98	6010	11/04/98	7440-23-5	Sodium	6	746	
3050	11/02/98	7841	11/06/98	7440-28-0	Thallium	0.6	0.6	U
3050	11/02/98	200.8	11/10/98	7440-61-1	Uranium	0.2	0.3	
3050	11/02/98	6010	11/04/98	7440-66-6	Zinc	0.4	19.7	

Km 12/9/98

U Analyte undetected at given RL

RL Reporting Limit

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ANALYTICAL
RESOURCES
INCORPORATED

INORGANICS ANALYSIS DATA SHEET
TOTAL METALS

Sample No: DMBG-11

Lab Sample ID: Y962T
LIMS ID: 98-21919
Matrix: Soil

QC Report No: Y962-Dames & Moore
Project: Holden Mine
17693-005-019
Date Sampled: 10/17/98
Date Received: 10/19/98

Data Release Authorized:
Reported: 11/13/98

Percent Total Solids: 90.1%

Prep Meth	Prep Date	Analysis Method	Analysis Date	CAS Number	Analyte	RL	mg/kg-dry	
3050	11/02/98	6010	11/04/98	7429-90-5	Aluminum	2	21,700	
3050	11/02/98	7060	11/04/98	7440-38-2	Arsenic	0.5	0.8	
3050	11/02/98	6010	11/04/98	7440-39-3	Barium	0.1	31.6	
3050	11/02/98	6010	11/04/98	7440-41-7	Beryllium	0.1	0.2	
3050	11/02/98	6010	11/04/98	7440-43-9	Cadmium	0.2	0.2	U
3050	11/02/98	6010	11/04/98	7440-70-2	Calcium	2	3,330	
3050	11/02/98	6010	11/04/98	7440-47-3	Chromium	0.5	4.7	
3050	11/02/98	6010	11/04/98	7440-50-8	Copper	0.2	5.2	
3050	11/02/98	6010	11/04/98	7439-89-6	Iron	2	10,100	
3050	11/02/98	6010	11/04/98	7439-92-1	Lead	2	3	
3050	11/02/98	6010	11/04/98	7439-95-4	Magnesium	2	528	
3050	11/02/98	6010	11/04/98	7439-96-5	Manganese	0.1	71.3	J
3050	11/02/98	6010	11/04/98	7439-98-7	Molybdenum	0.5	0.5	U
3050	11/02/98	6010	11/04/98	7440-02-0	Nickel	1	5	
3050	11/02/98	6010	11/04/98	7440-09-7	Potassium	50	220	
3050	11/02/98	6010	11/04/98	7440-22-4	Silver	0.3	0.3	U
3050	11/02/98	6010	11/04/98	7440-23-5	Sodium	5	903	
3050	11/02/98	7841	11/06/98	7440-28-0	Thallium	0.5	0.5	U
3050	11/02/98	200.8	11/10/98	7440-61-1	Uranium	0.2	0.4	
3050	11/02/98	6010	11/04/98	7440-66-6	Zinc	0.4	12.5	

KM 12/9/98

U Analyte undetected at given RL

RL Reporting Limit

FORM-I

ANALYTICAL
RESOURCES
INCORPORATED

INORGANICS ANALYSIS DATA SHEET
TOTAL METALS

Sample No: Method Blank

Lab Sample ID: Y962MB
LIMS ID: 98-21911
Matrix: Soil

QC Report No: Y962-Dames & Moore
Project: Holden Mine
17693-005-019
Date Sampled: NA
Date Received: NA

Data Release Authorized:
Reported: 11/17/98

Percent Total Solids: NA

Prep Meth	Prep Date	Analysis Method	Analysis Date	CAS Number	Analyte	RL	mg/kg-dry
3050	11/02/98	6010	11/04/98	7429-90-5	Aluminum	2	2 U
3050	11/02/98	7060	11/04/98	7440-38-2	Arsenic	0.1	0.1 U
3050	11/02/98	6010	11/04/98	7440-39-3	Barium	0.3	0.3 U
3050	11/02/98	6010	11/04/98	7440-41-7	Beryllium	0.1	0.1 U
3050	11/02/98	6010	11/04/98	7440-43-9	Cadmium	0.2	0.2 U
3050	11/02/98	6010	11/04/98	**7440-70-2**	**Calcium**	2	7
3050	11/02/98	6010	11/04/98	7440-47-3	Chromium	0.5	0.5 U
3050	11/02/98	6010	11/04/98	7440-50-8	Copper	0.2	0.2 U
3050	11/02/98	6010	11/04/98	7439-89-6	Iron	2	2 U
3050	11/02/98	6010	11/04/98	7439-92-1	Lead	2	2 U
3050	11/02/98	6010	11/04/98	7439-95-4	Magnesium	2	2 U
3050	11/02/98	6010	11/04/98	7439-96-5	Manganese	0.1	0.1 U
3050	11/02/98	6010	11/04/98	7439-98-7	Molybdenum	0.5	0.5 U
3050	11/02/98	6010	11/04/98	7440-02-0	Nickel	1	1 U
3050	11/02/98	6010	11/04/98	7440-09-7	Potassium	50	50 U
3050	11/02/98	6010	11/04/98	7440-22-4	Silver	0.3	0.3 U
3050	11/02/98	6010	11/04/98	7440-23-5	Sodium	5	5 U
3050	11/02/98	7841	11/06/98	7440-28-0	Thallium	0.1	0.1 U
3050	11/02/98	200.8	11/10/98	7440-61-1	Uranium	0.2	0.2 U
3050	11/02/98	6010	11/04/98	7440-66-6	Zinc	0.4	0.4 U

U	Analyte undetected at given RL
RL	Reporting Limit

FORM-I

ANALYTICAL
RESOURCES
INCORPORATED

INORGANICS ANALYSIS DATA SHEET

Sample No: STD REFERENCE
ERA Lot 239

Lab Sample ID: Y962-SRM
LIMS ID: 98-21911
Matrix: Sediment

QC Report No: Y962-Dames & Moore
Project: Holden Mine
17693-005-019
Date Sampled: NA
Date Received: NA

Data Release Authorized:
Reported: 11/17/98

Analyte	mg/kg-dry	Certified Value	Advisory Range
Aluminum	6640	5720	3760-7690
Arsenic	171	189	118-260
Barium	217	195	128-261
Beryllium	79.9	78.9	56.5-101
Cadmium	117	114	84.9-142
Calcium	1360	2610	903-1660
Chromium	179	175	121-229
Copper	91.7	91.0	64.6-117
Iron	9240	9080	4830-13300
Lead	70.5	66.0	44.7-87.3
Magnesium	1290	1210	888-1530
Manganese	268	261	204-319
Molybdenum	118	112	78.9-146
Nickel	66.8	68.3	38.1-98.6
Potassium	1740	1500	957-2040
Silver	58.4	57.2	40.8-73.5
Sodium	1380	1380	939-1830
Thallium	94.6	98.4	56.3-140
Zinc	200	190	144-236

ANALYTICAL
RESOURCES
INCORPORATED

INORGANIC ANALYSIS DATA SHEET
TOTAL METALS

Sample No: DMBG-16
Lab Sample ID: Y962L
QC Report No: Y962-Dames & Moore
LIMS ID: 98-21911
Project: Holden Mine
17693-005-019
Matrix: Soil
Date Received: 10/19/98

Data Release Authorized:
Reported: 11/13/98

MATRIX DUPLICATE QUALITY CONTROL REPORT

Analyte	Analysis Method	Sample mg/kg-dry	Duplicate mg/kg-dry	RPD	Control Limit	Q
Aluminum	6010	11200	12400	10.2%	+/- 20 %	
Arsenic	7060	0.8	1.0	22.2%	+/- 0.7	L
Barium	6010	250	264	5.4%	+/- 20 %	
Beryllium	6010	0.2	0.2	0.0%	+/- 0.1	L
Cadmium	6010	17.4	18.8	7.7%	+/- 20 %	
Calcium	6010	11000	10900	0.9%	+/- 20 %	
Chromium	6010	8.4	9.9	16.4%	+/- 20 %	
Copper	6010	24.8	27.2	9.2%	+/- 20 %	
Iron	6010	10500	11300	7.3%	+/- 20 %	
Lead	6010	7	7	0.0%	+/- 3	L
Magnesium	6010	2220	2130	4.1%	+/- 20 %	
Manganese	6010	1160	1430	20.8%	+/- 20 %	*
Molybdenum	6010	0.9	0.9	0.0%	+/- 0.7	L
Nickel	6010	12	13	8.0%	+/- 20 %	
Potassium	6010	1160	990	15.8%	+/- 20 %	
Silver	6010	0.4 U	0.4 U	0.0%	+/- 0.4	L
Sodium	6010	557	613	9.6%	+/- 20 %	
Thallium	7841	0.7 U	0.7 U	0.0%	+/- 0.7	L
Uranium	200.8	0.3	0.3	0.0%	+/- 0.3	L
Zinc	6010	298	316	5.9%	+/- 20 %	

'Q' codes:
* = control limit not met
L = RPD not valid, alternate limit = detection limit

ANALYTICAL
RESOURCES
INCORPORATED

INORGANICS ANALYSIS DATA SHEET
TOTAL METALS

Sample No: DMBG-16
Lab Sample ID: Y962L
QC Report No: Y962-Dames & Moore
LIMS ID: 98-21911
Project: Holden Mine
17693-005-019
Matrix: Soil
Date Received: 10/19/98

Data Release Authorized:
Reported: 11/13/98

MATRIX SPIKE QUALITY CONTROL REPORT

Analyte	Analysis Method	Sample mg/kg-dry	Spike mg/kg-dry	Spike Added	% Recovery	Q
Aluminum	6010	11200	12300	554	199%	H
Arsenic	7060	0.8	44.8	45.3	97.1%	
Barium	6010	250	786	554	96.8%	
Beryllium	6010	0.2	13.0	13.9	92.1%	
Cadmium	6010	17.4	31.4	13.9	101%	
Calcium	6010	11000	13800	2770	101%	
Chromium	6010	8.4	61.4	55.4	95.7%	
Copper	6010	24.8	93.3	69.3	98.8%	
Iron	6010	10500	11000	277	181%	H
Lead	6010	7	138	139	94.2%	
Magnesium	6010	2220	4650	2770	87.7%	
Manganese	6010	1160	1350	139	137%	H
Molybdenum	6010	0.9	34.2	34.6	96.2%	
Nickel	6010	12	143	139	94.2%	
Potassium	6010	1160	3680	2770	91.0%	
Silver	6010	0.4 U	13.0	13.9	93.5%	
Sodium	6010	557	3310	2770	99.4%	
Thallium	7841	0.7 U	52.7	48.1	110%	
Uranium	200.8	0.3	38.7	34.3	112%	
Zinc	6010	298	430	139	95.0%	

'Q' codes:
N = control limit not met
H = %R not applicable, sample concentration too high
* = RPD control limit not met
NA = Not applicable - analyte not spiked

Control Limits:
Percent Recovery: 75-125%
RPD: +/-20%

FORM-V

3.0 Y962 10.1,0.

98-21900 → 98-21919

CHAIN-OF-CUSTODY RECORD

WHITE COPY-Original (Accompanies Samples) YELLOW COPY-Collector * PINK COPY-Project Manager

Boring or Well Number	Sample Number	Depth	Time	Sample Type	Date Collected ~~Container Type~~	Analysis Required VOA 601/8010	VOA 602/8020	VOA 624/8240/8260	Semi Vol 625/8270	NWTPH-Gx	NWTPH-Dx	NWTPH-Dx-Ext	RCRA 8 Metals	PNA 610/8310	Pest/PCBs 8081	~~ASBESTOS~~ metals*	FIELD NOTES:	Total Number Of Containers	Laboratory Note Number
DMB6-10		0-6"	1550	soil	10-12-98											X		1	
DMB6-10X		0-6"	1555	soil	10-12-98											X		1	
DMB6-6		0-6"	1245	soil	10-13-98											X		1	
DMB6-5		0-6"	1415	soil	10-13-98											X		1	
DMB6-7		0-6"	1500	soil	10-13-98											X		1	
DMB6-4		0-6"	1605	soil	10-13-98											X		1	
DMB6-3		0-6"	1650	soil	10-13-98											X		1	
DMB6-8		0-6"	1720	soil	10-13-98											X		1	
DMB6-2		0-6"	1000	soil	10-15-98											X		1	
DMB6-1		0-6"	1105	soil	10-15-98											X		1	
DMB6-9		0-6"	1135	soil	10-15-98											X		1	
DMB6-16		0-6"	0930	soil	10-17-98												Hold	1	
DMB6-17		0-6"	1000	soil	10-17-98													1	
DMB6-18		0-6"	1045	soil	10-17-98													1	
DMB6-19		0-6"	1100	soil	10-17-98												↓	1	

RELINQUISHED BY: (Signature) DATE/TIME 10/19/98 0925 RECEIVED BY: (Signature) 10/19/98

RELINQUISHED BY: (Signature) DATE/TIME RECEIVED BY: (Signature)

RELINQUISHED BY: (Signature) DATE/TIME RECEIVED BY: (Signature)

LABORATORY NOTES:
metals * Al, As, Ba, Be, Cd, Ca, Cr, Cu, Fe, Pb, Mg, Mn, Mo, Ni, K, Ag, Na, Tl, V, Zn per info to Mark Harris.
Do not dispose of sample unless directed by D&M

ANALYTICAL LABORATORY: ARI

LABORATORY CONTACT: Mark Harris

D&M CONTACT: Karen Mixon PHONE: 728-0744

JOB NO.: 17693-005-019

PROJECT: Holden Mine

LOCATION: Holden, WA

COLLECTOR: KM/SCA DATE OF COLLECTION

DAMES & MOORE
A DAMES & MOORE GROUP COMPANY

500 Market Place Tower
2025 First Avenue
Seattle, Washington 98121
Phone (206) 728-0744
Fax (206) 727-3350

Background Soil Sample PG 2 OF 2 pa 42

CHAIN-OF-CUSTODY RECORD

3.0

WHITE COPY-Original (Accompanies Samples) YELLOW COPY-Collector PINK COPY-Project Manager

Boring or Well Number	Sample Number	Depth	Time	Sample Type	Date Collected ~~Container Type~~	Analysis Required VOA 601/8010	VOA 602/8020	VOA 624/8240/8260	Semi Vol 625/8270	NWTPH-Gx	NWTPH-Dx	NWTPH-Dx-Ext	RCRA 8 Metals	PNA 610/8310	Pest/PCBs 8081	ASBESTOS	FIELD NOTES:	Total Number Of Containers	Laboratory Note Number
DMBG-15		0-6"	1040	soil	10-17-98												Hold	1	
DMBG-14		0-6"	0955	soil	10-17-98													1	
DMBG-13		0-6"	1120	soil	10-17-98													1	
DMBG-12		0-6"	1037	soil	10-17-98													1	
DMBG-11		0-6"	1000	soil	10-17-98													1	

RELINQUISHED BY: (Signature)	DATE/TIME	RECEIVED BY: (Signature)
	10/19/98 0925	
RELINQUISHED BY: (Signature)	DATE/TIME	RECEIVED BY: (Signature)
RELINQUISHED BY: (Signature)	DATE/TIME	RECEIVED BY: (Signature)

LABORATORY NOTES:

see page 1

ANALYTICAL LABORATORY: ARI

LABORATORY CONTACT: Mark Harris

D&M CONTACT: Karen Moe PHONE: 728-0744

JOB NO.: 17693-005-019

PROJECT: Holden Mine

LOCATION: Holden, WA

LLECTOR: Km/Sck DATE OF COLLECTION

DAMES & MOORE
GROU
AMES & MOORE GROUP COMPANY

500 Market Place Tower
2025 First Avenue
Seattle, Washington 98121
Phone (206) 728-0744
Fax (206) 727-3350

MEMORANDUM

Date: December 8, 1998

To: Rik Langendoen, Project Manager

From: Karen Mixon, QA/QC Manager

Subject: Summary Data Quality Review
Holden Mine Remedial Investigation Phase III
Lagoon Soil Sample Data, Fall 1998
Dames & Moore Job #17693-005-019

The summary data quality review of 13 soil samples collected from October 14 through 15, 1998 has been completed. The samples were analyzed at the Analytical Resources, Incorporated (ARI) laboratory in Seattle, Washington for metals by EPA Method 6010A, (cadmium, copper, and lead). In addition, samples were analyzed for total petroleum hydrocarbons (diesel and heavier than diesel range) by Washington State Department of Ecology TPH methods. The analyses were performed in accordance with the methods specified in EPA Test Methods for Evaluating Solid Waste, SW-846, January 1995, and Washington State Department of Ecology Total Petroleum Hydrocarbons Methods, April 1992. A validation package containing method associated QA/QC data and sample data was provided by the laboratory. The following samples are associated with laboratory work order ARI# Y964:

Sample I.D.	ARI Sample #	Analyses Requested
DMLG-4-2	Y964A	Cadmium, Copper, Lead, WTPH-D ext
DMLG-4-4	Y964B	Cadmium, Copper, Lead, WTPH-D ext
DMLG-2-2	Y964C	Archive
DMLG-2-4	Y964D	Cadmium, Copper, Lead, WTPH-D ext
DMLG-1-surface	Y964E	Archive
DMLG-5-2	Y964F	Cadmium, Copper, Lead, WTPH-D ext
DMLG-1-2	Y964G	Cadmium, Copper, Lead, WTPH-D ext
DMLG-1-4	Y964H	Cadmium, Copper, Lead, WTPH-D ext
DMLG-3-2	Y964I	Cadmium, Copper, Lead, WTPH-D ext
DMLG-3-4	Y964J	Cadmium, Copper, Lead, WTPH-D ext
DMLG-5-4	Y964K	Cadmium, Copper, Lead, WTPH-D ext
DMLG-2-5	Y964L	Archive
DMLG-2-7 ½	Y964M	Cadmium, Copper, Lead, WTPH-D ext

The following comments refer to ARI's performance in meeting quality control specifications described in the EPA documents "EPA Test Methods for Evaluating Solid Waste, SW-846", January 1995, "USEPA Contract Laboratory Program (CLP) National Functional Guidelines for Inorganic Data Review", February 1994, and "USEPA Contract Laboratory Program (CLP) National Functional Guidelines for Organic Data Review", February 1994, and Washington State Department of Ecology Total Petroleum Hydrocarbons Methods, April 1992, and the Quality Assurance Project Plan (QAPP) prepared for the Phase III Remedial Investigation referenced in an addendum (August 28, 1998) to the Phase III Sampling and Analysis Plan.

The report is divided into subsections based on type of analyses performed.

Metals

Samples were prepared in the laboratory using EPA Method 3050. Samples were analyzed by ICP (EPA Method 6010A).

1. Holding Time - Acceptable

2. Initial Calibration - Acceptable

3. Continuing Calibration - Acceptable

4. Blanks

Copper (3.2 to 4.0 ug/L) was detected in calibration blanks (CCBs) associated with several of the sample analyses. As the copper concentration in the samples was substantially greater (100X) than the equivalent soil concentration detected in the CCB, data were not qualified.

5. ICP Interference Check (ICP analysis only) - Acceptable

6. Laboratory Control Sample - Acceptable

7. Laboratory Duplicate Sample - Acceptable

8. Field Duplicate

A field duplicate was not collected.

9. Matrix Spike

The matrix spike was performed on sample DMLG-4-2. The recoveries for cadmium (-21.4%), copper (-1550%), and lead (14.3%) were outside of the control limits (75-125%). The concentration of cadmium (150 mg/kg), copper (17,500 mg/kg), and lead (730 mg/kg) in the sample exceeded the spiking concentration by greater than 4X. Data qualification was not required.

10. ICP Serial Dilution (ICP analysis only) - Acceptable

11. Detection Limits - Acceptable

12. Type of Review - Summary

13. Overall Assessment of Data

The usefulness of the data is based on EPA guidance documents listed above. Upon consideration of the information presented above, the data are acceptable except where flagged with data qualifiers that modify the usefulness of the individual values.

Organic Analyses

Select samples (as noted in the report introduction) were analyzed for TPH (diesel extended range) by the Washington State methods previously referenced.

1. Hold Time

Samples DMLG-1-4, DMLG-2-7 ½. DMLG-3-2, DMLG-3-4, and DMLG-5-4 were reextracted due to low surrogate recoveries. The surrogate recoveries were acceptable in the reextracts; however, the reextraction occurred 6 days past the 14 day hold time for extraction. The reextract data was acceptable for site evaluation with qualification. The data are estimated and flagged "J" accordingly.

2. Initial Calibration - Acceptable

3. Continuing Calibration - Acceptable

4. Blanks - Acceptable

5. Surrogate Recoveries

Samples DMLG-1-4, DMLG-2-7 ½ , DMLG-3-2, DMLG-3-4, and DMLG-5-4 were reextracted due to low surrogate recoveries. The surrogate recoveries for the initial extraction and the reextraction are tabulated below:

Sample	% Recovery Initial	% Recovery Reextract
DMLG-1-4	24.3	66
DMLG-2-7½	30.7	52
DMLG-3-2	45.8	50
DMLG-3-4	3.4	75
DMLG-5-4	16.3	56

Due to the low recoveries from the initial extraction, the results for data evaluation were selected from the reextraction although past the method hold time (see discussion under Hold Time).

6. Laboratory Duplicate - Acceptable

7. Matrix Spike/Matrix Spike Duplicate (MS/MSD)

A MS/MSD was performed on sample DMLG-3-2. Due to low surrogate recoveries for the original, MS, and MSD samples, the QC set was reextracted. Surrogate recoveries were acceptable in the reextracted QC set. However, the recovery of diesel spiked in the first MS/MSD was outside of the laboratory control limits (38 - 160%) as the spike concentration was not recovered. The spike recoveries from the reextracted MS and MSD were 73% and -41%, respectively. The sample concentration was about 4X the spike level. Data are not generally qualified based on MS/MSD results alone. The MS/MSD sample results indicate a potential for variability related to sample DMLG-3-2. The data for this sample was previously qualified as estimated based on surrogate recoveries. Additional qualification based on MS/MSD results does not alter the estimated qualification already assigned.

8. Laboratory Control Sample/Blank Spike (LCS/BS) - Acceptable

9. Field Duplicate

A field duplicate was not collected.

10. Target Compound Identification

The sample results reported as diesel and motor oil in samples DMLG-1-4, DMLG-2-4, DMLG-2-7½, DMLG-3-2, DMLG-3-4, DMLG-4-2, DMLG-4-4, DMLG-5-2, and DMLG-5-4 do not match typical diesel or motor oil profiles, although the patterns are indicative of a heavy hydrocarbon component. The diesel and motor oil reported in sample DMLG-1-2 are not indicative of typical diesel or motor oil patterns.

11. Detection Limits - Acceptable

12. Type of Review - Summary

13. Overall Assessment of Data

The usefulness of the data is based on the EPA guidance documents listed above. Upon consideration of the information presented above, data are considered acceptable except where flagged with data qualifiers that modify the usefulness of the individual values.

Data Qualifiers

U	The analyte was analyzed for, but was not detected above the reported sample quantitation limit.
J	The analyte was positively identified; the associated numerical value is the approximate concentration of the analyte in the sample.
UJ	The analyte was not detected above the reported sample quantitation limit. However, the reported quantitation limit is approximate and may or may not represent the actual limit of quantitation necessary to accurately and precisely measure the analyte in the sample.
R	The sample results are rejected due to serious deficiencies in the ability to analyze the sample and meet quality control criteria. The presence or absence of the analyte cannot be verified.

ANALYTICAL
RESOURCES
INCORPORATED

INORGANICS ANALYSIS DATA SHEET
TOTAL METALS

Sample No: DMLG-4-2'

Lab Sample ID: Y964A
LIMS ID: 98-21921
Matrix: Soil

QC Report No: Y964-Dames & Moore
Project: Holden Mine
17693-005-019
Date Sampled: 10/14/98
Date Received: 10/19/98

Data Release Authorized:
Reported: 11/03/98

Percent Total Solids: 68.6%

Prep Meth	Prep Date	Analysis Method	Analysis Date	CAS Number	Analyte	RL	mg/kg-dry
3050	10/27/98	6010	10/30/98	7440-43-9	Cadmium	3	150
3050	10/27/98	6010	10/30/98	7440-50-8	Copper	3	17,300
3050	10/27/98	6010	10/30/98	7439-92-1	Lead	30	730

U	Analyte undetected at given RL
RL	Reporting Limit

FORM-I

ANALYTICAL
RESOURCES
INCORPORATE

INORGANICS ANALYSIS DATA SHEET
TOTAL METALS

Sample No: DMLG-4-4'

Lab Sample ID: Y964B
LIMS ID: 98-21922
Matrix: Soil

QC Report No: Y964-Dames & Moore
Project: Holden Mine
17693-005-019
Date Sampled: 10/14/98
Date Received: 10/19/98

Data Release Authorized:
Reported: 11/03/98

Percent Total Solids: 60.3%

Prep Meth	Prep Date	Analysis Method	Analysis Date	CAS Number	Analyte	RL	mg/kg-dry
3050	10/27/98	6010	10/30/98	7440-43-9	Cadmium	3	135
3050	10/27/98	6010	10/30/98	7440-50-8	Copper	3	22,100
3050	10/27/98	6010	10/30/98	7439-92-1	Lead	30	800

U Analyte undetected at given RL

RL Reporting Limit

FORM-I

ANALYTICAL
RESOURCES
INCORPORATED

INORGANICS ANALYSIS DATA SHEET
TOTAL METALS

Sample No: DMLG-2-4'

Lab Sample ID: Y964C
LIMS ID: 98-21923
Matrix: Soil

QC Report No: Y964-Dames & Moore
Project: Holden Mine
17693-005-019
Date Sampled: 10/14/98
Date Received: 10/19/98

Data Release Authorized:
Reported: 11/03/98

Percent Total Solids: 74.0%

Prep Meth	Prep Date	Analysis Method	Analysis Date	CAS Number	Analyte	RL	mg/kg-dry
3050	10/27/98	6010	10/30/98	7440-43-9	Cadmium	5	175
3050	10/27/98	6010	10/30/98	7440-50-8	Copper	5	22,500
3050	10/27/98	6010	10/30/98	7439-92-1	Lead	50	560

U Analyte undetected at given RL

RL Reporting Limit

FORM-I

ANALYTICAL
RESOURCES
INCORPORATED

INORGANICS ANALYSIS DATA SHEET
TOTAL METALS

Sample No: DMLG-5-2'

Lab Sample ID: Y964D
LIMS ID: 98-21924
Matrix: Soil

QC Report No: Y964-Dames & Moore
Project: Holden Mine
17693-005-019
Date Sampled: 10/14/98
Date Received: 10/19/98

Data Release Authorized:
Reported: 11/03/98

Percent Total Solids: 69.1%

Prep Meth	Prep Date	Analysis Method	Analysis Date	CAS Number	Analyte	RL	mg/kg-dry
3050	10/27/98	6010	10/30/98	7440-43-9	Cadmium	3	173
3050	10/27/98	6010	10/30/98	7440-50-8	Copper	3	23,900
3050	10/27/98	6010	10/30/98	7439-92-1	Lead	30	580

U Analyte undetected at given RL

RL Reporting Limit

FORM-I

INORGANICS ANALYSIS DATA SHEET
TOTAL METALS

Sample No: DMLG-1-2'

Lab Sample ID: Y964E
LIMS ID: 98-21925
Matrix: Soil

QC Report No: Y964-Dames & Moore
Project: Holden Mine
17693-005-019
Date Sampled: 10/15/98
Date Received: 10/19/98

Data Release Authorized:
Reported: 11/03/98

Percent Total Solids: 59.3%

Prep Meth	Prep Date	Analysis Method	Analysis Date	CAS Number	Analyte	RL	mg/kg-dry
3050	10/27/98	6010	10/30/98	7440-43-9	Cadmium	0.3	2.5
3050	10/27/98	6010	10/30/98	7440-50-8	Copper	0.3	1,390
3050	10/27/98	6010	10/30/98	7439-92-1	Lead	3	132

U Analyte undetected at given RL

RL Reporting Limit

FORM-I

ANALYTICAL
RESOURCES
INCORPORATED

INORGANICS ANALYSIS DATA SHEET
TOTAL METALS

Sample No: DMLG-1-4'

Lab Sample ID: Y964F
LIMS ID: 98-21926
Matrix: Soil

QC Report No: Y964-Dames & Moore
Project: Holden Mine
17693-005-019
Date Sampled: 10/15/98
Date Received: 10/19/98

Data Release Authorized:
Reported: 11/03/98

Percent Total Solids: 79.1%

Prep Meth	Prep Date	Analysis Method	Analysis Date	CAS Number	Analyte	RL	mg/kg-dry
3050	10/27/98	6010	10/30/98	7440-43-9	Cadmium	0.2	4.3
3050	10/27/98	6010	10/30/98	7440-50-8	Copper	0.2	1,120
3050	10/27/98	6010	10/30/98	7439-92-1	Lead	2	73

U Analyte undetected at given RL

RL Reporting Limit

FORM-I

ANALYTICAL
RESOURCES
INCORPORATED

INORGANICS ANALYSIS DATA SHEET
TOTAL METALS

Sample No: DMLG-3-2'

Lab Sample ID: Y964G
LIMS ID: 98-21927
Matrix: Soil

QC Report No: Y964-Dames & Moore
Project: Holden Mine
17693-005-019
Date Sampled: 10/15/98
Date Received: 10/19/98

Data Release Authorized:
Reported: 11/03/98

Percent Total Solids: 76.9%

Prep Meth	Prep Date	Analysis Method	Analysis Date	CAS Number	Analyte	RL	mg/kg-dry
3050	10/27/98	6010	10/30/98	7440-43-9	Cadmium	0.3	2.3
3050	10/27/98	6010	10/30/98	7440-50-8	Copper	0.3	1,020
3050	10/27/98	6010	10/30/98	7439-92-1	Lead	3	153

U	Analyte undetected at given RL
RL	Reporting Limit

FORM-I

ANALYTICAL
RESOURCES
INCORPORATED

INORGANICS ANALYSIS DATA SHEET
TOTAL METALS

Sample No: DMLG-3-4'

Lab Sample ID: Y964H
LIMS ID: 98-21928
Matrix: Soil

QC Report No: Y964-Dames & Moore
Project: Holden Mine
17693-005-019
Date Sampled: 10/15/98
Date Received: 10/19/98

Data Release Authorized:
Reported: 11/03/98

Percent Total Solids: 84.3%

Prep Meth	Prep Date	Analysis Method	Analysis Date	CAS Number	Analyte	RL	mg/kg-dry
3050	10/27/98	6010	10/30/98	7440-43-9	Cadmium	0.2	0.7
3050	10/27/98	6010	10/30/98	7440-50-8	Copper	0.2	294
3050	10/27/98	6010	10/30/98	7439-92-1	Lead	2	52

U Analyte undetected at given RL

RL Reporting Limit

FORM-I

ANALYTICAL
RESOURCES
INCORPORATED

INORGANICS ANALYSIS DATA SHEET
TOTAL METALS

Sample No: DMLG-5-4'

Lab Sample ID: Y964I
LIMS ID: 98-21929
Matrix: Soil

QC Report No: Y964-Dames & Moore
Project: Holden Mine
17693-005-019
Date Sampled: 10/15/98
Date Received: 10/19/98

Data Release Authorized:
Reported: 11/03/98

Percent Total Solids: 65.2%

Prep Meth	Prep Date	Analysis Method	Analysis Date	CAS Number	Analyte	RL	mg/kg-dry
3050	10/27/98	6010	10/30/98	7440-43-9	Cadmium	1	25
3050	10/27/98	6010	10/30/98	7440-50-8	Copper	1	4,000
3050	10/27/98	6010	10/30/98	7439-92-1	Lead	10	190

U Analyte undetected at given RL

RL Reporting Limit

FORM-I

INORGANICS ANALYSIS DATA SHEET
TOTAL METALS

Sample No: DMLG-2-7 1/2'

Lab Sample ID: Y964J
LIMS ID: 98-21930
Matrix: Soil

QC Report No: Y964-Dames & Moore
Project: Holden Mine
17693-005-019
Date Sampled: 10/15/98
Date Received: 10/19/98

Data Release Authorized:
Reported: 11/03/98

Percent Total Solids: 83.0%

Prep Meth	Prep Date	Analysis Method	Analysis Date	CAS Number	Analyte	RL	mg/kg-dry
3050	10/27/98	6010	10/30/98	7440-43-9	Cadmium	1	28
3050	10/27/98	6010	10/30/98	7440-50-8	Copper	1	3,610
3050	10/27/98	6010	10/30/98	7439-92-1	Lead	10	110

U	Analyte undetected at given RL
RL	Reporting Limit

FORM-I

INORGANICS ANALYSIS DATA SHEET
TOTAL METALS

Sample No: Method Blank

Lab Sample ID: Y964MB
LIMS ID: 98-21921
Matrix: Soil

QC Report No: Y964-Dames & Moore
Project: Holden Mine
17693-005-019
Date Sampled: NA
Date Received: NA

Data Release Authorized:
Reported: 11/03/98

Percent Total Solids: NA

Prep Meth	Prep Date	Analysis Method	Analysis Date	CAS Number	Analyte	RL	mg/kg-dry
3050	10/27/98	6010	10/30/98	7440-43-9	Cadmium	0.2	0.2 U
3050	10/27/98	6010	10/30/98	7440-50-8	Copper	0.2	0.2 U
3050	10/27/98	6010	10/30/98	7439-92-1	Lead	2	2 U

U Analyte undetected at given RL

RL Reporting Limit

FORM-I

ANALYTICAL
RESOURCES
INCORPORATED

INORGANICS ANALYSIS DATA SHEET

Sample No: STD REFERENCE
ERA Lot 239

Lab Sample ID: Y964-SRM
LIMS ID: 98-21921
Matrix: Sediment

QC Report No: Y964-Dames & Moore
Project: Holden Mine
17693-005-019
Date Sampled: NA
Date Received: NA

Data Release Authorized
Reported: 11/04/98

Analyte	mg/kg-dry	Certified Value	Advisory Range
Cadmium	116	114	84.9-142
Copper	92.0	91.0	64.6-117
Lead	70.0	66.0	44.7-87.3

FORM-VII

INORGANIC ANALYSIS DATA SHEET
TOTAL METALS

Sample No: DMLG-4-2'
Lab Sample ID: Y964A
QC Report No: Y964-Dames & Moore
LIMS ID: 98-21921
Project: Holden Mine
17693-005-019
Matrix: Soil
Date Received: 10/19/98

Data Release Authorized:
Reported: 11/03/98

MATRIX DUPLICATE QUALITY CONTROL REPORT

Analyte	Analysis Method	Sample mg/kg-dry	Duplicate mg/kg-dry	RPD	Control Limit	Q
Cadmium	6010	150	149	0.7%	+/- 20 %	
Copper	6010	17300	17800	2.8%	+/- 20 %	
Lead	6010	730	740	1.4%	+/- 20 %	

'Q' codes:
* = control limit not met
L = RPD not valid, alternate limit = detection limit

FORM-VI

ANALYTICAL
RESOURCES
INCORPORATED

INORGANICS ANALYSIS DATA SHEET
TOTAL METALS

Sample No: DMLG-4-2'
Lab Sample ID: Y964A
QC Report No: Y964-Dames & Moore
LIMS ID: 98-21921
Project: Holden Mine
17693-005-019
Matrix: Soil
Date Received: 10/19/98
Data Release Authorized:
Reported: 11/03/98

MATRIX SPIKE QUALITY CONTROL REPORT

Analyte	Analysis Method	Sample mg/kg-dry	Spike mg/kg-dry	Spike Added	% Recovery	Q
Cadmium	6010	150	147	14	-21.4%	H
Copper	6010	17300	16200	71	-1550%	H
Lead	6010	730	750	140	14.3%	H

'Q' codes:
N = control limit not met
H = %R not applicable, sample concentration too high
* = RPD control limit not met
NA = Not applicable - analyte not spiked

Control Limits:
Percent Recovery: 75-125%
RPD: +/-20%

FORM-V

ANALYTICAL
RESOURCES
INCORPORATED

TOTAL DIESEL RANGE HYDROCARBONS
WA TPHd Range C12 to C24 by GC/FID and Motor Oil

LIMS ID: 98-21921
Matrix: Soil
Data Release Authorized:
Reported: 11/17/98

QC Report No: Y964-Dames & Moore
Project: Holden Mine
17693-005-019
Date Received: 10/19/98

Lab ID	Sample ID	Date Analyzed	Dilution Factor	Diesel Range	*HC ID	Motor Oil Range	Surrogate Recovery
Y964MB	Method Blank	10/31/98	1:1	5.0 U	---	10 U	68.0%
Y964A	DMLG-4-2'	10/31/98	1:1	540	M.OIL+	850	54.3%
Y964B	DMLG-4-4'	10/31/98	1:1	930 E	M.OIL+	1,300	69.1%
Y964B	DMLG-4-4'	11/05/98	1:10	1,200	M.OIL+	1,700	D
Y964C	DMLG-2-4'	10/31/98	1:1	520	M.OIL+	960	60.5%
Y964D	DMLG-5-2'	10/31/98	1:1	280	M.OIL+	500	57.7%
Y964E	DMLG-1-2'	10/31/98	1:1	1,800 E	NO	1,200	73.8%
Y964E	DMLG-1-2'	11/05/98	1:20	2,200	NO	1,900	D
Y964ED	DMLG-1-2'-DUPL	11/05/98	1:20	1,500	NO	1,600	D
Y964MB	Method Blank	11/05/98	1:1	5.0 U	---	10 U	80.0%
Y964F	DMLG-1-4'	10/31/98	1:1	78 R	M.OIL+	110 R	24.3%
Y964FR	DMLG-1-4'	11/05/98	1:2	140 J	M.OIL+	170 J	66.0%
Y964G	DMLG-3-2'	10/31/98	1:1	480 R	M.OIL+	560 R	45.8%
Y964H	DMLG-3-4'	10/31/98	1:1	43 R	M.OIL+	67 R	34.4%
Y964HR	DMLG-3-4'	11/05/98	1:1	86 J	M.OIL+	120 J	75.0%

Values reported in ppm (mg/kg) on a dry weight basis.

Km 12/13/98

Surrogate is Methyl-Arachidate.

* ID indicates, in the opinion of the analyst, the petroleum product with the best pattern match. 'NO' indicates that there was not a good match for any of the requested products. Diesel quantitation on total peaks in the range from C12 to C24. Motor Oil quantitation on total peaks in the Motor Oil Standard range.

Data Qualifiers

U	Compound not detected at the given detection limit.
J	Indicates an estimated value below the calculated detection limit.
S	No value reported due to saturation of the detector. Dilution required.
D	Indicates the surrogate was not detected because of dilution of the extract.
E	Indicates a value above the linear range of the detector. Dilution required.
NR	Indicates no recovery due to matrix interference.
B	Indicates compound also detected in the method blank.

FORM-1 WA TPHD

ANALYTICAL
RESOURCES
INCORPORATED

TOTAL DIESEL RANGE HYDROCARBONS
WA TPHd Range C12 to C24 by GC/FID and Motor Oil

LIMS ID: 98-21929
Matrix: Soil

QC Report No: Y964-Dames & Moore
Project: Holden Mine
17693-005-019
Date Received: 10/19/98

Data Release Authorized:
Reported: 11/18/98

Lab ID	Sample ID	Date Analyzed	Dilution Factor	Diesel Range	*HC ID	Motor Oil Range	Surrogate Recovery
Y964I	DMLG-5-4'	10/31/98	1:1	200 R	M.OIL+	340 R	16.3%
Y964IR	DMLG-5-4'	11/05/98	1:2	170 J	M.OIL+	330 J	56.0%
Y964J	DMLG-2-7 1/2'	10/31/98	1:1	140 R	M.OIL+	140 R	30.7%
Y964JR	DMLG-2-7 1/2'	11/05/98	1:2	150 J	M.OIL+	170 J	52.0%
Y964G	DMLG-3-2'	11/05/98	1:10	520 J	M.OIL+	800 J	50.0%

KM 12/13/98

Values reported in ppm (mg/kg) on a dry weight basis.

Surrogate is Methyl-Arachidate.

* ID indicates, in the opinion of the analyst, the petroleum product with the best pattern match. 'NO' indicates that there was not a good match for any of the requested products. Diesel quantitation on total peaks in the range from C12 to C24. Motor Oil quantitation on total peaks in the range from C12 to C32.

Data Qualifiers

U	Compound not detected at the given detection limit.
J	Indicates an estimated value below the calculated detection limit.
S	No value reported due to saturation of the detector. Dilution required.
D	Indicates the surrogate was not detected because of dilution of the extract.
E	Indicates a value above the linear range of the detector. Dilution required.
NR	Indicates no recovery due to matrix interference.
B	Indicates compound also detected in the method blank.

FORM-1 WA TPHD

ANALYTICAL
RESOURCES
INCORPORATED

TOTAL DIESEL RANGE HYDROCARBONS
WA TPHd Range C12 to C24 by GC/FID

Lab Sample ID: Y964SB
LIMS ID: 98-21921
Matrix: Soil

QC Report No: Y964-Dames & Moore
Project: Holden Mine
17693-005-019

Data Release Authorized:
Reported: 11/17/98

LABORATORY CONTROL SAMPLE RECOVERY REPORT
Date extracted: 10/23/98
Date analyzed: 10/31/98

CONSTITUENT	SPIKE FOUND	SPIKE ADDED	% RECOVERY
Diesel Range Hydrocarbons	75.2	100	75.2%

<u>TPHd Surrogate Recovery</u>

Methylarachidate	57.9%

Values reported in ppm (mg/kg) on a dry weight basis.

TOTAL DIESEL RANGE HYDROCARBONS
WA TPHd Range C12 to C24 by GC/FID

ANALYTICAL
RESOURCES
INCORPORAT

Lab Sample ID: Y964G
LIMS ID: 98-21927
Matrix: Soil

Sample No: DMLG-3-2'
QC Report No: Y964-Dames & Moore
Project: Holden Mine
17693-005-019
Date Received: 10/19/98

Data Release Authorized:
Reported: 11/17/98

MATRIX SPIKE/SPIKE DUPLICATE RECOVERY

Date extracted: 10/23/98
Date analyzed: 10/31/98

CONSTITUENT	SAMPLE VALUE	SPIKE VALUE	SPIKE ADDED	% RECOVERY	RPD
MATRIX SPIKE					
Diesel Range Hydrocarbons	477	437	122	NA	
MATRIX SPIKE DUPLICATE					
Diesel Range Hydrocarbons	477	302	122	NA	NA

TPHd Surrogate Recovery

Matrix Spike	Methylarachidate	50.1%
MS Duplicate	Methylarachidate	30.7%

NA No recovery due to high sample concentration

Values reported in ppm (mg/kg) on a dry weight basis.

TOTAL DIESEL RANGE HYDROCARBONS
WA TPHd Range C12 to C24 by GC/FID

ANALYTICAL
RESOURCES
INCORPORATED

Lab Sample ID:	Y964SB	QC Report No:	Y964-Dames & Moore
LIMS ID:	98-21926	Project:	Holden Mine
Matrix:	Soil		17693-005-019

Data Release Authorized:
Reported: 11/17/98

LABORATORY CONTROL SAMPLE RECOVERY REPORT
Date extracted: 11/03/98
Date analyzed: 11/05/98

CONSTITUENT	**SPIKE FOUND**	**SPIKE ADDED**	**% RECOVERY**
Diesel Range Hydrocarbons	77.4	100	77.4%

TPHd Surrogate Recovery

Methylarachidate 84.0%

Values reported in ppm (mg/kg) on a dry weight basis.

FORM-III

TOTAL DIESEL RANGE HYDROCARBONS
WA TPHd Range C12 to C24 by GC/FID

ANALYTICAL
RESOURCES
INCORPORATED

Lab Sample ID: Y964G
LIMS ID: 98-22902
Matrix: Soil

Data Release Authorized:
Reported: 11/17/98

Sample No: DMLG-3-2'
QC Report No: Y964-Dames & Moore
Project: Holden Mine
17693-055-019
Date Received: 10/19/98

MATRIX SPIKE/SPIKE DUPLICATE RECOVERY

Date extracted: 11/03/98
Date analyzed: 11/05/98

CONSTITUENT	SAMPLE VALUE	SPIKE VALUE	SPIKE ADDED	% RECOVERY	RPD
MATRIX SPIKE					
Diesel Range Hydrocarbons	518	607	122	73.0%	
MATRIX SPIKE DUPLICATE					
Diesel Range Hydrocarbons	518	467	122	-41.%	737%

TPHd Surrogate Recovery

Matrix Spike	Methylarachidate	50.0%
MS Duplicate	Methylarachidate	50.0%

Values reported in ppm (mg/kg) on a dry weight basis.

Lagoon samples 3.0 PG. 1 of 1 pg 1 41

Y964

CHAIN-OF-CUSTODY RECORD

WHITE COPY-Original (Accompanies Samples) YELLOW COPY-Collector PINK COPY-Project Manager

Boring or Well Number	Sample Number	Depth	Time	Sample Type	Date Collected ~~Container Type~~	Analysis Required: VOA 601/8010	VOA 602/8020	VOA 624/8240/8260	Semi Vol 625/8270	NWTPH-Gx	NWTPH-Dx	NWTPH-Dx-Ext	RCRA 8 Metals	PNA 610/8310	Pest/PCBs 8081	ASBESTOS	FIELD NOTES:	Total Number Of Containers	Laboratory Note Number
DMLG	-4-2'	2'	1140	soil	10-14-98													1	
DMLG	-4-4'	4'	1155	soil	10-14-98													1	
DMLG-	2-2'	2'	1300	soil	10-14-98													1	
DMLG-	2-4'	4'	1315	soil	10-14-98													1	
DMLG	-1-surface	0"	1325	soil	10-14-98													1	
DMLG-	5-2'	2'	1350	soil	10-14-98													1	
DMLG-1	-2'	2'	1430	soil	10-15-98													1	
DMLG-	1-4'	4'	1435	soil	10-15-98													1	
DMLG-	3-2'	2'	1455	soil	10-15-98													1	
DMLG-	3-4'	4'	1505	soil	10-15-98													1	
DMLG-	5-4'	4'	1610	soil	10-15-98													1	
DMLG	-2-5'	5'	1630	soil	10-15-98													1	
DMLG-	2-7½	7½'	1645	soil	10-15-98													1	

RELINQUISHED BY: (Signature)	DATE/TIME	RECEIVED BY: (Signature)
	10/19/98 0430	
RELINQUISHED BY: (Signature)	DATE/TIME	RECEIVED BY: (Signature)
RELINQUISHED BY: (Signature)	DATE/TIME	RECEIVED BY: (Signature)

ANALYTICAL LABORATORY: ARE

LABORATORY CONTACT: Mark Harris

D&M CONTACT: Karen Mixon PHONE: 728-0744

LABORATORY NOTES:
Km will forward analytical info later this pm

JOB NO.: 17693-005-019

PROJECT: Holden mine

LOCATION: Holden, WA

COLLECTOR: Km / SCA DATE OF COLLECTION

DAMES & MOORE
A DAMES & MOORE GROUP COMPANY

500 Market Place Tower
2025 First Avenue
Seattle, Washington 98121
Phone (206) 728-0744
Fax (206) 727-3350

Fax Sheet

DAMES & MOORE
A DAMES & MOORE GROUP COMPANY

500 Market Place Tower
2025 First Avenue
Seattle, Washington 98121
206 728 0744 Telephone
206 727 3350 Fax

To: Mark Harris
Company: ARF
Fax: 621-7523
From: K. Mixon
(SEA) Ext.: 253
Date: 10-20-98
No. of Pages: 2
Subject: Holden Mine
Charge #: 17693-005-9007-019

Authorization for lagoon samples. Analyze as noted. Limits + methods per fax sent 10/8/98

thx
km

Also, please direct the laboratory to archive all unused sediment, background soil and lagoon samples rather than disposing on your typical schedule. D+M needs to be notified prior to disposal. When we are certain we have completed work with the samples, D+M will let ARF know.

Thx

This message is intended only for the use of the individual or entity to which it is addressed, and may contain information that is privileged, confidential, and exempt from disclosure under applicable law. If the reader of the message is not the intended recipient, or the employee or agent responsible for delivering the message, you are hereby notified that any dissemination, distribution or copying of the communication is strictly prohibited. If you have received this communication in error, please notify us immediately by telephone and return the original message to us at the above address via the U.S. Postal Service. Thank you.

b:\masters\faxsea.mst

Luyan sample, 98-21921-7 PG. 1 of 1 pg 1 of 1

98-21933

CHAIN-OF-CUSTODY RECORD

WHITE COPY-Original (Accompanies Samples) YELLOW COPY-Collector PINK COPY-Project Manager

Boring or Well Number	Sample Number	Depth	Time	Sample Type	Date (collected) ~~Container Type~~	Analysis Required: VOA 601/8010	VOA 602/8020	VOA 624/8240/8260	Semi Vol 625/8270	NWTPH-Gx	NWTPH-Dx	NWTPH-Dx-Ext	RCRA 8 Metals	TPH-D (extend) ~~PAH 610/8310~~	Pest/PCBs 8081	metals* ~~ASBESTOS~~	FIELD NOTES:	Total Number Of Containers	Laboratory Note Number
~~DMLG~~-4	2'	2'	1140	soil	10-14-98									X		X		1	
~~DMLG~~-4	4'	4'	1155	soil	10-14-98									X		X		1	
DMLG-2	2'	2'	1300	soil	10-14-98													1	
~~DMLG~~-2	4'	4'	1315	soil	10-14-98									X		X		1	
~~DMLG~~-1	surface	0"	1325	soil	10-14-98													1	
~~DMLG~~-5	2'	2'	1350	soil	10-14-98									X		X		1	
~~DMLG~~-1	2'	2'	1430	soil	10-15-98									X		X		1	
~~DMLG~~-1	4'	4'	1435	soil	10-15-98									X		X		1	
~~DMLG~~-3	2'	2'	1455	soil	10-15-98									X		X		1	
~~DMLG~~-3	4'	4'	1505	soil	10-15-98									X		X		1	
~~DMLG~~-5	4'	4'	1610	soil	10-15-98									X		X		1	
DMLG-2	5'	5'	1630	soil	10-15-98													1	
DMLG-2	7½'	7½'	1645	soil	10-15-98									X		X		1	

RELINQUISHED BY: (Signature)	DATE/TIME	RECEIVED BY: (Signature)
	10/19/98 0930	
RELINQUISHED BY: (Signature)	DATE/TIME	RECEIVED BY: (Signature)
RELINQUISHED BY: (Signature)	DATE/TIME	RECEIVED BY: (Signature)

LABORATORY NOTES:

Km will forward analytical info to this. PM

* metals - cadmium, copper, lead

ANALYTICAL LABORATORY: ARI

LABORATORY CONTACT: Mark Harris

D&M CONTACT: Kim Mann PHONE: 728-0744

JOB NO.: 17693.005.019

PROJECT: Holden Mine

LOCATION: Holden, WA

COLLECTOR: KM / SCA DATE OF COLLECTION

DAMES & MOORE
A DAMES & MOORE GROUP COMPANY

500 Market Place Tower
2025 First Avenue
Seattle, Washington 98121
Phone (206) 728-0744
Fax (206) 727-3350

APPENDIX M

ROCK STRUCTURAL DATA FIELD SHEETS

DRAFT

ROCK STRUCTURAL DATA FIELD SHEET

JOB NO.: 17693-005-019

Date: 10/13/98 Sheet 1 of 2

Recorded By: DMC Logged by SCW

Scanline No.: 1

Scanline Orientation: N30W

D (m)	*L* (m)	*EO*	Rock Type	Schmidt	*T*	*DO*	*C*	*R*	*JRC*	Apert.	Infilling	*JAN*	Roll/Photo#	Comments
0-2.7	2	N45E/V	Qtzite/schist	48,34,37	O	N54E70SE	P	R	5	< 1mm	recrystallized,	2	1/1,2	Joint spacing 0.25 to 0.5 m between 0-2.7, 0+0.0
											clean			
0-2.7	3	N45E/V	Qtzite/schist	41,34,38	O	N67W33NE	P	R	5	2-4cm	weathered rx	2	1/1,2	Schmidt not horizontal
0-2.7	1.5	N45E/V	Qtzite/schist	N/A	A/A	N70W34SW	P	R	5+	1-3mm	silt,clay,mica	4	1/1,2	Potential bedding
0-2.7	2	N45E/V	Qtzite/schist	N/A	A/O	N50W34NE	W	VR	14-16	1-20mm	weathered rx	2	1/1,2	
0+0.0	1	N60E/V	Qtzite/schist	40,30,33	O/O	N52E61SE	P	Sm/R	4-8	0-1mm	none	2	1/3,4	
0+0.0	2.5	N60E/V	Qtzite/schist	N/A	O/O	N75W52NE	W	VR	14-18	0-1mm	none	2	1/3,4	
0+0.0	1	N60E/V	Qtzite/schist	N/A	O/A	N31W51SW	P	R	12-16	1-20mm	recrystallized,	2	1/3,4	Potential bedding
											sandy			
0+4	1	N75E57NW	Qtzite/schist	64,64,55	I/O	N52E38SE	P	Sm	6-8	< 1mm	n/a	1	1/5	6 feet SW of scanline, joint spacing 0.4 m
Along Transect T1														
T1+9.7	2.5	EW-45N	Qtzite/schist	38,32,36	O/O	N54W55SW	I	St	18-20	2mm	none	1-4	1/6	
T1+10.4	1.5	EW-45N	Qtzite/schist	25,49,21	O/O	N14E84NW	P	St	4-6	N/A	N/A	N/A	1/7,8	
Along Transect T2														
T2+13.4		N80W40NE	GNEISS											On bedrock, believe ore zone due to weathering coloration
T2+13.9	0.5	N80W40NE	qtz+pyrite+	34,36,26	O/A	N78W55SW	W	Sm	4-6	0	N/A	1		
T2+14.1	1.7	N80W40NE	feldspars	N/A	O/I	N20W71NE	P	Sm	2-4	0	N/A	1		prominent crack
T2+19.4	0.5	N80W40NE	much pyrite	20,22,18	A/A	N-S/V	P	R	4-6	N/A	N/A	N/A		joint face only
T2+20.5	1	N80W40NE		47,49,40	O/O	N64E65SE	P	Sm	2-4	N/A	N/A	N/A	1/18	prominent joint face, no joint visible
T2> +20.5		N80W40NE												outcrop moss covered
1+37.0														start bedrock
1+38.2	1	N70W42NE	Plag + ??qtz in	52,46,57	O/O	N75E75SE	P	R	2-4	0	N/A	0-1	1/9	10 cm spacing
1+39			black groundmass											outcrop obscured

Legend

D - *D*istance (meters) along scanline to the point at which discontinuity intersects the scanline (Brady & Brown, 1985, p. 60)

L - Length of the discontinuity (meters) measured above or below the scanline (Brady & Brown, 1985, p. 60)

EO - Orientation of bedrock exposure (strike and dip)

Rock Type - Enter appropriate abbreviations for intact rock type in following order: rock name, mineral composition, texture, fabric, weathering (NGI, 1982, p. A.11-2)

Key to abbreviations:

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C - Curvature or waviness utilizing NGI, 1985, p. A.11-7&9 (P = Planar; W = Wavy; I = Irregular)

R - Roughness utilizing NGI, 1982, p. A.11-7&9 (PS = Polished slickensided; Sm = Smooth; R = Rough; VR = Very rough; St = Stepped)

JRC - Joint Roughness Coefficient utilizing NGI, 1982, Figure 3.5 (0 - 20)

Aperture - Aperture of discontinuity (millimeters) as noted in NGI, 1982, p. A.11-10

Infilling - Enter appropriate abbreviations for infilling type if present. **Key to abbreviations:**

JAN - Joint Alteration Number utilizing NGI, 1982, p. A.11-18 &19 (0 - 20)

DRAFT

ROCK STRUCTURAL DATA FIELD SHEET

JOB NO.: 17693-005-019

Date: 10/13/98 Sheet 2 of 2

Recorded By: DMC Logging by SCW

Scanline No.: 1

Scanline Orientation: N30W

D (m)	*L* (m)	*EO*	Rock Type	Schmidt	*T*	*DO*	*C*	*R*	*JRC*	Apert.	Infilling	*JAN*	Roll/Photo#	Comments
1+40.7		N70W42NE	Qtzite+tr plag,	30,28,20	O/O	N76E54SE	P	R	8-10	0	N/A	1	1/10,11	5-20cm spacing
			pyrite											
													1/12	Photo of Holden Village, use to number photos
1+41-1+48														outcrop obscured with rubble
1+48	3	N75E54NW	qtz schist + pyr	44,44,44	O/O	N44W7NE	P-W	R	4-6	1mm	sand	2	1/13	shows 3 outcrops with same joint
1+48.6	1.5	same	same	48,57,67	O/O	N85E75SE	W	R	4-6	N/A	N/A	N/A	1/13	shown on previous photo, 25 cm spacing
to 1+52														obscured by rubble
1+52.7	2.5	same	qtzite + pyrite	20,36,28	O/O	N65E22SE	W	R	10-12	2-10	sandy	2	1/14	
1+53.2	3.5	same	same	20,34,56,50	O/A	N56E80NW	P	R	4-6	N/A	N/A	N/A	1/15	joint face only
to 1+54.6														obscured by rubble
													1/16	overall photo of study area 1+40 to 1+53
along Transect 3														
T3+10.2	6	same	same	39,24,37	O/O	N55E84SE	W	R	8-10	N/A	N/A	N/A	1/17	photo looking ~S60E, N55E set on R edge of photo
T3+10.2	2	same	same	N/A	O/O	N18E/V	W	R	10-12	1-3mm	silty sd	2	1/17	N18E set coming in from L of photo

Legend

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L - Length of the discontinuity (meters) measured above or below the scanline (Brady & Brown, 1985, p. 60)

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R - Roughness utilizing NGI, 1982, p. A.11-7&9 (PS = Polished slickensided; Sm = Smooth; R = Rough; VR = Very rough; St = Stepped)

JRC - Joint Roughness Coefficient utilizing NGI, 1982, Figure 3.5 (0 - 20)

Aperture - Aperture of discontinuity (millimeters) as noted in NGI, 1982, p. A.11-10

Infilling - Enter appropriate abbreviations for infilling type if present. **Key to abbreviations:**

JAN - Joint Alteration Number utilizing NGI, 1982, p. A.11-18 &19 (0 - 20)

[illegible]

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ROCK STRUCTURAL DATA FIELD SHEET

JOB NO.: 17693-005-019

Notes: Wx = weathered, Rx = rock

Date: 10/14/98 Sheet 1 of 2

Recorded By: DMC Logging by SCW

Scanline No.: 1 (Note: Also includes Scanline 2)

Scanline Orientation: N30W

D (m)	*L* (m)	*EO*	Rock Type	Schmidt	*T*	*DO*	*C*	*R*	*JRC*	Apert.	Infilling	*JAN*	Roll/Photo#	Comments
T4+15.6														on bedrock
T4+16.55 to T4 + 16.68		N70W33NE	Schist	46, 47, 49	O/O	N26W 71SW	W	VR	14-16	6-13cm	sand & pyr.	1/2	1/20	Sheer Zone. 1st schmidt on rock below zone.
	4m			40, 40, 40									1/12	2nd schmidt on rock above. Photo 20 due S
Zone described is basal portion of larger discontinuity shear zone extending to foliated qtz + plg + pyrite														16.85m upper portion of K composed of, see comment time 11:10, 10/14/98
T4+18.55	2m	N20W/V	gneiss	53, 43, 41; 23, 24, 18	O/O	N15E 30NW	P	S	2-4	2-10mm	dark brown-red crystalline w/ sd + pyr	1-2	1/21	Joint. 1st schmidt below, 2nd schmidt above
T4+18.9	0.25m	same	gneiss	54, 43, 33	A/A	N72W 48NE	P	VR	14-16	0	--	1	1/22	Photos 21, 22, 23 S25W
T4+18.9	2m	same	gneiss	38, 24, 44	O/O	N23W 60SW	W	R	8-10	0	--	1	1/23	Schmidt on joint face. This face same as bedding measured @T4+16.55. Spacing still 0.25-0.4m
Along Scanline 2 (parallel to Scanline 1 but offset as noted on figure to document conditions at additional bedrock outcrop)														Trend SC2 = N78W
SC2+0.0	3.5m	N78W	gneiss	47, 58, 48,	O/I	E-W 78S	W	VR	16-18	1-5mm	red-brn crystalline	1	2/2	Joint face for portion of length. Photo S45W
SC2+1.0	0.7m	same	qtz (lt +drk)	50, 20, 56	O/A	N60W 59NE	P	R	8-10	0	N/A	N/A	2/3	Joint face (??) Photo S65W
SC2+1.55	0.8m	same	plag (Wx) +	39, 40, 24	A/O	N30W 65SW	W	R/St	12-14	< 1mm	healed	1	2/4	Photo S65W
SC2+1.7	1m	same	pyrite (Wx)	52, 49, 52	A/A	N15W 18NE	P	Sm/R	2-4	0	--	1	2/5	Parallel joints 8-15cm spacing, schmidt on joint face, photo E-W
SC2+4.5	2.5m	same	pyrite (Wx)	27, 35, 39	A/A	N40W 24SW	W	R	6-10	0	healed	1	2/6	Dip variable (24 to 60+/-), schmidt on Rx above joint, Photo S10W
SC2+4.7	0.7m	same	pyrite (Wx)	no room	A/I	N13E 89NW	P	Sm/R	4-6	0-2mm	healed hard Rx	1	2/7	Joint is healed or filled with hard rock like material, Photo S10E
SC2+5.3	2m	same	w/ aligned pyrite	31, 36, 38	O/I	N48W 78SW	W	VR	10-12	0	healed	1	2/8	schmidt on face photo S45E
SC2+7.4	3m	N80E	gneiss (A/A) no aligned pyrite	34, 29, 54	A/A	N80W 68SW	P	Sm/R	4-6	0	healed	1	2/9	SC2 orientation turns to N80E, Photo S80E, Multiple joints, subparallel 7 9cm @ E, 1-2cm @W
SC2+9.0	1.4m	N80E	same	30, 46, 25	A/A	N45E 80NW	W	R	8	0	healed	1	2/10	4 parallel joints, spacing 0.2-0.4m, schmidt on face, photo N35E

Legend

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EO - Orientation of bedrock exposure (strike and dip)

Rock Type - Enter appropriate abbreviations for intact rock type in following order: rock name, mineral composition, texture, fabric, weathering (NGI, 1982, p. A.11-2)

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R - Roughness utilizing NGI, 1982, p. A.11-7&9 (PS = Polished slickensided; Sm = Smooth; R = Rough; VR = Very rough; St = Stepped)

JRC - *Joint Roughness Coefficient utilizing NGI, 1982, Figure 3.5* (0 - 20)

Aperture - Aperture of discontinuity (millimeters) as noted in NGI, 1982, p. A.11-10

Infilling - Enter appropriate abbreviations for infilling type if present. **Key to abbreviations:**

JAN - Joint Alteration Number utilizing NGI, 1982, p. A.11-18 &19 (0 - 20)

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ROCK STRUCTURAL DATA FIELD SHEET

JOB NO.: 17693-005-019

Date: 10/14/98 Sheet 2 of 2

Recorded By: DMC Logging by SCW

Scanline No.: 3

Scanline Orientation: N37W

D (m)	*L* (m)	*EO*	Rock Type	Schmidt	*T*	*DO*	*C*	*R*	*JRC*	Apert.	Infilling	*JAN*	Roll/Photo#	Comments
3+0.5	4m	E-W/35N	gneiss	48, 46, 66	O/O	E-W/24N	W	R	4-6	N/A	N/A	N/A	2/13	Joint face photo looking E - horiz. face
3+1.6	2m	E-W/35N	(qtz + plag + pyrite)	56, 40, 46	O/A	N85W /V	P	VR	12-14	N/A	N/A	N/A	2/13	Joint face photo looking E - vert. face
3+4.9	2m	E-W/35N	(qtz + plag + pyrite)	see comm.	A/A	N60E /V	I	R	8-10	7-11 cm	see comm.	1	2/14	Fracture filling is amphibolite + ?biotite + pyrite in gray groundmass, schmidt on filling 71, 58, 50, photo N60E, dike top & bottom
3+5.4	1.3m	E-W/35N	(qtz + plag + pyrite)	64, 62. 67	I/A	N80E 70SE	W	R	12-14	0	N/A	1	2/14	SCW pointing to fracture
3+6.1	0.5m	E-W/35N	(qtz + plag + pyrite)	44, 26, 35	A/A	N5W 65SW	W	R	10-12	N/A	N/A	--	2/15	Bedding (?) more weathered joint face photo N50E, parallel joint 20cm spacing
3+6.3	1.2m	E-W/35N	(qtz + plag + pyrite)	60, 59, 42	A/A	E-W/ V	W	R	8-10	0-1mm	recrystallized red-brn	1	2/16	Schmidt on rocks both sides of joint, Photo N50W, Parallel joint 20cm spacing
3+6.9	1.4m	E-W/35N	(qtz + plag + pyrite)	52, 56, 47	A/A	N68E /V	W	VR	10-12	N/A	N/A	N/A	2/17	Joint face only, photo of vert. face, photo S45E
3+6.9	1.4m	E-W/35N	(qtz + plag + pyrite)	24, 58, 52	A/A	N80W 29NE	P	R	4-6	10mm	open		2/18	Schmidts taken on lower side of crack. Photo S45E
3+7.8	1.5m	E-W/35N	(qtz + plag + pyrite)	47, 49, 25	A/A	N85E/ V	W	VR	12-14	N/A	N/A	N/A	2/19	Single face at top of photo, photo S45E, schmidt on joint face
3+10.7														West edge of intermittent drainage from 3+8.4 to 3+10.7 is rubble covered.

Legend

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EO - Orientation of bedrock exposure (**strike and dip**)

Rock Type - Enter appropriate abbreviations for intact rock type in following order: rock name, mineral composition, texture, fabric, weathering (*NGI*, 1982, p. A.11-2)

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C - Curvature or waviness utilizing NGI, 1985, p. A.11-7&9 (P = Planar; W = Wavy; I = Irregular)

R - Roughness utilizing NGI, 1982, p. A.11-7&9 (PS = Polished slickensided; Sm = Smooth; R = Rough; VR = Very rough; St = Stepped)

JRC - Joint Roughness Coefficient utilizing NGI, 1982, Figure 3.5 (0 - 20)

Aperture - Aperture of discontinuity (millimeters) as noted in NGI, 1982, p. A.11-10

Infilling - Enter appropriate abbreviations for infilling type if present. **Key to abbreviations:**

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ROCK STRUCTURAL DATA FIELD SHEET

JOB NO.: 17693-005-019

Date: 10/15/98 Sheet 1 of 2
Recorded By: DMC Logging by SCW
Scanline No.: Transect T5 Transect crosses scanline 3 @ T5 +28.0
Scanline Orientation: N2E-N5E Photo 2/8R = Roll 2, 8 remaining

D (m)	*L* (m)	*EO*	Rock Type	Schmidt	*T*	*DO*	*C*	*R*	*JRC*	Apert.	Infilling	*JAN*	Roll/Photo#	Comments
T5+0.0														Trail crosses intermittent drainage
T5 + 0.0 to T5 + 13.5														Outcrop rubble covered. Photo 2/8R is transect
T5 + 13.5 to 20.0	1.0-2.5	ˉE-W	gneiss	37, 62, 66	A/A	N40W 14NE	W	R	8-10	most 0	N/A	1	2/7R	Approximately 10 mostly parallel joints. Spacing 2-10 cm. Joints are horizontal faces on photo, photo orientation S2W
				62, 52, 69	A/A	N60W 16NE	W	R	8-10	2 open -2mm	N/A	1		
				66, 44, 67	A/A	N68W 20NE	W	R	8-10		N/A	1		
T5 + 14.7	2	ˉE-W	gneiss	70, 68, 67	O/A	N62E, 86NW	I	R	16 -18	N/A	N/A	N/A	2/6R	Joint face. schmidt on joint face. Prominent vert face on photo. Photo S2W
T5 + 15.6	1.5	ˉE-W	gneiss	48, 62, 64	A/A	N60W/ V	I	VR	14-16	1-2mm	soil	1	2/5R	Schmidt on rock elevationally above. Photo vertical
T5 + 17.5	2.5	ˉE-W	gneiss	55, 40, 67	A/A	N85E/ V	I	R	18-20	N/A	N/A	N/A		Joint face only. Same setset as in photo2/6R above. Small parallel joints @17.55, 17.7, 18.0, 18.5
T5 + 18.1	4.5	ˉE-W	gneiss, much pyrite	47, 46, 46	A/O	N20W 67SW	W	Sm/R	12-14	< 1mm	none	1	2/4R	Photo N20W
T5 + 22.2	1	ˉE-W	gneiss/schist	50, 52, 64,	O/O	N37W 70SW	W	R	8-10	< 1mm	soil	1-2	2/3R	Schmidt above/ below. Photo vertical
T5 + 24.5	0.7	ˉE-W	gneiss	54, 60, 40	I/A	N20W 75SW	P	Sm	4-6	N/A	N/A	N/A	2/2R	*Joint face only. Photo S35W*
T5 + 25.5	2.5	ˉE-W	gneiss	52, 57, 60, 60	O/A	N18E 85NW	W	R	11-12	< 1mm	none	1	2/1R	Cross same orientation @T5 +26.1 Photo N18E, schmidt 2 above, 2 below
T5 + 25.9	2.5	ˉE-W	gneiss + pyrite	39, 38, 47	I/O	N70W /V	W	R	12-14	N/A	N/A	N/A	3/1	Joint face only. Vert face on photo. Photo S37E
T5 + 26.1	1.5	ˉE-W	gneiss + pyrite	50, 53, 47	I/I	N85W /V	I	R	16-18	N/A	N/A	N/A	3/2	Joint face only. Vert face on photo. Photo S37E
T5 + 26.6	0.25	ˉE-W	gneiss + pyrite	53, 51, 63	A/A	N60E 68SE	P	Sm/R	4	N/A	N/A	N/A	3/3	Joint face only. Vert face on photo. Photo S37E
T5 + 28.0		ˉE-W												Cross scanline
T5 + 28.4		ˉE-W												Cross dike measured yesterday
T5 + 29.4	2.5	ˉE-W	gneiss + pyrite	51, 51, 52	O/A	N32W 83SW	W	R	8-10	< 1mm	none	1	3/4	Photo N32W, Bedding??
T5 + 30.0	4	ˉE-W	gneiss / pyritic gneiss	53, 36, 57	O/O	N36W 74SW	P/W	R	4-6	1mm	soil	1.	3/5	Bedding in gneiss, photo N36W
T5 + 31.0	4.5	ˉE-W	gneiss + pyrite		O/O	N39W 66SW	W	R	8-10	< 1mm	none to soil	1	3/6	Contact between more/less stained rock
														Photo vertical

Legend

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JRC - Joint Roughness Coefficient utilizing NGI, 1982, Figure 3.5 (0 - 20)
Aperture - Aperture of discontinuity (millimeters) as noted in NGI, 1982, p. A.11-10
Infilling - Enter appropriate abbreviations for infilling type if present. **Key to abbreviations:**
JAN - Joint Alteration Number utilizing NGI, 1982, p. A.11-18 &19 (0 - 20)

[illegible]

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ROCK STRUCTURAL DATA FIELD SHEET

JOB NO.: 17693-005-019

Date: 10/15/98 Sheet 2 of 2
Recorded By: DMC Logging by SCW
Scanline No.: T5
Scanline Orientation: N2E

D (m)	*L* (m)	*EO*	Rock Type	Schmidt	*T*	*DO*	*C*	*R*	*JRC*	Apert.	Infilling	*JAN*	Roll/Photo#	Comments	
T5 + 33.0	2.5	¯E-W	Pyritized gneiss	N/A	A/A	N60W 20NE	W	R	8-10	1-5cm	open	N/A	3/7	Large crack, photo S32E, joints repeat 8-12cm, same trend, other joints closed	
T5 + 39.7	1	¯E-W	Pyritized gneiss		I/A	N30W 78NE	W	R/Sm	6-8	0	N/A	1	3/8	S2W orientaion on photo	
T5 + 43.0	0.2-1.0	¯E-W	Pyritized gneiss		I/I	N35E 87NW	P	Sm	4-6	N/A	N/A	N/A	3/9	10 parallel faces, 2-5cm spacing, joint faces	
T5 + 43.7	3		Gneiss/Marble		O/A	N15W 24SW	I	VR	18-20	N/A	N/A	N/A	3/10	Contact pyrite gneiss & injected marble, dike thickens 44.8 - 43.7	
T5 + 45.2 to T5 + 50	1.0 to 2.5	¯E-W	Gneiss		A/I	N55E 82NW	P/W	Sm/R	2-6	N/A	N/A	N/A	3/11	No repeating joints, spacing 3-20cm. Photo orientation N37W, vertical faces on photo 11.	
T5 + 45.6 to T5 + 47.7	2-Jan	¯E-W	Gneiss w/ shallow intrusives		I/O	N35W 10NE	P/W	Sm/R	4-8	N/A	N/A	N/A	3/11	4 parallel joints, spacing varies 5-10cm, horizontal faces on photo 11.	
T5 + 50.1 to T5 + 50.5	6m	¯E-W	Gneiss/Marble		O/O	N40W 81SW	I	VR	18-20	N/A	N/A	N/A	3/12	Marble dike photo S40E	
T5 + 51.8	3m	¯E-W	Pyritized gneiss		O/O	N45W 62SW to N80E 75SE	W	R	8-10	0 - < 1mm	well healed	1	3/13	Photo oriented S72E	
T5 + 52.8	2m	¯E-W	Pyritized gneiss		I/O	N85E /V	P	R	4-6	0	healed	1	3/14	Photo oriented S80E	
T5 + 53.0	2m	¯E-W	Pyritized gneiss		A/A	N80E 79SE	W	R	10-12	1-2mm	soil	1-2	3/15	Photo oriented E-W	
T5 + 55.0	6m	¯E-W	Pyritized gneiss		O/O	N22W 75SW	W	R	8-10	2-5mm	recrystallized mat. (sed)	1	3/16	3-4 parallel joints, Bedding? Photo S22E	
T5 + 58.4 to 64													3/17	Rubble	Photo 3/17 shows:
T5 + 55.0 to 58.5													3/17	*unaltered gneiss*	unaltered gneiss/ *rubble/pyrite gneiss*

Legend

D - *D*istance (meters) along scanline to the point at which discontinuity intersects the scanline (Brady & Brown, 1985, p. 60)
L - Length of the discontinuity (meters) measured above or below the scanline (Brady & Brown, 1985, p. 60)
EO - Orientation o **Key to abbreviations:**
Rock Type - Enter appropriate abbreviations for intact rock type in following order: rock name, mineral composition, texture, fabric, weathering (NGI, 1982, p. A.11-2)

Schmidt - Schmidt hammer readings in order to document relative hardness of rock (enter 3 readings from hammer)
T - Nature of the termination point (A = at another discontinuity; I = in rock material; O = obscured or extending beyond the extremity of the exposure)
DO - Orientation of discontinuity (strike and dip) measured at or near the point of the intersection with the scanline
C - Curvature or waviness utilizing NGI, 1985, p. A.11-7&9 (P = Planar; W = Wavy; I = Irregular)
R - Roughness utilizing NGI, 1982, p. A.11-7&9 (PS = Polished slickensided; Sm = Smooth; R = Rough; VR = Very rough; St = Stepped)
JRC - Joint Roughness Coefficient utilizing NGI, 1982, Figure 3.5 (0 - 20)
Aperture - Aperture of discontinuity (millimeters) as noted in NGI, 1982, p. A.11-10
Infilling - Enter appropriate abbreviations for infilling type if present. **Key to abbreviations:**
JAN - Joint Alteration Number utilizing NGI, 1982, p. A.11-18 &19 (0 - 20)

[illegible]

APPENDIX N

RESULTS OF STATISTICAL ANALYSES FOR SITE-SPECIFIC WATER BALANCE

Flow Comparisons

* = Measured flow in cfs

** = estimated flow in cfs from rating curve

Date	RC-1*	RC-4**	logRC-1*	logRC-4**
4/16/97	63	62.4	1.799341	1.795185
5/18/97	575	570.9	2.759668	2.75656
5/26/97	313	353.3	2.495544	2.548144
9/15/97	132	123	2.120574	2.089905

	RC-4*	RC-4**	logRC-4*	logRC-4**
4/16/97	60	56.8	1.778151	1.754348
5/21/97	370	391.1	2.568202	2.592288
5/25/97	300	330.5	2.477121	2.519171
5/31/97	780	810.6	2.892095	2.908807
6/1/97	823	962.4	2.9154	2.983356
6/2/97	567	548.9	2.753583	2.739493
6/9/97	424	462	2.627366	2.664642
7/10/97	496	506.3	2.695482	2.704408
9/15/97	123	104.6	2.089905	2.019532
9/22/97	87.5	89.6	1.942008	1.952308

	RC-2*	RC-4**	RC-2**	logRC-2*	logRC-4**	logRC-2**
4/17/97	86	68.4	85.9	1.934498	1.835056	1.933993
5/19/97	569	527.3	605.4	2.755112	2.722058	2.782042
5/26/97	376	353.3	386.4	2.575188	2.548144	2.587037
6/1/97	805	725	751.6	2.905796	2.860338	2.875987
6/2/97	605	589	611.5	2.781755	2.770115	2.786396
6/9/97	501	462	488.5	2.699838	2.664642	2.688865
9/15/97	136	103.1	119.8	2.133539	2.013259	2.078457
9/22/97	99	88.1	90.9	1.995635	1.944976	1.958564

	CC-1*	RC-4**	logCC-1*	logRC-4**
5/23/97	30	340.1	1.477121	2.531607
5/31/97	100	794.1	2	2.899875
6/1/97	91	714.7	1.959041	2.854124
6/2/97	84	593.5	1.924279	2.773421
6/9/97	58	462	1.763428	2.664642
7/10/97	59	438.8	1.770852	2.642267
9/14/97	17.5	111.1	1.243038	2.045714
9/15/97	14.6	104.6	1.164353	2.019532
9/16/97	11.8	92.5	1.071882	1.966142
9/22/97	13.6	88.1	1.133539	1.944976

Railraod Creek September 1998 Baseflow Survey

Table 1 - Station and Flow Four Replicate Flow Measurements at Each Station

Replicate	BF-1	BF-2	BF-3	BF-4	BF-5
1	27.84	26.89	31.5	25.32	28.43
2	28.68	27.74	30.98	29.05	27.74
3	27.09	29.84	27.07	27.47	29.46
4	28.84	27.59	31.96	29.6	27.31
Mean	28.11	28.02	30.38	27.86	28.24
Std. Dev.	0.81	1.27	2.24	1.92	0.94

Station Descriptions

BF-1	At RC-6
BF-2	Fifty feet downstream of P-5
BF-3	Seventy five feet downstream of the bend adjacent to the septic field
BF-4	Fifty feet downstream of the vehicle bridge
BF-5	At RC-4

APPENDIX O

MACROINVERTEBRATE DENSITY DATA, 1997

CHADWICK & ASSOCIATES, INC.
5575 South Sycamore Street, Suite 100
Littleton, Colorado 80120
Phone (303) 794-8976
Fax (303) 794-5041

January 20, 1998

Robert Quinlan
Dames & Moore
633 17th Street, Suite 2500
Denver, CO 80202-3625

Dear Mr. Quinlan:

Enclosed are the analyses of the 88 benthic macroinvertebrate samples collected from the Holden Mine sites in Washington in 1997. All sample replicates for a site are recorded on one data sheet and a composite density is given for the replicates.

Also enclosed is a diskette containing these tables in Lotus 1-2-3 format, and the reference collection for this set of samples. If you have any questions regarding these data, please give me a call.

Sincerely

CHADWICK & ASSOCIATES, INC.

Steven P. Canton
President

Enclosures

SPC/jar

MACROINVERTEBRATE DENSITY
CLIENT: DAMES & MOORE
SITE: RC-3
SAMPLED: 9-20-97

AXA	A	B	C	D	E	F	G	H	COMPOSITE DENSITY
NSECTA									
PLECOPTERA									
Capniidae		10	20	30					8
Despaxia augusta					10				1
Doroneuria baumanni	10	10		10	40	10	10	20	14
Megarcys signata		10		20					4
Paraleuctra sp.	20								3
Sweltsa sp.	30		30	20	10	30	20	50	24
Taenionema sp.			10						1
Visoka cataractae			10						1
Yoraperla brevis				10					1
Zapada cinctipes	170	40	120	20	20	30	80	200	85
Zapada oregonensis			30						4
EPHEMEROPTERA									
Ameletus sp.					10			10	3
Baetis bicaudatus	10		10				10		4
Cinygma sp.					10	10		10	4
Cinygmula sp.			20				10		4
Drunella doddsi	80	10	10	20	10	30			20
Drunella grandis					20				3
Epeorus grandis		20	10						4
Paraleptophlebia sp.	10								1
Rhithrogena robusta		20	40	10			10	20	13
Serratella tibialis								10	1
TRICHOPTERA									
Parapsyche almota	30		10				10	30	10
Rhyacophila angelita/perplana		20				10			4
Rhyacophila betteni gr.								10	1
DIPTERA									
Brillia sp.	30				10	10		10	8
Chelifera sp.								10	1
Cricotopus tremulus	100			30	60	40	20	70	40
Dicranota sp.			10						1
Empididae			10						1
Hemerodromia sp.	10				10	10			4
Rhabdomastix sp.	10	20	10	10	10			10	9
Rheocricotopus sp.	10	90	40	20			30	10	25
Rheotanytarsus sp.				10					1
Simulium sp.	20		30			10		30	11
Thienemaniella sp.				10	10				3
NNELIDA									
OLIGOCHAETA									
Aulodrilus americanus		180	60	10	60	120	10	30	59
TOTAL (#/sq. meter)	540	430	480	230	290	310	210	530	381
NUMBER OF TAXA	14	11	18	14	14	11	10	16	36
SHANNON-WEAVER (H')	3.07	2.65	3.65	3.68	3.37	2.85	2.83	3.16	3.98

MACROINVERTEBRATE DENSITY
CLIENT: DAMES & MOORE
SITE: RC-6
SAMPLED: 9-22-97

TAXA	I	J	K	L	M	N	O	P	COMPOSITE DENSITY
INSECTA									
PLECOPTERA									
Capniidae		10		50			40		13
Despaxia augusta				10		60	10		10
Doroneuria baumanni	30	10	20		10	10	20	30	16
Megarcys signata		10	10	10	20	10			8
Pteronarcella badia	10					10			3
Suwallia sp.			20			10		10	5
Sweltsa sp.	140	120	130	50	90	90	210	10	105
Taenionema sp.	30	60			80	60			29
Visoka cataractae		10		10			40		8
Yoraperla brevis	10								1
Zapada cinctipes		100		60			230		49
Zapada oregonensis	30			80	30	20	30	30	28
EPHEMEROPTERA									
Ameletus sp.			10				10		3
Baetis bicaudatus	40	10	40	30	20		30		21
Caudatella sp.				20			10		4
Cinygmula sp.		50		10			230		36
Drunella doddsi	220	250	30	70	180	240	190	230	176
Epeorus deceptivus		10	10	30	40	110	120	20	43
Epeorus grandis				10		10		100	15
Epeorus longimanus				10					1
Ephemerella infrequens	10	30	20	10	10	10	20	10	15
Paraleptophlebia sp.	110	110	30	50		10	130	10	56
Rhithrogena robusta	430	490	510	590	280	560	620	210	461
TRICHOPTERA									
Glossosoma sp.							20	10	4
Lepidostoma sp.				20					3
Limnephilidae		10					10		3
Neothremma sp.				10					1
Parapsyche almota	40	10		90	30	30	60		33
Parapsyche elsis				20					3
Rhyacophila betteni gr.			10		10	20	10		6
Rhyacophila brunnea gr.			10				10		3
Rhyacophila hyalinata/vocala					10				1
Rhyacophila sibirica gr.							10		1
DIPTERA									
Brillia sp.					10	10	50		9
Chelifera sp.						10			1
Cricotopus tremulus	20		10		50	20			13
Hexatoma sp.	10						10	10	4
Monohelea sp.	10				10			10	4
Polypedilum sp.							20		3
Rheocricotopus sp.		30		20			80	10	18
Rheotanytarsus sp.	10	40			10	10	20		11
Simulium sp.				10		10		10	4
Zavrelimyia sp.							10		1

MACROINVERTEBRATE DENSITY
CLIENT: DAMES & MOORE
SITE: RC-6
SAMPLED: 9-22-97

AXA	I	J	K	L	M	N	O	P	COMPOSITE DENSITY
URBELLARIA									
Polycelis coronata						10		10	3
NNELIDA									
OLIGOCHAETA									
Aulodrilus Americanus		420		240			330		124
Unid. Immature Tubificidae w/o Capilliform Chaetae	260		130		50	10		30	60
OTAL (#/sq. meter)	1410	1780	990	1510	940	1340	2580	750	1419
UMBER OF TAXA	17	19	15	24	18	23	29	17	46
HANNON-WEAVER (H')	3.05	3.11	2.50	3.28	3.29	3.01	3.77	2.95	3.79

MACROINVERTEBRATE DENSITY
CLIENT: DAMES & MOORE
SITE: RC-10
SAMPLED: 9-15-97

TAXA	A	B	C	D	E	F	G	H	COMPOSITE DENSITY
INSECTA									
PLECOPTERA									
Despaxia augusta							10		1
Doroneuria baumanni							10		1
Sweltsa sp.	20		40	30	10	20	30		19
Visoka cataractae	10								1
Zapada cinctipes	10								1
Zapada oregonensis		10	20	10		10	10		8
EPHEMEROPTERA									
Epeorus deceptivus				10					1
Rhithrogena robusta						20	10		4
TRICHOPTERA									
Parapsyche almota	10				30				5
Rhyacophila angelita/perplana								10	1
DIPTERA									
Rheocricotopus sp.	10	10	50	40	20		20	10	20
Rheotanytarsus sp.						20			3
Simulium sp.	10	10		10	20	10	20		10
TOTAL (#/sq. meter)	70	30	110	100	80	80	110	20	75
NUMBER OF TAXA	6	3	3	5	4	5	7	2	13
SHANNON-WEAVER (H')	2.52	1.58	1.49	2.05	1.91	2.25	2.66	1.00	2.91

MACROINVERTEBRATE DENSITY
CLIENT: DAMES & MOORE
SITE: SFAC-1
SAMPLED: 9-30-97

AXA	A	B	C	D	E	F	G	H	COMPOSITE DENSITY
NSECTA									
PLECOPTERA									
Capniidae						30			4
Doroneuria baumanni					10				1
Megarcys signata		10	60	30	30	20	40	20	26
Paraleuctra sp.			10						1
Podmosta/Prostoia		10			10				3
Suwallia sp.							10		1
Sweltsa sp.			10	20	30	60	30	10	20
Taenionema sp.	60	220	160	70	200	210	60	50	129
Visoka cataractae						40			5
Zapada cinctipes						330			41
Zapada columbiana		50			30	160	20		33
Zapada oregonensis	80	60	30	60			50		35
EPHEMEROPTERA									
Baetis bicaudatus			10		10				3
Caudatella sp.						10			1
Cinygmula sp.		10							1
Drunella doddsi	120	190	220	80	170	100	30	160	134
Epeorus deceptivus		20			10		10		5
Epeorus grandis	10	30	10		10	40			13
Epeorus longimanus		10							1
Ephemerella infrequens			10	10				10	4
Rhithrogena robusta	330	310	590	310	970	430	610	180	466
TRICHOPTERA									
Parapsyche almota				20			30	30	10
Parapsyche elsis		50				20			9
Rhyacophila angelita/perplana		10					20	10	5
Rhyacophila betteni gr.	20	10		20		20	10	10	11
Rhyacophila hyalinata/vocala						10			1
DIPTERA									
Antocha sp.			10						1
Brillia sp.	10	30		30	40	30			18
Cricotopus tremulus						50			6
Dicranota sp.		10	20						4
Oreogeton sp.						10			1
Polypedilum sp.		10							1
Rheotanytarsus sp.						10			1
Simulium sp.			10	10					3
NNELIDA									
OLIGOCHAETA									
Unid. Immature Tubificidae w/o Capilliform Chaetae			370				50		53

MACROINVERTEBRATE DENSITY
CLIENT: DAMES & MOORE
SITE: SFAC-1
SAMPLED: 9-30-97

TAXA	A	B	C	D	E	F	G	H	COMPOSITE DENSITY
NEMATODA									
Unid. Nematoda		10						10	3
HYDRACARINA									
Sperchon/Sperchonopsis	10			10	10				4
TOTAL (#/sq. meter)	640	1050	1520	670	1530	1580	970	490	1058
NUMBER OF TAXA	8	18	14	12	13	18	13	10	37
SHANNON-WEAVER (H')	2.08	3.07	2.48	2.66	1.91	3.20	2.20	2.40	3.07

MACROINVERTEBRATE DENSITY
CLIENT: DAMES & MOORE
SITE: RC-5A
SAMPLED: 9-16-97

TAXA	A	B	C	D	E	F	G	H	COMPOSITE DENSITY
INSECTA									
PLECOPTERA									
Sweltsa sp.	20	10	10			10			6
TRICHOPTERA									
Cheumatopsyche sp.						20			3
Limnephilidae							10		1
Parapsyche almota	20				10	20		10	8
Rhyacophila hyalinata/vocala			10						1
DIPTERA									
Brillia sp.	10	10	10	30	10	90	10	50	28
Monohelea sp.				10					1
Simulium sp.			10			10			3
NEMATODA									
Unid. Nematoda					10				1
TOTAL (#/sq. meter)	50	20	40	40	30	150	20	60	52
NUMBER OF TAXA	3	2	4	2	3	5	2	2	9
SHANNON-WEAVER (H')	1.52	1.00	2.00	0.81	1.58	1.74	1.00	0.65	2.17

MACROINVERTEBRATE DENSITY
CLIENT: DAMES & MOORE
SITE: BC-1
SAMPLED: 9-28-97

AXA	A	B	C	D	E	F	G	H	COMPOSITE DENSITY
NSECTA									
PLECOPTERA									
Capniidae		10		20					4
Despaxia augusta				80	40			10	16
Doroneuria baumanni	10			40	30	10	10	10	14
Megarcys signata	30		10		20	10			9
Pteronarcella badia		10							1
Pteronarcys californica						10			1
Suwallia sp.						10			1
Sweltsa sp.	10		30	20	50	10	70	20	26
Taenionema sp.	50	20	80	230	40	190	40		81
Visoka cataractae				10					1
Zapada cinctipes	30	10		110					19
Zapada columbiana						20			3
Zapada oregonensis	10	30	10	60	10	30	40	60	31
EPHEMEROPTERA									
Ameletus sp.								80	10
Baetis bicaudatus			10	30	20		20		10
Baetis sp.				10					1
Caudatella sp.		220		10					29
Cinygmula sp.				10					1
Drunella doddsi	60	140	180	110	30	120		30	84
Epeorus deceptivus		30	10		20				8
Epeorus grandis	10	1010	20	20	20				135
Epeorus longimanus		10							1
Ephemerella infrequens			30	10	10				6
Heptagenia elegantula							10	10	3
Paraleptophlebia sp.				10	10			10	4
Rhithrogena robusta	170	150	190	280	450	770	380	20	301
Serratella tibialis				10					1
TRICHOPTERA									
Apatania sp.	10	10		10					4
Glossosoma sp.			20				20	30	9
Mystacides sp.								10	1
Oligophlibodes sp.		10		30					5
Parapsyche elsis	40	70		10					15
Rhyacophila angelita/perplana	10			10		10		10	5
Rhyacophila betteni gr.		10	30	30	30	90	30	20	30
Rhyacophila hyalinata/vocala	20	40		10					9
Rhyacophila rayneri			10		10				3
DIPTERA									
Brillia sp.		10			20	10	20		8
Chelifera sp.								10	1
Cricotopus tremulus					40			10	6
Dicranota sp.			10	20			10		5
Empididae				30					4
Hemerodromia sp.			10						1
Hexatoma sp.				40	20	10		30	13
Monohelea sp.						20			3
Rheocricotopus sp.		10		50		10	10	10	11
Rheotanytarsus sp.	30		20	60	20	30		10	21
Simulium sp.		10							1
Zavrelimyia sp.	10			10		20	10	90	18

MACROINVERTEBRATE DENSITY
CLIENT: DAMES & MOORE
SITE: BC-1
SAMPLED: 9-28-97

AXA	A	B	C	D	E	F	G	H	COMPOSITE DENSITY
URBELLARIA									
Polycelis coronata				10	30	50			11
EMATODA									
Unid. Nematoda		10	10						3
YDRACARINA									
Hygrobates sp.				20					3
Sperchon/Sperchonopsis				10	10			30	6
OTAL (#/sq. meter)	500	1820	680	1420	930	1430	670	510	997
UMBER OF TAXA	15	20	17	33	21	19	13	20	52
HANNON-WEAVER (H')	3.23	2.44	3.15	4.15	3.14	2.53	2.40	3.85	4.01

MACROINVERTEBRATE DENSITY
CLIENT: DAMES & MOORE
SITE: RC-1
SAMPLED: 9-12-97

AXA	A	B	C	D	E	F	G	H	COMPOSITE DENSITY
NSECTA									
PLECOPTERA									
Capniidae			30		30			20	10
Claassenia sabulosa		10		10			10		4
Despaxia augusta		20	50				70		18
Doroneuria baumanni	10		50	10	20		20		14
Megarcys signata		10	10	10	10	10			6
Paraperla sp.			10						1
Pteronarcella badia			20						3
Pteronarcys californica				10					1
Sweltsa sp.	190	20	160		100	170	350	60	131
Taenionema sp.			20						3
Visoka cataractae					30			20	6
Yoraperla brevis					10				1
Zapada cinctipes			50		30			50	16
Zapada oregonensis	20	40	40	70	10	30	20	20	31
EPHEMEROPTERA									
Ameletus sp.			10						1
Baetis bicaudatus	20	50	80	120	30	40	60	20	53
Cinygmula sp.	50		90	10	20		10	60	30
Drunella coloradensis					10				1
Drunella doddsi	30	170	100	90	90	40	40	60	78
Drunella grandis					20	10			4
Epeorus deceptivus	20	10	80	90	90	60	70	50	59
Epeorus grandis			10						1
Ephemerella infrequens	20		10			20			6
Paraleptophlebia sp.	30	10	50	20	40	10	70	20	31
Rhithrogena robusta	370	500	640	480	310	80	530	170	385
Serratella tibialis		20		10					4
TRICHOPTERA									
Ecclisomyia sp.						10			1
Glossosoma sp.			20	20				10	6
Parapsyche almota	20	30	40	20			10	20	18
Rhyacophila betteni gr.		10	10			10			4
Rhyacophila brunnea gr.				20	10				4
DIPTERA									
Brillia sp.	20	10		10		50	90		23
Chelifera sp.			10		10				3
Cricotopus tremulus		30	20	20		30	10		14
Dicranota sp.			20			10			4
Hexatoma sp.		10	20	10					5
Rheocricotopus sp.			10	30	60	50	60	10	28
Rheotanytarsus sp.					20	20			5
Simulium sp.		10	30	20	10			10	10

MACROINVERTEBRATE DENSITY
CLIENT: DAMES & MOORE
SITE: RC-1
SAMPLED: 9-12-97

AXA	A	B	C	D	E	F	G	H	COMPOSITE DENSITY
URBELLARIA									
Polycelis coronata					10				1
NNELIDA									
OLIGOCHAETA									
Aulodrilus americanus					100			50	19
Unid. Immature Tubificidae w/o Capilliform Chaetae		60		20			70	20	21
HYDRACARINA									
Sperchon/Sperchonopsis			10						1
TOTAL (#/sq. meter)	800	1020	1700	1100	1070	650	1490	670	1065
NUMBER OF TAXA	12	18	29	21	23	17	16	17	43
SHANNON-WEAVER (H')	2.49	2.73	3.63	3.09	3.68	3.53	2.97	3.61	3.70

MACROINVERTEBRATE DENSITY
CLIENT: DAMES & MOORE
SITE: RC-7
SAMPLED: 9-13-97

TAXA	A	B	C	D	E	F	G	H	COMPOSITE DENSITY
INSECTA									
PLECOPTERA									
Despaxia augusta				10					1
Leuctra sp.						10			1
Sweltsa sp.				20		20			5
Zapada cinctipes				10					1
Zapada columbiana			10						1
Zapada oregonensis				20	20				5
EPHEMEROPTERA									
Baetis bicaudatus				10					1
TRICHOPTERA									
Leptoceridae				10					1
Parapsyche almota				10	10	10	10		5
Rhyacophila angelita/perplana			10						1
DIPTERA									
Chelifera sp.	10			10				10	4
Cricotopus tremulus			10						1
Diamesa sp.							20		3
Dicranota sp.					10				1
Dixa sp.	10								1
Hexatoma sp.		10					10		3
Monohelea sp.				10					1
Rheocricotopus sp.	40			20	10			100	21
Rheotanytarsus sp.			10	10					3
Simulium sp.	10				10				3
TURBELLARIA									
Polycelis coronata						10			1
TOTAL (#/sq. meter)	70	10	40	140	60	50	40	110	64
NUMBER OF TAXA	4	1	4	11	5	4	3	2	21
SHANNON-WEAVER (H')	1.66	0.00	2.00	3.38	2.25	1.92	1.50	0.44	3.59

MACROINVERTEBRATE DENSITY
CLIENT: DAMES & MOORE
SITE: RC-9
SAMPLED: 9-13-97

TAXA	A	B	C	D	E	F	G	H	COMPOSITE DENSITY
INSECTA									
PLECOPTERA									
Capniidae	60							10	9
Despaxia augusta	10	20							4
Doroneuria baumanni	30								4
Kathroperla sp.								10	1
Sweltsa sp.	200	30		10		10		50	38
Taenionema sp.			10	20					4
Zapada cinctipes	170							20	24
Zapada oregonensis		70		20		70		10	21
EPHEMEROPTERA									
Ameletus sp.	80								10
Baetis bicaudatus	110			20		10		10	19
Cinygmula sp.	270			10		10		10	38
Drunella coloradensis	10							10	3
Drunella doddsi	30			20					6
Drunella grandis		10			10	20			5
Epeorus deceptivus	50			40		10			13
Epeorus grandis	30	20		10					8
Ephemerella infrequens	10								1
Paraleptophlebia sp.	40								5
Rhithrogena hageni	10								1
Rhithrogena robusta	210								26
TRICHOPTERA									
Parapsyche almota		20		20		10			6
Parapsyche elsis								30	4
Rhacophila brunnea gr.		10							1
Rhyacophila betteni gr.								10	1
Rhyacophila sibirica gr.	20								3
DIPTERA									
Brillia sp.	40	10		20		40	70		23
Chelifera sp.		10							1
Cricotopus tremulus		70		40					14
Diamesa sp.			10						1
Dicranota sp.	10							10	3
Hexatoma sp.	10					10			3
Monohelea sp.	20			10		10			5
Oreogeton sp.	20								3
Rheocricotopus sp.	50							70	15
Rheotanytarsus sp.	10								1
Simulium sp.	10	30							5
Zavrelimyia sp.								10	1
TOTAL (#/sq. meter)	1510	300	20	240	10	200	70	260	330
NUMBER OF TAXA	25	11	2	12	1	10	1	13	37
SHANNON-WEAVER (H')	3.84	3.08	1.00	3.42	0.00	2.84	0.00	3.24	4.47

MACROINVERTEBRATE DENSITY
CLIENT: DAMES & MOORE
SITE: RC-6
SAMPLED: 9-11-97

TAXA	A	B	C	D	E	F	G	H	COMPOSITE DENSITY
INSECTA									
PLECOPTERA									
Calineuria californica	10								1
Capniidae	70		10	10					11
Despaxia augusta	30		10	20					8
Doroneuria baumanni	10	10				30		20	9
Megarcys signata				10					1
Pteronarcys californica						10			1
Suwallia sp.			10				10		3
Sweltsa sp.	270	190	160	30	50	230		50	123
Taenionema sp.	10			20					4
Visoka cataractae	20		10	20					6
Yoraperla brevis		10			10				3
Zapada cinctipes			70	60					16
Zapada columbiana				10					1
Zapada oregonensis		60	20			30	10		15
EPHEMEROPTERA									
Ameletus sp.	10	20							4
Baetis bicaudadtus	40	20	90	20	100	40	10	80	50
Caudatella sp.			20						3
Cinygmula sp.	300		20	30					44
Drunella doddsi	130	70	120	50	70	130	130	150	106
Drunella spinifera		20			10				4
Epeorus deceptivus	70	20	20	20	30	40	20	50	34
Epeorus grandis			40	10			10		8
Ephemerella infrequens			10	10	10				4
Paraleptopohlebia sp.	40	70	10	100		50			34
Rhithrogena robusta	150	260	560	220	250	820		150	301
TRICHOPTERA									
Cheumatopsyche sp.		30				10	20	20	10
Glossosoma sp.	10	10	10	10	20		50	20	16
Leptoceridae	30								4
Parapsyche almota	10			30			20	10	9
Rhyacophila betteni gr.	10			10		20			5
Rhyacophila brunnea gr.				10					1
Rhyacophila hyalinata/vocala			10						1
Rhyacophila sibirica gr.			20						3
Rhyacophila sibirica/perplana								40	5
DIPTERA									
Brillia sp.	10	20		30		30			11
Chelifera sp.		10			10				3
Diamesa sp.					20				3
Dicranota sp.	10			10		30		30	10
Hexatoma sp.	10	10			10	10			5
Monohelea sp.	10	10			20		10	10	8
Rhabdomastix sp.						10			1
Rheocricotopus sp.	100		30	60		40	10	20	33
Rheotanytarsus sp.	20	10	60	30		10	20		19
Simulium sp.			50	10		10	10		10
Thienemanniella sp.	10								1

MACROINVERTEBRATE DENSITY
CLIENT: DAMES & MOORE
SITE: RC-6
SAMPLED: 9-11-97

TAXA	A	B	C	D	E	F	G	H	COMPOSITE DENSITY
TURBELLARIA									
Dugesia sp.		30							4
Polycelis coronata			10						1
ANNELIDA									
OLIGOCHAETA									
Unid. Immature Tubificidae w/o Capilliform Chaetae		280		60	40	10			49
TOTAL (#/sq. meter)	1390	1160	1370	900	650	1560	330	650	1006
NUMBER OF TAXA	25	20	23	26	14	19	13	13	48
SHANNON-WEAVER (H')	3.63	3.31	3.23	4.01	2.96	2.61	2.99	3.17	3.96

MACROINVERTEBRATE DENSITY
CLIENT: DAMES & MOORE
SITE: CC-1
SAMPLED: 10-2-97

AXA	A	B	C	D	E	F	G	H	COMPOSITE DENSITY
NSECTA									
PLECOPTERA									
Capniidae			10						1
Despaxia augusta	30	10			10	10		20	10
Doroneuria baumanni		20	30		10	10		10	10
Megarcys signata	10			10	20		10		6
Moselia infuscata		10							1
Suwallia sp.			10						1
Sweltsa sp.	110	40	100	20	10	40	60	150	66
Taenionema sp.	30	10	250	20	50	50	10	230	81
Visoka cataractae			30					50	10
Yoraperla brevis	10								1
Zapada cinctipes		20						30	6
Zapada oregonensis			10	40	10	120	10	10	25
EPHEMEROPTERA									
Baetis bicaudatus	40	50	50	80	60	60	70	90	63
Caudatella sp.		10							1
Cinygmula sp.		120	160					190	59
Drunella doddsi	60	40	190	30	110	50	40	10	66
Epeorus deceptivus	10	10	10	90	10	40		10	23
Epeorus grandis			10	30		20		10	9
Epeorus longimanus						10			1
Paraleptophlebia sp.								10	1
Rhithrogena robusta	330	240	430	170	240	120	30	320	235
TRICHOPTERA									
Apatania sp.			10						1
Dolophilodes sp.							20		3
Glossosoma sp.	10								1
Parapsyche almota		20	10	90	50	60	70	70	46
Parapsyche elsis								10	1
Rhyacophila angelita/perplana					10				1
Rhyacophila hyalinata/vocala								10	1
DIPTERA									
Brillia sp.	40	10						40	11
Chelifera sp.	10	10	20					20	8
Dicranota sp.	20		30		10		30	10	13
Rheocricotopus sp.				50				40	11
Rheotanytarsus sp.		30	40			40	10		15
Simulium sp.			10	10	10	10	40	20	13
TURBELLARIA									
Polycelis coronata	10								1
ANNELIDA									
OLIGOCHAETA									
Aulodrilus americanus		220	80			240			68
Unid. Immature Tubificidae w/o Capilliform Chaetae	300		580	290	90		260	1590	389

MACROINVERTEBRATE DENSITY
CLIENT: DAMES & MOORE
SITE: CC-1
SAMPLED: 10-2-97

AXA	A	B	C	D	E	F	G	H	COMPOSITE DENSITY
EMATODA									
Unid. Nematoda			10	20		10	10		6
YDRACARINA									
Sperchon/Sperchonopsis						10			1
OTAL (#/sq. meter)	1020	870	2080	950	700	900	670	2950	1266
UMBER OF TAXA	15	17	22	14	15	17	14	23	39
HANNON-WEAVER (H')	2.80	3.11	3.24	3.13	3.02	3.42	3.01	2.60	3.55

DAMES AND MOORE HOLDEN MINE REFERENCE COLLECTION

Vial Number	Order	Taxa	Site
P-1	Plecoptera	*Pteronarcys callifornica*	RC-1D
P-2	Plecoptera	*Yoraperla brevis*	CC-1A
P-3	Plecoptera	*Taenionema* sp.	CC-1A
P-4	Plecoptera	*Zapada cinctipes*	RC-3G
P-5	Plecoptera	*Zapada columbiana*	RC-7C
P-6	Plecoptera	*Zapada oregonensis*	RC-10D
P-7	Plecoptera	*Despaxia augusta*	RC-3E
P-8	Plecoptera	*Leuctra* sp.	RC-7F
P-9	Plecoptera	*Paraleuctra* sp.	RC-3A
P-10	Plecoptera	*Claassenia sabulosa*	RC-1B
P-11	Plecoptera	*Doroneuria baumanni*	RC-3A
P-12	Plecoptera	*Megarcys signata*	RC-1B
P-13	Plecoptera	*Suwallia* sp.	RC-6G
P-14	Plecoptera	*Sweltsa* sp.	RC-6K
P-15	Plecoptera	*Calineuria californica*	RC-6A
P-16	Plecoptera	*Visoka cataractae*	RC-6O
P-17	Plecoptera	*Moselia infuscata*	CC-1B
P-18	Plecoptera	*Kathroperla* sp.	RC-9A
E-1	Ephemeroptera	*Ameletus* sp.	BC-1H
E-2	Ephemeroptera	*Baetis bicaudatus*	RC-3G
E-3	Ephemeroptera	*Cinygma* sp.	RC-3E
E-4	Ephemeroptera	*Cinygmula* sp.	RC-3G
E-5	Ephemeroptera	*Epeorus deceptivus*	RC-6P
E-6	Ephemeroptera	*Epeorus grandis*	CC-1D
E-7	Ephemeroptera	*Heptagenia elegantula*	BC-1H

DAMES AND MOORE HOLDEN MINE REFERENCE COLLECTION

Vial Number	Order	Taxa	Site
E-8	Ephemeroptera	*Rhithrogena robusta*	RC-3G
E-9	Ephemeroptera	*Drunella doddsi*	RC-6P
E-10	Ephemeroptera	*Drunella grandis*	RC-9D
E-11	Ephemeroptera	*Ephemerella infrequens*	SFAC-C
E-12	Ephemeroptera	*Serratella tibialis*	RC-3H
E-13	Ephemeroptera	*Paraleptophlebia* sp.	RC-6P
E-14	Ephemeroptera	*Caudatella* sp.	BC-1B
E-15	Ephemeroptera	*Epeorus longimanus*	BC-1B
E-16	Ephemeroptera	*Drunella coloradensis*	RC-1E
E-17	Ephemeroptera	*Rhithrogena hageni*	RC-9A
T-1	Trichoptera	*Dolophilodes* sp.	CC-1G
T-2	Trichoptera	*Parapsyche almota*	RC-3H
T-3	Trichoptera	*Rhyacophila angelita/perplana*	RC-3F
T-4	Trichoptera	*Rhyacophila betteni* gr.	RC-3H
T-5	Trichoptera	*Rhyacophila brunnea* gr.	RC-9B
T-6	Trichoptera	*Rhyacophila hyalinata/vocala*	RC-5A and C
T-7	Trichoptera	*Rhyacophila rayneri*	BC-1C
T-8	Trichoptera	*Glossossoma* sp.	RC-6P
T-9	Trichoptera	*Ecclisomyia* sp.	RC1-F
T-10	Trichoptera	Limnophilidae pupae	RC-5A and G
T-11	Trichoptera	*Mystacides* sp.	BC-1H
T-12	Trichoptera	*Neothremma* sp.	RC-6L
T-13	Trichoptera	*Parapsyche elsis*	BC-1B
T-14	Trichoptera	*Apatania* sp.	CC-1C
T-15	Trichoptera	*Oligophlebodes* sp.	BC-1B

DAMES AND MOORE HOLDEN MINE REFERENCE COLLECTION

Vial Number	Order	Taxa	Site
D-1	Diptera	*Monohelea* sp.	RC-6B
D-2	Diptera	*Simulium* sp.	RC-3H
D-3	Diptera	*Antocha* sp.	SFAC-C
D-4	Diptera	*Dicranota* sp.	CC-1A
D-5	Diptera	*Hexatoma* sp.	RC-1B
D-6	Diptera	*Rhabdomastix* sp.	RC-3A
D-7	Diptera	*Chelifera* sp.	RC-3H
D-8	Diptera	*Hemerodromia* sp.	RC-3A
D-9	Diptera	*Oreogeton* sp.	RC-9A
D-10	Diptera	*Dixa* sp.	RC-7A
Tu-1	Turbellaria	*Polycelis coronata*	RC-6N
H-1	Hydracarina	*Sperchon/Sperchonopsis*	BC-1E
H-2	Hydracarina	*Hygrobates* sp.	BC-1D

DAMES AND MOORE HOLDEN MINE REFERENCE COLLECTION
CHIRONOMID/OLIGOCHAETE

Slide Number	Label Name	Taxa	Site
DM1097-1	Or-1	*Cricotopus tremulus*	RC-3A
DM1097-1	Or-2	*Brillia* sp.	RC-3A
DM1097-1	Or-3	*Rheocricotopus* sp.	RC-3A
DM1097-2	Or-4	*Thienemanniella* sp.	RC-3A
DM1097-7	Tt-1	*Rheotanytarsus* sp.	RC-7A
DM1097-10	Di-1	*Diamesa* sp.	RC-7A
DM1097-18	Tp-1	*Zavrelimyia* sp.	BC-1C
DM1097B-1	Ch-1	*Polypedilum* sp.	SFAC-1A

APPENDIX P

WASHINGTON NATURAL HERITAGE PROGRAM INFORMATION

August 13, 1997

WASHINGTON STATE DEPARTMENT OF
Natural Resources

JENNIFER M. BELCHER
Commissioner of Public Lands

Linda Krippner
Dames & Moore
500 Market Place Tower
2025 1st Avenue
Seattle WA 98121

SUBJECT: **Remedial Investigation/Feasibility Study for Holden Mine Site, Chelan County (T31N R17E S07)**

We've searched the Natural Heritage Information System for information on significant natural features in your study area. Currently, we have no records for rare plants or high quality ecosystems in the vicinity of your project. However, two state sensitive plant species, *Pellaea breweri* (Brewer's cliff-brake) and *Cryptogramma stelleri* (Steller's rockbrake) occur within about three miles of your project area. I have enclosed a list of rare plant species for Chelan County for your use.

The Washington Natural Heritage Program is responsible for information on the state's endangered, threatened, and sensitive plants as well as high quality ecosystems. **The Department of Fish and Wildlife manages and interprets data on wildlife species of concern in the state. For information on animals of concern in the state, please contact Priority Habitats and Species, Washington Department of Fish and Wildlife, 600 Capitol Way N, Olympia, WA 98501-1091, or by phone (360) 902-2543.**

The information provided by the Washington Natural Heritage Program is based solely on existing information in the database. In the absence of field inventories, we cannot state whether or not a given site contains high quality ecosystems or rare species; there may be significant natural features in your study area of which we are not aware.

We are currently re-evaluating our data distribution policies and fees. We are considering offering our products via subscription services and the Internet. If you have the opportunity and technology, visit our new World Wide Web site at www.wa.gov/dnr. We would appreciate your comments on how we can better serve you. If you have any questions, please do not hesitate to call me at (360) 902-1667, or by E-Mail: sandra.moody@wadnr.gov.

Sincerely,

Sandy Swope Moody

Sandy Swope Moody, Environmental Coordinator
Washington Natural Heritage Program
Division of Forest Resources
PO Box 47016
Olympia WA 98504-7016

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