Draft Final Feasibility Study
Holden Mine Site

prepared for
INTALCO

by
URS Corporation

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ACRONYM AND ABBREVIATION GLOSSARY

µg/kg	micrograms per kilogram (same as ppb)
AKART	all known available and reasonable methods of treatment
ALDs	anoxic limestone drains
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
BAT	Best Available Technology
BCT	Best Conventional Technology
BPT	Best Practicable Technology
BOM	Bureau of Mines
CFR	Code of Federal Regulations
cfs	cubic feet per second
CERCLA	Comprehensive Environmental Response, Compensation and Liability Act
CLP	Contract Laboratory Program
COC	Contaminants of Concern
COPC	Constituents of Potential Concern
CPOC	Conditional Point of Compliance
CPOM	Coarse Particular Organic Material
CRSP	Colorado Rockfall Simulation Program
CSM	Conceptual Site Model
CSZ	Cascadia Subduction Zone
CTP	Consolidated Tailings Pile
CWA	Clean Water Act
CWCQ	Chronic Water Quality Criteria
DFS	Draft Feasibility Study
DNR	Washington State Department of Natural Resources
DO	Dissolved Oxygen
DOI	U.S. Department of the Interior
DQO	Data Quality Objectives
DRI	Draft Remedial Investigation Report
Ecology	Washington State Department of Ecology
EM	electromagnetic
EMSL	Electron Microscopy Services Laboratory, Inc.
EPA	United States Environmental Protection Agency Region 10
EPT	Ephemeroptera, Plecoptera, and Tricoptera
ERA	Ecological Risk Assessment
ER-L	Effects Range-Low
ER-M	Effects Range-Median
FS	Feasibility Study
Forest Service	U.S. Department of Agriculture Forest Service Region 6

FSQV	Freshwater Sediment Quality Values
FWPOCA	Federal Water Pollution Control Act
GPS	Global Positioning System
GRA	General Response Action
HDPE	high-density polyethylene
HDS	high density sludge
HEC	Hydrologic Engineering Center
HELP	Hydrologic Evaluation of Landfill Performance
HHRA	Human Health Risk Assessment
HI	hazard index
HPA	Hydraulic Project Approval
HQ	Hazard quotient
HRC	High rate clarification
HSWA	Hazardous and Solid Waste Amendments
IC	Institutional Controls
ICMP	Institutional Control Management Plan
ID	Injury Determination
IHS	Indicator Hazardous Substances
LEL	Lowest Effect Level
LOEC	Lowest Effect Concentration
MATC	Maximum Acceptable Toxicant Concentration
MCLs	Maximum Containment Levels
MCLGs	Maximum Contaminant Level Goals
MDL	Method Detection Limit
MNA	Monitored Natural Attenuation
MRT	Molecular recognition technology
MSHA	Mine Safety and Health Administration
msl	mean sea level
MTCA	Model Toxics Control Act
NAWQC	National Ambient Water Quality Criteria
NCP	National Contingency Plan
NOEC	No Observed Effect Concentrations
NOV	Notice of Violation
NPDES	National Pollutant Discharge Elimination System
NRCS	Natural Resource Conservation Service
NRWQC	National Recommended Water Quality Criteria
NSPS	New Source Performance Standards
NTR	National Toxics Rule
O&M	Operations and maintenance
OMMP	Operations and Maintenance Monitoring Plan
ORP	Oxidation Reduction Potential
OHSA	Occupational Safety and Health Act
OSWER	Office of Solid Waste and Emergency Response
PA	Preliminary Assessment
PAC	Polyaluminum chloride
PAET	Probable Apparent Effects Threshold

PCB	Polychlorinated Biphenyls
PCOC	Potential Constituent of Concern
PEF	Particulate Emission Factor
PLM	Polarized Light Microscopy
PNL	Pacific Northwest Laboratories
PQL	Practical Quantitation Limit
PRB	Permeable reactive barrier
QAPP	Quality Assurance Project Plan
PRGs	Preliminary Remediation Goals
RAO	Remedial Action Objectives
RBP	Rapid Bioassessment Protocols
RCRA	Resource Conservation and Recovery Act
RD/RA	Remedial Design/Remedial Action
RI	Remedial Investigation
RI/FS	Remedial Investigation/Feasibility Study
RME	Reasonable Maximum Exposure
RBSL	Risk Based Screening Levels
RME	Reasonable Maximum Exposure
ROC	Receptors of Concern
ROD	Record of Decision
ROPC	Receptors of Potential Concern
RQD	Rock Quality Designation
SAMM	Self-assembled monolayers on mesoporous support, a type of nanoporous absorbent
SAP	Sampling and Analysis Plan
SCL	Screening Level Concentration
SCS	Soil Conservation Service
SOW	Statement of Work
SWQC	Washington State Surface Water Quality Criteria
SU	standard units
TBC	To Be Considered
TPH	total petroleum hydrocarbons
TRV	Toxicity Reference Values
UCL	Upper Confidence Limit
USACOE	United States Army Corps of Engineers
USC	United States Code
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
WDOH	Washington Department of Health
WNF	Wenatchee National Forest

WNHP	Washington Natural Heritage Program
WTP	Water Treatment Plant

EXECUTIVE SUMMARY

INTRODUCTION

The draft final Feasibility Study (FS) for the Holden Mine Site (Site), located in Chelan County Washington is submitted pursuant to an Administrative Order on Consent (AOC), dated April 11, 1998. The AOC was executed between Alumet (now known as Intalco) and the US Department of Agriculture Forest Service Region 6 (Forest Service), Washington State Department of Ecology (Ecology), and the U.S. Environmental Protection Agency Region 10 (EPA).

In accordance with the AOC, a revised Draft Remedial Investigation (DRI) report was prepared by URS Corporation (formerly Dames & Moore) on behalf of Intalco to document the results of the remedial investigation (RI) and characterize the nature and extent of potential impacts to site media from historic mining activities. Ecological and human health risk assessments were also performed for the Site as part of the RI. The revised DRI report was submitted on July 28, 1999, and was accepted as final by the Forest Service, Ecology, and EPA (Agencies), with associated comment resolution documents, on February 8, 2002. Consistent with the AOC, a draft Injury Determination (ID) report (URS 2002b) was also prepared to evaluate the potential for coordinated remedial and natural resource restoration activities. Natural resource restoration negotiations are currently ongoing.

Following acceptance of the RI, a Draft FS (DFS) report was prepared and submitted to the Agencies on June 12, 2002. The purpose of the DFS was to present remedial action objectives (RAOs), identify and screen potentially applicable technologies to address site concerns, and to assemble and evaluate candidate site-wide alternatives for their ability to meet RAOs. During the DFS review process, the Agencies provided direction for preparing a draft final FS report in correspondence dated July 26, 2002, December 18, 2002, and January 2, 2003. Subsequent to the Agencies' December 18, 2002 comment letter, a number of technical meetings related to FS analyses were held between representatives of Intalco and the Agencies, and the following comment and comment response documents were submitted:

- Letter from David Jackson, David E. Jackson & Associates, to Norman Day, Forest Service, dated January 22, 2003, providing Intalco's responses to the December 18, 2002, and January 2, 2003 Agencies' direction for preparing the Holden Mine Site Draft Final Feasibility Study (Intalco 2003a).

- Letter from Norman Day, Forest Service, to David Jackson, David E. Jackson & Associates, dated March 6, 2003, providing the Agencies' comments on Intalco's response to Agency comments regarding ARARs, dated January 22, 2003 (USFS 2003a).

- Letter from Theodore Garrett, Covington & Burling, to Norman Day, Forest Service, dated June 4, 2003, providing Intalco's response to the Agencies' comments regarding Holden Mine ARARs, dated March 6, 2003 (Intalco 2003b).

- Letter from Norman Day, Forest Service, to Theodore Garrett, Covington & Burling, dated July 28, 2003, providing the Agencies' response to Intalco's June 4, 2003 letter regarding ARARs (USFS 2003b).

- Letter from Jennifer Deters, URS, to Norman Day, Forest Service, dated August 27, 2003, providing Intalco's responses to the Agencies' July 28, 2003 comment letter (Intalco 2003c).

- Letter from Norman Day, Forest Service, to Theodore Garrett, Covington & Burling, dated September 11, 2003, providing the Agencies' direction for completion of the Holden Mine Feasibility Study (USFS 2003c).

The Agencies' comments and results of the technical meetings were incorporated into this FS report.

OVERVIEW OF THE FEASIBILITY STUDY PROCESS

In accordance with the AOC, the feasibility study process for the Holden Mine site is being conducted in accordance with the Comprehensive Environmental Response, Compensation and Liability Act (CERCLA); the State of Washington Model Toxics Control Act (MTCA); and consistent with the National Contingency Plan (NCP) and applicable Agency guidance documents. The EPA and MTCA processes provide for a systematic approach to establish site-specific RAOs for environmental concerns across the Site, the detailed review and screening steps for potentially applicable remedial technologies, and the detailed evaluation of candidate site-wide remedial alternatives. In addition, as part of the draft FS process, Intalco has worked closely with the Agencies to formulate a range of candidate remedial alternatives to be considered for implementation at the Site. A total of eight candidate alternatives were assembled through the collaborative process between the Agencies and Intalco. Several subalternatives were developed within these eight broad alternatives, resulting in a total of 16 unique site-wide alternatives that are described and evaluated in this report. A description of the FS process is provided below.

The Feasibility Study Process - CERCLA

The following seven criteria are used in the detailed analysis of candidate remedial alternatives, in accordance with the National Contingency Plan (NCP) (40 CFR 300.430):

- Overall protection of human health and the environment;
- Compliance with applicable or relevant and appropriate requirements (ARARs);
- Long-term effectiveness and permanence;
- Reduction of toxicity, mobility, or volume;
- Short-term effectiveness;
- Implementability;
- Cost.

The first two criteria are considered “threshold” criteria that an alternative must meet in order to be considered for implementation. The next five criteria are considered to be “primary balancing” criteria, and are used in conjunction with the threshold criteria in the comparative analysis of alternatives. The results of the comparative analysis are used to identify a preferred remedy for the Site, which is presented as part of a Proposed Plan, along with the basis for selection. Two additional criteria, state acceptance and community acceptance, are then evaluated based on comments received during the public comment period of the Proposed Plan. The selected remedy is subsequently modified as needed, based on state and community acceptance, and a Record of Decision (ROD) is issued.

In addition to the nine CERCLA criteria discussed above, an additional criterion was added in accordance with the AOC to evaluate the extent to which candidate remedial alternatives achieve natural resource restoration.

The Feasibility Study Process – MTCA

Consistent with CERCLA and the NCP, the purpose of the feasibility study under MTCA is to develop and evaluate potential cleanup action alternatives (i.e., candidate remedial alternatives) to enable a cleanup action (i.e., final remedy) to be selected for the Site. The FS process under MTCA is generally consistent with the CERCLA process and is followed in this FS report.

The MTCA specifies the following general requirements for cleanup actions completed in the State of Washington (WAC 173-340-360):

- Protect human health and the environment;
- Comply with cleanup standards specified in WAC 173-340-700 through 760;
- Comply with applicable state and federal laws;
- Provide for compliance monitoring as specified under WAC 173-340-410 and 173-340-720 through 760;
- Use permanent solutions to the maximum extent practicable, which requires the use of a disproportionate cost analysis to compare the costs and benefits of candidate remedial alternatives;
- Provide for a reasonable restoration time frame as described in WAC 173-340-360(4);
- Consider public concerns.

The regulation recognizes that some of the minimum requirements listed above contain flexibility and require the use of professional judgment in determining how they are applied at particular sites. The first four requirements listed above are considered to be “threshold” requirements under MTCA that the selected remedy must meet. The remaining three requirements must be considered along with the threshold requirements in the comparative analysis of remedial alternatives. As possible, the seven MTCA requirements listed above are evaluated in this FS within the discussions provided in the detailed analysis for corresponding CERCLA criteria as follows:

- Protection of human health and the environment is addressed under the CERCLA criterion for overall protection of human health and the environment.

- Compliance with MTCA cleanup standard and compliance with applicable state and federal laws are addressed under the CERCLA criterion for compliance with potential ARARs.

- Providing for compliance monitoring is addressed generally under the CERCLA criteria for short-term effectiveness and long-term effectiveness and permanence. However, the identification of specific compliance monitoring locations and frequency will be determined following preparation of the proposed plan.

- Use of permanent solutions to the maximum extent practicable is encompassed under several CERCLA criteria including long-term effectiveness and permanence. This criterion requires the use of a disproportionate cost analysis, which includes the evaluation of overall protectiveness of human health and the environment, permanence, cost, effectiveness over the long term, management of short-term risks, technical and administrative implementability, and consideration of public concerns. Because the disproportionate cost analysis includes components evaluated under a number of CERCLA criteria, this criterion will be addressed separately in the detailed analysis following the CERCLA criteria evaluation.

- Providing for reasonable restoration time frame is also addressed separately in the detailed analysis following the CERCLA criteria evaluation to address the MTCA-specific requirements specified in WAC 173-340-360(4).

Similar to the CERCLA process, the consideration of public concerns will be addressed during the final remedy selection process, and will be evaluated following preparation of the proposed plan.

SITE CHARACTERISTICS

The Site is situated in a remote area on the eastern slopes of the Cascade Mountains in Washington State, within the Lake Chelan watershed (Figure ES-1). The mine was developed and operated by the Howe Sound Company, from the late 1930s through the 1950s for the primary production of copper, zinc, silver and gold. The Site is surrounded on three sides by designated wilderness and on one side by National Forest System-managed land, and is located near the center of the Railroad Creek watershed (Figure ES-2).

Approximately 60 miles of underground mine workings were developed during the period of operation. 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 that 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 impoundments (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 operations. 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 subsequently deeded to the Lutheran Bible Institute, which became Holden Village Inc., in 1961 and the Holden Village 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. Following mine closure, the underground mine workings eventually flooded resulting in the discharge of water from the 1500-level main portal of the mine.

No human health risks have been identified due to releases from the Site. The main portal drainage and seeps and groundwater from the western portion of the Site (West Area) contain elevated concentrations of cadmium, copper, and zinc that are released to Railroad Creek causing seasonal exceedances of aquatic life criteria (Figure ES-3). The three tailings piles constructed during mining operations are located on the eastern portion of the Site adjacent to Railroad Creek (East Area). Groundwater originating from the three piles contributes iron and some cadmium, copper, and zinc to Railroad Creek.

Sampling and analytical data presented in the DRI indicate that seasonal aluminum, cadmium, copper, iron, and zinc concentrations in Railroad Creek were detected above potential state and/or federal aquatic life criteria in Railroad Creek. Data were compared to both the Washington State promulgated surface water quality criteria (SWQC) for dissolved cadmium, copper, and zinc, and the National Recommended Water Quality Criteria (NRWQC)[1] for dissolved cadmium, copper, and zinc, and for total aluminum and iron. Based on this comparison, aluminum, cadmium, copper, and zinc concentrations were detected above the potential SWQC and/or NRWQC from the portal drainage confluence (station P-5) to the mouth of Railroad Creek at Lake Chelan (station RC-3) during the high flow period in the spring (Figures ES-4 and ES-5). Concentrations of aluminum and cadmium have also been detected above the NRWQC in the spring at background station RC-6. Dissolved metals concentrations measured in composite samples collected from Railroad Creek adjacent to the Site between 1997 and 2003 ranged from 0.048 to 0.68 μg/L for cadmium, 0.5 to 41.9 μg/L for copper, and 10 to 114 μg/L for zinc. Total metals concentrations measured in composite samples collected adjacent to the Site ranged from 40 to 340 μg/L for aluminum and 0.06 to 2.62 mg/L for iron.

Concentrations of aluminum, cadmium, copper, and zinc in Railroad Creek are generally lower during low-flow conditions, which occur for most of the year. Total iron concentrations are generally higher during low-flow conditions. During the 1997 RI sampling and subsequent investigations, iron concentrations were measured above the NRWQC from adjacent to the tailings piles (station RC-7) to less than approximately one mile downstream of the Site (station

[1] Intalco has provided legal justification and technical documentation showing that the NRWQC (1999 and 2002 publications) are not relevant and appropriate to the Holden Mine site. Intalco's justification has been provided in written correspondence with the Agencies between January and September 2003. This correspondence is part of the administrative record and is incorporated into this FS. Intalco's rationale is also summarized and presented in Section 3 and Appendix B.

RC-5). Cadmium concentrations were measured to be slightly above the NRWQC from immediately downstream of the Site (station RC-2) to approximately three miles downstream of the Site (station RC-10). Zinc concentrations were measured at levels slightly above SWQC but below the NRWQC in Railroad Creek during low-flow conditions from station RC-2 to station RC-5. Copper and aluminum were below the SWQC, area background, and/or the NRWQC during the low-flow period, with the exception of a slight exceedance of the NRWQC for copper. No exceedances of federal or state MCLs were recorded in Railroad Creek as part of the DRI or subsequent sampling activities.

Results of aquatic studies performed for the RI suggest reduced fish and benthic macroinvertebrates populations in Railroad Creek resulting from site discharges. Although fish were present at all survey stations, reduced fish populations were observed in Railroad Creek from adjacent to the Site at station RC-7, to approximately three miles downstream of the Site (station RC-10). Reduced benthic macroinvertebrate populations were observed from the adjacent to the Site at station RC-9 to the mouth of Railroad Creek at Lucerne (station RC-3). Data presented in the DRI indicate the reduced populations may be due to a combination of chemical effects related to concentrations of metals such as copper and zinc, and physical effects. Physical effects observed at the Site include the presence of iron oxy-hydroxide precipitant (flocculant) and limited areas of ferricrete formation in the Railroad Creek streambed.

During the RI and subsequent sampling programs, cadmium, copper, lead, manganese, nickel and zinc were detected above potential groundwater ARARs in one or more site seeps or groundwater monitoring locations. Approximate seep sampling locations are shown on Figure ES-5. The potential groundwater ARARs include federal and state maximum containment levels (MCLs) and MTCA Method B groundwater values. A number of site seeps that discharge directly into Railroad Creek also exceeded potential surface water ARARs for aluminum, cadmium, copper, iron, and zinc.

During the RI, cadmium, copper, and total petroleum hydrocarbons (TPH) were detected above potential ARARs in maintenance yard soils. Cadmium, copper, silver, zinc, and TPH were detected above potential ARARs in the lagoon area, and cadmium, copper, and zinc were measured above potential ARARs in the former surface water retention area. Soil samples were not collected from the mill building during the RI or subsequent field investigations. However, seep samples collected from this area indicate that the mill building provides a source of metals loading to groundwater and Railroad Creek.

Results of water quality monitoring and the site-wide loading analysis indicate that aluminum, cadmium, copper, and zinc loading is highest during the spring snowmelt, when flows from the portal drainage and seeps are the highest, and when groundwater levels are highest in the wells beneath the tailings piles. During the high-flow period, the data indicate that the portal drainage and seep SP-23 contribute a majority of the measured cadmium, copper, and zinc load at station RC-2.

Groundwater and seeps entering the creek adjacent to tailings pile 1 also contain concentrations of cadmium, copper and zinc, which may be due to the presence of a paleo-channel extending from upstream of the lagoon area to a location near the eastern toe of tailings pile 1. RI data indicate that this paleo-channel may provide a preferential pathway for these potential constituents of concern (PCOCs) from the West Area to Railroad Creek.

During the seasonal low flow period, represented for purposes of the FS analysis by September 1997 sampling data, a majority of the seeps were observed to be dry and the data indicate that groundwater baseflow and seep flow entering the creek adjacent to tailings pile 1 contributes most of the metals loading to Railroad Creek. The data indicate that a majority of the aluminum and iron enters Railroad Creek adjacent to the three tailings piles, between stations RC-4 and RC-2. Tailings pile 1 appears to individually contribute most of the loading within this reach.

REMEDIAL ACTION OBJECTIVES

The site-specific remedial action objectives (RAOs) describe requirements that must be met by the selected site remedy. The RAOs are designed to guide the development of candidate alternatives appropriate for site remediation, and generally indicate the contaminants, media of concern, exposure routes, and potential receptors. Acceptable concentration limits or ranges for each PCOC by media, exposure routes, and receptors is incorporated by reference into applicable state and federal standards.

The following three RAOs for were developed for the Site:

- Protect human health and the environment within a reasonable timeframe for:
  - Groundwater quality to meet State groundwater quality standards
  - Surface water quality to meet State water quality standards
  - Surface soil quality to protect human health and the environment
  - Sediment quality to protect human health and the environment

- Perform appropriate natural resource damage assessment activities as agreed by the Parties consistent with 43 CFR Part 11 in order to evaluate the potential for coordinated remedial and natural resource restoration activities.

- Implement the remedial action in a manner that protects human health and the environment, including the Holden Village residential community during and after construction.

CANDIDATE SITE-WIDE REMEDIAL ALTERNATIVE DESCRIPTIONS

Based on the results of the technology evaluation step, and through a collaborative process with the Agencies, retained technologies were assembled into eight candidate site-wide remedial alternatives to address Site RAOs. As described previously, for purposes of the FS, the Site has been divided into two areas based on the unique surface water and groundwater chemical characteristics exhibited in the East and West Areas (Figure ES-3). Figures ES-4 and ES-5 provide seep and surface water sampling locations used to delineate the specific characteristics of the two areas.

Descriptions of the eight candidate site-wide remedial alternatives are provided below. A summary of the remediation components included under each of the candidate alternatives is provided on Table ES-1.

Alternative 1 – No Action/Institutional Controls

The No Action/Institutional Controls alternative is evaluated as required by the NCP and is intended to represent a baseline alternative for comparison with other candidate alternatives. No engineering controls would be provided under the Alternative 1. The portal drainage and site surface water, groundwater, and seasonal seeps would continue to flow into Railroad Creek without control or treatment, and source materials and impacted soils would remain in place. The following actions would be implemented under Alternative 1:

- Institutional Controls and Physical Access Restrictions - Institutional controls, such as land use restrictions, deed notices, or building permits, would be implemented to limit potential future exposures to human and ecological receptors from source materials and PCOCs remaining on site. Existing physical access restrictions, including the security fence installed around the mill building; locking steel gates placed at the entrance to the 300- and 1100-level portals; the locking steel door located on the 1500-level main portal; and signage would be maintained under this alternative to provide protection for residents and visitors from potential physical hazards associated with these features.

- Environmental and Slope Stability Monitoring - Surface water and groundwater quality monitoring would be performed to monitor environmental site conditions. The specific locations of the surface water and groundwater monitoring points would be determined during the RD/RA. Annual visual monitoring of tailings pile side slopes and riprap condition would also be performed to evaluate the potential for slope failure and accidental release of tailings to Railroad Creek.

- Limited Mine Actions - Limited mine actions would be conducted under Alternative 1 to maintain the 1500-level main portal supports installed by Intalco during rehabilitation of the portal in the fall of 2000. Under Alternative 1, debris (such as railroad ties) and metal precipitates (slimes) remaining within accessible portions of the 1500 level would also be removed and disposed of on site to reduce the potential for accidental release.

Under this alternative, tailings pile revegetation would continue naturally by migration of both native plant species and existing plants placed as part of previous Forest Service revegetation programs.

Remediation Components Common to Alternatives 2 through 8

Several remediation components are common to all candidate site-wide alternatives with the exception of Alternative 1. These components include a combination of engineering actions and institutional controls designed to protect Holden Village residents and visitors from potential physical hazards associated with site features, protect terrestrial and aquatic ecological receptors, and reduce metals loading to groundwater and surface water.

To avoid repetition, this section describes the components common to Alternatives 2 through 8:

- Institutional Controls and Physical Access Restrictions – Institutional controls, such as land use restrictions, deed notices, or building permits, would be implemented to limit potential future exposures to human and ecological receptors from source materials and PCOCs remaining on site. Existing physical access restrictions, including the security fence installed around the mill building; locking steel gates placed at the entrance to the 300- and 1100-level portals; the locking steel door located on the 1500-level main portal; and signage would be maintained under this alternative to provide protection for residents and visitors from the potential physical hazards associated with these features.

- Environmental and Slope Stability Monitoring – Surface-water and groundwater sampling would be performed to monitor site conditions, confirm adequate protection of human health and the environment, and assess performance of the selected remedy over time. The specific locations of the groundwater and surface-water monitoring points would be determined during the RD/RA. Surface-water monitoring points would include Railroad Creek stations upstream, adjacent to, and downstream of the Site. Annual visual monitoring of tailings pile side slopes and riprap condition would also be performed to evaluate the potential for slope failure and accidental release of tailings to Railroad Creek.

- Limited Mine Actions – Limited mine actions would be conducted under Alternative 2 through 8 to maintain the 1500-level main portal supports installed by Intalco during rehabilitation of the portal in the fall of 2000. Debris (such as railroad ties) and metal precipitates (slimes) remaining within accessible portions of the 1500 level would be removed and disposed of on site to reduce the potential for accidental release. Mine actions would also include the installation of airflow restrictions within open portals on and above the 1500 level to reduce oxygen transport through the mine. Potentially open drill holes would also be sealed on an opportunistic basis under each of the alternatives, if identified at the Site.

- Mill Building Actions – Soils and residuals in the mill building with metals concentrations above potential cleanup criteria would be excavated and relocated to a containment area on site (e.g., tailings pile 1) or covered in place. As possible, residuals contained in the former concentrate tank and ore bin would be excavated and relocated to an on site containment area due to the impracticability of installing an effective cover over these features.

- Maintenance Yard Actions – An asphalt or concrete cover would be placed over soils in the maintenance yard area with metals and/or petroleum hydrocarbon concentrations exceeding the potential clean-up levels. The use of a concrete or asphalt cover would allow continued use of the area by Holden Village residents. Soils that cannot be effectively covered would be excavated and relocated to a suitable containment area on site.

- Lagoon Area Actions – Soils in the lagoon area containing constituent concentrations above potential cleanup levels would be excavated and relocated to a suitable containment area on site.

- Former Surface Water Retention Area Actions – Soils in this area would be excavated and relocated to a suitable containment area on site, or covered with clean soil obtained from surrounding areas. If covered, the soils would be compacted and revegetated to provide a suitable cover to reduce surface water infiltration and PCOC mobility. The area would then be graded to direct surface water around the feature and reduce potential erosion of the soil cover.

- Copper Creek Channel Modifications Between Tailings Piles 1 and 2 – Modification of the Copper Creek channel between tailings piles 1 and 2, and an evaluation of the two existing culverts beneath the access road would be performed under all of the candidate alternatives to mitigate the potential for future channel migrations. The methods used to protect the channel (e.g., riprap, culverts, etc.) would depend on the selected remedial action.

- Copper Creek Diversion Culvert – The Copper Creek diversion would be placed in a lined channel or culvert from the hydroelectric plant discharge pipe to the confluence with Railroad Creek. The open channel or culvert would be constructed of concrete or high-density polyethylene (HDPE).

- Riprap Source Development – A source of large-diameter rock for use as riprap or in the construction of other remedial features would be needed under all of the candidate remedial alternatives. A preliminary assessment of potential riprap sources was performed as part of the RI and during subsequent field programs in 2003. The preliminary assessments identified a number of potential outcrop and talus sources within several miles from the Site. Additional exploration and testing would be needed during the remedial design/remedial action (RD/RA) to select an appropriate source, and the selected source would need to be developed.

- Railroad Creek Bank Protection in the West Area – Based on observations made during the fall of 2003, riprap or other means of stream bank protection would be placed along the Railroad Creek stream banks to mitigate the potential for erosion as needed.

Alternative 2 – Water Management

Alternative 2 would include the common remediation components described previously with the addition of:

- Diversion of Upgradient Surface and Near-surface Water around East and West Area Features – Upgradient water diversion would be implemented to reduce the contact between unimpacted upgradient water and potential source materials in the mill building, maintenance yard, waste rock piles, lagoon area, and tailings piles. The upgradient water would be diverted using shallow trenches or French drains installed upslope of mine features.

- Closure of Tailings Pile 1 Decant Tower – The partially open decant tower would be filled with grout or other inert material and abandoned to minimize the flow of water and oxygen to subsurface tailings.

- Regrading and Enhanced Revegetation of the Tailings Piles - Under this alternative, the top surfaces of the three piles would be regraded as necessary to minimize surface water ponding and infiltration. Revegetation efforts undertaken by the U.S. Bureau of Mines and the Forest Service from the mid-1960s through the early 1990s would be continued and enhanced to establish a successful plant community on the three piles.

- Tailings Pile Slope Actions - Tailings piles 1 and 2 side slopes with slope angles steeper than the angle of repose (estimated to be approximately 34 degrees or 1.5H to 1V), would be regraded. The tailings pile 1 side slopes and a portion of tailings pile 2 adjacent to copper creek would also be regraded to a final configuration of 1.5H to 1V. Tailings pile 2 slopes adjacent to Railroad Creek would be regraded to a final configuration of approximately 2H to 1V. The tailings pile 3 slopes would not be disturbed under this alternative, allowing the mature vegetation and trees on the upper-most portions of these slopes to remain in place. To contain tailings potentially transported downslope due to sloughing or slope failure, low rock-fill buttresses would be constructed at the base of tailings pile 3, as required. The existing riprap placed at the base of the three tailings piles during site reclamation efforts completed by the Forest Service between 1989 and 1991 would also be enhanced.

- Monitored Natural Attenuation in the East and West Areas – Monitored natural attenuation (MNA) relies on natural attenuation processes to achieve site-specific remediation objectives within a time frame that is reasonable. Geochemical analysis conducted for the Site document that natural attenuation is occurring, and the release of PCOCs from the underground mine workings, waste rock, and tailings piles will continue to decline over time. MNA, in conjunction with the source controls and other measures included under Alternative 2 are expected to significantly reduce the release of PCOCs over time.

Two subalternatives (2a and 2b) were developed under this alternative that provide different approaches to portal drainage control. Under both subalternatives, the portal drainage would continue to flow to Railroad Creek in its current alignment.

- Alternative 2a (Open Portal) – Airflow restrictions would be placed within the 1500-level main portal, allowing unrestricted water flow from the mine. The water level within the mine would remain unchanged from current conditions and the existing drainage alignment from the portal to Railroad Creek would not be modified.

- Alternative 2b (Hydrostatic Bulkheads) – Two or more hydrostatic bulkheads would be installed in strategic locations within the 1500-level main portal and ventilator tunnel to control water flow rates from the underground mine. Portal drainage control would be used to provide surge storage and reduce seasonal loading spikes to Railroad Creek to the extent practical. Other in-mine water controls that would be evaluated under Alternative 2b during the RD/RA include the circulation of drainage from the upper mine workings through the lower workings prior to discharge from the 1500-level main portal. During the RD/RA, the construction of a lined detention pond on top of tailings pile 1 would be evaluated in the event that installation of hydrostatic bulkheads within the underground workings is determined to be less practicable or would significantly increase risks to workers. The pond would be sized to provide surge storage and reduce seasonal loading spikes to Railroad Creek to the extent possible.

Remediation components included under Alternative 2 are summarized on Table ES-1.

Alternative 3 – Water Management and Low-energy West Area Treatment

Alternative 3 would include the common remediation components described previously for the East and West Areas and the actions described under Alternative 2 with the addition of:

- Downgradient Collection of the Portal Drainage and West Area Groundwater and Seeps – The portal drainage, and seeps SP-23 and SP-12 would be collected in trenches or catch basins for treatment prior to discharge to Railroad Creek.

- Upper West Area Barrier Wall and Collection System – A barrier wall/collection system would be installed downgradient of the east and west waste rock piles, maintenance yard, and mill building to intercept groundwater and seeps SP-6, SP-7, SP-8, SP-15W, SP-15E, and SP-19 for treatment prior to discharge to Railroad Creek.

- Low-energy Physical/Chemical Treatment of Collected West Area Water – Intercepted West Area water would be directed toward the lagoon area for the removal of aluminum, cadmium, copper, iron, zinc, and other metals through controlled chemical addition, aeration, precipitation, clarification, and media filtration in unlined treatment ponds. The system would be designed to be energy efficient, utilizing existing topography to convey water through the system and features such as drop structures to provide aeration. The energy-efficient conventional alkaline precipitation system included under this alternative is termed the "low-energy" treatment system in this FS.

As described for Alternative 2, there are two subalternatives under Alternative 3 (designated as 3a and 3b) providing varying degrees of 1500-level main portal drainage control. These two subalternatives include:

- Alternative 3a – No portal drainage flow control; and
- Alternative 3b – Hydrostatic bulkheads and other in-mine flow controls in the 1500-level.

Remediation components included under Alternative 3 are summarized on Table ES-1.

Alternative 4 – Water Management and East Area Collection and Treatment (Low-energy Treatment)

Alternative 4 would include the common remediation components described for the East and West Areas and the actions described under Alternative 2b (Hydrostatic Bulkhead) with the addition of:

- Downgradient Collection of East Area Seeps and Groundwater – East area seeps and groundwater would be intercepted and directed to treatment systems constructed using area available at the southeastern corners of tailings piles 1and/or 3.
- Low-energy Chemical/Physical Treatment of Collected East Area Water – Intercepted East Area water would be treated for the removal of iron and other metals through chemical addition, aeration, precipitation, clarification, and aerobic wetland polishing in unlined treatment ponds.
- Railroad Creek Rehabilitation – Select reaches of Railroad Creek would be rehabilitated to remove ferricrete and enhance aquatic and terrestrial habitat along the stream corridor adjacent to the Site.
- Monitored Natural Attenuation in the East and West Areas – MNA would be implemented in the East (Alternative 4a only) and West Areas in conjunction with the remedial measures included under Alternative 4 to reduce the release of PCOCs over time.

Collection and treatment in the West Area is not included under Alternative 4. Remediation components included under Alternative 4 would be designed to divert upgradient surface water and shallow groundwater around source areas, and collect and treat groundwater and seepage downgradient from the tailings piles in the East Area. There are three subalternatives under Alternative 4 (designated as 4a, 4b, and 4c) that vary the method and extent of East Area water collection and treatment. These three subalternatives include:

- Alternative 4a – Partial East Area Collection and Treatment – Partial open-trench collection systems, approximately 1,000 feet long would be installed along the base of tailings piles 1 and 3 to collect groundwater and seeps naturally flowing toward these areas. To enhance groundwater collection efficiencies and minimize losses from Railroad Creek to the collection trenches, barrier walls would be installed to the low-permeability till or bedrock between the creek and collection trenches. The partial relocation of Railroad Creek would be required for the construction of a treatment system to the east of tailings pile 1.
- Alternative 4b – Extended East Area Collection and Treatment – Extended collection systems, consisting of deep collection trenches and barrier walls would be installed along the entire base of tailings piles 1, 2, and 3. The partial relocation of Railroad Creek would be required under this subalternative.

- Alternative 4c – Extended Relocation of Railroad Creek and East Area Collection and Treatment – An extended segment of Railroad Creek, from approximately the mid-point of tailings pile 1 to downstream of tailings pile 3, would be relocated to the north ,and an open-trench collection system would be installed along the length of the former Railroad Creek channel.

Remediation components included under Alternative 4 are summarized on Table ES-1.

Alternative 5 – Water Management and East/West Area Collection and Treatment (Low-energy Treatment)

Alternative 5 would include the common remediation components described for the East and West Areas and combine the additional components included under Alternatives 3b (Water Management and West Area Collection and Treatment - Hydrostatic Bulkhead) and Alternative 4 (Water Management and East Area Collection and Treatment).

Actions included under Alternative 5 would be designed to divert upgradient surface water and shallow groundwater around source areas and collect downgradient groundwater and seepage in the East and West Areas. Collection and treatment of East and West Area waters would be performed to reduce the loading of aluminum, cadmium, copper, iron, and zinc to groundwater and surface water, and improve aquatic habitat in Railroad Creek. There are four subalternatives under Alternative 5 (designated as 5a, 5b, and 5c, and 5d) that vary the method and extent of water collection and treatment. These four subalternatives include:

- Alternative 5a – Partial East Area Collection and East/West Area Treatment (Low-energy WTP) – Combines the remedial components described under Alternatives 3b and 4a.

- Alternative 5b – Extended East Area Collection and East/West Area Treatment (Low-energy WTP) – Combines the remedial components described under Alternatives 3b and 4b.

- Alternative 5c – Extended Railroad Creek Relocation and East/West Area Treatment (Low-energy WTP) – Combines the remedial components described under Alternatives 3b and 4c.

- Alternative 5d – Secondary West Area Collection, Extended Railroad Creek Relocation, and East/West Area Treatment (Low-energy WTP) – Combines the remedial components described under Alternatives 3b and 4c, and adds the secondary collection of lower West Area groundwater through the installation of a barrier wall/collection drain adjacent to Railroad Creek from the approximate location of station P-5 to the western edge of tailings pile 1. Water collected in the secondary collection system would be conveyed to the East Area for treatment.

To efficiently treat both East and West Area water, treated overflow from the West Area treatment systems under Alternatives 5a through 5d would possibly be diverted to the East Area to provide alkalinity addition and pH control. Remediation components included under Alternative 5 are summarized on Table ES-1.

Alternative 6 – Water Management and West/East Area Collection and Treatment (Mechanical Treatment)

Alternative 6 was proposed for inclusion in the FS by the Agencies in a transmittal dated January 2, 2003. Alternative 6 would combine the remedial components included under Alternative 3 (Water Management and West Area Treatment) and 4c (Water Management, Extended Railroad Creek Relocation, and Extended East Area Collection and Treatment) and add the following:

- Mechanical Water Treatment in the West Area – A mechanical water treatment system would be constructed in the West Area for treatment of the portal drainage, groundwater and seeps. For purposes of the FS, a high density sludge (HDS) system was assumed for the mechanical treatment of West Area waters.

- Extended Lower (Secondary) West Area Collection – A barrier wall and collection trench system, extending approximately 3,500 linear feet west of tailings pile 1 to the approximate location of seep SP-26 would be installed on the south side of Railroad Creek to collect seeps and groundwater from the lower West Area for treatment prior to discharge. The barrier wall would be keyed into depth till or bedrock in this area.

As described for Alternative 3, there are two subalternatives under Alternative 6 (designated as 6a and 6b) providing varying degrees of 1500-level main portal drainage control. These two subalternatives include:

- Alternative 6a – No portal drainage flow control; and
- Alternative 6b – Hydrostatic bulkheads and other in-mine flow controls in the 1500-level.

Remediation components included under Alternative 6 are summarized on Table ES-1.

Alternative 7 – Capping, Consolidation, Water Management and West Area Treatment

Alternative 7 would include the common remediation components described for the East and West Areas and the actions included under Alternative 3b (Water Management and West Area Treatment with Hydrostatic Bulkhead), with the addition of:

- Consolidation of Tailings Pile 1, 2, and 3 – The three tailings piles would be consolidated onto the approximate footprint of tailings pile 2.

- Low-permeability Cover Placement - A low-permeability cover would be installed on the consolidated tailings pile to reduce surface water infiltration. Under this alternative, Railroad Creek would not be relocated and riprap would be placed along the banks of Railroad Creek to reduce the potential for contact with the consolidated pile during high stream flows.

Tailings pile consolidation would be performed to reduce contact between tailings materials and surface water and groundwater by reducing the overall surface area and footprint of the pile. Remediation components included under Alternative 7 are summarized on Table ES-1.

Alternative 8 – Source Control and East/West Area Treatment

Alternative 8 would include the remediation components described under Alternative 7 (Capping, Consolidation, Water Management and West Area Treatment) with the addition of:

- Waste Rock Pile Consolidation - The east and west waste rock piles would be relocated onto the consolidated tailings pile.

- Extended East Area Collection and Treatment – A deep barrier wall and collection trench would be installed at the base of the consolidated pile to intercept East Area groundwater for low-energy treatment prior to discharge.

Actions included under this alternative are designed to provide full containment of source materials to the extent possible. Following consolidation of waste rock and tailings materials, the consolidated pile would be covered, and groundwater and seeps in the East Area would be collected and treated prior to discharge. West Area treatment would be performed as described under Alternative 3b. Remediation components included under Alternative 8 are summarized on Table ES-1.

RESULTS OF THE COMPARATIVE ANALYSIS

A detailed analysis of the eight candidate remedial alternatives was conducted with respect to the criteria developed in accordance with CERCLA, MTCA, and the AOC, followed by a comparative evaluation. Results of the comparative analysis are summarized in the following subsections.

Threshold Criteria

The following subsections provide the results of the comparative analysis for the two threshold criteria:

- Overall protection of human health and the environment; and
- Compliance with potential ARARs.

Overall Protection of Human Health and the Environment

The comparative analysis of overall protection of human health and the environment, including the protection of human health and terrestrial ecological receptors, the protection of aquatic life, and the potential for short-term impacts to workers, the local community, and environment during remedy implementation is summarized on Table 8-1 and in the following subsections.

Protection of Human Health and Terrestrial Ecological Receptors. Results of the human health risk assessment presented in the DRI indicate no existing unacceptable risks to Holden Village residents or visitors based on current reasonable maximum exposures to PCOCs within Site surface water, groundwater, sediment, and air. Alternatives 1 through 8 would eliminate potential future risks to human health resulting from possible land use scenarios through the implementation of institutional controls. Physical access restrictions included under Alternatives

1 through 8 would also reduce potential physical hazards to residents and visitors associated with site features related to historical mining activities.

Alternative 2a through 8 would further protect human health and terrestrial ecological receptors though the removal, containment, and/or covering of site soils with PCOCs above potential ARARs. Under these alternatives, the soil RAO to achieve soil quality that is protective of human health and the environment would be achieved following remedy implementation.

Protection of Aquatic Life. Alternatives 2a through 8 would reduce PCOC loadings to surface water and groundwater in the short term through the implementation of a combination of source controls, upgradient water diversion, and collection and treatment of the portal drainage, seeps, and groundwater downgradient of site sources. Based on site-specific geochemical evaluations, additional reductions in PCOC loadings from sources, including the underground mine, waste rock, and tailings piles, are expected under all of the alternatives in the long term through natural attenuation.

Alternatives 3a, 3b, and 5a through 8, which include the collection and treatment of the portal drainage and upper West Area seeps and groundwater, would significantly reduce the release of cadmium, copper, and zinc to groundwater and surface water. Based on the results of the post-remediation loading analysis, summarized on Tables ES-2 through ES-4, and site-specific toxicological evaluations, these alternatives are all expected to result in PCOC concentrations in Railroad Creek that are protective of resident aquatic species, including salmonids and their prey, following remedy implementation. While Alternatives 2a, 2b, 4a, 4b, and 4c, would also reduce copper, cadmium, and zinc loading to groundwater and surface water, predicted short-term seasonal PCOC concentrations in Railroad Creek may result in continued potential risks to aquatic life.

Groundwater and seeps from the East Area contribute a majority of the seasonal aluminum and iron loading to Railroad Creek. However, the toxicological evaluations provided in Appendix H indicate that existing concentrations of aluminum and iron are not expected to impact aquatic life in Railroad Creek. Alternatives 4a through 8, which include the collection and treatment of East Area seeps and groundwater, and/or consolidation and capping of the tailings piles, would provide greater reductions in iron loadings to groundwater and surface water in the short term. All of the alternatives are expected to meet potential ARARs in the long term through natural attenuation.

The RAOs for groundwater and surface water are to meet potential ARARs within a reasonable restoration time frame. Compliance with ARARs is discussed below.

Potential for Short-term Impacts. Appropriate measures would be implemented under Alternatives 1 through 8 to protect workers, Holden Village residents, and visitors from potential risks due to increased traffic and heavy equipment operation during remedy implementation. A temporary stream crossing would likely be constructed over Railroad Creek at the northeast corner of tailings pile 3 to allow some of the vehicles and equipment to bypass the Village during construction activities under Alternatives 2a through 8. As a result, the RAO to implement the remedial action in a manner that is protective of human health, including the Holden Village community, would be met under Alternatives 2a through 8. However, under all of the alternatives, the increased heavy equipment and truck traffic on the road to the east of the Holden Village would result in short-term impacts to the local community, including the routine Holden Village bus and supply vehicle traffic, disruption to pedestrian use in the area, and increased noise levels.

Alternatives 1 through 3b would result in the lowest level of potential impacts to workers and the local community. Alternatives 4a through 5d would present increased safety concerns relative to Alternatives 1 through 3b due to the additional construction activities required for tailings regrading and the collection and treatment of East Area waters. Alternatives 4a through 5d also include partial or extended relocation of Railroad Creek, which would result in increased equipment operation on the north side of the current Railroad Creek channel, presenting increased safety risks and potential noise impacts to the Holden Village. The relocation of Railroad Creek to the north would also result in visual impacts due to tree removal. Potential safety concerns would be further increased under Alternatives 6a and 6b due to the implementation of mechanical treatment in the West Area. The additional construction, operation and maintenance, fuel delivery, and fuel storage requirements under Alternatives 6a and 6b would result in increased traffic and risk of fire or accidents at the Site, as well as increased barge traffic on Lake Chelan. Potential safety concerns and impacts to the local community would be the highest under Alternatives 7 and 8 due to the significantly increased construction effort, transportation of cover materials, extended duration of construction required for tailings pile capping and/or consolidation, and greater potential for the generation of fugitive dust and vehicle emissions.

Alternatives 2a, 3a, and 3b provide the lowest potential for short-term environmental impacts during remedy implementation, followed by Alternative 2b (hydrostatic bulkheads without treatment) and Alternatives 4a, 4c, 5a, 5c, and 5d. Alternatives 4b, 5b, 6a, 6b, 7, and 8 present a higher potential for short-term water quality degradation due to extended barrier wall construction along the south bank of Railroad Creek, large volumes of unoxidized tailings exposed during regrading and consolidation activities, and greater potential for material erosion and impacted runoff during construction.

Compliance with Potential ARARs

Compliance with potential chemical-specific, location-specific, and action-specific ARARs is evaluated in the following subsections.

Potential Chemical-specific ARARs – Surface Water. Under all of the alternatives, potential chemical-specific ARARs for surface water are currently being met, and would continue to be met, in Copper Creek, Lake Chelan, and Railroad Creek upstream of the Site. Alternatives 2a through 8 would all result in short- and long-term improvements to surface water quality in Railroad Creek adjacent to and downstream of the Site. Under Alternative 1 (No Action) seasonal PCOC concentrations in Railroad Creek are expected to decline over time through natural attenuation. However, seasonal exceedances of potential ARARs are expected to continue under Alternative 1 in the long term.

Results of the post-remediation loading analysis, presented in Tables ES-1 through ES-4, indicate Alternatives 5a, 5b, 5c, 5d, 6a, 6b, 7, and 8 would achieve the potential SWQC within approximately 50 years. Alternatives 3a and 3b are predicted to achieve the SWQC for dissolved cadmium and copper within 50 years, but seasonal concentrations of zinc are predicted to slightly exceed the SWQC. The analysis predicts the SWQC for zinc would be achieved under Alternatives 3a and 3b within approximately 250 years. Alternatives 2a, 2b, 4a, 4b, and 4c, which do not include West Area treatment, are predicted to achieve the SWQC for cadmium within approximately 50 years, and the SWQC for copper and/or zinc within approximately 250 years.

Alternatives 3b, 5a, 5b, 5c, 5d, 7, and 8 are predicted to achieve the NRWQC within approximately 50 years. Alternatives 6a and 6b are predicted to achieve the NRWQC for copper and zinc within approximately 50 years and the NRWQC for cadmium within approximately 250 and 150 years, respectively. Alternatives 2a, 2b, 3a, 4a, 4b, and 4c are predicted to achieve the NRWQC within approximately 250 years. Although the post-remediation loading analysis could not be performed for total aluminum or iron, the site-specific geochemical analyses indicate that aluminum concentrations would approach background (background concentrations seasonally exceed the chronic NRWQC) and iron concentrations would be below the potential NRWQC within approximately 50 years under all of the alternatives.

Although the results of the loading analysis indicate seasonal PCOC concentrations in Railroad Creek may exceed potential chemical-specific ARARs in the short term under all of the alternatives, the site-specific toxicological evaluations conclude that water quality under Alternatives 3a, 3b, and 5a through 8 would be protective of resident aquatic species in the short term following remedy implementation.

Potential Chemical-specific ARARs - Groundwater. Under all of the alternatives, portions of the seeps and groundwater beneath the Site would not meet potential chemical-specific ARARs in the long term. Based on the analyses presented in this FS, there is no practical approach to achieve potential groundwater ARARs throughout the Site. Therefore, a conditional point of compliance would be required to establish cleanup standards for site groundwater. Under MTCA, the establishment of a conditional point of compliance would require that groundwater discharges be treated using AKART before being released into surface water. The extent to which each of the alternatives would meet the AKART requirement is based on the extent to which groundwater collection and treatment at the Site is practicable.

Conditional points of compliance for groundwater in surface water would be appropriate for both the East and West Areas for Alternatives 3a, 3b, and 5a, through 8. Based on the evaluations included in this FS, upgradient water diversions and source controls in the East and West Areas, combined with upper West Area collection and treatment (using either low-energy or mechanical alkaline precipitation systems) constitute AKART for this site.

Based on the results of the loading analysis and information provided above, Alternatives 5a, 5b, 5c, 5d, 7, and 8 are expected to achieve potential chemical-specific ARARs for groundwater at points within Railroad Creek (represented by stations RC-4 and RC-2) within approximately 50 years. These stations are considered to be generally representative of water quality in Railroad Creek downstream of West and East Area sources. However, it may take longer for some locations within the creek to achieve potential ARARs. Alternative 5d, which includes the installation of a secondary barrier wall and groundwater collection system in the lower West

Area is also likely to achieve potential groundwater ARARs in the short term upstream of RC-4, with the exception of seep SP-26. Alternatives 6a and 6b, which include the installation of an extended secondary barrier wall and groundwater collection system in the lower West Area, would likely achieve potential groundwater ARARs in the short term upstream of RC-4. However, under Alternatives 6a and 6b, seasonal concentrations of cadmium are predicted to slightly exceed potential groundwater ARARs downstream of RC-4 for approximately 250 years and 150 years, respectively. Alternative 3b is expected to meet potential groundwater ARARs at points in Railroad Creek within approximately 50 years, with the exception of minor seasonal exceedances for zinc. Potential groundwater ARARs are expected to be met within approximately 250 years under both Alternatives 3a and 3b.

Because Alternatives 2a, 2b, 4a, 4b, and 4c do not include West Area collection and treatment, these alternatives would not likely meet potential chemical-specific ARARs for West Area groundwater in the short or long term. Alternatives 2a, 2b, 4a, 4b, and 4c would likely meet potential groundwater ARARs in the East Area within approximately 250 years through natural attenuation.

Potential Chemical-specific ARARs - Soils. Potential chemical-specific ARARs for soils would not be achieved under Alternative 1. Under Alternatives 2a through 8, soils with concentrations above the potential MTCA Method B soil cleanup standards would be excavated and contained on site or covered in-place. These alternatives would meet the potential chemical-specific ARARs for soil.

Potential Location-Specific ARARs. No location specific ARARs would apply under Alternative 1. Alternatives 2a through 8 would meet all potentially applicable location-specific ARARs. The specific requirements of these ARARs would be identified through consultation with the federal and state agencies during the RD/RA. The remedial actions included under Alternatives 2a through 8 are not expected to influence archaeological and/or historic sites of significance. Construction-related activities, including excavation or earthmoving would consider the presence of historic or culturally important sites, structures or objects, historical and archeological data, and Native American burial sites, and if present, minimize impacts to such resources.

Construction activities would also be conducted to minimize potential impacts to fish and wildlife, and coordination with WDFW and USFWS would be conducted during the remedial design to identify potentially applicable substantive requirements and incorporate mitigative measures into the design as necessary.

Potential Action-Specific ARARs. The institutional controls, physical access restrictions, and long-term monitoring included under Alternative 1 would meet potential action-specific ARARs. The activities included under Alternatives 2a through 8 would comply with potential action-specific ARARs through the use of best management practices, the implementation of institutional controls, and monitoring. Substantive compliance with potential action specific ARARs would be evaluated during the design through consultation with WDFW, USACOE, EPA, DNR, and Ecology.

Primary Balancing Criteria

The following subsections provide the results of the comparative analysis for the five balancing criteria:

- Long-term effectiveness and permanence;
- Reduction of toxicity, mobility, and volume;
- Short-term effectiveness;
- Implementability; and
- Cost.

Long-term Effectiveness and Permanence

The comparative evaluation of long-term effectiveness and permanence, including magnitude of residual risk and the adequacy of reliability of environmental controls is provided in the following subsections.

Magnitude of Residual Risk. As stated previously, the results of the DRI indicate that there are no human health risks at the Site under current exposure and land use scenarios. Alternatives 1 through 8 would provide adequate protection of human health under potential future scenarios through the implementation of institutional controls. The installation of physical access restrictions would also reduce potential physical hazards to residents and visitors associated with historical mining activities. As a result, the magnitude of remaining human health risks would be low under Alternatives 1 through 8.

Alternatives 2a through 8 include the removal and/or covering of soils in areas with PCOC concentrations above potential Agency-required ARARs for the protection of terrestrial ecological receptors. Therefore the magnitude of residual risks to terrestrial ecological receptors would also be low under Alternatives 2a through 8. Areas identified as presenting a potential risk to terrestrial ecological receptors would not be addressed under Alternative 1.

Significant long-term improvements in Railroad Creek water quality are expected under Alternatives 3a, 3b, and 5b through 8, through the implementation of source controls, upgradient water diversions, West Area collection and treatment, and natural attenuation. Based on the results of the post-remediation loading analysis, summarized in Tables ES-2 through ES-5, and site-specific toxicological analyses, post-remediation PCOC concentrations in Railroad Creek would be protective of resident aquatic species, including salmonids and their prey, following the implementation of these alternatives. Because Alternative 3a does not include equalization of the portal drainage prior to treatment, the magnitude of seasonal exceedances for cadmium and copper are expected to be slightly higher in the long term than for Alternatives 3b, and 5a through 6b. Alternatives 4a, 4b, and 4c include the collection and treatment of East Area groundwater and seeps; however, these alternatives are expected to provide lower reductions in PCOC concentrations than Alternatives 3a, 3b, and 5a through 8, which include West Area collection and treatment. Alternatives 2a and 2b would provide the lowest reductions in PCOC concentrations in Railroad Creek.

The tailings pile slope stability actions included under Alternatives 2a through 8 would be expected to significantly reduce the potential for release of tailings to Railroad Creek in the event of a slope failure. The installation of hydrostatic bulkheads and other in-mine flow controls (or equalization basins outside of the mine) under Alternatives 2b, and 3b through 8 would also reduce the potential risk of sudden surge flows from the 1500-level main portal.

Adequacy and Reliability of Environmental Controls. The actions included under Alternative 3b, including institutional controls, physical access restrictions, source controls, upgradient water diversions, tailings pile regrading, West Area flow equalization, and the collection and low-energy treatment of the portal drainage and upper West Area seeps and groundwater are expected to significantly reduce PCOC releases to groundwater and surface water in the short and long term. These actions, including low-energy treatment using controlled chemical addition, aeration, and settling ponds would be expected to have a high degree of reliability in the long term. The low-energy treatment process would utilize equivalent unit processes as included for the mechanical treatment system under Alternatives 6a and 6b. Alternative 3a, which includes low-energy treatment in the West Area without flow equalization would also provide significant reductions in PCOC loadings to groundwater and surface water, but is expected to be less reliable due to the rapid fluctuations observed in portal drainage and groundwater flows during the spring flush.

The collection and treatment of East Area groundwater and seeps under Alternatives 4a through 5d, and 8 is predicted to result in additional short-term reductions in PCOC loadings from the tailings piles (primarily aluminum, iron, and zinc), however these actions are expected to provide a lower degree of reliability in the long-term. Collection and treatment systems installed at the base of the tailings piles under these alternatives would be difficult to construct due to the depth to low-permeability glacial till or bedrock, variable subsurface conditions, relatively flat grade, and proximity to Railroad Creek. The long-term operation of collection and treatment systems in the East Area would also have a lower degree of reliability due to the difficulty in providing adequate flow equalization, high concentrations of iron in the East Area groundwater and seeps that would likely cause fouling of collection systems, significant chemical addition requirements, and sludge generation rates. The extended groundwater collection system under Alternatives 4b and 5b would be particularly prone to fouling and plugging with metal precipitates compared to the open collection systems included under Alternatives 4a, 4c, 5a, 5c, 5d, 6a, and 6b.

The effectiveness of the additional West Area actions included under Alternatives 6a and 6b would rely on the ability to provide adequate power and operation and maintenance of treatment system equipment, including pumps, mixers, clarifiers, filters, and scrapers in the long term. As a result, these actions are expected to have lower long-term reliability, especially during the winter months when access to the Site from Lake Chelan is not possible. Additionally, a mechanical treatment system that utilizes tanks, pumps, and other mechanical equipment would have a more limited operating range, and is not expected to be as flexible as a low-energy system in handling flow or water quality variations.

The long-term effectiveness of consolidation and capping of the tailings piles and/or waste rock piles under Alternatives 7 and 8 would be highly dependent on the ability to maintain the large cover system. Long-term maintenance would be required under these alternatives to ensure cover integrity and prevent the establishment of deep-rooted plants.

The actions included under Alternatives 2a and 2b are expected to be adequate and reliable in protecting human health and terrestrial ecological receptors and reducing PCOC loadings to groundwater and surface water. However, the collection and low-energy treatment of the portal drainage and West Area seeps and groundwater under Alternatives 3a, 3b, 5a, 5b, 5c, 5d, 7, and 8 is expected to provide greater short-term improvements in groundwater and surface-water quality with a high degree of reliability.

The institutional controls and physical access restrictions included under Alternative 1 would be adequate and reliable in mitigating potential risks to human health related to historical mining features. However, these actions are not expected to adequately protect terrestrial ecological receptors, or mitigate PCOC releases to groundwater or surface water in the short term.

Reduction of Toxicity, Mobility, and Volume

The alkaline precipitation processes included for the East and West Areas under Alternatives 3a through 8 would reduce the mass and volume of PCOCs released to groundwater and surface water. The treatment processes would produce stable treatment residuals, and thus reduce the mobility and toxicity of PCOCs to environmental receptors. The volume of impacted materials requiring management would increase with the sludge generated from the water treatment processes.

Additionally, the mass, and therefore volume, of PCOCs released to groundwater and surface water would be reduced from site sources over time through the natural geochemical processes described in Appendix E.

Stabilization processes included under Alternatives 2a through 8 for limited quantities of solid media determined to be characteristic hazardous wastes would produce a stable product and reduce constituent mobility to environmental receptors.

Short-term Effectiveness

The comparative evaluation of short-term effectiveness, including protection of local communities, worker protection, environmental impacts, and time required to reach remediation goals is provided in the following subsections.

Protection of Local Communities. Alternative 1, which does not include significant construction or operation and maintenance activities, would present the lowest short-term risks to the local community. Appropriate measures would be implemented under Alternatives 2a through 8 to protect Holden Village residents and visitors from potential risks due to increased traffic and heavy equipment operation during remedy construction and implementation. A temporary stream crossing would be constructed over Railroad Creek at the northeast corner of tailings pile 3, to allow some of the vehicles and equipment to bypass the Village during construction. However, the increased heavy equipment and truck traffic on the road to the east of the Village would result in short-term impacts to the local community, including the routine Village bus and supply vehicle traffic, disruption to pedestrian use in the area, and increased noise levels.

Alternatives 1 through 3b would present fewer short-term safety concerns and noise impacts to Holden Village residents and visitors than Alternatives 4a through 8. Alternatives 4a through 5d would present increased risks and noise impacts to the Holden Village community due to the partial or extended relocation of Railroad Creek to the north. Railroad Creek relocation would require increased construction on the north side of Railroad Creek near several of the Holden Village facilities, and removal of trees that currently provide a visual screen of the tailings piles. Additional long-term risks to the Holden Village community would result from the implementation of mechanical treatment in the West Area under Alternatives 6a and 6b. The significant long-term equipment operation and maintenance, power generation, fuel delivery, and fuel storage requirements under these alternatives would result in increased traffic and potential for accidents or fire at the Site, and increased barge traffic on Lake Chelan. The estimated fuel consumption for a mechanical treatment facility would be approximately 95,000 to 125,000 gallons per year. This would require storage of approximately 50,000 gallons of fuel on site during the winter months for continued operation.

Alternatives 7 and 8, which include the consolidation and capping of the tailings piles, would present the greatest short-term risks to the Holden Village community, due to the significantly increased traffic and heavy equipment operation required for tailing consolidation and capping, and the increased potential for fugitive dust and other air emissions (e.g., carbon dioxide, hydrocarbons, and nitrogen oxides). These alternatives would require a large fleet of heavy equipment operating for at least three seasons, and consuming approximately 700,000 gallons of diesel fuel.

Alternatives 2a though 8 would also present potential physical hazards related to the development of the talus slope west of Tenmile Creek, which would be used as a source of rip rap. However, engineering controls such as the construction of gabion walls would be expected to adequately reduce this risk.

Worker Protection. Alternative 1, which does not include significant construction or operation and maintenance activities, would present the lowest potential short-term risks to workers, followed by Alternatives 2a and 3a. There would be an increased potential risk under Alternatives 2b and 3b due to the installation of hydrostatic bulkheads and in-mine water controls underground within the 1500 level of the mine. Adherence to MSHA standard safety protocols would be maintained to reduce this potential risk.

In general, the risk of worker injury increases with the overall level of construction, operation, and maintenance activities required by an alternative. Above-ground construction activities are estimated to present similar levels of risk to workers. Therefore, increased risk is proportional to the increased level of effort required for alternative implementation, as described above. For example, the application of accident rates recorded by the Washington State Department of Labor and Industry for heavy construction activities in 2001 to the estimated crew size required to implement Alternatives 7 and 8 (approximately 100 people per season) indicates approximately 8 to 9 injuries and the potential for a fatality (estimated fatality rate of approximately 0.5 deaths) could be expected over the 3-year implementation period.

Environmental Impacts. Alternatives 2a, 3a, and 3b provide the lowest potential for short-term environmental impacts during remedy implementation, followed by Alternative 2b (hydrostatic bulkheads without treatment) and Alternatives 4a, 4c, 5a, 5c, and 5d. Alternatives 4b, 5b, 6a, 6b, 7, and 8 present a higher potential for short-term water quality degradation due to extended barrier wall construction along the south bank of Railroad Creek, large volumes of unoxidized tailings exposed during regrading and consolidation activities, and greater potential for material erosion and impacted runoff during construction.

The increased fuel requirements for construction and/or long-term operations under Alternatives 4b, 5b, 6a, 6b, 7, and 8 would significantly increase the potential for accidental fuel releases to the environment during transport up Lake Chelan and the Railroad Creek valley.

Time Required to Reach Remediation Goals. Implementation of Alternatives 2a through 8 would be expected to occur over a one- to three-year period at which time soil RAOs would be met. Alternatives 7 and 8 would take the longest to implement due to the large material handling and low-permeability capping requirements. Alternatives 2a, 2b, 3a, 3b, 4a, and 5a would take the least amount of time to implement.

Under all of the alternatives, surface-water RAOs are currently being met, and would continue to be met, in Copper Creek, Lake Chelan and Railroad Creek upstream of the Site. Alternatives 5a, 5b, 5c, 5d, 7, and 8 are predicted to achieve the surface-water RAOs within approximately 50 years. Alternative 3b is also predicted to achieve surface-water RAOs within approximately 50 years, with the exception of seasonal concentrations of zinc that are predicted to slightly exceed the chronic SWQC. Alternative 3b is expected to achieve the SWQC for zinc within approximately 250 years. Similarly, Alternatives 6a and 6b are predicted to meet surface-water RAOs within approximately 50 years, with the exception of cadmium concentrations, which are predicted to slightly exceed the Agency-required NRWQC. Through natural attenuation, the NRWQC for cadmium is predicted to be met under Alternatives 6a and 6b within approximately 250 and 150 years, respectively.

Alternatives 2a, 2b, 3a, 4a, 4b, and 4c are predicted to achieve surface-water RAOs within approximately 250 years. Under Alternative 1 (No Action) seasonal PCOC concentrations in Railroad Creek are expected to decline over time through natural attenuation. However, potential surface water RAOs are not expected to be met under this alternatives in the long term.

Alternatives 5a, 5b, 5c, 5d, 7, and 8 are expected to achieve groundwater RAOs within approximately 50 years. Alternative 5d, which includes the installation of a secondary barrier wall and groundwater collection system in the lower West Area is also likely to achieve groundwater RAOs in the short term upstream of RC-4, with the exception of seep SP-26. Similarly, Alternatives 6a and 6b, which include the installation of an extended secondary barrier wall and groundwater collection system in the lower West Area, would also likely achieve groundwater RAOs in the short term upstream of RC-4. Alternatives 3a and 3b are expected to achieve groundwater RAOs within approximately 50 years, with the exception of minor seasonal exceedances for zinc. Potential groundwater RAOs are expected to be met under Alternatives 3a and 3b within approximately 250 years.

Although site groundwater quality would improve over time under Alternatives 2a, 2b, 4a, 4b, and 4c, through natural attenuation, West Area groundwater would not likely meet RAOs in the short or long term under these alternatives. Alternatives 2a, 2b, 4a, 4b, and 4c are expected to meet potential groundwater ARARs in the East Area within approximately 250 years through natural attenuation. Alternative 1 is also not expected to meet Groundwater RAOs in the short or long term.

Implementability

The comparative evaluation of implementability, including technical and administrative feasibility and the availability of services and materials is provided in the following subsections.

Technical and Administrative Feasibility. Alternatives 1, 2a and 2b would have the highest degree of technical implementability, followed by Alternatives 3a and 3b. While Alternatives 3a and 3b involve long-term treatment of the portal drainage and downgradient West Area water, the collection and low-energy treatment systems proposed under this alternative have been successfully implemented at other sites, and are based on conventional construction techniques and treatment technologies. Alternative 3b would be more implementable than Alternative 3a due to the control and equalization of the portal drainage and upper West Area seeps and groundwater.

Alternatives including treatment of downgradient East Area water (Alternatives 4a through 6b and 8) would be generally less implementable than Alternatives 2a through 3b due to the increased complexity of installing systems to collect and treat East Area ground water and the long-term chemical addition and sludge disposal requirements. Of these alternatives, the East Area collection and treatment systems proposed under Alternatives 4c, 5c, 5d, 6a, and 6b would be generally more implementable due to reduced slope regrading requirements and the use of open collection trenches with limited barrier wall construction.

The mechanical treatment system and extended secondary barrier wall/collection system included under Alternatives 6a and 6b would have generally lower technical implementability than the West Area actions included under Alternatives 3a through 5d, 7, and 8. The extended lower barrier wall/collection system would be difficult to effectively implement due to construction on steep side slopes, variable topography, and variable subsurface conditions. The long-term operation of a mechanical treatment system in the West Area would also be difficult due to the significant operation and maintenance requirements, and reliance on diesel-powered electricity generation and fuel storage.

Although the actions included under Alternatives 7 and 8 would use conventional equipment and construction techniques, these alternatives would have lower technical implementability relative to the other alternatives due to the magnitude and duration of construction activities required for remedy implementation. A large fleet of heavy equipment operating over at least three construction seasons would be required to complete tailings pile consolidation and capping.

Because Alternative 1 does not include any active remedial measures, this alternative would have the lowest administrative implementability. In general, for Alternatives 2a through 8, the administrative implementability of an alternative is reduced with increasing complexity and construction duration. For example, Alternatives 4c and 5c through 6b would require significantly increased coordination with local Agencies and the Holden Village for relocation of Railroad Creek. Alternatives 7 and 8 would have a reduced administrative implementability relative to the other alternatives due to the increased traffic, borrow source development, and construction duration for consolidation and capping of the tailings piles.

Availability of Services and Materials. Specialized equipment and personnel required for the underground mine actions proposed under Alternatives 2a through 8 are expected to be readily available in the area. Alternatives 3a through 8 would require on site personnel for long-term collection and treatment system O&M. Treatment system chemicals and fuel required for implementation of Alternatives 3a through 8 would need to be continuously imported to the Site by barge and truck.

Suitable rip rap and rock required for implementation of Alternative 2a through 8 would be available within approximately 2 miles of the Site near Tenmile Creek. Gravel would likely be obtained from the Dan's Camp quarry located near Lucerne, as needed.

Due to the Site setting within a narrow glacial valley, limited sources of soil suitable for development exist within the Railroad Creek watershed. As a result, soil requirements to provide adequate protection of a low-permeability cover system would reduce the implementability of Alternatives 7 and 8. To provide sufficient cover protection, a large local source of material would need to be developed, or material would need to be imported to the Site by barge and truck.

Cost

Total capital and O&M costs are summarized on Table ES-6. Total costs are provided in 2004 dollars at a 7-percent discount rate). Alternative 1 (No Action/ Institutional Controls) has the lowest estimated total project cost at $2,730,000, followed by Alternatives 2a and 2b. The estimated total costs for Alternatives 2 and 3 range between $18,760,000 and $34,420,000. The estimated costs for Alternatives 4 and 5 are higher than Alternatives 1, 2, and 3, with Alternatives 4b and 5b having higher estimated capital costs than the other subalternatives. The estimated costs of Alternatives 6a and 6b are higher than for Alternative 5d, due to the extended secondary collection and treatment of lower West Area groundwater, and the implementation of mechanical treatment in the West Area. Alternatives 7 and 8 have the highest estimated costs due to consolidation and capping of the tailings piles and/or waste rock piles. The total estimated costs associated with Alternatives 7 and 8 are approximately $100,400,000 and $112,960,000, respectively.

Additional requirement under MTCA and the AOC

The following subsections provide the results of the comparative analysis for following additional criteria under MTCA and the AOC:

- Use of permanent solutions to the maximum extent practicable;
- Reasonable restoration timeframe; and
- Natural resource restoration.

Use of Permanent Solutions to the Maximum Extent Practicable

Based on the comparative analysis of alternatives Alternative 3b would provide a permanent solution to the maximum extent practicable. Alternative 3b is expected to provide a high-level of overall protection of human health, terrestrial ecological receptors, and aquatic life following remedy implementation in the short and long term. The results of the post-remediation loading analysis indicate that Alternatives 3b would achieve ARARs over time through institutional controls, physical access restrictions, source control actions, upgradient water diversions, the collection and low-energy treatment of the portal drainage and upper West Area seeps/groundwater, and natural attenuation. Therefore, the actions included under Alternative 3b constitute permanent solutions under MTCA. As described previously, Alternative 3b would also adequately manage short-term risks to human health and the environment, including the local community, during remedy implementation, and is technically and administratively implementable.

Alternative 3b is expected to provide a greater degree of overall protection of human health and the environment, permanence, long-term effectiveness, management of short-term risks, and technical and administrative implementability to Alternatives 1, 2a, 2b, 3a, 4a, 4b, and 4c.

The incremental costs associated with Alternatives 5a through 8 relative to Alternative 3b are summarized on Table ES-6 and range from approximately $12,220,000 to $84,800,000. Results of the post-remediation loading analysis indicate that Alternatives 5a, 5b, 5c, 5d, 7, and 8 would potentially achieve surface water and groundwater ARARs within a shorter restoration time frame. However, as described previously, short-term PCOC concentrations in Railroad Creek are expected to be protective of resident aquatic species under Alternatives 3a, 3b, and 5a through 8, and the predicted differences in long term dissolved concentrations (within 50 years) under Alternatives 5a through 8 compared to alternative 3b are minor (i.e., within approximately 0.02 μg/L for cadmium, 0.2 μg/l for copper, 0.79 mg/l for iron, and 11 μg/l for zinc). Therefore, the additional costs associated with Alternatives 5a through 8 would be disproportionate to the potential incremental benefits to aquatic life in Railroad Creek, and the additional construction and operations and maintenance requirements under these alternatives would result in lower implementability and increased requirements to manage short-term risks and potential disruption to the local community.

Reasonable Restoration Timeframe

The MTCA specifies that cleanup actions provide for a reasonable restoration time frame and consideration of the following factors:

Potential Risks Posed by the Site to Human Health and the Environment. Alternatives 1 through 8 would be protective of human health through the implementation of institutional controls and physical access restrictions. Alternatives 2a through 8 would further protect human health and terrestrial ecological receptors though the removal, containment, and/or covering of site soils with PCOCs above potential risk-based ARARs.

Alternatives 3a, 3b, and 5a through 8 are all expected to result in PCOC concentrations in Railroad Creek that are protective of resident aquatic species, including salmonids and their prey, following remedy implementation as shown in the results of the post-remediation loading analysis (Tables ES-2 through ES-5) and site-specific toxicological evaluations. Seasonal PCOC concentrations predicted under Alternatives 1, 2a, 2b, 4a, 4b, and 4c may result in continued potential risks to aquatic life in the short term.

Practicability of Achieving a Shorter Restoration Time Frame. As described previously, Alternatives 3a, 3b, and 5a through 8 are expected to result in PCOC concentrations in Railroad Creek that are protective of resident aquatic species, including salmonids and their prey, following remedy implementation. These alternatives are all predicted to achieve potential ARARs in the long term.

Results of the post-remediation loading analysis indicate that Alternatives 5a, 5b, 5c, 5d, 7, and 8 would potentially achieve surface water and groundwater ARARs within a shorter restoration time frame than other alternatives, including Alternative 3b. However, the predicted concentrations in the long-term (within 50 years) under Alternative 3b are relatively similar to the predicted long-term concentrations under Alternatives 5a through 8 (i.e., within approximately 0.02 μg/L for cadmium, 0.2 μg/l for copper, 0.79 mg/l for iron, and 11 μg/l for zinc).

There is uncertainty and reduced practicability related to achieving the shorter restoration timeframe under Alternatives 5a, 5b, 5c, 5d, 7, and 8. In addition, the overall costs of implementing these alternatives are high without achieving any potential incremental benefit to human health and the environment. Alternatives 5, 7, and 8 have lower implementability, and additional short-term risks and potential disruption to the local community.

For these reasons, the additional costs associated with Alternatives 5a, 5b, 5c, 5d, 7, and 8 would be disproportionate to the potential incremental benefits to aquatic life in Railroad Creek.

Current and Potential Future Uses of the Site, Surrounding Areas, and Associated Resources that Are, or May be Affected by Releases from the Site. The Site is situated in a remote area on the eastern slopes of the Cascade Mountains within the Lake Chelan watershed. The Site is surrounded on three sides by designated wilderness and on one side by National Forest System-managed land. The Holden Village, which operates under a special-use permit issued by the Forest Service, is located north of the Site across Railroad Creek. As described under previous evaluation criteria, Alternatives 2 through 8 would result in different levels of impacts to the Holden Village, and provide varying extents of natural resource restoration in the short term. However each of these alternatives would achieve RAOs and would not preclude current or similar future site uses.

Availability of Alternative Water Supplies. There are no current or planned uses of surface water or groundwater as a drinking water supply downgradient of site influences. The Holden Village currently obtains potable water from Copper Creek upstream of the Site. No exceedances of human health-based criteria have been measured in site surface water, including Railroad Creek downgradient of the Site, or in groundwater near Lucerne. There are no differences between the alternatives with respect to this criterion.

Likely Effectiveness and Reliability of Institutional Controls. Institutional controls would be implemented under Alternatives 1 through 8 to address potential future risks to human health associated with groundwater and potential physical risks associated with the underground mine and mill building. The institutional controls would include land use restrictions; security devices to limit access; and informational devices to notify users about potential risks. Land use restrictions are expected to be implementable, reliable, and adequate in providing long-term protection of human health under all of the alternatives. The installation of access restrictions around select site features is also expected to be reliable in protecting Holden Village residents and visitors from potential physical hazards. There are no differences between the alternatives with respect to this criterion.

Ability to Control and Monitor Migration of Hazardous Substances from the Site. Based on the results of the post-remediation loading analysis, the source controls, upgradient water diversions, upper West Area collection and treatment, and natural attenuation included under Alternatives 3a, 3b, and 5a through 8 would effectively control the migration of hazardous substances from the West Area of the Site. As described under previous evaluation criteria, metals loading to East Area groundwater would be reduced over time through natural attenuation, and groundwater discharges would not result in exceedances of potential ARARs in the long term or cause an impact to aquatic life under Alternatives 3 through 8.

Surface-water monitoring in Railroad Creek and groundwater monitoring in surface water and existing groundwater monitoring wells would be performed under Alternatives 1 through 8 to monitor site conditions over time.

Toxicity of the Hazardous Substances at the Site. Site PCOCs include metals constituents in surface water and groundwater, and metals and total petroleum hydrocarbons (limited areas) in soils. Results of the human health risk assessment presented in the DRI indicate no existing unacceptable risks to Holden Village residents or visitors based on current reasonable maximum exposures to PCOCs within Site surface water, groundwater, sediment, and air. The Ecological Risk Assessment presented in the DRI indicated PCOC concentrations in soils in limited areas present a low potential for risk to terrestrial receptors in limited areas of the Site. The ERA also indicated a potential for risk to aquatic life in Railroad Creek due to seasonal PCOC concentrations.

Alternatives 1 through 8 would be protective of human health through the implementation of institutional controls and physical access restrictions. Alternative 2a through 8 would further protect human health and terrestrial ecological receptors though the removal, containment, and/or covering of soils with PCOCs above potential risk-based ARARs. Alternatives 3a, 3b, and 5a through 8 are all expected to result in PCOC concentrations in Railroad Creek that are protective of resident aquatic species, including salmonids and their prey, following remedy implementation.

Natural Processes that Reduce Concentrations of Hazardous Substances have been documented to Occur at the Site or Under Similar Site Conditions. The attenuation of metals loading from mining residuals is a well understood and documented process. The site-specific geochemical analyses document that natural attenuation is occurring in residuals located in the underground mine, waste rock piles, and tailings piles, and that long-term reductions in loading from these source areas are expected. These natural geochemical processes contribute to the predicted long-term achievement of potential ARARs for Alternatives 2 through 8.

Natural Resource Restoration

Through the implementation of source control measures in the West Area, Alternatives 2a through 8 would reduce potential risks to terrestrial ecological receptors and restore terrestrial habitat. Although the tailings piles are not injured resources, the tailings pile revegetation efforts included under Alternatives 2a through 6b are expected to provide replacement terrestrial habitat over time for other potentially injured areas of the Site. Through tailings pile consolidation, Alternatives 7 and 8 would also restore potential habitat to the current location of tailings pile 1. Alternatives 4c, 5c, 5d, 6a, and 6b would provide restoration of aquatic habitat in Railroad Creek adjacent to the Site, by relocating the current channel alignment to the north.

The remedial actions and natural attenuation included under Alternatives 2a through 8 would reduce potential risks to aquatic organisms, including trout and benthic macroinvertebrates, over time by reducing the release of PCOCs to Railroad Creek. Based on the results of the post-remediation loading analysis and site-specific toxicological evaluations, Alternatives 3a, 3b, and 5a through 8, which include the collection and treatment of the portal drainage and upper West Area seeps and groundwater, are all expected to result in PCOC concentrations in Railroad Creek that are protective of resident aquatic species following remedy implementation in the short term.

Table ES-1
Candidate Site-wide Remedial Alternative Summary Matrix

No.	Site-Wide Alternative	***Institutional Controls/Physical Access Restrictions***	Physical Access Restrictions	Deed Restrictions	***Monitoring***	Surface/Groundwater Quality Monitoring	Tailings Pile Slope Stability Monitoring	Cover Monitoring	***Natural Attenuation***	Natural Attenuation - East Area	Natural Attenuation - West Area	***Mine Actions***	Access/Air-flow Restrictions In Adits	1500-level Hydrostatic Bulkheads	Collection & Treatment of Portal Drainage	***Mill Building/Maint Yard Actions***	Upgradient Water Diversion	Engineered Cover for Impacted Soils	Excavate Impacted Soils & Onsite Relocation	Downgradient Water Collection & Treatment	***Waste Rock Pile Actions***	Upgradient Water Diversion	Downgradient Water Collection & Treatment	Low Permeability Cover	Relocate to Consolidated Tailings Pile	***Lagoon Soil Actions***	Excavate Impacted Soils & Onsite Relocation	Downgradient Water Collection & Treatment	***Secondary West Area Collection System***	Lower West Area Collection System	Extended Lower West Area Collection System	***West Area Treatment System***	Low-energy Alkaline Precipitation System	Mechanical HDS Treatment System	***Tailings Actions***	Revegetation	Upgradient Water Diversion	Extended Copper Creek Culvert	Slope Stability Actions	Develop Rip-rap Source	Enhance Rip-rap at Toe of Tailings	Partial Seep/Groundwater Collection & Treat	Extended Seep/Groundwater Collect & Treat	Low-permeability Cover	Tailings Pile Consolidation	***Railroad Creek Actions***	Partial Relocation of Railroad Creek	Extended Relocation of Railroad Creek
1	**1 - No Action/Institutional Controls**		·	·		·	·																																									
2	**2a - Water Management (Open Portal):**		·	·		·	·	·		·	·		·				·	·	·			·					·									·	·		·	·	·							
	2b - Water Management (Hydrostatic Bulkheads):		·	·		·	·	·		·	·		·	·			·	·	·			·					·									·	·		·	·	·							
3	**3a - Water Management and Low-Energy West Area Treatment (Open Portal):**		·	·		·	·	·		·	·		·		·		·	·	·	·		·	●				·						·			·	·		·	·	·							
	3b - Water Management and Low-Energy West Area Treatment (Hydrostatic Bulkheads):		·	·		·	·	·		·	·		·	·	·		·	·	·	·		·	●				·						·			·	·		·	·	·							
4	**4a - Water Management, and Partial East Area Collection and Treatment:**		·	·		·	·	·		·	·		·	·			·	·	·			·					·									·	·	·	·	·	·	·					·	
	4b - Water Management, and Extended East Area Collection and Treatment:		·	·		·	·	·			·		·	·			·	·	·			·					·									·	·	·	·	·			·				·	
	4c - Water Management, Extended Railroad Creek Relocation, and Extended East Area Collection and Treatment:		·	·		·	·	·			·		·	·			·	·	·			·					·									·	·	·	·	·			·					·
5	**5a - Water Management, Partial East Area Collection, and East/West Area Treatment (Low-Energy WTP):**		·	·		·	·	·		·	·		·	·	·		·	·	·	·		·	●				·						·			·	·	·	·	·	·	·					·	
	5b - Water Management, Extended East Area Collection, and East/West Area Treat. (Low-Energy WTP):		·	·		·	·	·			·		·	·	·		·	·	·	·		·	●				·						·			·	·	·	·	·			·				·	
	5c - Water Management, Extended Railroad Creek Relocation, and East/West Area Treat (Low-Energy WTP):		·	·		·	·	·			·		·	·	·		·	·	·	·		·	●				·						·			·	·	·	·	·			·					·
	5d - Water Management, Secondary West Area Collection, Extended Railroad Creek Relocation, and East/West Area Treat (Low-Energy WTP):		·	·		·	·	·					·	·	·		·	·	·	·		·	●				·	●		·			·			·	·	·	·	·			·					·

Table ES-1
Candidate Site-wide Remedial Alternative Summary Matrix

No.	Site-Wide Alternative	*Institutional Controls/Physical Access Restrictions*	Physical Access Restrictions	Deed Restrictions	*Monitoring*	Surface/Groundwater Quality Monitoring	Tailings Pile Slope Stability Monitoring	Cover Monitoring	*Natural Attenuation*	Natural Attenuation - East Area	Natural Attenuation - West Area	*Mine Actions*	Access/Air-flow Restrictions In Adits	1500-level Hydrostatic Bulkheads	Collection & Treatment of Portal Drainage	*Mill Building/Maint Yard Actions*	Upgradient Water Diversion	Engineered Cover for Impacted Soils	Excavate Impacted Soils & Onsite Relocation	Downgradient Water Collection & Treatment	*Waste Rock Pile Actions*	Upgradient Water Diversion	Downgradient Water Collection & Treatment	Low Permeability Cover	Relocate to Consolidated Tailings Pile	*Lagoon Soil Actions*	Excavate Impacted Soils & Onsite Relocation	Downgradient Water Collection & Treatment	*Secondary West Area Collection System*	Lower West Area Collection System	Extended Lower West Area Collection System	*West Area Treatment System*	Low-energy Alkaline Precipitation System	Mechanical HDS Treatment System	*Tailings Actions*	Revegetation	Upgradient Water Diversion	Extended Copper Creek Culvert	Slope Stability Actions	Develop Rip-rap Source	Enhance Rip-rap at Toe of Tailings	Partial Seep/Groundwater Collection & Treat	Extended Seep/Groundwater Collect & Treat	Low-permeability Cover	Tailings Pile Consolidation	*Railroad Creek Actions*	Partial Relocation of Railroad Creek	Extended Relocation of Railroad Creek
6	**6a - Water Management, Extended Secondary West Area Collection, Extended Railroad Creek Relocation, and East/West Area Treatment (Mechanical West Area WTP):**		·	·		·	·	·					·		·		·	·	·	·		·	●				·	●			·			·		·	·	·	·	·			·					·
	6b - Water Management, Extended Secondary West Area Barrier Wall, Extended Railroad Creek Relocation, and East/West Area Treat (Mechanical West Area WTP with Bulkhead):		·	·		·	·	·					·	·	·		·	·	·	·		·	●				·	●			·			·		·	·	·	·	·			·					·
7	**7 - Capping, Consolidation, Water Management, and West Area Treatment (Low-Energy WTP):**		·	·		·	·	·		·	·		·	·	·		·	·	·	·		·	●	·			·										·		·	·	·			·	·			
8	**8 - Source Control and East/West Area Treatment (Low-Energy WTP):**		·	·		·	·	·			·		·	·	·		·	·	·	·		·			·		·	●					·				·	·	·	·	·		·	·	·			

Table ES-2
Estimated Short-Term Post-Remediation Water Quality Summary- Railroad Creek

	Water Quality and Pre-Remediation Concentrations (May 1997)					Alternative 2		Alternative 3		Alternative 4			Alternative 5				Alternative 6		Alternative 7	Alternative 8
Dissolved metal	Acute SWQC (ug/L) (1)	Chronic SWQC (ug/L) (1)	Acute 2002 NRWQC (ug/L) (2)	Chronic 2002 NRWQC (ug/L) (2)	Pre-remediation Concentration at Station RC-2 (ug/L)	2a	2b	3a	3b	4a	4b	4c	5a	5b	5c	5d	6a	6b	7	8
Railroad Creek Station RC-4																				
Cd	0.40	0.23	0.28	0.06	0.44	0.39	0.18	0.08	0.05	0.18	0.18	0.18	0.05	0.05	0.05	0.05	0.07	0.05	0.05	0.04
Cu	2.5	2	2	1.6	26.4	23.7	22.3	2.3	2.2	22.3	22.3	22.3	2.2	2.2	2.2	1.8	1.8	1.7	2.2	2.0
Fe	NA	NA	1000	1000	20	20	20	21	20	20	20	20	20	20	20	20	21	20	20	20
Zn	20	19	21	21	73	66	38	15	14	38	38	38	14	14	14	14	15	14	14	13
Railroad Creek Downstream of RC-2																				
Cd	0.47	0.25	0.32	0.07	0.53	0.47	0.27	0.17	0.14	0.28	0.24	0.26	0.16	0.11	0.13	0.13	0.15	0.14	0.12	0.09
Cu	2.8	2.2	2.3	1.8	23.6	21.5	20.4	3.6	3.4	20.3	19.4	19.5	3.3	2.5	2.6	2.3	2.3	2.2	3.2	2.3
Fe	NA	NA	1000	1000	300	301	301	301	301	180	71	72	180	71	72	72	72	72	127	54
Zn	23	21	23.5	23.7	84	76	50	27	26	47	42	44	23	19	20	20	21	21	20	17

	Water Quality and Pre-Remediation Concentrations (September 1997)					Alternative 2		Alternative 3		Alternative 4			Alternative 5				Alternative 6		Alternative 7	Alternative 8
Dissolved metal	Acute SWQC (ug/L) (1)	Chronic SWQC (ug/L) (1)	Acute 2002 NRWQC (ug/L) (2)	Chronic 2002 NRWQC (ug/L) (2)	Pre-remediation Concentration at Station RC-2 (ug/L)	2a	2b	3a	3b	4a	4b	4c	5a	5b	5c	5d	6a	6b	7	8
Railroad Creek Station RC-4																				
Cd	0.37	0.21	0.26	0.06	0.06	0.05	0.16	0.06	0.06	0.16	0.16	0.16	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.04
Cu	2.3	1.9	1.8	1.5	1.8	1.5	15.4	0.9	0.9	15.4	15.4	15.4	0.9	0.9	0.9	0.6	0.6	0.6	0.9	0.7
Fe	NA	NA	1000	1000	40	40	42	41	41	42	42	42	41	41	41	41	41	41	41	40
Zn	19	17	19.4	19.6	11.0	8.9	30.5	5.0	5.1	30.5	30.5	30.5	5.1	5.1	5.1	3.9	3.9	3.9	5.1	3.6
Railroad Creek Downstream of RC-2																				
Cd	0.47	0.25	0.32	0.07	0.10	0.09	0.19	0.10	0.11	0.21	0.18	0.24	0.12	0.09	0.15	0.14	0.16	0.16	0.09	0.05
Cu	2.8	2.2	2.3	1.8	1.2	1.2	6.7	1.0	1.0	6.7	6.4	6.8	1.0	0.6	1.0	0.9	1.0	1.0	0.6	0.4
Fe	NA	NA	1000	1000	1080	1231	1232	1232	1232	445	246	249	444	246	248	248	249	249	404	156
Zn	23	21	23.5	23.7	23	22	41	18	18	38	32	36	15	9	13	12	13	13	11	6

Boxed Cell Result is above the Acute or Chronic SWQC
Shaded Cell Result is above the Acute or Chronic 2002 NRWQC
Pre-Remediation water quality criteria and Railroad Creek concentrations for May 1997 and September 1997 are from the May 19, 1997 and September 15, 1997 sampling events at stations RC-2 and RC-4.
(1) State of Washington hardness adjusted surface water quality criteria calculated based on 13 ppm (RC-4, spring), 12 ppm (RC-4, fall) and 15 ppm (RC-2, spring and fall) hardness values (WAC 173-201A).
(2) 2002 National Recommended Water Quality Criteria hardness adjusted values based on 13 ppm (RC-4, spring), 12 ppm (RC-4, fall) and 15 ppm (RC-2, spring and fall) hardness. Note, the NRWQC for total iron is not hardness dependent.

Table ES-3
Estimated Long-term (Approximately 50 yrs) Post-remediation Water Quality Summary - Railroad Creek Downstream of RC-2

	Water Quality and Pre-remediation Concentrations (May 1997)					Alternative 2		Alternative 3		Alternative 4			Alternative 5				Alternative 6		Alternative 7	Alternative 8
Dissolved metal	Acute SWQC (ug/L) (1)	Chronic SWQC (ug/L) (1)	Acute 2002 NRWQC (ug/L) (2)	Chronic 2002 NRWQC (ug/L) (2)	Pre-remediation Concentration at Station RC-2 (ug/L)	2a	2b	3a	3b	4a	4b	4c	5a	5b	5c	5d	6a	6b	7	8
Cd	0.47	0.25	0.32	0.07	0.53	0.25	0.12	0.09	0.06	0.12	0.11	0.11	0.06	0.06	0.06	0.06	0.12	0.09	0.05	0.04
Cu	2.8	2.2	2.3	1.8	23.6	12.3	8.3	1.6	1.5	8.3	8.3	8.3	1.5	1.5	1.5	1.7	1.8	1.7	1.3	1.3
Fe	NA	NA	1000	1000	300	202	202	202	202	122	51	51	122	51	51	52	52	52	13	13
Zn	23	21	23.5	23.7	84	54	34	25	23	32	28	30	21	18	19	19	21	20	13	12

	Water Quality and Pre-remediation Concentrations (September 1997)					Alternative 2		Alternative 3		Alternative 4			Alternative 5				Alternative 6		Alternative 7	Alternative 8
Dissolved metal	Acute SWQC (ug/L) (1)	Chronic SWQC (ug/L) (1)	Acute 2002 NRWQC (ug/L) (2)	Chronic 2002 NRWQC (ug/L) (2)	Pre-remediation Concentration at Station RC-2 (ug/L)	2a	2b	3a	3b	4a	4b	4c	5a	5b	5c	5d	6a	6b	7	8
Cd	0.47	0.25	0.32	0.07	0.10	0.05	0.05	0.06	0.06	0.05	0.05	0.05	0.06	0.06	0.06	0.07	0.14	0.12	0.06	0.03
Cu	2.8	2.2	2.3	1.8	1.2	0.5	0.5	0.4	0.4	0.6	0.6	0.6	0.4	0.5	0.5	0.9	1.1	1.0	0.4	0.3
Fe	NA	NA	1000	1000	1080	740	740	740	825	304	173	176	304	173	176	176	176	176	36	35
Zn	23	21	23.5	23.7	23	17	18	15	15	16	11	15	13	8	12	12	14	13	4	3

Boxed Cell Result is above the Acute or Chronic SWQC
Shaded Cell Result is above the Acute or Chronic 2002 NRWQC
Pre-Remediation water quality criteria and Railroad Creek concentrations for May 1997 and September 1997 are from the May 19, 1997 and September 15, 1997 sampling events at stations RC-2.
(1) State of Washington hardness adjusted surface water quality criteria calculated based on 15 ppm (RC-2, spring and fall) hardness values (WAC 173-201A).
(2) 2002 National Recommended Water Quality Criteria hardness adjusted values based on 15 ppm (RC-2, spring and fall) hardness. Note, the NRWQC for total iron is not hardness dependent.

Table ES-4
Estimated Long-term (Approximately 150 yrs) Post-remediation Water Quality Summary - Railroad Creek Downstream of RC-2

	Water Quality and Pre-remediation Concentrations (May 1997)					Alternative 2		Alternative 3		Alternative 4			Alternative 5				Alternative 6		Alternative 7	Alternative 8
Dissolved metal	Acute SWQC (ug/L) (1)	Chronic SWQC (ug/L) (1)	Acute 2002 NRWQC (ug/L) (2)	Chronic 2002 NRWQC (ug/L) (2)	Pre-remediation Concentration at Station RC-2 (ug/L)	2a	2b	3a	3b	4a	4b	4c	5a	5b	5c	5d	6a	6b	7	8
Cd	0.47	0.25	0.32	0.07	0.53	0.10	0.06	0.09	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.10	0.07	0.05	0.04
Cu	2.8	2.2	2.3	1.8	23.6	4.3	3.1	1.3	1.2	3.1	3.1	3.1	1.2	1.2	1.2	1.4	1.5	1.4	0.9	0.9
Fe	NA	NA	1000	1000	300	176	176	176	176	107	45	46	107	45	46	46	47	47	14	13
Zn	23	21	23.5	23.7	84	30	24	23	22	22	19	21	20	17	19	19	21	19	13	12

	Water Quality and Pre-remediation Concentrations (September 1997)					Alternative 2		Alternative 3		Alternative 4			Alternative 5				Alternative 6		Alternative 7	Alternative 8
Dissolved metal	Acute SWQC (ug/L) (1)	Chronic SWQC (ug/L) (1)	Acute 2002 NRWQC (ug/L) (2)	Chronic 2002 NRWQC (ug/L) (2)	Pre-remediation Concentration at Station RC-2 (ug/L)	2a	2b	3a	3b	4a	4b	4c	5a	5b	5c	5d	6a	6b	7	8
Cd	0.47	0.25	0.32	0.07	0.10	0.04	0.04	0.06	0.06	0.04	0.04	0.04	0.06	0.06	0.06	0.06	0.09	0.08	0.06	0.03
Cu	2.8	2.2	2.3	1.8	1.2	0.4	0.4	0.4	0.4	0.4	0.5	0.5	0.4	0.5	0.5	0.9	1.1	1.0	0.3	0.3
Fe	NA	NA	1000	1000	1080	646	646	646	720	268	155	157	268	155	157	157	158	158	38	35
Zn	23	21	23.5	23.7	23	13	13	13	14	11	7	11	12	7	11	11	13	13	4	3

Boxed Cell Result is above the Acute or Chronic SWQC
Shaded Cell Result is above the Acute or Chronic 2002 NRWQC
Pre-Remediation water quality criteria and Railroad Creek concentrations for May 1997 and September 1997 are from the May 19, 1997 and September 15, 1997 sampling events at stations RC-2.
(1) State of Washington hardness adjusted surface water quality criteria calculated based on 15 ppm (RC-2, spring and fall) hardness values (WAC 173-201A).
(2) 2002 National Recommended Water Quality Criteria hardness adjusted values based on 15 ppm (RC-2, spring and fall) hardness. Note, the NRWQC for total iron is not hardness dependent.

Table ES-5
Estimated Long-term (Approximately 250 yrs) Post-remediation Water Quality Summary - Railroad Creek Downstream of RC-2

	Water Quality and Pre-remediation Concentrations (May 1997)					Alternative 2		Alternative 3		Alternative 4			Alternative 5				Alternative 6		Alternative 7	Alternative 8
Dissolved metal	Acute SWQC (ug/L) (1)	Chronic SWQC (ug/L) (1)	Acute 2002 NRWQC (ug/L) (2)	Chronic 2002 NRWQC (ug/L) (2)	Pre-remediation Concentration at Station RC-2 (ug/L)	2a	2b	3a	3b	4a	4b	4c	5a	5b	5c	5d	6a	6b	7	8
Cd	0.47	0.25	0.32	0.07	0.53	0.05	0.04	0.06	0.05	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.06	0.04	0.03	0.03
Cu	2.8	2.2	2.3	1.8	23.6	1.8	1.5	1.1	1.0	1.5	1.5	1.5	1.0	1.0	1.1	1.1	1.4	1.3	0.8	0.8
Fe	NA	NA	1000	1000	300	130	130	130	130	81	36	37	81	36	37	37	38	37	13	13
Zn	23	21	23.5	23.7	84	20	19	20	19	18	16	18	18	16	18	18	20	18	13	12

	Water Quality and Pre-remediation Concentrations (September 1997)					Alternative 2		Alternative 3		Alternative 4			Alternative 5				Alternative 6		Alternative 7	Alternative 8
Dissolved metal	Acute SWQC (ug/L) (1)	Chronic SWQC (ug/L) (1)	Acute 2002 NRWQC (ug/L) (2)	Chronic 2002 NRWQC (ug/L) (2)	Pre-remediation Concentration at Station RC-2 (ug/L)	2a	2b	3a	3b	4a	4b	4c	5a	5b	5c	5d	6a	6b	7	8
Cd	0.47	0.25	0.32	0.07	0.10	0.03	0.03	0.04	0.04	0.03	0.03	0.03	0.04	0.04	0.04	0.04	0.05	0.04	0.03	0.03
Cu	2.8	2.2	2.3	1.8	1.2	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.5	0.5	0.6	1.1	1.0	0.3	0.3
Fe	NA	NA	1000	1000	1080	475	475	475	528	202	121	123	202	121	123	123	124	124	36	34
Zn	23	21	23.5	23.7	23	9	9	10	11	9	6	8	10	7	9	9	10	9	4	3

Boxed Cell Result is above the Acute or Chronic SWQC
Shaded Cell Result is above the Acute or Chronic 2002 NRWQC
Pre-Remediation water quality criteria and Railroad Creek concentrations for May 1997 and September 1997 are from the May 19, 1997 and September 15, 1997 sampling events at stations RC-2.
(1) State of Washington hardness adjusted surface water quality criteria calculated based on 15 ppm (RC-2, spring and fall) hardness values (WAC 173-201A).
(2) 2002 National Recommended Water Quality Criteria hardness adjusted values based on 15 ppm (RC-2, spring and fall) hardness. Note, the NRWQC for total iron is not hardness dependent.

Table ES-6
Candidate Site-Wide Alternative Cost Summary
(US Dollars)

Alternative Number and Description	Capital Cost (Direct)	Engineering, Construction Mgmt.	Project Mgmt.	Total Capital Cost	Annual O&M Cost	Total O&M Cost - Present Worth (30 yrs @ 7%)	Subtotal Cost	Contingency (50%)	Total Estimated Project Costs
1 - No Action/Institutional Controls	450,000	112,500	18,000	581,000	100,000	1,240,000	1,821,000	910,000	**2,731,000**
2A- Water Management (Open Portal)	7,766,000	1,941,500	310,640	10,018,000	150,000	1,486,500	11,505,000	5,752,000	**17,257,000**
2B- Water Management (Hydrostatic Bulkheads)	8,541,000	2,135,250	341,640	11,018,000	150,000	1,486,500	12,504,000	6,252,000	**18,757,000**
3A- Water Management & Low-Energy West Area Treatment (Open Portal)	11,827,000	2,956,750	473,080	15,257,000	256,000	2,801,000	18,058,000	9,029,000	**27,087,000**
3B - Water Management & Low-Energy West Area Treatment (Hydrostatic Bulkheads)	12,382,700	3,095,675	495,308	15,974,000	256,000	2,801,000	18,775,000	9,387,000	**28,162,000**
4A - Water Management & Partial East Area Collection/Treatment	15,916,500	3,183,300	477,495	19,577,000	302,000	3,372,000	22,949,000	11,475,000	**34,424,000**
4B - Water Management & Extended East Area Collection/Treatment	34,233,500	5,135,025	1,027,005	40,396,000	399,500	4,581,000	44,977,000	22,488,000	**67,465,000**
4C - Water Management, Extended Railroad Creek Relocation & Extended East Area Collection/Treatment	14,271,500	2,854,300	428,145	17,554,000	377,500	4,076,000	21,630,000	10,815,000	**32,445,000**
5A - Water Management, Partial East Area Collection & East/West Area Treatment (Low-Energy WTP)	19,563,700	3,717,103	586,911	23,868,000	323,500	3,638,000	27,506,000	13,753,000	**41,259,000**
5B - Water Management, Extended East Area Collection & East/West Area Treatment (Low-Energy WTP)	37,880,700	5,682,105	1,136,421	44,699,000	421,000	4,847,000	49,546,000	24,773,000	**74,319,000**
5C - Water Management, Extended Railroad Creek Relocation & East/West Area Treat (Low-Energy WTP)	18,507,600	3,516,444	555,228	22,579,000	399,000	4,342,000	26,921,000	13,461,000	**40,382,000**
5D - Water Management, Secondary West Area Collection, Extended Railroad Creek Relocation, & East/West Area Treat (Low-Energy WTP)	21,166,900	4,021,711	635,007	25,824,000	427,000	4,689,000	30,513,000	15,256,000	**45,769,000**
6A - Water Management, Extended Secondary West Area Collection, Extended Railroad Creek Relocation & East/West Area Treat (Mechanical WTP)	34,058,400	5,108,760	1,021,752	40,189,000	969,000	11,410,000	51,599,000	25,800,000	**77,399,000**
6B - Water Managment, Extended Secondary West Area Collection, Extended Railroad Creek Relocation & East/West Area Treat (Mechanical WTP - Bulkhead)	32,419,700	4,862,955	972,591	38,255,300	969,000	11,410,000	49,665,300	24,832,650	**74,498,000**
7 - Capping, Consolidation, Water Management & West Area Treatment (Low-Energy WTP)	54,917,600	7,139,288	1,098,352	63,155,000	305,000	3,782,000	66,937,000	33,469,000	**100,406,000**
8 - Source Control & East/West Area Treatment (Low-energy WTP)	61,268,000	7,964,840	1,225,360	70,458,000	391,000	4,848,400	75,307,000	37,653,000	**112,960,000**

* Cost estimates represent order-of-magnitude costs consistent with US Environmental Protection Agency guidelines for evaluating candidate remedial alternatives.

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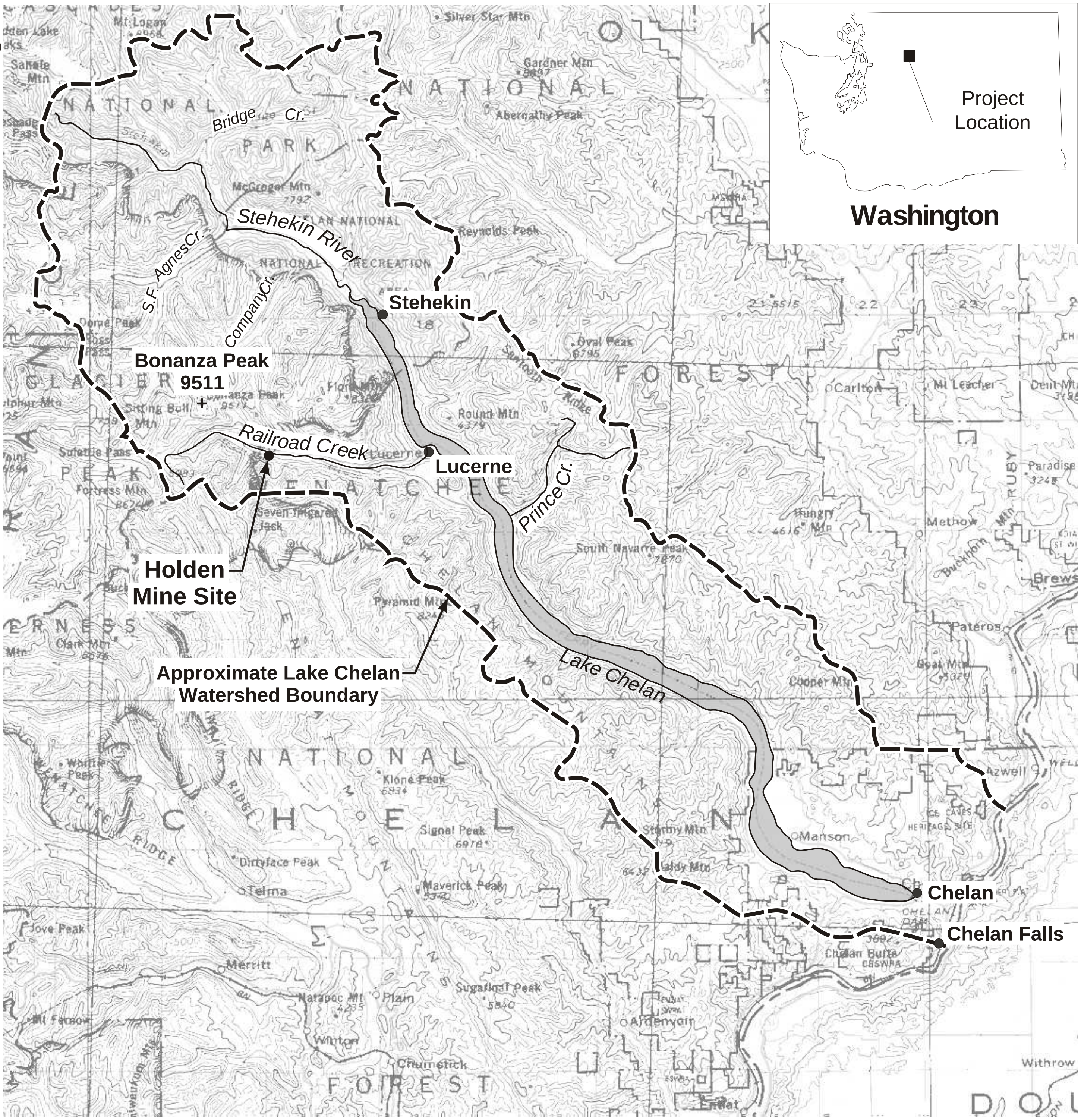
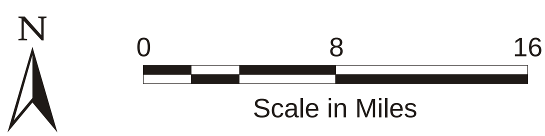


SOURCE: USGS Topographic Map, State of Washington, Scale 1:500,000, Compiled 1961, Revised 1982



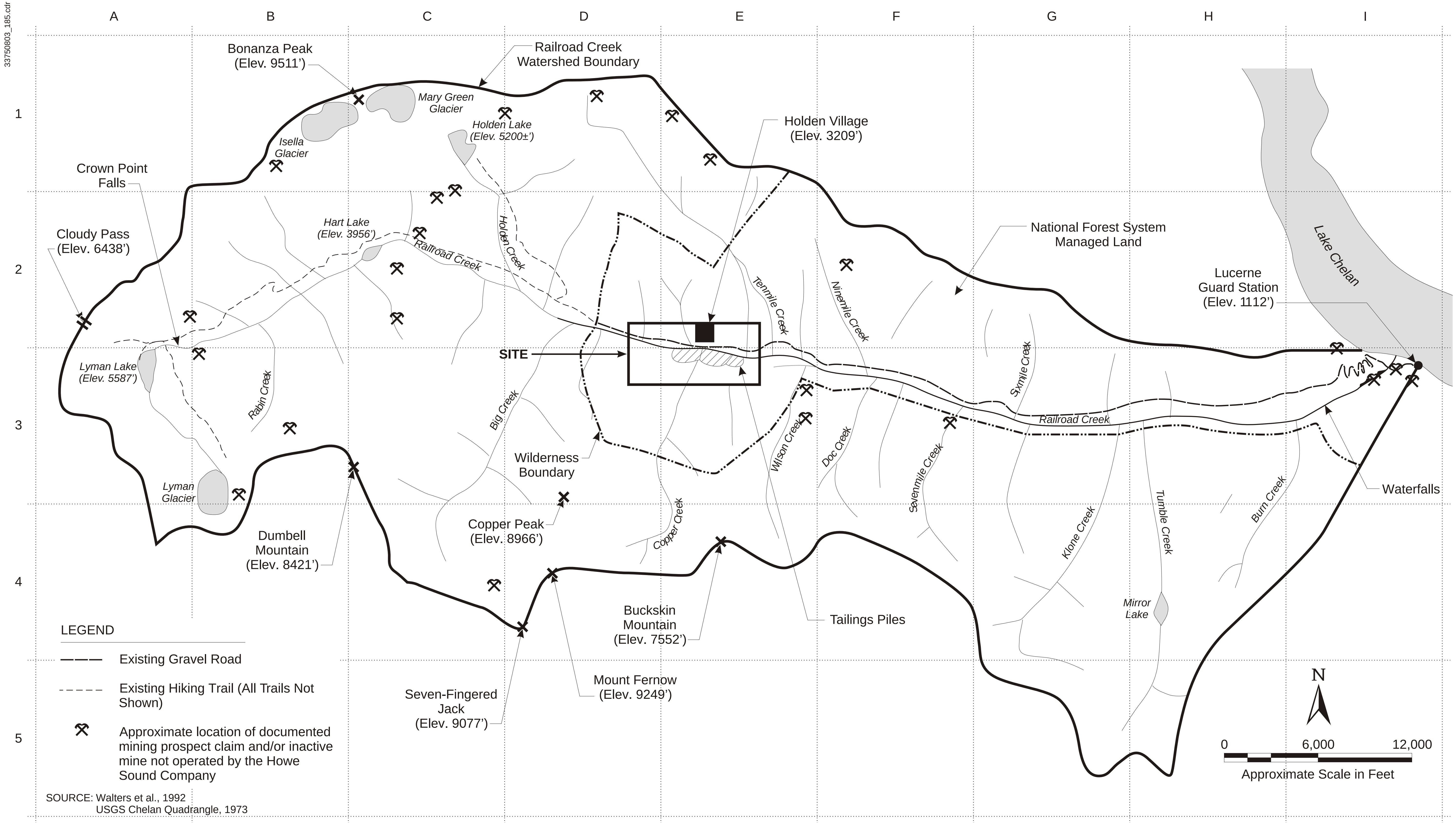
Job No. 33750803

Figure ES-1

Site Location and Lake Chelan Watershed Map

URS

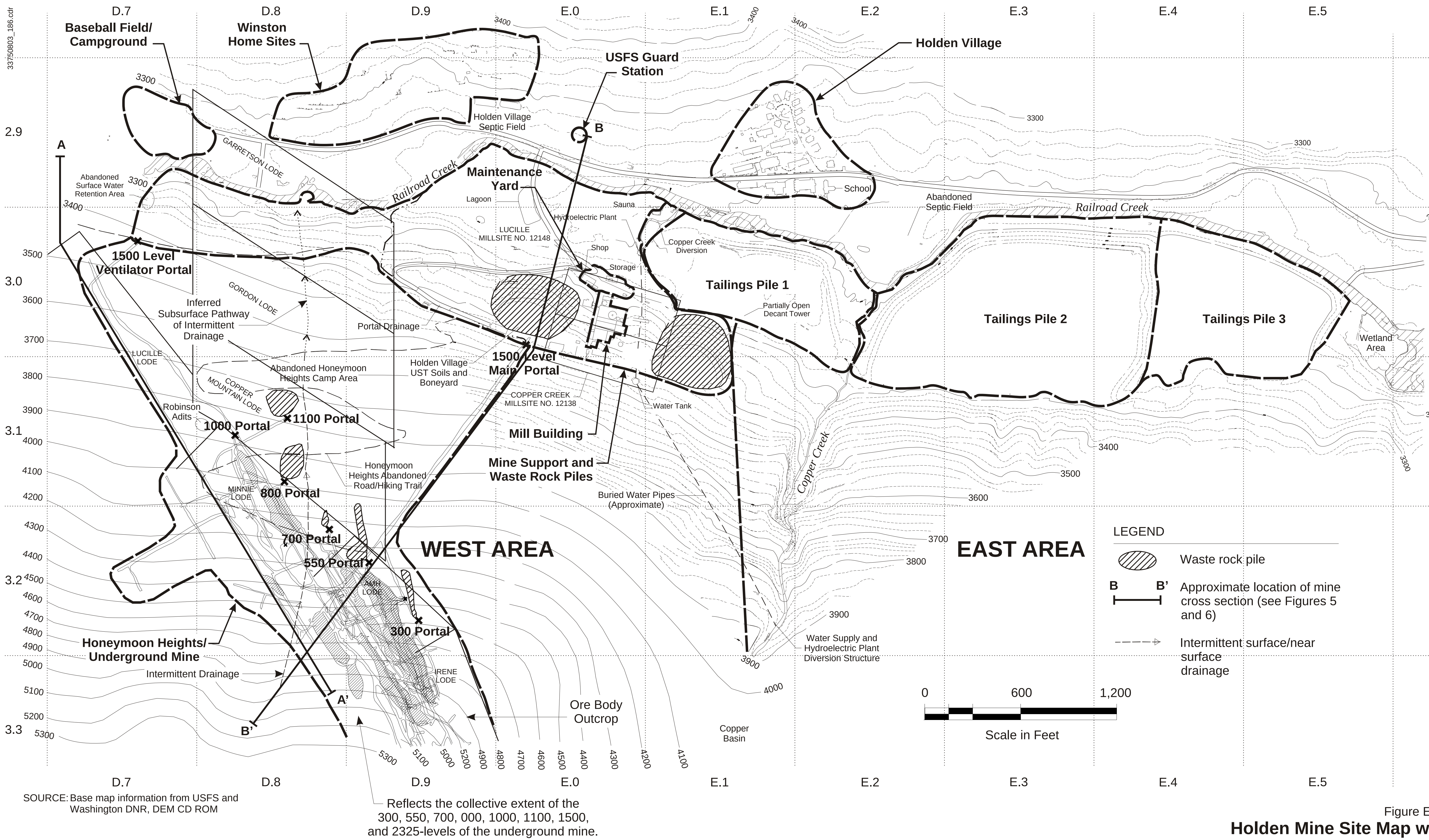
Holden Mine RI/FS
Draft Final FS Report
February 2004



Job No. 33750803

Figure ES-2
Railroad Creek Watershed Map

URS



Job No. 33750803

Figure ES-3
Holden Mine Site Map with Principal Underground Mine Workings

URS

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February 2004

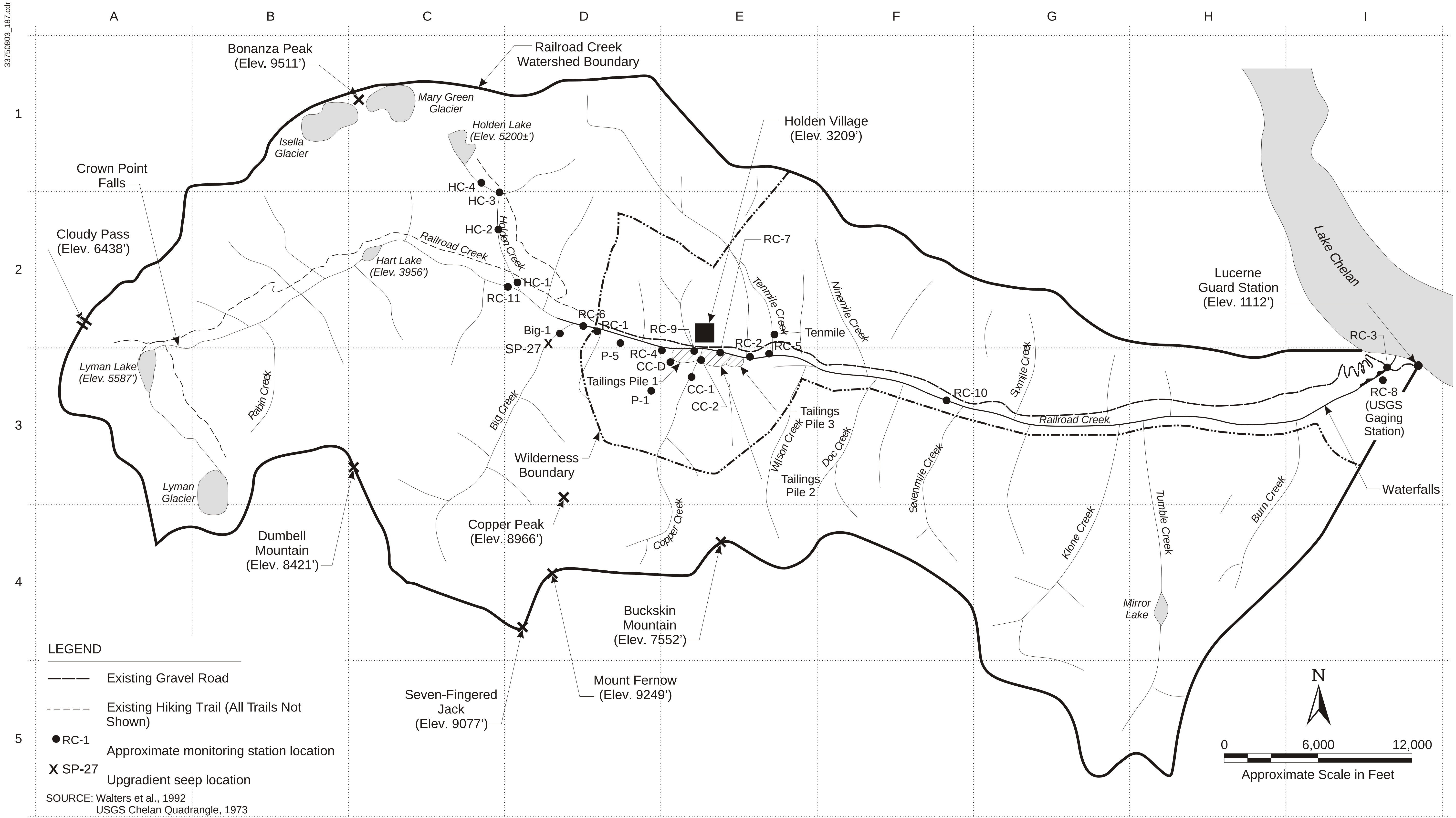
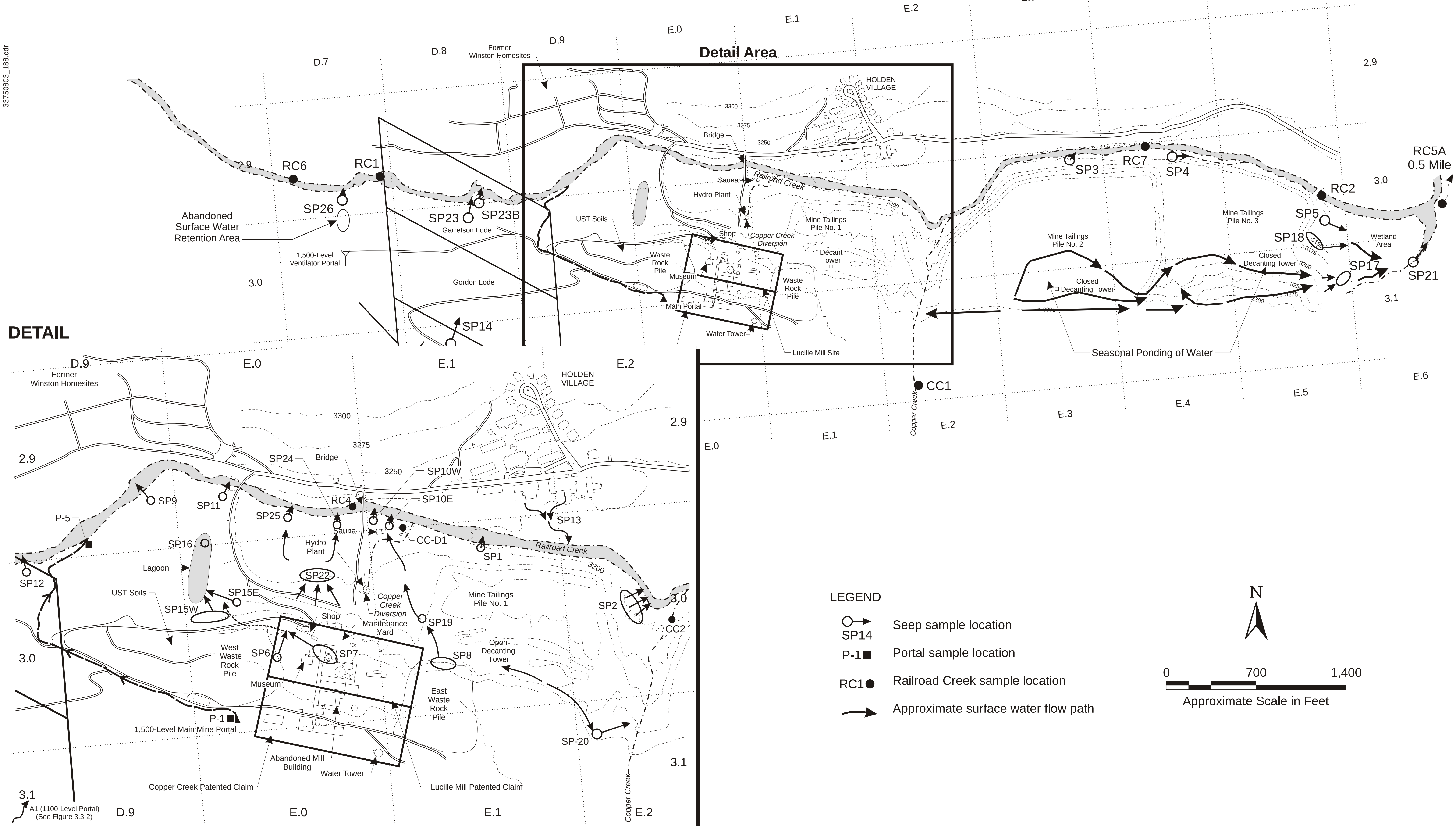


Figure ES-4
Streamflow and Water Quality Monitoring Stations - Railroad Creek

Job No. 33750803

URS

Holden Mine RI/FS
Draft Final FS Report
February 2004



SOURCE: ORB, 1975

Job No. 33750803

Figure ES-5

Approximate Locations of Surface Water Runon and Runoff and Seep Sample Locations

URS

Holden Mine RI/FS
Draft Final FS Report
February 2004

1.0 INTRODUCTION

This report presents the Draft Final Feasibility Study (FS) for the Holden Mine Site (Site), located in Chelan County, Washington. This FS is being conducted pursuant to an Administrative Order on Consent (AOC), dated February 12, 1998, between Alumet (now known as Intalco) and the U.S. Department of Agriculture Forest Service Region 6 (Forest Service), the Washington State Department of Ecology (Ecology), and the U.S. Environmental Protection Agency Region 10 (EPA). The objectives of the parties, as stated in Paragraph 7(c) of the AOC, are to:

- Characterize the nature and extent of contamination at the Site by conducting a remedial investigation (RI),

- Identify and evaluate candidate alternatives for remedial action(s) by conducting an FS, and

- Perform an injury determination in order to evaluate the potential for coordinated remedial and natural resources restoration activities.

Additionally, the AOC expresses the intent of the parties to perform work related to the Site "in a streamlined, focused, and cost-effective manner."

In accordance with the AOC, the revised Draft Final Remedial Investigation (DRI) report was prepared by URS Corporation (formerly Dames & Moore) on behalf of Intalco to document the results of the RI and characterize the nature and extent of contamination from historic mining activities at the Site. Ecological and human health risk assessments were also performed for the Site as part of the RI. The revised DRI report was submitted on July 28, 1999, and was accepted as final by the Forest Service, Ecology, and EPA (Agencies), with associated comment resolution documents, on February 8, 2002. Key results of the RI are summarized in Section 2 of this report.

Subsequent to submittal of the revised DRI report, a number of additional field investigations have been completed in support of the FS process. These investigations were completed under Agency oversight and include the following:

- Underground mine investigations (URS 2001a; URS 2001b),
- Downgradient hydrogeologic investigations (URS 2002a; URS 2002e; URS 2002f; URS 2003b),
- Geochemical/geotechnical investigations of the tailings piles (URS 2002c),
- Additional Lake Chelan sediment sampling (URS 2002d; URS 2003c),
- Bat monitoring and surveys of underground mine workings (URS 2003a),
- Railroad Creek surface water sampling (URS 2003d), and
- West area hydrogeologic investigation conducted in October 2003 (report pending).

The findings of the RI and subsequent investigations were used to prepare a draft Injury Determination (ID) report (URS 2002b) in accordance with the AOC to evaluate the potential for coordinated remedial and natural resource restoration activities. The ID report was reviewed by the natural resource Trustees identified for the Site, and negotiations related to potential natural resource restoration activities are ongoing.

Following acceptance of the RI, a Draft FS (DFS) report was prepared and submitted to the Agencies on June 12, 2002. The purpose of the DFS was to present remedial action objectives (RAOs), identify and screen potentially applicable technologies to address site concerns, and to assemble and evaluate candidate site-wide alternatives for their ability to meet RAOs. During the DFS review process, the Agencies provided direction for preparing a draft final FS report in correspondence dated July 26, 2002, December 18, 2002, and January 2, 2003. Subsequent to the Agencies' December 18, 2002 comment letter, a number of technical meetings related to FS analyses were held between representatives of Intalco and the Agencies and the following comment and comment response documents were submitted:

- Letter from David Jackson, David E. Jackson & Associates, to Norman Day, Forest Service, dated January 22, 2003, providing Intalco's responses to the December 18, 2002, and January 2, 2003 Agencies' direction for preparing the Holden Mine site Draft Final Feasibility Study (Intalco 2003a).

- Letter from Norman Day, Forest Service, to David Jackson, David E. Jackson & Associates, dated March 6, 2003, providing the Agencies' comments on Intalco's response to Agency comments regarding applicable or relevant and appropriate requirements (ARARs), dated January 22, 2003 (USFS 2003a).

- Letter from Theodore Garrett, Covington & Burling, to Norman Day, Forest Service, dated June 4, 2003, providing Intalco's response to the Agencies' comments regarding Holden Mine ARARs, dated March 6, 2003 (Intalco 2003b).

- Letter from Norman Day, Forest Service, to Theodore Garrett, Covington & Burling, dated July 28, 2003, providing the Agencies' response to Intalco's June 4, 2003 letter regarding ARARs (USFS 2003b).

- Letter from Jennifer Deters, URS, to Norman Day, Forest Service, dated August 27, 2003, providing Intalco's responses to the Agencies' July 28, 2003 comments (Intalco 2003c).

- Letter from Norman Day, Forest Service, to Theodore Garrett, Covington & Burling, dated September 11, 2003, providing the Agencies' direction for completion of the Holden Mine Feasibility Study (USFS 2003c).

The Agencies' comments and results of the technical meetings were incorporated into this FS report.

1.1 OVERVIEW OF THE FEASIBILITY STUDY PROCESS

In accordance with the AOC, the Feasibility Study process for the Holden Mine site is being conducted in accordance with the Comprehensive Environmental Response, Compensation and Liability Act (CERCLA); the State of Washington Model Toxics Control Act (MTCA); and consistent with the National Contingency Plan (NCP) and applicable Agency guidance documents. A description of the FS process is provided below.

1.1.1 The Feasibility Study Process - CERCLA

In accordance with EPA's Interim Final Guidance for Conducting Remedial Investigations and Feasibility Studies Under CERCLA (USEPA 1988), the FS process consists of the following:

- Establishment of RAOs for contaminants and media of concern. These objectives are developed based on the findings of the baseline risk assessment and potential chemical-specific applicable or relevant and appropriate requirements (ARARs).

- Identification of applicable general response actions (GRAs) for site-specific conditions (e.g., containment, removal, and treatment).

- Estimation of areas and volumes of contaminated media that exceed potential ARARs based on information developed during the RI.

- Identification and screening of potentially applicable technologies for use in achieving site-specific RAOs for each contaminated medium. Technologies are evaluated based on effectiveness, implementability, and relative cost, and representative process options are retained for each technology type.

- Assemble retained technologies and process options into candidate site-wide remedial alternatives that represent the full range of possible response actions.

- Further development and detailed analysis of candidate remedial alternatives to support the selection of a remedy.

The following seven criteria are used in the detailed analysis of candidate remedial alternatives, in accordance with the NCP (40 CFR 300.430):

- Overall protection of human health and the environment,
- Compliance with potential ARARs,
- Long-term effectiveness and permanence,
- Reduction of toxicity, mobility, or volume,
- Short-term effectiveness,
- Implementability, and
- Cost.

The first two criteria are considered "threshold" criteria that an alternative must meet in order to be considered for implementation, unless an ARAR waiver is invoked as provided in 40 CFR

300.430(f)(1)(ii)(C). The next five criteria are considered to be "primary balancing" criteria, and are used in conjunction with the threshold criteria in the comparative analysis of alternatives. The results of the comparative analysis are used to identify a preferred remedy for the Site, which is presented as part of a Proposed Plan, along with the basis for selection. Two additional criteria, state acceptance and community acceptance, are considered "modifying criteria", which are evaluated based on comments received during the public comment period of the Proposed Plan. The selected remedy is subsequently modified as needed, based on state and community acceptance, and a Record of Decision (ROD) is issued.

In addition to the nine CERCLA criteria discussed above, a tenth criterion is used in the detailed analysis of candidate alternatives for the Site, consistent with the intent of the AOC. The tenth criterion is to evaluate the extent to which candidate remedial alternatives would achieve natural resource restoration goals and the potential for coordinated remedial and natural resource restoration activities.

1.1.2 The Feasibility Study Process - MTCA

Consistent with CERCLA and the NCP, the purpose of the feasibility study under MTCA is to develop and evaluate potential cleanup action alternatives (i.e., candidate remedial alternatives) to enable a cleanup action (i.e., final remedy) to be selected for the Site. The FS process under MTCA consists of the following:

- Identification and preliminary screening of potentially applicable alternatives or components (i.e., technologies) that do not meet the MTCA minimum requirements (discussed below), including those alternatives for which costs are clearly disproportionate under WAC 173-340-360(3) and alternatives that are technically not possible at the Site.

- Identification and evaluation of a reasonable number and type of alternatives that protect human health and the environment by eliminating, reducing or otherwise controlling risks posed through potential exposure pathways and migration routes and that meet the MTCA minimum requirements (discussed below).

- Development, as appropriate, of remediation levels that define when particular cleanup action components will be used as described in the Washington Administrative Code WAC 173-340-355.

- Identification and evaluation, where possible, of potential alternatives that would potentially achieve compliance at a standard point of compliance, unless such alternatives have been eliminated in the preliminary screening process. In this case, alternatives with conditional points of compliance are to be evaluated.

- Identification, where appropriate, of a preferred cleanup action. (WAC 173-340-355(8)).

The FS process described above is generally consistent with the CERCLA process and is followed in this FS report. However, the development of remediation levels and identification of a preferred cleanup action (i.e., final remedy), will be performed during development of the proposed plan and ROD and are not included in the FS.

The MTCA specifies the following requirements for cleanup actions completed in the State of Washington (WAC 173-340-360):

- Protect human health and the environment.
- Comply with cleanup standards specified in WAC 173-340-700 through 760.
- Comply with applicable state and federal laws.
- Provide for compliance monitoring as specified under WAC 173-340-410 and 173-340-720 through 760.
- Use permanent solutions to the maximum extent practicable, which requires the use of a disproportionate cost analysis to compare the costs and benefits of candidate remedial alternatives.
- Provide for a reasonable restoration time frame as described in WAC 173-340-360(4).
- Consider public concerns.

The regulation recognizes that some of the requirements listed above contain flexibility and require use of professional judgment in determining how to apply them at particular sites. The first four requirements listed above are considered to be "threshold" requirements under MTCA that the selected final remedy must meet. The remaining three requirements must be considered along with the threshold requirements in the comparative analysis of remedial alternatives. As possible, the seven MTCA requirements listed above are identified and evaluated in this FS within the discussions provided in the detailed analysis for corresponding CERCLA criteria as follows:

- Protection of human health and the environment is addressed under the CERCLA criterion for overall protection of human health and the environment.
- Compliance with MTCA cleanup standard and compliance with applicable state and federal laws are addressed under the CERCLA criterion for compliance with potential ARARs.
- Providing for compliance monitoring is addressed generally under the CERCLA criteria for short-term effectiveness and long-term effectiveness and permanence. However, the identification of specific compliance monitoring locations and frequency will be determined following preparation of the proposed plan.
- Use of permanent solutions to the maximum extent practicable is encompassed under several CERCLA criteria including long-term effectiveness and permanence. This criterion requires the use of a MTCA-specified disproportionate cost analysis, which

includes the evaluation of overall protectiveness of human health and the environment, permanence, cost, effectiveness over the long term, management of short-term risks, technical and administrative implementability, and consideration of public concerns. Because the disproportionate cost analysis includes components evaluated under a number of CERCLA criteria, this criterion will be addressed separately following the CERCLA criteria evaluation.

- Providing for reasonable restoration time frame is addressed separately following the CERCLA criteria evaluation to address the MTCA-specific requirements specified in WAC 173-340-360(4).

Similar to the CERCLA process, the consideration of public concerns will be addressed during the final remedy selection process, and will be evaluated following preparation of the proposed plan.

Within the general MTCA requirements described above, where it is not practicable to meet a groundwater cleanup level at a point of compliance within groundwater before entering surface water within a reasonable restoration time frame, and the groundwater cleanup action is based on the protection of surface water, a conditional point of compliance may be set in the abutting surface water. This FS presents the basis for setting a conditional point of compliance for groundwater in surface water. The requirements for establishing a conditional point of compliance for groundwater will be discussed primarily in the compliance with ARARs sections, expect for the requirement that groundwater discharges be provided with “all known available and reasonable methods of treatment” (AKART) before being released into surface water. The technology identification and screening process, remedial alternative development, and detailed analysis of alternatives are intended to provide the information necessary to demonstrate AKART and establish conditional point(s) of compliance for the selected remedy.

1.2 REPORT ORGANIZATION

The FS is organized into the following sections:

- **Section 1: Introduction –** This section.

- **Section 2: Site Characteristics –** This section summarizes the findings of the revised DRI, ecological risk assessment, human health risk assessment, and other site investigation activities, conducted subsequent to submittal of the revised DRI, relevant to the development and analysis of candidate remedial alternatives.

- **Section 3: Potential Applicable or Relevant and Appropriate Requirements –** This section summarizes the potential chemical-specific, location-specific, and action-specific ARARs for the Site.

- **Section 4: Identification of Remedial Action Objectives –** This section provides discussion of RAOs developed for the Site based on the potential contaminants and media of concern, exposure routes and potential receptors.

- **Section 5: Identification and Screening of Remedial Technologies –** This section summarizes the GRAs and potential remedial technologies identified for the Site, and provides the initial technology screening and evaluation and selection of representative technologies.

- **Section 6: Development of Candidate Site-wide Remedial Alternatives –** This section summarizes each of the candidate site-wide remedial alternatives developed for the Site.

- **Section 7: Detailed Analysis of Alternatives –** This section provides the detailed analysis of candidate site-wide alternatives.

- **Section 8: Comparative Analysis of Alternatives –** This section provides the comparative analysis of remedial alternatives with respect to the threshold and primary balancing criteria.

- **Section 9: References –** This section provides a listing of documents referenced in the FS report.

2.0 SITE CHARACTERISTICS

The Holden Mine site is situated in a remote area on the eastern slopes of the Cascade Mountains in Washington State, within the Lake Chelan watershed (Figure 2-1). The mine was developed and operated by the Howe Sound Company from the late 1930s through the 1950s for the primary production of copper, zinc, silver and gold. The Site is surrounded on three sides by designated wilderness and on one side by National Forest System-managed land. The Site is located near the center of the Railroad Creek watershed (Figure 2-2), which is the second largest hydrologic input source to Lake Chelan.

Discharges from the Site contribute metals to groundwater and Railroad Creek causing seasonal exceedances of water quality criteria developed for the protection of aquatic life, including the Washington State promulgated surface water quality criteria (SWQC) for cadmium, copper and zinc. Dissolved metals concentrations measured in composite samples collected in Railroad Creek adjacent to the Site between 1997 and 2003 ranged from 0.048 to 0.68 μg/L for cadmium, 0.5 to 41.9 μg/L for copper, and 10 to 114 μg/L for zinc. As required by the Agencies, the data were also compared to the federal National Recommended Water Quality Criteria (NRWQC) for freshwater aquatic life.[1] Based on this comparison, seasonal concentrations were measured above the NRWQC established for aluminum, cadmium, copper, iron, and zinc. The NRWQC for copper, cadmium, and zinc is based on dissolved concentrations as described for the SWQC. The NRWQC for aluminum and iron is based on total recoverable concentrations. Total metals concentrations measured in composite samples collected in Railroad Creek adjacent to the Site between 1997 and 2003 ranged from 40 to 340 μg/L for aluminum and 60 to 2620 μg/L for iron.

Concentrations of metals above background concentrations have also been detected in surface soils and groundwater located within specific areas associated with historic mining activities. A discussion of potentially applicable or relevant and appropriate requirements (ARARs) is provided in Section 3.

Data presented in the DRI indicate that the release of metal constituents from the Site may contribute to reduced populations of fish and aquatic macroinvertebrates in Railroad Creek. Aquatic macroinvertebrates are the primary food source for fish in Railroad Creek. Results of the RI indicate reduced fish populations in Railroad Creek from the Site to approximately three miles downstream.

The results of the ecological risk assessment (ERA) completed as part of the DRI indicate that metals concentrations in site soils may also present a potential risk in isolated locations to terrestrial wildlife and vegetation. The results of the human health risk assessment (HHRA)

[1] Intalco has provided legal justification and technical documentation showing that the NRWQC (1999 and 2002 publications) are not relevant and appropriate to the Holden Mine site. Intalco's justification has been provided in written correspondence with the Agencies between January and September 2003. This correspondence is part of the administrative record and is incorporated into this FS. Intalco's rationale is also summarized and presented in Section 3 and Appendix B.

presented in the DRI indicate that no significant potential risks to human health for both Holden Village residents and visitors due to site exposure are present.

This section is organized as follows:

- Section 2.1 Sources of Relevant Site Information and Data
- Section 2.2 Site History and Land Use
- Section 2.3 Physical Setting
- Section 2.4 Potential Source Areas
- Section 2.5 Affected Media
- Section 2.6 Site-wide Baseline Loading Analysis
- Section 2.7 June 2000 Portal Drainage Treatability Study

A more detailed discussion of the site characteristics is presented in Section 4 of the DRI (URS 1999).

2.1 SOURCES OF RELEVANT SITE INFORMATION AND DATA

In accordance with the AOC, the DRI report for the Holden Mine site was prepared to document the results of the RI conducted in 1997 and 1998 to characterize the nature and extent of contamination from historic mining activities. Ecological and human health risk assessments were also performed as part of the RI. Following submittal of the draft final report in 1999, two iterations of Agency comments and subsequent responses from Intalco were documented. The DRI and associated comment resolution documents were accepted by the Agencies as final on February 8, 2002.

The following transmittals, summarizing the results of additional site investigations completed subsequent to submittal of the DRI report, are also relevant to the development and analysis of candidate remedial alternatives:

- *Holden Mine Fall 2000 and Spring 2001 Underground Investigation Data Transmittals* (URS 2001a; URS 2001b) – present the findings of three investigations into the 300, 1100, and 1500 levels of the underground mine in November 2000, April 2001, and May 2001.

- *Fall 2001 and Spring/Summer/Fall 2002 Hydrogeologic Investigation Data Transmittals* (URS 2002a; URS 2002e; URS 2002f; URS 2003b) – present the results of the installation and sampling of five new downgradient groundwater monitoring wells from November 2001 through October 2002.

- *Fall 2001 Geotechnical/Geochemical Investigation Data Transmittal* (URS 2002c) – presents the results of geotechnical and geochemical sampling and analysis of tailings performed in conjunction with the fall 2001 hydrogeologic investigation noted above.

- *Fall 2001 and Fall 2002 Additional Lake Chelan Sediment Sampling Data Transmittals* (URS 2002d; URS 2003c) – present sediment chemistry, grain size analyses, and toxicity testing data associated with sediment sampling performed at Lucerne bar and Stehekin (the reference site) in Lake Chelan. Sampling was conducted in November 2001 and October 2002.

- *Draft Monitoring Report – Bat Monitoring and Winter Survey of Underground Mine Workings at the Holden Mine Site* (URS 2003a) – presents the results of site surveys and remote monitoring conducted in 2001 and 2002 within the underground workings of the Holden Mine to determine the presence or absence of bats.

- *Spring 2003 Surface Water Monitoring Data Transmittal* (URS 2003d) – presents the results of Railroad Creek and portal drainage water quality sampling conducted from May 20 through May 21, 2003.

- *Results of Humidity Cell Testing on Tailings* (SRK 2003) – presents the results of humidity cell testing conducted in 2002 and 2003 on three tailings samples collected from the Holden Mine site during the fall 2001 geochemical investigation.

In addition, as agreed upon in the AOC, a Draft Injury Determination Memo, dated February 15, 2002, was prepared to summarize the potential injuries to natural resources at the Site to evaluate the potential for coordinated remedial and natural resource restoration activities.

As stated previously, the HHRA found that no significant potential risks were present for both Holden Village residents and visitors based on reasonable maximum exposure scenarios. The results of the ERA found potential risks to certain aquatic and terrestrial biota resulting from historical mining activities. Findings of the ERA are discussed further in the DRI and Section 2.5 of this report.

2.2 SITE HISTORY AND LAND USE

The following subsections provide summaries of historical mining operations; site restoration efforts completed by the Forest Service in 1989 through 1991; activities conducted during the RI; rehabilitation of the 1500-level portal by Intalco; emergency activities performed by Intalco, the Holden Village, and Forest Service in October 2003 to stabilize flood damaged areas within the Copper Creek and Railroad Creek drainages; and current land use.

2.2.1 Historical Mining Operations

The Site was initially developed in the late 1800s and early 1900s along Railroad Creek, approximately 9 miles upstream from the creek's outlet at Lake Chelan (Figure 2-2). The underground mine and facilities were initially developed south of Railroad Creek in the area known as Honeymoon Heights which is situated to the southwest and upslope of the remnants of the mill building (Figures 2-3 and 2-4).

The Honeymoon Heights area consists of six mine portals and associated underground tunnels that were developed before Howe Sound Company became involved at the Site. The portals were numbered to reflect the approximate number of vertical feet below the initial outcrop of mineralized rock discovered in late 1800s and were located, progressing downward, at the 300, 550, 700, 800, 1000, and 1100 levels. These mine portals were apparently not used after the main haul-out and ventilator tunnels were established at the 1500 level in 1937 by Howe Sound Company. Portals associated with the 1500 level are referred to as the 1500-level main portal and 1500-level ventilator portal (Figure 2-4).

Waste rock piles are associated with all of the mine portals in the Honeymoon Heights area. The piles are believed to contain relatively low concentrations of minerals that have economic value (e.g., copper, zinc, gold and/or silver). The quantity of waste rock associated with early mining activities at the Site is less than either the west or east waste rock piles located near the abandoned mill facility.

After Howe Sound Company took over mining operations, ore haul-out and mine ventilation tunnels were constructed near the level of the mill facility, noted on the mine maps as the 1500 mine level. The mining company also acquired permits from the Forest Service and other relevant agencies to further develop the mine and construct the mill and related facilities, as well as Holden Village.

Processing of ore began in 1938 and continued until 1957. The removal of the ore resulted in the development of about 56 miles of underground mine workings. Mine maps reviewed as part of the RI indicate 14 primary mine levels and approximately the same number of secondary levels (Figures 2-4, 2-5, and 2-6). The removal of the rock within the ore body resulted in the development of relatively large openings or stopes, the largest of which are found above the 1500 level of the mine. The largest of the stopes in the upper workings were developed to within approximately 50 feet of the ground surface.

Horizontal levels were developed for ore removal every 50 to 100 feet from the uppermost to lowermost extent of the mine. The different levels of the mine were connected by a series of inclines, two shafts, and air passageways. Mining occurred to a depth of approximately 800 feet below the floor of the Railroad Creek valley.

Economic minerals (primarily copper, zinc, silver and gold) were removed from the ore materials through crushing and processing in the on-site mill (Figure 2-4). The resulting ore concentrate was then transported off site for smelting. The on-site processing of ore generated approximately 10 million tons of tailings material (a mixture of silt and fine sand resulting from the crushing of rock ore), of which approximately 1.5 million tons were backfilled in the mine during the operations to increase the stability of the underground openings below the 1500 level of the underground mine.

The remainder of the tailings was hydraulically placed in three piles covering approximately 90 acres to the north and east of the mill building (Figure 2-4). The construction of the tailings piles required relocating Railroad Creek to the north of the pre-existing stream channel; therefore, portions of the tailings piles are situated over the abandoned channel.

Two waste rock piles were also generated on the west and east sides of the mill building (Figure 2-4). The piles consist of an estimated 250,000 tons of rock removed from the underground mine that did not contain sufficient concentrations of economic minerals to warrant processing in the mill.

The Holden Mine ceased operations in 1957 due to economic factors. The mine properties were subsequently deeded to the Lutheran Bible Institute in 1960, which then transferred the properties to Holden Village Inc. in 1961.

The structural support for the 1500-level main and ventilator portals apparently collapsed after the mine ceased operations. Anecdotal reports indicate that individuals associated with Holden Village entered the underground mine through the 1500-level main portal as late as the mid-1960s. However, in the late 1960s the portal apparently collapsed, causing water to back up behind the soil mass and resulting in an eventual surge of water, soil, and tailings from the mine. Mine water has apparently discharged from flow paths formed through the collapsed debris on a continuous basis since that time.

As shown on Figure 2-2, several mining prospects reportedly not associated with the Holden Mine were also developed both upstream and downstream of the Site. However, based on data collected during the RI, none of the other mining-related activities appear to have resulted in increased concentrations of potential constituents of concern (PCOCs) in surface water above relevant regulatory standards.

2.2.2 Site Restoration Efforts by Forest Service

After mining operations were discontinued in 1957 the underground mine eventually filled with water that started discharging from the portal of the lowest tunnel constructed in the mine (1500-level main portal). Between 1989 and 1991, the Forest Service redirected the water to Railroad Creek through the construction of a ditch referred to as the 1500-level main portal drainage (portal drainage). At that time, the Forest Service also: 1) regraded the tailings pile surfaces to increase surface water run off; 2) constructed diversion ditches to reduce surface water run-on to the tailings piles; 3) constructed two channels within the Copper Creek drainage to direct flow between tailings piles 1 and 2 through two culverts located at the southern edge of the piles; 4) reduced erosion of the tailings piles by Railroad Creek through the placement of rip rap along the stream banks; and 5) placed about six inches of gravel over the surface of the tailings piles to reduce wind-borne transport of tailings from the Site.

Active treatment of the mine discharge water was not included in the Forest Service actions. However, with the intent of adding alkalinity and increasing the precipitation of metals from the portal drainage before reaching Railroad Creek, limestone rock fragments were placed on the drainage substrate as a form of passive treatment. This method was found not to be successful due to the blinding of the limestone surfaces by metal precipitates.

The Forest Service, with help from the Holden Village, has also revegetated portions of the tailings piles and conducted revegetation studies in several test plots constructed on the piles since 1991. Recent reports from the Forest Service indicate that the efforts have been relatively successful, especially when biosolids were added as a soil amendment (presentation by George Scherer, Forest Service, at Holden Mine Acid Mine Drainage Workshop, October 1999). The vegetation test plots created through past efforts are readily visible on Figures 2-3 and 2-7. The vegetation plots have assisted in the propagation of less mature vegetative growth that is filling in the areas between the plots. Some of this vegetation can be seen on Figure 2-7.

Groundwater monitoring wells were also installed across the Site (primarily within the tailings piles and some in adjacent areas) by Battelle Northwest – Pacific Northwest Laboratories (PNL) and the U.S. Bureau of Mines (BOM) in 1992 and 1996, respectively. The wells were installed to assist in the characterization of groundwater conditions after Forest Service site restoration efforts were completed.

2.2.3 Remedial Investigation

As noted in Section 2.1, the RI was completed by URS between 1997 and 1998. The RI included the sampling and analysis of soil, surface water, groundwater, and sediments, and was accepted as final by the Agencies on February 8, 2002. An ERA and HHRA were also conducted as part of the RI. No additional groundwater monitoring wells were installed at the time of the RI field program. However, since the completion of the RI, Intalco has collected additional data as requested by the Agencies, including the installation of downgradient groundwater monitoring wells; the installation of groundwater monitoring wells, test pits, and geologic borings in the West Area; and the installation of a limited number of geologic borings installed on the north side of Railroad Creek in the East Area. The results of the additional data collection efforts are presented in the documents noted in Section 2.1.

2.2.4 1500-Level Main Portal Rehabilitation by Intalco

As requested by the Agencies, rehabilitation of the collapsed 1500-level main portal was performed by Intalco in the fall of 2000 to allow safe human access and facilitate further characterization of the underground mine geology, geotechnical characteristics, and groundwater and rock geochemistry. The effort required removal of approximately 90 lateral feet of collapsed soil, re-establishing structural support for the collapsed portion of the tunnel, and removal of approximately 400 lateral feet of metal precipitates, or “slimes”, and debris present on the floor of the 1500-level main tunnel before the operation was terminated due to inclement weather conditions. Prior to demobilizing from the Site, two partial bulkheads were constructed within the 1500-level main tunnel to reduce the potential for discharge of metal precipitates or other suspended solids from the portal. Placement of the two partial bulkheads allowed access by boat to a portion of the underground mine for sampling and visual assessment in 2000 and 2001.

2.2.5 Emergency Actions Performed to Stabilize Flood Damaged Areas in the Railroad Creek and Copper Creek Drainages Adjacent to the Site.

On October 20, 2003 more than four inches of rainfall fell in the area of the Site. The rainfall event caused a rapid rise in the discharge of Railroad Creek and Copper Creek creating overbank flooding conditions. As a result of these conditions in Railroad Creek, erosion and deposition patterns within portions of the channel changed, the foundations of three bridges were partially eroded and/or destabilized, the Holden Village waterline was further exposed, and new logjams were created. Copper Creek overflowed to the east and the west above the access road at the top of tailings pile 1 and eroded portions of tailings pile 1 and the base of the western slope of tailings pile 2.

By letter dated October 31, 2003, the Agencies requested emergency actions to be completed by Intalco to address these concerns. In November 2003, URS construction crews, working on behalf of Intalco, and crews working for the Holden Village and Forest Service, performed emergency activities to address some of the conditions caused by the flooding.

2.2.6 Bat Monitoring

To evaluate if remedial actions performed at the Site may affect bats potentially using the underground mine, Intalco and the Agencies conducted underground surveys in 2000, 2001, and 2002, and installed continuous remote monitoring equipment that operated from November 2001 through November 2002. No bats were observed within the accessible areas of the mine (300, 1100 and 1500 levels) during the underground assessments conducted in August/November 2000, April/May/August/November 2001 and March/November 2002. However, indications of possible bat use, based on deposits of guano, were noted near the portal of the 300-level and the 1500-level ventilator portal during the survey conducted by the Forest Service and Intalco in August 2001.

To further investigate the possible usage of the mine by bats, motion sensors were placed in all open mine portals in November 2001. Temperature and humidity monitors were also placed within the underground mine workings on the 300, 1100 and 1500 levels. Data were continuously collected by the remote monitors over the one-year period from November 2001 to November 2002. The temperature data collected over this period indicate internal mine temperatures ranged between 40 and 51 degrees Fahrenheit, which is in the preferred temperature range for most hibernating bats. Relative humidity was stable, between 60 and 63 percent. Data recorded by the motion sensors indicate that no bat colonies are using the Holden Mine at this time.

2.2.7 Current Land Use

The Site is situated within the Wenatchee National Forest, and the Glacier Peak Wilderness generally bounds the Site to the west, north and south. The Holden Village is located immediately to the north of Railroad Creek and the Site (Figures 2-3 and 2-4). The village has operated since 1961 in conjunction with the Lutheran Church as an interdenominational religious retreat under a Conditional Use Permit issued by the Forest Service. All of the buildings in the village are located on National Forest System managed land. Approximately 50 to 60 Holden Village staff resides at the village year round. In addition, approximately 5,000 to 6,000 people reportedly visit the facility each year, each person staying from an average of two to seven days.

With exception of facilities located in the maintenance yard and on the surface of the west waste rock pile, the Site and associated tailings piles are not currently utilized, except on an occasional basis by Holden Village residents, visitors, and/or recreational users. The maintenance yard and surface of the west waste rock pile are currently used by the Holden Village for equipment maintenance and storage, and the storage of miscellaneous materials.

A fence was constructed around the abandoned mill building by Intalco in the fall of 2000 to restrict access due to concerns regarding potential physical hazards associated with the partially demolished condition of the structure.

A hiking trail provides access from the mill building and maintenance yard area to Honeymoon Heights. Therefore, in the fall of 2000, Intalco installed locking bat-friendly gates in the 300- and 1100-level mine portals to prevent unauthorized persons from freely entering the underground mine. The remaining portals have collapsed since the mine ceased operations. The rehabilitated 1500-level main portal was fitted with locking steel doors to restrict underground access by unauthorized persons.

The Site is bounded by Railroad Creek to the north. The creek is utilized occasionally by Holden Village residents and visitors for recreational purposes such as sport fishing during the warmer summer months, as well as occasional religious rituals. Based on knowledgeable Holden Village residents, most of the fishing within the Railroad Creek drainage is catch and release fly-fishing. A vast majority of fish brought to the Holden Village kitchen for consumption reportedly originate from Hart Lake, approximately four miles upgradient from the Site. However, some fish are reportedly caught within the segment of Railroad Creek adjacent to and downstream of the Site.

The Site is situated at the western terminus of the approximately 12-mile-long road that originates at Lucerne on Lake Chelan. Visitors and residents generally access the Site via motor vehicles after taking the regularly scheduled passenger boat from Chelan. Hikers, backpackers and horse packers can also gain access to the Site from Lake Chelan or the Glacier Peak Wilderness via the trail system.

Holden Village drinking water is obtained from Copper Creek upstream of the mine influence. Groundwater beneath the Site is not consumed, and is unlikely to be used as a drinking water source in the future because groundwater flow is low when compared with surface water flow in the area.

At Lucerne, approximately nine miles east of the Site at the mouth of Railroad Creek, water from Railroad Creek is reportedly consumed by several seasonal and possibly full-time residents. However, Railroad Creek is not committed for use as a public drinking water supply. One drinking water well is situated within alluvial materials at Lucerne and reportedly provides potable water for, and is maintained by, the Forest Service for seasonal employees and visitors to the nearby campground and Forest Service cabin.

2.3 PHYSICAL SETTING

Summaries of the site topography and setting, climatic conditions, geology, hydrology and hydrogeology, and the site-specific water balance are provided in the following subsections. More detailed information regarding the physical setting is provided in Section 4 of the DRI report.

2.3.1 Topography and Setting

The Railroad Creek watershed is situated approximately three quarters of the way up the west side of Lake Chelan (Figures 2-1 and 2-2). The watershed is generally oriented in an east-west direction, and is approximately 20 miles in length. The drainage was glacially carved and is generally U-shaped with relatively 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, upgradient from the Site, again becomes steeper before reaching Lyman Lake and Lyman Glacier. The waterfalls located near Lucerne serve as a natural barrier to fish migration up Railroad Creek from Lake Chelan. Similarly, waterfalls immediately downstream of Hart Lake and Lyman Lake prevent migration of fish further upstream.

The elevations within the watershed range from the level of Lake Chelan at approximately 1,100 feet above sea level to more than 9,500 feet above sea level (Bonanza Peak) several miles west and north of Holden Village. Railroad Creek elevations range from 1,100 feet above sea level at Lucerne 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.

Most of the abandoned mine facilities are situated between 3,200 and 3,400 feet above sea level, approximately 200 feet above Railroad Creek and Holden Village (Figure 2-4). The original mine workings are situated above the main site features in the area noted as Honeymoon Heights, extending up the hillside to approximately 4,600 feet above sea level.

2.3.2 Site Climatic Conditions

The climate at the Site is characterized by relatively warm to hot, dry summers and mild to severe winters. Average monthly temperatures at the Site vary from highs in the mid 70s to lower 80s (in degrees Fahrenheit) in July and August, to low temperatures well below freezing in January. Average temperatures are generally below freezing between the months of November and March.

Average precipitation at Holden Village from 1962 to 1997 was approximately 38 inches annually, with the highest monthly amounts occurring predominantly as snowfall between November and January, and the lowest between May and August. During the winter of 1996/1997, the second highest recorded snowfall occurred, with approximately 500 inches measured through the winter.

Potential evapotranspiration from the Site was estimated based on the average temperature values and estimated percent cloud cover. The cloud cover data were based on an average of percentages observed at Seattle and Yakima (data are 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 and actual evapotranspiration approximately 10 inches.

2.3.3 Geology

The Site geology was evaluated during the RI and subsequent investigations using a combination of existing literature, field observations, and field exploration methods. The subsurface soil and rock conditions at the Site were characterized using a combination of geophysical (seismic refraction) methods and traditional drilling and sampling methods, as well as the use of shallow trenches excavated with track-mounted backhoe equipment.

Seismic refraction is a tool by which the densities of the subsurface materials are characterized, without actually seeing them, by using scientific equipment. The use of drilling and sampling equipment allows for visual assessment and measurement of the density of the subsurface materials. Backhoe-excavated test pits provide the best method for visually assessing subsurface materials, but are limited to a typical maximum depth of approximately 12 to 18 feet below the ground surface.

Even with the use of a combination of characterization methods, the geologic stratigraphy within alpine glaciated valleys is commonly difficult to determine due to relatively extreme ranges in particle size (from silt to large boulders) and densities (from loose soils to dense till and bedrock), as well as variable bedrock depths resulting from repetitive advances and recessions of the glaciation, and variable bedrock conditions resulting from the processes associated with mountain building.

2.3.3.1 Overview of Stratigraphy

Based on the field observations and subsurface data collected during the RI and subsequent investigations, the Site geology generally consists of stream alluvium and glacial materials overlying bedrock within the valley bottom and lower valley walls of the Railroad Creek drainage. Figures 2-9 through 2-12 provide north-south trending geologic cross sections. Figure 2-13 is a cross-section oriented generally parallel to Railroad Creek. The locations of the explorations from which the geologic interpretations were derived are presented on Figure 2-14 and Figure 2-15.

Alluvium consists of geologic materials that are deposited by rivers and streams. At the Site, the alluvium ranges from silty, sandy gravel to relatively clean gravel containing little fine material.

The glacial materials were interpreted to consist of a combination of glacial drift and basal till. Glacial drift is silt- to boulder-sized material deposited either by retreating glaciers or from rivers draining glaciers. The glacial drift at the Site has, in some locations, been further reworked by subsequent stream action. In contrast, basal till is glacial silt- to boulder-sized material deposited beneath or ahead of the glacier, and this material is concurrently or subsequently densified by the weight of the glacier and hydrologic processes.

The alluvium and glacial materials are underlain at variable depths by bedrock that has been carved by the glaciation process and includes sedimentary, metamorphic and igneous rock types.

2.3.3.2 Alluvium and Glacial Drift

Based on the seismic refraction data collected as part of the RI and recent boring data, the alluvium and glacial drift are interpreted to exist from near the ground surface to approximately 40 feet below the ground surface in the vicinity of Railroad Creek in the western portion of the Site, and from near ground surface to as much as 100 feet below ground surface in the vicinity of Railroad Creek in the eastern portion of the Site.

The saturated thickness of the alluvium/glacial drift is indicated on Figure 2-16. The saturated thickness generally increases both from the edges of the valley to the center, and in a downstream direction. Figures 2-9 through 2-12 show the alluvially reworked glacial drift and glacial drift units separately. The distinction is based on differences in seismic velocity measured using the seismic refraction method. The permeability of the alluvium has been observed to be variable, and is higher where few fines are present. The permeability of the glacial drift is also variable, from relatively high near the ground surface and the center of the valley, and decreasing with increasing depth or distance from the center of the valley. Local variations in the permeability of the near-surface alluvium can also be expected due to historic meandering of Railroad Creek across the valley bottom.

2.3.3.3 Basal Till and Bedrock

Dense basal till has been observed to blanket the bedrock in geologic borings completed in the vicinity of Railroad Creek at the Site. Based on the subsurface data collected across the Site, the basal till appears to be variable in both lateral and vertical extent. Due to limitations associated with the seismic refraction method, as well as challenges in using drilling and sampling methods within dense soils that contain cobbles and boulders, it is difficult to distinguish between dense basal till and bedrock at depth.

The permeability of the basal till is expected to be low, based on the higher proportion of fines and increased density of the material. The permeability of the bedrock is also anticipated to be relatively low. The potential exists for preferential groundwater pathways along fractures, joints and faults within the bedrock. However, even within the preferential pathways, the movement of groundwater is anticipated to be relatively low based on observations made during the underground mine investigations.

The interpreted elevation of either the top of the relatively lower-permeability and higher-density basal till or the bedrock surface, based on geologic borings and interpretation of seismic refraction data, is shown on Figure 2-17. However, due to limitations associated with the data collection methods, the bedrock surface may be as much as 5 to 10 feet deeper than indicated on the cross sections.

On the south side of Railroad Creek at the Site, the basal till has been interpreted to partially cover the bedrock from the valley bottom up slope to slightly above the 1100-level mine portal in the Honeymoon Heights area. Above the 1100-level mine portal, bedrock and weathered bedrock soil is generally exposed at the surface. Basal till is also exposed in isolated stream banks upstream of the Site and was encountered in several borings completed in October 2003.

2.3.3.4 Historic Rerouting of Railroad Creek

Available documentation indicates that Railroad Creek was rerouted in 1937 to accommodate the use of portions of the Site located south of the existing creek location, including the placement of the tailings piles. The creek was apparently rerouted by constructing a dike consisting of gravel, cobbles, boulders, and placing wood timbers along portions of the southern banks of the creek to reduce stream-bank erosion.

A segment of the previous Railroad Creek stream bed appears to exist beneath the lagoon area (which was constructed north of the maintenance yard and abandoned mill building within the higher permeability reworked till/alluvium), and portions of tailings piles 1, 2 and 3. The near-surface, alluvial material associated with the abandoned streambed appears to act as a preferential pathway for near-surface groundwater movement through the western portion of the Site and beneath the tailings piles.

2.3.3.5 Mining-related Materials

Mining-related materials on the Site include the tailings piles, which consist of relatively low permeability, fine-grained silt and sand that resulted from the processing of the ore-bearing bedrock, and waste rock piles which consist of angular rock fragments that are generally non-mineralized.

Approximately 85 percent of the tailings were 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) (PNL, 1992). As discussed in Appendix B, the mineralogy of the tailing materials was confirmed by evaluating the chemistry of the seeps and groundwater sampled and analyzed as part of the RI.

2.3.3.6 Underground Mine

Based on the review of available underground mine maps, and observations made during the underground mine investigations conducted by URS, the bedrock exposed in the underground mine is composed of interlying sequences of metamorphic and 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 reportedly one of several in the watershed and was found to be approximately 2,500 feet long and the width of economic mineralization is about 80 feet. The shear zone and ore body are oriented in a nearly east-west direction, and were found to be relatively steep to nearly vertical. The zone of economic mineralization is exposed at the surface near the zero level of the mine high up on the valley slope, which allowed it to be found by prospectors in the late 1800s.

The ore body is situated within a rock formation named the Buckskin schist that consists of a thick series of quartz-amphibolite schist containing two horizons of intermittent marble beds and calcareous schists (Youngberg and Wilson, 1952). As discussed in Section 2.4.1.1 and Appendix E, the mineralogy of the underground mine was also confirmed by evaluating the chemistry of the mine discharge (1500-level main portal drainage) which was sampled and analyzed as part of the RI.

2.3.4 Hydrology and Hydrogeology

Surface water and groundwater are the primary pathways for the transport and release of PCOCs at the Site. The Site surface water and groundwater are generally controlled by the physical conditions of the watershed, including the topography, geology, and climate.

The surface water and groundwater conditions vary across the Site due to variations in topography and geology. The topography is the result of pre-historic glacial activity that created a U-shaped valley and partially filled it with glacial sands and gravels. As noted above, the elevations within Railroad Creek watershed vary from about 1,100 feet above sea level at Lucerne on Lake Chelan to more than 9,500 feet at the top of Bonanza Peak, located approximately 2 to 3 miles northwest of the Site (Figure 2-2). The majority of the precipitation within the watershed falls in the form of snow during the winter months. The snow generally accumulates and then melts due to relatively mild temperatures during the spring and early summer months.

2.3.4.1 Site Surface Water and Groundwater Interactions

Railroad Creek is the primary receptor of surface water and groundwater drainage from the Site. The creek also receives baseflow contribution from glaciers located upstream of the Site. A plan view of Site surface water pathways is illustrated on Figure 2-18. Conceptual groundwater flow paths under spring and fall conditions are provided on Figures 2-19 and 2-20. Figures 2-21 through 2-24 depict the relatively complex relationship between the surface water and groundwater, and the conceptual surface water and groundwater transport pathways from the Site to Railroad Creek, beginning upstream of the Site and progressing downstream.

2.3.4.2 Railroad Creek

There are significant differences in snow accumulations throughout the Railroad Creek watershed due to variations in elevation. In addition, the increase in elevation between the mouth and headwaters of the creek results in spring snow melt that typically progresses upvalley from Lake Chelan as the temperatures increase in spring. Therefore, there is commonly a lag period for snowmelt between the Site and the portion of the watershed upstream of the Site.

The surface water and groundwater conditions within the Railroad Creek watershed also vary significantly through the year. From autumn through early spring, baseflow discharge measurements for Railroad Creek adjacent to the Site are generally average on the order of 60 cubic feet per second (cfs). In contrast, average springtime peak discharge measurements at the Site are normally on the order of 800 cfs. Figure 2-25 provides a graph of Railroad Creek discharge vs. time for periods between April 1998 and October 2003, recorded by a pressure transducer/data logger installed adjacent to the Site at monitoring station RC-4, located adjacent to the covered pedestrian bridge.

During the spring snowmelt period (generally April through July), the primary surface water and groundwater discharges to Railroad Creek occur upstream of the Site and originate as glacial waters and snow melt. For the remainder of the year, storage within the weathered bedrock soil and glacial sands and gravels, as well as storm event precipitation, provide the baseflow for Railroad Creek.

2.3.4.3 Groundwater

Hydrogeologic conditions were characterized through the use of groundwater monitoring wells installed across the Site (Figure 2-14). Based on the analysis of groundwater data, conceptual groundwater flow paths under spring and fall conditions were developed (Figures 2-19 and 2-20). The groundwater flow paths were found to change from spring to fall, shifting from nearly perpendicular to Railroad Creek in the spring (Figure 2-19) to nearly parallel to Railroad Creek in the fall (Figure 2-20). Conditions observed in the fall are suspected to generally continue until the following spring.

Hydrologically downgradient of the Site, all of the alluvial groundwater is believed to eventually discharge into Railroad Creek. This is based on the observed creek flow directly atop bedrock in the vicinity of Sevenmile Creek, located approximately 2.5 miles downstream of the Site. The bedrock depth in the immediate proximity of Railroad Creek at the Site has been interpreted to vary from as shallow as 40 feet to approximately 100 feet below the ground surface.

Subsequent to the submittal of the DRI report, five groundwater-monitoring wells were installed downgradient of the Site in November 2001 (DS-3 through DS-5). The downgradient wells were sampled in November 2001, June 2002, and October 2002. In October 2003, five additional monitoring wells (2003-MW1 through 2003-MW4S/4D) were installed and sampled in the West Area. Eight geologic borings and four test pits were also completed at the Site as part of the October 2003 hydrogeologic investigation. The hydrogeologic investigation locations, including the monitoring wells installed in 2001 and 2003, are shown on Figure 2-14.

Surface water elevations and groundwater level measurements were collected periodically from downgradient monitoring locations over the period from November 2001 through July 2002. Pressure transducers/data loggers were also installed in the downgradient monitoring wells in July 2002 to provide continuous monitoring at these locations. Key findings from the downgradient hydrogeologic investigations include the following:

- Consistent with the conceptual site model presented in the DRI, the groundwater flow is generally parallel to Railroad Creek both adjacent to and down stream of the Site. As noted in the DRI, the groundwater flow varies throughout the year and immediately after storm events. Based on observations of Railroad Creek flowing directly atop bedrock downstream of the Site (at Sevenmile Creek) before the creek enters Lake Chelan, it is assumed that all of the site groundwater eventually becomes surface water prior to discharge to the Lake.

- Groundwater elevations measured in the downgradient monitoring wells indicate the same general trends (rise and fall) as surface water elevations recorded at RC-4 (adjacent to the pedestrian bridge), suggesting that the monitoring wells are in direct hydraulic connection with Railroad Creek.

- Railroad Creek is generally a losing stream at the DS-3/DS-4/DS-5 locations downstream of the Site (Figure 2-14).

- Groundwater flow at the DS-3 and DS-4 locations is primarily downward. An apparent short-term relative restriction to vertical flow occurs during storm events at these locations.

- There is a slight horizontal gradient away from Railroad Creek in the shallow water-bearing materials at monitoring wells DS-3/DS-4. However, there is a larger horizontal gradient towards Railroad Creek in the deeper water-bearing materials at monitoring wells DS-3 and DS-4.

Surface water elevations and groundwater level measurements were collected from the newly installed West Area monitoring wells in October 2003. Key findings from the 2003 hydrogeologic investigations include the following:

- Site geology (as described previously in Section 2.3.3) is composed of alluvium/glacial drift, overlying a thin (and potentially discontinuous) layer of basal or dense till, overlying bedrock. The thickness of the alluvium/glacial drift layer ranges from approximately 40 feet at the west end of the Site to approximately 100 feet at the east end. Based on boring logs, and slug tests completed in the new wells, the alluvium/glacial drift may become less permeable with depth.

- Slug tests were completed to assess hydraulic conductivity in the new wells completed in the alluvium/glacial drift. Hydraulic conductivity values for the alluvium/glacial drift ranged from 0.009 to 0.112 cm/sec based on slug test results. The new hydraulic conductivity values were included in the data set of hydraulic conductivity values from the RI and used to further refine the flow tube analysis presented in Section 2.6.

- One open borehole hydraulic conductivity test was completed in the basal till unit. Preliminary evaluation indicates a hydraulic conductivity of 0.000019 cm/sec for the basal till unit.

- Groundwater flow has a downward component at the MW-4 location in the West Area, based on water-level data collected on October 9, 2003 at wells MW-4S and MW-4D.

- Depth to dense basal till is approximately 14 feet bgs at the base of the west waste rock pile, and greater than 18 feet at the base of the east waste rock pile.

2.3.5 Site-Specific and Conceptual Tailings Pile Water Balance

A site-specific water balance was completed as part of the RI. In addition, a conceptual water balance was completed for the tailings piles to further refine the site-specific water balance and support the metals loading analysis in the FS (URS 2002g). The results of the analyses indicate that the key surface water and groundwater components have been identified for the Site, and the site-specific water balance is at a sufficient level of detail in order to be used in the FS.

2.4 POTENTIAL SOURCE AREAS

The following subsections describe potential source areas and surface water and groundwater pathways for the PCOCs identified for the Site. A detailed discussion related to the identification of PCOCs is provided in Section 3.0. For purposes of the RI/FS, the Site has been divided into the “West” and “East” areas. The West Area includes sources associated with the mine support area and Honeymoon Heights that were observed to have elevated concentrations of mostly copper, cadmium and zinc in select surface water, groundwater and soils. The East Area includes the three tailings piles from which groundwater and seeps containing elevated concentrations of primarily iron originates (Figure 2-4).

2.4.1 West Area

Potential sources of metals loading and transport pathways to Railroad Creek were investigated during the RI. The investigation of potential West Area sources included the following components:

- Initial detailed field reconnaissance with Agency representatives.
- Observation of site features and conditions.
- Field screening of observed seeps using pH and conductivity.
- Completion of remote sensing (electromagnetic and seismic refraction) surveys to characterize subsurface geology and affected groundwater flowpaths.
- Completion of four test pits, five new groundwater monitoring wells, and five additional geologic borings in October 2003 to further characterize subsurface geology and hydrogeology in the West Area.

The West Area seep and portal drainage sampling locations reported in the DRI were based on field observations made during field reconnaissance surveys by URS and Agency personnel. After a potential sampling location was identified, discharge volume was either measured (where feasible) or estimated, and field screening of basic water chemistry parameters (pH, conductivity, temperature) was completed. Based on the measured discharge, conductivity, and pH, potential source seeps were designated for inclusion in the spring 1997 RI sampling program.

To further characterize the subsurface geology and potentially affected groundwater flow paths in the West Area, remote surveys, including seismic refraction and electromagnetic (EM) surveys, were conducted during the 1997 RI field program. Additional subsurface data were also collected from the West Area in the fall of 2003 through the installation of several new groundwater monitoring wells and geologic borings. The key findings of the seismic refraction survey and the 2003 field program pertaining to the geology of the West Area are summarized in section 2.3.3.

A number of EM lines were completed at the Site in June 1997 to assist in the characterization of potentially affected groundwater based on the subsurface conductivity. Electromagnetic induction surveying is a surface geophysical technique used to measure terrain conductivity, a term referring to the bulk electrical conductivity of subsurface materials. Terrain conductivity measurements are often used to map areas where subsurface conductivity is elevated due to the presence of conductive inorganic compounds, such as metal oxides, in the ground water (NGA 1997).

The EM methods utilized in 1997 provided a minimum characterization depth of approximately 6 meters. Two EM survey lines, EM-1 and EM-2, were completed within and upstream of the West Area (Figure 2-26). Line EM-1 (Figure 2-27) was completed generally parallel to Railroad Creek from upstream of the portal drainage to the base of TP-1. Line EM-2 (Figure 2-28) was completed from upstream of seep SP-23 to the base of the east waste rock pile.

Key findings of survey line EM-1 include:

- The survey characterized the western end of the profile (upgradient of the portal drainage channel) as having low soil conductivity.

- Increasing conductivities were noted downgradient (east) of the portal drainage channel, which is indicative of diffuse groundwater flow with elevated metals concentrations.

- Three distinct conductivity anomalies (in the form of discrete or diffuse conductivity increases) were noted along the profile (1a, 1b, and 1c). The anomalies correlate with field observations of potential mineralized sources, including the loss of water from the portal drainage channel, and diffuse groundwater flow east and downgradient of the portal drainage channel. A detailed discussion of these three anomalies is provided in Appendix A of the DRI report.

Key findings of survey line EM-2 include:

- As indicated by survey line EM-1, the EM-2 survey characterized the western end of the profile (upgradient of the portal drainage) as having low soil conductivity.

- The measured conductivities gradually increased by a factor of three in the vicinity of the waste rock piles (eastern end of EM-2).

- The increase in soil conductivity in the vicinity of the waste rock piles is likely indicative of diffuse groundwater flow that contains elevated metals concentrations.

- The EM data indicate that diffuse groundwater flow with elevated metals concentrations is not expected upgradient of the waste rock piles.

- Nine conductivity anomalies (in the form of discrete or diffuse conductivity increases) were noted along the profile (2a through 2i). The anomalies correlate with field observations of potential sources of metals loading, including seeps SP-23, SP-12, the portal drainage, and diffuse groundwater flow east of the portal drainage channel. The anomalies also correlate with metallic objects or culverts that were observed along the profile. A detailed discussion of these anomalies is provided in Appendix A of the DRI report.

The results of the field investigations and remote sensing surveys were reviewed in conjunction with RI sampling data and the results of the baseline site-wide loading analysis described in Section 2.6. The results of the analyses indicate that all of the significant sources of metals loading to Railroad Creek have been identified. Based on the observations and data collected during, and subsequent to the RI, the primary West Area sources include the following:

- The underground mine,
- Honeymoon Heights area,
- West and east waste rock piles,
- Maintenance yard,
- Mill building, and
- Lagoon area.

The following subsections provide an overview of the identified West Area sources listed above and potential transport pathways to Railroad Creek and groundwater. Although not characterized as potential source areas, Copper Creek and the Copper Creek diversion are also discussed below, as they relate to site hydrology/hydrogeology and the potential transport of PCOCs from site source areas.

2.4.1.1 Underground Mine

Following closure of the mine in 1957, the underground workings eventually flooded resulting in the discharge of water from the 1500-level main portal (Figures 2-4, 2-29, and 2-30). The portal drainage contains elevated concentrations of primarily cadmium, copper, and zinc, and serves as a transport pathway for these metals from the mine to West Area groundwater and Railroad Creek. An understanding of the processes occurring in the underground mine is based on the review of underground mine maps, the evaluation of portal drainage water chemistry, as well as information and data collected during three underground mine investigations performed in 2000 and 2001. Available information and analytical data indicate that air (oxygen) and water flow through the underground mine workings are the primary factors contributing to elevated metals concentrations in the portal drainage.

Air and Water Flow Characteristics

Air flows in and out of the 300-, 1100- and 1500-level mine portals and circulates through the open underground workings. This results in the oxidation of exposed ore materials present within the open stopes and tunnels. The direction of airflow through the mine is mostly dependent on the relative temperature and pressure differences between the mine and the ground surface.

As shown on Figures 2-29 and 2-30, precipitation and/or snowmelt is thought to enter the mine as diffuse flow through saturated bedrock at the ground surface. The infiltrated water eventually flows through the underground workings and comes into contact with mineralized rock and metal salts that form on the exposed rock surfaces before discharging from the 1500-level main portal. Water present within the flooded portion of the mine below the 1500 level also contributes flow to the portal drainage through the No. 2 shaft.

The underground investigations conducted in 2000 and 2001 were limited to the portions of the underground mine that were readily accessible. The areas investigated include the entire 300 level; the portion of the 1100 level from the portal to the No. 1 shaft; the portion of the 1500 level from the main portal to No. 1 and 2 shafts; and the 198, 257 and other raises (Figures 2-29 through 2-33). Other portions were not evaluated due to the lack of physical access or observed safety concerns.

The results of the underground investigations suggest that there are three primary types of water flowing through the mine workings that contribute to the 1500-level main portal drainage (Figures 2-29 through 2-33).

- Type 1 - Relatively dilute, near neutral water containing low alkalinity draining down the No. 1 shaft from the upper mine workings.
- Type 2 - Near neutral water containing elevated alkalinity upwelling from the lower mine workings through the No. 2 shaft.
- Type 3 - Strongly acidic water draining from the main tunnel in the vicinity of the large stopes.

Qualitative observations made during the investigations indicate the amount of airflow through the mine appears to have increased since the 1500-level portal was rehabilitated in the fall of 2000, as indicated by the apparent increase in the amount of airflow from the 1100 and 300 level openings.

Feasibility of Hydrostatic Bulkhead Installation

The underground investigation also included an evaluation of the bedrock integrity within the mine for the installation of hydrostatic bulkheads in the 1500-level main and ventilator tunnels, and to further evaluate the potential for mine-related subsidence. Access to the ventilator tunnel was not possible due to the partially collapsed condition of the tunnel in the immediate vicinity of the No. 2 shaft. Access is currently not possible through the 1500-level ventilator portal.

The underground investigations confirmed the integrity of the bedrock within the 1500-level main tunnel is sufficient to allow for the installation of a hydrostatic bulkhead within that portion of the mine. Although physical access to the 1500-level ventilator tunnel was not possible during the underground investigations, initial observations of the mine geology within the immediate vicinity of the No. 2 shaft indicate construction of a bulkhead would likely be feasible at some location within the ventilator tunnel.

Faults and Potential for Groundwater Leakage

The results of the underground investigations confirmed the presence of two primary faults within the mine. Referring to Figure 2-34, the bedrock within the Railroad Creek watershed has been mapped by others as containing a series of faults that are generally oriented parallel to sub-parallel to Railroad Creek. The two primary faults expressed within the mine are consistent with the watershed-wide structural geology, and appear to intersect both the 1500-level main and ventilator tunnels (Figures 2-4, 2-5, and 2-6). However, it is not likely that significant mine leakage is occurring below the 1500-level under current conditions based on the orientation of the faults, the fact that they plunge relatively steeply downward, the relatively "tight" nature of the faulted bedrock, the lack of evidence suggesting recent movement, and the presence of relatively low permeability glacial till overlying the bedrock below the 1100-mine level. This is further supported by the fact that the lateral projections of the mapped faults are intersected by Copper Creek, which based on RI data does not contain elevated metals concentrations. The results of the baseline loading analysis presented in Section 2.6 also do not support the potential for mine leakage below the 1500 level.

Mine Subsidence Potential

Due to the shallow nature of one or more of the underground stopes, the potential for subsidence at the Holden Mine was evaluated as part of the RI. However, due to the large vertical and lateral extent of the stopes, it is not possible to gain access to the top portions in order to evaluate the structural integrity of the bedrock that forms the "crown pillar". Therefore, the scope of work for the RI included conducting relatively detailed field mapping along exposed portions of the bedrock between the 300- and 550-level portals, and the 700- and 1100-level portals. The results indicate that the bedrock spanning the largest of the underground openings is marginally stable, based on comparisons with historical data collected and analyzed from other similar mines.

Additional bedrock-related structural data were collected during the underground investigations from the 300- and 1100-mine levels, with a focus on the areas immediately adjacent to the largest stopes. Qualitative observations were also made of the condition of the 1500 and 1100 mine levels. Limited collapse of areas adjacent to the largest of the accessible openings (near the junction of 1500-level main tunnel and passageway to the No. 2 shaft, and in the passageway adjacent to the largest of the stopes that intersect the 1100 level) prevented physical access inside the openings.

The results of both the underground and above-ground studies were analyzed using three-dimensional projections. The projection data were then compared with mine subsidence data collected from other similar underground mines. The results of the combined analyses indicate that the bedrock spanning the largest of the underground openings is marginally stable.

1500-Level Main Portal Drainage

As noted above, precipitation and spring snowmelt enters the bedrock and the underground mine as diffuse flow through fractures and joints, and come into contact with mineralized rock and metal salts exposed in the underground workings. The water discharges from the 1500-level main portal that represents the elevation of the water level within the underground mine. The mineralized groundwater discharges as surface water at the main portal opening (P-1), and flows via the portal drainage channel to the confluence of Railroad Creek (P-5 on Figure 2-18, column D.9 and row 2.9). Table 2-1 summarizes portal drainage chemistry data collected between 1997 and 2003.

The observed discharge rates for the portal drainage vary from an average base flow of about 0.15 cfs to a maximum recorded peak flow of about 3.5 cfs during spring snowmelt. The average daily portal drainage flows from October 1997 through October 2003 are shown on

Figure 2-35. Data collected between November 15, 1999 and August 3, 2000 were determined to be suspect due to transducer malfunction and have been omitted from this graph.

As indicated previously, the portal drainage flows into Railroad Creek upstream of the influence of the tailings piles and Railroad Creek monitoring station RC-4. Observations made during the RI indicate that a small component of the portal drainage flow also likely infiltrates the ground surface between P-1 and P-5, eventually discharging to Railroad Creek as groundwater (column D.9 on Figure 2-18). The site-specific loading analysis noted above illustrates that, during high flow periods in the spring the 1500-level main portal drainage is the primary source of cadmium, copper, and zinc loading to Railroad Creek (approximately 60 to 70 percent of the measured load at Railroad Creek monitoring station RC-2). This situation is normally exacerbated by the increase in discharge from the portal drainage before flow rates increase in Railroad Creek due to the elevation and related temperature differences within the watershed. Figures 2-36 and 2-37 provide Railroad Creek discharges and cadmium copper, and zinc concentrations over time. The data indicate that peak concentrations of these metals occur just prior to peak Railroad Creek flows during the rising limb of the hydrograph.

The portal drainage also contributes aluminum (approximately 42 percent of the dissolved load measured at RC-2) and small amounts of iron (less than 0.5 percent of the dissolved load measured at RC-2) to Railroad Creek. However, a majority of the loading of these constituents appears to be contributed by East Area sources. Railroad creek discharges are plotted with aluminum and iron concentrations on Figures 2-38 and 2-39. As shown on Figures 2-38 and 2-39, peak aluminum concentrations were observed to occur in Railroad Creek during the spring flush and peak iron concentrations were observed during the low-flow period.

1500-Level Ventilator Portal and Abandoned Surface Water Retention Area

A relatively small volume of water was observed discharging from the 1500-level ventilator portal during the RI. Analytical results indicate that this water is meteoric in nature and does not originate from the underground mine. The water flows into a former retention area that was apparently associated with mine backfilling activities discussed previously (column D.7 and row 2.9 on Figure 2-18). Soils in the retention area were sampled and analyzed during the fall of 2001, and analytical results indicate that the near surface soils contain tailings with elevated concentrations of copper, cadmium and zinc above State of Washington soil criteria.

Water seepage from the former retention area likely influences seep SP-26, which discharges from the Railroad Creek stream bank downgradient of the former retention area. The seep water was sampled and analyzed and found to contain low to background concentrations of aluminum, cadmium, copper, iron, and zinc (less than 0.1 percent of the measured load at RC-2). Based on these data, while the former retention area contains soils with elevated metals concentrations, it does not appear to be a significant source of metals loading to Railroad Creek.

1100-Level Portal

The 1100 level of the underground mine slopes gently towards the 1100-level portal. The portal originally consisted of timbers that supported a relatively shallow layer of weathered bedrock, which collapsed following closure of the mine. Water flows into this portion of the mine from the surface, travels along the 1100-level floor, and seasonally collects behind soil present at the failed portal. In the spring, the water seeps through the collapsed material, flows overland for a short distance, and then infiltrates waste rock associated with the 1100-level mine workings. The water is thought to continue to flow down slope through the alluvium and colluvium associated with the adjacent intermittent drainage and avalanche chute, consisting mostly of sand and gravel. The water is likely expressed as seep SP-23, and possibly seep SP-12, as described below under "Honeymoon Heights" (column D.8 and row 3.0 on Figure 2-18).

2.4.1.2 Honeymoon Heights

Honeymoon Heights is situated south to southwest and upslope from the mill building (Figure 2-4). Precipitation in this area generally infiltrates the ground surface and does not result in overland flow, except for an intermittent drainage feature described below. Even during the spring, the majority of snowmelt upslope of the Site infiltrates the weathered bedrock soil and the glacial sand and gravel that cover the bedrock on the lower valley side slopes. The majority of this water is believed to eventually discharge into Railroad Creek (see "Honeymoon Heights" in the left-hand column of Figure 2-21), and a portion of the water is likely lost due to evapotranspiration.

Surface water in the Honeymoon Heights area comes into contact with partially mineralized waste rock associated with the 800- and 1100-level mine workings, and is likely associated with seasonal seeps SP-12 and SP-23. Seeps SP-12 and SP-23 emanate from the bank adjacent to Railroad Creek during spring months (columns D.8 and D.9, row 3.0, Figure 2-18), and were observed to have a combined maximum flow of approximately 210 gpm (13 L/s) in the spring. These seeps were not observed to flow during the remainder of the year.

The baseline loading analysis illustrates that, in the spring, the SP-12 and SP-23 seeps are the second largest source of cadmium, copper, and zinc loading to Railroad Creek (approximately 8, 31 and 7 percent of the measured load at Railroad Creek monitoring station RC-2, respectively). These two seeps also contain elevated concentrations of aluminum (approximately 9 percent of the measured dissolved load at RC-2). However, as stated previously, available data indicate that a majority of the aluminum loading to Railroad Creek is contributed by East Area sources.

2.4.1.3 East and West Waste Rock Piles

During mining operations, two waste rock piles were constructed to the west and east of the mill building (columns E.0 and E.1 on Figure 2-4). The piles consist of rock that was removed from the underground mine but did not contain sufficient concentrations of mineralized ore to warrant processing. The piles are estimated to contain less than 250,000 cubic yards of rock fragments and weathered rock of varying sizes that cover an area of about 10 acres. The waste rock was placed on a slope consisting of a thin (approximately 10 to 20 feet thick) soil and colluvium layer underlain by relatively low permeability compact glacial till.

The west waste rock pile is situated to the west of the mill building. Water that infiltrates the pile collects at the sloped contact with the glacial soil. The water travels downslope along the contact and discharges as intermittent seeps SP-6 and SP-15 that flow as surface water to the lagoon area, where the water infiltrates and eventually flows into Railroad Creek as groundwater

(Figure 2-18). The seeps were only observed to flow during the spring snowmelt period. However, intermittent discharges may also occur during the remainder of the year as a result of storm-related precipitation events. The conceptual transport pathways for the west waste rock pile are shown on Figure 2-21 (see "West Waste Rock Pile" in the left-hand column).

Seeps from the west waste rock pile contain elevated concentrations of aluminum, cadmium, copper, and zinc resulting from contact with mineralized rock and soils. However, the baseline loading analysis suggests that in the spring, the west waste rock pile contributes less than 2 percent of the measured load of these constituents at monitoring station RC-2.

The RI qualitatively evaluated the potential for failure of the waste rock piles in terms of delivery to the road located near the base of the pile. Based on the observed angular nature of the waste rock, it is estimated that the potential for slope failure is relatively low. However, isolated shallow failures have the potential to occur on the steepest slopes of the west waste rock pile located immediately south of the road from the maintenance yard to the portal drainage in an area where a wood wall was constructed and has since partially decomposed.

The east waste rock pile, located to the east of the mill building, was constructed in the same general manner and at the same time as the west waste rock pile. Two test pits completed in 2003 at the base of the east waste rock pile encountered tailings to a depth of about 18 feet bgs, indicating that a portion of the pile may have been placed after tailings pile 1 was completed. Snowmelt infiltrates the surface of the east waste rock pile and discharges as seasonal seep SP-8, which discharges into seep SP-19 that flows as surface water to the Copper Creek diversion. The Copper Creek diversion water discharges directly into Railroad Creek (Figure 2-18). The site-wide loading analysis suggests that in the spring, the east waste rock pile contributes less than approximately 3 percent of the measured load of aluminum, cadmium, copper, and zinc at RC-2 and less than 0.1 percent of the measured load of dissolved iron. Seep SP-8 was not observed to flow during the remainder of the year.

Seep SP-19 includes snowmelt and surface run-on from the area upslope of tailings pile 1 in addition to the flow from seep SP-8. A small component of seep SP-19 likely infiltrates tailings pile 1 as it flows toward the Copper Creek diversion. Conceptual transport pathways for the east waste rock pile are shown on Figure 2-21 (see "East Waste Rock Pile" in the left-hand column).

2.4.1.4 Maintenance Yard

The maintenance yard was constructed to serve the mine operation but continues to be used by Holden Village (Figure 2-40). The area is less than 1 acre in size and includes several buildings and a gravel-covered yard with access road. Precipitation from storm events and snowmelt infiltrates the surface of the maintenance yard. A portion of the infiltrated water is thought to discharge as seep SP-22 that flows into Railroad Creek (Figure 2-18). The seep was observed during the RI to only flow during the spring snowmelt period. A surface water component of runoff from the maintenance yard also flows via a ditch into the lagoon, where the water infiltrates into the groundwater and eventually flows into Railroad Creek. The conceptual transport pathways for the maintenance yard are shown on Figure 2-21 (see "Maintenance Yard" in the left-hand column).

The surface soil in the maintenance yard area contains elevated concentrations of barium, cadmium, copper, zinc, and total petroleum hydrocarbons (TPH) in the form of gasoline, diesel, and motor oil. The metals are assumed to be associated with the historic mining activities by Howe Sound Company. However, the TPH may be associated with equipment operation and maintenance by both Howe Sound Company and Holden Village. Surface water runoff from these areas eventually flows into the lagoon, and subsurface flow may be expressed as intermittent seep SP-22. The site-wide loading analysis suggests that, in the spring, seep SP-22 contributes less than 1 percent of the measured loading of aluminum, cadmium, copper, iron, and zinc at Railroad Creek monitoring station RC-2. This seep was not observed to flow in the fall.

2.4.1.5 Mill Building

The mill building was constructed on a relatively steep slope situated between the west and east waste rock piles and within glacial till soil (Figure 2-40). The building covers an area of about 1 acre. Precipitation from storm events, snowmelt, and shallow groundwater from upslope areas flow into the mill building and come into contact with unprocessed ore and mineral salts present on the surface of abandoned tanks and other equipment. The surface water runoff component discharges as seep SP-7 that flows via the maintenance yard ditch to the lagoon, where the water infiltrates the substrate and eventually flows into Railroad Creek as groundwater (Figure 2-18). A groundwater component from the mill building is also thought to potentially influence seep SP-22. The conceptual transport pathways for the mill building are shown on Figure 2-21 (see "Building" in the left-hand column).

Surface water and seeps from the mill building areas (seeps SP-7 and SP-22) contain elevated concentrations of copper, cadmium and zinc resulting from contact with mineralized rock, ore materials and soils. The site-wide loading analysis suggests that in the spring seeps SP-7 and SP-22 contribute less than about 2.5 percent of the cadmium, 4 percent of the copper, and 2 percent of the zinc load measured at Railroad Creek monitoring station RC-2. The analysis indicates that seeps SP-7 and SP-22 are not significant sources of aluminum or iron loading to Railroad Creek. These seeps were observed to be dry during the remainder of the year.

2.4.1.6 Lagoon Area

The lagoon was constructed during mining operations to collect surface water from the mill building and maintenance yard areas, and covers approximately 1 acre (Figure 2-40). The lagoon was constructed within reworked sands and gravels that are relatively permeable, and water that collects in the lagoon does not flow directly into Railroad Creek but instead infiltrates through the bottom to groundwater.

Based on water chemistry data collected from seeps downgradient of the lagoon, it appears that the groundwater from the lagoon eventually flows into Railroad Creek. The lagoon generally contains standing water from early spring through early summer, and evaporation alone does not appear to account for the loss of water from this feature. Based on historical maps, it appears that the lagoon was constructed on top of a former channel of Railroad Creek that likely contains higher permeability soils and, therefore, may act as a preferential pathway for groundwater movement from the lagoon to Railroad Creek.

Surface water runoff and seeps from the west waste rock pile, maintenance yard and mill building flow into the lagoon and contain elevated concentrations of copper, cadmium and zinc resulting from contact with mineralized rock and soils. Therefore, water that collects in the lagoon and surrounding low-lying areas also contain concentrations of cadmium, copper and zinc. The collected water infiltrates the subsurface and eventually flows to Railroad Creek.

The baseline loading analysis suggests that in the spring, water within the lagoon may contribute approximately 4, 2, and 3 percent of the cadmium, copper, and zinc load measured at Railroad Creek monitoring station RC-2, respectively. This is based on the assumption that the total metals loading from the Copper Creek diversion and seeps SP-1, SP-9, SP-10E/10W, SP-11, SP-24, and SP-25 are potentially related to groundwater flow from the lagoon (Figure 2-18). This is a conservative assumption, as a number of sources described previously contribute loading to the lagoon area, and therefore likely impact the water quality at these locations. The lagoon area and these seeps were observed to be dry in the fall, however, both the loading analysis and groundwater monitoring data obtained in October 2003, indicate elevated concentrations of PCOCs within groundwater during the period of sampling.

Based on the results of the loading analysis, the lagoon area does not appear to be a significant source of aluminum or iron (likely less than 1 percent of the dissolved load measured at RC-2).

2.4.1.7 Copper Creek

Copper Creek originates in Copper Basin south of the Site (column E.1 and row 3.3 on Figure 2-4. The stream flows between tailings piles 1 and 2 before entering Railroad Creek (column E-2 and row 3.0 on Figure 2-4). The stream does not appear to come into direct contact with the tailings materials. However, it does appear that some of the instream water from Copper Creek is lost to the subsurface sands and gravels, and flows underneath the adjacent tailings piles.

2.4.1.8 Copper Creek Diversion

The Copper Creek diversion also originates in Copper Basin south of the Site at a diversion structure in Copper Creek (column E.1 and row 3.2 on Figure 2-4). The water is piped downslope to the hydroelectric plant to produce electrical power for the Holden Village. The water discharges from the hydroelectric plant, flows north along the western margin of tailings pile 1 and makes contact with the tailings materials before entering Railroad Creek (column E.1 and row 3.0 on Figure 2-4). The drainage also intercepts seep SP-19 that originates from the vicinity of the east waste rock pile, flows across tailings pile 1, and then discharges into Copper Creek diversion (column E.1 and row 3.0 on Figure 2-18). It is likely the drainage also intercepts some upgradient groundwater transported from the lagoon and maintenance yard/mill building areas via the former Railroad Creek stream channel as discussed in Section 2.4.1.6.

The baseline loading analysis indicates that the Copper Creek diversion transports approximately 3 and 1.5 percent of the measured load of cadmium and zinc at RC-2 in the spring (excluding SP-19) and 5, 4, and 1 percent of the measured cadmium, copper, and zinc load in the fall, respectively. The results of the analysis indicate that the Copper Creek diversion is not a significant source of aluminum or iron loading to Railroad Creek (less than approximately 1 percent of the measured dissolved loads at Railroad Creek monitoring station RC-2).

2.4.2 East Area

The primary features of the East Area of the Site include tailings piles 1, 2 and 3 (Figure 2-4). As stated previously, the three piles are the primary source of iron and aluminum loading to Railroad Creek.

The tailings piles cover a combined area of about 90 acres and were constructed during operations from the waste materials generated from the milling process. Tailings consist of the finely ground rock remaining after the mineralized ore is crushed and the majority of the economic minerals are removed. The piles were hydraulically placed on top of the native alluvium and glacial drift that overlie the bedrock within valley bottom (Figures 2-8, 2-10, and 2-11). Permits were issued by the Forest Service during the operation of the mine to allow the construction of the tailings piles and to move Railroad Creek to the north in order to maximize the storage area on the south side of the creek. The tailings consist of relatively fine-grained silt and sand that were observed during the RI to have a range of permeability between 1.63×10^{-3} to 4.4×10^{-3} centimeters per second (cm/s) (5.35×10^{-5} to 1.44×10^{-4} ft/s) based on infiltration tests and data collected by Hart Crowser in 1975. The tailings contain relatively high concentrations of pyrite (an iron sulfide mineral).

The surfaces of the tailings piles were regraded and covered with gravel by the Forest Service between 1989 and 1991 to reduce the ponding of water and windborne transport of tailings materials. Unlined drainage ditches were also constructed to intercept and divert surface water from the surfaces of the piles; however, seasonal water continues to pond on portions of the surfaces of tailings piles 2 and 3 (Figure 2-18). Several decanting towers, or vertical drainpipes, installed during the construction of the piles to prevent the direct discharge of the tailings to Railroad Creek, were reportedly backfilled and sealed to prevent transport of surface water through the tailings piles and into Railroad Creek. During the RI, one decanting tower near the southern margin of tailings pile 1 was observed to be open and receiving surface water from a drainage ditch (Figure 2-18), thereby transporting water into tailings pile 1.

Groundwater and Surface Water Interaction

Groundwater monitoring wells were installed in 1992 and 1996 by the Forest Service in order to characterize groundwater conditions within the three tailings piles, as well as upgradient and downgradient of the piles (Figure 2-14). Figures 2-19 and 2-20 present the plan views and Figures 2-41 and 2-42 present conceptual hydrogeologic cross-sections showing anticipated water flow through and beneath the tailings piles in May and September of 1997, respectively, based on data collected from these wells during the RI. Additional groundwater monitoring wells were installed downgradient of the Site in 2001 and geologic borings were completed on the north side of the creek adjacent to the tailings piles in 2003. Data collected during the RI and subsequent field investigations indicate that the tailings piles are underlain by between approximately 30 and 100 feet of alluvium/reworked glacial drift.

Water that collects on the surface of tailings piles 1, 2 and 3, infiltrates the surface, runs off of the piles via the surface water drainage system and/or evaporates. Precipitation-related water and oxygen that infiltrates the piles oxidizes the pyrite within the tailings and creates acid-rock drainage. The acidic water continues to migrate slowly downward through the tailings and flows into the creek as surface water after emerging as seeps (seeps SP-1 through SP-5, and seep SP-18 on Figure 2-18 or as diffuse groundwater. A combination of surface water runoff from the top of tailings piles 2 and 3 and seep and groundwater discharges from the base of the eastern face of tailings pile 3 collects as a surface water drainage that eventually discharges into Railroad Creek as SP-21 (Figure 2-18).

The observed discharge rate for the East Area seeps decreases after the spring snowmelt period. However, even though seeps originating from the tailings piles are not evident for a majority of the year, water quality data from Railroad Creek suggest that groundwater from the tailings piles continues to discharge to Railroad Creek.

Metals Loading to Railroad Creek

Drainage from the tailings piles is the primary source of aluminum and iron loading to Railroad Creek. The tailings piles are not primary sources of cadmium, copper, or zinc during the spring runoff. Results of the site-specific loading analysis indicate that tailings pile 1 may contribute approximately 4, 2 and 8 percent of the measured load of dissolved cadmium, copper and zinc at RC-2 in the spring, and approximately 22, 82 and 34 percent of the measured load of dissolved cadmium, copper and zinc at RC-2 in the fall, respectively. However, some of the metals released to Railroad Creek adjacent to TP-1 may originate from West Area sources. Aluminum and iron are released to Railroad Creek from the tailings piles throughout the year. The conceptual transport pathways for tailings piles 1 through 3 are presented on Figures 2-22 through 2-24.

Potential for Mass Release of Tailings

Railroad Creek flows adjacent to the northern margins of the three tailings piles. Due to the proximity of the creek to the tailings piles, the potential exists for the delivery of tailings materials into Railroad Creek due to a hypothetical slope failure within the tailings materials. The slope angle of a majority of the lower- to mid-slopes facing Railroad Creek for tailings piles 1 and 3 was observed to range between 22 and 33 degrees, with isolated portions of the upper slopes of tailings pile 1 in excess of 60 degrees. The majority of the mid- to upper-slopes of tailings pile 2 facing Railroad Creek were observed to be greater than 44 degrees. In addition, several past releases of tailings were reported to have occurred in the area of tailings pile 2, immediately downstream of the Copper Creek confluence.

The potential for mass releases of tailings and associated metals to Railroad Creek was evaluated as part of the RI. The analyses were performed utilizing geotechnical engineering data collected by Hart Crowser & Associates in 1975 for the Forest Service, as well as groundwater levels measured in the monitoring wells installed in the tailings piles by the Forest Service. The results of the analyses suggest that current slopes that are equal to or less than 33 degrees in angle are generally stable under static (non-seismic) and seismic conditions. However, slopes steeper than 33 degrees were determined to be marginally stable under both static and hypothetical (but realistic) seismic conditions. Therefore, the majority of tailings pile 2 and the upper steeper slopes of tailings pile 1 are considered marginally stable. The lower- to mid-slopes of tailings pile 1 and all of the slopes for tailings pile 3 are considered stable under both static and seismic conditions.

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 steep slopes have been relatively stable since their construction, but are steeper than the angle of repose as determined by the range in the angle of internal friction (34 to 37 degrees) resulting from laboratory testing completed by Hart Crowser. In addition, the Site apparently experienced a relatively significant seismic event in 1990 that did not result in slope failure. Therefore, based on the completed analyses, the parameters used in the slope stability analyses may have been conservative. However, any erosion and/or removal of material at the toe of the slopes (such as Railroad Creek cutting into the slope) would reduce the factors of safety.

Potential Erosion of the Tailings by Railroad Creek

The base of the tailings pile slopes have the potential to be eroded by Railroad Creek during storm events, resulting in the potential movement of tailings with elevated metals to the creek. The existing riprap was placed along Railroad Creek between 1989 and 1991 with the intent of mitigating 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 a site known as Dan's Camp. An assessment of the existing riprap was conducted as part of the RI, and the results of the assessment indicated that a number of rocks exposed at the surface are in poor condition and eroding relatively rapidly.

As described in Section 2.2.5, a flood event that occurred on October 20, 2003 eroded portions of the Railroad Creek and Copper Creek drainages adjacent to the tailings piles. Damage resulting from the high flows included erosion of the base of the riprap protecting a 75-foot-long section of the south bank of Railroad Creek adjacent to tailings pile 2, and the erosion of portions of tailings piles 1 and 2 along the Copper Creek drainage. The following emergency activities were performed by Intalco at the Agencies' request in November 2003 to stabilize the flood-damaged areas and reduce the potential for erosion during the 2003 – 2004 winter/spring period:

- Placement of large boulders over the failed section of riprap to minimize the potential for further erosion under high flow conditions.

- Deepened the two channels within Copper Creek and built a berm in areas where the channel had overtopped its banks during the flood event.

- Regraded portions of surface of tailings pile 1 with existing sand and gravel and placed sandbag traps to reduce exposure to runoff.

- Removed a log-jam that had formed in Railroad Creek adjacent to tailings pile 1.

Potential for Delivery of Avalanche Debris

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, Forest Service, 1997). The potential exists for an avalanche to transport avalanche debris to the southern margin of the tailings pile, and possibly onto the southernmost portion of the pile; such an event would potentially deliver debris onto the tailings pile but not result in stability issues.

2.5 AFFECTED MEDIA

The results of the RI indicate that surface water, groundwater, soil, sediment, and aquatic and terrestrial biota have potentially been impacted by historic mining operations at the Site. A detailed discussion of potential ARARs is provided in Section 3.

2.5.1 Surface Water

Available surface water chemistry data from Railroad Creek indicate seasonal exceedances of the Washington State promulgated SWQC for the protection of aquatic life established for dissolved cadmium, copper and zinc. Railroad Creek water quality data for monitoring stations upstream, adjacent to, and downstream of the Site are provided in Tables 2-2 through 2-4, and surface water sampling stations are shown on Figure 2-43. No exceedances of SWQC have been measured off-site in Lake Chelan at the mouth of Railroad Creek. Available water quality data for Lake Chelan are provided on Table 2-5.

The SWQC for dissolved copper, cadmium and zinc were exceeded in the following areas and seasons (based upon high- and low-flow periods) as follows:

- ***Copper.*** During high-flow periods in the spring, exceedances of the SWQC for dissolved copper were measured from Railroad Creek monitoring station RC-4, which is located downstream of the point where the portal drainage enters Railroad Creek (P-5), to the mouth of Railroad Creek (RC-3). During typical low-flow conditions, no exceedances of the SWQC for dissolved copper were measured.

- ***Cadmium***. During high-flow periods, exceedances of the SWQC for dissolved cadmium were measured from station RC-4 to RC-10. During low-flow conditions, no exceedances of the SWQC were measured for dissolved cadmium.

- ***Zinc.*** During high-flow periods in the spring, exceedances of the SWQC for dissolved zinc were measured from station RC-4 to RC-3. During low-flow periods, dissolved zinc concentrations above the SWQC were detected from immediately downstream of the tailings piles (RC-2) to station RC-5, located less than approximately one mile downstream of the Site.

Concentrations of cadmium, copper and zinc generally decrease through the late spring/early summer, as the flows in Railroad Creek increase in proportion to the discharge rates from the portal drainage and seeps (primarily SP-12 and SP-23), and as a result of seasonal variations in portal drainage chemistry. The measured cadmium, copper, and zinc concentrations are correlated with Railroad Creek discharge measurements for the period between March and October 1997 on Figures 2-36 and 2-37. Concentrations of dissolved copper and cadmium in Railroad Creek also decrease with distance downstream due to chemical reaction processes occurring in the surface water and dilution from tributaries.

No exceedances of primary state and federal Maximum Contaminant Levels (MCLs) for drinking water were detected in Railroad Creek.

As required by the Agencies, the available surface water chemistry data from Railroad Creek were compared to the federal NRWQC published in 1999 and 2002. Based on these comparisons, seasonal concentrations of dissolved cadmium, copper, and zinc in Railroad Creek exceed the 1999 and 2002 NRWQC established for freshwater aquatic life. The 1999 and 2002 NRWQC chronic criteria for total aluminum and iron were also exceeded seasonally.

Because the 2002 and 1999 NRWQC values for cadmium and copper are more stringent than the corresponding SWQC, additional exceedances were indicated when comparing these values to the surface water chemistry data. Additionally, the 2002 NRWQC value for cadmium at some stations and the 1999/2002 NRWQC for aluminum are below the statistically calculated area background value. The 1999 and 2002 NRWQC for dissolved copper, cadmium, zinc, and chronic criteria for total aluminum and iron were exceeded in the following areas and seasons (based upon high- and low-flow periods):

- ***Copper.*** During high flow periods in the spring, exceedances of the 1999 and 2002 NRWQC for dissolved copper were measured from Railroad Creek station RC-4 to RC-3. During low-flow conditions, a slight exceedance of the 1999 and 2002 chronic criterion for copper was measured at station RC-4.

- ***Cadmium.*** During high flow periods, exceedances of the 1999 NRWQC for dissolved cadmium were measured from RC-4 to RC-2. No exceedances of the 1999 NRWQC were measured during the low flow periods. Exceedances of the lower 2002 NRWQC for dissolved cadmium were measured from RC-6 to RC-3 during the high flow periods, and from RC-2 to RC-10 during the low flow periods. The calculated chronic criterion for cadmium under the 2002 NRWQC was below area background in several instances.

- ***Zinc.*** During high flow periods, exceedances of the NRWQC for dissolved zinc were measured from RC-4 to RC-3. During low flow periods, dissolved zinc concentrations were below the 1999 and 2002 NRWQC at all sampling locations.

- ***Aluminum.*** During high flow periods in the spring, aluminum concentrations greater than the area background value and the chronic 1999 and 2002 NRWQC were measured in Railroad Creek from background station RC-6 to downstream station RC-3. During low-flow conditions in Railroad Creek, aluminum concentrations were below the 1999 and 2002 NRWQC and/or area background.

- ***Iron.*** During spring high-flow conditions, available water quality data indicate no exceedances of the NRWQC for iron. During low-flow conditions, however, exceedances of the 1999 and 2002 NRWQC for iron were measured from station RC-7 to RC-5.

Available data indicate that aluminum concentrations are higher during the spring flush and generally decrease during the early summer and fall. Aluminum concentrations were observed to increase from background station RC-6 to station RC-2. Iron concentrations, like aluminum, generally increase from background station RC-6 to RC-2 and then decrease with distance downstream. The data indicate higher iron concentrations during the low-flow period in the fall and winter, decreasing with higher creek flows in the spring. Measured aluminum and iron concentrations are correlated with Railroad Creek flow measurements at RC-4 on Figures 2-38 and 2-39.

No exceedances of NRWQC have been measured off-site in Lake Chelan at the mouth of Railroad Creek (Table 2-5).

2.5.2 Groundwater

The RI data indicate that concentrations of cadmium, copper, lead, manganese, nickel, and zinc in groundwater beneath portions of the Site were detected above potential ARARs (i.e., federal and state maximum MCLs, MCLs adjusted according to the Washington State Model Toxics Control Act (MTCA) requirements, and MTCA Method B groundwater values). Although groundwater at the Site is not used as a drinking water source, groundwater quality data were compared to these human health-based ARARs as discussed in Section 3. Figure 2-11 provides approximate seep sampling locations and Figure 2-16 provides hydrogeologic investigation locations. Groundwater quality data collected during the RI are provided on Table 2-6.

Available data indicate the following exceedances of potential groundwater ARARs:

- Seeps associated with the Honeymoon Heights area (SP-23, SP-23b, and SP-12) currently exceed the Federal or adjusted MCL and MTCA Method B groundwater values for cadmium and copper as well as the MTCA Method B groundwater value for zinc.

- Seeps associated with the west waste rock pile (SP-6 and SP-15W) currently exceed the Federal MCL or adjusted MCL for cadmium, copper and lead, as well as the MTCA Method B groundwater values for cadmium, copper, manganese and zinc.

- Seeps associated with the mill building (SP-7 and SP-22) currently exceed the Federal MCL or adjusted MCL for cadmium and copper, as well as the MTCA Method B groundwater values for cadmium, copper, and zinc.

- Seeps associated with the east waste rock pile (SP-8 and SP-19) exceed the Federal MCL or adjusted MCL for cadmium and copper as well as the MTCA Method B groundwater values for cadmium, copper, and zinc.

- Groundwater beneath the West Area (measured in wells 2003-MW1 though 2003-MW4S/4D and Seeps SP-9 and SP-11) currently exceeds the Federal MCL or adjusted MCL and MTCA Method B values for cadmium and copper.

- Groundwater beneath the eastern portion of the West Area (measured in groundwater monitoring well HBKG-1 and Seeps SP-24, SP-25, SP-10W, and SP-10E) currently exceeds the Federal MCL or adjusted MCL for cadmium, copper, and lead, as well as the MTCA Method B groundwater value for cadmium, copper, and zinc.

- Groundwater beneath tailings pile 1 (measured in monitoring wells and Seeps SP-1 and SP-2) currently exceeds the Federal MCL, State MCL or adjusted MCL for cadmium, copper, and nickel, as well as the MTCA Method B groundwater values for cadmium, copper, manganese and zinc.

- Groundwater beneath tailings pile 2 (measured in monitoring wells and Seeps SP-3 and SP-4) has similar exceedances to tailings pile 1 groundwater for cadmium, copper, and manganese.

- Groundwater beneath tailings pile 3 (measured in groundwater monitoring wells) currently exceeds the MTCA Method B value for groundwater for manganese.

- In the area east of tailings pile 3, well DS-2 currently exceeds the MTCA Method B groundwater value for manganese. Area seeps (SP-5, SP-17, SP-18, and SP-21) currently exceed the Federal MCL or adjusted MCL for cadmium and copper and the MTCA Method B groundwater values for cadmium, copper, and manganese.

Five groundwater areas of the Site were assessed for their potential impact to surface water with respect to surface water PCOCs. These areas include seeps entering Railroad Creek associated with the former surface water retention area, Honeymoon Heights drainage, West Area seeps upstream and downstream of RC-4, tailings piles 1 and 2, and east of tailings pile 3. The potential ARARs associated with the surface water PCOCs were evaluated to assess potential groundwater impacts to surface water, and are discussed in Section 3.

The potential surface water ARARs (SWQC and 1999/2002 NRWQC) for dissolved cadmium, copper and zinc were exceeded in seeps from the areas described above as follows:

- Former surface water retention area – Seep SP-26;
- Honeymoon Heights – Seeps SP-12 and SP-23;
- West Area seeps – Seeps SP-9, SP-11, SP-25, SP-24, SP-10E, and SP-10W;
- Tailings piles 1 and 2 – Seeps SP-1, SP-2, SP-3 and SP-4; and
- Downgradient (east) of tailings pile 3 – Seep SP-21.

Since the SWQC and NRWQC for cadmium, copper, and zinc are hardness corrected, an average hardness of 14 mg/L was used to assess the surface water criteria for comparison of the seep data. Seep data for the five areas listed above were also compared to the Agency-required 1999/2002 NRWQC for total aluminum and iron. Seep data are available for the dissolved fraction of these constituents only, and so the dissolved data was compared to the NRWQC values. The NRWQC for aluminum and/or iron were exceeded at the following locations:

- Honeymoon Heights – The NRWQC for aluminum was exceeded for seeps SP-12 and SP-23.

- West Area seeps – The NRWQC for aluminum was exceeded for seeps SP-11, SP-24, SP-25, SP-10W, and SP-10E. The NRWQC for iron was exceeded at seep SP-10E.

- Tailings piles 1 and 2 – The NRWQC for aluminum and iron were exceeded at seeps SP-1, SP-2, SP-3 and SP-4.

- Downgradient of tailings pile 3 – The NRWQC for aluminum and iron were exceeded at seep SP-21.

2.5.3 Soils and Sediments

The following subsections summarize areas of potentially impacted soils and sediments.

2.5.3.1 Soils

During the RI and subsequent investigations, soil samples were collected across the Site, including the area immediately downwind of the tailings piles; maintenance yard; lagoon and surrounding area; former retention area associated with the 1500-level ventilator portal; Holden Village; and the baseball field (Figures 2-40 and 2-44). Soil samples were analyzed for total metals and physical characteristics, such as pH, and the soil chemistry results are provided on Table 2-7.

Referring to Figures 2-40 and 2-44, analytical data collected during the RI indicate that potential soils ARARs are exceeded in the following areas:

- Maintenance yard,
- Lagoon area,
- Former surface water retention area,
- Mill building, and
- Holden Village.

Section 3 presents the potential ARARs that will be evaluated to establish cleanup levels for these areas.

The PCOCs identified for Site soils include cadmium, copper, lead, silver, zinc, and total petroleum hydrocarbons. The following summarizes exceedances of potential ARARs, including the MTCA Method B protection of groundwater screening levels and MTCA Method B direct contact levels, for each of the five areas listed above:

- Maintenance yard - Soils in the maintenance yard currently exceed the MTCA Method B protection of groundwater screening levels for cadmium and copper and the direct contact level (for unrestricted land use) for copper. Total petroleum hydrocarbons (TPH) were also detected in the maintenance yard (gasoline, diesel and motor oil range). Assessment of the data indicates that the gasoline range TPH concentrations were below the calculated MTCA Method B direct contact values but above the screening value calculated for the protection of groundwater. Diesel and motor oil range TPH concentrations were measured above the MTCA Method B direct contact values. Diesel range TPH concentrations were also above the protection of groundwater screening values.

- Lagoon area - The lagoon soils currently exceed the screening values calculated for protection of groundwater for cadmium, copper, silver, and zinc and the MTCA Method B direct contact values for cadmium and copper. Total petroleum hydrocarbons were also detected in the lagoon (diesel and motor oil range). The concentrations of diesel range hydrocarbons exceed the protection of groundwater screening levels.

- Former surface water retention area – Tailings materials that are present in the former retention area currently exceed the protection of groundwater screening levels for cadmium, copper, and zinc.

- Mill building – Due to safety concerns, no soil samples were collected from within the mill building. However, surface water and seep sampling data indicate the presence of materials within the mill building that likely contain metals concentrations above potential ARARs. As a result, this area is being addressed under the candidate remedial alternatives.

- Holden Village - Data collected during the RI indicate a limited number of surface soil samples (two of seven) collected in Holden Village currently exceed the low, screening value calculated for the protection of groundwater level for copper. However, based on the human health risk assessment presented in the DRI, surface soils in Holden Village are not considered to pose a risk to human health. Additionally, groundwater data collected at HV-3 located in the vicinity of one of the surface soil samples do not indicate elevated levels of copper, and results of the loading analysis discussed in Section 2.6 indicate that groundwater on the north side of Railroad Creek is not a source of metals loading. Therefore, these soils are not addressed under the candidate alternatives.

All potential soil ARARs for arsenic are below the calculated area background, resulting in the upward adjustment of the ARARs to the calculated background value (Section 3). Arsenic was detected above background concentrations on the south side of Railroad Creek at a single location in the maintenance yard and in three surface soil samples collected from the area located to the west of the lagoon (in the vicinity of 2003-MW1 through 2003-MW4). Arsenic concentrations above area background were also measured during the RI at background locations on the north side of Railroad Creek near the USFS guard station and wilderness boundary, and several miles upstream near Hart Lake.

There are no documented arsenic-bearing minerals in the ore body. Tailings sampling and analysis data also indicate low arsenic concentrations, suggesting a low arsenic content in the pyrite (an iron-rich sulfide material that is abundant in the underground mine). Isolated occurrences of naturally elevated arsenic concentrations are not uncommon in the region, and the relatively uniform concentrations of arsenic measured in the West Area soils and soils near the Forest Service guard station (in contrast to elements associated with the ore body, including cadmium, copper, and zinc) are consistent with well-mixed sediment from a distant source. The arsenic concentrations measured in background soils and in the West Area were likely transported by glacial activity and/or surface water from sources up valley, such as the Cloudy Pass Pluton, and are not believed to be a result of historic mining operations. Therefore, arsenic is not considered to be a soil or groundwater PCOC.

An evaluation of Site soils with respect to the protection of ecological receptors is provided below in Section 2.5.4.

2.5.3.2 Sediment

Due to the relatively large granular nature of the sediment present in Railroad Creek, it is not reasonably possible to collect representative sediment samples, and the assessment of sediment chemical characteristics is difficult. However, in 1997, Ecology compared metals concentrations in sediment samples collected from Railroad Creek in 1996 to assumed background levels for stream sediments in Washington and proposed freshwater sediment quality guidelines (FSQVs). Measured concentrations were below the FSQVs and no adverse effects were determined for Railroad Creek sediments based on bioassays conducted by Ecology in 1997. During the RI investigations, limited areas of sediment affected by the formation of ferricrete (cemented sand and gravel caused by the co-precipitation of iron and other metals) were observed. The presence of ferricrete has been documented in areas located in direct proximity to seeps SP-1, SP-2, and SP-3, which contain elevated concentrations of iron and flow directly to Railroad Creek (Figure 2-45). Based on review of the data collected by Ecology in 1996 and 1997, and samples collected by URS during the RI, only sediment in the areas where ferricrete has been observed will be addressed in the FS.

Sediment samples were collected by URS in 1998, 2001, and 2002 from Lake Chelan near the mouth of Railroad Creek at Lucerne and from a reference site located near Stehekin (Figures 2-46 and 2-47). Sediment samples were analyzed for total metals and physical characteristics such as grain size and pH. Based on the sediment chemistry and grain size results, bioassays were performed on select Lake Chelan sediment samples collected from the Lucerne bar and Stehekin in 2001 and 2002. The results indicated no significant chemical toxicity in the samples collected from the Lucerne bar when compared to the control tests and results from the reference locations (URS 2002d; URS 2003b). Based on these results, Lake Chelan sediment will not be addressed in the FS.

2.5.4 Aquatic and Terrestrial Biota

Potential impacts to aquatic and terrestrial biota including fish, benthic macroinvertebrates, wildlife and vegetation are discussed in the following subsections.

2.5.4.1 Aquatic Biota

The results of aquatic studies performed for the RI suggest fish within Railroad Creek have potentially been affected by a possible combination of physical and chemical effects. The following observations were noted with respect to potential impacts to fish in Railroad Creek:

- Snorkel surveys conducted during the RI found fish throughout Railroad Creek. However, reduced fish populations were observed in Railroad Creek adjacent to the Site (RC-7) and immediately downstream of the Site at station RC-5 (Figure 2-43). Table 2-8 provides a summary of trout population estimates for Railroad Creek. The data suggest fish populations recover to reference reach values approximately three miles downstream of the Site.

- Benthic macroinvertebrates, one of the food sources for fish, were reduced within Railroad Creek from station RC-9 (near the northeast corner of tailings pile 1) to the mouth of Railroad Creek at Lucerne (station RC-3 on Figure 2-43). Table 2-9 provides benthic macroinvertebrate data collected for Railroad Creek during the RI. However, it is possible that fish consume other food sources in the lower reaches of Railroad Creek where macroinvertebrate populations are reduced.

- Fish and macroinvertebrate populations were observed at or above reference site values between the portal drainage confluence (P-5) and tailings pile 1 (station RC-9) where the flocculent is first observed in the creek (Figure 2-43).

- The presence of iron oxy-hydroxide precipitates, or flocculent, in slow moving reaches of Railroad Creek, is first observed adjacent to tailings pile 1 in the vicinity of station RC-9. The formation of flocculent is caused by the upwelling of iron-rich groundwater into Railroad Creek from the tailings piles. Results of the ecological field studies and ERA indicate a possible correlation between the presence of flocculent on creek sediments and reduced populations of fish from the Site to about three miles downstream. Figure 2-48 shows the reduction in macroinvertebrate populations in the area adjacent to tailings pile 1 where flocculent is first observed.

- Limited areas of cemented Railroad Creek substrate, or ferricrete, was observed in the immediate proximity of three groundwater seeps that discharge from the tailings piles into Railroad Creek (Figure 2-45). The formation of ferricrete results in the cementation of the substratum, which likely results in reduced biological production within the aquatic environment due to the loss of habitat in these areas.

2.5.4.2 Terrestrial Biota – Wildlife and Soil Biota

The ERA performed in conjunction with the RI evaluated reasonable exposure scenarios for the wildlife and soil biota on the Site. Areas evaluated in the ERA are shown on Figures 2-40 and 2-49.

The results of the ERA found a low, but potential risk to the American robin in the lagoon area and maintenance yard due to cadmium, lead and zinc under a worst-case exposure scenario. Under a reasonable exposure scenario, the ERA found a potential risk to robins only due to lead concentrations. No risk to robins was found in the Holden Village. The results of the ERA also indicate that the risk to robins may be overstated as the absence of earthworms in the lagoon area and maintenance yard (due to lack of suitable physical habitat) results in an incomplete exposure pathway. The proposed remedial alternatives address the maintenance yard and lagoon area to mitigate this low potential risk.

The results of the ERA found a potential risk to earthworms from cadmium, copper, lead and zinc in the maintenance yard and lagoon area under worst-case scenarios. Proposed remedial alternatives for the maintenance yard and lagoon areas will address this potential risk. The ERA also concluded that that suitable earthworm habitat may not exist in areas of the Site due to the physical qualities of the substrate. The results of the ERA also found a potential risk to earthworms from copper in the Holden Village. However, as stated previously, it is believed that the copper concentrations in this area are unrelated to mining activities, and the Holden Village soils are not addressed in this FS.

After evaluating scenarios that are considered typical for the Site, the ERA determined that there was not a risk to mammals due to metals toxicity associated with terrestrial habitat.

Based on the information provided above, the calculation of soil cleanup values for the protection of terrestrial ecological receptors is unnecessary as all proposed remedial alternatives address areas of the Site where a potential risk to robins and soil biota were identified in the ERA. However, preliminary cleanup values for soils based upon terrestrial ecological receptors have been calculated and presented in Appendix K and Section 3 as requested by the Agencies. These preliminary values may be used as indicators to identify areas where further evaluation may be performed, if needed for the final selected remedy. A comparison of Site soil data to the preliminary values for soil biota and wildlife indicate the following:

- Holden Village – Copper concentrations measured in one surface soil sample collected from a landscaped area within the Holden Village are above the preliminary value identified for the protection of soil biota (earthworms).

- Maintenance yard – Cadmium, copper, and zinc concentrations measured in soils from the maintenance yard are above the preliminary protection of soil biota values. Copper, lead, and zinc concentrations were also measured to be above the preliminary protection of wildlife (American robin) values.

- Lagoon area – Cadmium, copper, lead, and zinc concentrations in subsurface soils (two to four feet below the ground surface) were measured above the preliminary protection of soil biota and/or wildlife values. Copper and zinc concentrations measured in surface soils were above the preliminary protection of wildlife and/or soil biota values.

- Former surface water retention area – Cadmium, copper, and zinc concentrations measured in subsurface soils were above the preliminary protection of soil biota and/or wildlife values. Copper concentrations measured in surface soils were above the preliminary protection of soil biota values.

The results of remote monitoring and surveys conducted at the Site by Intalco and the Agencies over the period between August 2000 and November 2002 indicate that colonies of bats are not using the underground mine. Based on these results, potential impacts to bats during remedy implementation will not be assessed in the FS.

2.5.4.3 Terrestrial Biota – Vegetation

The results of the ERA found no risk to plants from metal PCOCs, except for copper in limited areas, when soil concentrations from the Site were compared with other mine sites where plants are growing successfully.

As required by the Agencies, a preliminary cleanup value for copper for the protection of terrestrial plants was developed based on the findings of the ERA (Appendix K and Section 3). This preliminary value is exceeded in surface and subsurface soils within the lagoon and maintenance yard and in surface soils at one location within the Holden Village and former surface water retention area. All proposed remedial alternatives would address soils in these areas.

Additionally, although not specifically evaluated in the ERA, distressed vegetation has been observed in the abandoned surface water retention area, between tailing piles l and 2, and immediately east of tailings pile 3, and these areas may have been adversely affected based on direct contact with soils containing elevated metals (Figure 2-49).

2.5.5 Air

The available data from air studies that have been performed at the Site do not suggest that air resources have been adversely affected. In addition, the HHRA performed as part of the RI concluded that there are no risks related to the soil to air pathway.

2.6 SITE-WIDE BASELINE LOADING ANALYSIS

As described in the previous subsections, dissolved metals enter Railroad Creek as seep flow, drainage flow and groundwater baseflow. 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 via 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. Some of the dissolved metals also precipitate out of the water column and settle on the bottom of Railroad Creek. Surface water and groundwater quality data collected during the RI are summarized in Tables 2-2 through 2-6.

Seasonal metals concentrations indicate that copper, zinc, and cadmium are at their highest levels during spring snowmelt (April/May/June) when seeps and discharge from the portal drainage are at their highest (Figures 2-36 and 2-37). Aluminum concentrations in Railroad Creek are also observed to be higher during the spring high flows (Figure 2-38). Iron concentrations are at their highest in Railroad Creek during periods of lower flow (Figure 2-39). Cadmium and copper concentrations mostly increase between Railroad Creek stations RC-1 and RC-4, and aluminum and iron concentrations mostly increase between Railroad Creek stations RC-4 and RC-7 (Figure 2-43). Zinc concentrations also mostly increase between RC-1 and RC-4, however during low-flow conditions there is an increase in zinc concentrations between RC-4 and RC-2. These observations indicate that cadmium and copper enter Railroad Creek from the portal drainage and associated seeps and drainages west of the tailings piles (West Area), and that aluminum and iron are introduced primarily from seepage and groundwater flow from the tailings (East Area). Zinc appears to enter Railroad Creek primarily from the portal drainage and West Area sources, however there also appears to be a contribution of zinc to Railroad Creek in the East Area, notably tailings pile 1.

To further evaluate the effects of metals loading to Railroad Creek, a loading 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 loading analysis was to:

- Assess dissolved metals contributions from site sources measured during the RI in relation to metal concentrations in Railroad Creek upstream and downstream of mine influences;

- Determine the point source discharges that contribute the highest dissolved metal concentrations to Railroad Creek;

- Assess the magnitude of non-point-source metal loading (assumed to be groundwater baseflow) along specific reaches of Railroad Creek; and

- Establish a baseline loading analysis for use in evaluating estimated relative post-remediation loading reductions under different candidate site-wide remedial alternatives in Section 7 of this report.

Flow and dissolved metal concentrations of seeps and drainages were measured during May and September 1997 and late April/May 1998 field seasons to assess the metal loading contributions from various sources to Railroad Creek. As 1997 is the only year which there is a complete set of data for both fall and spring conditions, these data were selected for use in this loading analysis. The data collected during the spring and fall of 1997 represent flow conditions at the Site during peak flows (e.g. spring runoff) and at lower, steady state conditions (during the fall sampling event).

Due to the limited total recoverable aluminum and iron data available for Site groundwater and seeps, and the non-conservative nature of these metals in surface water, these parameters were not incorporated into the loading analysis model. However, the baseline loading analysis was completed for dissolved (< 0.45 um) aluminum and iron. The relationship between the measured dissolved and total recoverable fractions for these metals, and an evaluation of the estimated post-remediation conditions with respect to the NRWQC (which were established for total aluminum and iron), is provided in Section 7.

The results of the site-wide baseline loading analysis are provided in Appendix A. The results indicate that all major sources of metals loading have been identified and support the findings of the site-specific water balance presented in Section 4 of the DRI. The analysis provides a sufficient baseline with which the relative loading contributions from different source areas may be evaluated and the estimated relative effectiveness of different remedial alternatives may be assessed. The following subsections provide summaries of the loading analysis methodology, format, West Area loading analysis, East Area loading analysis, accuracy of flow measurements, accuracy of concentration measurements, and uncertainty analysis.

2.6.1 Loading Analysis Methodology

Tables A-1 through A-4 included in Appendix A provide the results of the loading analysis calculations performed using the spring and fall 1997 data. The methodology used to conduct the loading analysis calculations is described in this section.

Metals loading to Railroad Creek and the subsurface from seeps and drainages and the loading within Railroad Creek was computed using flow measurement data and analytical results for water samples collected in May 1997 and September 1997. Metals loading from groundwater beneath the tailings piles was estimated based on groundwater flow through native materials and tailings as presented in the revised flow tube analysis, included as Attachment A-1 to Appendix A in this report. Groundwater monitoring well and piezometer data were selected to be representative of metals concentrations in East Area groundwater, as summarized in Attachment A-1. The source of the flow and concentration data for each line item within the loading analysis is described in the notes accompanying the tables. Specifically, loading (L) was calculated as the measured concentration for each metal for each source (C) times the flow rate (Q) of each source at the time the sample was collected:

$$L=Q*C$$

In order to provide a relative comparison of the magnitude of loading from each individual source area, the calculated loading values on Tables A-1 through A-4 were compared to the computed loading at station RC-2 in Railroad Creek. For the purposes of this study, loading is reported both as mass per unit time (kilograms per day, kg/D) and as the percentage of the measured loading at RC-2.

Evaluation of the unaccounted loading to Railroad Creek was performed by subtracting the cumulative loads calculated from background and individual source areas between RC-6 to RC-1, RC-1 to RC-4, and RC-4 to RC-2 from the measured loads at RC-1, RC-4 and RC-2, respectively. The results are referred to in the tables as “Unaccounted Load to Railroad Creek". In general, these unaccounted loads represent a combination of effects including the accuracy of measurement techniques and non-point-source discharges (groundwater) to Railroad Creek. Negative estimated unaccounted loads are likely indicative of losses due to chemical effects (i.e., precipitation, etc).

2.6.2 Loading Analysis Format

Tables A-1 through A-4 include loading calculations for magnesium, aluminum, cadmium, copper, iron, sulfate, and zinc for spring and fall 1997. 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 for each source area. The cumulative load from each source area was then compared to the total load calculated for Railroad Creek at station RC-2. The analyses for spring and fall 1997 were performed for Railroad Creek in both the East and West Areas. Figures A-1 through A-6 provide loading values for magnesium, aluminum, cadmium, copper, iron, and zinc by individual seep, tributary, or groundwater component, and metals loading schematics by source area. The revised groundwater flownet analysis performed for East Area groundwater is provided on Figures A-7 through A-11 and in Attachment A-1.

2.6.3 West Area Loading Analysis

The West Area includes the segment of Railroad Creek from RC-6 to the Copper Creek Diversion (CCD-1) downstream of RC-4. Loading calculations performed for the West Area are summarized on Tables A-1 and A-2 and Figures A-1 through A-4. Source areas associated with the West Area include Seep SP-26, Seep SP-23/Honeymoon Heights, underground mine, West Area seeps (Upstream of RC-4), west waste rock pile, mill building, West Area seeps (downstream of RC-4), east waste rock pile and Copper Creek diversion. Several of these source areas (west waste rock pile and mill building) do not discharge directly to Railroad Creek, however the loading to subsurface from these sources is included on the summary tables for the purpose of providing a more complete depiction of metals mass loading at the Site. Estimated losses to groundwater are also presented for the portal drainage (P-1 to P-5) and the east waste rock pile (SP-8 to SP-19). The measured loading at SP-19 was subtracted from the measured loading from the Copper Creek diversion (CCD-1) in order to differentiate between the metals contribution from the Copper Creek diversion and the east waste rock pile (SP-19).

Unaccounted loading at stations RC-1 and RC-4 were calculated by subtracting the cumulative loading to those stations from the measured loading at each station. This unaccounted loading is assumed to represent a combination of the accuracy of measurement techniques, groundwater baseflow, and/or metals attenuation in Railroad Creek.

Flow data for the stream discharge at stations RC-6, RC-1 and RC-4, Copper Creek diversion, and selected seeps were taken from revised DRI Tables 6.6-1, 6.6-2 and 6.6-4. As discussed below, these stream and seep discharges have been adjusted to maintain the continuity of flow relationships along Railroad Creek during a period of variable streamflow. Flow data for the remaining seeps and the portal drainage were taken from revised DRI Tables 4.3-6 and 5.3-30, respectively. The source of each flow measurement and water quality measurement are provided in the notes to Tables A-1 and A-2.

2.6.4 East Area Loading Analysis

The East Area includes the reach of Railroad Creek adjacent to tailings piles 1, 2 and 3, Copper Creek, and the reach immediately downstream of tailings pile 3 in the vicinity of seep SP-21. Loading calculations performed for the East Area are summarized on Tables A-3 and A-4, and Figures A-5 through A-10 in Appendix A. In addition to the seeps located in the East Area along Railroad creek (SP-1, SP-2, SP-3, SP-4, and SP-21), groundwater baseflow from the native material and tailings contribute metal loading to Railroad Creek. In order to estimate the groundwater contribution from native materials and tailings in the eastern portion of the Site, a groundwater flow tube analysis was performed using hydrogeologic data collected concurrently with the surface water sampling events in spring and fall 1997.

The flow tube analysis was originally included as Appendix I to the revised DRI. This analysis has been revised for use in the baseline loading analysis and is included as Attachment A-1 to this report. The flow-tube analysis utilizes available site data related to groundwater flow gradients, hydraulic conductivities, and metals concentrations to estimate the groundwater discharge and metals loading from each of the flow "tubes" shown on Figures A-7 through A-10.

Revisions made to the flow tube analysis subsequent to submittal of the DRI include:

- Evaluation of groundwater flow through native material downstream of RC-2 in the fall, including the incorporation of two new flow tubes (SL4 and SL5) and the contribution from tubes S8-Out, SL1, SL2, and SL3 downstream of RC-2.

- Revisions to the monitoring wells/seeps associated with select flow tubes for the evaluation of water quality and metals loading.

- Revisions to the assumed thickness and hydraulic conductivities for select flow tubes in native material based on information collected during the October 2003 hydrogeologic field program.

It was not possible to calculate the metals loading contribution from groundwater within the tailings material of tailings pile 1 using the flow tube analysis due to the limited availability of hydrogeologic data (there are no groundwater monitoring wells completed in the tailings materials of tailings pile 1). Therefore, the contribution of metals loading from the tailings material in tailings pile 1 was estimated by assuming that the flow (discharge) contribution from tailings pile 1 would be proportional to that from tailings pile 2 and tailings pile 3. The average groundwater flow from the tailings materials per foot of stream length was calculated by summing the groundwater flows from the tailings materials in tailings pile 2 and tailings pile 3 and then dividing the total by the length of Railroad Creek adjacent to tailings pile 2 tailings pile 3. The estimated groundwater contribution from tailings material in tailings pile 1 was then calculated by multiplying the length of Railroad Creek adjacent to tailings pile 1 by the average groundwater contribution from tailings material per foot of stream (calculated from tailings pile 2 and tailings pile 3). The resulting estimated groundwater discharge from TP-1 was then multiplied by the average of metals concentrations measured in seeps SP-1 and SP-2 in the spring and SP-2 in the fall (SP-1 was dry in the fall) to calculate metals loading from this source. This calculation is presented in the Notes to Tables A-3 and A-4 in Appendix A and on Tables 1 and 3 of Attachment A-1.

A variation in the groundwater flow pattern through the native material is evident between the spring and fall at the eastern edge of tailings pile 3 near seep SP-21. The data indicate that the segment of Railroad Creek at the eastern edge of tailings pile 3 transitions from a gaining reach to a losing reach following the spring flush period. This change in groundwater flow regime is illustrated in Figures A-9 and A-10. The data indicate that a loss of metals loading from Railroad Creek to groundwater occurs just upstream of RC-2 during relatively steady-state, fall conditions. This flow from Railroad Creek travels as groundwater through the native material beneath tailings pile 3 and re-enters Railroad Creek downstream of station RC-2, as illustrated by flowtubes S8, SL1, SL2, and SL3 on Figure A-10.

The discharge rates at stations RC-7 and RC-2, Copper Creek and for East Area seeps were taken from DRI Tables 6.6-1, 6.6-2 and 6.6-4. As discussed below, these stream and seep discharges have been adjusted to maintain the continuity of flow relationships along Railroad Creek during the period of highly variant streamflow (May 1997). Flow data for the groundwater flow tubes are provided in Attachment A-1. Representative groundwater monitoring wells and piezometers were selected for each flow tube as summarized in Attachment A-1 (Tables A1-1 through A1-4). The source of each flow measurement and water quality measurement are provided in the notes to Tables A-3 and A-4.

2.6.5 Uncertainty Analysis

The numerical results of the loading analysis represent an estimate of the true conditions at the Site during the spring and fall sampling periods in 1997. A statistical analysis of the loading calculations is not feasible due to the limited amount of available data for the sources that were evaluated. Therefore, a probabilistic analysis was developed to evaluate the uncertainty associated with the model. This analysis focuses on two key components:

- The specific uncertainties associated with the calculated loadings presented on Tables A-1 through A-4, and

- The representativeness of measured and calculated flows and concentrations for spring and fall 1997 to actual conditions within the Railroad Creek watershed.

The uncertainty analysis is provided in Tables A-5 and A-6 in Appendix A. The analysis presents a probabilistic evaluation of the uncertainties associated with the measured and calculated flows and concentrations, and the cumulative effects of these uncertainties on the loading analysis for magnesium, cadmium, copper, iron and zinc. A description of each table column is included in the Notes to Tables A-5 and A-6.

The probabilistic analysis is based on the assumption that the natural variability in stream flows and transported metal concentrations and loadings generally follow a pattern called a *lognormal probability distribution*, or simply, a *lognormal distribution*. The lognormal distribution is a pattern commonly found in the natural world. The theoretical explanation as to why stream flows and metal concentrations and loadings should follow lognormal distributions comes from the physics and mathematics of probability and random processes ("laws of chance"), including the Theory of Successive Random Dilutions, the Law of Proportional Effect, and the Central Limit Theorem. Lognormally distributed parameters are always positive, since there can be no negative concentrations, flows or metal loads. The restriction to positive values and a skewing of higher values in the tail of the distributions is characteristic of lognormal distributions.

Lognormal distributions "fit" the available measurements of metal concentrations and loadings for Railroad Creek. The assumption that metal concentrations and loadings in Railroad Creek are lognormally distributed was verified graphically by plotting the least-squares regression of the normal standard variate of the data (u) against the natural log of the data sets for stations RC-2 and RC-4. The square of the correlation coefficient for the regressions were then calculated and found to be greater than 0.9 (with a majority greater than 0.95) for cadmium, copper, iron and zinc loading.

A lognormal distribution of a variable "X" can be described by two probabilistic parameters – the expected value, E[X], and the coefficient of variation, CV[X]. The expected value can be considered the best estimate of the true, but unknown, value of X. The coefficient of variation is a measure of the variability or uncertainty of potential estimates of X around its expected value, E[X]. The greater the coefficient of variation, the greater the uncertainty in X, and vice versa. In relative terms, CV[X] less than 0.2 can be considered "low" uncertainty; a CV[X] greater than 0.5 can be considered "high" uncertainty and a CV[X] greater than 1.0 can be considered "very high" uncertainty.

For the baseline loading uncertainty analysis, the reported values for metal concentrations are assumed to be the best estimate of the expected value of the concentration, E[C]. Surface water flow measurements and calculated groundwater flows are assumed to be the best estimate of the expected value of the flow, E[Q]. The accuracy of each concentration measurement is assumed to equal the coefficient of variation for the concentration (CV[C]), a measure of the uncertainty around the estimate of the expected concentration, E[C] and each surface water or groundwater flow accuracy is assumed to equal the coefficient of variation for the flow (CV[Q]), a measure of the uncertainty around the estimate of the expected flow, E[Q]. The estimated flow and concentration accuracies are discussed in the following subsections.

2.6.5.1 Accuracy of Flow Measurements

The flow data used to compute the loading from seeps and drainages, and the loading within Railroad Creek were estimated and/or measured directly in the field at the time that the water quality sample was collected. Field flow measurement methods are described in Sections 3 and 4 of the DRI report. Flow measurement accuracy is directly related to the flow volume measured at each station and the measurement tools utilized. The accuracies of flow measurements discussed below represent the estimated accuracies of the measurement method. Uncertainty in flow values due to natural variability (i.e., seasonal variability, etc.) was not factored into the accuracy estimates in order to keep the uncertainty estimates at a reasonable level while still allowing a comparison of the relative contribution from individual source areas to the overall uncertainty of the model.

The accuracy of the flow measurements for the surface water in Railroad Creek ranges between 0.05 and 0.07 when using a flow meter (Swoffer or Price AA), and 0.10 to 0.12 when utilizing a bridgeboard, as used at RC-2 and RC-4 during high flow conditions.

The accuracy of seep flow measurements at seeps SP-6 through SP-9, SP-14 through SP-19, SP-21, SP-23A and SP-23B was estimated to be 0.25.

Seep flow estimates for SP-1 through SP-5; SP-10E/W through SP-13; and SP-24 through SP-26 are assumed to have a coefficient of variation of 0.50 because of limited flow volumes and the difficulty in capturing and measuring flow emerging as diffuse seepage.

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 1997 sampling round). Consequently, the flow measurements recorded at the time of seep sampling did not always reflect established 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:

- The measured flow was used if flow conditions were not changing during the sampling program (e.g., September 1997).
- The flow was estimated during dynamic flow conditions such that flow was consistent with established downstream flow relationships between stations as presented in Section 4 of the revised DRI report.
- The creek drainage and seep water quality concentrations were assumed to be representative for the flow conditions encountered or estimated during the loading period.

These assumptions are consistent with the methodology used to prepare the surface water loading analysis presented in Section 6.6 of the revised DRI. Spring flows in Railroad Creek were adjusted by 59%, 13%, 35% and 7% for stations RC-6, RC-1, RC-4 and RC-2, respectively. Railroad Creek flows that were estimated are assumed to have a coefficient of variation of 0.10.

The hydraulic conductivity ("k" value) used in the Darcy's law calculations for the groundwater flow tube analysis is the largest source of uncertainty in the calculations. Accuracies of the hydraulic conductivities for tailings and native material were estimated based on the available datasets for the respective media. For tailings materials, the available data set is fairly limited and includes hydraulic conductivity measurements from three locations by URS during the RI and five locations from Hart Crowser (1975). The reported hydraulic conductivities from these sources, provided in the DRI report, vary by more than an order of magnitude (6.76×10^{-6} ft/sec to 1.44×10^{-4} ft/sec). The coefficient of variation for hydraulic conductivity in tailings material was estimated to be 1.95 based on a lognormal regression of this available data. The relatively high magnitude of this coefficient of variation is a result of the limited data available for this parameter.

For native material, the hydraulic conductivity used in the flow tube analysis and the associated coefficient of variation were calculated statistically from the data set. The data set for hydraulic conductivity through native material includes 45 test results collected by URS during the RI and subsequent field efforts (URS 1999). The range of measured hydraulic conductivities for native materials (2.95×10^{-5} ft/sec to 6.04×10^{-3} ft/sec) spans more than two orders of magnitude, which is considered a normal range of values. The coefficient of variation for the hydraulic conductivity for native material was estimated to be 1.28 based on the dataset. This value is lower than the coefficient of variation estimated for tailings due to the higher number of data points available for use in the analysis.

As described above, the metals loading contribution from groundwater within the tailings materials in tailings pile 1 was estimated by assuming that the contribution of groundwater flow (discharge) from tailings pile 1 would be proportional to that from tailings pile 2 and tailings pile 3. This calculation is presented in the Notes to Tables A-3 and A-4 in Appendix A and on Tables 1 and 3 of Attachment A-1. The coefficient of variation for this groundwater flow was assumed to be 1.95 based on the range of hydraulic conductivities reported for the tailings material, as discussed above.

2.6.5.2 Accuracy of Concentration Measurements

Due to the limited amount of analytical data available for the 1997 spring and fall periods, creek drainage and seep water quality concentrations were assumed to be representative for the flow conditions measured or estimated during the loading periods. Corrections were not made to measured Railroad Creek or seep concentrations for stations with adjusted flowrates based on downstream flow relations at the Site. A discussion of the variability inherent in natural stream systems and the representativeness of the baseline loading analysis is provided in Section 2.6.6.

For the purpose of the uncertainty analysis, a coefficient of variation of 0.05 was assumed for all surface water measurements at stations where flows were not adjusted. A coefficient of variation of 0.1 was assumed for stations with adjusted flows. These coefficients of variations were chosen to represent error associated with sampling technique, laboratory analysis and fluctuating conditions within the surface waters being sampled. A coefficient of variation of 0.50 was selected to represent the error associated with the groundwater metals concentrations. As the amount and locations of groundwater monitoring wells and piezometers within the tailings piles areas are limited, concentrations from multiple wells and/or piezometers were averaged to estimate the metals concentrations within a given groundwater flow tube. The coefficient of variation of 0.50 is a conservative estimate that accounts for error associated with actual spatial distribution of dissolved metals, sampling method and laboratory analysis. As with flow accuracies, the uncertainty due to natural variability in concentrations over time was not included in the estimates of concentration accuracy in order keep the overall uncertainty at a reasonable level.

2.6.5.3 Method of Calculation

The cumulative uncertainty associated with the calculated metals loading to Railroad Creek for spring and fall 1997 was calculated as follows:

- The measured/calculated flows (Q), the measured concentrations (C) and the calculated loads (L) were assumed to be the best estimates of the actual expected flow (E[Q]), expected concentration (E[Q]) and expected load (E[L]). The calculated cumulative loading ($L_{Cumulative}$) was assumed to be the expected cumulative loading ($E[L_{Cumulative}]$).

- The estimated accuracies for each parameter (as discussed in Sections 2.6.5.1 and 2.6.5.2) were assumed to represent the coefficients of variation (CV[Q] or CV[C]) for the given parameter.

- The variance of the expected load from each source (V[L]) was calculated from the coefficients of variation and the expected values of the flows and concentrations.

- The variance of the calculated cumulative load, $V[L_{Cumulative}]$, was calculated from the variances of the loadings from each source, V[L].

- The coefficient of variation for the cumulative loading, $CV[L_{Cumulative}]$, was back-calculated from $V[L_{Cumulative}]$ and the expected value of cumulative loading, $E[L_{Cumulative}]$. The coefficient of variation for the expected cumulative loading is probabilistically equal to the accuracy of the calculated loading, where the "true" loading is approximated as the calculated loading plus or minus the product of the coefficient of variation and the expected cumulative loading.

2.6.5.4 Theoretical Background

Probabilistically, the uncertainty associated with estimates of the "true" value X is evaluated in terms of the coefficient of variation, CV[X]. The coefficient of variation is a measure of variability or uncertainty of estimates of the expected value. Mathematically, the coefficient of variation, is related to the expected value and standard deviation by the equation:

$$CV[X] = SD[X] / E[X]$$

where:
CV[X] = Coefficient of variation for X
SD[X] = Standard deviation of X
E[X] = Expected value of X

When the variability (as measured by the CV) around an estimate of X is low, the lognormal distribution of X appears very similar to a normal distribution and the "true" value of X is generally considered to occur within the range of the +/- one standard deviation, SD[X], of the expected value:

$$X = E[X] \pm SD[X]$$

The standard deviation is equal to the product of the expected value and the coefficient of variation:

$$SD[X] = E[X] * CV[X]$$

Substitution yields:

$$X = E[X] \pm E[X] * CV[X]$$

$$= E[X](1 \pm CV[X])$$

As the variability of X increases (as measured by the CV), this approximation becomes less reasonable for lognormally distributed variables and a more complicated approach (such as Bayesian estimation) must be used to evaluate the potential range of values for estimates of X.

The variance of a value V[X] is defined as the square of the standard deviation:

$$V[X] = SD[X]^2$$

(1) $$V[X] = (E[X] * CV[X])^2$$

The variance of a value is therefore a function of both the expected value and the coefficient of variation. The variance is an important factor when assessing the uncertainty associated with calculations (e.g. multiplication, addition) involving uncertain variables. For the purpose of this uncertainty analysis, flow, concentration and loading are considered to be independent variables for which the coefficient of correlation between variables equals zero. Using this assumption, the expected value of the product of two variables, E[Y] is equal to the product of the individual expected variables, $E[X_1]$ and $E[X_2]$:

$$E[Y] = E[X_1] * E[X_2]$$

The coefficient of variation for the expected value of the product is expressed as:

(2) $$CV[Y] = \{(CV[X_1]^2 + 1)*(CV[X_2]^2 + 1) - 1\}^{1/2}$$

For addition or subtraction of independent variables, the variances of each variable are summed to give the variance for the expected result of the addition or subtraction

$[Y] = [X_1] + [X_2]$ $\qquad$ $[Y] = [X_1] - [X_2]$

$E[Y] = E[X_1] + E[X_2]$ $\qquad$ $E[Y] = E[X_1] - E[X_2]$

(3) $V[Y] = V[X_1] + V[X_2]$ $\qquad$ $V[Y] = V[X_1] + V[X_2]$

It is important to note that the variance is summed for both addition and subtraction.

The equations marked (1), (2) and (3) above are the fundamental equations used for the probabilistic calculation of the uncertainty associated with calculated loading to Railroad Creek.

2.6.5.5 Calculation Detail

This section describes specific loading analysis calculations and key assumptions. The total loading from each source is as presented in the Loading Analysis Tables A-1 through A-4 in Appendix A. The loading (L) is equal to the flow (Q) multiplied by the concentration (C), or

$$L = Q * C$$

For the purpose of this uncertainty analysis, flow (Q) and concentration (C), and thus loading (L) are assumed to be independent variables (i.e. the correlation coefficient between flow and concentration equals zero). With this assumption, the loading calculation above is written as:

$$E[L] = E[Q] * E[C]$$

in which case the expected value of metals loading (E[L]) is equal to the product of the expected values of flow and concentration. The expected value of loading (E[L]) is assumed to be equivalent with the calculated metal loadings presented in Tables A-1 through A-4.

The cumulative loading in Railroad Creek represents the sum of calculated loads to Railroad Creek after the addition of any given seep, source or groundwater flow tube contribution. For the purpose of this analysis, the calculated cumulative load is assumed to represent the expected value of true loading, $E[L_{Cumulative}]$, and may be represented as the sum of two or more expected loads, $E[L_i]$, where all $E[L_i]$ are assumed to be independent:

$$E[L_{Cumulative}] = E[L_1] + E[L_2] + E[L_3] + \ldots.$$

The coefficient of variation for the calculated (expected) load, $CV[L_i]$, is a measure of the variability or uncertainty associated with the calculated load. Assuming that Q, C and L are independent variables, then $CV[L_i]$ is expressed as:

$$CV[L_i] = [(CV[Q_i]^2 + 1)(CV[C_i]^2 + 1) - 1]^{1/2}$$

The variance for each calculated load is expressed as:

$$V[L_i] = (CV[L_i] * E[L_i])^2$$

The variance of the calculated loadings are then used to estimate the variance of the calculated cumulative loading to Railroad Creek. The variance of the sum of calculated (expected) loading may be expressed as the sum of the individual variances, or

$$V[L_{Cumulative}] = V[L_1] + V[L_2] + V[L_3] + \ldots.$$

The cumulative variance for the difference of calculated loads is represented by the same equation. This is important when assessing the uncertainty associated with the calculations of Unaccounted Loading and the Total Loading Attributed to the East and West Areas.

The coefficient of variation for the cumulative loading ($CV[L_{Cumulative}]$) is calculated with the expression:

$$CV[L_{Cumulative}] = (V[L_{Cumulative}]^{1/2}) / E[L_{Cumulative}]$$

The coefficient of variation for the cumulative loading $CV[L_{Cumulative}]$ represents the variability or uncertainty associated with the calculated metals loading to Railroad Creek given the input parameters (flow and concentration), their associated uncertainties (percent accuracies) and the assumptions described in the notes above.

2.6.5.6 Baseline Uncertainty Analysis Results

The objective of the baseline uncertainty analysis is to quantify the uncertainty associated with calculated metal loadings from Site sources using the method and assumptions described in the previous subsections. The baseline uncertainty analysis calculations and results are presented in Appendix A Tables A-5.1 through A-5.6 (spring) and A-6.1 through A-6.6 (fall). The analysis provides a first-order approximation of the uncertainty associated with calculated metal loadings from Site sources, and demonstrates that the baseline loading analysis is a valid model for evaluating the relative contributions of metals loading to Railroad Creek from individual sources and source areas. The following paragraphs summarize the outcome of the baseline uncertainty analysis for individual metals loading sources, the cumulative effects of uncertainty on the loading calculations, and the calculated uncertainties associated with unaccounted loading to Railroad Creek.

Uncertainty Associated with Individual Loading Sources

The uncertainty associated with the calculated loading from each seep, tributary, or groundwater flow tube is presented as the coefficient of variation (CV[L]). The CV[L] incorporates the uncertainty associated with flow and concentration measurements into a single value. In the baseline loading analysis, the largest CV[L] values (>1.5) are associated with the calculated loads from groundwater flow tubes due to the relatively high uncertainty associated with baseline concentrations (CV[C] of 0.5) and flows (CV[Q] of 1.28 to 1.95). The CV[L] values for groundwater flow tubes are reasonable considering the variability in subsurface hydrogeologic conditions and groundwater chemistry that are demonstrated by field measurements and analytical results for the Site.

The contribution of uncertainty from each loading source to the overall baseline loading analysis is calculated as its variance (V[L]). The V[L] combines both the calculated loading (E[L]) and the loading uncertainty (CV[L]) into a single term. The magnitude of the V[L] is an indicator of the contribution from each source area to the overall uncertainty associated with the analysis (i.e., the larger the V[L], the more uncertainty is contributed by that source). Sources with a high CV[L] but a relatively low loading (due to low concentrations and/or flows) may contribute less variability to the loading analysis calculations than larger loading sources with lower coefficients of variation, as evident from the magnitudes of V[L].

Uncertainty Associated with Cumulative Loading Calculations

As metals loading from individual sources are combined, the additive effects of the uncertainty associated with the metals loading from each source area are represented by the cumulative variance ($V[L_{CUMULATIVE}]$). The $V[L_{CUMULATIVE}]$ is calculated as the sum of the variances associated with each loading source V[L]. As multiple loading sources are summed to calculate the cumulative loading to Railroad Creek ($E[L_{CUMULATIVE}]$), the uncertainty associated with the total loading ($CV[L_{CUMULATIVE}]$) is back-calculated from $V[L_{CUMULATIVE}]$ and $E[L_{CUMULATIVE}]$. The $CV[L_{CUMULATIVE}]$ is therefore the calculated uncertainty associated with the loading analysis at any given point along Railroad Creek. In relative terms, CVs less than 0.2 can be considered "low" uncertainty, a CV greater than 0.5 can be considered "high" uncertainty, and a CV greater than 1.0 can be considered "very high" uncertainty.

For baseline spring conditions, the predominant sources of variability include the portal drainage (aluminum, cadmium, copper, and zinc), SP-23 (copper and zinc), groundwater flowtube S1 (copper), and groundwater seeps or flowtubes in the East Area (aluminum, copper, iron, and zinc). The reasons for the elevated variability contributed by these sources and the effects of this variability on the overall calculations are described for each PCOC below.

Aluminum – The V[L]s for the underground portal and seep SP-4 are relatively high due to the large aluminum load calculated from these sources. However, these variances have little effect on the overall uncertainty associated with the loading calculations as indicated by the limited increases in $CV[L_{CUMULATIVE}]$ after the V[L] from each of these sources is incorporated.

Loading sources associated with tailings pile 1 also have large V[L] values due to the magnitude of the estimated loads and CV[L]s. The effect on the overall uncertainty is an increase CV[$L_{CUMULATIVE}$] from approximately 0.1 (upstream of TP1) to approximately 0.5 (downstream of TP1). Loading from tailings pile 1 therefore introduces a significant amount of uncertainty into the loading calculations, however the effect on the overall uncertainty for the loading calculations (measured by CV[$L_{CUMULATIVE}$]) is moderate.

Cadmium – The portal drainage is largest single source of cadmium loading in the spring. However, the uncertainty associated with the loading calculations for cadmium remains relatively low (approximately 0.17) following the addition of cadmium loading from the portal to the cumulative cadmium loading in Railroad Creek.

Copper – The variances associated with copper loading from the portal, seeps SP-23 and SP-4, and groundwater flow tube S1 are relatively high, and are attributable to the relatively large copper loads associated with these sources. However, the additive effects of these variances on the cumulative loading does not noticeably increase the CV[$L_{CUMULATIVE}$], which remains relatively low (approximately 0.15 to 0.2).

Iron - Tailings pile 1 contributes a large degree of uncertainty to the baseline loading analysis for iron due to the relatively high iron loads calculated for groundwater from tailings pile 1, and the elevated CV[L]s associated with these loads. The effect on the overall uncertainty is moderate, with an increase in the CV[$L_{CUMULATIVE}$] from approximately 0.1 (upstream of TP1) to approximately 0.5 (downstream of TP1).

Zinc - The relatively high variances associated with zinc loading from the portal and seep SP-23 are attributable to the relatively large zinc loads associated with these sources. However, these variances have little effect on the cumulative uncertainty. Calculated zinc loading from the tailings piles also contributes a relatively high degree of uncertainty due to the significant zinc loads calculated for groundwater from the tailings piles and the elevated CV[L]s associated with these loads. However, as for the portal drainage and SP-23, the effect on the overall uncertainty is minimal, as the CV[$L_{CUMULATIVE}$] remains low (below 0.15) throughout the East Area.

For baseline fall conditions, the predominant source of variability for each PCOC is associated with groundwater flow from tailings and native material associated with tailings pile 1. The reasons for the elevated variability and the effects of this variability on the overall calculations are described for each PCOC below.

Aluminum, iron, and zinc - The relatively high variances associated with aluminum, iron and zinc loading from groundwater from the tailings and native materials associated with tailings pile 1 are due to the relatively high estimated loads and associated CV[L]s. The effect on the overall uncertainty for aluminum and iron is significant, as the CV[$L_{CUMULATIVE}$) increase to greater than 1 due to the uncertainty associated with iron and aluminum loading from TP1. The effects on the cumulative uncertainty associated with zinc loading are less pronounced, as the CV[$L_{CUMULATIVE}$] only increases to approximately 0.35. The cumulative uncertainty for aluminum, iron, and zinc decrease after tailings pile 1.

Cadmium and copper – The V[L]s associated with cadmium and copper loading from groundwater flow tube S1 are relatively high due to the large metals load calculated for this source. The effects of the uncertainty associated with flow tube S1 on the overall uncertainty is illustrated by the increase in CV[$L_{CUMULATIVE}$] from approximately 0.1 (before flow tube S1) to approximately 0.4 and 0.5 for cadmium and copper, respectively. Flow tube S1 is the largest source of uncertainty associated with the loading calculations for cadmium and copper in the fall, however the effect of this uncertainty on the loading calculations is moderate.

Uncertainty Associated with Unaccounted Loads

The unaccounted loading to Railroad Creek is calculated for the reaches between stations RC-6 and RC-1, RC-1 and RC-4, and RC-4 and RC-2. These unaccounted loadings are assumed to represent the contribution from unaccounted groundwater, metals attenuation within Railroad Creek, and measurement error. The uncertainty associated with the unaccounted loading was calculated based on the cumulative variance (V[$L_{CUMULATIVE}$]) at each downstream station, the variance for the measured loading at the downstream station (V[L]), and the estimated unaccounted loading values (E[L]). The CVs for the calculated unaccounted loadings are generally higher in the fall than in the spring, because the relative contribution of metals loading from groundwater is higher in the fall than in the spring. The CVs for the calculated unaccounted loadings in the spring are approximately 0.2, while in the fall the CVs associated with the calculated unaccounted loadings for each PCOC are close to or greater than 1 at one or more locations:

- Aluminum – unaccounted loads at RC-4 (CV>2) and RC-2 (CV>2.5)
- Cadmium – unaccounted loads at RC-1 (CV>23) and RC-2 (CV>2.6)
- Copper – unaccounted loads at RC-1 (CV>1.2) and RC-2 (CV>0.9)
- Iron – unaccounted loads at RC-1 (CV>19), RC-4 (CV>2), and RC-2 (CV>5.5)
- Zinc – unaccounted load at RC-2 (CV>1.6)

Although the CVs for unaccounted loading at stations RC-1 and RC-4 in the fall are relatively high, the calculated unaccounted loading values for cadmium, copper, and iron at these stations only represent approximately 0.1%, 4%, and <0.1%, respectively, of the measured loading to Railroad Creek at station RC-2. Because the CV associated with the unaccounted loading is calculated by dividing the square root of the variance by the expected value, the low unaccounted loading values elevate the calculated CVs. The same holds true for unaccounted loading for aluminum and iron at station RC-4, where the unaccounted loadings represent <2% and <1%, respectively, of the aluminum and iron loading measured at RC-2.

The calculated unaccounted loadings at station RC-2 for PCOCs for fall baseline conditions range from approximately 1 to 5.5. The elevated CVs for unaccounted loading at station RC-2 are the result of a combination of the increase in relative contribution of groundwater loading in the fall and the high CV[L]s associated with metals loading from the groundwater flow tubes in the East Area. While the CVs associated with the unaccounted loading for the PCOCs are relatively high, they are not unreasonable given the assumed uncertainties associated with groundwater flow tube discharges and metals concentrations.

Summary

The baseline loading uncertainty analysis provides a first-order approximation of the uncertainty associated with loading analysis calculations. The analysis demonstrates that the assumed uncertainties for discharges and concentrations do not introduce an unreasonable degree of uncertainty into the overall loading calculations. The baseline uncertainty analysis also effectively approximates the uncertainty associated with unaccounted metals loading from groundwater, metals attenuation in Railroad Creek, and measurement error, by evaluating the uncertainty associated with calculated unaccounted loading to Railroad Creek at stations RC-1, RC-4, and RC-2.

2.6.6 Representativeness of the Baseline Loading Analysis

Stream flows and the transported metal concentrations and loads in Railroad Creek show a high degree of natural variability, as evident by the summary of RI water quality data for stations in Railroad Creek on Tables 2-2 through 2-4. This natural variability is the result of spatial and temporal variability in metal loading sources, variability in metal fate and transport, variability in surface water and groundwater discharge rates, and variability in mixing processes as water flows downgradient. Any measurement or estimation of the true flow, concentration or load will have a degree of uncertainty due to this natural variability. The uncertainty associated with measurements of stream flows and metal concentrations may be minimized at the time of sampling, however conditions will vary at other times and locations. As such, measured flows and concentrations offer a snapshot of conditions at the time and location of sampling.

The RI water quality data from May and September 1997 describe site conditions at the specific time of measurement, and while the data do not describe site conditions for other time periods, the data can be used to develop a valid model to describe relative contributions from different source areas. The baseline loading analysis is therefore a quantitative model for metal fate and transport at the time of measurement. Based on the data collected between 1997 and 2002, the 1997 sampling events appear to be indicative of high spring flow conditions. The dissolved zinc result for the May 21, 1997 sample collected from station RC-4 (73 µg/L) is comparable to results for samples collected in during spring 1998 (114 µg/L), 2001 (35 µg/L) and 2002 (43 µg/L) (Table 2-3). The results for dissolved zinc at station RC-2 show a similar agreement between the spring 1997 result (84 µg/L) and the results for spring 1998 (113 µg/L), 2001 (47 µg/L) and 2002 (44 µg/L). These data demonstrate that 1997 was neither the “worst-case” nor the “best-case” year for Railroad Creek water quality.

Streamflow measurements in Railroad Creek station RC-4 are plotted with water quality data at station RC-2 in Figures 2-36 through 2-39. These data demonstrate that the May 19, 1997 sampling event occurred shortly after the first peak runoff event of the spring freshet when copper and zinc concentrations in the creek were highest. Transducer discharge versus time data for station RC-4 is presented on Figure 2-25. A comparison of discharge data between these figures demonstrates that the hydrograph for 1997 is representative of a relatively wet year, with four separate events where the measured discharge in the creek was greater than 700 cfs. The relatively large runoff experienced in spring 1997 was advantageous in that many seeps were flowing at rates sufficient to allow measurement and sampling. Many of the seeps measured and sampled in spring 1997 have had relatively little flow since, thereby making the spring 1997 data a preferable data set for describing potential source areas at the site.

A review of available portal drainage and Railroad Creek sampling data from 1997 through 2002 demonstrate that metals concentrations measured in Railroad Creek vary depending on the time of sampling relative to the position of the Railroad Creek discharge hydrograph. Higher concentrations of cadmium, copper, and zinc are observed during periods of higher portal drainage and seep discharge relative to Railroad Creek flows. However, this variability (and potential for higher or lower Railroad Creek concentrations) would apply equally to candidate remedial alternatives, whether or not they include collection and treatment of the portal drainage, seeps, and groundwater. Therefore, while the additional uncertainty associated with natural system variability has not been directly incorporated into the loading analysis, the analysis is sufficient for use as the basis for the evaluation of candidate site-wide alternatives.

The 1997 data for the Site may therefore be considered as representative. Based on the available data, both the streamflow and water quality measurements completed in 1997 are typical of conditions measured at the site to date and neither data set appears anomalous when compared to subsequent sampling events. These data and the baseline loading analysis provide a sufficient baseline with which the relative loading contribution from difference source areas may be evaluated and the estimated relative effectiveness of different remedial alternatives may be assessed.

2.7 JUNE 2000 PORTAL DRAINAGE TREATABILITY STUDY

A treatability study was performed in June 2000 to obtain order-of-magnitude data for evaluation of chemical addition/precipitation options for the portal drainage in support of the 1500-level main portal rehabilitation. Test results obtained during the treatability study indicate between 97 and 99 percent removal of total aluminum, cadmium, copper, iron, and zinc from portal drainage water at a pH between approximately 9.1 and 9.2. The data also suggest the potential for enhanced removal of aluminum, copper, iron, and zinc through co-precipitation with ferric iron.

2.7.1 Methods

The treatability tests were conducted on portal drainage water collected at the entrance to the 1500-level main portal (P-1) to evaluate the following:

- The potential effectiveness of hydrated lime and caustic addition for the reduction of metals concentrations;
- The potential effectiveness of the addition of Railroad Creek water for alkalinity addition and the reduction of metals concentrations;
- Ferric chloride addition on metal precipitation; and
- Polymer addition to enhance the flocculation process for metal precipitation.

The following tests were conducted:

- Test 1 – Neutralization with hydrated lime ($Ca(OH)_2$);
- Test 2 – Neutralization with caustic (NaOH);
- Test 3 – Neutralization with Railroad Creek water;
- Test 4 – Neutralization with hydrated lime and the addition of Ferric Chloride; and
- Test 5 – Neutralization with hydrated lime and the addition of polymer.

Table 2-10 provides a summary of the tests performed, chemical doses, starting and final pH values, and analytical data obtained during the five tests. The procedures followed during the treatability tests are summarized below and are described in more detailed in the 1500-level Portal Repairs and Investigation Work Plan (URS 2000).

A pre-test titration was performed to determine approximate chemical doses for use during the tests. The procedure was performed once with 10 percent lime solution and once with 10 percent caustic solution as described below:

- Placed 1000 mL of portal drainage sample in a 1L nominal size beaker on the jar tester.

- Simulated rapid mixing such as influent drop structures etc., at 100 rpm.

- Added chemical and monitored the pH continuously. Adjusted the pH of the sample to 7.0, 8.0, 9.0, and 10.0 and recorded the volume of chemical required to obtain each value.

The treatability testing procedures followed for Tests 1 through 5 included the following:

- Placed 1000 mL of portal drainage sample in 1L nominal size beaker on the jar tester. There was a maximum of 5 samples (4 samples and 1 blank sample).

- Simulated rapid mixing, such as influent drop structures etc., at 100 rpm.

- Adjusted the pH of each sample as indicated on Table 2-10.

- For Tests 4 and 5 added the appropriate amount of ferric chloride or polymer as summarized in Table 2-10.

- Following chemical addition, mixed at 100 rpm for 15 seconds.

- Reduced the mixing speed to 25 rpm for 3 minutes.

- Allowed beakers to settle for 1 hour (avoiding exposure to direct sunlight).

- Poured the water through a pre-weighed laboratory supplied filter into a sample container.

- Collected water quality measurements – Recorded sample temperature and pH using an Orion pH probe. Prepared samples for shipment to the off-site laboratory. Laboratory results are provided on Table 2-10.

2.7.2 Results

The samples collected from each of the tests were analyzed for aluminum, cadmium, copper, iron, zinc, hardness, alkalinity, and sulfate. A blank (untreated) sample was also run for each of the tests to provide baseline concentrations for comparison. Results of the total metals analyses performed for the five tests are provided on Table 2-10. Problems with the 5-micron field filtration apparatus prevented the collection of reliable dissolved metals data. The analytical results indicate greater than 99 percent removal of aluminum, copper, and iron and between 52 and 78 percent removal of cadmium in samples treated with hydrated lime or caustic to raise the pH between 8.0 and 8.2 (Tests 1 and 2). The analytical data indicated greater than 99 percent removal of aluminum, copper, iron, and zinc and between 97 and 99 percent removal of cadmium at pH values between approximately 9.1 and 9.2.

The addition of Railroad Creek water to the samples in ratios of 1:3 and 1:1 (volume to volume Railroad Creek water to portal drainage sample) did not provide sufficient alkalinity to enhance the removal of cadmium, copper, and zinc above the dilution factor. Slightly higher reductions were obtained for aluminum and iron; however, the reductions were much lower than those measured at near neutral pH using lime or caustic.

The addition of ferric chloride at a dose of approximately 50 mg/L resulted in enhanced removal of aluminum (< 99%), copper (74%), iron (52%) and zinc (13%) at a final pH of approximately 4.8. Significant removal of cadmium was not observed (2%). These results suggest co-precipitation and removal of these metals from solution with ferric iron. The results indicated generally lower removal percentages with higher ferric chloride doses and lower pH. This indicates sufficient alkalinity addition would be needed to neutralize the incoming acidity for a treatment scenario including the mixing of intercepted East and West Area water. Consistent analytical results were also not obtained for higher doses of ferric chloride due to interferences with analytical equipment.

Data collected during Test 5 did not indicate significant improvements in metals removal with the addition of polymer for the test conditions. The test was conducted with variable polymer doses at a pH between 8.0 and 8.1. A dose of 0.5 percent polymer resulted in similar reductions in metals concentrations to the tests conducted without polymer. Reductions of greater than 98 percent for aluminum, copper, iron, and zinc, and 64 percent removal of cadmium were obtained during the test. The addition of higher doses of polymer did not provide improved metals removal.

Table 2-1
1500-Level Main Portal Drainage Water Quality Data Summary - (1997 - 2003)
Holden Mine RI/FS

Parameters	P-1												P-5										
	05/18/97	07/12/97	09/15/97	05/01/98	06/09/00	08/19/00	11/15/00	04/19/01	05/09/01	6/7/2001*	05/20/03	10/07/03	05/18/97	05/26/97	06/02/97	06/09/97	06/16/97	07/12/97	09/15/97	05/01/98	06/10/00	05/03/01	10/07/03
Total Metals, (ug/L)																							
Aluminum	13,400	4,850	2,570	22,600	7,090		310	430	7,470		9,480	400	7,290	6,320	8,270	6,650J	6,500	3,790	2,810	13,600		6,350	240
Arsenic	0.3	1U	1U	1U	0.3		0.2U	1 U	0.2		0.2 U	0.2 U	0.2U					1U	1U	1U		0.2	0.2 U
Barium	12.1	13	10	12								9.7	14.3	13.3	14.4	13.0J	13	13	10	19		11.8	9.8
Beryllium	0.3	1U	1U	1U								0.2 U	0.2U	0.2U	4U	0.2U	4U	1U	1U	1U		0.2 U	0.2 U
Cadmium	82.2	23	8	170	32.5		3.5	3.8	49.6		51.2	3.3	49.7	40.7	45.4	35.8J	36	23	8	80	31.4	40.2	3.2
Calcium	50,600	70,300	130,000	58,400	61,400		154,000	139,000	83,500		63,300	133,000	30,200	37,000	38,300	48,000J	52,000	71,400	128,000	28,000	64,700	62,900	130,000
Chromium	1U	5U	5U	5U							0.5 U	0.5 U	1U	1U	1U	1U	5U	5U	5U	5U		0.5 U	0.5 U
Copper	6,350	912	235	10,400	1,930		40	94.3	2,350		2,870	62.5	4,040	2,620	3,200	2,270J	2,000	914	237	4,800	1,860	1,990	38.4
Iron	960	540	930	2,030	540		310	440	910		730	330	480	440J	830J	500J	520	390	970	2,320	500	870	170
Lead	57J	20	8	64	34		1	5 U	18			1	29J	30	37	29J	30	18	8	36		22	1 U
Magnesium	10,800	8,210	9,820	14,500	8,290		10,400	9,100	9,810		9,960	9,320	8,540	6,400	7,020	7,540J	7,590	8,310	9,630	6,620	8,670	7,420	9,260
Manganese	444	287	373	703	333		418	412	410		365	358	239	229	259	260J	267	291	365	321		309	347
Mercury	0.00313	0.00024J											0.00249					0.00031J					
Molybdenum	0.4	5U	5U	5U								1.3	0.2U					5U	5U	10		0.6	1.4
Nickel	8J	10U	10U	10U							5.1	2.2	5J	5	6	5J	10U	10U	10U	10U		4.4	2.4
Potassium	2,620	4,100	6,300	3,460	3,820		6,780	6,560	4,030		3,650	6,250	2,110	2,480	2,970	3,280J	2,990	4,300	5,810	1,920		3,020	6,290
Selenium	1U	1U											1U					1U					
Silver	0.2U	0.2U	0.2U	0.2	0.5U		0.5U	0.5U	0.5U		0.5 U	0.5 U	0.2U	0.2UJ	0.2U	0.2U	4U	0.2U	0.2U	0.2U	0.5U	0.5U	0.5 U
Sodium	5,670	12,600	24,600	6,310	9,510		31,500	27,800	13,400		9,540	29,100	3,700	5,380	5,180	7,140J	7,800	12,700	24,200	3,310		10,100	28,600
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	27,800	7,170		1,910	1,360	9,950		10,900	2,050	8,620	7,050	7,930	6,790J	6,880	5,380	3,230	12,300	7,330	7,670	1,790
Dissolved Metals, (ug/L)																							
Aluminum	13,200	1,460	40U	21,100	5,460	3,160	20U	20	4,410	7,800	6,390	50 U	5,840	4,910	7,070	4,860J	4,430	1,360	40U	8,960		2,350	50 U
Arsenic	0.25	1U	1U	1U	0.3	0.2	0.2U	1.0U	0.2	0.2U	0.2 U	0.2 U	0.15					1U	1U	1U		0.2 U	0.2 U
Barium	23.0J	20	11	12								9.3	32.6J	26.4	24.4	26.1J	22	20	10	17		11.4	9.9
Beryllium	0.34	1U	1U	1U								0.2 U	0.4U	0.2U	4U	0.2U	4U	1U	1U	1U		0.2 U	0.2 U
Cadmium	81.2	22	8	160	36.2	11	3.5	3.7	50.2	59	54.4	3.2	52.5	41.0	47.0	37.0J	36	22	8	70	35.9	40.5	3.2
Calcium	50,300	73,200	130,000	57,300	62,700	121,000	156,000	141,000	78,600		60,000	131,000	30,500	36,900	38,700	49,100J	53,800	71,900	131,000	28,300	64,800	62,300	131,000
Chromium	0.3	5U	5U	5U							0.5 U	0.5 U	0.2U	1U	1U	1U	5U	5U	5U	5U		0.5 U	0.5 U
Copper	5,780	907	77	10,300	1,980	395	19	48.5	2,240	2,480	2,890	27.7	2,340	2,570	3,240	2,360J	2,060	901	28	4,790	1,860	1,920	17.2
Iron	240	280	110	430	240	1,180	20U	20U	310	370	220	50 U	190	130J	140J	150J	170	180	20U	150	180	220	50 U
Lead	48J	19	5U	58	34	9	1U	1.0U	14	35		1 U	27J	28	33	28J	30	17	1U	22		17	1 U
Magnesium	10,700	8,430	9,840	14,600	8,600	10,000	10,500	9,290	9,410		9,390	9,180	9,290	6,350	7,160	7,730J	7,530	8,280	9,850	6,650	8,780	7,300	9,230
Manganese	420	299	374	695	327	366	423	413	440	443	345	349	255	228	261	267J	274	293	372	314		304	341
Mercury	0.00257	0.00038J											0.00069					0.00039J					
Molybdenum	0.05	5U	5U	5U								1.3	0.09					5U	5U	5U		0.3	1.4
Nickel	7.7	10U	10U	10U							5.2	2.2	5.0	5	5	5J	10U	10U	10U	10U		4.4	2.2
Potassium	3,160	4,420	6,150	3,430	3,550	5,360	6,970	6,520	4,050		3,450	6,150	1,750	2,640	2,590	3,420J	2,950	4,020	6,400	1,880		3,370	6,210
Selenium	1.1	1U											0.6					1U					
Silver	0.04U	0.2U	0.2U	0.2U	0.5U	0.5U	0.5U	0.5U	0.5U	0.5U	0.5 U	0.5 U	0.16	0.2UJ	0.2	0.2U	4U	0.2U	0.2	0.2U	0.5U	0.5 U	0.5 U
Sodium	5,800	13,000	24,600	6,340	9,740	22,300	31,900	28,500	13,000		9,050	28,200	3,830	5,380	5,390	7,470J	7,770	12,600	24,800	3,290		9,900	28,400
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	27,500	7,610	4,300	1,920	1,360	9,450	11,400	10,400	1,980	8,820	7,020	7,970	6,960J	6,820	5,330	2,980	12,700	7,580	7,590	1,750
Stream Discharge, (cfs)	2.63	0.42	0.21	2.54			0.14	0.12	0.31		0.74	Pending	3.42	1.55	0.99	1.07	0.45	0.31	0.15	3.8		0.37	

Data Notes:

* 6/7/01 Sample Collected at P-1 by Agency Personnel. Sampling procedures and analytical data not reviewed or validated by URS

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 analyte concentration or discharge rate was not determined.

Table 2-1
1500-Level Main Portal Drainage Water Quality Data Summary - (1997 - 2003)
Holden Mine RI/FS

Parameters	P-1												P-5										
	05/18/97	07/12/97	09/15/97	05/01/98	06/09/00	08/19/00	11/15/00	04/19/01	05/09/01	06/07/01*	05/20/03	10/07/03	05/18/97	05/26/97	06/02/97	06/09/97	06/16/97	07/12/97	09/15/97	05/01/98	06/10/00	05/03/01	10/07/03
Conventional Analysis																							
Post Chlorination Cyanide (mg/L)	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/L)	270	370	630J	540	400		690	700J	470			330	210	270J	260J	290	320	380	610J	260		380	650
Total Phosphorous (mg/L)	0.025	0.018			0.016U		0.016U		0.017				0.028					0.018				0.016U	
Total Suspended Solids (mg/L)	2.0	14	11J	9.1	11		2.7	3.1J	16			3.6	9.2	9.9J	12J	10	9.6	9.7	14J	39	10	19	1.8
Chloride (mg/L)	1.0U	4.0	6.5		2.9		8	9.1	3.6			9.0	1.0U					3.3	6.2			2.9	9.1
Fluoride (mg/L)					0.4J		0.56J	4.2J	0.5	0.5		0.68										0.3J	0.75
NO_2 & NO_3 (mg/L)	0.038	0.050	0.024		0.036J		0.052J	0.025	0.071	0.022		0.010 U	0.034					0.025	0.023			0.057	0.010 U
Sulfate (mg/L)	270	260	310	310	240		450J	450	260	240	280	380	190	160	190	200	170	260	340	140		220	380
Silicates (mg/L)																		10					
Alkalinity (mg/L $CaCO_3$)	1.0U	1.0U	16	1.0U	1.0U		23		1.0U	1.0 U	1.0 U	24	1.0U	1.0U	1.0U	1.0U	1.0U	1.0U	14	1U	1.0U	1.0U	22
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/L)	170	220	360	200	190	343	433	390	240		190	360	120	120	130	150	160	210	370	98	200	190	360
Field Measurements:																							
pH	4.8	5.8	7.0	4.3	4.8	6.1	6.6	6.2	4.9	4.93	4.47	5.28	4.9	5.28	4.4	5.3	4.3	5.56	6.7	4.8	4.67	4.86	5.24
Specific Conductivity (uS/cm)	692	575	1010	570	479		980	1110	602	624	585	1050	441	379	522	586	610	572	782	292	468	467	1040
Temperature (^oC)	8.4	10	10.5	9.6	9.7	10	2.4	4.7	6.8	8.9	8.6	9.8	6.3	6.7	7.4	9.7	11.9	12.1	11.1	7.2	9.7	6.2	9.8
Redox (mV)	420	188			49		220	301	342				346	285	230	182	210	185			5	281	
Ferrous Iron (ion)		positive									19.99			negative		negative		positive					

Data Notes:
* 6/7/01 Sample Collected at P-1 by Agency Personnel. Sampling procedures and analytical data not reviewed or validated by URS
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 analyte concentration or discharge rate was not determined.

Table 2-2
Summary of Railroad Creek Water Quality Data for
Upstream Stations (1997 - 2003)

Parameters / Station No. / Sampling Date	Surface Water Area Background Value [1]	RC-11		RC-6 Station													
				RC-6A	RC-6B	RC-6C	RC-6									RC-6 North Bank	RC-6 North Bank X
		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	5/20/03	10/8/03	9/15/97	9/15/97
Total Metals, (ug/L)																	
Aluminum	144	140U	70U	20U	20U	20	90	40J	160	80J	180	150	150J	60	50 U	60	60
Arsenic	1.44	1.56	1.12	1U	1U	1U	0.80					0.76	1.07	0.79	0.71	1.07	1.09
Barium	6.24	4.13	4.14	3	3	4	4.92	4.43	4.87	4.43J	5	4.61	5.1		4.8	4.38	4.52
Beryllium	< 0.04	0.08U	0.04U	1U	1U	1U	0.04U	0.2U	0.04U	0.04U	0.2U	0.04U	0.04U		0.04 U	0.04U	0.04U
Cadmium	0.10	0.04U	0.04U	0.2U	0.2U	0.2U	0.04U	0.04U	0.04	0.04U	0.2U	0.04U	0.04U	0.04 U	0.016	0.04U	0.04U
Calcium	6,814	2,540	2410	6,720	6,660	6,740	3,820	4,020	3,430	3,530J	2,820	3,030	3,800	5,430	4,890	4,100	4,020
Chromium	0.46	0.2U	0.2U	5U	5U	5U	0.2U	0.2U	0.2U	0.2U	5U	0.2U	0.2U	0.1	0.1 U	0.2U	0.2U
Copper	1.83	1.2	1	2U	2U	2U	0.9U	0.7	1.3	0.8J	4	1.1	1.8J	0.8	0.5	0.6	1.0
Iron	177	220	90	70	70	70	140	80J	150	70J	170	150	180	120	50	110	120
Lead	0.3	0.4	0.143	1U	1U	1U	0.3U	0.3	4.8	0.3J	1U	0.3UJ	0.128			0.2UJ	0.3UJ
Magnesium	647	290	240	680	670	670	360	400	340	340J	310	310	360	520	430	360	360
Manganese	5.06	6.02	3.83	2	2	2	3.7	1.67	4.41	1.95J	5	3.90	6.52	2	1.6	3.02	3.53
Mercury	0.00066			0.1U	0.1U	0.1U	0.00046J					0.00064					
Molybdenum	0.79	0.66	0.65				0.49					0.39	0.53		0.75	0.74	0.74
Nickel	0.4	0.4	0.3	10U	10U	10U	0.3J	0.4	0.4	0.2U	10U	0.3	0.3	0.2	0.2	0.2	0.3
Potassium	672	500U	500U	600	810	650	500U	500U	500U	510J	500U	500U	500U	520	500 U	500U	500U
Selenium	< 0.2			1U	1U	1U	0.2U					0.2U					
Silver	0.1	0.04U	0.04U	0.2U	0.2U	0.2U	0.04U	0.04U	0.04U	0.04UJ	0.2U	0.04U	0.04U	0.1 U	0.1 U	0.04U	0.04U
Sodium	1,034	540U	670	1,120	1,120	1,140	760	810	610	610J	600	700	690	890	780	580	570
Thallium	< 0.04			1U	1U	1U	0.04U					0.04U				0.04U	0.04U
Uranium	0.06						0.04U					0.04U				0.04U	0.04U
Zinc	5	5	4U	4U	4U	4U	4U	4U	4U	4U	11	4U	4U	6 U	6	5	4U
Dissolved Metals, (ug/L)																	
Aluminum	37.4	40U	30	20	40	20U	30U	20	60	40J	30	30U	40	50 U	50 U	30	20U
Arsenic	0.9	0.94	0.73	1U	1U	1U	0.50					0.52	0.54	0.6	0.58	0.81	0.82
Barium	17.5	3.42	3.61	5	5	5	15.4J	24.3	17.6	16.0J	14	10.9	4.14		4.7	4.33	4.33
Beryllium	< 0.04	0.04U	0.04U	1U	1U	1U	0.04U	0.04U	0.04U	0.04U	0.04U	0.04U	0.04U		0.04 U	0.04U	0.04U
Cadmium	0.07	0.04U	0.04U	0.2U	0.2U	0.2U	0.04U	0.04U	0.04U	0.04U	0.04U	0.04U	0.08	0.04 U	0.017	0.04U	0.08
Calcium	6,703	2,520	2310	6,750	6,810	6,490	3,870	3,780	3,510	3,480J	2,800	3,000	3,630	5,320	4,910	4,170	4,150
Chromium	< 0.2	0.2U	0.2U	5U	5U	5U	0.2U	0.2U	0.2U	0.2U	5U	0.2U	0.2U	0.1 U	0.1 U	0.2U	0.2U
Copper	1.06	1.1	0.7	2U	2U	2U	0.7	1.0	0.9	1.2U	2U	0.6	0.6	0.5	0.4	0.4	0.5
Iron	40	60	30	30	40	40	30	30J	30	20U	20U	20U	30	50 U	50 U	40	40
Lead	0.54	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
Magnesium	626	260	230	640	650	660	360	370	340	310J	250	260	320	500	440	350	350
Manganese	2.42	3.17	2.88	2	1	1	1.94	1.40	1.23	0.96J	1	1.18	2.08	2	1.0	1.74	1.72
Mercury	0.05			0.1UJ	0.1UJ	0.1UJ	0.00003J					0.00033J					
Molybdenum	0.78	0.67	0.59				0.51					0.41	0.48		0.74	0.73	0.73
Nickel	0.39	0.3	0.3	10U	10U	10U	0.3	0.6	0.4	0.2U	10U	0.2U	0.2U	0.2	0.2	0.2	0.2
Potassium	660	500U	500U	780	660	500U	500U	500U	710	500U	500U	500U	500U	500 U	500 U	500U	500U
Selenium	< 0.2			1U	1U	1U	0.2U					0.2U					
Silver	< 0.04	0.04U	0.04U	0.2U	0.2U	0.2U	0.04U	0.04U	0.04UJ	0.04UJ	0.04U	0.04U	0.04U	0.1 U	0.1 U	0.04U	0.04U
Sodium	1,078	560U	630	1,100	1,160	1,120	800J	820	660	660J	570U	490	700	860	650	600	610
Thallium	< 0.04			1U	1U	1U	0.04U					0.04U				0.04U	0.04U
Uranium	0.172						0.04U					0.04U				0.04U	0.04U
Zinc	7.81	5	4U	6	6	5	16	14U	13U	16U	12	6	4U	6 U	6 U	16	4
Stream Discharge (cfs)	--	60-70		54.9				314							47.0	131.2	

Table 2-2
Summary of Railroad Creek Water Quality Data for
Upstream Stations (1997 - 2003)

Parameters / Station No. / Sampling Date	Surface Water Area Background Value [1]	RC-11		RC-6 Station													
				RC-6A	RC-6B	RC-6C	RC-6									RC-6 North Bank	RC-6 North Bank X
		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	5/20/03	10/8/03	9/15/97	9/15/97
Total Petroleum Hydrocarbon (mg/L)																	
Gasoline Range Hydrocarbons	NE						0.25U					0.25U				0.25U	0.25U
Diesel Range Hydrocarbons	NE						0.25UJ			0.25U		0.25U				0.25U	0.25U
Motor Oil	NE						0.50UJ			0.50U		0.50U				0.50U	0.50U
Polychlorinated Biphenyls (ug/L)																	
Aroclor 1016	NE						0.017U					0.033U					
Aroclor 1221	NE						0.033U					0.067U					
Aroclor 1232	NE						0.017U					0.033U					
Aroclor 1242	NE						0.017U					0.033U					
Aroclor 1248	NE						0.017U					0.033U					
Aroclor 1254	NE						0.017U					0.033U					
Aroclor 1260	NE						0.017U					0.033U					
Conventional Analyses																	
Ortho-Phosphorous (mg/L)	NE						0.004U					0.008J				0.004UJ	0.004UJ
Post Chlorination Cyanide (mg/L)	NE						0.004U					0.004U				0.004UJ	0.004UJ
Total Cyanide (mg/L)	NE						0.004					0.004U				0.004UJ	0.004UJ
Total Dissolved Solids (mg/L)	NE	31J	11	33	32	34	16	19J	5.0UJ	15	7.0	15J	22	17	16	31J	34J
Total Phosphorous (mg/L)	NE						0.019					0.016U				0.016U	0.016U
Total Suspended Solids (mg/L)	NE	3.8	1.3	1.8U	1.0U	1.0U	1.1U	1.0UJ	1.8J	1.1U	3.1	1.2	1.5	1.1 U	1.1 U	1.1U	1.1U
Chloride (mg/L)	NE			1.0U	1.0U	1.0U	1.0U					1.2		1.0 U	1.0 U	1.0U	1.0U
Fluoride (mg/L)	NE														0.1 U		
NO_2 & NO_3 (mg/L)	NE			0.12	0.12	0.12	0.17					0.059			0.01 U	0.023	0.012
Sulfate (mg/L)	NE	2.5U	2.5U	5.4	4.8	6.9	4.9	3.7	4.2	4.9	7.7	2.5U	2.5U	3.0	3.4	5.0	4.6
Silicates (mg/L)	NE																
Alkalinity (mg/L $CaCO_3$)	NE	5.5	6.1	17	17	18	10	10	8.8	10	7.9	7.8	8.6	14	12	7.6	12
Carbonate (mg/L $CaCO_3$)	NE													1.0 U	1.0 U		
Bicarbonate (mg/L)	NE													14	12		
Amenable Cyanide (mg/L)	NE						0.004					0.004U				0.004UJ	0.004UJ
Color (Pt-CO)	NE						10					5UJ				10J	5J
Hardness, Dissolved (mg/L)	NE	7	6.7	20	20	19	11	11	10	10	8.0	8.6	10	15	14	12	12
Field Measurements:																	
pH	5.0 - 8.3	6.2	7.6	5.96	5.5	6	5.9	7.1		6.3	5	7.8	5.7	6.56	*6.70 / 6.11	6.1	
Specific Conductivity (uS/cm)	NE	15					28	40		35	61	51	20	58	*41 / 35	29	
Temperature (^oC)	NE	7	6.6				7.4	5.5		6.9	6.9	7.3	6.8	5.5	*8.0 / 8.0	8.9	
Redox (mV)	NE							157		190	208						
Iron (ion)	NE																
Turbidity (NTU)	NE		1	0.10UJ	0.14J	0.14J				31	210		37	0.64	*0.67 / 0.51	0	
Dissolved Oxygen (mg/L)	NE		15.7					15.5		16.06	14.76		10.9 (W)	19.99	*12.16 / 12.24	10.5	

Table 2-2
Summary of Railroad Creek Water Quality Data for
Upstream Stations (1997 - 2003)

Parameters / Station No. / Sampling Date	Surface Water Area Background Value [1]	RC-1 Station												
		RC-1A	RC-1B	RC-1C	RC-1						RC-1 North Bank		RC-1 South Bank	
		4/16/97	4/16/97	4/16/97	5/19/97	7/10/97	9/15/97	5/3/98	5/4/01	06/11/02	5/19/97	9/15/97	5/19/97	9/15/97
Total Metals, (ug/L)														
Aluminum	144	20	20U	20U	90	160	70	100J	40J	110	100	40	100U	60
Arsenic	1.44	1	1	2	0.72	0.76	1.07	0.86	0.73	0.80				
Barium	6.24	3	3	4	4.98	4.62	4.42	4.91	4.7	4.3	5.02	4.40	4.80	4.39
Beryllium	< 0.04	1U	1U	1U	0.04U	0.04U	0.04U	0.04U	0.04U	0.04 U	0.04U	0.04U	0.04U	0.04U
Cadmium	0.10	0.2U	0.2U	0.2U	0.04U	0.04U	0.04U	0.04U	0.04U	0.25 J	0.05	0.04U	0.04U	0.04U
Calcium	6,814	6,480	6,480	6,470	3,800	3,050	4,080	3,860	5,410	3,880	3,850	4,060	3,840	4,100
Chromium	0.46	5U	5U	5U	0.2U	0.2U	0.2U	0.2U	0.1U	0.2 U	0.2U	0.2U	0.2U	0.2U
Copper	1.83	2U	2U	2U	1.1U	1.0	0.6	1.1	0.7U	0.8 U	1.2U	0.6	1.1U	0.7
Iron	177	70	90	70	120	160	110	110	70J	70	130	100	140	110
Lead	0.3	1U	1U	1U	0.2U	0.3UJ	0.2UJ	0.107	0.031	0.2	0.3U	0.3UJ	0.4U	0.2UJ
Magnesium	647	650	640	650	360	320	350	360	500	360	370	360	390	360
Manganese	5.06	2	2	2	4.70	3.87	3.09	4.45	1.3	2.1	3.49	2.70	3.30	3.20
Mercury	0.00066	0.1U	0.1U	0.1U	0.00039	0.00032J								
Molybdenum	0.79				0.49	0.39	0.74	0.52	0.85	0.53				
Nickel	0.4	10U	10U	10U	0.3J	0.3	0.2	0.3	0.2	0.3	0.3J	0.2	0.3J	0.2
Potassium	672	780	630	730	500U	500U	500U	500U	500	500 U	500U	500U	610	500U
Selenium	< 0.2	1U	1U	1U	0.2U	0.2U								
Silver	0.1	0.2U	0.2U	0.2U	0.14U	0.04U	0.04U	0.04U	0.1U	0.1 U	0.12U	0.12	0.05U	0.04U
Sodium	1,034	1,090	1,090	1,090	780	490	580	730	860	640	750	590	800	590
Thallium	< 0.04	1U	1U	1U	0.04U	0.04U	0.04U							
Uranium	0.06				0.04U	0.04U	0.04U							
Zinc	5	4U	4U	4U	4U	5	4U	4U	6.0U	6 U	4U	4U	5	4U
Dissolved Metals, (ug/L)														
Aluminum	37.4	20	20U	20	30	20U	20U	30	20U	50	30U	20U	30	20U
Arsenic	0.9	1U	1U	1U	0.50	0.51	0.82	0.53	0.61	0.61				
Barium	17.5	5	6	6	22.0J	10.4	4.32	4.38	4.6	3.9	17.2J	4.30	15.0J	4.29
Beryllium	< 0.04	1U	1U	1U	0.04U	0.04U	0.04U	0.04U	0.04U	0.04 U	0.04U	0.04U	0.04U	0.04U
Cadmium	0.07	0.2U	0.2U	0.2U	0.04U	0.04U	0.04U	0.04U	0.04U	0.11 J	0.06	0.04U	0.04	0.09
Calcium	6,703	6,430	6,430	6,400	3,770	3,120	4,120	3,730	5,430	3,810	3,800	4,150	3,760	4,180
Chromium	< 0.2	5U	5U	5U	0.2U	0.2U	0.2U	0.2U	0.1	0.2 U	0.2U	0.2U	0.2U	0.2U
Copper	1.06	2U	2U	2U	1.1	0.6	0.4	0.8	0.6U	0.8 U	1.0	0.6	1.0	0.6
Iron	40	40	40	40	30	20U	40	20	30	50 U	20U	40	20U	40
Lead	0.54	1U	1U	1U	0.2U	0.3J	0.5	0.011U	0.017	0.008 U	1.1U	0.2U	0.7U	0.2
Magnesium	626	660	660	660	360	270	350	330	500	340	360	340	360	350
Manganese	2.42	2	1	1	1.82	1.13	1.65	2	0.9	0.9 J	1.86	1.67	1.83	1.68
Mercury	0.05	0.1UJ	0.1UJ	0.1UJ	0.00031J	0.00028J								
Molybdenum	0.78				0.49	0.40	0.82	0.49	0.88	0.52				
Nickel	0.39	10U	10U	10U	0.2	0.2U	0.2	0.2U	0.2	0.2	0.3	0.2	0.2	0.2
Potassium	660	690	500	500	500U	500U	500U	500U	630	500 U	500U	500U	500U	500U
Selenium	< 0.2	1U	1U	1U	0.2U	0.2U								
Silver	< 0.04	0.2U	0.2U	0.2U	0.04U	0.04U	0.04U	0.04U	0.1U	0.1 U	0.04U	0.04U	0.04U	0.04U
Sodium	1,078	1,240	1,220	1,280	810J	490	620	690	920	630	850J	600	780U	630
Thallium	< 0.04	1U	1U	1U	0.04U	0.04U	0.04U							
Uranium	0.172				0.04U	0.04U	0.04U							
Zinc	7.81	5	5	4U	13	6	4U	4U	6	6 U	16	9	13	4U
Stream Discharge (cfs)	--	63.1			575		132.27		102					

Table 2-2
Summary of Railroad Creek Water Quality Data for
Upstream Stations (1997 - 2003)
Holden Mine RI/FS

Table 2-2
Summary of Railroad Creek Water Quality Data for
Upstream Stations (1997 - 2003)

Parameters / Station No. / Sampling Date	Surface Water Area Background Value [1]	RC-1 Station												
		RC-1A	RC-1B	RC-1C	RC-1						RC-1 North Bank		RC-1 South Bank	
		4/16/97	4/16/97	4/16/97	5/19/97	7/10/97	9/15/97	5/3/98	5/4/01	06/11/02	5/19/97	9/15/97	5/19/97	9/15/97
Total Petroleum Hydrocarbon (mg/L)														
Gasoline Range Hydrocarbons	NE													
Diesel Range Hydrocarbons	NE													
Motor Oil	NE													
Polychlorinated Biphenyls (ug/L)														
Aroclor 1016	NE													
Aroclor 1221	NE													
Aroclor 1232	NE													
Aroclor 1242	NE													
Aroclor 1248	NE													
Aroclor 1254	NE													
Aroclor 1260	NE													
Conventional Analyses														
Ortho-Phosphorous (mg/L)	NE				0.004U	0.022J								
Post Chlorination Cyanide (mg/L)	NE				0.004U	0.004U	0.004UJ							
Total Cyanide (mg/L)	NE				0.004U	0.004U	0.004UJ							
Total Dissolved Solids (mg/L)	NE	27	34	24	17	14J	32J	22	24	21	910	32J	15	34J
Total Phosphorous (mg/L)	NE				0.028	0.031			0.016U					
Total Suspended Solids (mg/L)	NE	1.0U	1.0U	1.0U	3.7	1.7	1.1U	1.1	1.0U	1.1 U	1.2	1.1U	1.1U	1.1U
Chloride (mg/L)	NE	1.0U	1.0U	1.0U	1.0U	1.0U	1.0U		1.0	1.0 U				
Fluoride (mg/L)	NE								0.10UJ	0.10 U				
NO_2 & NO_3 (mg/L)	NE	0.12	0.10	0.11	0.19	0.062	0.017		0.16	0.12				
Sulfate (mg/L)	NE	4.4	4.5	4.3	7.7	2.5U	3.6	2.5U	3.8	4.4	2.5U	3.4	2.5U	4.2
Silicates (mg/L)	NE													
Alkalinity (mg/L $CaCO_3$)	NE	17	17	17	10	8.6	10	10	14	9.4	8.8	11	8.3	12
Carbonate (mg/L $CaCO_3$)	NE								1.0U	1.0 U				
Bicarbonate (mg/L)	NE								14	9.4				
Amenable Cyanide (mg/L)	NE				0.004U	0.004U	0.004UJ							
Color (Pt-CO)	NE				5	5UJ								
Hardness, Dissolved (mg/L)	NE	19	19	19	11	8.9	12	11	16	11	11	12	11	12
Field Measurements:														
pH	5.0 - 8.3	5.9	5.8	5.8	5.45	8	5.8	7.64	6.1	8.48	6.1	6.3	5.73	6.3
Specific Conductivity (uS/cm)	NE	57	56	55	50	22	29	2	39	97	29	29	29	29
Temperature (^oC)	NE	4.7	4.6	47	5.9	6.6	9.7	6.3	3.58		5.6	8.9	6.2	8.9
Redox (mV)	NE								270	229				
Iron (ion)	NE													
Turbidity (NTU)	NE				111			3	13	0.78	5	0	4	0
Dissolved Oxygen (mg/L)	NE				15.44			16	13.5	10.15	15.85	10.3	15.28	10.3

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.

(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 analyte concentration or discharge rate was not determined.

* Field measurements collected from both banks: South Bank / North Bank.

1 - Values are the calculated 90th percentile using data collected from Railroad Creek upstream stations, Holden Creek, Big Creek, Copper Creek upstream stations, Tenmile Creek, South Fork Agnes Creek, and Company Creek.

Additional explanation included in DRI. (Dames and Moore, July 1999) Section 5.3. pH is the range of values from background stations.

Table 2-3
Summary of Railroad Creek Water Quality Data for
Stations Adjacent to Site (1997 - 2003)

Parameters	Surface Water	RC-4 Station																		RC-7 Station				
Station No.	Area Background Value [1]	RC-4A	RC-4X	RC-4 Grab	RC-4								RC-4X	RC-4 South Bank					RC-4X South Bank	RC-7A	RC-7			
Sampling Date		4/16/97	4/16/97	4/16/97	5/21/97	7/10/97	9/15/97	5/3/98	5/4/01	06/11/02	05/20/03	10/8/03	5/3/98	5/21/97	7/10/97	9/15/97	06/11/02	10/8/03	5/21/97	4/16/97	5/20/97	7/10/97	9/15/97	5/3/98
Total Metals, (ug/L)																								
Aluminum	144	40	40	40	100	160	50	200J	40J	100	110	50 U	160J	170	170	50	140	50 U	160	160	180	190	100	220
Arsenic	1.44	1U	1U	1				0.93	0.69	0.78	0.72	0.68	0.85				0.78	0.71		1U				0.76
Barium	6.24	3	4	3	4.90	4.77	4.36	5.48	4.9	4.4		4.9	5.32	5.30	4.75	4.45	4.5	4.8	5.03	4	5.16	4.91	4.54	5.48
Beryllium	< 0.04	1U	1U	1U	0.04U	0.04U	0.04U	0.04U	0.04U	0.04 U		0.04 U	0.04U	0.04U	0.04U	0.04U	0.04 U	0.04 U	0.04U	1U	0.04U	0.04U	0.04U	0.04U
Cadmium	0.10	0.2	0.3	0.2	0.47	0.08U	0.07	0.73J	0.24	0.24	0.6	0.049	0.75J	1.09	0.12U	0.12	0.42	0.069	1.08	0.4	0.51	0.10	0.10	0.75J
Calcium	6,814	7,490	7,470	7,410	4,350	3,310	4,360	4,370	5,950	4,080	6,360	5,190	4,310	4,870	3,340	4,400	4,410	5,330	4,980	8,720	4,500	3,550	4,770	4,670
Chromium	0.46	5U	5U	5U	0.2U	0.2U	0.2U	0.2U	0.1	0.2 U	0.1 U	0.1 U	0.2U	0.2U	0.2U	0.2U	0.2 U	0.1 U	0.2U	5U	0.2U	0.2U	0.2U	0.2U
Copper	1.83	12	11	9	32.4	4.4	2.3	56.7	11.9	15.4	35.3	2.2	58.6	79	6.8	4.9	26.2	3.2	77	15	33.7	3.9	2.1	52.8
Iron	177	60	60	60	90	170	90	140	70J	60	90	50	100	90	180	100	70	50	90	2,290	650	530	1,280	590
Lead	0.3	1U	1U	1U	0.7J	0.4UJ	0.5UJ	0.280	0.070	0.4			0.283	0.4J	0.3UJ	0.2UJ	0.3		0.4J	1U	0.2U	0.7UJ	0.2UJ	0.299
Magnesium	647	770	770	760	460	350	380	450	570	400	650	470	450	550	350	380	440	480	560	1,190	580	440	540	550
Manganese	5.06	3	3	3	3.58	4.34	2.75	8.22	2.3	3.2	5	1.7	7.53	6.08	4.83	3.51	4.2	1.8	5.86	26	9.44	7.91	10.8	11.8
Mercury	0.00066	0.1U	0.1U	0.1U																0.1U				
Molybdenum	0.79							0.52	0.88	0.52		0.78	0.53				0.53	0.76						0.52
Nickel	0.4	10U	10U	10U	0.4	0.3	0.2	0.5	0.2	0.2	0.3	0.2	0.5	0.6	0.4	0.3	0.3	0.2	0.6	10U	0.5	0.4	0.3	0.6
Potassium	672	660	660	880	500U	500U	500U	500U	640	500 U	550	500 U	500U	560	500U	500U	500 U	500 U	850	1,010	780	590	500U	500U
Selenium	< 0.2	1U	1U	1U																1U				
Silver	0.1	0.2U	0.2U	0.2U	0.04U	0.04U	0.04U	0.04U	0.1U	0.1 U	0.1 U	0.1 U	0.04U	0.17	0.04U	0.04U	0.1 U	0.1 U	0.12	0.2U	0.06	0.04U	0.04U	0.04U
Sodium	1,034	1,230	1,230	1,210	800	510	650	780	980	670	1,020	720	740	910	520	640	710	760	890	1,310	810	540	650	770
Thallium	< 0.04	1U	1U	1U																1U				
Uranium	0.06																							
Zinc	5	48	48	34	67	12	18	115	36	42	114	10	114	177	22	20	82	13	185	85	79	15	25	119
Dissolved Metals, (ug/L)																								
Aluminum	37.4	30	30	20	30	30U	20U	60	30	60	80	50 U	70	50	30U	20U	80	50 U	50	20U	60	40U	40	90
Arsenic	0.9	1U	1U	1U				0.46	0.56	0.55	0.47	0.60	0.45				0.4	0.56		1U				0.36
Barium	17.5	6	6	6	9.90	13.4	4.37	4.69	4.6	4.1		4.8	4.6	10.2	13.0	4.31	4.1	4.8	11.2	6	10.7	12.6	4.52	4.88
Beryllium	< 0.04	1U	1U	1U	0.04U	0.04U	0.04U	0.04U	0.04U	0.04 U		0.04 U	0.04U	0.04U	0.04U	0.04U	0.04 U	0.04 U	0.04	1U	0.04U	0.04U	0.04U	0.04U
Cadmium	0.07	0.3	0.3	0.2	0.44	0.09	0.06	0.66	0.21	0.36 J	0.57	0.048	0.67	1.10	0.11	0.14	0.41	0.067	1.14	0.5	0.58	0.09	0.09	0.67
Calcium	6,703	7,760	7,550	7,470	4,540	3,260	4,390	4,250	5,830	4,110	6,360	5,100	4,240	5,110	3,230	4,420	4,390	5,260	5,050	8,880	4,740	3,540	4,720	4,520
Chromium	< 0.2	5U	5U	5U	0.2U	0.2U	0.2U	0.2U	0.1U	0.2 U	0.1 U	0.1 U	0.2U	0.2U	0.2U	0.2U	0.2 U	0.1 U	0.2	5U	0.2U	0.2U	0.2U	0.2U
Copper	1.06	11	11	9	26.4	3.4	1.8	41.7	11.2J	13.5	28.0	1.6	41.9	58.5	5.3	3.9	21.9	2.7	59.8	3	23.0	2.6	1.3	37.5
Iron	40	40	30	50	20	20U	40	20U	30	50 U	50 U	50 U	20U	20	20U	40	50 U	50 U	20U	1,680	480	330	1,150	380
Lead	0.54	1U	1U	1U	0.6J	0.4J	0.3	0.092	0.036	0.061 U			0.089	0.6J	0.2UJ	0.4	0.10 U		0.2	1U	0.5J	0.5J	0.4	0.130
Magnesium	626	810	790	790	470	300	370	420	550	390	660	460	420	560	290	390	420	480	550	1,250	590	380	530	510
Manganese	2.42	4	3	4	2.94	1.53	1.86	4.83	2.0	2.0	6	1.3	4.94	7.46	1.81	2.10	3.0	1.2	7.68	27	11.8	5.48	9.96	9.6
Mercury	0.05	0.1UJ	0.1UJ	0.1UJ																0.1UJ				
Molybdenum	0.78							0.49	0.87	0.51		0.77	0.61				0.51	0.77						0.48
Nickel	0.39	10U	10U	10U	0.3	0.2	0.2	0.5	0.2	0.2	0.4	0.1	0.5	1.0	0.2U	0.3	0.2	0.2	0.6	10U	0.4	0.2	0.4	0.4
Potassium	660	690	660	520	520	500U	500U	500U	500U	500 U	540	500 U	500U	690	500U	500U	500 U	500 U	500U	610	530	500U	500U	500U
Selenium	< 0.2	1U	1U	1U																1U				
Silver	< 0.04	0.2U	0.2U	0.2U	0.08U	0.04U	0.04U	0.04U	0.1U	0.1 U	0.1 U	0.1 U	0.04U	0.14U	0.04U	0.04U	0.1 U	0.1 U	0.10	0.2U	0.54U	0.04U	0.04U	0.04U
Sodium	1,078	1,440	1,300	1,380	840	520	650	740	940	670	1,030	720	750	910	530	640	710	720	890	1,500	860	590	660	760
Thallium	< 0.04	1U	1U	1U																1U				
Uranium	0.172																							
Zinc	7.81	55	50	39	73	17	11	114	35	43	109	10	114	191	24	20	76	13	191	90	85	20	19	115
Stream Discharge (cfs)	--	60.4			370	496	123	508	95		120[++]	54.7								77.12			145.8	

Table 2-3
Summary of Railroad Creek Water Quality Data for
Stations Adjacent to Site (1997 - 2003)

Parameters / Station No. / Sampling Date	Surface Water Area Background Value [1]	RC-4 Station																		RC-7 Station				
Station No.		RC-4A	RC-4X	RC-4 Grab	RC-4								RC-4X	RC-4 South Bank					RC-4X South Bank	RC-7A	RC-7			
Sampling Date		4/16/97	4/16/97	4/16/97	5/21/97	7/10/97	9/15/97	5/3/98	5/4/01	06/11/02	05/20/03	10/8/03	5/3/98	5/21/97	7/10/97	9/15/97	06/11/02	10/8/03	5/21/97	4/16/97	5/20/97	7/10/97	9/15/97	5/3/98
Total Petroleum Hydrocarbon (mg/L)																								
Gasoline Range Hydrocarbons	NE																							
Diesel Range Hydrocarbons	NE																							
Motor Oil	NE																							
Polychlorinated Biphenyls (ug/L)																								
Aroclor 1016	NE																							
Aroclor 1221	NE																							
Aroclor 1232	NE																							
Aroclor 1242	NE																							
Aroclor 1248	NE																							
Aroclor 1254	NE																							
Aroclor 1260	NE																							
Conventional Analyses																								
Ortho-Phosphorous (mg/L)	NE																							
Post Chlorination Cyanide (mg/L)	NE																							
Total Cyanide (mg/L)	NE																							
Total Dissolved Solids (mg/L)	NE	33	44	40	19	9.0J	39J	24	33	29	20	22	27	24	11J	24J	26	19	23	47	26	13J	20J	23
Total Phosphorous (mg/L)	NE								0.016U															
Total Suspended Solids (mg/L)	NE	1.0U	1.0U	1.0U	1.1U	1.7	1.1U	1.8	1.0U	2.8	1.1 U	1.0 U	1.8	1.1U	1.6	1.1U	1.4	1.0 U	1.1U	6.3	1.1	1.8	3.8	1.7
Chloride (mg/L)	NE	1.0U	1.0U	1.0U					1.4	1.0 U	1.0 U	1.0 U					1.0 U	1.0 U		1.0				
Fluoride (mg/L)	NE								0.10UJ	0.10 U		0.1 U					0.10 U	0.1 U						
NO_2 & NO_3 (mg/L)	NE	0.13	0.11	0.12					0.21	0.12		0.01 U					0.12	0.016		0.14				
Sulfate (mg/L)	NE	6.5	5.7	5.9	7.0	2.5U	4.0	3	5.8	2.5 U	5.7	4.1	3.4	4.1	2.5U	3.8	4.6	3.9	5.6	16	4.6	2.5U	6.4	4.8
Silicates (mg/L)	NE																							
Alkalinity (mg/L $CaCO_3$)	NE	20	20	20	15	9.0	9.9	9.3	14	9.3	13	13	9.3	11	8.6	11	8.8	13	14	13	8.1	7.8	7.7	8.1
Carbonate (mg/L $CaCO_3$)	NE								1.0U	1.0 U	1.0 U	1.0 U					1.0 U	1.0 U						
Bicarbonate (mg/L)	NE								14	9.3	13	13					8.8	13						
Amenable Cyanide (mg/L)	NE	1.0U																						
Color (Pt-CO)	NE																							
Hardness, Dissolved (mg/L)	NE	23	22	22	13	9.4	12	12	17	12	19	15	12	15	9.3	13	13	15	15	27	14	10	14	13
Field Measurements:																								
pH	5.0 - 8.3	5.5	5.7	5.7	7.1	7.7	6.7	7.8	6.5	7.48	**6.94 / 6.32	**6.02 / 6.09		7.3	7.6	6.8	7.12	6.02		5.8	7.1	7.6	7	6.5
Specific Conductivity (uS/cm)	NE	67	65	85	42	26	32	10	46	28	**60 / 50	**39 / 39		38	24	33	35	39		94	42	28	42	30
Temperature (^oC)	NE	4.2	3.9	6	4.4	9.8	10	7.1	5.95	7.9	**6.3 / 6.6	**7.9 / 7.8		4.2	7.7	9.6	7.2	7.9		5	6.4	8.7	9.7	8.7
Redox (mV)	NE				142				277	232				142			240				151			
Iron (ion)	NE																							
Turbidity (NTU)	NE					3		135		0.86	**0.58 / 0.56	**0.81 / 0.45		5			1.06	0.81		4.0J				223
Dissolved Oxygen (mg/L)	NE					13.48		16.8	12.8	12.43	**19.99 / 19.99	**12.51 / 12.42		15.26			10.6	12.51						15.8

Table 2-3
Summary of Railroad Creek Water Quality Data for
Stations Adjacent to Site (1997 - 2003)

Parameters	Surface Water	RC-2 Station																		
Station No.	Area Background Value [1]	RC-2A	RC-2											RC-2X			RC-2 South Bank			
Sampling Date		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	5/4/01	06/11/02	05/20/03	9/15/97	5/4/01	5/20/03	5/19/97	7/10/97	9/15/97	06/11/02
Total Metals, (ug/L)																				
Aluminum	144	160	230	160	190	150J	220	210	90	250	110J	140	210	90	100J	210	240	140	90	130
Arsenic	1.44	1U	0.61					0.66	0.87	0.83	0.64	0.66	0.59	0.88	0.62	0.63	0.65	0.58	0.85	0.67
Barium	6.24	6	5.51	5.08	5.11	4.87J	5	5.04	4.71	5.75	5.2	4.6		4.71	5.1		5.74	4.70	4.61	4.6
Beryllium	< 0.04	1U	0.04U	0.04U	0.04U	0.04U	0.2U	0.04U	0.04U	0.04U	0.04U	0.04 U		0.04U	0.04U		0.04U	0.04U	0.04U	0.04 U
Cadmium	0.10	0.5	0.52	0.44	0.33	0.25J	0.2U	0.10U	0.11	0.77J	0.31	0.22	0.59	0.11	0.3	0.62	0.55	0.08U	0.14	0.27
Calcium	6,814	8,150	4,800	4,890	4,180	4,260J	3,330	3,510	4,750	4,700	7,150	4,430	7,060	4,740	6,930	7,190	4,800	3,450	4,920	4,560
Chromium	0.46	5U	0.2U	0.2U	0.2U	0.2U	5U	0.2U	0.2U	0.2	0.1U	0.2 U	0.2 U	0.2U	0.1	0.2 U	0.2U	0.2U	0.2U	0.2 U
Copper	1.83	14	33.2	30.2	23.2	15.0J	10	3.8	2.2	52.3	11.7	13.3	28.6	2.2	11.7	29.8	38	3.7	2.2	13.5
Iron	177	2,250	600	710J	510J	520J	440	500	1,330	630	1,280J	300	960	1,340	1,290J	990	620	440	1,350	310
Lead	0.3	1U	1.4U	0.3	0.6	1.4J	1U	0.6UJ	0.3UJ	0.288	0.068	0.2		0.7	0.073		0.5U	0.2UJ	0.8UJ	0.2
Magnesium	647	1,170	610	670	550	540J	410	440	540	570	850	490	880	560	820	910	640	410	570	510
Manganese	5.06	26	11.6	11.6	9.82	8.06J	9	8.61	12.2	12.7	12	6.1	15	12.2	12.6	15	12.4	6.82	12.3	6.3
Mercury	0.00066	0.1U	0.00039J					0.00029J									0.00066J	0.00021J		
Molybdenum	0.79		0.46					0.36	0.73	0.53	0.88	0.52		0.72	0.87		0.48	0.43	0.71	0.53
Nickel	0.4	10U	2.3J	0.5	0.6	0.4J	10U	0.4	0.4	0.6	0.4	0.4	0.5	0.4	0.4	0.5	0.5J	0.4	0.4	0.3
Potassium	672	640	500U	590	770	880J	500U	500U	500U	500U	940	500 U	580	500U	760	660	530	500U	500U	500 U
Selenium	< 0.2	1U	0.2U					0.2U									0.2U	0.2U		
Silver	0.1	0.2U	0.04U	0.04U	0.04U	0.04U	0.2U	0.14	0.11	0.04U	0.1U	0.1 U	0.1 U	0.07	0.1U	0.1 U	0.04U	0.04	0.04U	0.1 U
Sodium	1,034	1,270	840	880	750	820J	590U	530	640	790	1,080	690	1,050	670	980	1,080	840	520	660	700
Thallium	< 0.04	1U	0.2U					0.04U	0.04U					0.04U			0.04U	0.04U	0.04U	
Uranium	0.06		0.4U					0.04	0.04U					0.04U			0.05	0.04U	0.04U	
Zinc	5	76	86	76	52	43J	24	16	21	116	56	48	113	20	55	113	87	15	21	46
Dissolved Metals, (ug/L)																				
Aluminum	37.4	20U	90	60	70	80J	50	50U	40	100	20U	90	50 U	40	20U	50 U	60U	50U	40	80
Arsenic	0.9	1U	0.30					0.33	0.49	0.35	0.09	0.48	0.08	0.50	0.09	0.08	0.22	0.36	0.52	0.48
Barium	17.5	6	10.6J	18.2	31.1	20.2J	15	17.7	4.55	5.02	4.8	4.4		4.5	5.1		12.1J	14.2	4.56	4.4
Beryllium	< 0.04	1U	0.04U	0.04U	0.04U	0.04U	0.04U	0.04U	0.08U	0.04U	0.04U	0.04 U		0.04U	0.04U		0.04U	0.04U	0.04U	0.04 U
Cadmium	0.07	0.4	0.53	0.45	0.32	0.23J	0.14	0.08	0.10	0.68	0.27	0.23	0.57	0.11	0.33	0.56	0.55	0.09	0.10	0.24
Calcium	6,703	8,320	4,900	4,800	4,260	4,200J	3,280	3,560	4,940	4,680	6,300	4,430	7,100	5,120	6,720	7,230	4,970	3,420	5,020	4,500
Chromium	< 0.2	5U	0.4	0.2U	0.2U	0.2U	5U	0.2U	0.2U	0.2U	0.1U	0.2 U	0.2 U	0.2	0.1U	0.2 U	0.2U	0.2U	0.2U	0.2 U
Copper	1.06	2	23.6	19.1	15.1	10.3J	8	2.3	1.2	35.7	1.9J	11.7	5.1	1.3	2.0J	4.9	26	2.6	1.4	11.6
Iron	40	1,430	300	480J	360J	380J	220	270	1,080	350	100	230	50 U	1,160	120	50 U	420	280	1,150	240
Lead	0.54	1U	1.4U	0.7U	1.4U	0.4J	0.4U	0.2UJ	0.2U	0.111	0.01U	0.073 U		0.3	0.01U		0.6U	0.2J	0.2U	0.072 U
Magnesium	626	1,190	630	640	530	490J	350	370	570	550	740	480	900	590	790	910	650	380	580	480
Manganese	2.42	26	12.8	10.9	8.47	7.42J	6	5.52	11.1	9.9	12.2	5.2	16	11.4	12	16	11.7	5.64	11.4	5.5
Mercury	0.05	0.1UJ	0.00047J					0.00053									0.00036J	0.00030J		
Molybdenum	0.78		0.47					0.37	0.71	0.48	0.8	0.53		0.72	0.82		0.48	0.41	0.70	0.52
Nickel	0.39	10U	0.9	0.6	0.4	0.4J	10U	0.2	0.4	0.4	0.3	0.3	0.6	0.4	0.3	0.5	0.6	0.2	0.4	0.3
Potassium	660	640	500U	500U	500U	630J	500U	500U	500U	500U	560	500 U	670	500U	620	680	600	500U	500U	500 U
Selenium	< 0.2	1U	0.2U					0.2U									0.2U	0.2U		
Silver	< 0.04	0.2U	0.07	0.04U	0.04UJ	0.04U	0.04U	0.04U	0.04U	0.04U	0.1U	0.1 U	0.1 U	0.04U	0.1U		0.04U	0.04U	0.04U	0.1 U
Sodium	1,078	1,360	1,800J	910	1,010	770J	590U	580	670	800	1,000	690	1,060	730	980	0.1 U	920J	550	690	690
Thallium	< 0.04	1U	0.04U					0.04U	0.04U					0.04U		1,080	0.04U	0.04U	0.04U	
Uranium	0.172		0.2U					0.04U	0.04U					0.04U			0.04U	0.04U	0.04U	
Zinc	7.81	77	84	84	60	51J	27	24	23	113	47	44	109	28	55	110	97	21	23	43
Stream Discharge (cfs)	--	86.4	569	376	605	501	822	619	135.8	647	94		150		94					

Table 2-3
Summary of Railroad Creek Water Quality Data for
Stations Adjacent to Site (1997 - 2003)

Parameters	Station No.	Surface Water	RC-2 Station																	
		Area Background Value [1]	RC-2A	RC-2											RC-2X			RC-2 South Bank		
	Sampling Date		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	5/4/01	06/11/02	05/20/03	9/15/97	5/4/01	5/20/03	5/19/97	7/10/97	9/15/97	06/11/02
Total Petroleum Hydrocarbon (mg/L)																					
Gasoline Range Hydrocarbons		NE		0.25U					0.25U	0.25U	0.25U				0.25			0.25U	0.25U	0.25U	
Diesel Range Hydrocarbons		NE		0.25UJ			0.25U		0.25U	0.25U	0.25U				0.25			0.25UJ	0.25U	0.25U	
Motor Oil		NE		0.50UJ			0.50U		0.50U	0.50U	0.5U				0.50			0.25UJ	0.50U	0.50U	
Polychlorinated Biphenyls (ug/L)																					
Aroclor 1016		NE		0.20UJ					0.033U									0.017U	0.033U		
Aroclor 1221		NE		0.40UJ					0.067U									0.033U	0.067U		
Aroclor 1232		NE		0.20UJ					0.033U									0.017U	0.033U		
Aroclor 1242		NE		0.20UJ					0.033U									0.017U	0.033U		
Aroclor 1248		NE		0.20UJ					0.033U									0.017U	0.033U		
Aroclor 1254		NE		0.20UJ					0.033U									0.017U	0.033U		
Aroclor 1260		NE		0.20UJ					0.033U									0.017U	0.033U		
Conventional Analyses																					
Ortho-Phosphorous (mg/L)		NE		0.004U					0.009J	0.004UJ					0.004UJ			0.004U	0.013J	0.004UJ	
Post Chlorination Cyanide (mg/L)		NE		0.004U					0.004U	0.004UJ					0.004UJ			0.004U	0.004U	0.004UJ	
Total Cyanide (mg/L)		NE		0.004U					0.004U	0.004UJ					0.004UJ			0.004U	0.004U	0.004UJ	
Total Dissolved Solids (mg/L)		NE	43	22	30J	17J	29	8.0	12J	26J	23	36	27	26	40J	26	17	25	9.0J	40J	28
Total Phosphorous (mg/L)		NE		0.034					0.016U	0.016U		0.016U			0.016U	0.016U		0.037	0.018	0.016U	
Total Suspended Solids (mg/L)		NE	6.7	2.2U	1.1UJ	1.0UJ	1.1U	3.6	1.6	3.6	3.1	1.0U	1.1 U	2.8	3.3	1.0U	2.7	1.5	1.4	3.3	1.8
Chloride (mg/L)		NE	1.0U	1.0U					1.0	1.0U		1.3	1.0 U	1.0 U	1.0U	1.4	1.0 U	1.0	1.0U	1.0U	1.0 U
Fluoride (mg/L)		NE										0.10UJ	0.10 U			0.10UJ					0.10 U
NO_2 & NO_3 (mg/L)		NE	0.13	0.13					0.072	0.041		0.2	0.13		0.020	0.17		0.14	0.064	0.021	0.13
Sulfate (mg/L)		NE	16	8.3	8.6	6.7	6.7	2.5U	2.5U	6.9	6.2	10	5.0	9.8	7.4	10	10	7.1	2.5U	6.9	5.2
Silicates (mg/L)		NE																			
Alkalinity (mg/L $CaCO_3$)		NE	13	9.6	8.8	8.4	8.2	7.5	8.3	7.5	8.4	12	9.4	11	6.5	12	12	7.7	6.9	8.4	9.3
Carbonate (mg/L $CaCO_3$)		NE										1.0U	1.0 U	1.0 U		1.0U	1.0 U				1.0 U
Bicarbonate (mg/L)		NE										12	9.4	11		12	12				9.3
Amenable Cyanide (mg/L)		NE		0.004U					0.004U	0.004R					0.004UR			0.004U	0.004U	0.004UR	
Color (Pt-CO)		NE		15					5UJ	15J					15J			8	5UJ	15J	
Hardness, Dissolved (mg/L)		NE	26	15	15	13	12	9.6	10	15	14	19	13	21	15	20	22	15	10	15	13
Field Measurements:																					
pH		5.0 - 8.3	6.2	6.7	7.4	6.9	6	6	8	5.7	8.2	6.5	7.44	**6.32 / 6.15		6.5		6.8	7.7	6.2	8.54
Specific Conductivity (uS/cm)		NE	103	38	51	46	34	27	27	76	12	57	49	**68 / 63		57		42	30		40
Temperature (^oC)		NE	5.7	4.2	6.8	7.9	11.3	9	9.5	10	7.7	6.29	10.1	**6.8 / 6.7		6.29		4.6	10.4		10.6
Redox (mV)		NE			137	114	170	238				295	110			295			21.8		90
Iron (ion)		NE																			
Turbidity (NTU)		NE	3.4J	4	1	6					20	3.3/19.4 [d]	1.34	**1.25 / 1.52		3.3/19.4 [d]		66	213		0.99
Dissolved Oxygen (mg/L)		NE		13.1	13.68	14.7				10.4	9.7 (W)	13.4	11.55	**19.99 / 19.99		13.4		14.1	14.48		11.75

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.

(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 analyte concentration or discharge rate was not determined.

* These metals require hardness correction specific to the sample data. Exceedences indicated are based on calculated criteria as shown on supplemental tables.

1 - Values are the calculated 90th percentile using data collected from Railroad Creek upstream stations, Holden Creek, Big Creek, Copper Creek upstream stations, Tenmile Creek, South Fork Agnes Creek, and Company Creek.

Additional explanation included in DRI. (Dames and Moore, July 1999) Section 5.3. pH is the range of values from background stations.

** Field parameters for RC-4 and RC-2 on 5/20/03 and for RC-4 on 10/08/03 were collected from the south bank and the north bank (south bank / north bank).

++ - Actual field measurements based on Swoffer meter. A discrepancy was noted between the actual field measurement and the transducer at RC-4.

Table 2-4
Summary of Railroad Creek Water Quality Data for
Downstream Stations (1997 - 2003)
Holden Mine RI/FS

Table 2-4
Summary of Railroad Creek Water Quality Data for
Downstream Stations (1997 - 2003)

Parameters / Station No. / Sampling Date	Surface Water Area Background Value [1]	RC-13 Station			RC-5 Station						RC-10 Station		
		RC-13			RC-5A[1]	RC-5[2]	RC-5A[3]				RC-10		
		11/18/01	06/11/02	10/23/02	4/17/97	5/20/97	5/22/97	7/10/97	9/16/97	5/4/98	9/16/97	5/4/98	5/5/01
Total Metals, (ug/L)													
Aluminum	144	340 J	140	100	160	210	240	200	120	250	80	300	100J
Arsenic	1.44	0.56	0.66	0.41	1U					0.76		0.72	0.47
Barium	6.24	4.9	4.6	5.5	6	5.68	6	5.27	5.01	6.22	5.60	6.74	6
Beryllium	< 0.04	0.04 U	0.04 U	0.04 U	1U	0.04U	0.04U	0.04U	0.04U	0.04U	0.04U	0.04U	0.04U
Cadmium	0.10	0.13	0.29	0.34 J	0.4	0.50	0.54	0.11U	0.13	0.66J	0.11	0.45	0.25
Calcium	6,814	6,590	4,520	8,640	8,280	4,940	6,070	3,840	5,570	5210	6,480	5,730	7,930
Chromium	0.46	0.1 U	0.2 U	0.2	5U	0.2U	5U	0.2U	0.2U	0.2U	0.2U	0.2	0.1U
Copper	1.83	1.9 J	12.9	3.3	14	32.3	32	4.2	2.4	43.5	2.3	30.3	7.6
Iron	177	840	310	2,620	2,300	580	750	500	1,440	650	990	790	730J
Lead	0.3	0.075	0.2	0.023 U	1U	0.3J	0.5U	0.4UJ	0.2UJ	0.253	0.2UJ	0.205	0.049
Magnesium	647	680	500	1,120	1,190	660	850	490	690	660	780	720	1,010
Manganese	5.06	7.9	6.1	22.4	26	12.3	20	9.72	15.4	15	14.0	13.4	12.7
Mercury	0.00066				0.1U								
Molybdenum	0.79	0.69	0.53	0.85						0.52		0.55	0.75
Nickel	0.4	0.3	1.0	0.5	10U	0.6	10U	0.4	0.4	0.6	0.5	0.6	0.4
Potassium	672	500 U	500 U	680	810	870	560	690	620	500U	500U	500U	950
Selenium	< 0.2				1U								
Silver	0.1	0.1 U	0.1 U	0.1 U	0.2U	0.04U	0.20J	0.04U	0.04U	0.04U	0.04U	0.04U	0.1U
Sodium	1,034	970	700	1,070	1,290	840	910	560	730	820	780	850	1,000
Thallium	< 0.04				1								
Uranium	0.06												
Zinc	5	26	46	51	78	81	88	18	33	101	25	75	37
Dissolved Metals, (ug/L)													
Aluminum	37.4	80 UJ	70	50 U	20U	70	20U	30U	50	90	40	80	50
Arsenic	0.9	0.42	0.46	0.14	1U					0.28		0.26	0.25
Barium	17.5	4.9	4.2	5.3	6	10.8	6	15.9	5.00	5.4	5.56	5.51	5.8
Beryllium	< 0.04	0.04 U	0.04 U	0.04 U	1U	0.04U	4U	0.04U	0.04U	0.04U	0.04U	0.04U	0.04U
Cadmium	0.07	0.12	0.46 J	0.24	0.4	0.50	0.51	0.10	0.12	0.58	0.12	0.4	0.21
Calcium	6,703	5,720	4,540	8,690	8,370	5,010	5,800	3,830	5,600	5,040	6,580	5,410	8,150
Chromium	< 0.2	0.5 U	0.2 U	0.1 U	5U	0.2U	5U	0.2U	0.2U	0.2U	0.2U	0.2U	0.1U
Copper	1.06	2.8 J	9.9	0.5 J	3	21.5	7	2.4	1.6	26.9	1.3	18.5	5.0J
Iron	40	680	190	1,690	1,290	350	40	250	1,250	300	740	220	420
Lead	0.54	0.037 U	0.070 U	0.015 U	1U	0.2J	0.2U	0.2UJ	0.2U	0.11	0.2	0.086	0.033
Magnesium	626	610	490	1,120	1,210	670	780	420	680	620	800	640	1,020
Manganese	2.42	8.9	5.4	21.9	26	10.9	18	7.04	14.8	12	13.5	9.29	11.8
Mercury	0.05				0.1UJ								
Molybdenum	0.78	0.73	0.53	0.82						0.45		0.43	0.72
Nickel	0.39	0.3	0.4	0.5	10U	0.6	10U	0.2	0.4	0.4	0.4	0.5	0.4
Potassium	660	660	500 U	640	690	700	500U	500U	500U	500U	550	500U	640
Selenium	< 0.2				1U								
Silver	< 0.04	0.1 U	0.1 U	0.1 U	0.2U	0.14U	0.04U	0.04U	0.04U	0.04U	0.09J	0.04U	0.1U
Sodium	1,078	860	710	1,070	1,430	860	900	630	700	780	800	810	960
Thallium	< 0.04				1U								
Uranium	0.172												
Zinc	7.81	24	43	49	86	84	80	24	30	98	22	69	35
Stream Discharge (cfs)	--								129.2		126.3		132

Table 2-4
Summary of Railroad Creek Water Quality Data for
Downstream Stations (1997 - 2003)

Parameters / Station No. / Sampling Date	Surface Water Area Background Value [1]	RC-13 Station			RC-5 Station						RC-10 Station		
		RC-13			RC-5A[1]	RC-5[2]	RC-5A[3]				RC-10		
		11/18/01	06/11/02	10/23/02	4/17/97	5/20/97	5/22/97	7/10/97	9/16/97	5/4/98	9/16/97	5/4/98	5/5/01
Total Petroleum Hydrocarbon (mg/L)													
Gasoline Range Hydrocarbons	NE												
Diesel Range Hydrocarbons	NE												
Motor Oil	NE												
Polychlorinated Biphenyls (ug/L)													
Aroclor 1016	NE												
Aroclor 1221	NE												
Aroclor 1232	NE												
Aroclor 1242	NE												
Aroclor 1248	NE												
Aroclor 1254	NE												
Aroclor 1260	NE												
Conventional Analyses													
Ortho-Phosphorous (mg/L)	NE												
Post Chlorination Cyanide (mg/L)	NE												
Total Cyanide (mg/L)	NE												
Total Dissolved Solids (mg/L)	NE	14	26	46	42	27	32J	12J	36J	20	46J	25	53
Total Phosphorous (mg/L)	NE												0.016U
Total Suspended Solids (mg/L)	NE	1.2 U	1.1 U	4.7	7.7	1.4	1.9J	1.4	3.4	2.5	2.4	3.8	1.0U
Chloride (mg/L)	NE	1.0 U	1.0 U	1.0	1.0U								1.1
Fluoride (mg/L)	NE	0.10 UJ	0.10 U	0.10 U									0.10UJ
NO_2 & NO_3 (mg/L)	NE	0.12	0.12	0.043	0.12								0.16
Sulfate (mg/L)	NE	11	5.2	20	16	8.1	11	3.0	11	5.6	12	5.5	12
Silicates (mg/L)	NE												
Alkalinity (mg/L $CaCO_3$)	NE	12	9.3	9.8	12	8.7	8.6	7.1	1.0U	8.1	11	11	14
Carbonate (mg/L $CaCO_3$)	NE	1.0 U	1.0 U	1.0 U									1.0U
Bicarbonate (mg/L)	NE	12	9.3	9.8									14
Amenable Cyanide (mg/L)	NE												
Color (Pt-CO)	NE												
Hardness, Dissolved (mg/L)	NE	17	13	26	26	15	18	11	17	15	20	16	24
Field Measurements:													
pH	5.0 - 8.3	5.94	7.99/8.30	6.5	6.1	7	7.6	7.6	7.1	7.6	7	5.8	5.99
Specific Conductivity (uS/cm)	NE	37	35/42	6.1	95	50	63	30	53	16	57	38	79
Temperature (^oC)	NE	2.3	11.2/12.1	5.0	4.3	3.8	6.2	8.4	8.5	9.6	9.8	7.1	3.56
Redox (mV)	NE		70/139	79			155						273
Iron (ion)	NE												
Turbidity (NTU)	NE	<10	1.16/0.96	1.5						440		33	
Dissolved Oxygen (mg/L)	NE	13.62	11.66/11.12	10.87						18		16.3	12.9

Table 2-4
Summary of Railroad Creek Water Quality Data for
Downstream Stations (1997 - 2003)
Holden Mine RI/FS

Parameters	Station No. / Sampling Date	Surface Water Area Background Value [1]	RC-8 Station			RC-3 Station								
	Station No.		RC-8A	RC-8B	RC-8	RC-3A	RC-3						RC-3X	
	Sampling Date		4/18/97	4/18/97	9/16/97	4/18/97	5/22/97	7/11/97	9/16/97	5/5/98	5/5/01	5/21/03	5/22/97	7/11/97
Total Metals, (ug/L)														
Aluminum		144	110		70	100	170	160	70	250	90J	130	150	150
Arsenic		1.44	***1U***			1U	0.35	0.40	0.46	0.5	0.37	0.32	0.33	0.39
Barium		6.24	10		6.47	10	7	5.62	6.47	7.07	6.5		7	5.63
Beryllium		< 0.04	***1U***		0.04U	1U	0.04U	0.04U	0.04U	0.04U	0.04U		0.04U	0.04U
Cadmium		0.10	0.2		0.10	0.3	0.27	0.07U	0.09	0.37	0.16	0.32	0.34	0.08U
Calcium		6,814	9,950		6,540	9,740	6,350	4,620	6,570	5,520	8,170	8,280	6,420	4,800
Chromium		0.46	5U		0.2U	5U	5U	0.2U	0.2U	0.2	0.1U	0.2 U	5U	0.2U
Copper		1.83	7		1.7	6	16	3.2	1.6	19.7	6.2	13.5	16	3.3
Iron		177	900		640	870	450	330	620	580	650J	470	430	330
Lead		0.3	1U		0.2UJ	1U	0.5U	0.3UJ	0.2UJ	0.163	0.042		0.9U	0.3UJ
Magnesium		647	1,490		800	1,480	850	570	810	700	1,060	1,090	850	580
Manganese		5.06	15		10.7	14	11	6.66	10.1	10.7	8.2	9	10	6.46
Mercury		0.00066	0.1U			0.1U	0.00034J	0.00014J					0.00047J	0.00015J
Molybdenum		0.79					0.55J	0.47	0.68	0.55	0.78		0.57J	0.54
Nickel		0.4	10U		0.4	10U	10U	0.4	0.4	0.5	0.4	0.4	10U	0.4
Potassium		672	850		500U	600	500U	500U	630	530	850	710	590	610
Selenium		< 0.2	1U			1U	0.2U	0.2U					0.2U	0.2U
Silver		0.1	0.2U		0.04U	0.2U	0.04U	0.04U	0.04U	0.04U	0.1U	0.1 U	0.09J	0.04U
Sodium		1,034	1,610		860	1,570	1,070	700	860	930	1,080	1,230	1,070	750
Thallium		< 0.04	1U			1U	0.04U	0.04U	0.04U				0.04U	0.04U
Uranium		0.06					0.10	0.06	0.06				0.09	0.05
Zinc		5	40		25	36	45	14	22	56	28	65	47	13
Dissolved Metals, (ug/L)														
Aluminum		37.4	50	20U	50	50	70	30U	40	70	50	70	80	30U
Arsenic		0.9	1U	1U		1U	0.19	0.23	0.31	0.2	0.24	0.11	0.18	0.23
Barium		17.5	9	9	6.43	9	7	16.2	6.95	5.8	6.6		7	14.8
Beryllium		< 0.04	1U	1U	0.04U	1U	0.2U	0.04U	0.04U	0.04U	0.04U		0.2U	0.04U
Cadmium		0.07	0.2U	0.2U	Note [a]	0.2U	0.24	0.07	0.10	0.26	0.16	0.28	0.24	0.08
Calcium		6,703	10,000	10,100	6,640	10,100	6,070	4,630	6,690	5,250	7,810	8,460	6,220	4,720
Chromium		< 0.2	5U	5U	0.2U	5U	5U	0.2U	0.2U	0.2U	0.1U	0.2 U	5U	0.2U
Copper		1.06	4	3	1.4	4	10	1.9	1.2	12.6	4.4J	4.4	11	2.0
Iron		40	430	60	420	370	230	140	420	170	390	90	240	140
Lead		0.54	1U	1U	0.5	1U	0.4U	0.2UJ	0.2	0.057	0.027		0.6U	0.2UJ
Magnesium		626	1,510	1,520	800	1,510	800	540	820	620	1,000	1,130	810	540
Manganese		2.42	15	14	9.97	15	10	4.96	9.83	6.48	7.8	9	9	4.88
Mercury		0.05	0.1UJ	0.1UJ		0.1UJ	0.00064	0.00019J					0.00040J	0.00007J
Molybdenum		0.78					0.54J	0.54	0.64	0.51	0.79		0.54J	0.54
Nickel		0.39	10U	10U	0.5	10U	10U	0.2U	0.4	0.3	0.3	0.3	10U	0.2U
Potassium		660	880	930	500U	810	510	500U	500U	500U	550	730	500U	520
Selenium		< 0.2	1U	1U		1U	0.2U	0.2U					0.2U	0.2U
Silver		< 0.04	0.2U	0.2U	0.04U	0.2U	0.04U	0.04U	0.04U	0.04U	0.1U	0.1 U	0.04U	0.08
Sodium		1,078	1,750	1,740	860	1,660	1,020	730	870	870	1,060	1,290	1,100	740
Thallium		< 0.04	1U	1U		1U	0.04U	0.04U	0.04U				0.04U	0.04U
Uranium		0.172					0.07	0.04U	0.04				0.07	0.04U
Zinc		7.81	37	32	20	41	38	17	20	45	24	49	40	16
Stream Discharge (cfs)		--	est. 186			195.6	748	665	149.7	1105				

Table 2-4
Summary of Railroad Creek Water Quality Data for
Downstream Stations (1997 - 2003)
Holden Mine RI/FS

Table 2-4
Summary of Railroad Creek Water Quality Data for
Downstream Stations (1997 - 2003)

Parameters	Surface Water Area Background Value [1]	RC-8 Station			RC-3 Station								
Station No.		RC-8A	RC-8B	RC-8	RC-3A	RC-3						RC-3X	
Sampling Date		4/18/97	4/18/97	9/16/97	4/18/97	5/22/97	7/11/97	9/16/97	5/5/98	5/5/01	5/21/03	5/22/97	7/11/97
Total Petroleum Hydrocarbon (mg/L)													
Gasoline Range Hydrocarbons	NE					0.25U	0.25U	0.25U				0.25U	0.25U
Diesel Range Hydrocarbons	NE					0.25U	0.25U	0.25U				0.25U	0.25U
Motor Oil	NE					0.50U	0.50U	0.50U				0.50U	0.50U
Polychlorinated Biphenyls (ug/L)													
Aroclor 1016	NE					0.050U	0.033U					0.050U	0.033U
Aroclor 1221	NE					0.10U	0.067U					0.10U	0.067U
Aroclor 1232	NE					0.050U	0.033U					0.050U	0.033U
Aroclor 1242	NE					0.050U	0.033U					0.050U	0.033U
Aroclor 1248	NE					0.050U	0.033U					0.050U	0.033U
Aroclor 1254	NE					0.050U	0.033U					0.050U	0.033U
Aroclor 1260	NE					0.050U	0.033U					0.050U	0.033U
Conventional Analyses													
Ortho-Phosphorous (mg/L)	NE					0.004UJ	0.004UJ	0.004UJ				0.004UJ	0.004UJ
Post Chlorination Cyanide (mg/L)	NE					0.004U	0.004U	0.004UJ				0.004U	0.004U
Total Cyanide (mg/L)	NE					0.004U	0.004U	0.004UJ				0.004U	0.004U
Total Dissolved Solids (mg/L)	NE	46		38J	48	26J	18J	40J	29	19	38	29J	14J
Total Phosphorous (mg/L)	NE					0.016U	0.016U	0.016U		0.016U		0.016U	0.016U
Total Suspended Solids (mg/L)	NE	1.6		1.1U	1.5	2.2UJ	2.1	1.1U	4.3	1.0U	1.0 U	1.2J	1.2
Chloride (mg/L)	NE	1.0U			1.0U	1.0	1.0U	1.0U		1.2	1.0 U	1.0U	1.0U
Fluoride (mg/L)	NE									0.10UJ			
NO_2 & NO_3 (mg/L)	NE	0.076			0.078	0.10	0.051	0.028		0.15		0.10	0.054
Sulfate (mg/L)	NE	14		10	13	7.7	2.5U	12	5.3	11	9.5	7.6	5.5
Silicates (mg/L)	NE												
Alkalinity (mg/L $CaCO_3$)	NE	25		9.0	26	14	10	12	12	18	17	13	10
Carbonate (mg/L $CaCO_3$)	NE									1.0U	1.0 U		
Bicarbonate (mg/L)	NE									18	17		
Amenable Cyanide (mg/L)	NE					0.004U	0.004U	0.004UJ				0.004U	0.004U
Color (Pt-CO)	NE					5UJ	5UJ	15J				5UJ	5UJ
Hardness, Dissolved (mg/L)	NE	31	32	20	31	18	14	20	16	24	26	19	14
Field Measurements:													
pH	5.0 - 8.3	6.1	6.2	6.5	6.2	8.1	7.8	6.6	5.8	6.3	*6.67/6.36		
Specific Conductivity (uS/cm)	NE	148	110	60	40	57	37	56	26	65	*68/70		
Temperature (^oC)	NE	6.3	5.7	10.7	5.7	9.8	10.5	10.7	8.5	5.06	*7.9/7.4		
Redox (mV)	NE					176				287			
Iron (ion)	NE												
Turbidity (NTU)	NE				11				11		*1.50/1.46		
Dissolved Oxygen (mg/L)	NE							11.08	10.9 (W)	13.3	*19.99/19.99		

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.

(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 analyte concentration or discharge rate was not determined.

1 - Values are the calculated 90th percentile using data collected from Railroad Creek upstream stations, Holden Creek, Big Creek, Copper Creek upstream stations, Tenmile Creek, South Fork Agnes Creek, and Company Creek.

Additional explanation included in DRI. (Dames and Moore, July 1999) Section 5.3. pH is the range of values from background stations.

a - Anomalous result, reported as 0.72 ug/L. Refer to DRI (Dames & Moore, 1997) for explanation.

* Field parameters for RC-3 on 5/21/03 were collected from the south bank and the north bank (south bank / north bank).

Table 2-5
Summary of Water Quality Data for Lake Chelan - Fall 2002
Holden Mine RI/FS

Parameters	Station No. / Sampling Date	Surface Water Area Background Value [1]	Lucerne					Stehekin
	Station No.		LUC-SW-1	LUC-SW-2	LUC-SW-3	LUC-SW-3 DUP	LUC-SW-4	STE-SW-11
	Sampling Date		10/22/02	10/22/02	10/22/02	10/22/02	10/22/02	10/22/02
Total Metals, (ug/L)								
Aluminum		144	50 U	50 U	50 U	50 U	50 U	50 U
Arsenic		1.44	0.29	0.29	0.28	0.28	0.29	0.29
Cadmium		0.10	0.04 UJ	0.06 J	0.04 UJ	0.04 UJ	0.08 J	0.06 J
Calcium		6,814	6,840	6,590	6,730	6,780	6,810	6,720
Copper		1.83	0.5 U	0.6 U	0.5 U	0.5 U	0.6 U	0.4 U
Iron		177	50 U	50 U	50 U	50 U	50 U	50 U
Lead		0.3	0.017 U	0.508	0.015 U	0.026 U	0.033 U	0.023 U
Magnesium		647	950	930	940	930	980	930
Manganese		5.06	0.5	0.4	0.4	0.4	0.4	0.5
Zinc		5	6 U	6 U	6 U	13	6 U	6 U
Dissolved Metals, (ug/L)								
Aluminum		37.4	50 U	50 U	50 U	50 U	50 U	50 U
Arsenic		0.9	0.26	0.28	0.26	0.27	0.27	0.28
Cadmium		0.07	0.04 U	0.04 U	0.06	0.04 U	0.04 U	0.07
Calcium		6,703	6,780	6,620	6,710	6,770	6,670	6,640
Copper		1.06	0.4 UJ	0.5 UJ	0.4 UJ	0.4 UJ	0.6 UJ	0.5 UJ
Iron		40	50 U	50 U	50 U	50 U	50 U	50 U
Lead		0.54	0.019 U	0.079 U	0.015 U	0.015 U	0.093 U	0.024 U
Magnesium		626	940	970	930	940	1,020	930
Manganese		2.42	0.4	0.2	0.2	0.2	0.2	0.2
Zinc		7.81	6 U	6 U	6 U	6 U	6 U	6 U
Conventional Analyses								
Total Dissolved Solids (mg/L)		NE	26 J	26 J	30 J	31 J	26 J	34 J
Total Phosphorous (mg-P/L)		NE	0.016 U	0.016 U	0.016 U	0.016 U	0.016 U	0.016 U
Total Suspended Solids (mg/L)		NE	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U
Chloride (mg/L)		NE	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U
Fluoride (mg/L)		NE	0.10 U	0.10 U	0.10 U	0.10 U	0.10 U	0.10 U
NO_2 & NO_3 (mg-N/L)		NE	0.040	0.087	0.036	0.026	0.095	0.043
Sulfate (mg/L)		NE	2.8	3.5	3.1	3.1	2.5 U	2.5
Alkalinity (mg/L $CaCO_3$)		NE	22	20	17	21	21	21
Carbonate (mg/L $CaCO_3$)		NE	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U
Bicarbonate (mg/L $CaCO_3$)		NE	22	20	17	21	21	21
Dissolved Organic Carbon (mg/L)		NE	1.7	2.2	1.5 U	1.5 U	1.5 U	1.5 U
Hardness, Dissolved (mg $CaCO_3$/L)		NE	21	20	21	21	21	20
pH (Laboratory Analyzed)		5.0 - 8.3	7.67 J	7.61 J	7.68 J	7.66 J	7.68 J	7.71 J
Field Measurements:								
pH		5.0 - 8.3	7.86	7.87	7.98	NA	7.99	8.04
Specific Conductivity (uS/cm)		NE	37.2	36.3	36.5	NA	36.3	36.3
Temperature (^oC)		NE	13.45	13.61	13.82	NA	13.63	13.72
Turbidity (NTU)		NE	0.3	0.7	0.2	NA	0	6.6
Dissolved Oxygen (mg/L)		NE	8.52	8.63	8.58	NA	8.84	8.74

Data Notes:

U - Parameter was analyzed for, but not detected above the reporting limit shown.

* These metals require hardness correction specific to the sample data.

1 - Values are the calculated 90th percentile using data collected from Railroad Creek upstream stations, Holden Creek, Big Creek, Copper Creek upstream stations, Tenmile Creek, South Fork Agnes Creek, and Company Creek. Additional explanations included in DRI (Dames and Moore, July 1999) Section 5.3. pH is the range of values from background stations.

Table 2-6
Summary of Groundwater Quality Data (1997 - 2003)
Holden Mine RI/FS

Parameters	Holden Village								Upstream	Ventilator Portal		1100 Level Portal	Honeymoon Heights			
Sample ID	HV-3 (H-3)		HV-3X (H-3)	HV-3 (H-3)				SP-13	SP-27	SP-26		A-1	SP-14 Upper	SP-14		SP-14 Lower
Sampling Date	6/9/97	9/20/97	9/20/97	11/18/01	6/13/02	10/24/02	10/9/03	6/2/97	5/7/98	7/11/97	9/16/97	7/11/97	10/3/97	5/23/97	9/18/97	10/3/97
Dissolved Metals, (ug/L)																
Aluminum	20U	20U	20U	50 UJ	50 U	50 U	100	20U	20U	30	20U	20U	70	410	160U	900
Arsenic				0.1 U	0.2 U	0.2 U	0.2 U		1U							
Barium	14U	2J	2J	1.7	1.9	1.6	2.6	41	1U	14	3	14.4	2	33	20	51
Beryllium	0.2U	1U	1U	0.04 U	0.2 U	0.2 U	0.2 U	0.8U	1U	1U	1U	0.04U	1U	4U	1U	1U
Cadmium	0.2U	0.2U	0.2U	0.04 U	0.2 U	0.2 U	0.2 U	0.31	0.2U	0.3	0.3	2.32	0.2U	3.46	1.2	12
Calcium	13,200	12,800	12,900	13900	13800	12,700	12,400	10400	4610	3,760	4,640	20,100	700	1800	1730	5020
Chromium	5U	5U	5U	0.5 U	0.5 U	0.5 U	0.7	5U	5U	5U	5U	0.2U	5U	5U	5U	5U
Copper	3	2U	2U	3.2 J	0.5	1.4	1.2	2U	2U	28	22	120	2U	788	52	1410
Iron	20U	30	20	50 U	50 U	50 U	80	330	20U	20U	20U	20U	20U	20	480	30
Lead	1U	1U	1U	2.6	1 U	1 U	1 U	0.8U	1U	1U	1U	0.4U J	1U	4.8U	3	11
Magnesium	1,890	1,800	1,810	1980	1990	1,860 J	1,870	1460	430	470	540	1,910	130	290	350	910
Manganese	2	1U	1U	0.7	0.5 U	0.5 U	2.3	74	1	1U	1U	27.8	1U	8	4	43
Mercury																
Molybdenum				1.15	0.9	1.0	1.1		5U							
Nickel	10U	10U	10U	0.1 U	0.6 J	0.5 U	0.6	10U	10U	10U	10U	1.0	10U	10U	10U	10U
Potassium	3,140	920	960	1050	910	940	860	1010	500U	640	790	1,770	500U	500U	750UJ	560
Selenium																
Silver	0.2U	0.2UJ	0.2UJ	0.1 U	0.5 U	0.5 U	0.5 U	1.1U	0.2U	0.2U	0.2U	0.04U	0.2U	0.04U	0.2U	0.2U
Sodium	4,750	1,500	1,530	1460	1480	1,850 J	1,400	1950	1110	970	1,020	1,220	310U	730	590UJ	650
Thallium																
Uranium																
Zinc	6	7	4U	6 U	6 U	6 U	6 U	71	4U	32	22	257	5	423	151	1610
Total Petroleum Hydrocarbon, (mg/L)																
Diesel Range Hydrocarbons																
Gasoline 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)	74	65J	56J	47	65	55	63	40J	350	39	30J	86J	5.0U	23	24J	32
Total Suspended Solids (mg/L)	160	2,400	2,800	880	57	350	46	1.5	2.2U	1.1U	1.1UJ	3.5	1.4	1.0U	5.8	1.1U
Chloride (mg/L)				1.0 U	1.0 U	1.4	1 U									
Fluoride (mg/L)				0.10 U	0.10 U	0.10 U	0.1 U									
NO_2 & NO_3 (mg-N/L)				0.057	0.023	0.042	0.020									
Sulfate (mg/L)	4.6	5.8	7.6	6.0	4.3	6.0	4.0	4.4	2.6	6.2	2.5U	40	2.5U	11	6.9	22
Acidity (mg/L $CaCO_3$)																
Alkalinity (mg/L $CaCO_3$)	52	38	42	49	47	39	42	32	14	10	14	23	1.7	1.0U	1.0U	1.0U
Carbonate (mg/L $CaCO_3$)				1.0 U	1.0 U	1.0 U	1 U									
Bicarbonate (mg/L $CaCO_3$)				49	47	39	42									
Amenable Cyanide (mg/L)																
Color (Pt-CO)																
Hardness, Dissolved (mg/L)	41	39	40	43	43	39	39	32	13	11	14	58	2	6	6	16
pH (Laboratory Analyzed)					6.70 J	6.62 J										
Total Phosphorous (mg/L)																
Field Measurements:																
pH	6.64	6.54		6.08	6.87	6.2	5.98	6	7.5	8.26	6	8	5.8	5.1	6.05	4.5
Specific Conductivity (uS/cm)	172	770		85	96	69	98	90	6	25	31.8	141	2(?)	36	17.5	71
Temperature (^{o}C)	7.8	9.8		6	8.3	6.6	6.5	8	4.6	7.2	7.2	6.6	5.5	2.3		7.7
Redox (mV)	181			-	366	258						154		199		
Iron (ferrous iron, ug/L)	Negative			-								Negative		Negative		
Turbidity (NTU)	48			254	57.5	****	22									
Dissolved Oxygen (mg/L)				11.56	9.45	12.25	9.8									

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.
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.
* 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.
*** Suspected interference from zinc or copper in field test resulting in biased high ferrous iron result.
**** Instrument Malfunction
Grey shading — Analysis not performed.

Table 2-6
Summary of Groundwater Quality Data (1997 - 2003)
Holden Mine RI/FS

Parameters / Location	Honeymoon Heights													Ball Field		West Waste Rock Pile		Mill Building				
Sample ID	SP-23								SP-23 UP	SP-23 Vent Rd	SP-23B	SP-12		HBKG-2		SP-6	SP-15W	SP-7			SP-7X	SP-22
Sampling Date	5/23/97	5/26/97	6/2/97	6/9/97	6/16/97	10/5/97	5/2/98	5/10/01	7/11/97	10/5/97	5/23/97	5/23/97	7/12/97	6/3/97	9/20/97	5/21/97	5/22/97	5/21/97	7/12/97	9/19/97	5/21/97	5/23/97
Dissolved Metals, (ug/L)																						
Aluminum	7,890	7,940	7,440	6,850J	5,390	4,670	5620	5230	5,820	4,520	5,250	1380	1590	20U	20U	14,600	30	190	20	1,790	200	190
Arsenic							1U	0.2U										0.2U	1U	1U	0.2U	
Barium	33	40.0	26.5	28.5J	23	27	22	20.1	32	20	35	50	27	39	2J	12.0	23	12.9	27	21	12.5	33
Beryllium	20U	0.2	4U	0.3J	4U	1U	1U	0.2	1U	1U	4U	0.8U	1U	0.8U	1U	8U	0.04U	0.2U	1U	1U	0.04	20U
Cadmium	38.9	41.8	32.0	27.1J	22	23	34	29.6	26	22	28	14.1	18	3.18	0.4	173	9.37	34.0	26	48	35.3	47.5
Calcium	17,000	15,900	11,100	10,300J	7,940	11,200	15500	15700	10,900	10,500	14,100	9610	16200	9,830	10,100	134,000	23,000	15,800	28,700	60,100	15,900	58,000
Chromium	5U	1U	1U	1U	5U	5U	5U	0.5U	5U	5U	5U	5U	5U	5U	5U	4U	5U	1U	5U	5U	1U	5U
Copper	6,850	6,470	6,100	5,940J	4,880	4,920	5340	4970	5,560	4,520	4,900	2000	1910	10	2U	12,700	206	2,810	1,930	7,560	2,800	2,140
Iron	20U	20U	20U	20U	20U	20U	20U	20U	20U	20U	20U	20U	20U	20U	20U	30	20U	120	220	710	120	20U
Lead	20U	1U	1U	3J	20U	1U	0.22	1	1U	1U	4U	0.2U	1U	0.5U	1U	15J	1.4U	3J	3	13	4J	2.8U
Magnesium	5,130	4,660	2,660	2,500J	1,630	2,290	3620	4850	2,540	2,150	3,920	1470	2920	1,050	980	15,000	2,590	4,810	6,680	11,500	4,860	6,880
Manganese	248	223	130	115J	79	128	199	238	114	109	177	53	93	3U	1U	1,160	37	116	185	451	144	264
Mercury																		0.00068J	0.00023J		0.00051J	
Molybdenum							5U	0.2U										0.2UJ	5U	5U	0.2UJ	
Nickel	20	22	14	12J	10U	10	20	15.3	10	10	10	10U	10U	10U	10U	86	10U	6	10U	10	7	20
Potassium	1,160	1,280	1,360	1,120J	840	1,340	1110	1160	1,420	890	1,000	1140	1840	2,450	1,210	10,500	2,120	1,230	2,390	3,200UJ	1,260	3,980
Selenium																		1UJ	1U		1UJ	
Silver	0.04U	0.2UJ	0.2U	0.2U	4U	0.2U	0.2U	0.5U	0.2U	0.2U	0.04U	0.04U	0.2U	0.8U	0.2UJ	8U	0.8U	0.2U	0.2U	0.2U	0.13U	0.04U
Sodium	1,600	1,710	1,140	1,240J	1,000	1,360	1430	1700	1,380	1,330	1,650	1630	3130	2,150	1,380	4,910	3,380	2,170	3,830	6,470J	2,170	3,340
Thallium																		0.2UJ	1U	1U	0.2UJ	
Uranium																		0.3J	20U	1U	0.33J	
Zinc	5,000	5,020	3,400	2,870J	2,250	2,460	4110	3350	2,610	2,570	3,610	2230	2270	30	11	22,100	2,260	4,330	3,470	6,430	4,390	7,350
Total Petroleum Hydrocarbon, (mg/L)																						
Diesel Range Hydrocarbons																						0.25U
Gasoline Range Hydrocarbons																						
Motor Oil																						0.50U
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
Conventional Analyses:																						
Ortho-Phosphorous (mg/L)																		0.004U	0.009J		0.004U	
Post Chlorination Cyanide (mg/L)																		0.004U	0.004U		0.004U	
Total Cyanide (mg/L)																		0.004	0.004U		0.004U	
Total Dissolved Solids (mg/L)	200	190	140J	140	95	110J	160	180	140	110J	160	76	140	47J	66J	880	130J	130	180	390J	120	300
Total Suspended Solids (mg/L)	1.0U	1.1UJ	1.1UJ	1.5	1.0U	1.0U	1.5	1.0U	1.1U	1.0U	1.1U	1.1U	2.5	53	1,000	1.0U	2.1J	17	4.1	16	17	16
Chloride (mg/L)								1.0U										1.0U	1.3	1.0U	1.0U	
Fluoride (mg/L)																						
NO_2 & NO_3 (mg-N/L)								0.65										0.031	0.03		0.031	
Sulfate (mg/L)	130	110	81	72	59	66	88	90	70	68	100	45	62	6.0	11	600	78	79	120	260	80	200
Acidity (mg/L $CaCO_3$)																						
Alkalinity (mg/L $CaCO_3$)	1.0U	1.0U	1.0U	1.0U	1.0U	1.0U	1U	1.0U	1.0U	1.0U	1.0U	1.0U	1.0U	30	32	15	3.1	4.3	1.4	1.0U	4	6.8
Carbonate (mg/L $CaCO_3$)																						
Bicarbonate (mg/L $CaCO_3$)																						
Amenable Cyanide (mg/L)																		0.004	0.004U		0.004U	
Color (Pt-CO)																		10	5UJ		10	
Hardness, Dissolved (mg/L)	64	59	39	36	26	37	54	59	38	35	51	30	53	29	29	400	68	59	99	200	60	170
pH (Laboratory Analyzed)																						
Total Phosphorous (mg/L)								0.017										0.016U	0.018		0.016U	
Field Measurements:																						
pH	4.2	4.9	4.25	5	4	4.57	4.9	4.6		4.54	4.3	5.03	5.48	6.01	6.3	4.2	6.5	5.63	6.91	4.69		6
Specific Conductivity (uS/cm)	360	276	277	260	203	196	179	234		182	285	114-263	197	73	92	1040	226	240	264	505		433
Temperature (^{o}C)	2.5	4.2	3.4	4.2	7	6.6	4.5	4.2		6.3	2.6	3.5-5.9	5.1	5.5	8	4.8	5.6	6.9	19.1			9.5
Redox (mV)	327	290	344	187	207						325		206	195		336	269	267	170			282
Iron (ferrous iron, ug/L)	Negative	Negative									Negative	Negative	Negative	Negative		Negative	Negative	Negative	Positive			Negative
Turbidity (NTU)								120						610								
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.

* 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.

*** Suspected interference from zinc or copper in field test resulting in biased high ferrous iron result.

**** Instrument Malfunction

Grey shading — Analysis not performed.

Table 2-6
Summary of Groundwater Quality Data (1997 - 2003)

Parameters	Mill Building						West Area																		
Sample ID	**SP-15E**						**HBKG-1**			**2003-MW1**	**2003-MW2**	**2003-MW3**	**2003-MW4S**	**2003-MW4SX**	**2003-MW4D**	**SP-9**	**SP-9X**	**SP-11**	**SP-11X**	**SP-16**			**SP-16X**	**SP-24**	**SP-25**
Sampling Date	**5/22/97**	**6/2/97**	**6/9/97**	**6/16/97**	**7/12/97**	**10/5/97**	**6/3/97**	**9/20/97**	**10/9/03**	**10/9/03**	**10/9/03**	**10/9/03**	**10/9/03**	**10/9/03**	**10/9/03**	**5/23/97**	**5/23/97**	**5/22/97**	**5/22/97**	**5/22/97**	**7/12/97**	**9/16/97**	**7/12/97**	**5/23/97**	**5/23/97**
Dissolved Metals, (ug/L)																									
Aluminum	1,940	2,240	3,350J	2,560	20U	680	660	800	910	50 U	50 U	1,290	440	440	370	30	20	150	150	2,040	3,490	2,630	3,350	2,410	890
Arsenic									0.2	0.2 U	0.2 U	0.2 U	0.4	0.4	0.2 U			0.3	0.2U	0.8U	1U	1U	1U		
Barium	18	36.1	34.6J	43	43	36	30	22J	25.1	5.7	25.9	25.2	23.9	23.4	24.5	30	29	44.6	45.3	21.6	37	24	37	36	42
Beryllium	0.09	4U	0.3J	4U	1U	1U	0.8U	1U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.8U	0.04U	0.04U	0.2U	0.8U	1U	1U	1U	20U	4U
Cadmium	54.6	55.8	66.9J	74	28	63	43.1	39	55.6	0.2 U	9.8	25.5	19.9	19.6	19.8	0.75	0.76	12.8	13.2	53.5	38	34	38	47.7	34.1
Calcium	47,900	38,300	46,800J	52,900	30,100	51,500	37,000	53,500	49,500	7,080	30,700	102,000	58,300	57,000	59,600	19,000	18,600	25300	24100	48,300	44,900	49,800	43,900	45,300	37,400
Chromium	5U	1U	1U	5U	5U	5U	5U	5U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	5U	5U	1U	1U	4U	5U	5U	5U	5U	5U
Copper	3,560	3,950	4,930J	4,470	899	4,180	3,030	2,370	4,030	1.2	201	1,340	713	691	588	3	2	460	472	3,450	3,100	2,110	2,970	3,660	1,880
Iron	80	80J	100J	110	20U	170	240	910	2,810	50 U	50 U	50 U	50 U	50 U	50 U	20U	20U	20U	20U	60	500	80	450	220	20U
Lead	6.7U	8	14J	20U	1U	6	5	2U	1	1 U	1 U	1 U	1 U	1 U	1 U	0.4U	0.3U	1U	1U	5J	9	8	10	4.3U	2.2U
Magnesium	6,330	5,820	7,170J	8,260	5,930	9,040	4,860	7,710	7,710	770	2,970	8,460	5,650	5,520	5,770	2,090	2,070	3180	3000	6,530	6,500	4,560	6,270	6,240	5,090
Manganese	247	198	250J	295	148	312	129	175	157	0.8	6.8	205	93.2	91.3	89.7	1U	1U	37.3	36.3	253	993	2,030	960	270	157
Mercury																				0.00056J	0.00093		0.00067		
Molybdenum									0.2 U	0.9	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U					0.8UJ	5U	5U	5U		
Nickel	20	16	20J	20	10U	20	10	10	15	0.5 U	2.2	5.8	4.7	4.6	4.8	10U	10U	6	5	28	30	20	30	20	10
Potassium	3,460	3,910	5,270J	4,760	3,040	3,830	3,390	4,220	4,070	500 U	1,940	4,680	3,270	3,160	3,150	1,010	1,020	2410	2060	3,500	4,760	5,230	4,700	3,730	2,700
Selenium																				4UJ	1U		1U		
Silver	0.05U	0.2U	0.2U	4U	0.2U	0.2U	0.8U	0.2UJ	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.8U	0.8U	0.05U	0.2U	0.04U	0.2U	0.2U	0.2U	0.14	0.08
Sodium	2,500	3,010	3,420J	3,940	3,450	3,710	3,330	4,900	4,610	1,000	6,280	21,300	12,000	11,700	12,200	3,470	3,440	3.65	3410	2,980	4,820	3,350	4,600	3,140	3,300
Thallium																				0.8UJ	1U	1U	1U		
Uranium																				0.8UJ	20U	20U	20U		
Zinc	7,970	7,210	8,580J	9,810	3,590	8,960	4,900	5,170	6,080	13	2,010	4,750	4,000	3,930	4,120	267	267	2340	2280	7,690	4,920	4,050	4,810	7,560	5,550
Total Petroleum Hydrocarbon, (mg/L)																									
Diesel Range Hydrocarbons							0.27X	0.25U												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												0.50U	0.60X	0.50U			
Polychlorinated Biphenyls, (ug/L)																									
Aroclor 1016							0.050U													0.050U	0.033U				
Aroclor 1221							0.10U													0.10U	0.067U				
Aroclor 1232							0.050U													0.050U	0.033U				
Aroclor 1242							0.050U													0.050U	0.033U				
Aroclor 1248							0.050U													0.050U	0.033U				
Aroclor 1254							0.050U													0.050U	0.033U				
Aroclor 1260							0.050U													0.050U	0.033U				
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)	280J	240J	270	320	180	280J	190J	290J	310	32	170	530	320	320	320	94	87	140	150	280	270	270J	280	280	230
Total Suspended Solids (mg/L)	13J	6.6J	6.1	7.8	19	2.4	18	11	1.1 U	1.6	1 U	1 U	1 U	1 U	1 U	2	1.0U	7.8	5.2	7.9	1.1U	1.7J	1.1U	2.3	1.0U
Chloride (mg/L)									1 U	1 U	2.8	7.2	4.2	3.7	4.8					1.0U	1.0U	2.1	1.0U		
Fluoride (mg/L)									0.18	0.1 U	0.16	0.45	0.29	0.29	0.24										
NO_2 & NO_3 (mg-N/L)									0.010 U	0.018	0.041	0.057	0.051	0.050	0.063					0.051	0.010U	0.010U	0.010U		
Sulfate (mg/L)	180	140	170	180	110	200	130	150	190	5.4	96	330	200	190	190	44	46	82	84	200	130	140	140	180	170
Acidity (mg/L $CaCO_3$)																									
Alkalinity (mg/L $CaCO_3$)	1.0U	1.0U	1.0U	1.0U	2.5	1.0U	4.4	7.9	4.7	17	5.9	1 U	1 U	2.3	2.1	15	15	7.8	8.3	2.2	1.0U	1.0U	1.0U	1.0U	1.0U
Carbonate (mg/L $CaCO_3$)									1 U	1 U	1 U	1 U	1 U	1 U	1 U										
Bicarbonate (mg/L $CaCO_3$)									4.7	17	5.9	1 U	1 U	2.3	2.1										
Amenable Cyanide (mg/L)																				0.004U	0.004U	0.004U	0.004U		
Color (Pt-CO)																				5U	5UJ		5UJ		
Hardness, Dissolved (mg/L)	150	120	150	170	100	170	110	160	160	21	89	290	170	160	170	56	55	76	72	150	140	140	140	140	110
pH (Laboratory Analyzed)																									
Total Phosphorous (mg/L)																				0.058	0.016U		0.018		
Field Measurements:																									
pH	5.5	5.62	5.11	4.69	7	4.9	5.13	5.11	5.4	5.77	4.69	5.20	3.87		3.93	6.4		5.8		5.36	4.76	4.43		4.9	5.5
Specific Conductivity (uS/cm)	460	423	544	569	252	471	383	430	467	58	275	797	509		511	198		258		467	403	423		382	323
Temperature (^0C)	8.2	13.5	16.6	13.2	17.6	8.2	5	9.6	9.0	9.4	8.9	9.4	8.5		8.0	5.2		4		8.1	23.9	12		7.8	4.4
Redox (mV)	318	258	180	208	163		229													326	186			282	301
Iron (ferrous iron, ug/L)			Negative	Negative	Negative		Positive											Negative		Negative	Positive			Negative	Negative
Turbidity (NTU)							3		0.28	0.29	0.42	0.10	0.24		0.30										
Dissolved Oxygen (mg/L)									0	8.17		8.62													

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.

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.

* 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.

*** Suspected interference from zinc or copper in field test resulting in biased high ferrous iron result.

**** Instrument Malfunction

Grey shading — Analysis not performed.

Table 2-6
Summary of Groundwater Quality Data (1997 - 2003)
Holden Mine RI/FS

Parameters	West Area			East Waste Rock Pile		Tailings Pile 1 (TP-1)														
Sample ID	SP-10W		SP-10E	SP-8	SP-19	SP-1			SP-2								SP-2X		TP1-1A	
Sampling Date	5/21/97	7/12/97	5/21/97	5/21/97	5/21/97	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	6/3/97	9/18/97
Dissolved Metals, (ug/L)																				
Aluminum	4,740	3,530	9850	9,620	4640	27,100	41,200	30700	94,600	71,800	70,000J	49,800	115,000	67,900	82,500	100000	121,000	99800	2,290	1,210
Arsenic								1U	1.5				5U	5U		5U	5U	5U		
Barium	15.4	27	18.4	22.2	21.3	15	13	11	15.2J	19	14J	9	12	5	5	2	10	3	37	22J
Beryllium	0.8U	1U	0.2U	0.8U	0.8U	0.7	5U	2U	1.7	20U	20U	20U	5U	2U	2U	2U	5U	2U	20U	2U
Cadmium	25.7	36	7	87.8	50.1	22.7	6	7	22.8	15	11J	20U	9	3.9	6	9	10	9	20U	0.2U
Calcium	27,400	30,600	5780	56,500	33600	102,000	200,000	140000	155,000	183,000	188,000J	189,000	241,000	180,000	173,000	232000	246,000	174000	62,300	79,700
Chromium	4U	5U	1U	4U	40	10U	20U	10U	5	20U	20U	10U	20U	10U	10U	10U	20U	10U	5U	10U
Copper	2,210	2,110	760	7,880	4180	698	240	321	914	860	660J	224	790	101	181	475	870	474	2U	4U
Iron	30	30	14100	30	70	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	218,000	519,000
Lead	4U	1U	20J	13J	6J	1U	10U	5U	4U	20U	20U	100U	10U	10U	5U	5U	10U	5U	100U	2U
Magnesium	3,870J	4,270	1400	5,380	3290	53,500	106,000	61200	96,800	107,000	106,000J	99,000	153,000	94,200	95,100	125000	155,000	125000	21,900J	37,400
Manganese	160	191	58.9	419	247	3,380	6,310	3870	6,120	6,280	5,890J	5,220	8,570	5,250	4,980	6260	8,780	6280	1,170	2,880
Mercury									0.00244				0.00309				0.00308			
Molybdenum								10U	0.8U				20U	10U		10U	20U	10U		
Nickel	11	10	3	46	29	20	50U	20U	119	60	60J	100	70	100	120	190	50U	200	10U	20U
Potassium	2,500	3,490	3650	3,980	3190	9,870	16,300	11100	9,040	12,900	13,300J	14,700	9,640	9,840	7,380	9990	7,620	10100	7,250	9,660
Selenium									4				5U				5U			
Silver	0.8U	0.2U	0.2U	0.8U	0.8U	0.2U	0.2U	0.2U	0.8U	4U	4U	20U	0.2U	0.2U	0.2U	0.2U	0.2U	0.2U	20U	0.2UJ
Sodium	2,760	2,920	1400	2,440	1670	12,800	20,100	14400	16,200	19,700	19,900J	21,300	23,300	13,600	13,100	19800	22,700	19600	6,670	7,950
Thallium									0.8U				50U	10U			50U			
Uranium									10.2				50U	50U			50U			
Zinc	3,210	4,350	7.14	11,200	6170	3,490	2,590	2050	5,600	4,570	4,430J	4,700	4,120	5,700	6,120	4630	3,890	4620	466J	130
Total Petroleum Hydrocarbon, (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						
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							
Conventional Analyses:																				
Ortho-Phosphorous (mg/L)									0.017J				0.030J				0.029J			
Post Chlorination Cyanide (mg/L)									0.004UJ				0.004U	0.004U			0.004U			
Total Cyanide (mg/L)									0.004UJ				0.004U	0.004U			0.004			
Total Dissolved Solids (mg/L)	210	230	210	380	240	2800	5900	3200	3700	4,700J	4900	4700	5400	3,800J	3,300J	4400	5800	4400	1,100J	2,000J
Total Suspended Solids (mg/L)	1.1U	2.4	1.1U	1.1U	1.4	13	8.9	22	4.5	5.6J	23	17	4.5	1.6J	6.4	9.1	2.7	6.1	170	64
Chloride (mg/L)									1.0U				2.9	1.0U			2.4			
Fluoride (mg/L)																				
NO_2 & NO_3 (mg-N/L)									0.14				0.032	0.010U			0.01U			
Sulfate (mg/L)	170	110	120	240	130	1700	3200	2000	2100	3200	2700	3400	3800	2200	2300	2700	4000	2800	620	1,200
Acidity (mg/L $CaCO_3$)																				
Alkalinity (mg/L $CaCO_3$)	1.0U	1.0U	1.0U	1.0U	1.0U	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
Carbonate (mg/L $CaCO_3$)																				
Bicarbonate (mg/L $CaCO_3$)																				
Amenable Cyanide (mg/L)									0.004UJ				0.004U	0.004U			0.004			
Color (Pt-CO)									40J				20J				25J			
Hardness, Dissolved (mg/L)	84	94	20	160	98	480	940	600	790	900	910	880	1200	840	820	1100	1200	950	240	350
pH (Laboratory Analyzed)																				
Total Phosphorous (mg/L)									0.04				0.04				0.034			
Field Measurements:																				
pH	4.15	4.69	3.3	4.61	4.61	3.3	3.56	3.3	2.9-3.1	3.32	3	3.2	2.9	3.12	3.87	2.7			5.54	5.51
Specific Conductivity (uS/cm)	370	301	594	623	418	2,240-2,570	4310	2830	2,370-3,910	3710	3580	3790	4495	3050	2810	3810			1120	1690
Temperature (°C)	4.2	11.1	7	5.1	6.9	7.6	9.5	7.4	4.3-8.8	6.5	15.1	8.4	16	10	9.3	8.3			6.1	6.4
Redox (mV)	382	165	497	409	363	332	318			377	300	386	360						187	
Iron (ferrous iron, ug/L)	Negative	Negative	Positive	Negative	Negative	Positive	Positive					Positive	Positive						Positive	
Turbidity (NTU)																			137	
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.
* 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.
*** Suspected interference from zinc or copper in field test resulting in biased high ferrous iron result.
**** Instrument Malfunction
Grey shading — Analysis not performed.

Table 2-6
Summary of Groundwater Quality Data (1997 - 2003)
Holden Mine RI/FS

Parameters / Location	Tailings Pile 1 (TP-1)										Tailings Pile 2 (TP-2)									
Sample ID	TP1-2A		TP1-3A		TP1-4A		TP1-5A		TP1-6A		PZ-1A	PZ-1B		PZ-1BX		PZ-3A		SP-3		
Sampling Date	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	5/20/97	7/12/97	9/16/97
Dissolved Metals, (ug/L)																				
Aluminum	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	33,400	22,500	3,920
Arsenic																6	5	1.6	1U	2U
Barium	22	11J	18	15J	67	41J	30	8J	26	11J	28	19	7J	22	7J	47	25J	14.7	21	23
Beryllium	0.4	5U	20U	5U	0.2U	1U	20U	1U	20U	1U	0.2U	4U	1U	4U	1U	4U	1U	0.6	1U	1U
Cadmium	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	40.3	6	2.0
Calcium	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	137,000	184,000	278,000
Chromium	5U	20U	5U	20U	5U	5U	5U	5U	5U	5U	5U	5U	5U	5U	5U	5U	5U	1	5U	5U
Copper	2U	10U	2U	10U	2U	2U	196	48	1,100	811	2U	2U	2U	2U	2U	2U	2U	1,280	583	90
Iron	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	154,000	263,000	251,000
Lead	1U	4U	1U	4U	1U	2U	100U	1U	100U	1U	1U	1U	2U	1U	2U	20U	1U	1J	5U	5U
Magnesium	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	47,900	54,400	62,300
Manganese	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	3,000	3,410	3,850
Mercury																0.00128		0.00193J	0.00072	
Molybdenum																4U	5U	0.2UJ	5U	5U
Nickel	20	50U	40	60	10U	10U	120	30	20	10U	10U	10U	10U	10U	10U	10U	10U	17	10U	10U
Potassium	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	14,100	17,400	29,300
Selenium																20U		1J	2U	
Silver	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	0.2U	0.2U	0.2U
Sodium	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	8,610	11,300	11,500
Thallium																4U	1U	0.2UJ	5U	5U
Uranium																4U	20U	2.9J	50U	50U
Zinc	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	4,030	1,620	611
Total Petroleum Hydrocarbon, (mg/L)																				
Diesel Range Hydrocarbons																				
Gasoline 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)																0.004UJ		0.004UJ	0.006J	
Post Chlorination Cyanide (mg/L)																0.011	0.016	0.004U	0.004U	0.005UJ
Total Cyanide (mg/L)																0.012	0.017	0.004U	0.004U	0.005UJ
Total Dissolved Solids (mg/L)	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	1700	2000	2,100J
Total Suspended Solids (mg/L)	37	93	35	280	480	390	320	380	26	13	4.2J	35	66	36	58	28	46	3.4	10	36J
Chloride (mg/L)																1.0	1.9	1.0U	1.0U	1.1
Fluoride (mg/L)																				
NO_2 & NO_3 (mg-N/L)																0.039	0.12	0.15	0.044	0.010U
Sulfate (mg/L)	1,000	3,700	1,500	3,800	160	300	1,700	1,000	850	330	190	850	750	840	720	670	510	880	1100	1300
Acidity (mg/L $CaCO_3$)																				
Alkalinity (mg/L $CaCO_3$)	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	1.0U	1.0U	1.0U
Carbonate (mg/L $CaCO_3$)																				
Bicarbonate (mg/L $CaCO_3$)																				
Amenable Cyanide (mg/L)																0.004U	0.004U	0.004U	0.004U	0.004UJ
Color (Pt-CO)																60J		15J	5J	
Hardness, Dissolved (mg/L)	350	1,300	870	1,300	190	300	680	450	290	140	230	810	740	820	740	630	590	540	680	950
pH (Laboratory Analyzed)																				
Total Phosphorous (mg/L)																0.078		0.016U	0.031	
Field Measurements:																				
pH	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	3.61	3.5	3.5
Specific Conductivity (uS/cm)	1560	4710	2400	4470	537	804	250	1820	1750	659	743	1680	1420			1160	1150	1790	2030	2040
Temperature (^oC)	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	5.2	13.2	14
Redox (mV)	214		202		122		257		196			140				115		386	331	
Iron (ferrous iron, ug/L)	Positive		Positive		Negative		Positive		Positive		Positive	Positive				Positive		Positive	Positive	
Turbidity (NTU)	26		200		126		395		9		122	72				148				
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.

* 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.

*** Suspected interference from zinc or copper in field test resulting in biased high ferrous iron result.

**** Instrument Malfunction

Grey shading — Analysis not performed.

Table 2-6
Summary of Groundwater Quality Data (1997 - 2003)
Holden Mine RI/FS

Parameters / Location	Tailings Pile 2 (TP-2)										Tailings Pile 3 (TP-3)									
Sample ID	SP-4			TP2-4A		TP2-5A	TP2-8A		TP2-11A		PZ-6A		TP3-4	TP3-6A		TP3-8		TP3-8X	TP3-9	
Sampling Date	5/20/97	7/12/97	5/2/98	6/6/97	9/18/97	6/7/97	6/6/97	9/19/97	6/5/97	9/19/97	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
Dissolved Metals, (ug/L)																				
Aluminum	19,000	20,100	5570	20U	20U	20U	4,980	680	330	440	20U	40U	9,870	540	60U	120	1,090	130	11,500	9,690
Arsenic			1U																	
Barium	36.7	30	61	49	37J	26	29	20J	32	26J	25	13J	25	47	17J	24	16J	24	18	17J
Beryllium	4U	1U	1U	4U	1U	0.8U	4U	1U	0.4U	1U	4U	2U	0.4U	0.4U	1U	0.8U	1U	0.8U	0.8	1U
Cadmium	7.3	6	1.6	4U	0.2U	0.9	7	4.9	1.6	2.9	4U	0.2U	4.8	2.2	0.7	0.8U	0.8	0.8U	1.9	3.5
Calcium	114,000	117,000	37500	232,000	187,000	83,700	243,000	308,000	57,100	127,000	449,000	563,000	12,900	16,800	10,900	76,200	269,000	77,500	46,100	291,000
Chromium	2U	5U	5U	5U	5U	5U	5U	5U	5U	5U	5U	10U	5U	5U	5U	5U	5U	5U	5U	5U
Copper	670	344	133	3	2U	47	31	11	10	10	2U	4U	137	67	14	2U	10	2U	48	51
Iron	74,900	53,000	9730	7,040	5,630	20U	20U	20U	20U	100	58,300	75,700	250	20U	20U	55,400	274,000	56,200	400	125,000
Lead	2U	2U	1U	20U	1U	4U	20U	2U	1U	1U	20U	2U	14	3U	1U	4U	4U	4U	2U	2U
Magnesium	36,300	34,100	9840	27,400	29,600	8,150	37,700	39,100	4,870	12,800	65,100	83,300	3,150J	2,040J	1,330	17,400J	68,300	17,700J	8,230J	41,400
Manganese	1,750	1,710	522	186	153	1	2,910	1,860	122	265	1,500	1,490	183	57	3	656	2,560	667	1,370	3,490
Mercury																				
Molybdenum			5U																	
Nickel	13	10	10U	10U	10U	10U	30	10	10U	10	10U	20U	10	10U	10U	10U	10U	10U	40	40
Potassium	9,530	13,700	3550	31,600	27,400	12,500	32,700	31,100	9,960	12,700	62,100	75,700	1,570	3,390	1500	19,800	37,600	19,900	6,740	18,900
Selenium																				
Silver	4U	0.2U	0.2U	4U	0.2UJ	0.8U	4U	0.2UJ	0.4U	0.2UJ	4U	0.3J	0.4U	0.4U	0.2UJ	0.8U	0.2UJ	0.8U	0.4U	0.2UJ
Sodium	7,310	7,760	2190	7,190	6,580	3,100	9,120	9,160	2,820	4,310	15,000	17,200	2,080	1,500	1,160	4,620	11,200	4,710	3,110	10,700
Thallium																				
Uranium																				
Zinc	904	921	248	11U	7	80	556	280	169	309	15	25	590J	403J	102	58J	395	57J	194J	402
Total Petroleum Hydrocarbon, (mg/L)																				
Diesel Range Hydrocarbons																				
Gasoline 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)	1100	980	280	1,100	920J	370	1,200	1,400J	250	580J	2,400	2,800J	170	86	59J	500	2,200J	570	350	1,800J
Total Suspended Solids (mg/L)	11	1.0U	1U	73	62	75	270	2,000	260	1,600	36	190	9.1	9.1	200	5.8	30	5.5	36	65
Chloride (mg/L)																				
Fluoride (mg/L)																				
NO_2 & NO_3 (mg-N/L)																				
Sulfate (mg/L)	660	610	190	720	570	280	820	970	150	390	1,500	1,700	83	49	25	340	1,400	340	200	1,100
Acidity (mg/L $CaCO_3$)																				
Alkalinity (mg/L $CaCO_3$)	1.0U	1.0U	1U	65	61	26	1.0U	7.3	3.2	4.2	110	43	1.0U	2.3	7.2	8.8	1.0U	10	1.0U	1.0U
Carbonate (mg/L $CaCO_3$)																				
Bicarbonate (mg/L $CaCO_3$)																				
Amenable Cyanide (mg/L)																				
Color (Pt-CO)																				
Hardness, Dissolved (mg/L)	440	430	130	690	590	240	760	930	160	370	1,400	1,800	45	50	33	260	950	270	150	900
pH (Laboratory Analyzed)																				
Total Phosphorous (mg/L)																				
Field Measurements:																				
pH	3.64	3.5	3.6	7.21	6.94	6.02	5.12	5.32	5.06	5.36	5.95	6.45	3.97	5.2	6.14	5.65	5.53		3.81	4.37
Specific Conductivity (uS/cm)	1290	1260	338	1320	1120	740	1410	1440	432	914	2430	2800	340	154	103	844	2120		709	1820
Temperature (^oC)	6	4.4	9.8	8	7.5	7.7	7.1	9.8	8.3	8	11.6	8	4.8	4.7	6.4	7	8.1		5.9	6.2
Redox (mV)	400	331		114		133	162		145		98		282	225		212			258	
Iron (ferrous iron, ug/L)	Positive	Positive		Positive		Negative	Negative		Negative		Positive		Positive	Negative		Positive			Positive	
Turbidity (NTU)				78		210	173				213		52			12			6	
Dissolved Oxygen (mg/L)																				

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.
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.
* 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.
*** Suspected interference from zinc or copper in field test resulting in biased high ferrous iron result.
**** Instrument Malfunction
Grey shading — Analysis not performed.

Table 2-6
Summary of Groundwater Quality Data (1997 - 2003)
Holden Mine RI/FS

Table 2-6
Summary of Groundwater Quality Data (1997 - 2003)

Parameters / Location	Tailings Pile 3 (TP-3)		East of Tailings Pile 3 (TP-3)																								
Sample ID	TP3-10 (TP3-10A)		DS-1		DS-1X	DS-1			DS-2		DS-2X	DS-2			DS-3S			DS-3D			DS-4S			DS-4SX	DS-4D		
Sampling Date	6/4/97	9/19/97	6/3/97	9/20/97	6/3/97	11/20/01	6/12/02	10/24/02	6/5/97	9/20/97	9/20/97	11/20/01	6/12/02	10/24/02	11/19/01	6/12/02	10/24/02	11/19/01	6/12/02	10/24/02	11/19/01	6/12/02	10/24/02	6/12/02	11/19/01	6/12/02	10/24/02
Dissolved Metals, (ug/L)																											
Aluminum	290	540	170	250	120	80	110	60	5470	19,800	20,800	10,200	4,200	27,200	50 U	50	70	170	60	210	50 U	50 U	240	50 U	840	880	1,120
Arsenic						0.2 U	0.2 U	0.2 U	0.8U	1U	2U	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 U	0.2 U
Barium	27	17J	33	18J	29	22.6	16.7	22.2	14	22	22J	9.6	10.4	19.3	14.6	16.2	16.8	13.1	19	18.6	16.7	10.1	12.8	10.1	18.3	21.7	18.5
Beryllium	0.4U	1U	0.8U	1U	0.8U	0.2 U	0.2 U	0.2 U	0.8	1U	1U	0.3	0.2 U	0.5	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
Cadmium	0.6	4.4	3.1	1.4	4.1	1	0.6 U	0.5	1.2	2.5	2.4	0.5	1.0	3.0	0.3	0.4	0.4	0.4	0.4	0.4	0.4	0.2	0.3	0.2	0.9	1.1	0.8
Calcium	33,400	192,000	96,200	44,200	86,600	190,000	81,300	135,000	51400	123,000	127,000	17,300	41,400	112,000	5550	7290	6,530	8780	8690	8,960	9120	6620	8,910	6540	23200	32700	28,200
Chromium	5U	5U	5U	5U	5U	0.5 U	0.5 U	0.5 U	5U	5U	5U	1 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U
Copper	13	6	25	39	23	16.4	13	11.1	43	110	110	35.3	25.9	69.1	0.8	0.6	0.5 U	1	0.6	0.6	0.8	0.6	0.5 U	0.6	3	2.7	3.9
Iron	20	47,000	20U	20U	20U	50 U	50 U	50 U	30	72,300	76,800	50	50 U	120,000	50 U	50 U	50 U	50 U	50 U	50 U	50 U	50 U	50 U	50 U	50 U	50 U	50 U
Lead	2U	1U	4U	5U	4U	1 U	1 U	1 U	4U	4U	1U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U
Magnesium	3,590J	37,400	11,000J	4,960	9,590J	22,600	8,980	14,900	6,950J	37,100	39,700	4,060	5,810	42,100	840	1200	1,030	1490	1550	1,460	1330	940	1,250	930	3830	5400	4,950
Manganese	62	1,400	524	116	376	76.3	82.3	90	338	1,860	1,950	201	241	2,440	5.8	4.5	6.2	73.1	9.7	32.4	4.6	3.5	2.8	3.5	235	284	245
Mercury									0.1U																		
Molybdenum						0.2 U	0.2 U	0.2 U	0.8U	5U	5U	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 U	0.2 U
Nickel	10U	20	10	10U	10	9.6	6.2 J	6.9	10U	20	20	7.1	11 J	21.7	0.8	0.9 J	0.8	2.1	1.1 J	1.5	1.4	1 J	1.1	1 J	5.8	6.9 J	7.3
Potassium	7,410	22,200	10,300	7,970	9,380	11,600	9,440	10,700	9510	13,600	14200	4,670	8,130	12,600	710	750	820	1060	890	1,250	980	750	810	740	2980	3100	4,060
Selenium									4U																		
Silver	0.4U	0.2UJ	0.8U	0.2UJ	0.8U	0.5 U	0.5 U	0.5 U	0.8U	0.2UJ	0.2UJ	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U
Sodium	2,000	7,990	3,910	2,180	3,820	6,000	3,730	4,400 J	2,770	6,760	7,010	1,500	2,470	6,890 J	850	1170	1,350 J	1,630	1,300	1,300	940	970	1,140	950	2160	2290	2,360
Thallium									0.8U	2U	8U																
Uranium									0.8	1.9	20U																
Zinc	68J	534	222J	79	194J	97	90	78	174J	355	375	75	141	438	35	52	44	50	53	51	60	43	47	43	116	139	105
Total Petroleum Hydrocarbon, (mg/L)																											
Diesel Range Hydrocarbons									0.25U	0.25U	0.25U																
Gasoline Range Hydrocarbons									0.25U	0.25U	0.25U																
Motor Oil									0.5U	0.5U	0.5U																
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																		
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)	160	1,100J	490J	210J	420J	1,000	370	610	310	1,100J	1,100J	220	260	1,300	34	48	46	64	52	55	66	42	45	36	150	180	160
Total Suspended Solids (mg/L)	78	260	15	6.9	7.4	1.1 U	1.1 U	1.0 U	7.9	11	16	1.1 U	1.1 U	1.0 U	1.1 U	1.1 U	14	28	1.1 U	1.1 U	1.1 U	1.1 U	1.0 U	1.1 U	2.4	1.1 U	1.1
Chloride (mg/L)						1.0 U	1.0 U	1.0 U	1.0U	1.0U	1.0U	1.0 U	1.0 U	24	1.0 U	1.0 U	9.7	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.1	3.1	1.0 U	1.0 U	8.5 J
Fluoride (mg/L)						0.10 J	0.2	0.10				0.50 J	0.3	0.70	0.10 UJ	0.10 U	0.10 U	0.10 UJ	0.10 U	0.10 U	0.10 UJ	0.10 U	0.10 U	0.10 U	0.10 J	0.1	0.10 U
NO_2 & NO_3 (mg-N/L)						0.010 U	0.12	0.071	0.29	0.053	0.057	0.26	0.3	0.014	0.14	0.074	0.034	0.097	0.063	0.045	0.19	0.12	0.060	0.12	0.10	0.11	0.086
Sulfate (mg/L)	100	660	330	120	260	680	240	420	200	640	650	110	150	840	18	19	23	38	25	33	26	16	22	15	89	110	94
Acidity (mg/L $CaCO_3$)																											
Alkalinity (mg/L $CaCO_3$)	1.7	1.0U	9.6	1.3	7.9	27	8.6	14	1.0U	1.0U	1.0U	1.0 U	1.0 U	1.0 U	5.0	5.2	2.1	3.1	4.4	1.0 U	9.0	6.5	4.9	6.1	1.2	1.0 U	1.3
Carbonate (mg/L $CaCO_3$)						1.0 U	1.0 U	1.0 U				1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U
Bicarbonate (mg/L $CaCO_3$)						27	8.6	14				1.0 U	1.0 U	1.0 U	5.0	5.2	2.1	3.1	4.4	1.0 U	9.0	6.5	4.9	6.1	1.2	1.0 U	1.3
Amenable Cyanide (mg/L)									0.004U	0.004U	0.004U																
Color (Pt-CO)									5U																		
Hardness, Dissolved (mg/L)	98	630	290	130	260	570	240	400	160	460	480	60	130	450	17	23	20	28	28	28	28	20	27	20	74	100	91
pH (Laboratory Analyzed)							5.67 J	5.56 J					4.35 J	3.84 J		5.91 J	5.52 J		5.72 J	5.31 J		6.12 J	5.91 J	6.14 J		4.94 J	4.75 J
Total Phosphorous (mg/L)									0.035																		
Field Measurements:																											
pH	4.99	5.43	5.44	5.24		5.3	5.58	5.9	4.01	4.07		3.65	4.37	4.3	4.95	5.75	5.6	4.69	5.6	5.3	5.03	5.91	5.5		4.19	4.98	5.0
Specific Conductivity (uS/cm)	2870	1210	655	529		1210	535	645	516	1050		284	347	1,460	46	65	46	86	77	65	72	54	56		186	261	186
Temperature (°C)	5.7	6.7	8.8	6.1		5.1	8	5.3	6.3	6.8		7.5	8	6.6	8.2	6.9	9.0	8.1	8.1	8.5	7.8	7.1	8.0		7.4	6.4	7.4
Redox (mV)	184		169			-	339	271	165			-	456	238	-	411	349	-	441	363	-	437	332		-	452	392
Iron (ferrous iron, ug/L)	Negative		Negative			-			Positive			-			-			-			-				-		
Turbidity (NTU)	88		9			****	0.18	****				****	0.55	****	****	0.31	****	0	0.58	****	****	0.1	****		****	0.62	****
Dissolved Oxygen (mg/L)						12.63	2.54	1.58				11.38	9.08	1.54	11.21	9.45	11.52	10.49	9.72	11.28	10.88	9.7	10.78		11.7	8.22	6.42

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.

* 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.

*** Suspected interference from zinc or copper in field test resulting in biased high ferrous iron result.

**** Instrument Malfunction

Grey shading — Analysis not performed.

Table 2-6
Summary of Groundwater Quality Data (1997 - 2003)
Holden Mine RI/FS

Parameters	East of Tailings Pile 3 (TP-3)															Lucerne (US Forest Service Guard Station)	
Sample ID	DS-4DX	DS-5			SP-5		SP-17		SP-18		SP-21					LUCERNE	
Sampling Date	10/24/02	11/19/01	6/12/02	10/24/02	5/20/97	7/12/97	5/20/97	7/12/97	5/19/97	7/12/97	5/22/97	7/12/97	9/15/97	10/5/97	6/15/97	10/3/97
Dissolved Metals, (ug/L)																	
Aluminum	1,120	180	50 U	50 U	25,600	10,400	40	70	34,100	38,300	1,500	1,300	1,800	2,410	20U	20U
Arsenic	0.2 U	0.2 U	0.2 U	0.2 U												
Barium	19.2	12.5	3.9	9.2	18.6	22	18.7	23	33.1	21	14.0	22	21	26	30	11
Beryllium	0.2 U	0.2 U	0.2 U	0.2 U	0.4	1U	0.04U	1U	0.84	1	0.06	1U	1U	1U	0.2U	1U
Cadmium	0.8	0.2 U	0.2 U	0.2 U	8.2	1.8	0.38	0.6	12.3	25	1.06	0.7	1.1	0.8	0.2U	0.2U
Calcium	28,700	5220	4060	8,960	103,000	49,000	5,290	4,570	103,000	77,000	22,800	18,000	44,800	42,100	14,200	14,500
Chromium	0.5 U	0.5 U	0.5 U	0.5 U	2	5U	0.2U	5U	0.6	5U	0.2U	5U	5U	5U	5U	5U
Copper	4.1	0.7	0.8	0.5 U	1,100	402	11.0	8	950	1,220	51.8	34	34	34	2U	2U
Iron	50 U	70	50 U	50 U	19,500	8,670	60	70	23,900	33,700	1,000	690	1,530	2,370	310	200
Lead	1 U	1 U	1 U	1 U	2J	2	0.2U	1U	1U	2U	0.5J	1U	1U	1U	1U	1U
Magnesium	5,060	700	580	1,170	23,800	10,700	690	670	17,300	14,200	3,820	2,870	7,630	7,810	2,140	2,010
Manganese	251	6.6	0.5 U	2.0	1,100	453	8.94	8	1,810	1,290	174	108	304	348	8	5
Mercury											0.1U					
Molybdenum	0.2 U	0.8	0.6	0.5												
Nickel	7.2	0.5 U	0.5 UJ	0.5	14	10U	0.7	10U	26.1	40	4.3	10U	10U	10	10U	10U
Potassium	4,050	530	500 U	640	10,000	8,560	740	1,100	4,140	4,210	2290	2,660	5,030	3,960	1,470	1,340
Selenium																
Silver	0.5 U	0.5 U	0.5 U	0.5 U	0.2U	0.2U	0.04U	0.2U	0.04U	0.2U	0.2U	0.2U	0.2U	0.2U	0.2U	0.2U
Sodium	2,510	2280	890	1,470	6,780	3,480	960	850	4,670	3,640	1750	1,470	2,550	2,390	3,480	3,420
Thallium																
Uranium																
Zinc	106	7	6 U	21	654	232	45	77	1,080	2,230	109	109	133	132	147	124
Total Petroleum Hydrocarbon, (mg/L)																
Diesel Range Hydrocarbons																
Gasoline 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)	180	34	28	47	840	370	32	28	470	810	130	110	290J	220J	68	91J
Total Suspended Solids (mg/L)	1.1 U	64	1.1 U	2.3	6	1.1U	1.0U	1.1U	1.2	11	2.9	1.2	1.4J	2	1.0U	1.4
Chloride (mg/L)	3.8 J	1.0	1.0 U	1.0 U												
Fluoride (mg/L)	0.10 U	0.10 UJ	0.10 U	0.10 U												
NO_2 & NO_3 (mg-N/L)	0.084	0.16	0.010	0.058												
Sulfate (mg/L)	90	11	2.6	21	530	230	5.2	11	560	380	84	61	140	140	6.5	2.9
Acidity (mg/L $CaCO_3$)																
Alkalinity (mg/L $CaCO_3$)	1.0 U	12	12	10	1.0U	1.0U	9.1	4.5	1.0U	1.0U	2.4	1.0U	1.0U	1.0U	51	52
Carbonate (mg/L $CaCO_3$)	1.0 U	1.0 U	1.0 U	1.0 U												
Bicarbonate (mg/L $CaCO_3$)	1.0 U	12	12	10												
Amenable Cyanide (mg/L)																
Color (Pt-CO)																
Hardness, Dissolved (mg/L)	92	16	12	27	360	170	16	14	330	250	73	57	140	140	44	44
pH (Laboratory Analyzed)	4.80 J		6.71 J	6.30 J												
Total Phosphorous (mg/L)																
Field Measurements:																
pH	-	5.44	6.63	5.7	3.37	3.78	6.38	7.4	3.34	3.6	5.42	4.98	4.6	4.92	5.49	5.25
Specific Conductivity (uS/cm)	-	42	29	58	1160	608	43	47	1080	1040	285	220	448	374	140	105
Temperature (^oC)	-	3.6	6.8	6.2	5	8.6	4.6	8.9	10.8	6.9	7.2	8.5	8.5	7.2	9	9.1
Redox (mV)	-	-	374	215	372	265	127	90	460	303	228	114				
Iron (ferrous iron, ug/L)					Positive	Positive	Positive	Postive	Positive	Positive	Positive	Positive			Positive	
Turbidity (NTU)	-	0	0.14	****											5	
Dissolved Oxygen (mg/L)	-	13.63	11.29	10.98												

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.
* 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.
*** Suspected interference from zinc or copper in field test resulting in biased high ferrous iron result.
**** Instrument Malfunction
Grey shading Analysis not performed.

Table 2-6
Summary of Groundwater Quality Data (1997 - 2003)
Holden Mine RI/FS

Parameters	Location	Lysimeters															
	Sample ID	TP1-2L		TP1-3L		TP1-4L		TP1-6L		TP1-7L	TP2-12L	TP3-4L		TP3-6L**	TP3-6BL**	TP3-10L	
	Sampling Date	6/3/97	9/20/97*	6/3/97	9/19/97	6/3/97	9/19/97	6/3/97	9/19/97	6/13/02	6/13/02	6/3/97	9/19/97	6/3/97	9/19/97	6/3/97	9/19/97
Dissolved Metals, (ug/L)																	
Aluminum		7,230	5,980	130U	100U	3,580	1,530	930	610	45300	11800	120	330	20U	20U	140	310
Arsenic										20 U	0.5 U						
Barium		14	8	15	5J	20	4J	20	5	50 U	13.2	35	7	17	6J	21	9
Beryllium		4U	5U	4U	5U	20U	1U	0.8	5	20 U	0.4	0.8U	1U	20U	1U	20U	1U
Cadmium		0.8U	10U	0.8U	0.2U	20U	0.2U	0.8	0.2	2620	4.2	0.8U	2U	20U	0.2U	20U	2U
Calcium		394,000	420,000	414,000	438,000	446,000	392,000	79,200	158,000	96200	19100	61,800	54,900	485,000	419,000	474,000	462,000
Chromium		20U	20U	20U	20U	5U	5U	10	20	50 U	1 U	5U	5U	5U	5U	5U	5U
Copper		10U	10U	10U	10U	2U	2U	4	10	239000	1180	2U	2	2U	2U	2U	2U
Iron		1,680,000	1,440,000	1,480,000	1,400,000	350,000	275,000	593,000	1,070,000	1130	70	165,000	249,000	181,000	105,000	196,000	184,000
Lead		4U	100U	4U	4U	100U	2U	4	2	100 U	2	4U	1U	100U	4U	100U	5U
Magnesium		173,000	80,200	68,200	62,700	29,200J	27,100	42,700	103,000	12700	3510	32,700J	38,700	50,400J	57,400	24,200J	22,000
Manganese		10,800	8,540	4,530	4,460	4,250	2,490	3,740	6,210	1240	189	1,580	1,790	2,430	1,680	2,320	2,190
Mercury																	
Molybdenum										20 U	1.1						
Nickel		50U	50U	50U	50U	10U	10U	20	50	760 J	5.8 J	10U	10U	10U	10U	10U	10U
Potassium		69,200	55,000	39,900	51,200	18,400	13,800	27,300	33,800	13900	7700	26,500	26,700	50,600	47,400	38,200	38,400
Selenium																	
Silver		4U	20U	4U	0.2UJ	20U	0.2UJ	0.8	0.2	50 U	0.5 U	0.8U	3U	20U	0.2J	30	3U
Sodium		52,500	46,700	103,000	24,800	13,700	13,000	11,400	10,700	17400	58600	10,400	10,500	36,400	87,500	34,300	112,000
Thallium																	
Uranium																	
Zinc		690	580	260	120	280J	88	32	40	224000	932	49J	36U	22J	52	32J	27U
Total Petroleum Hydrocarbon, (mg/L)																	
Diesel Range Hydrocarbons																	
Gasoline 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)																	
Total Suspended Solids (mg/L)																	
Chloride (mg/L)																	
Fluoride (mg/L)																	
NO_2 & NO_3 (mg-N/L)																	
Sulfate (mg/L)		4,500		3,800	3,800	2,000	2,000	1,200		1300	270	600		1,800	1,900	1,800	
Acidity (mg/L $CaCO_3$)										1,400 J	110 J						
Alkalinity (mg/L $CaCO_3$)		1.0U		1.0U	1.0U	1.0U	1.0U	1.0		1.0 U	1.0 U	9.4		12	44	2.3	
Carbonate (mg/L $CaCO_3$)										1.0 U	1.0 U						
Bicarbonate (mg/L $CaCO_3$)										1.0 U	1.0 U						
Amenable Cyanide (mg/L)																	
Color (Pt-CO)																	
Hardness, Dissolved (mg/L)		1,700		1,300	1400	1,200	1,100	370	820			290		1,400	1,300	1,300	
pH (Laboratory Analyzed)										3.45 J	3.44 J						
Total Phosphorous (mg/L)																	
Field Measurements:																	
pH		6.28	5.75	5.43	6	4.2	4.81	5.06	4.3	3.21	3.49	6.16	5.72	6.23	6.77	6.69	6.36
Specific Conductivity (uS/cm)		5630	4840	4760	4520	2790	3570	1850	3180	1110	738	1027	1350	2790	2940	2640	2710
Temperature (^oC)		10.7	10.2	7.3	9.8	10.7	9.1	10	8.7	173	19.7	9.7	12	9.1	9.8	10.7	8.8
Redox (mV)		80		195		128		116		476	435	215		183		117	
Iron (ferrous iron, ug/L)		Positive		Positive		Positive		Positive		1,430***	90	Positive		Positive		Positive	
Turbidity (NTU)		8		81		1		0		0.29	0.55	145		0		21	
Dissolved Oxygen (mg/L)		13.6		13.42		13.74		14.3		4.85	****	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.
* 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.
*** Suspected interference from zinc or copper in field test resulting in biased high ferrous iron result.
**** Instrument Malfunction
Grey shading Analysis not performed.

Table 2-7
Summary of Soil Chemistry Data (1997 - 2003)
Holden Mine RI/FS

Parameters	Sampling Location		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
	Area Background[a]	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	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	310		93.1	72.5	102	380	156	333	136	104	104	116	101
Beryllium	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	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	37.2 (total)		20.8	27.8	39.4	23.8	48.3	28.7	29.1	26.3	26.5	24.0	29.4
Copper	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	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	1,430		365	455	435	315	542	613	637	427	419	317	537
Mercury	0.05[b]												
Molybdenum	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	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	NE												
Silver	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	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	1		2U	4	2U	2U	3U	3U	2U	2U	2U	2U	2U
Zinc	253		303	121	132	284	112	356	137	201	161	145	129
Polychlorinated Biphenyls (ug/kg)													
Aroclor 1016	NA												
Aroclor 1221	NA												
Aroclor 1232	NA												
Aroclor 1242	NA												
Aroclor 1248	NA												
Aroclor 1254	NA												
Aroclor 1260	NA												
Total PCBs	NA												
Total Petroleum Hydrocarbons (mg/kg)													
Gasoline	NA												
Diesel	NA												
Motor Oil	NA												
Conventional Analyses													
Total Solids (%)	NA												
Total Organic Carbon (%)	NA												
pH (Laboratory Analyzed)	NA												

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 Aroclor 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 analyte concentration was not determined. Note all results are reported on a dry weight basis. Total solids were not tabulated separately prior to 2003.

a - Area Background values based on Statistical Analysis per MTCA using data collected from Railroad Creek drainage in 1998. Discussed in DRI (Dames and Moore, 1999) Section 5.2.

b - 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 2-7
Summary of Soil Chemistry Data (1997 - 2003)
Holden Mine RI/FS

Parameters		Sampling Location	Maintenance Yard							
		Station No.	DMSS-8	DMSS-8 2'	DMSS-9	DMSS-9 2'	DMSS-10	DMSS-10X*	DMSS-10 2'	Storage
	Area Background[a]	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	11.6		2.7	1.7	4.3	2.6	3.0	2.8	4.1	60
Barium	310		321	34.1	717	58.2	161	133	163	192
Beryllium	0.2		0.1	0.2	0.2U	0.1	0.1	0.1	0.2	0.2
Cadmium	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	37.2 (total)		22.5	19.1	33	16.6	21.6	22	23.4	18.5
Copper	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	20.6		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	1,430		334	150	426	223	203	186	267	230
Mercury	0.05[b]									
Molybdenum	1.2		7.3	0.6U	16	0.6U	2.4	2.1	0.6U	4.4
Nickel	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	NE									
Silver	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	0.4		2U	2U	2U	0.6U	2U	2U	2U	2U
Uranium	1		2U	2U	2U	2U	2U	2U	2U	2U
Zinc	253		1,860	576	3,240	147	550	584	170	1,440
Polychlorinated Biphenyls (ug/kg)										
Aroclor 1016	NA		36U	36U	39U	37U	38U	38U	41U	39U
Aroclor 1221	NA		72U	72U	77U	73U	77U	75U	82U	78U
Aroclor 1232	NA		36U	36U	39U	37U	38U	38U	41U	39U
Aroclor 1242	NA		36U	36U	39U	37U	38U	38U	41U	39U
Aroclor 1248	NA		36U	36U	39U	37U	38U	38U	41U	39U
Aroclor 1254	NA		36U	36U	39U	37U	38U	38U	41U	39U
Aroclor 1260	NA		36U	36U	17JX	37U	46X	36JX	41U	18JX
Total PCBs	NA		ND	ND	17	ND	46	36	ND	18
Total Petroleum Hydrocarbons (mg/kg)										
Gasoline	NA		5.9U	140X	29X	5.9U	1,200X	1,700	200X	
Diesel	NA		520X	9,300J	3,100XJ	5.5U	12,000J	8,400J	480	390X
Motor Oil	NA		870X	1,100U	3,400XJ	11U	9,800J	8,900J	950	1,000X
Conventional Analyses										
Total Solids (%)	NA									
Total Organic Carbon (%)	NA									
pH (Laboratory Analyzed)	NA									

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 Aroclor 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 analyte concentration was not determined. Note all results are reported on a dry weight basis. Total solids were not tabulated separately prior to 2003.

a - Area Background values based on Statistical Analysis per MTCA using data collected from Railroad Creek drainage in 1998. Discussed in DRI (Dames and Moore, 1999) Section 5.2.

b - 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 2-7
Summary of Soil Chemistry Data (1997 - 2003)
Holden Mine RI/FS

Parameters		Sampling Location	Lagoon Area									
					Pre-Construction Samples		Post-Construction Samples					
		Station No.	Lagoon 6"	Lagoon 2'	L-1-6"	L-1-2'	L4-0 to 6"	L4- 1 1/2 to 2'	DMLG-1-2'	DMLG-1-4'	DMLG-2-4'	DMLG-2-7 1/2'
	Area Background[a]	Sampling Date	10/3/97	10/3/97	6/8/00	6/8/00	4/17/01	4/17/01	10/15/98	10/15/98	10/14/98	10/15/98
Total Metals (mg/kg)												
Aluminum	20,900		33,500	31,300	51,500	31,600	38,900	36,000				
Arsenic	11.6		3.7	5.0	3	4.6	2	3.6				
Barium	310		343	287								
Beryllium	0.2		0.3	1U								
Cadmium	5.4		1.9	184	2.9	10.8	2	3.1	2.5	4.3	175	28
Calcium	12,100		5,150	6,120								
Chromium	37.2 (total)		20.6	21								
Copper	57.4		1,190	24,100	1,730	4,630	1,290	1,040	1,390	1,120	22,500	3,610
Iron	24,100		36,200	101,000	54,200	109,000	50,000	29,300				
Lead	20.6		129	620	309	694	233	135	132	73	560	110
Magnesium	9,200		6,760	18,100								
Manganese	1,430		255	625	270	562	324	206				
Mercury	0.05[b]											
Molybdenum	1.2		6.6	74								
Nickel	22.7		13	10U								
Potassium	1,260		1,840	4,370								
Selenium	NE											
Silver	0.5		2.0	27	3.6	21	9.1	2.2				
Sodium	827		931	900								
Thallium	0.4		3U	3								
Uranium	1		7	6								
Zinc	253		387	23,700	566	1,540	528J	526J				
Polychlorinated Biphenyls (ug/kg)												
Aroclor 1016	NA		51U	46U								
Aroclor 1221	NA		100U	92U								
Aroclor 1232	NA		51U	46U								
Aroclor 1242	NA		51U	46U								
Aroclor 1248	NA		51U	46U								
Aroclor 1254	NA		51U	46U								
Aroclor 1260	NA		51U	46U								
Total PCBs	NA											
Total Petroleum Hydrocarbons (mg/kg)												
Gasoline	NA		11.0U	9.0U								
Diesel	NA		98X	230X					2,200 X	140 JY	520 Y	150 JY
Motor Oil	NA		310	440					1,900 X	170 J	960	170 J
Conventional Analyses												
Total Solids (%)	NA											
Total Organic Carbon (%)	NA											
pH (Laboratory Analyzed)	NA											

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 Aroclor 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 analyte concentration was not determined. Note all results are reported on a dry weight basis. Total solids were not tabulated separately prior to 2003.
a - Area Background values based on Statistical Analysis per MTCA using data collected from Railroad Creek drainage in 1998. Discussed in DRI (Dames and Moore, 1999) Section 5.2.
b - 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 2-7
Summary of Soil Chemistry Data (1997 - 2003)
Holden Mine RI/FS

Parameters		Sampling Location	Lagoon Area										Abandoned Retention Pond		West Area Soils		
			Pre-Construction Samples		Post-Construction Samples										2003-MW2: 0 to 16"	2003-MW3: 0 to 24"	2003-MW4X: 0 to 28"
		Station No.	L-2-6"	L-2-2'	L3-0 to 6"	L3- 1 1/2 to 2'	DMLG-3-2'	DMLG-3-4'	DMLG-4-2'	DMLG-4-4'	DMLG-5-2'	DMLG-5-4'	RT-1 Oxidized	RT-2 Unoxidized	2003-MW2	2003-MW3	2003-MW4
	Area Background[a]	Sampling Date	6/8/00	6/8/00	4/17/01	4/17/01	10/15/98	10/15/98	10/14/98	10/14/98	10/14/98	10/15/98	9/27/01	9/27/01	10/9/03	10/10/03	10/10/03
Total Metals (mg/kg)																	
Aluminum	20,900		37,900	20,000	29,100	23,500							24,300	37,600	16,100	16,500	15,500
Arsenic	11.6		3.5	3.1	2.5	1.9							3.5	2.6	22	18	20
Barium	310												856 J	186 J	70.9	63.6	55.2
Beryllium	0.2												0.4 U	0.4			
Cadmium	5.4		2.6	48.1	1.1	27.7	2.3	0.7	150	135	173	25	0.8 U	23.0	0.6	3.9	0.4
Calcium	12,100												2,470	8,270	5,180	3,790	4,220
Chromium	37.2 (total)												27	27	24.2	24.1	25.9
Copper	57.4		1,760	10,200	607	13,500	1,020	294	17,300	22,100	23,900	4,000	1,180	1,950	49.3	255	14
Iron	24,100		45,100	78,600	27,900	75,900							94,100 J	52,600 J	22,000	23,300	22,300
Lead	20.6		224	199	79	482	153	52	730	800	580	190	148	153	13	12	11
Magnesium	9,200												18,300	19,700	8,150	8,740	8,680
Manganese	1,430		299	467	240	459							581	689	401	397	396
Mercury	0.05[b]																
Molybdenum	1.2												22	21			
Nickel	22.7												5	20	14	14	14
Potassium	1,260														1,080	1,030	910
Selenium	NE																
Silver	0.5		3.0	10.8	0.7	19							10	4	0.3 U	0.3 U	0.3 U
Sodium	827														520	420	460
Thallium	0.4																
Uranium	1																
Zinc	253		559	6,420	244J	3,780J							217 J	6,350 J	109	346	79.6
Polychlorinated Biphenyls (ug/kg)																	
Aroclor 1016	NA																
Aroclor 1221	NA																
Aroclor 1232	NA																
Aroclor 1242	NA																
Aroclor 1248	NA																
Aroclor 1254	NA																
Aroclor 1260	NA																
Total PCBs	NA																
Total Petroleum Hydrocarbons (mg/kg)																	
Gasoline	NA																
Diesel	NA						520 JY	86 JY	540 Y	1,200 Y	280 Y	170 JY					
Motor Oil	NA						800 J	120 J	850	1,700	500	330 J					
Conventional Analyses																	
Total Solids (%)	NA														94.0	92.9	96.8
Total Organic Carbon (%)	NA														3.3	2.1	1.4
pH (Laboratory Analyzed)	NA														6.02 J	5.58 J	5.76 J

Notes:

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NE - Not Established

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X - Pattern profile does not match typical standard profile. In the case of PCBs, pattern was more indicative of Aroclor 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 analyte concentration was not determined. Note all results are reported on a dry weight basis. Total solids were not tabulated separately prior to 2003.

a - Area Background values based on Statistical Analysis per MTCA using data collected from Railroad Creek drainage in 1998. Discussed in DRI (Dames and Moore, 1999) Section 5.2.

b - 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 2-8
1997 Trout Population Estimate Results,
Railroad Creek and Reference Locations
Holden Mine RI/FS

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 Tenmiile Creek (87 meters; 0.10 hectare)	20	2	20	2
RC-10; Railroad Creek near Sevenmile 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

Source: DRI Table 4.6-3

Table 2-9
1997 Benthic Macroinvertebrate Evaluation Results
Railroad Creek and Reference Locations
Holden Mine RI/FS

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 Tenmiile Creek	9	0	0.40	54	5	0.54	52
RC-10; Railroad Creek near Sevenmile 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

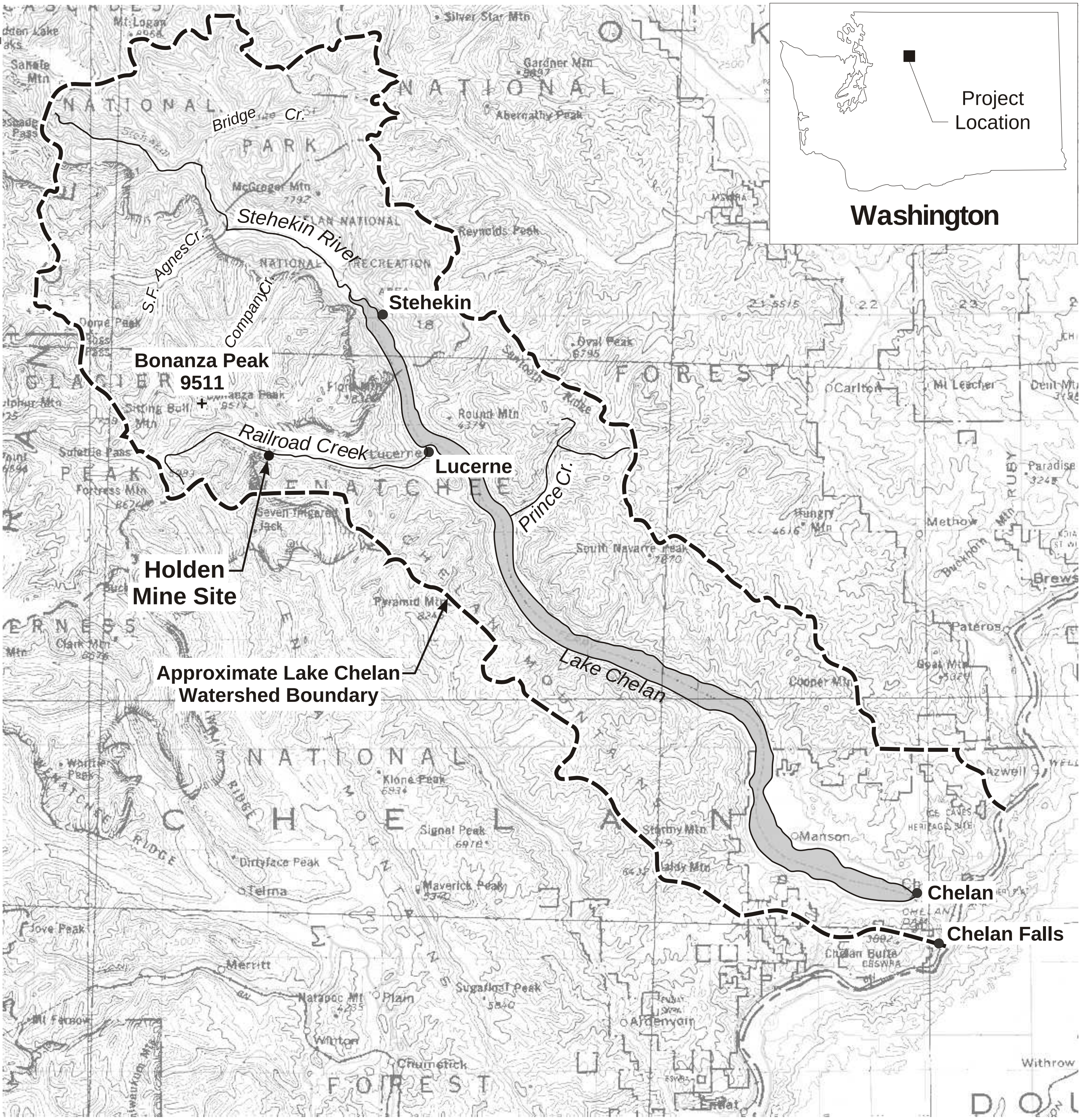
Macroinvertebrate community analysis results are presented as means for all replicates at a given location.

Source: DRI Table 4.6-2A

Table 2-10
Treatability Study Analytical Results - 1500-level Main Portal Drainage
Holden Mine RI/FS

Sample Identification	Initial pH	Hydrated Lime Dose (mL)	Final pH	Total Metals (ug/L) Aluminum	(% Reduction)	Cadmium	(% Reduction)	Copper	(% Reduction)	Iron	(% Reduction)	Zinc	(% Reduction)	Hardness (mg $CaCO_3$/L)	Alkalinity (mg/L $CaCO_3$)	Sulfate (mg/L)
Test 1- Addition of 1% Hydrated Lime ($Ca(OH)_2$)Soln.																
Sample 1	4.94	3	7.03	20 U	> 99%	25.9	22%	6.6	> 99%	20 U	> 99%	3,990	40%	240	33 J	240
Sample 2	4.9	4	8.16	20 U	> 99%	16	52%	1.5	> 99%	20 U	> 99%	574	91%	240	36 J	250
Sample 3	4.92	4.5	9.18	20 U	> 99%	1.1	97%	1.4	> 99%	20 U	> 99%	8	> 99%	250	40 J	260
Sample 4	4.92	5.5	10.02	130	97%	1.2	96%	15.6	99%	20 U	> 99%	207	97%	NA	24 J	260
Blank	4.94	0	4.94	3,980	----	33	----	1,970	----	210	----	6,650	----	200	2.1 J	250
Test 2- Caustic Solution*																
Sample 1	5.04	3.3	7.06	40	99%	24.5	23%	35	98%	20 U	> 99%	2,380	66%	190	51 J	260
Sample 2	4.97	4.2	8.06	20 U	> 99%	7.1	78%	3.5	> 99%	70	67%	80	99%	190	29 J	270
Sample 3	5	4.5	9.1	20 U	> 99%	0.2 U	> 99%	2.7	> 99%	20 U	> 99%	16	> 99%	200	35 J	270
Sample 4	4.98	5.5	10.0	30	99%	0.2 U	> 99%	1.7	> 99%	20 U	> 99%	10	> 99%	190	52 J	280
Blank				3,520	----	32	----	1,830	----	200	----	7,090	----	190	3.8 J	270
Test 3- Railroad Creek Water Addn																
Sample 1 (750 ml Sample : 250 ml RRC)	4.88	0	5.06	2,370	43%	24	27%	1,370	28%	150	32%	5,090	27%	160	7.8 J	200
Sample 2 (500 ml Sample : 500 ml RRC)	4.86	0	5.2	740	82%	16	52%	882	53%	80	64%	3,440	51%	110	30 J	140
Sample 1 (1000 ml Sample)	4.85	0	4.94	4,190	----	33	----	1,890	----	220	----	6,960	----	200	23 J	260
Test 4- Neutralize w/Hydrated Lime and Addn of Ferric Chloride																
Sample 1 (50 mg/L $FeCl_3$)	4.92	4.3	4.84	20 U	> 99%	32.2	2%	498	74%	100	52%	6,360	13%	260	58 J	250
Sample 2 (100 mg/L $FeCl_3$)	4.9	4.5	4.02	1,500	63%	33	0%	1,700	12%	400	----	7,130	2%	250	5.2 J	240
Sample 3 (1000 mg/L $FeCl_3$)	4.87	4.3	2.97	6,760	----	31	6%	1,860	4%	85,200	----	6,790	7%	240	1.0 U	110
Blank	4.87	0	4.87	4,010	----	33	----	1,940	----	210	----	7,280	----	210	81 J	260
Test 5- Neutralize w/Hydrated Lime and Addn of Polymer																
Sample 1 (0.5 mL polymer)	4.83	4	8.1	20 U	> 99%	13.2	64%	2.8	> 99%	20 U	> 99%	181	98%	230	46 J	250
Sample 2 (1 mL polymer)	4.97	4	8.1	100	98%	9.3	75%	43.8	98%	30	88%	571	93%	240	55 J	280
Sample 3 (0.25 mL polymer)	5.02	4	8.03	100	98%	13.7	63%	53.3	97%	20 U	> 99%	875	89%	250	15 J	270
Blank	4.81	0	4.82	4,340	----	37	----	1,980	----	260	----	7,630	----	200	2.8 J	270

Data Notes:
J - Estimated Value
U - Analyte is not detected above the reporting limit shown.
Shaded results indicate that duplicates run for this analysis showed a large variability. These values should not be used for final consideration for engineering analysis.
* A 1% sodium hydroxide solution added to sample instead of hydrated lime.



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

N

0 8 16

Scale in Miles

Figure 2-1

Site Location and Lake Chelan Watershed Map

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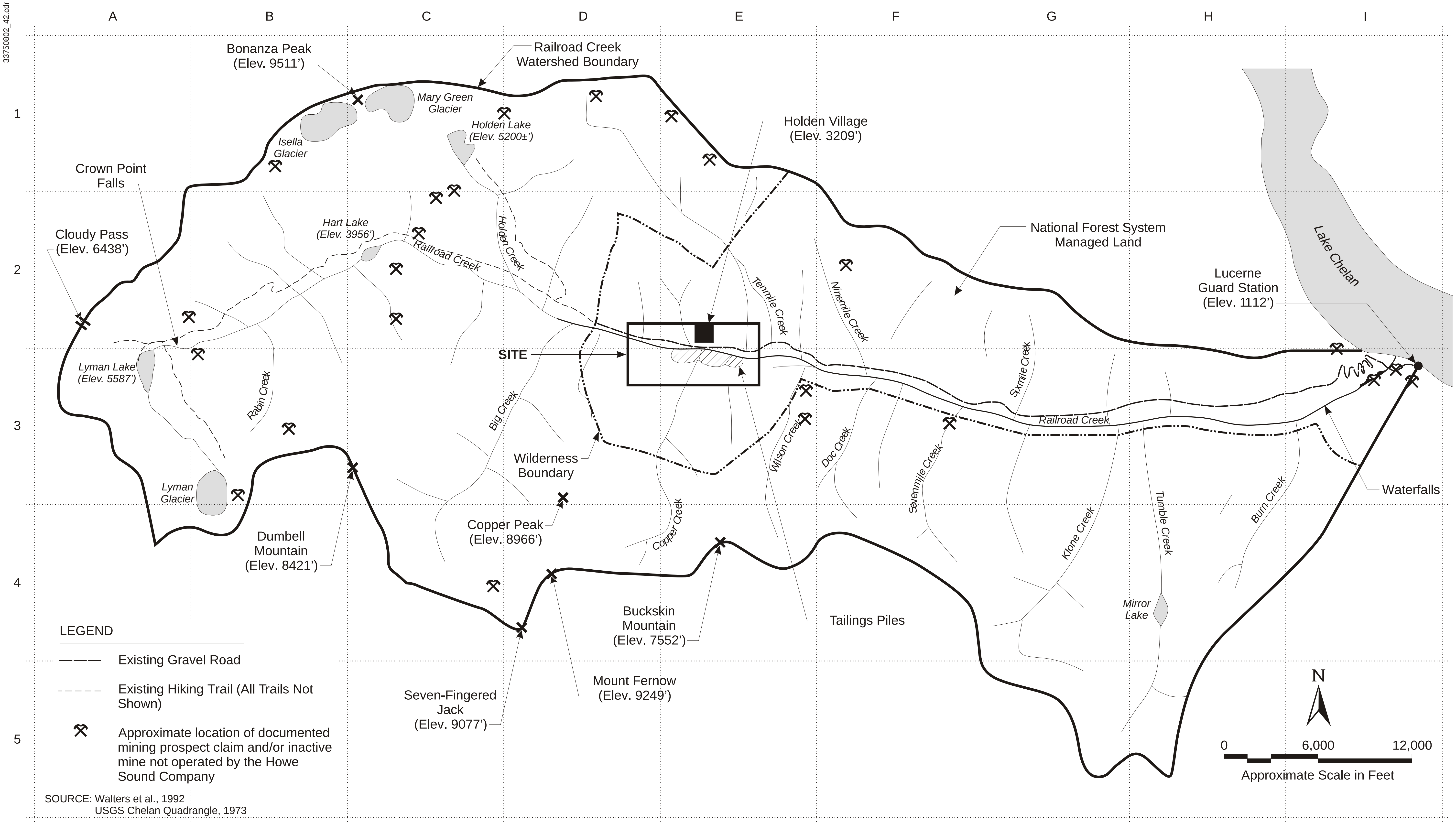

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Job No. 33750803

Figure 2-2
Railroad Creek Watershed Map

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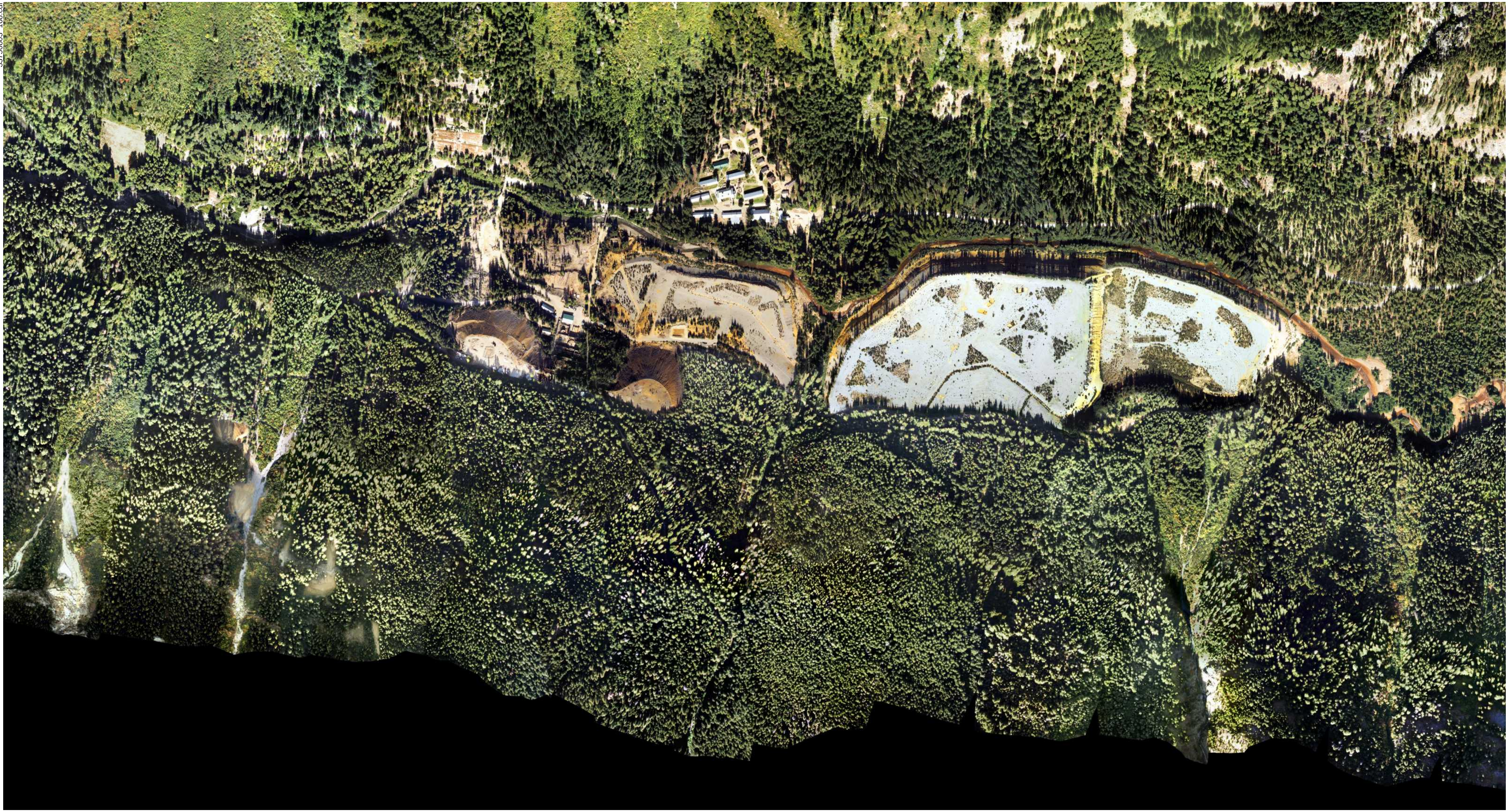
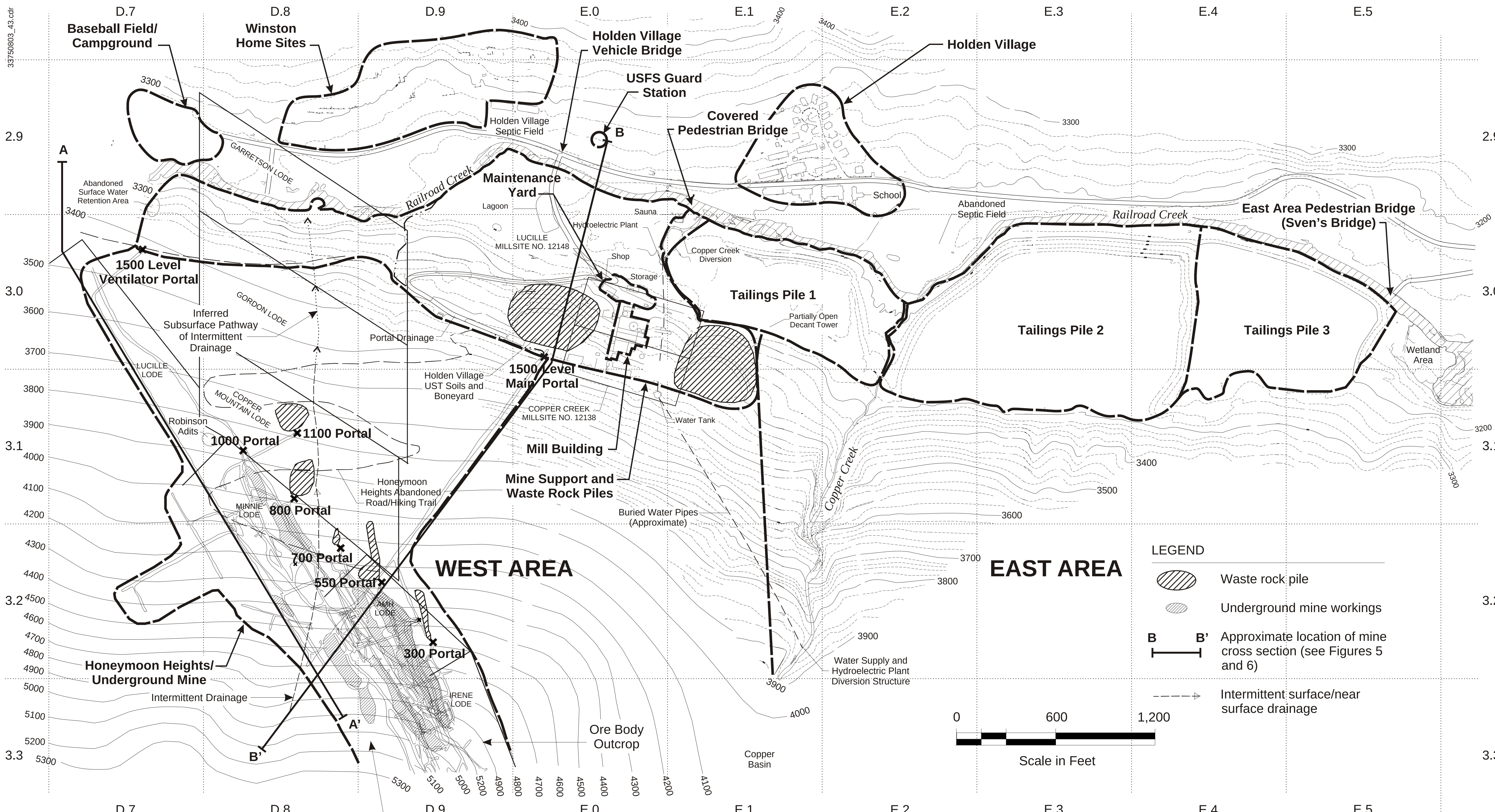


Figure 2-3
Aerial Photograph of the Holden Mine Site

Job No. 33750803

URS



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

Reflects the collective extent of the 300, 550, 700, 000, 1000, 1100, 1500, and 2325-levels of the underground mine.

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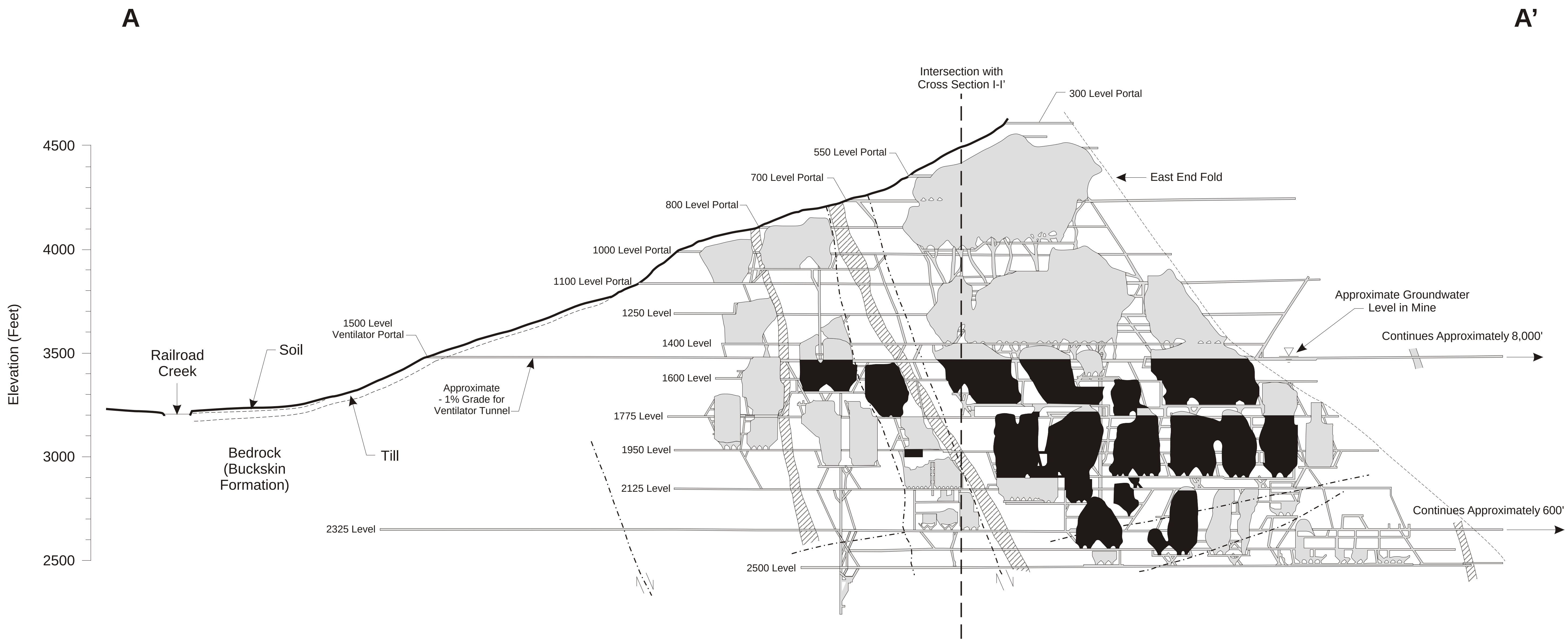
Figure 2-4
Holden Mine Site Map with Principal Underground Mine Workings

URS



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

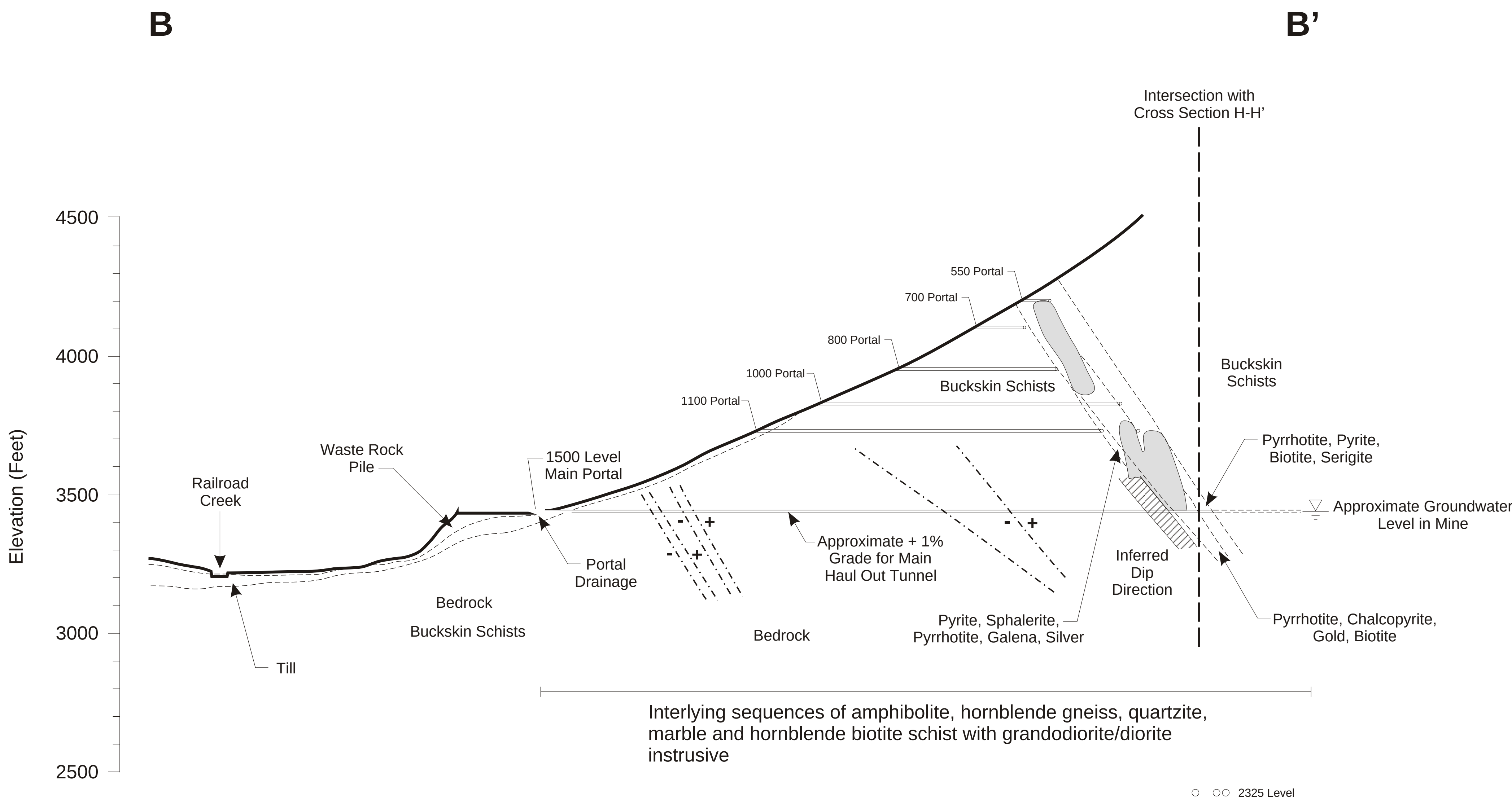
Howe Sound Co, 1957, Holden Mine, East West Section

LEGEND

- Open stope
- Backfilled stope
- Dike
- Transform fault

0 500 1,000

Approximate Horizontal and Vertical Scale in Feet



Note: This cross-section is generally perpendicular to ore body and parallel to 1500 level main tunnel.

LEGEND

- Open stope
- Diorite and quartz diorite intrusives
- Transform fault
- \+ Transform fault, away
- \-

0 500 1,000

Approximate Horizontal and Vertical Scale in Feet

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

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Figure 2-6

Holden Mine Site
Geologic Cross Section B-B'

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October 2003
Photograph Showing Mature Vegetation on Tailings Pile 1

October 2003
Photograph Showing Mature Vegetation on Tailings Pile 2

May 2002
Photograph Showing Mature Vegetation along the Tailings Pile 1 Base and Side Slopes

May 2002
Photograph Showing Vegetation Along Top Edge of Tailings Pile3

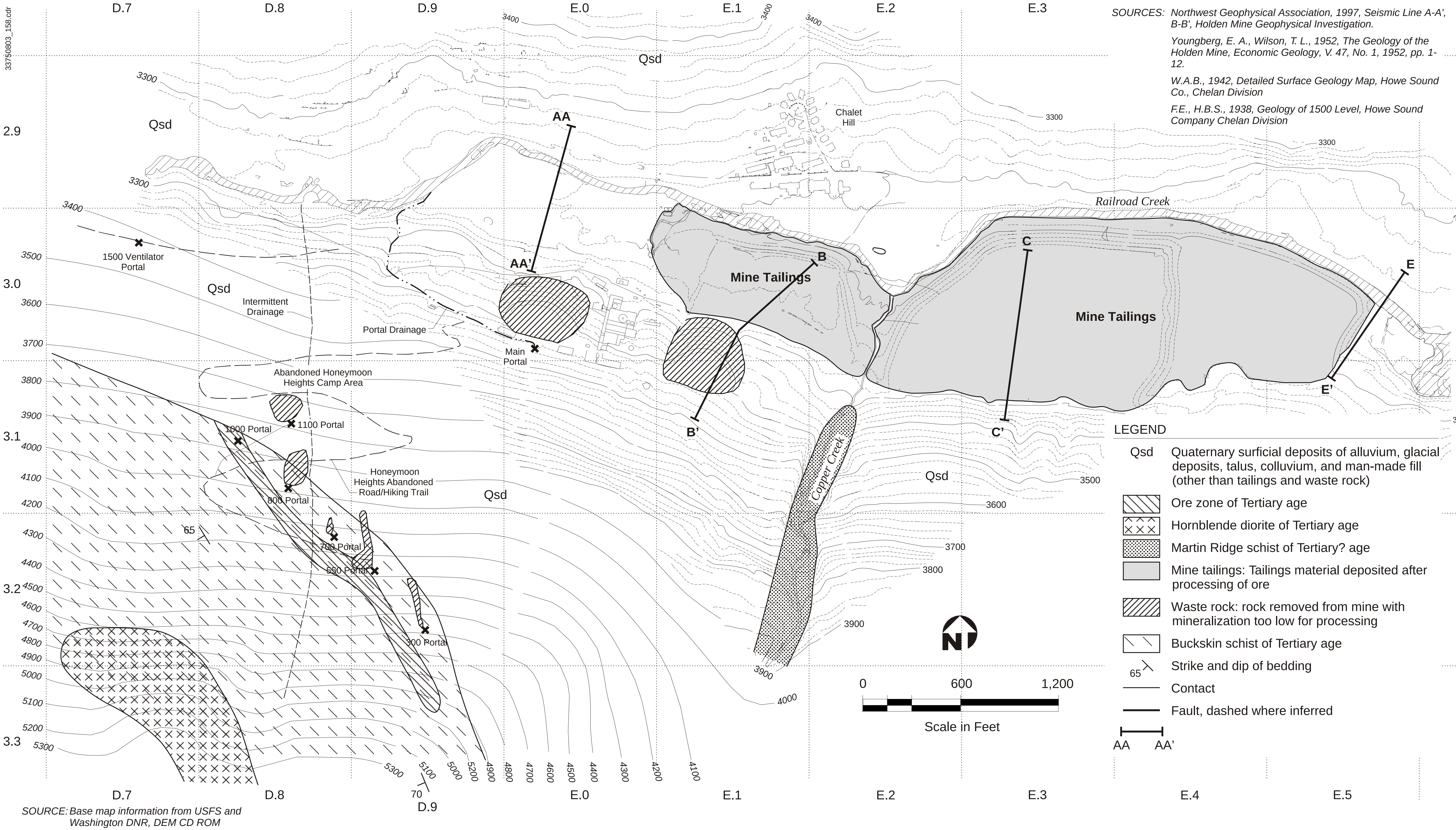

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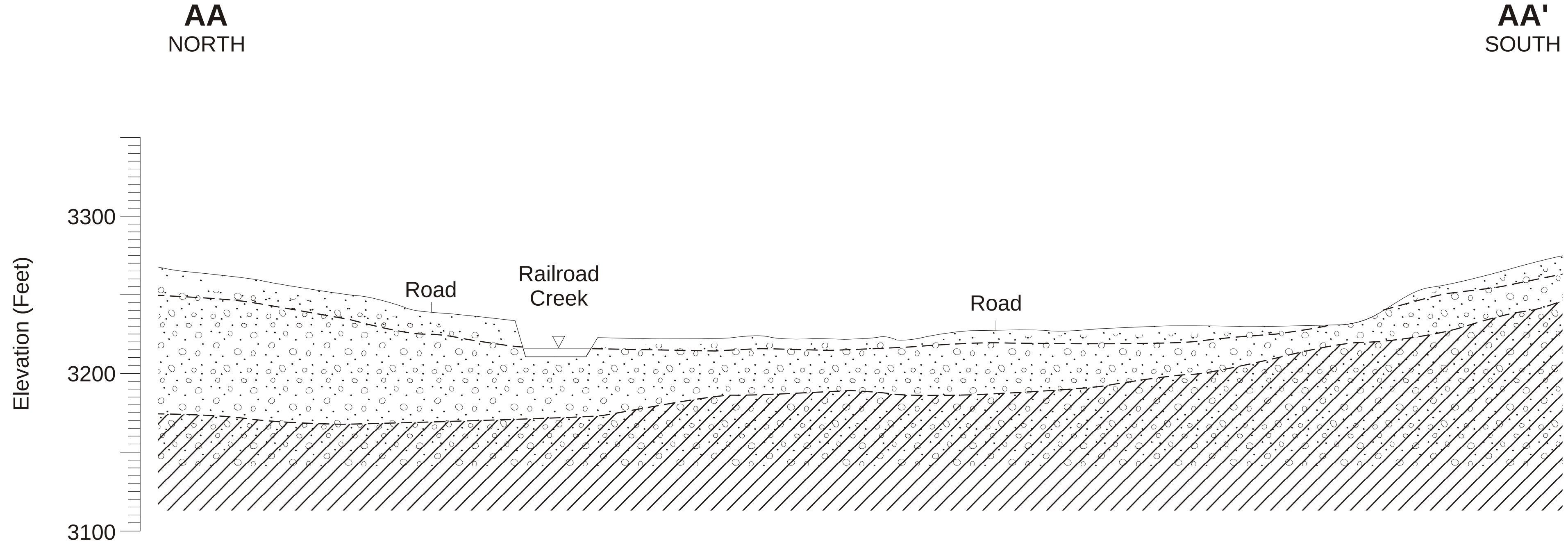
Figure 2-8

Holden Mine Site Geologic Map

URS



LEGEND

- Soil or Fill
- Glacial Drift
- Basal till\bedrock

0 100 200
Horizontal and Vertical Scale in Feet

NOTE

Top of basal till\bedrock approximate to within 5 to 10 feet.

SOURCE: Northwest Geophysical Association, 1997, Seismic Line A-A', Holden Mine Geophysical Investigation

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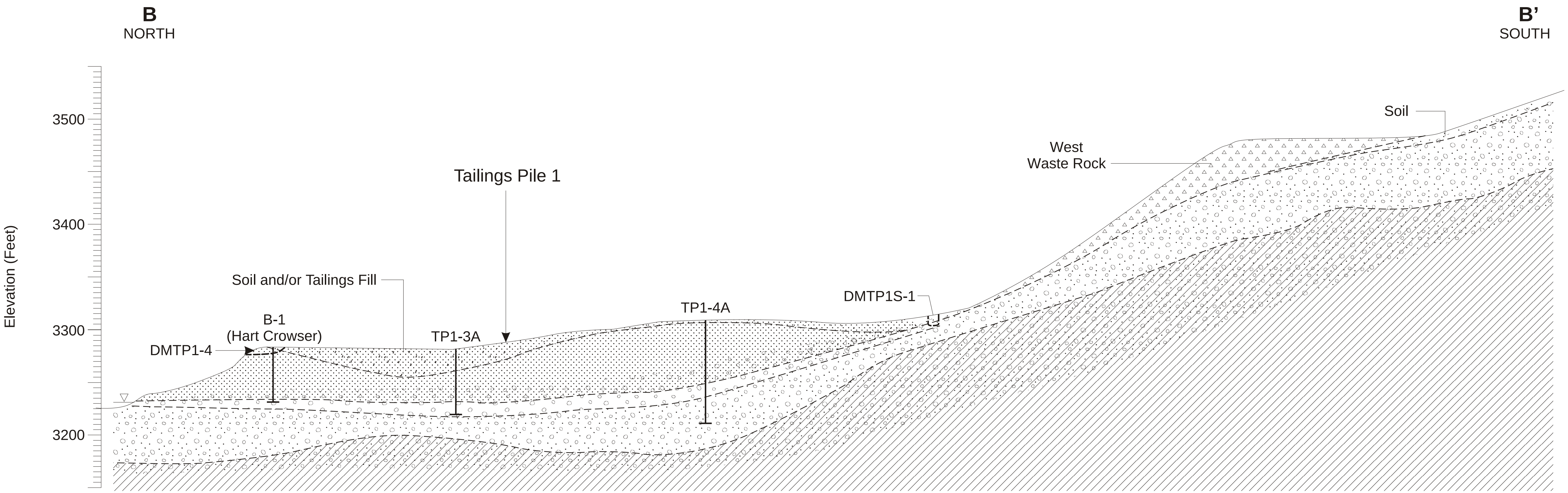
Figure 2-9
Holden Mine Site
Tailings Pile
Geologic Cross Section AA-AA'

URS



LEGEND

Soil or fill		B-1	Number and approximate location of boring completed by Hart Crowser, 1975.
Waste rock		TP1-4A	Number and approximate location of groundwater monitoring well installed by USBM, 1995.
Tailings		DMTP1S-1	Number and aproximate location of test pit completed by Dames & Moore, 1997.
Alluvially reworked glacial drift			
Glacial drift			
Basal till\bedrock			

0 100 200

Horizontal and Vertical Scale in Feet

NOTE

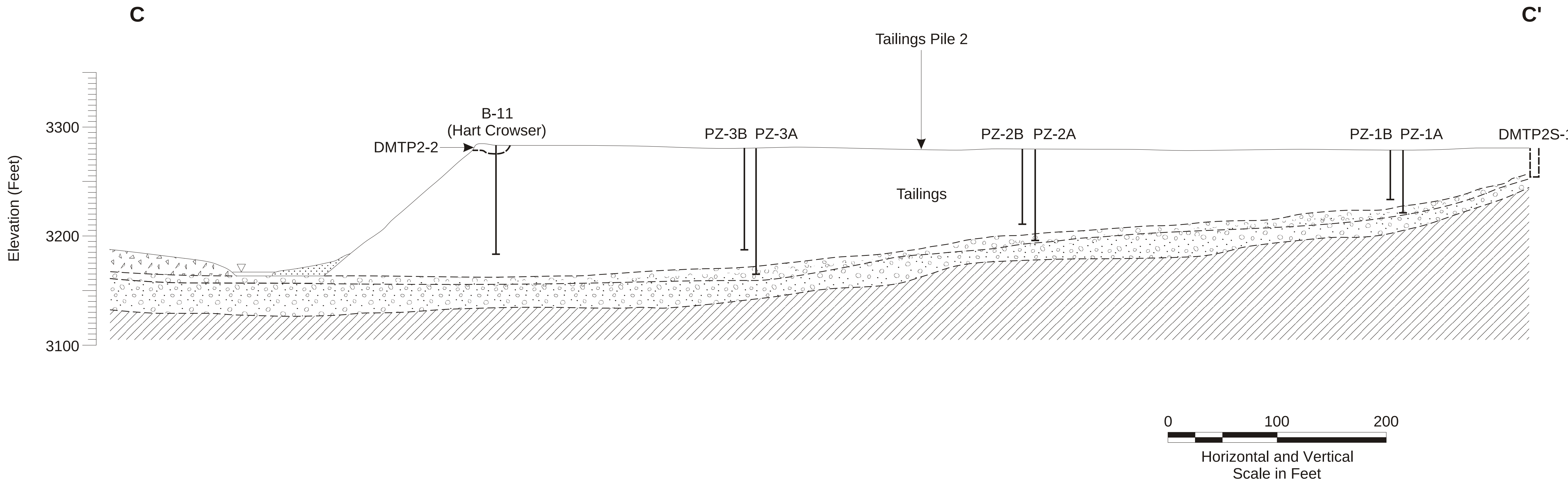
Top of basal till\bedrock approximate to within 5 to 10 feet.

SOURCE: Northwest Geophysical Association, 1997, Seismic Line B-B’, Holden Mine Geophysical Investigation

Figure 2-10

Holden Mine Site
Tailings Pile
Geologic Cross Section B-B'

Job No. 33750803



LEGEND

	Colluvium
	Alluvially reworked glacial drift
	Glacial drift
	Colluvium – tailings
	Basal till\bedrock

B-11	Number and approximate location of boring completed by Hart Crowser, 1975.
PZ-3B	Number and approximate location of groundwater monitoring well installed by PNL, 1991
DMTP1S-1	Number and approximate location of test pit completed by Dames & Moore, 1997.

NOTE

Top of basal till\bedrock approximate to within 5 to 10 feet.

SOURCE: Northwest Geophysical Association, 1997, Seismic Line C-C', Holden Mine Geophysical Investigation

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Figure 2-11
Holden Mine Site
Tailings Pile
Geologic Cross Section C-C'

URS

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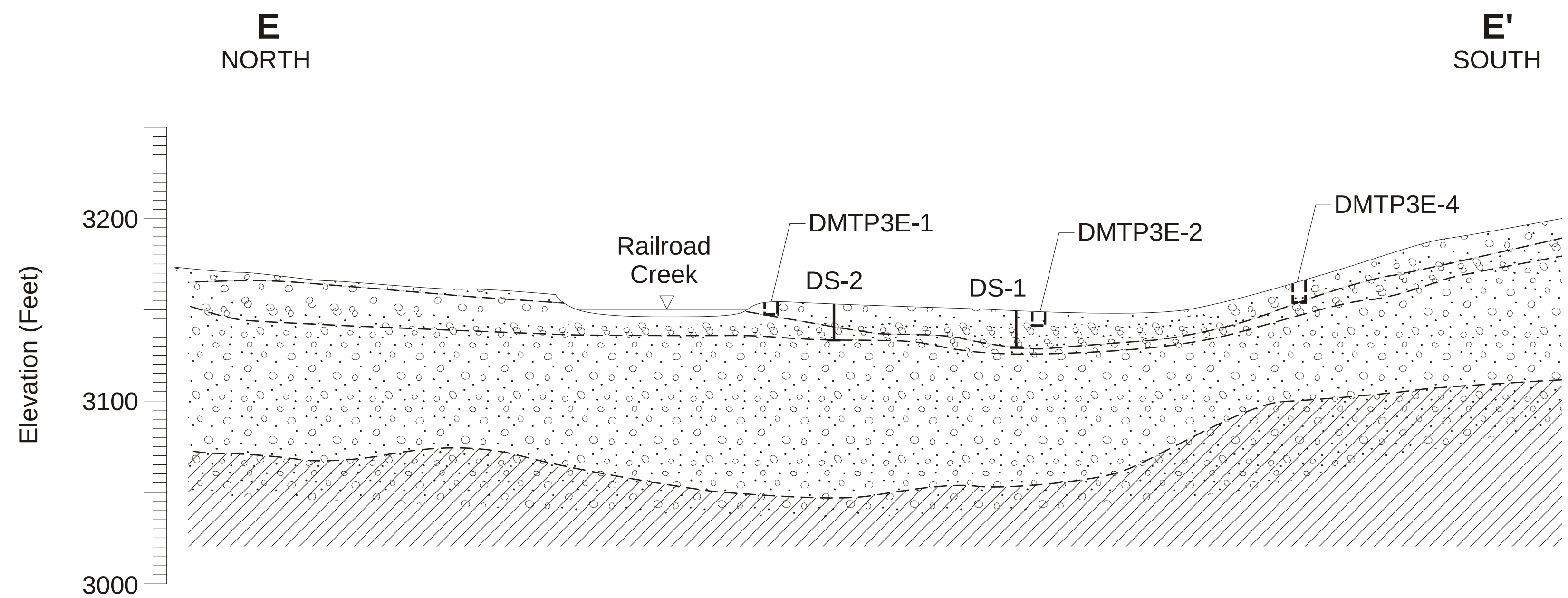

LEGEND

Soil or fill	
Alluvially reworked glacial drift	
Glacial drift	
Basal till\bedrock	
DS-2	Number and approximate location of groundwater monitoring well installed by USBM, 1995.
DMTP3E-1	Number and approximate location of test pit completed by Dames & Moore, 1997.

0 100 200

Horizontal and Vertical
Scale in Feet

NOTE

Top of basal till\bedrock approximate to within 5 to 10 feet.

SOURCE: Northwest Geophysical Association, 1997, Seismic Line E-E', Holden Mine Geophysical Investigation

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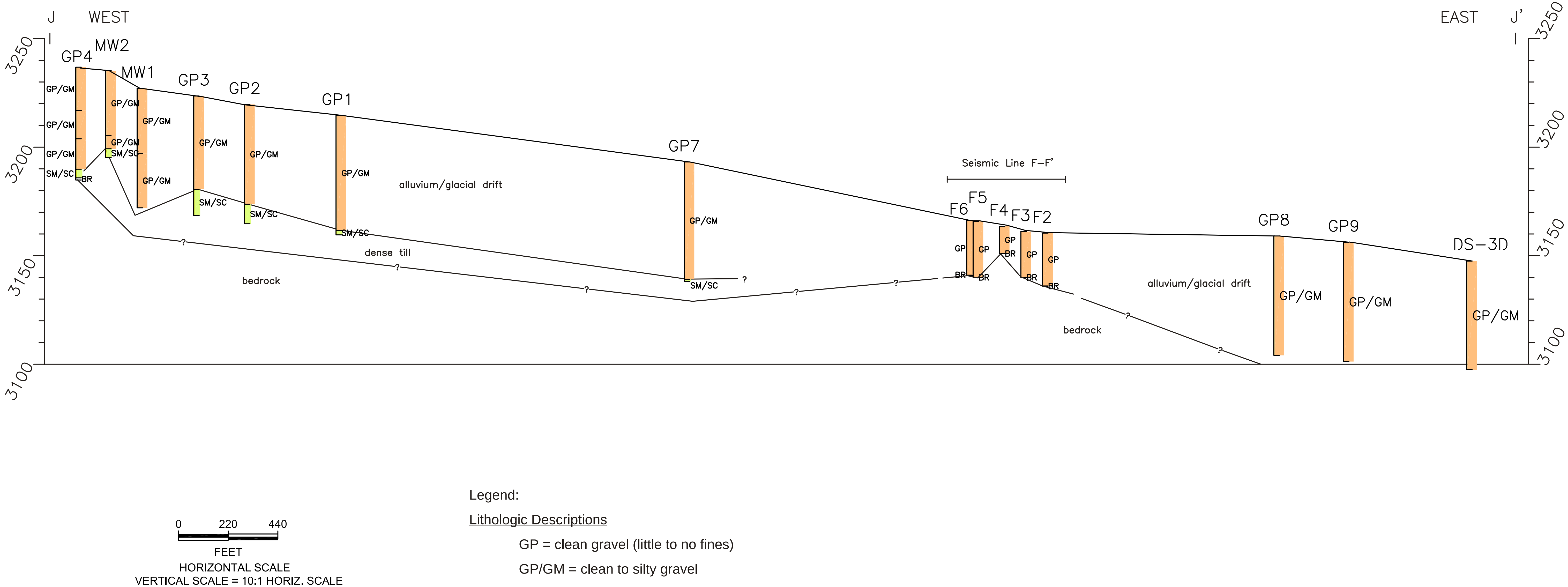
Figure 2-12
Holden Mine Site
Tailings Pile
Geologic Cross Section E-E'

URS



Legend:

Lithologic Descriptions

GP = clean gravel (little to no fines)

GP/GM = clean to silty gravel

SM/SC = silty sand to clayey sand

BR = bedrock

Boring Designations

GP = geologic boring

MW, DS = monitoring well

Note: Data points labeled F2 through F6 are from surveyed locations on seismic line F-F'

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Figure 2-13

Holden Mine Site
Geologic Cross Section J-J'

URS

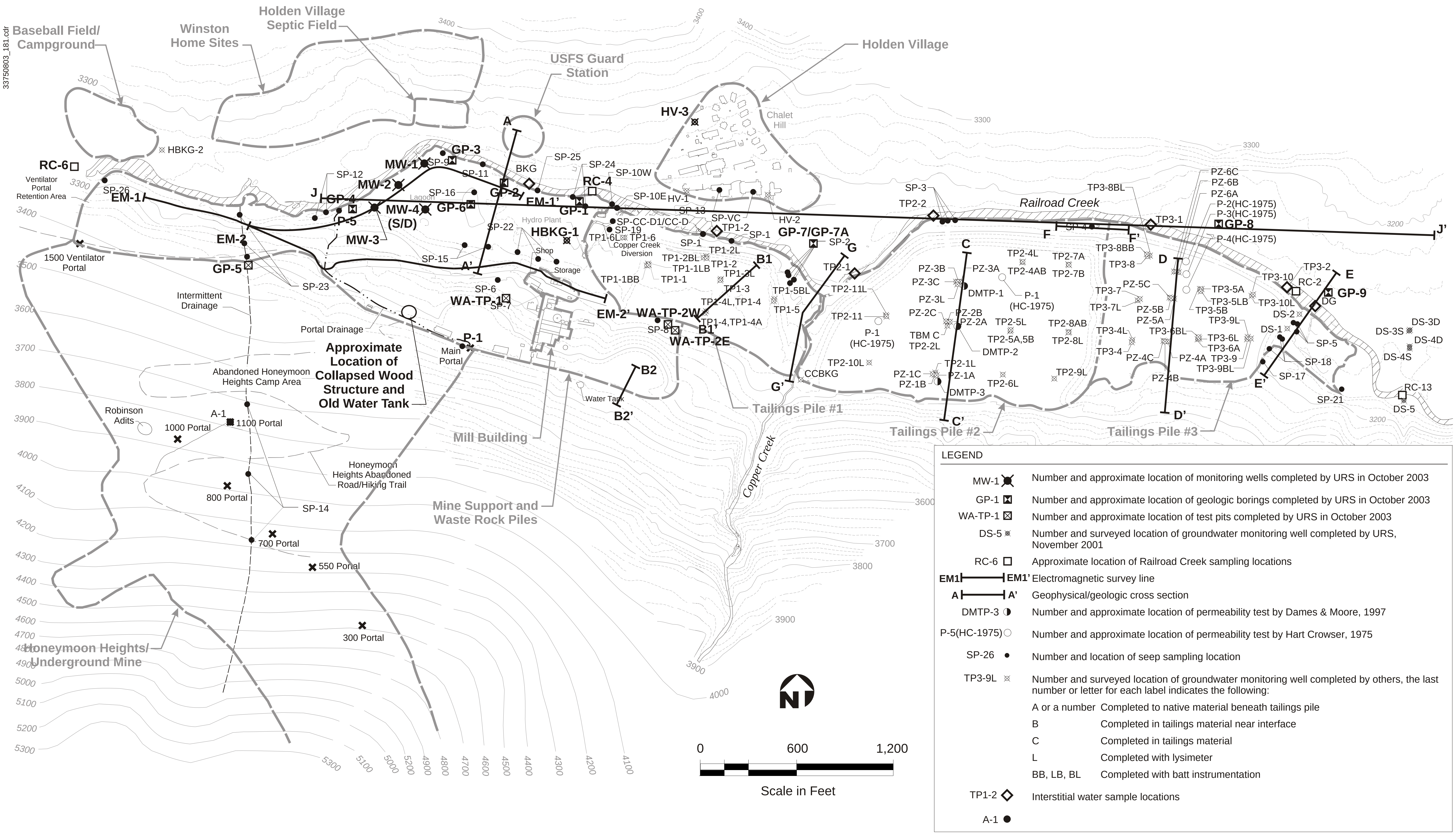
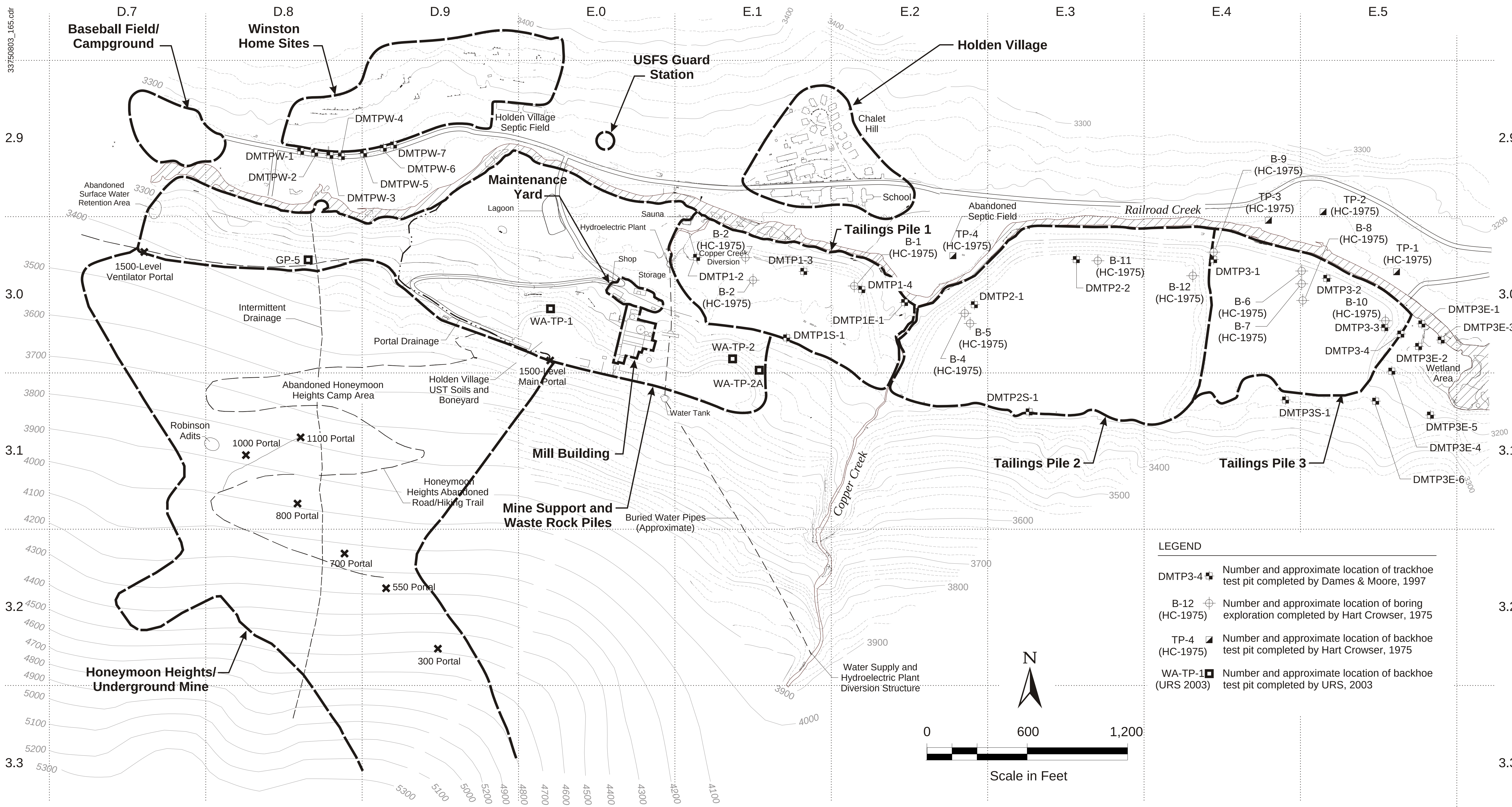


Figure 2-14
Holden Mine Hydrogeologic Investigation Locations

Job No. 33750803

URS



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

Job No. 33750803

Figure 2-15
Holden Mine Site
Geologic Investigation Locations

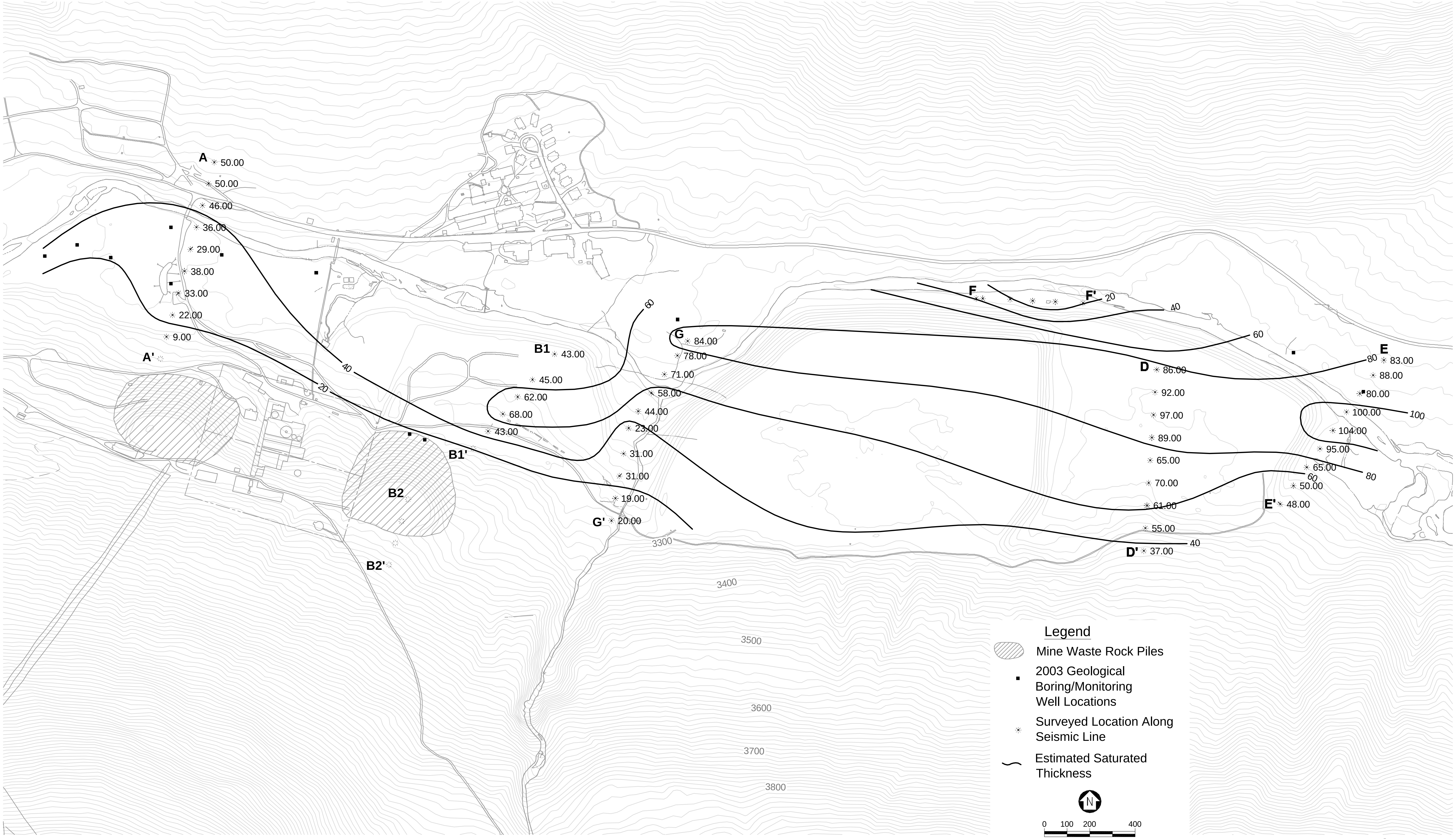


Figure 2-16
Estimated Saturated Thickness (ft), "Spring" Conditions

FILENAME: Q:\Geo\Holden Mine\SubTasks\FS\Figure 2-16.dwg
EDIT DATE: 03/02/04 AT: 10:16

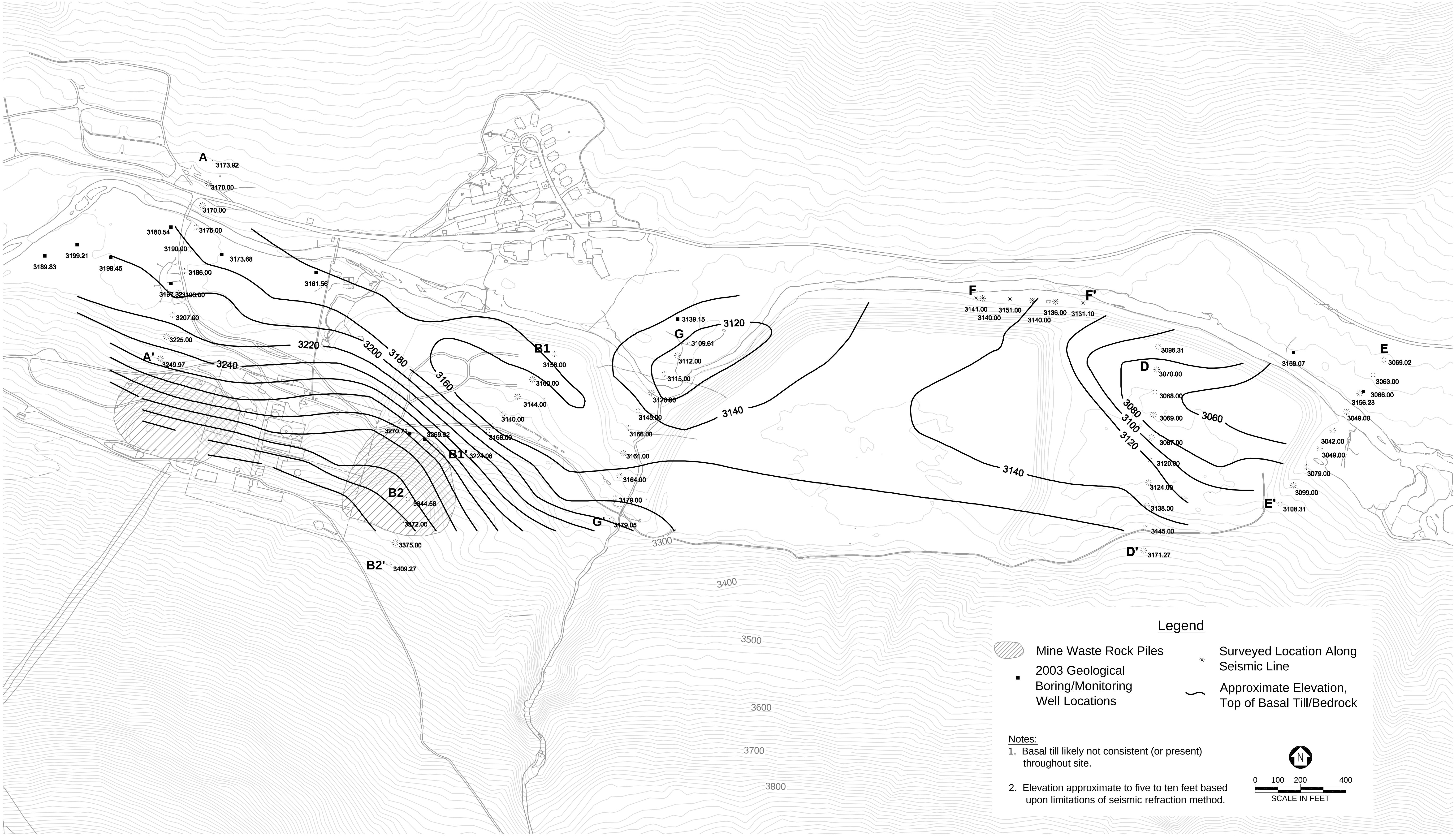


Figure 2-17
Approximate Elevation, Top of Basal Till/Bedrock

FILENAME: Q:\Geo\Holden Mine\SubTasks\FS\Figure 2-17.dwg
EDIT DATE: 03/02/04 AT: 10:18

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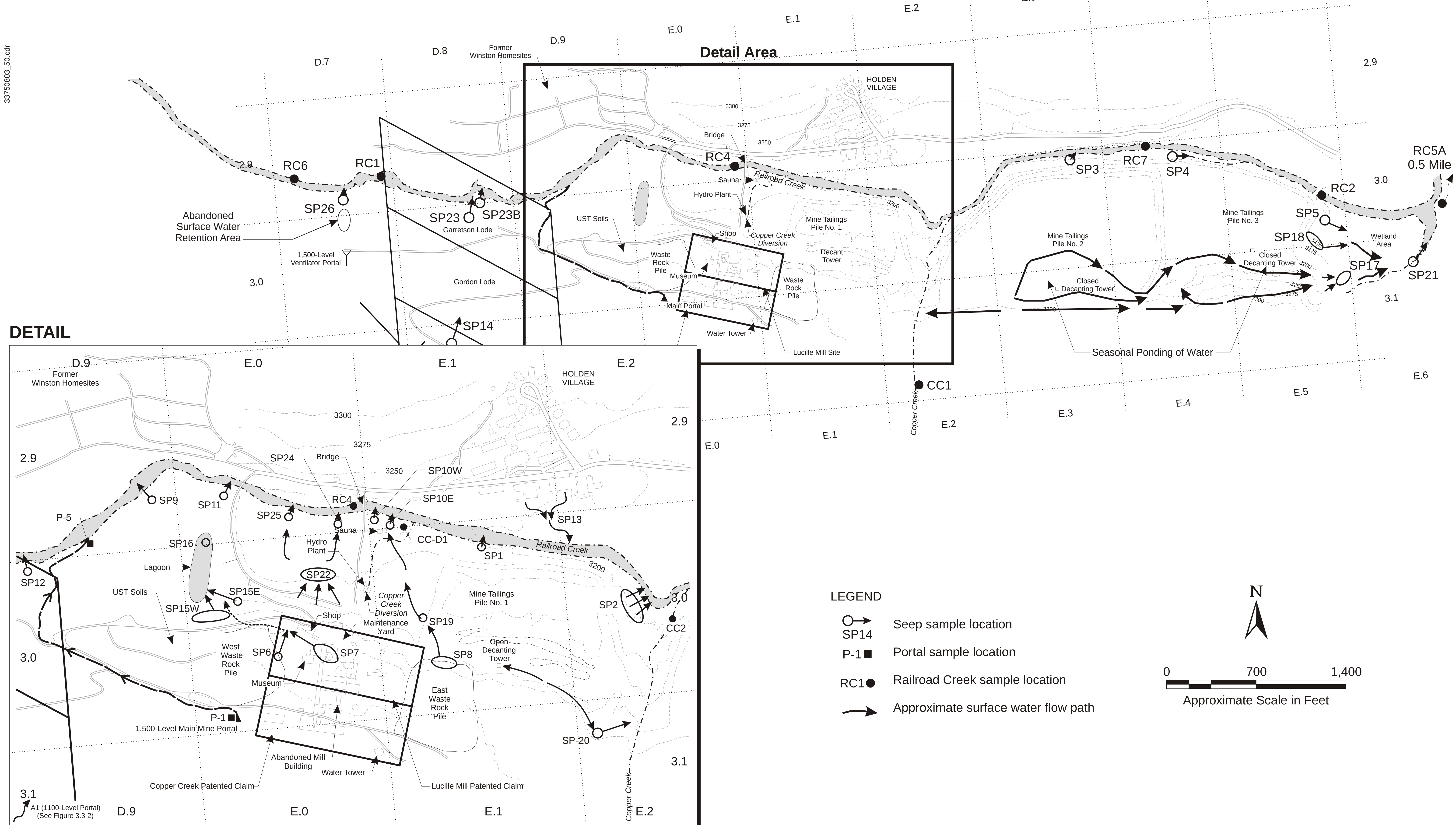

SOURCE: ORB, 1975

Job No. 33750803

Figure 2-18
Approximate Locations of Surface Water Runon and Runoff and Seep Sample Locations

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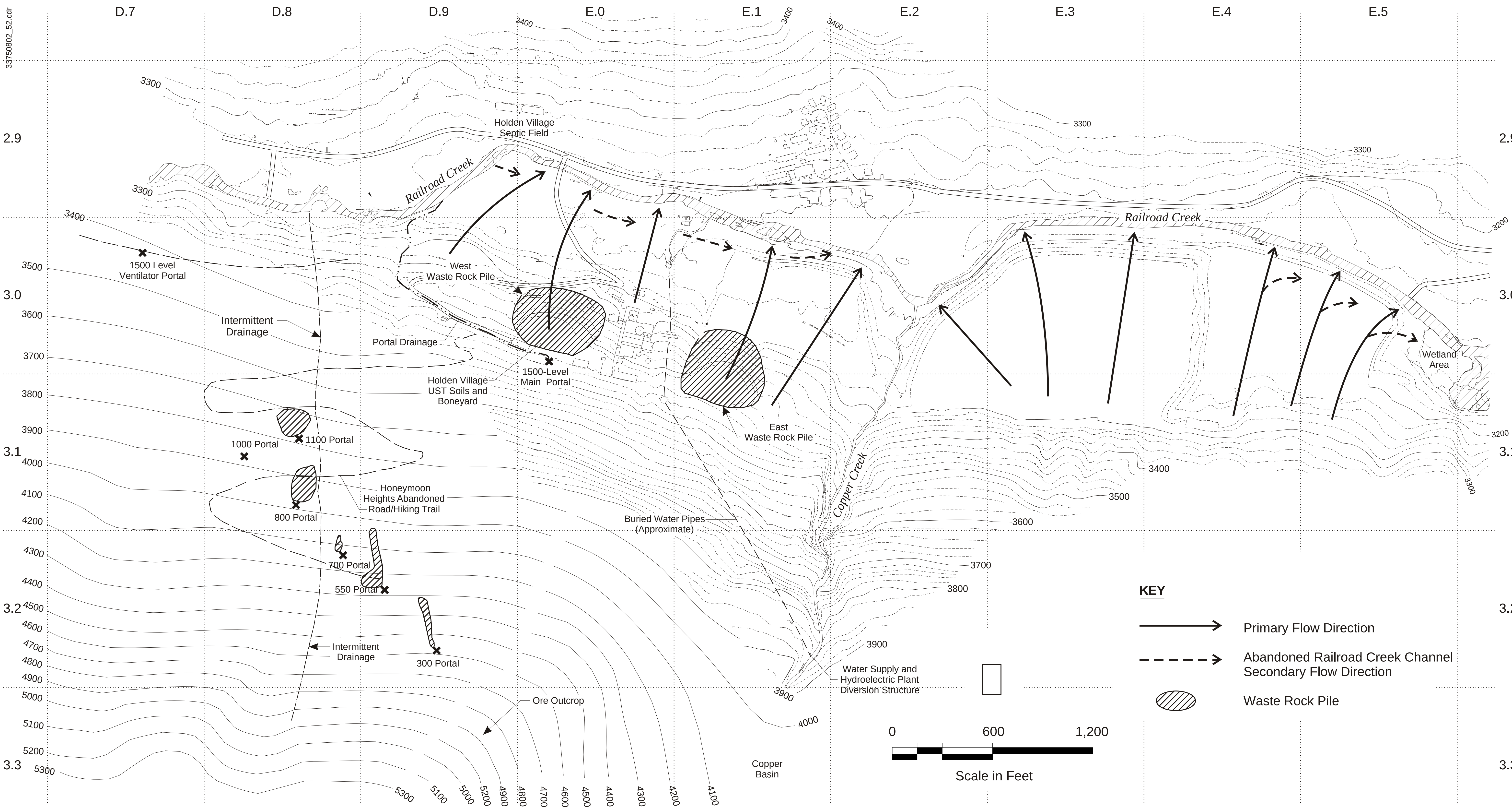
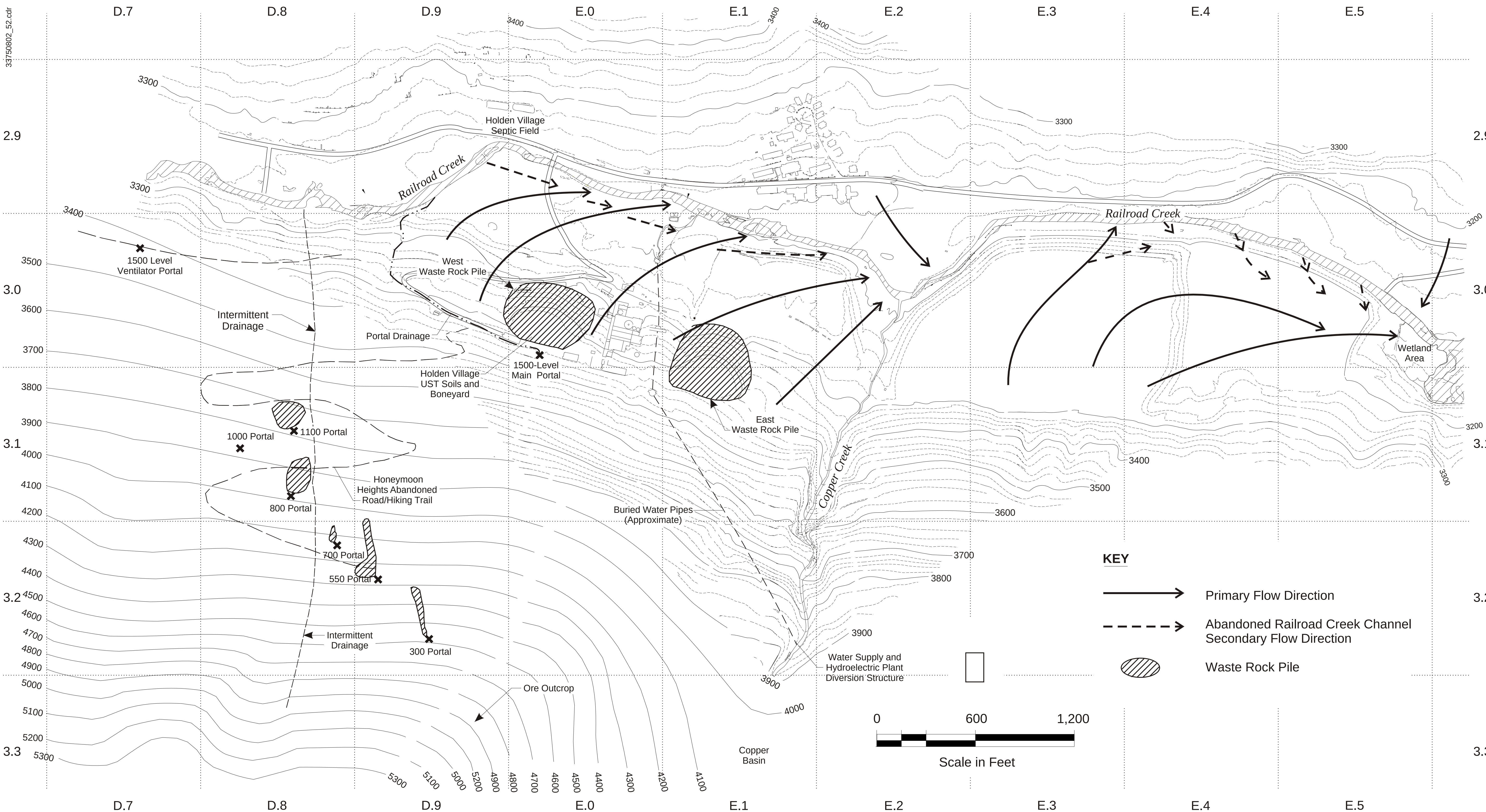


SOURCE: Base map information from USFS and Washington DNR, DEM CD ROM

Job No. 33750803

Figure 2-19
Conceptual Groundwater Flowpaths
Holden Mine Site - Spring Conditions



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

Job No. 33750803

Figure 2-20

Conceptual Groundwater Flowpaths Holden Mine Site - Fall Conditions

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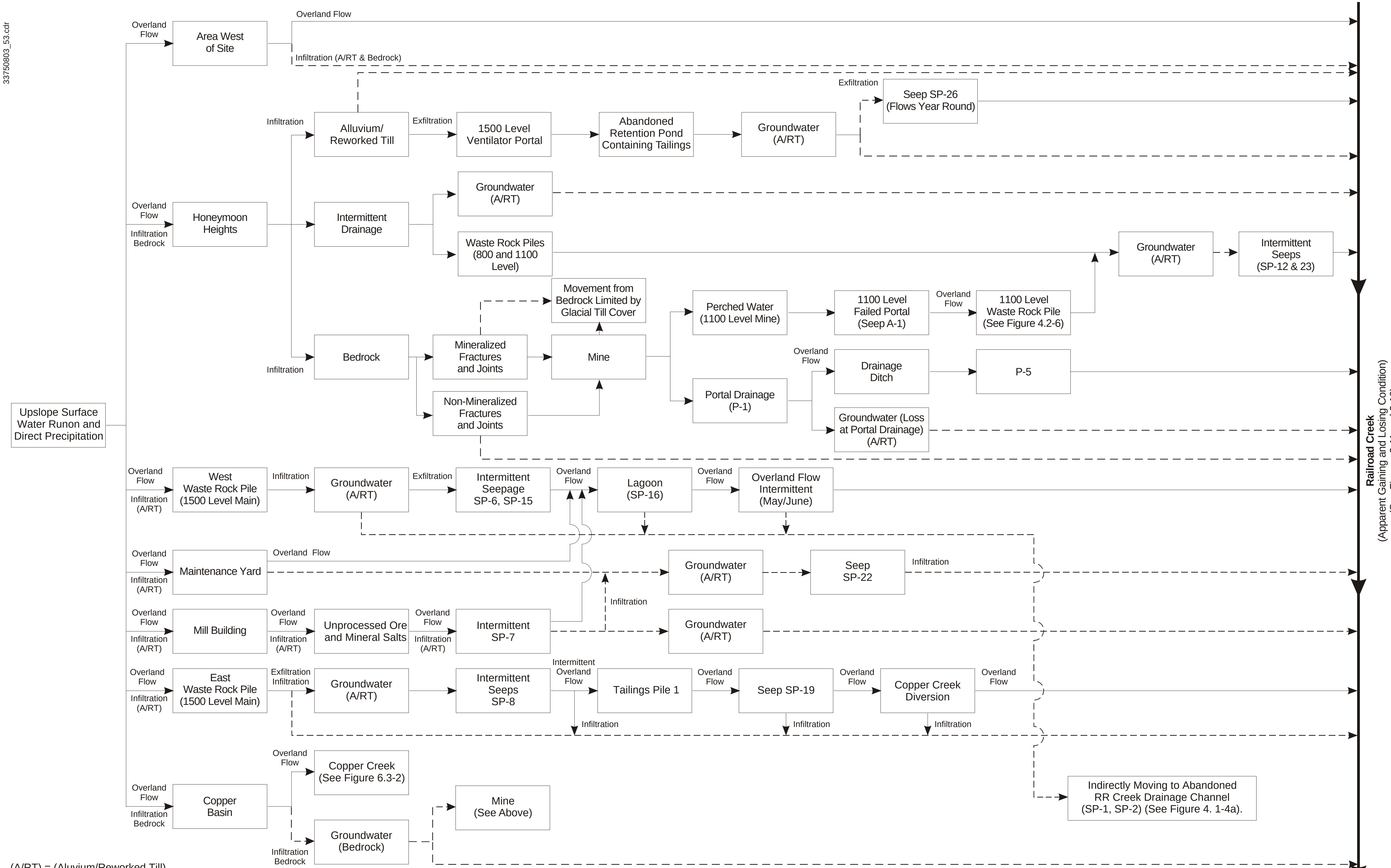

Job No. 33750803

Figure 2-21
Honeymoon Heights and Mine Support Areas Conceptual Transport Pathways

URS

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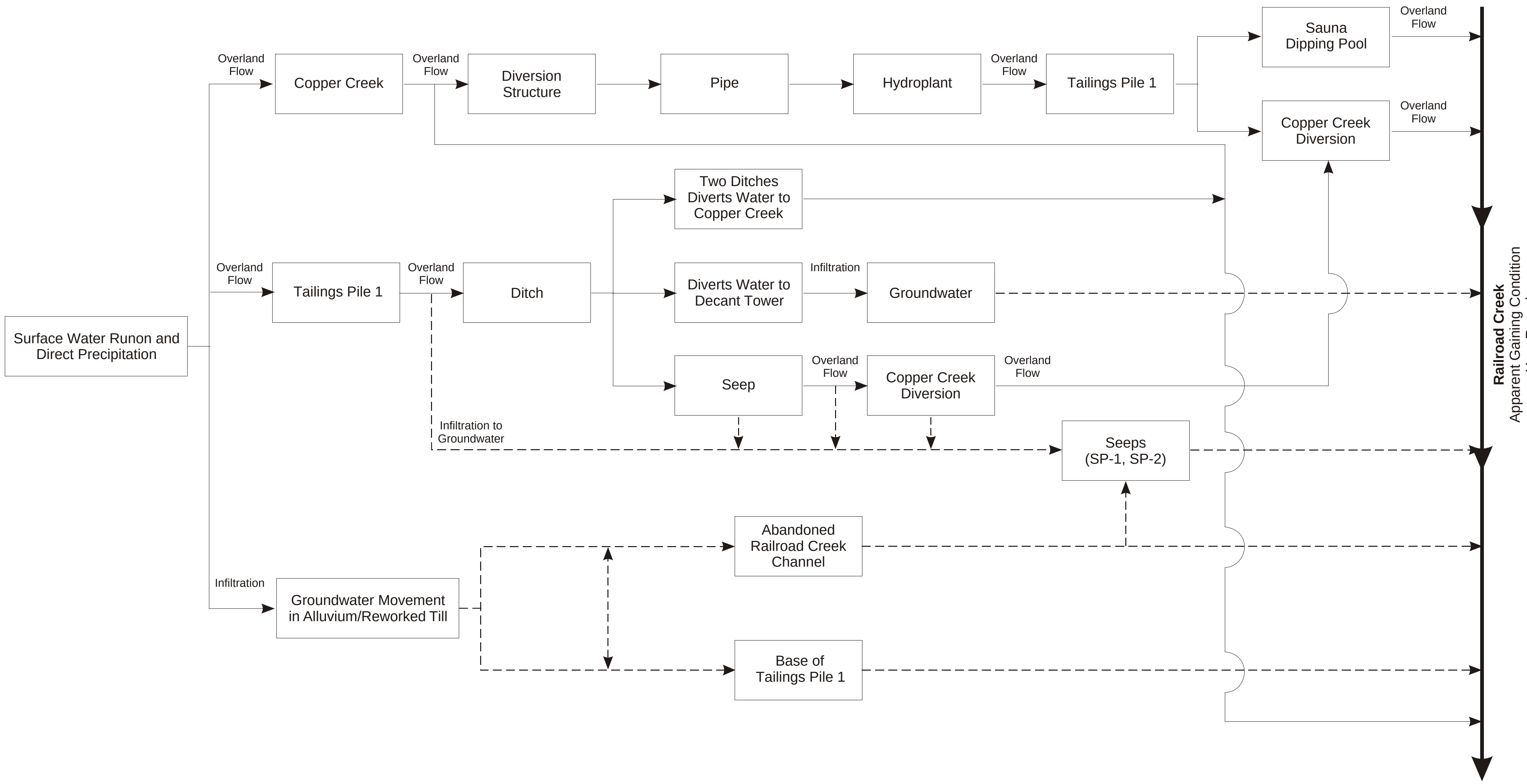


Figure 2-22
Tailings Pile 1
Conceptual Transport Pathways

Job No. 33750803

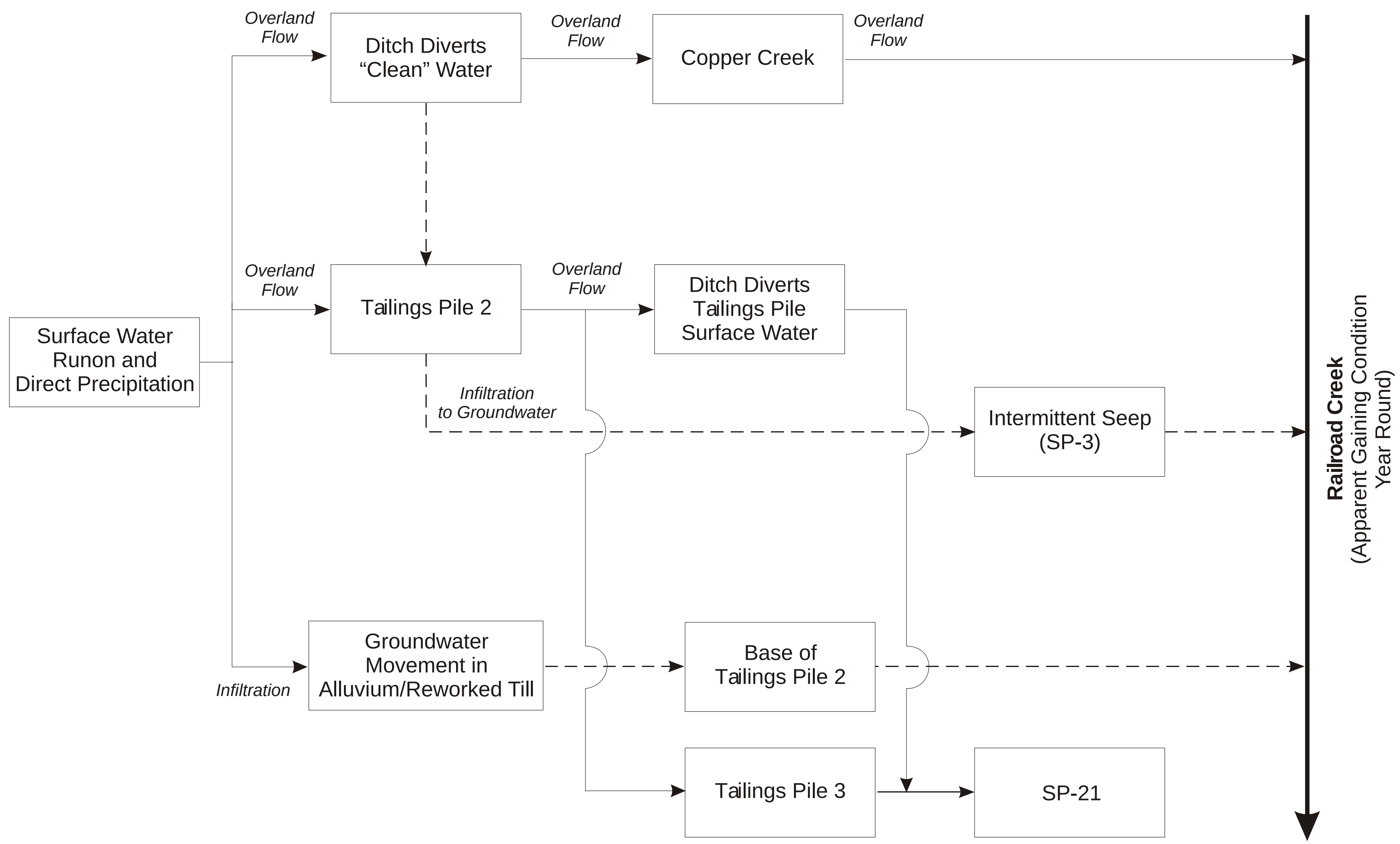


Figure 2-23
Tailings Pile 2
Conceptual Transport Pathways

Job No. 33750803

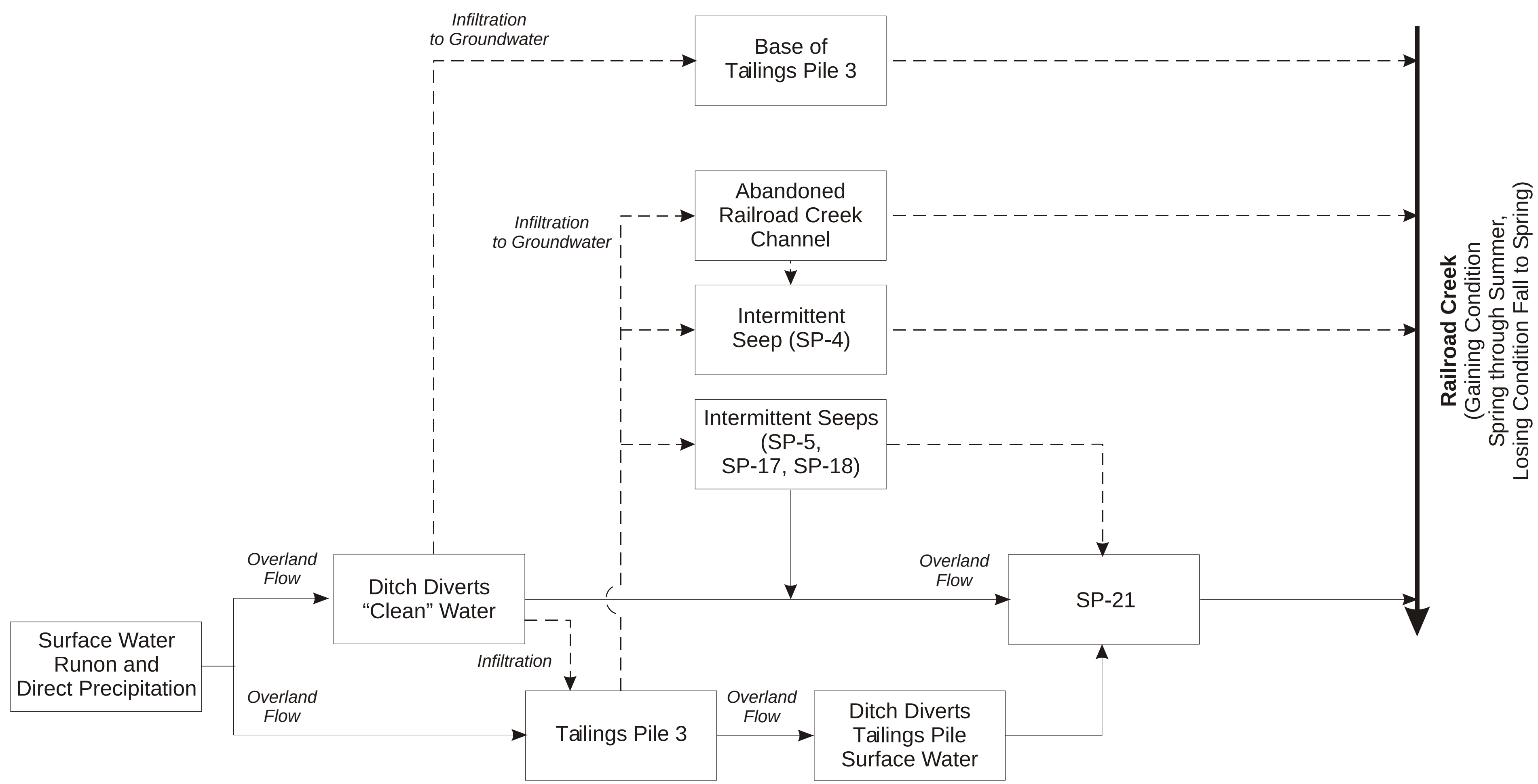


Figure 2-24
Tailings Pile 3
Conceptual Transport Pathways

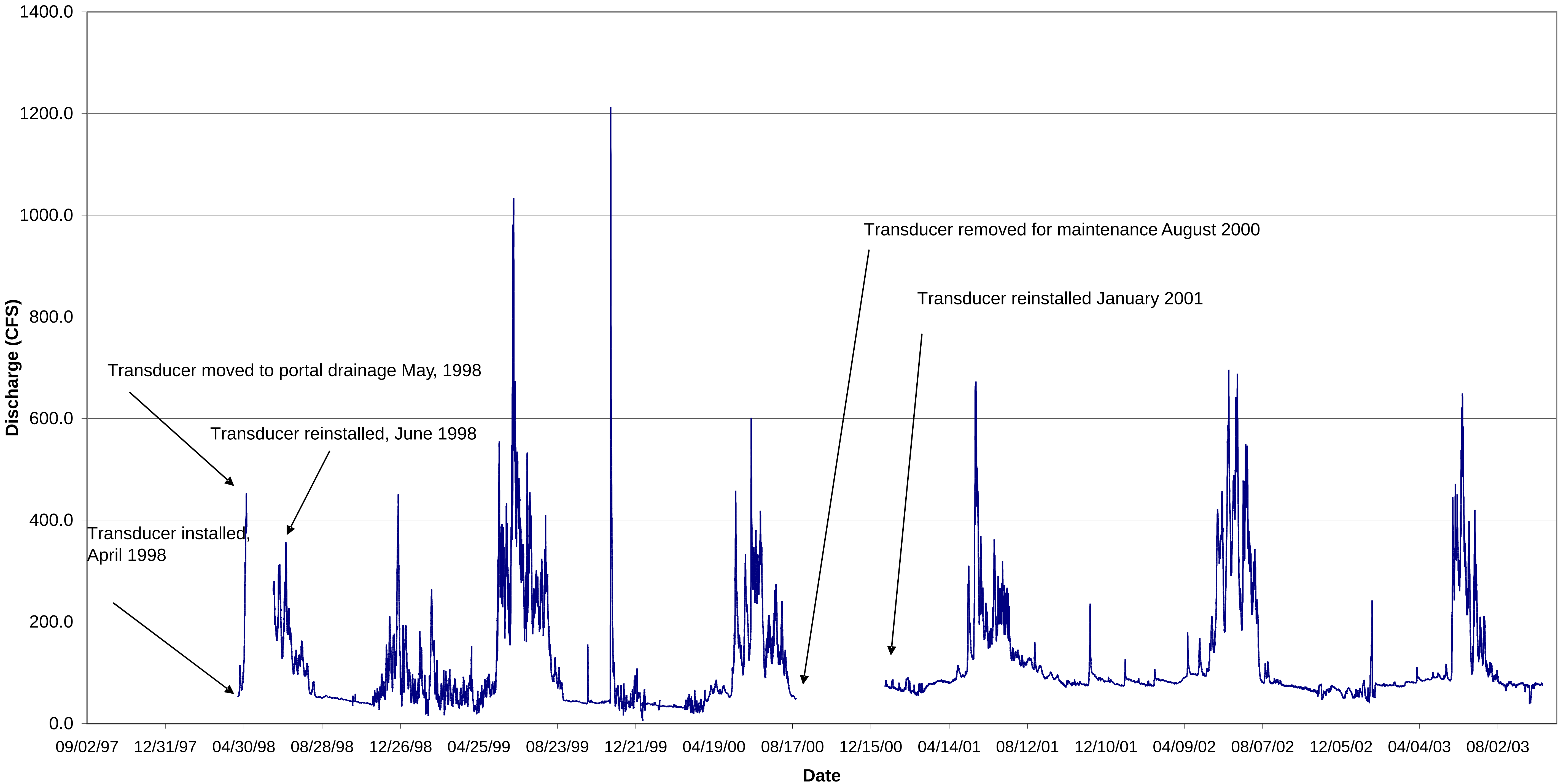
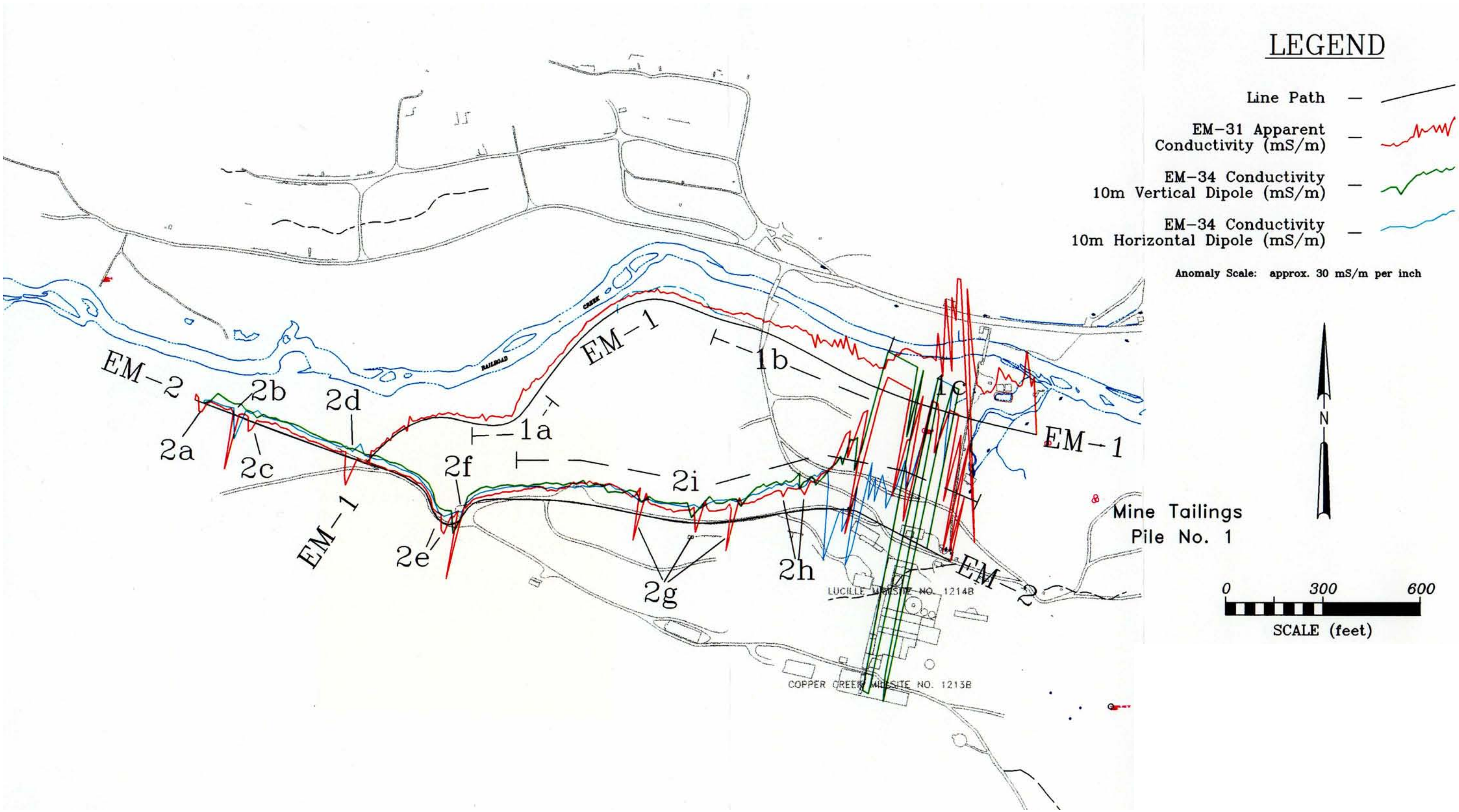


Figure 2-25
Discharge vs. Time
Railroad Creek



Source: Northwest Geophysical Associates, Inc.

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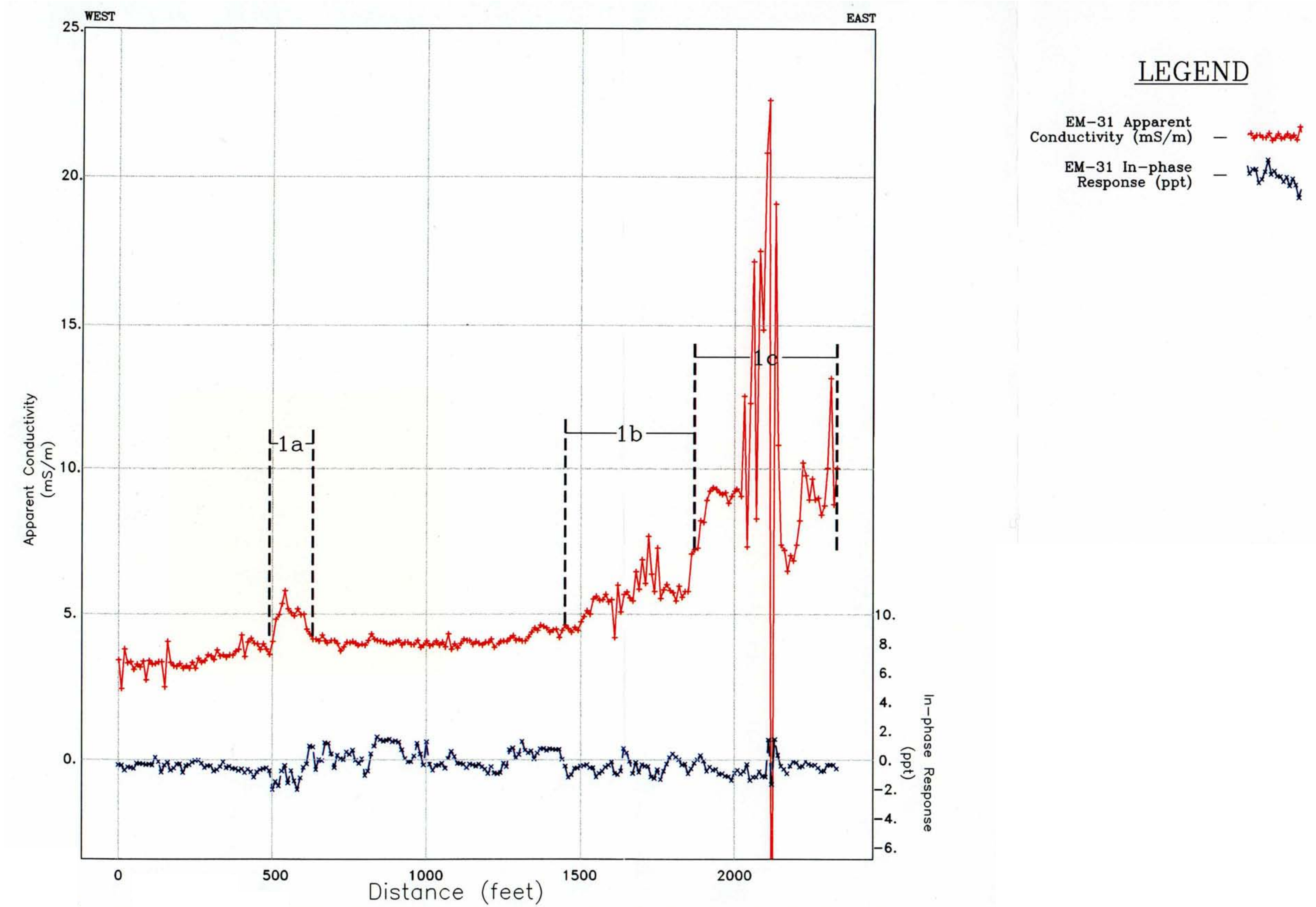
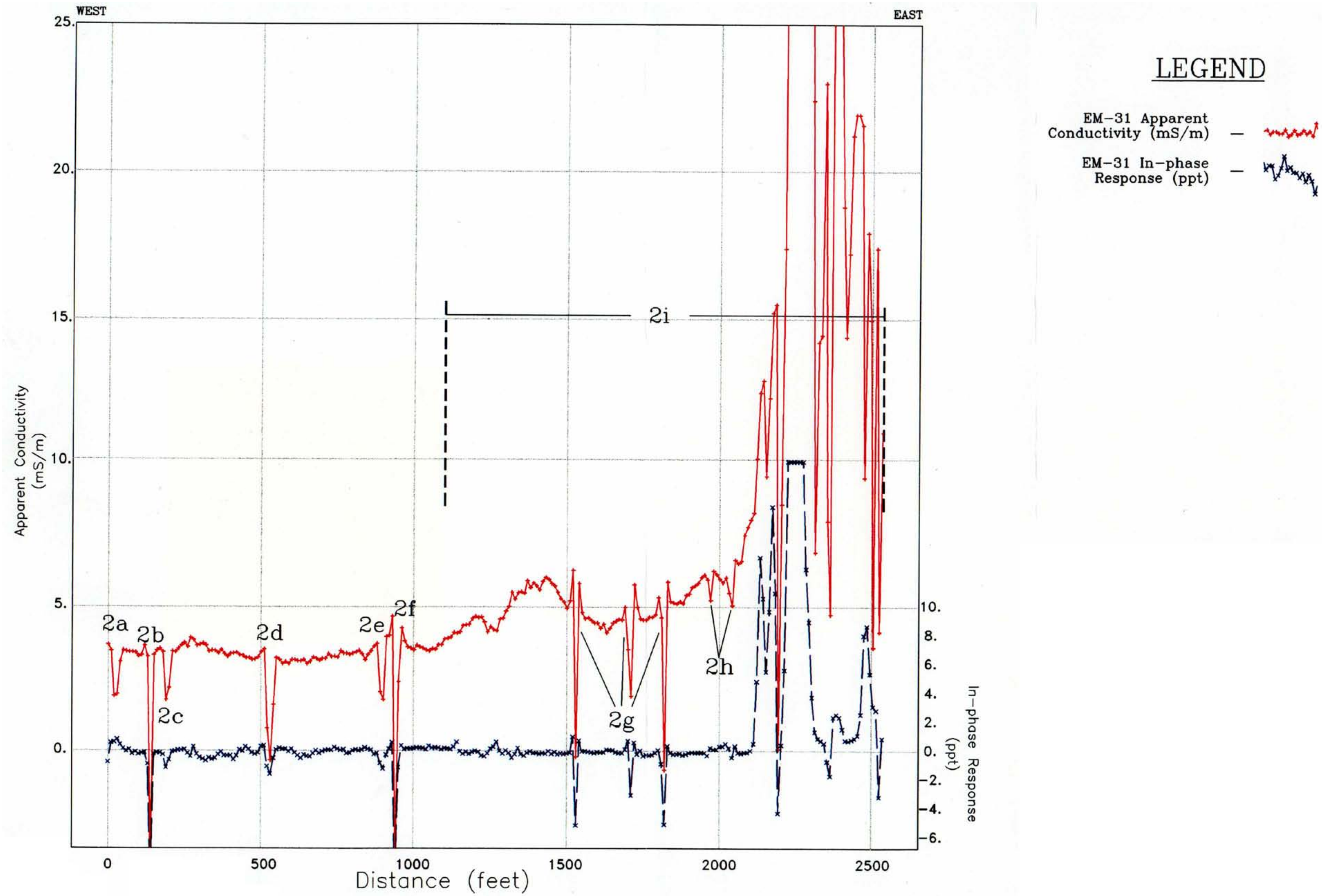
Figure 2-26
West Area Electromagnetic Survey Lines EM-1 and EM-2



Source: Northwest Geophysical Associates, Inc.

Job No. 33750803

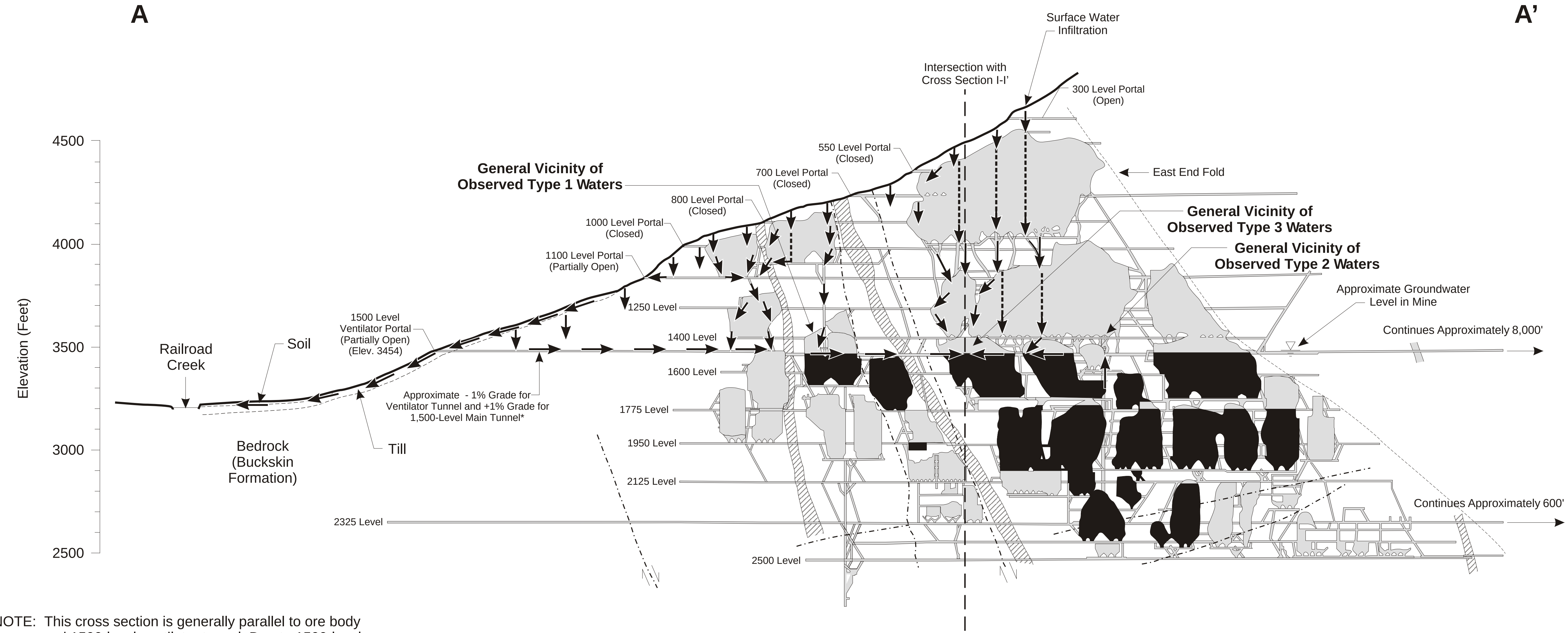
Figure 2-27
West Area
Electromagnetic Survey Line EM-1
Apparent Conductivity and
In-phase Response



Source: Northwest Geophysical Associates, Inc.

Job No. 33750803

Figure 2-28
West Area
Electromagnetic Survey Line EM-2
Apparent Conductivity and
In-phase Response



* 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)

LEGEND

- Open stope
- Backfilled stope
- Dike
- Transform fault
- Direction of inferred water movement

0 500 1,000

Approximate
Horizontal and Vertical
Scale in Feet

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

Figure 2-29
Holden Mine Site
Conceptual Transport Pathway of
Mine Cross Section A-A'

Job No. 33750803

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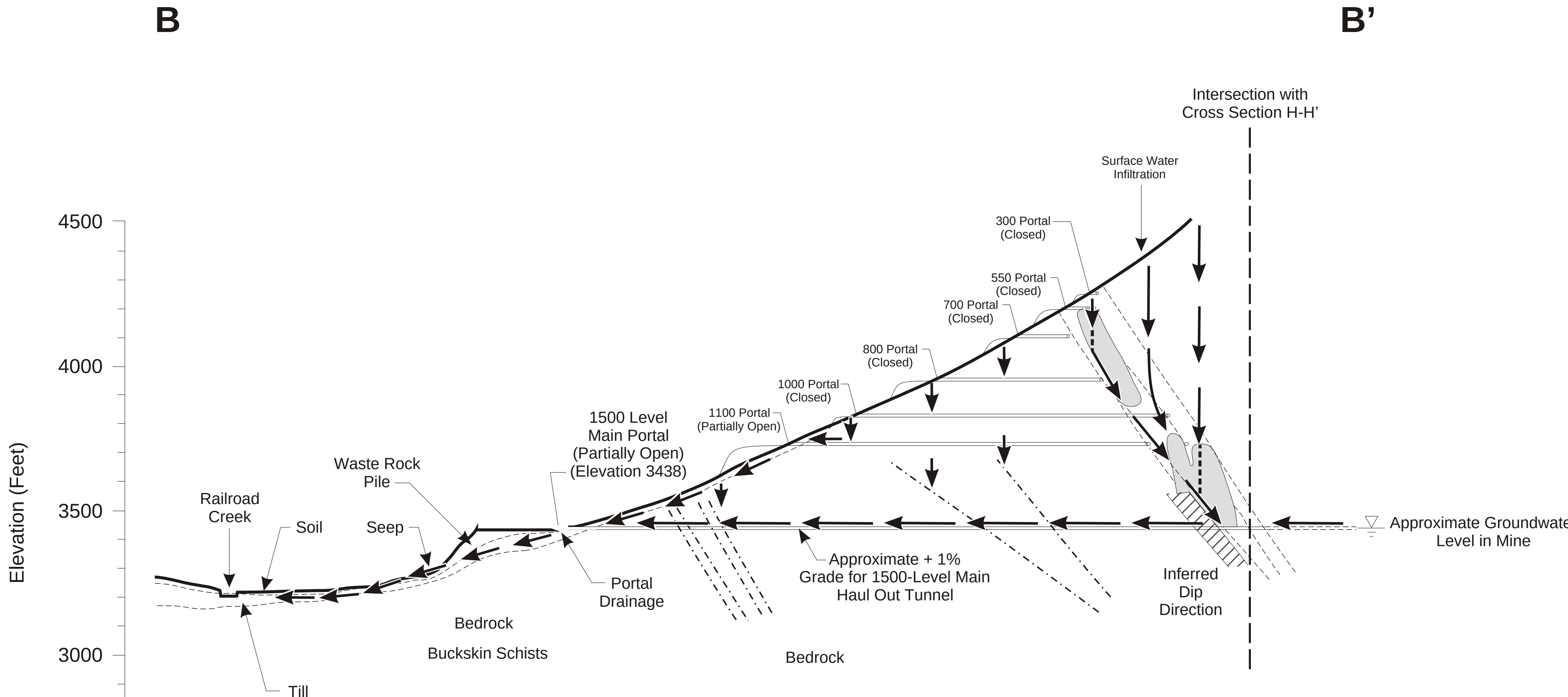
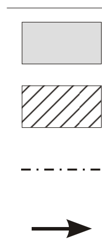
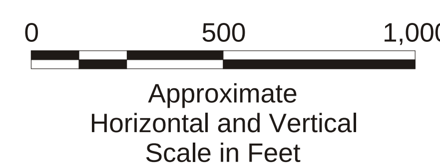


LEGEND





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

Figure 2-30
Holden Mine Site
Conceptual Transport Pathway of
Mine Cross Section B-B'

Job No. 33750803

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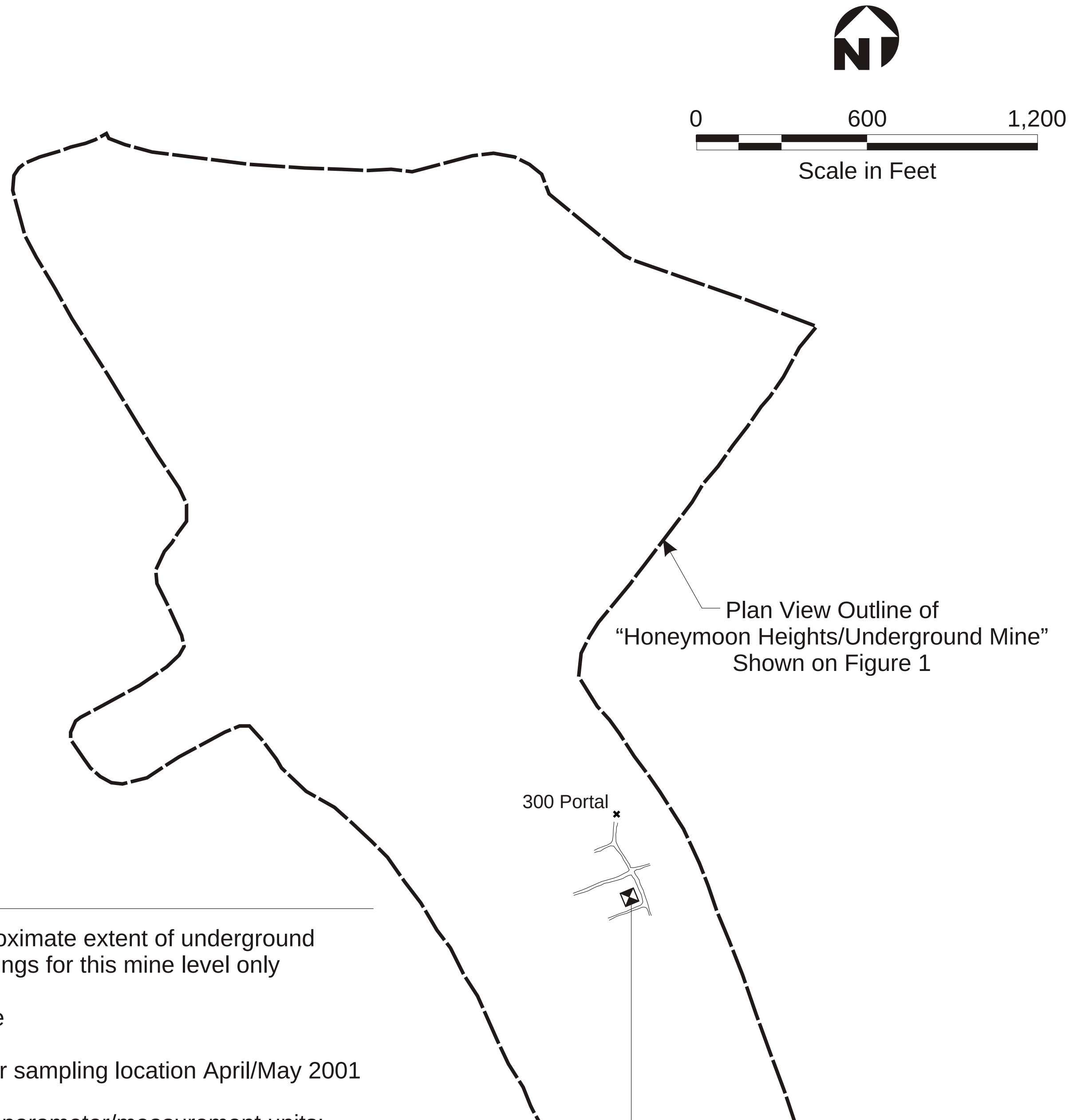

LEGEND

Approximate extent of underground workings for this mine level only

Raise

Water sampling location April/May 2001

Field parameter/measurement units:

Specific conductivity (SC): S/cm

Temperature (T): °C

Redox: (mv)

Dissolved oxygen (DO): mg/L

Flow: gpm

Water quality parameters:

Dissolved metals: g/L

Sulfate (SO_4): mg/L

No flow observed in April 2001

Unnamed Raise					
	April 2001	May 2001		April 2001	May 2001
Al	–	20U	pH	–	4.9
Cd	–	0.2U	SC	–	151
Cu	–	3.2	T	–	6.3
Fe	–	30	Redox	–	90
Zn	–	15	DO	–	–
SO_4	–	29	Flow	0	0.2

Figure 2-31

April/May 2001
Geochemical Assessment Sampling Locations
300 Level

Job No. 33750803

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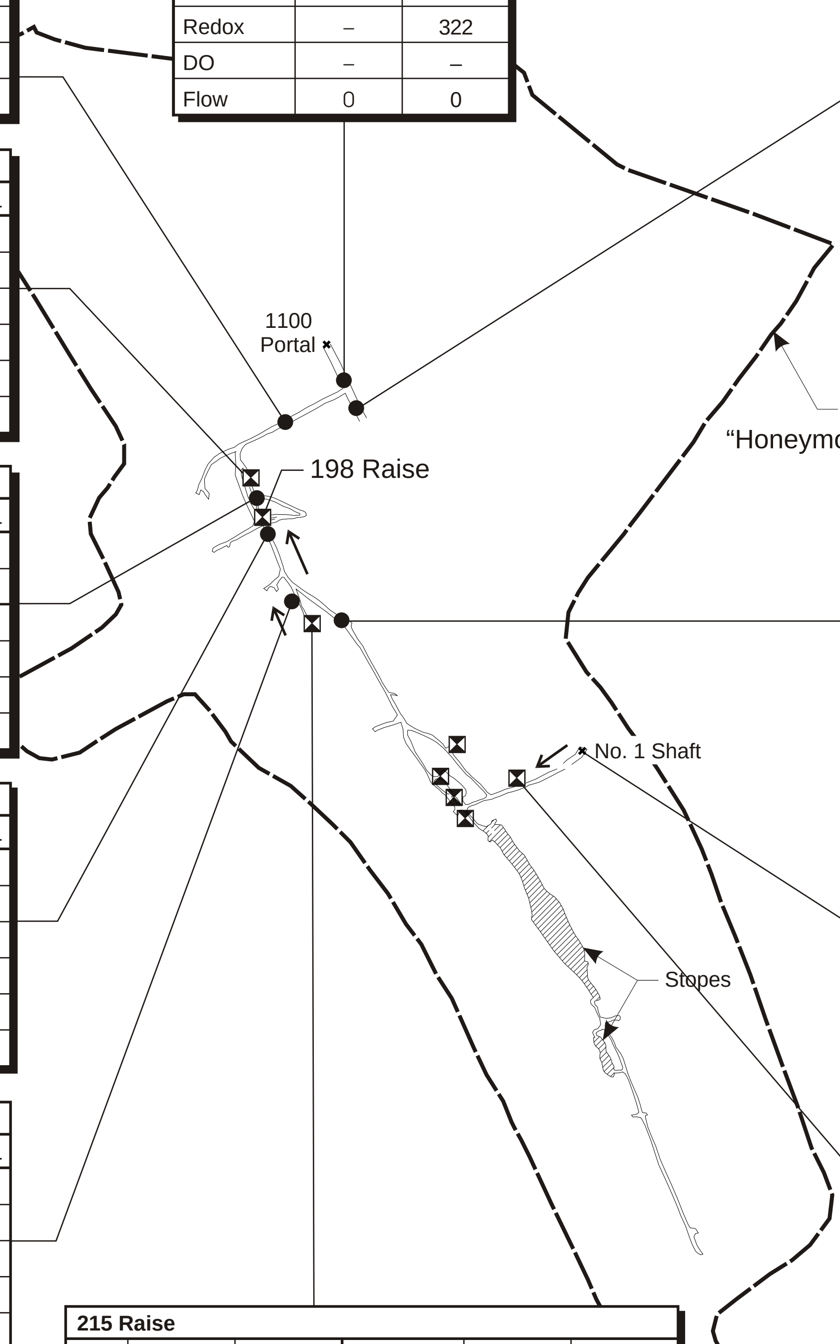
200'	April 2001	May 2001
pH	–	5.5
SC	–	361
T	–	1.0
Redox	–	339
DO	–	–
Flow	0	0

100'	April 2001	May 2001
pH	–	6.2
SC	–	317
T	–	2.0
Redox	–	322
DO	–	–
Flow	0	0

100'/20' N	April 2001	May 2001		April 2001	May 2001
Al	20U	–	pH	6.6	6.3
Cd	53.9	–	SC	1,330	148
Cu	407	–	T	2.9	2.9
Fe	20U	–	Redox	273	311
Zn	5,600	–	DO	11.75	–
SO_4	590	–	Flow	0	0

Drawpoint	April 2001	May 2001
pH	–	5.9
SC	–	181
T	–	6.5
Redox	–	267
DO	–	–
Flow	0	<1 ?

600' + 50'	April 2001	May 2001
pH	–	4.7
SC	–	514
T	–	4.8
Redox	–	371
DO	–	–
Flow	0	0



700' + 40'	April 2001	May 2001		April 2001	May 2001
Al	–	17,700	pH	5.4	4.2
Cd	–	89.8	SC	360	572
Cu	–	4,950	T	4.6	5.5
Fe	–	610	Redox	274	358
Zn	–	13,100	DO	12.48	–
SO_4	–	260	Flow	<1	5

215 Raise Drift	April 2001	May 2001
pH	–	3.6
SC	–	706
T	–	6.2
Redox	–	415
DO	–	–
Flow	–	2.5

215 Raise	April 2001	May 2001		April 2001	May 2001
Al	–	23,600	pH	–	3.6
Cd	–	114	SC	–	704
Cu	–	6,590	T	–	6.3
Fe	–	1,200	Redox	–	415
Zn	–	16,900	DO	–	–
SO_4	–	340	Flow	<1	–

1000'	April 2001	May 2001
pH	–	6.1
SC	–	177
T	–	5.9
Redox	–	285
DO	–	–
Flow	0	<0.5

No. 1 Shaft	April 2001	May 2001
pH	–	6.1
SC	–	137
T	–	7.8
Redox	–	305
DO	–	–
Flow	0	–

No. 1 Shaft Drift Raise	April 2001	May 2001
pH	–	6.1
SC	–	157
T	–	7.8
Redox	–	300
DO	–	–
Flow	–	0.2

LEGEND

- Approximate extent of underground workings for this mine level only
- Approximate extent of stope
- Raise/drawpoint
- Approximate water flow direction
- Water sampling location April/May 2001

Field parameter/measurement units:
- Specific conductivity (SC): mS/cm
- Temperature (T): °C
- Redox: (mv)
- Dissolved oxygen (DO): mg/L
- Flow: gpm

Water quality parameters:
- Dissolved metals: mg/L
- Sulfate (SO_4): mg/L

– Not measured/analyzed

Dissolved metals are not shown for locations where only field parameters were collected.

N

0 600 1,200
Scale in Feet

Figure 2-32
April/May 2001 Geochemical Assessment Sampling Locations 1100 Level

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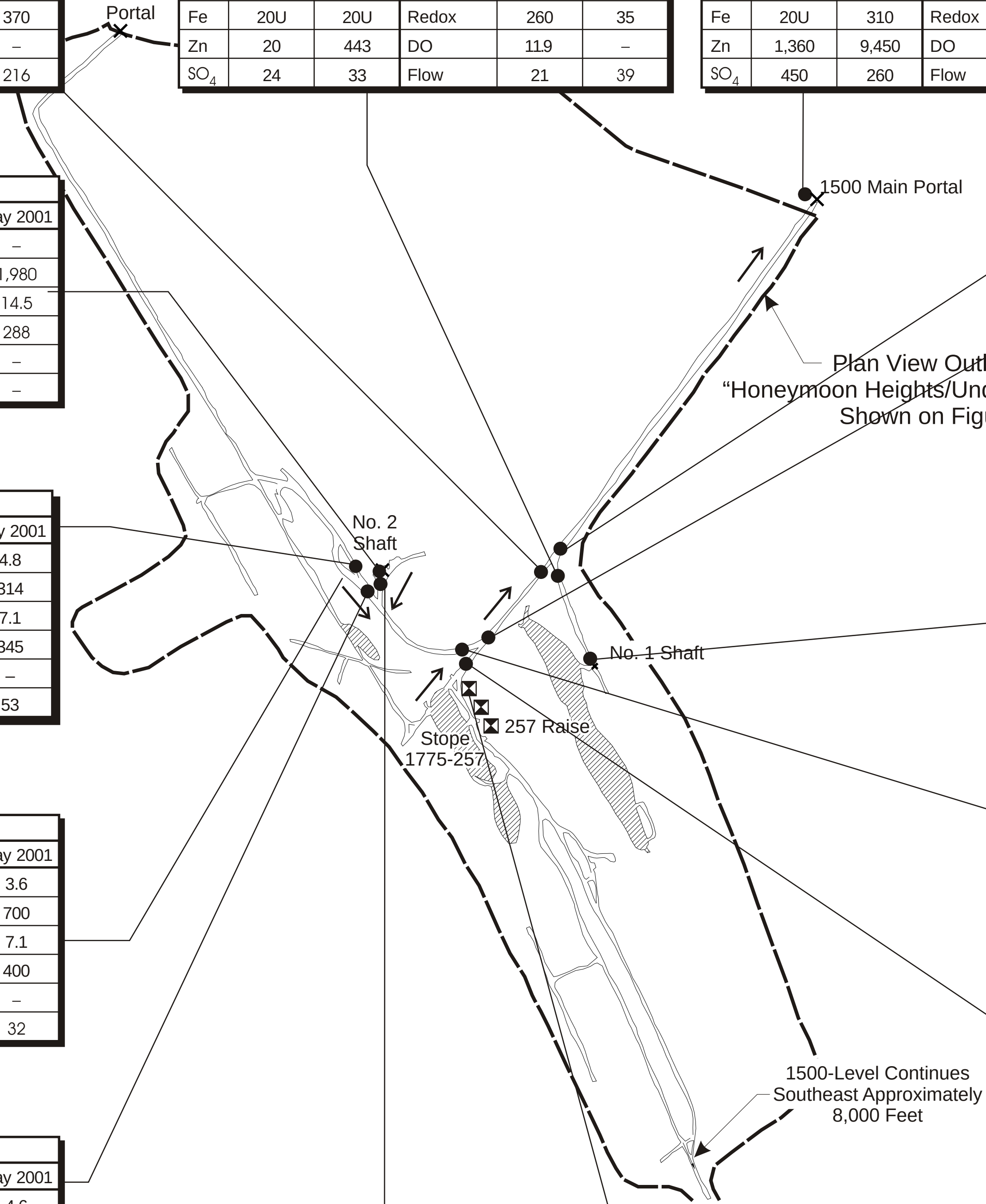

1500' + 80'/#2 Shaft

	April 2001	May 2001		April 2001	May 2001
Al	180	13,500	pH	6.2	4.5
Cd	5	90.6	SC	1,270	877
Cu	177	4,100	T	10.1	9.3
Fe	580	770	Redox	315	370
Zn	1,860	16,700	DO	12.3	–
SO_4	530	460	Flow	37	216

1500' + 80'/#1 Shaft

	April 2001	May 2001		April 2001	May 2001
Al	20	20U	pH	7.0	8.0
Cd	0.3	4.3	SC	137	168
Cu	5.2	190	T	9.2	9.3
Fe	20U	20U	Redox	260	35
Zn	20	443	DO	11.9	–
SO_4	24	33	Flow	21	39

P1

	April 2001	May 2001		April 2001	May 2001
Al	20	4,410	pH	6.2	4.9
Cd	3.7	50.2	SC	1110	602
Cu	48.5	2,240	T	4.7	6.8
Fe	20U	310	Redox	301	342
Zn	1,360	9,450	DO	13.1	–
SO_4	450	260	Flow	55	140

1500' + 80'/Main

	April 2001	May 2001
pH	6.3	4.8
SC	942	693
T	9.7	9
Redox	297	358
DO	–	–
Flow	–	130

#2 Shaft Surface

	April 2001	May 2001		April 2001	May 2001
Al	20	20U	pH	6.9	–
Cd	0.2	0.2U	SC	2,140	1,980
Cu	1.0	1.5	T	14.7	14.5
Fe	4,630	4,860	Redox	296	288
Zn	6	7	DO	1.6	–
SO_4	1,000	910	Flow	–	–

1900' + 30'/Main

	April 2001	May 2001
pH	6.1	–
SC	1330	–
T	10.5	–
Redox	320	–
DO	–	–
Flow	–	–

2600' Ventilator NE Fork

	April 2001	May 2001
pH	–	4.8
SC	–	314
T	–	7.1
Redox	–	345
DO	–	–
Flow	–	53

2000' + 21'/#1 Shaft

	April 2001	May 2001		April 2001	May 2001
Al	30	90	pH	6.7	7.1
Cd	8	13.6	SC	153	194
Cu	199	519	T	8.8	8.5
Fe	20U	20U	Redox	276	115
Zn	613	1,330	DO	12.0	–
SO_4	49	55	Flow	–	–

2000' + 30'/#2 Shaft

	April 2001	May 2001		April 2001	May 2001
Al	–	270	pH	6.4	5.5
Cd	–	21.5	SC	1540	985
Cu	–	1,000	T	11.2	9.7
Fe	–	1,150	Redox	317	339
Zn	–	3,430	DO	–	–
SO_4	–	490	Flow	33	210

215 Raise

	April 2001	May 2001		April 2001	May 2001
Al	–	23,600	pH	–	3.6
Cd	–	75.6	SC	–	700
Cu	–	4,610	T	–	7.1
Fe	–	1,410	Redox	–	400
Zn	–	13,100	DO	–	–
SO_4	–	310	Flow	–	32

2000' + 30'/Main

	April 2001	May 2001		April 2001	May 2001
Al	14,300	29,200	pH	3.8	3.4
Cd	18.2	172	SC	637	888
Cu	1,220	7,720	T	8.9	8.8
Fe	910	1,350	Redox	409	419
Zn	7,060	34,000	DO	13.3	–
SO_4	300	400	Flow	–	58

2400' + 80'/Ventilator

	April 2001	May 2001		April 2001	May 2001
Al	40	7,570	pH	6.9	4.6
Cd	0.5	38.5	SC	152	377
Cu	12.8	2,520	T	7.7	7.3
Fe	20U	140	Redox	272	376
Zn	266	6,120	DO	13.2	–
SO_4	41	150	Flow	17	34

2400' + 70'/#2 Shaft

	April 2001	May 2001		April 2001	May 2001
Al	20U	20U	pH	6.9	6.3
Cd	0.2U	0.2U	SC	2,030	1,970
Cu	0.9	1.3	T	13.4	13.2
Fe	2,570	2,730	Redox	312	309
Zn	11	6U	DO	4.9	–
SO_4	1,000	950	Flow	22	38

247 Raise

	April 2001	May 2001
pH	–	–
SC	–	–
T	–	–
Redox	–	–
DO	–	–
Flow	–	16

LEGEND

- Approximate extent of underground workings for this mine level only
- Approximate extent of stope
- Raise/drawpoint
- Approximate water flow direction
- Water sampling location April/May 2001

Field parameter/measurement units:
- Specific conductivity (SC): mS/cm
- Temperature (T): °C
- Redox: (mv)
- Dissolved oxygen (DO): mg/L
- Flow: gpm

Water quality parameters:
- Dissolved metals: mg/L
- Sulfate (SO_4): mg/L

– Not measured/analyzed

Dissolved metals are not shown for locations where only field parameters were collected.

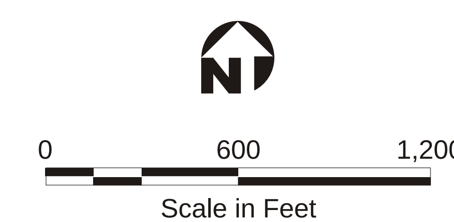

Figure 2-33
April/May 2001 Geochemical Assessment Sampling Locations 1500 Level

Job No. 33750803

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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 2-34
Railroad Creek Watershed Structural Geology Map

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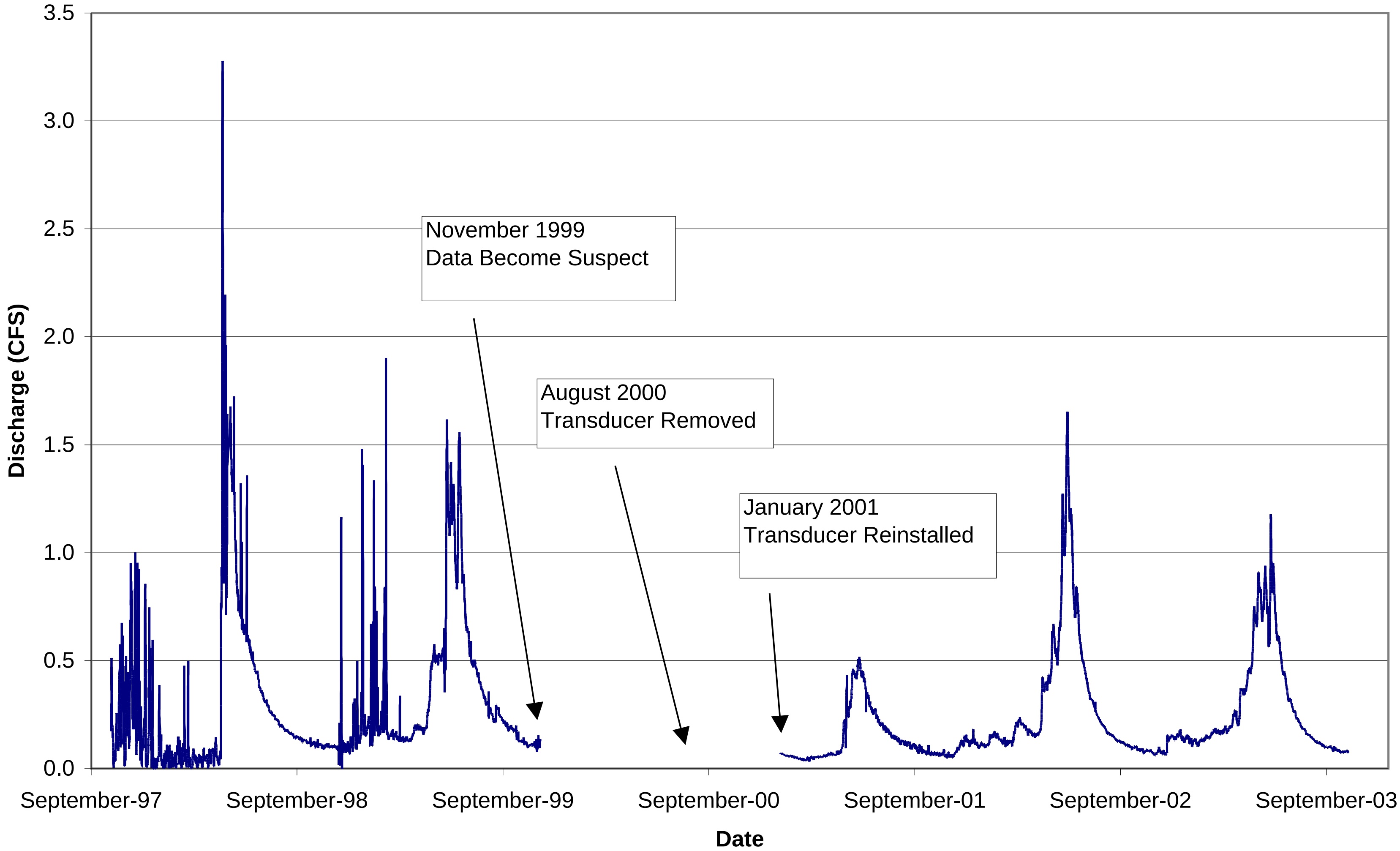

Figure 2-35
Discharge vs. Time
Portal Drainage (P-1)

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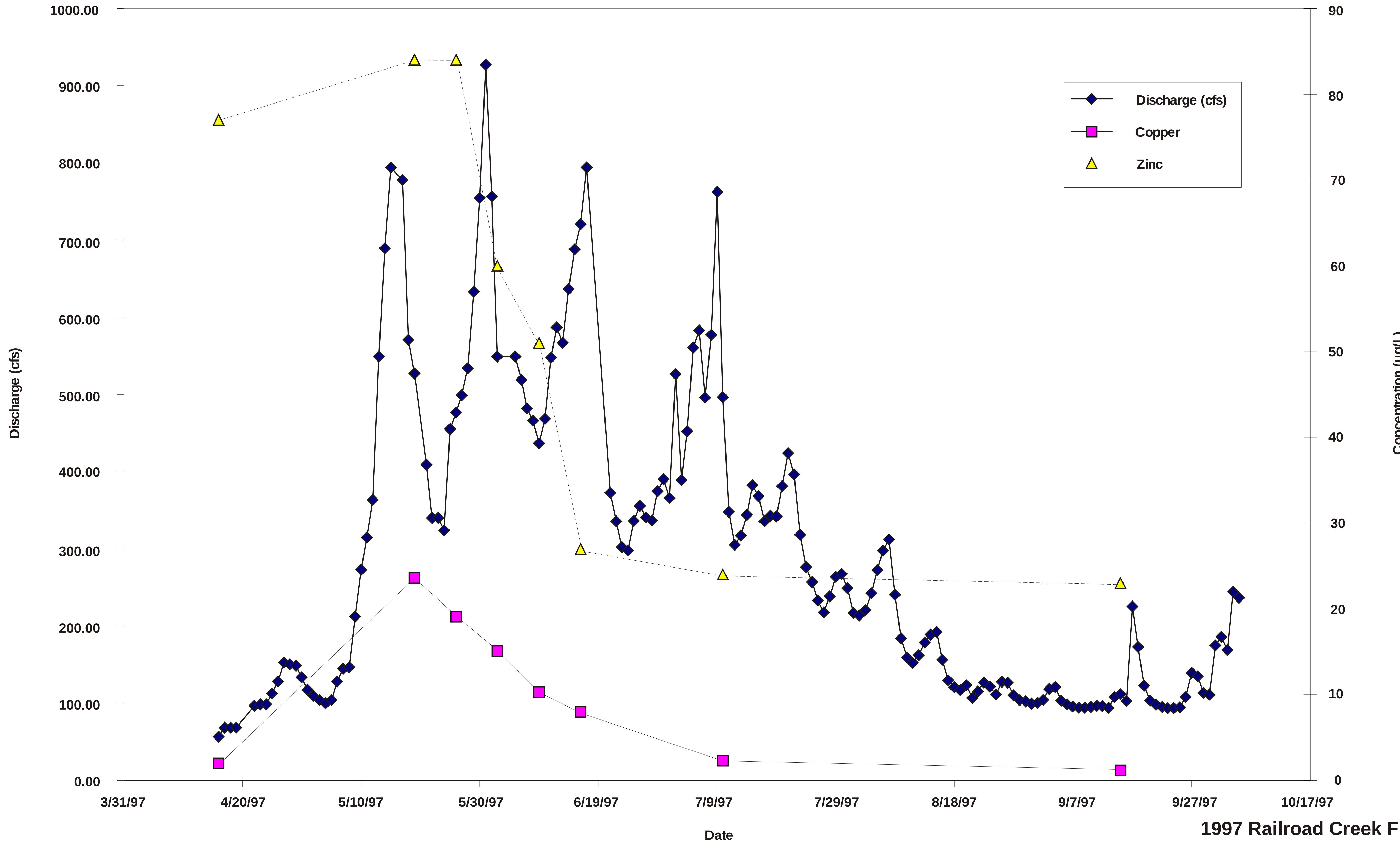

Figure 2-36
1997 Railroad Creek Flow (RC-4) vs. Copper and Zinc Concentration (µg/L) at RC-2

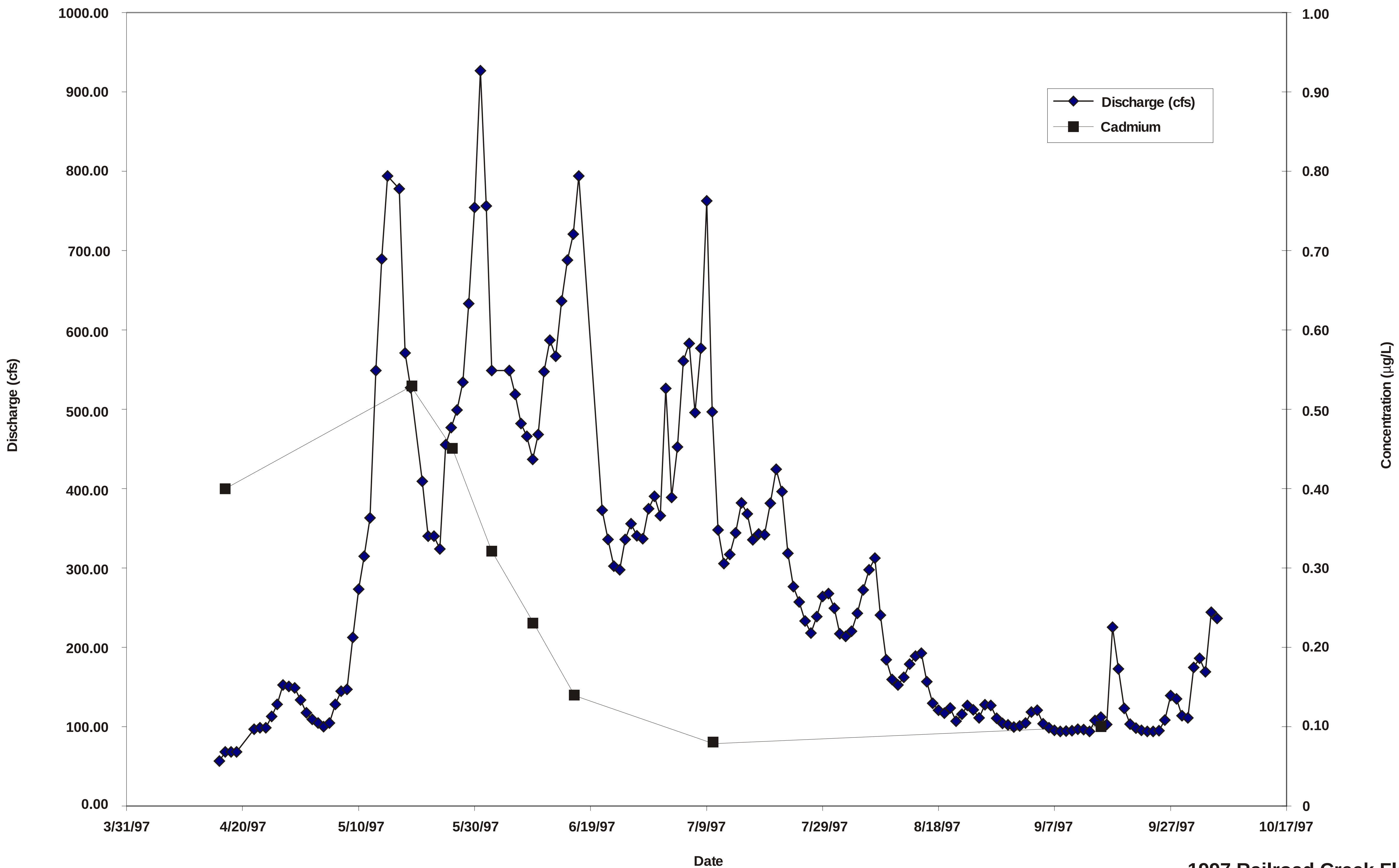

Figure 2-37
1997 Railroad Creek Flow (RC-4) vs. Cadmium Concentration (µg/L) at RC-2

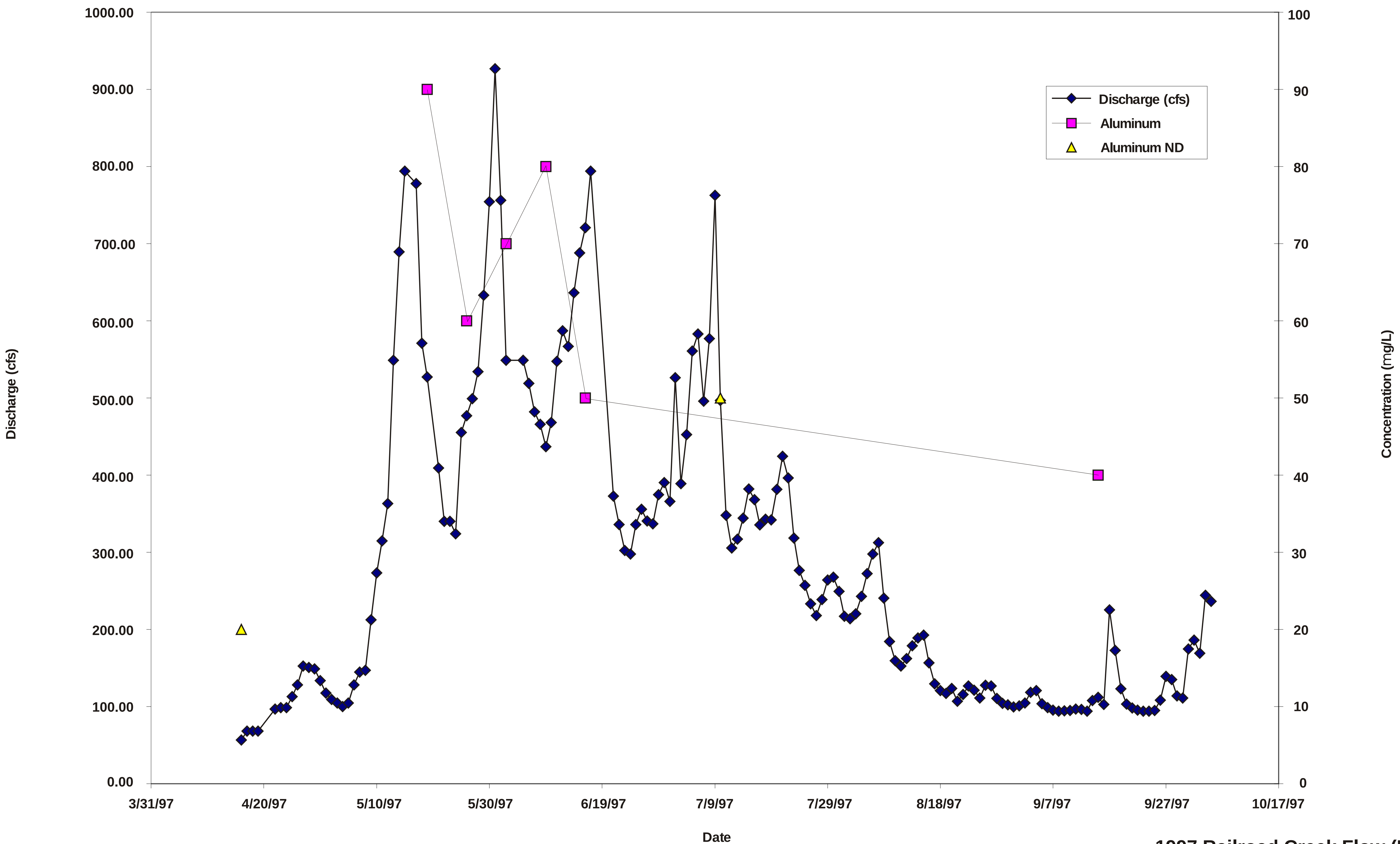

Figure 2-38
1997 Railroad Creek Flow (RC-4) vs. Aluminum Concentration (g/L) at RC-2

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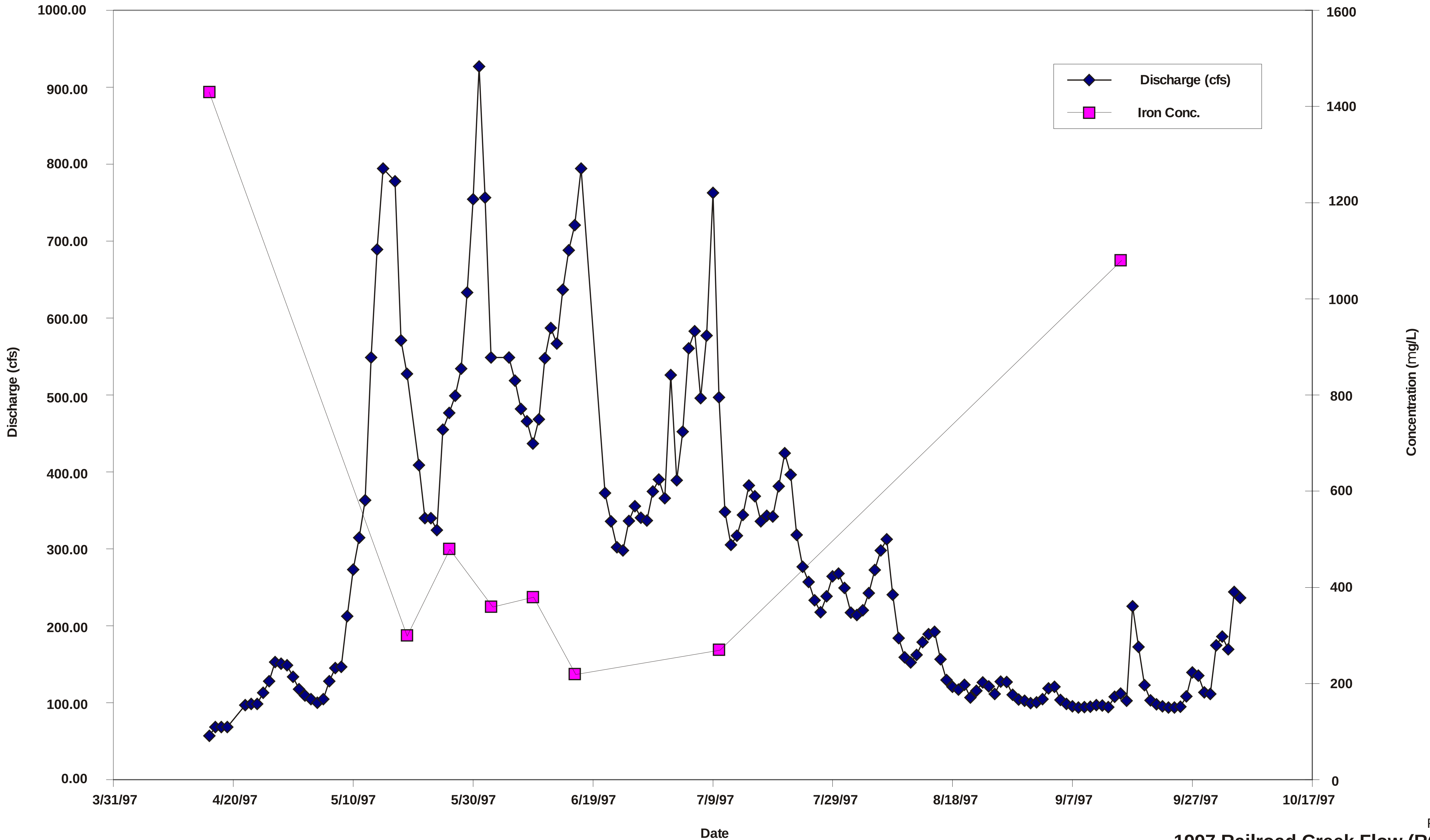

Figure 2-39
1997 Railroad Creek Flow (RC-4) vs. Iron Concentration (g/L) at RC-2

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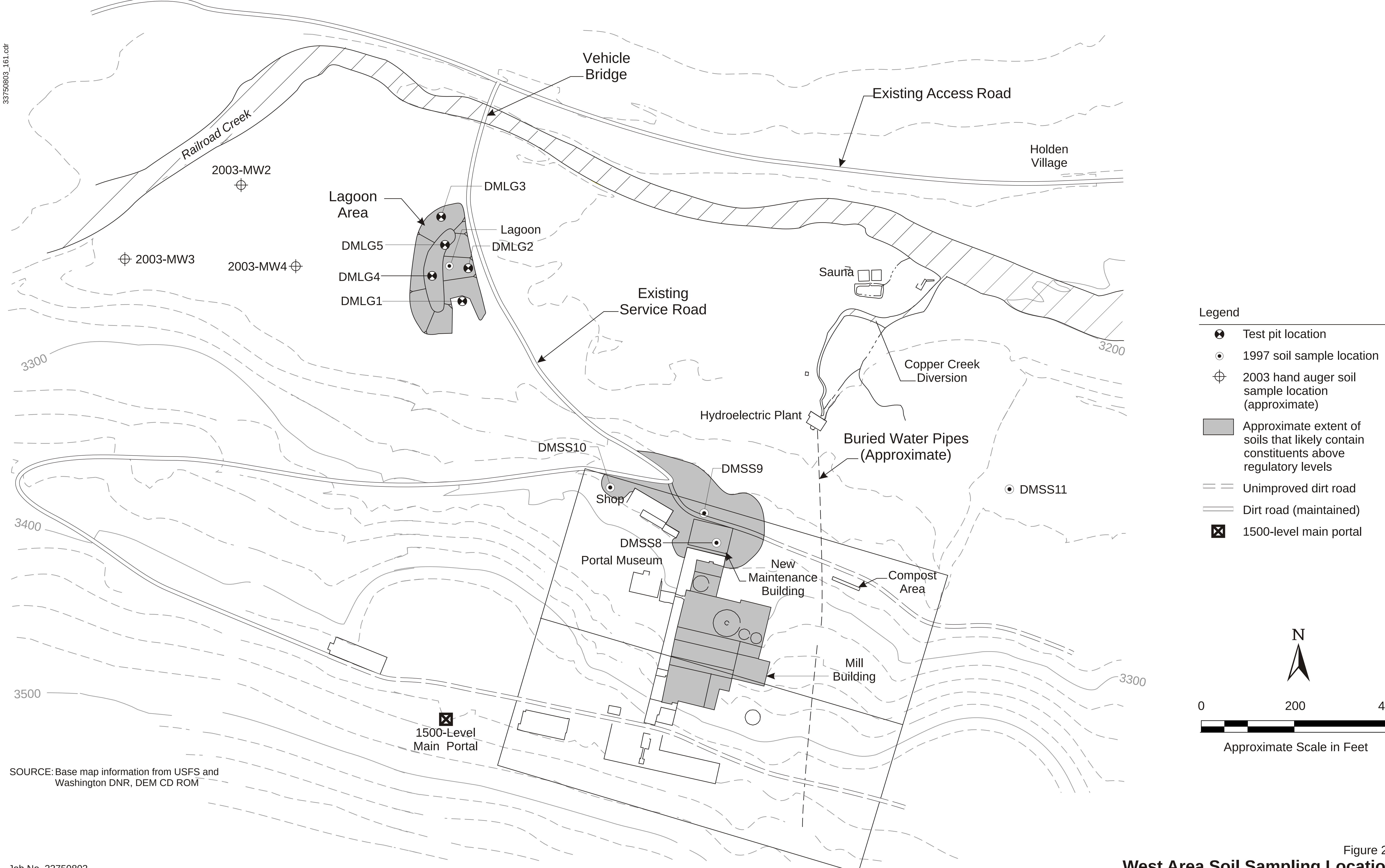

SOURCE: Base map information from USFS and Washington DNR, DEM CD ROM

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Figure 2-40
West Area Soil Sampling Locations

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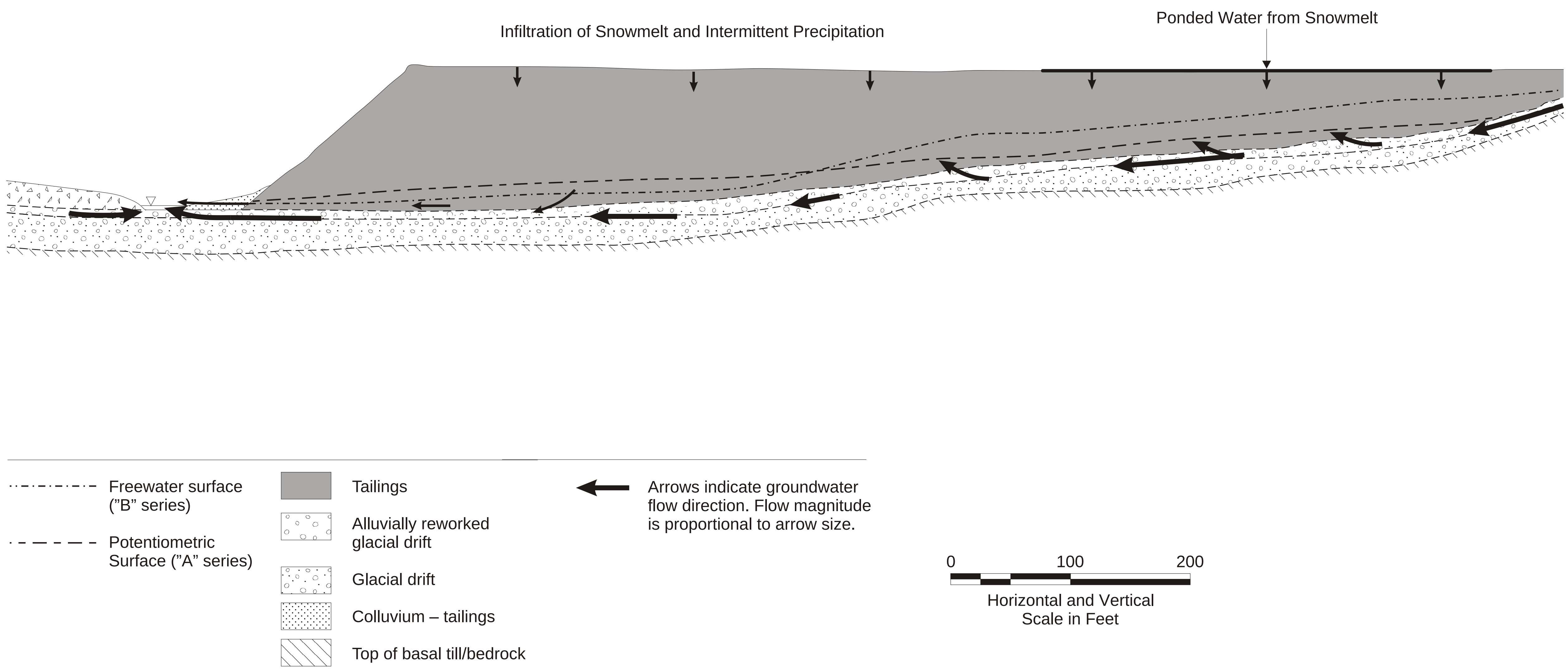

Figure 2-41
Conceptual Hydrogeologic Cross Section
Tailings Piles 1, 2, and 3 - May

Job No. 33750803

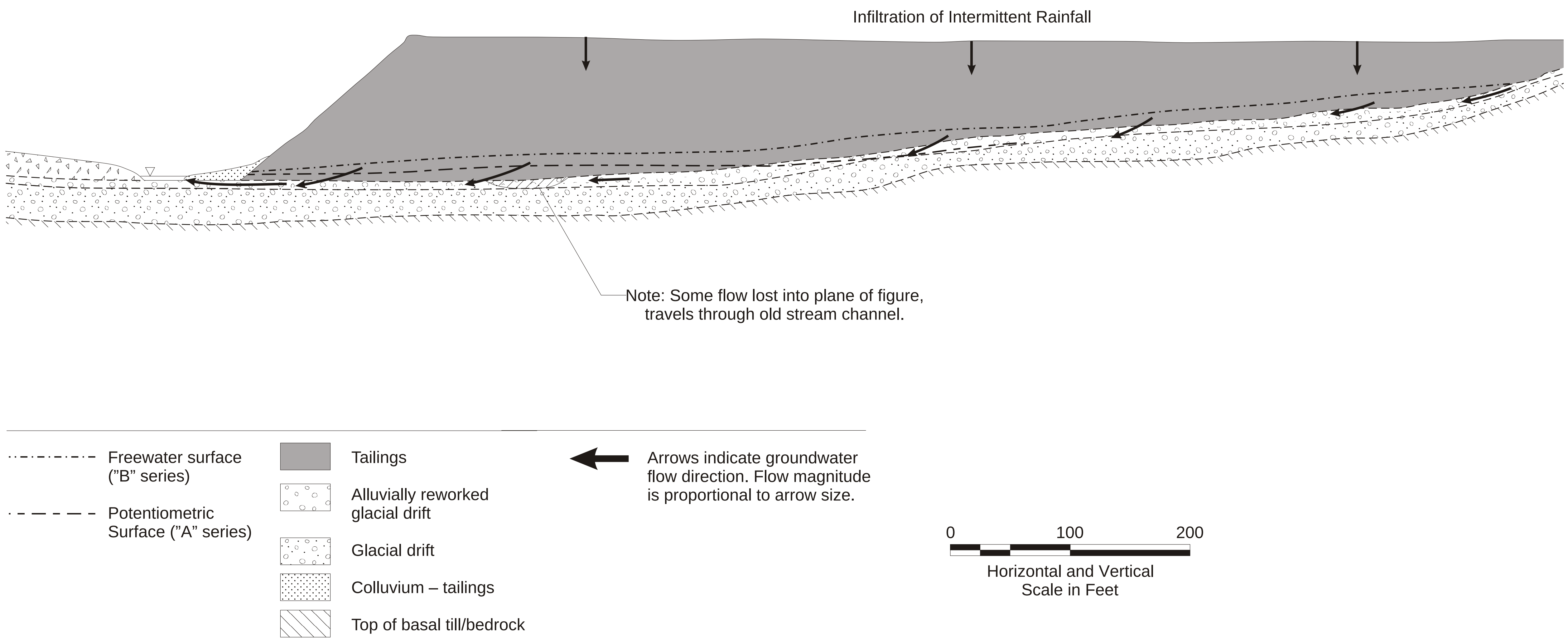

Figure 2-42

Conceptual Hydrogeologic Cross Section
Tailings Piles 1, 2, and 3 - September

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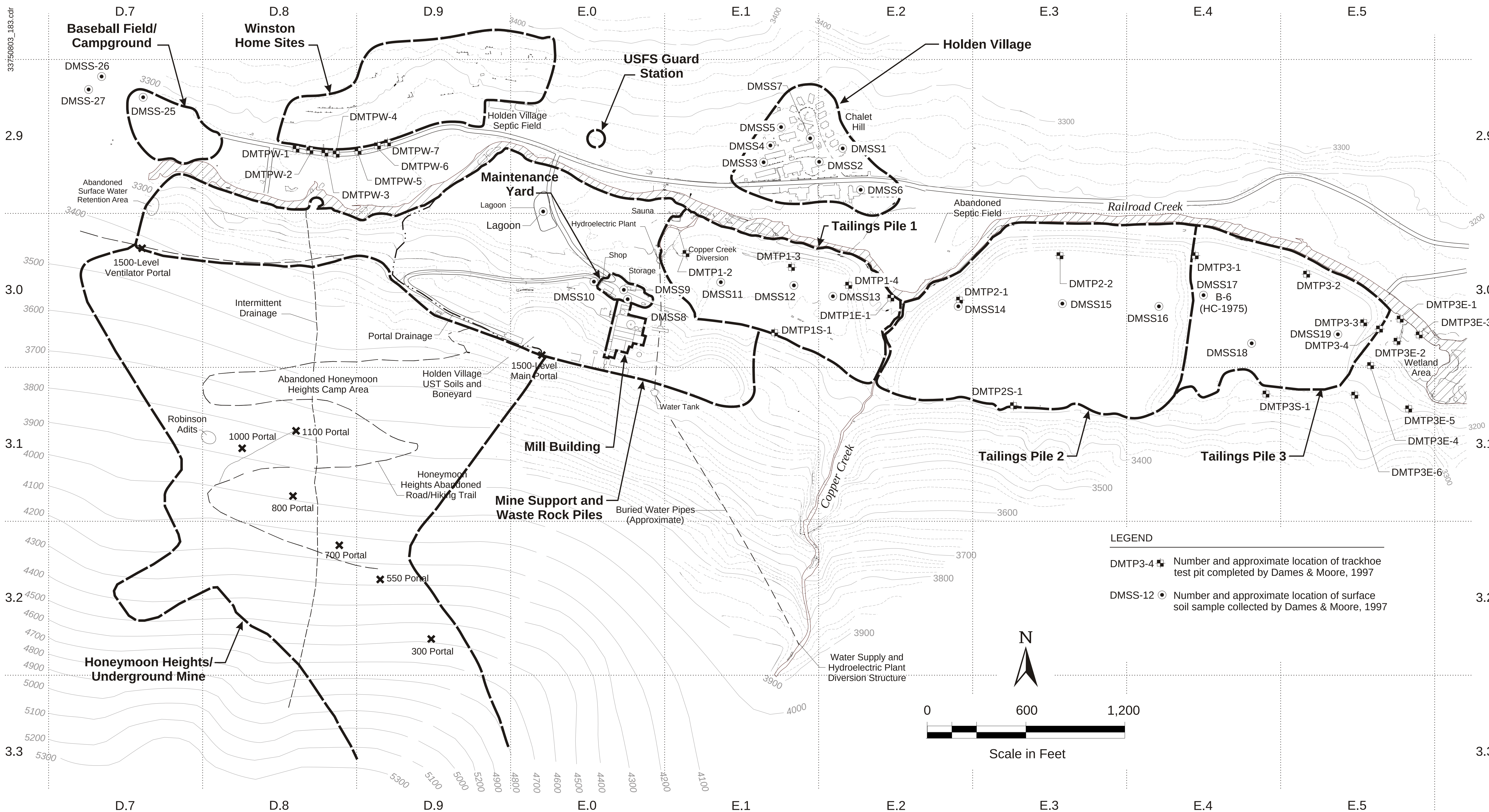
Job No. 33750803

Figure 2-43

Streamflow and Water Quality Monitoring Stations - Railroad Creek



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

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Figure 2-44
RI Soil Investigation Locations

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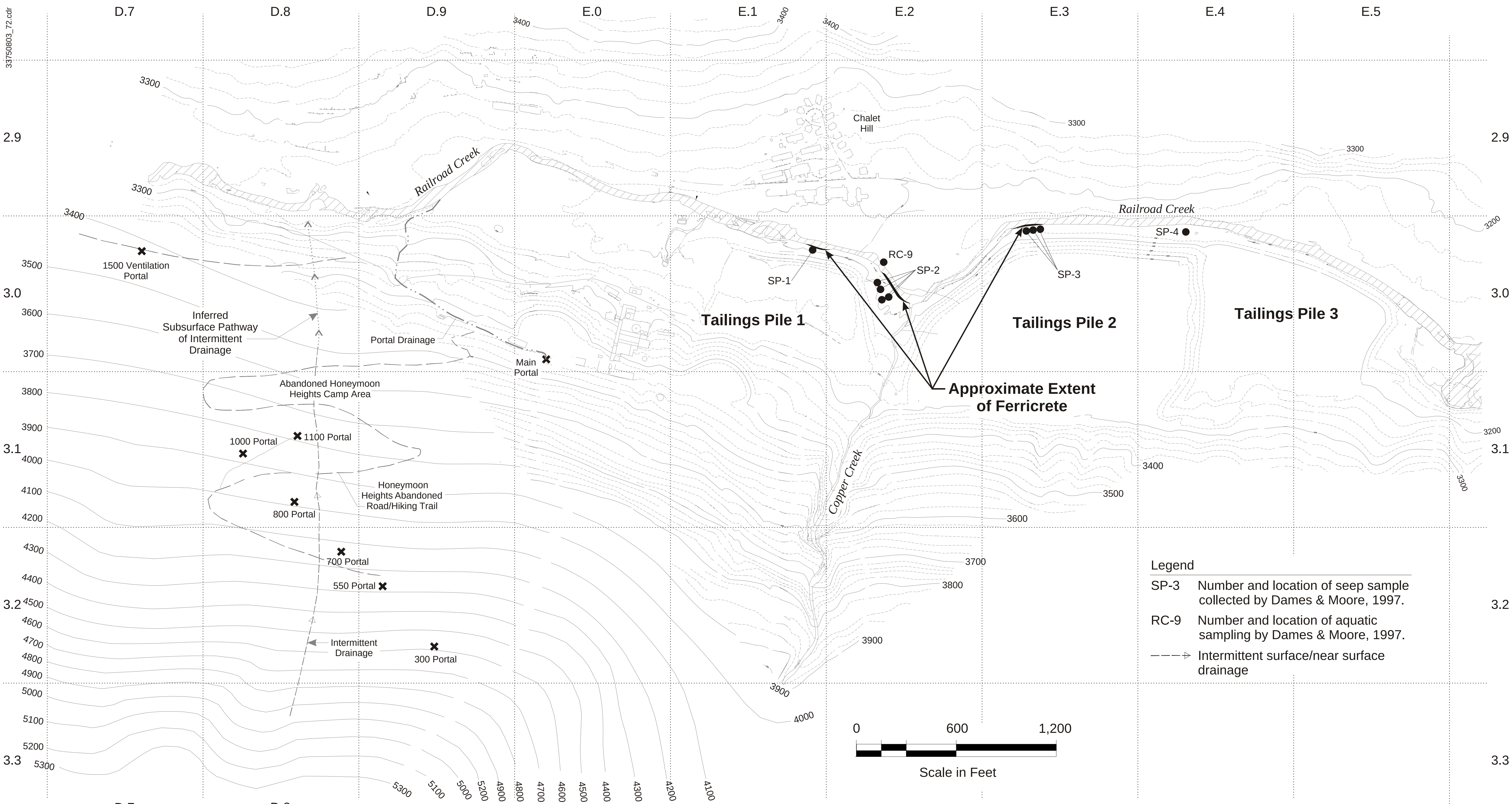

SOURCES: Base map information from USFS and Washington DNR, DEM CD ROM
USBM (unpublished), 1994
Dames & Moore RI, 1997

Figure 2-45
Approximate Extent of Exposed Ferricrete in Railroad Creek

Job No. 33750803

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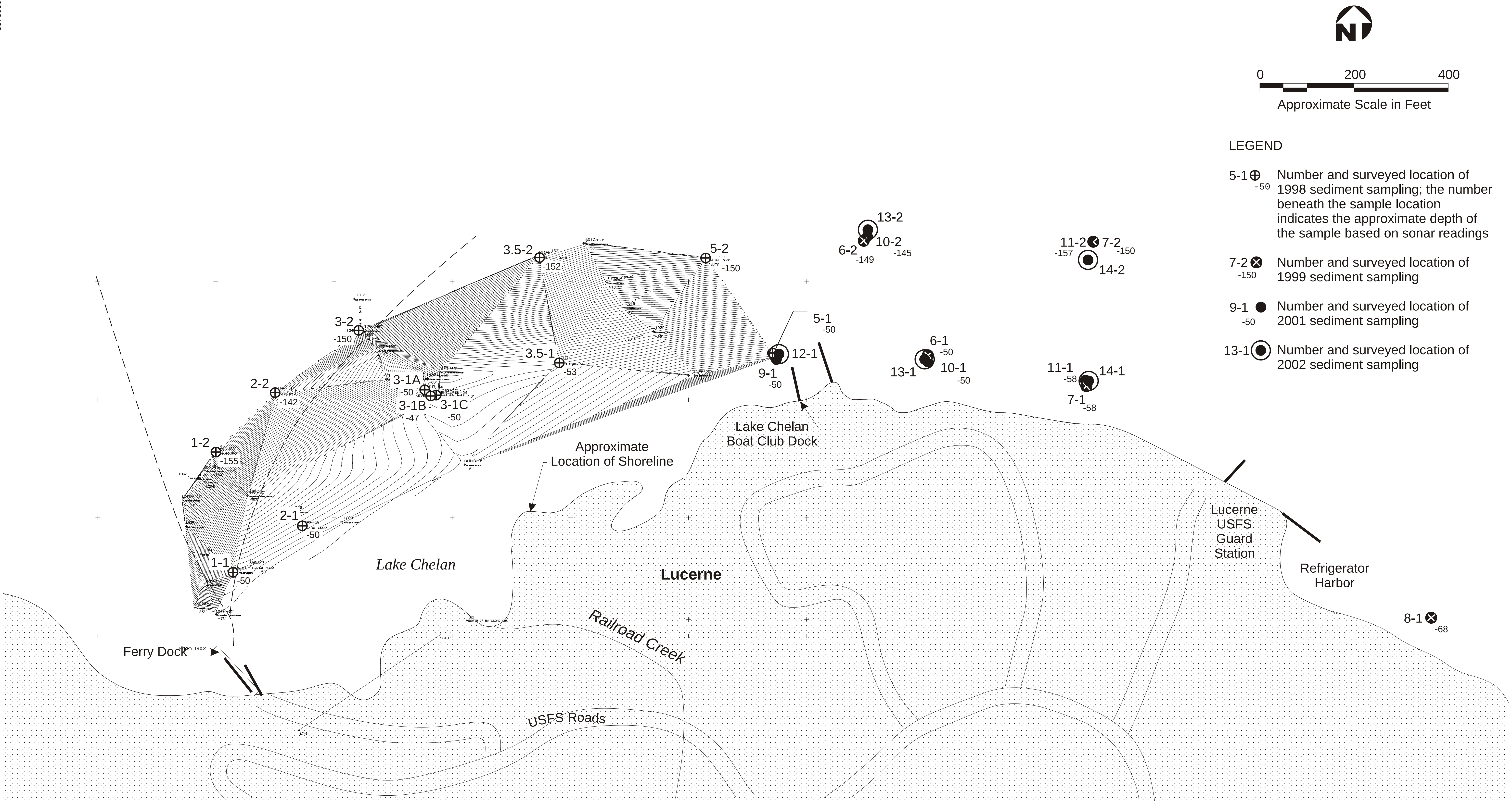

Figure 2-46
Lucerne Sediment Sample Locations 1998-2002

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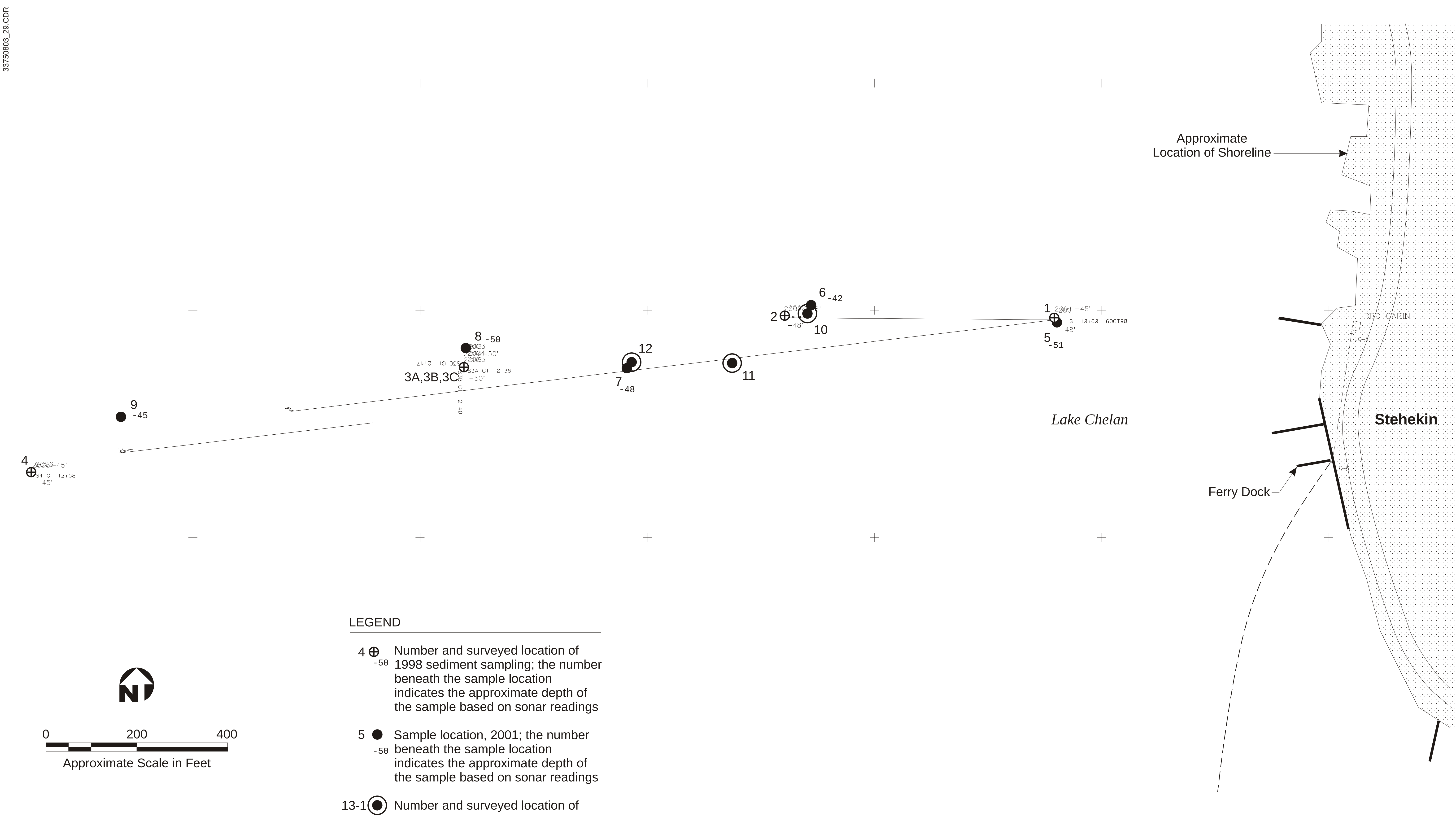

Figure 2-47
Stehekin River Watershed
Reference Sediment Sampling Locations

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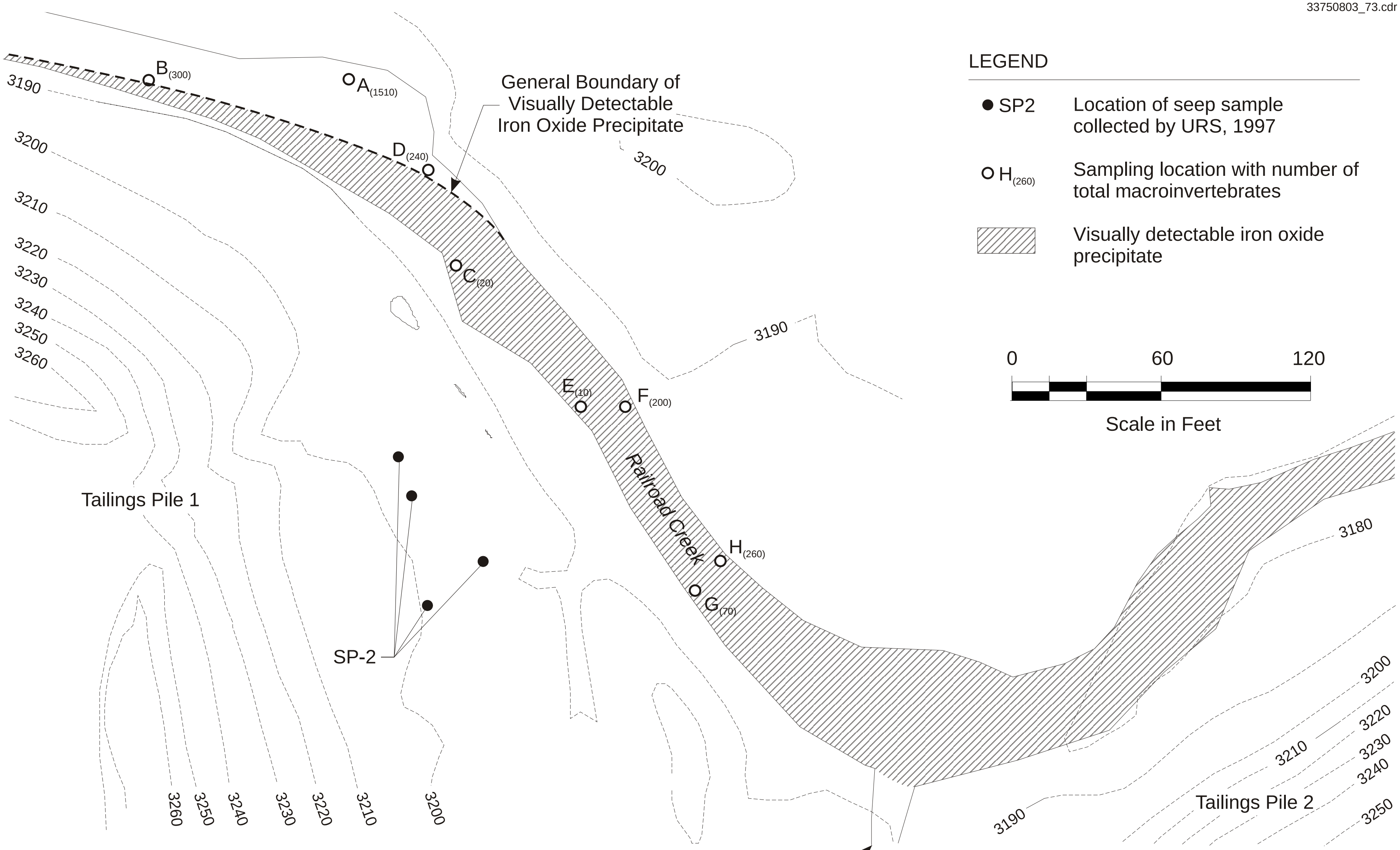

SOURCE: Base map information from USFS and Washington DNR, DEM CD ROM

Job No. 33750803

Figure 2-48

1997 Aquatic Sampling
RC-9 Benthic Macroinvertebrate Replicate Results
(Number of Organisms/m²)

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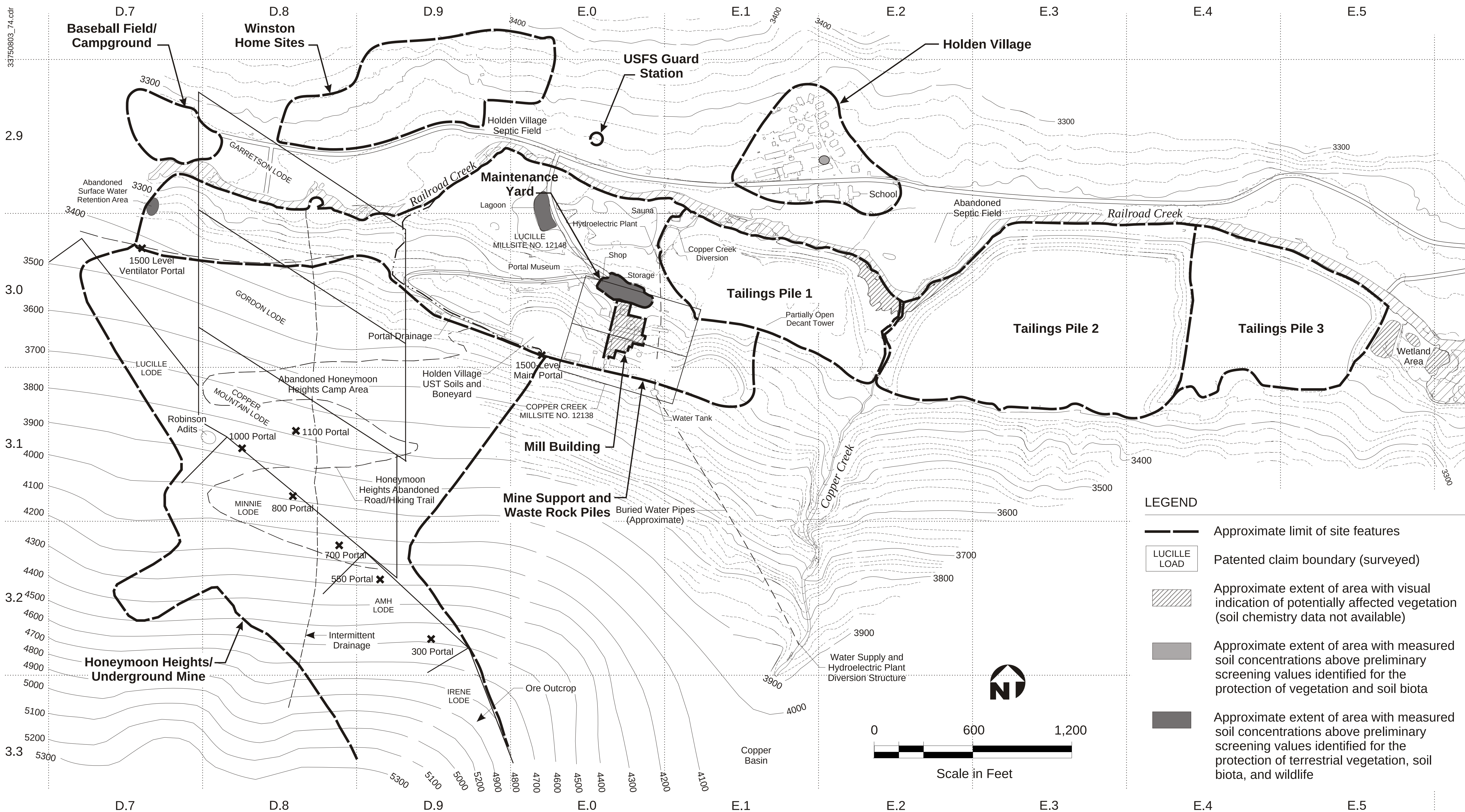

SOURCE: Base map information from USFS and Washington DNR, DEM CD ROM

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Figure 2-49

Approximate Extent of Potentially Affected Terrestrial Vegetation, Soil Biota, and\or Wildlife

3.0 POTENTIALLY APPLICABLE OR RELEVANT AND APPROPRIATE REQUIREMENTS

Remedial actions under CERCLA must meet standards, requirements, criteria, or limitations that are determined to be "applicable or relevant and appropriate requirements" (ARARs). CERCLA section 121(d) (42 U.S.C. 9621(d)) requires that remedial response actions selected under CERCLA attain a level or standard of control of hazardous substances that complies with ARARs of federal environmental laws and more stringent state environmental and facility siting laws identified in a timely manner.

The identification of ARARs is an iterative process throughout the RI/FS. The state and federal laws and regulations discussed in this FS are identified as potential ARARs. The final determination of ARARs will be made as part of the final remedy selection. Several terms used throughout this section are defined below:

Applicable Requirements. Under the National Contingency Plan (NCP), applicable requirements are defined as, "those cleanup standards, standards of control and other substantive requirements, criteria or limitations promulgated under federal environmental or state environmental or facility siting laws that specifically address a hazardous substance, pollutant, contaminant, remedial action, location, or other circumstance found at a CERCLA site" [40 CFR 300.5].

Relevant and Appropriate Requirements. Relevant and appropriate requirements are, "those cleanup standards, standards of control, and other substantive requirements, criteria, or limitations promulgated under federal environmental or state environmental or facility siting laws that, while not "applicable" to a hazardous substance, pollutant, contaminant, remedial action, location, or other circumstance at a CERCLA site, address problems or situations sufficiently similar to those encountered at the CERCLA site that their use is well suited to the particular site" [40 CFR 300.5].

To-Be-Considereds (TBCs). TBCs are non-promulgated advisories or guidance issued by federal or state government that are not legally binding and do not have the status of potential ARARs.

State Standards. State standards are ARARs if they are "promulgated, are identified by the state in a timely manner, and are more stringent than federal requirements." The term "promulgated" means that the standards are of general applicability and are legally enforceable [40 CFR 300.400(g)(4)].

Substantive Standards. CERCLA 121(e), 42 U.S.C. 9621(e), states that no federal, state or local permits are required for remedial actions conducted entirely on site. On site remedial actions, however, must meet the ARARs substantive requirements. Actions that occur off site are subject to the full requirements of federal, state, and local regulations.

ARAR Waiver Criteria. CERCLA 121(d)(4), 42 U.S.C. 9621(d)(4), provides that ARARs may be waived under certain circumstances. The waiver criteria include the following:

- The remedial action is being conducted as an interim measure;
- Compliance with the ARAR would result in greater risk to health and the environment;
- Compliance with the ARAR is technically impractical;
- Equivalent standard of performance;
- Inconsistent application of state requirements; and
- Fund balancing (applicable to Superfund-funded sites only).

No ARAR waivers are specifically identified or requested in this FS as Intalco believes such ARAR waivers are not necessary. Intalco, however, plans to submit documentation under separate cover demonstrating how ARAR waivers and other mechanisms allowable under state and federal law may be utilized.

The following subsections provide summaries of potential chemical-specific, location-specific, and action-specific ARARs identified for the Holden Mine Site. Potential ARARs are also summarized in Tables 3-1 through 3-6.

3.1 POTENTIAL CHEMICAL-SPECIFIC ARARS

Chemical-specific ARARs are health-based or risk-based numerical values or methodologies, which when applied to site-specific conditions, result in establishment of numerical values. The values establish the acceptable amount or concentration of a hazardous substance that may be found in or discharged to the environment. A summary of the potential chemical-specific ARARs identified for the Holden Mine Site is presented in Table 3-1. Numerical values for the potential chemical-specific ARARs are presented in Tables 3-2, 3-3a, 3-3b, 3-4a, and 3-4b, for groundwater, surface water and soils, respectively. The numerical values for the potential chemical-specific ARARs are indicated on Tables 3-2 through 3-4 for the PCOCs identified for each media. The PCOCs are those substances on-site that exceeded a potential chemical specific ARAR.

Groundwater at the site has no present or reasonably foreseeable use for drinking water purposes. Although MTCA requires consideration of the potential beneficial use of site groundwater, the relevant and appropriate requirements presented in this section must be considered in light of this present and future intended and planned use as a non-potable, non-drinking water use.

3.1.1 Safe Drinking Water Act (42 USC 300 et. seq.); National Primary Drinking Water Regulations (40 CFR Part 141.61(a) and (c), 141.62(b))

The federal primary drinking water regulations establish health-based maximum contaminant levels (MCLs) for public water systems. Although Site groundwater and surface water, including Railroad Creek, Copper Creek downstream of the Holden Village water structure, and Lake Chelan, are not public water systems, the federal MCLs are potentially relevant and appropriate requirements for these waters. Railroad Creek, Copper Creek, and Lake Chelan are not specifically listed in the Washington State Water Quality Regulations (Chapter 173-201A

WAC) but are generally categorized as having a potential designated use as a domestic water supply. The primary MCLs that are potentially relevant and appropriate for the PCOCs in groundwater and surface water are presented in Table 3-2 and Tables 3-3a and 3-3b, respectively. The MCLs are not exceeded in any Site surface waters.

3.1.2 Safe Drinking Water Act (42 USC 300 et. seq.); National Maximum Contaminant Level Goals (40 CFR Part 141.50(b) and 141.51(b))

MCL Goals (MCLGs) are non-enforceable health goals for public water systems. CERCLA 121(d)(2) and the NCP (40 CFR 300) require consideration of non-zero MCLGs where such goals are relevant and appropriate under the circumstances of the release. These non-enforceable goals are potentially relevant and appropriate to groundwater and surface water at the Site. Non-zero MCLGs for the PCOCs in groundwater and surface water at the Site are equal to the MCLs. Therefore, non-zero MCLGs are not considered a potential ARAR, but are provided on Tables 3-2, 3-3a, and 3-3b for illustrative purposes only.

3.1.3 Washington State Department of Health Drinking Water Standards (RCW 70.19A; WAC 246-290-310(3) and (8))

The Washington Department of Health (WDOH) primary drinking water regulations establish primary MCLs for public water systems. Those state MCLs that are more stringent than federal primary MCLs are potentially relevant and appropriate to groundwater and surface water at the Site. Nickel is the only Washington State MCL that is more stringent than the federal MCL and is potentially relevant and appropriate to groundwater as shown in Table 3-2. However, the state MCL for nickel is not exceeded in Railroad Creek, Copper Creek or Lake Chelan, and thus is not a surface-water PCOC.

3.1.4 Safe Drinking Water Act (42 USC 300 et. seq.) National Secondary Drinking Water Regulations (40 CFR 143.3); Washington State Department of Health Secondary Drinking Water Standards (RCW 70.19A; WAC 246-290-310(3))

The EPA and WDOH have established secondary drinking water requirements for public water systems. These secondary MCLs are not health-based standards, but based upon aesthetic criteria. These federal and state secondary MCLs are not potential ARARs for groundwater and surface water at the Holden Mine Site.[1]

3.1.5 Washington State Water Quality Standards for Surface Waters (RCW 90.48; WAC 173-201A-240 (3) and (5), WAC 173-201A-400 through –450 and WAC 173-201A-600)

Under Section 303(c) of the Clean Water Act (CWA), states are required to designate water body uses and adopt state surface water quality criteria (SWQC) based those uses. In promulgating SWQC, states are to consider national recommended water quality criteria (NRWQC) published by the EPA under Section 304(a) of the CWA.

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[1] Forest Service, July 28, 2003, Attachment 1, page 5.

The State of Washington has designated uses specifically and generally for surface waters of the state and established SWQC for the protection of human health and aquatic life. As discussed below, the National Toxics Rule (NTR) is the established human-health based criteria for surface waters in Washington State and is incorporated by reference into Chapter 173-201A WAC. Thus, the NTR are the potentially applicable human-health based criteria for surface water bodies of the state with potential domestic water supply uses.

For aquatic life criteria, the State of Washington, after review of the NRWQC, established criteria for hazardous substances in freshwater water and marine water bodies. These aquatic life criteria are identified in WAC 173-201A-240(3).

As previously discussed, Railroad Creek, Copper Creek and Lake Chelan are generally identified as having potential designated uses for domestic water supply (i.e., human health) and aquatic life. These SWQC are potentially applicable to surface water at the Holden Mine Site. Where hazardous substances in groundwater are likely to reach surface water, the SWQC may be potentially relevant and appropriate to groundwater at the Site. The SWQC that are potentially applicable to the PCOCs in surface water are presented in Table 3-3a and 3-3b.

The State of Washington has not specifically designated uses for Railroad Creek and Copper Creek; the uses currently identified in Chapter 173-201A WAC are only a general categorization. WAC 173-201A-410 through -450 specify requirements for applying or modifying the use designations and SWQC on a site-specific basis. These include but are not limited to, establishment of short-term water quality modification, applying for a variance, development of site-specific water quality criteria, conducting a use attainability analysis, and applying for water quality offsets. These requirements are potentially applicable to establishing potential chemical-specific ARARs for groundwater and surface water at the Site.

Intalco has submitted to the Agencies technical documentation demonstrating that the SWQC are based upon sensitive species that would not naturally inhabit Railroad Creek or Copper Creek and thus, the potential justification for a modification to the SWQC (Hansen 2003a). This documentation is provided in Appendix B. Although Intalco believes that a modification of the SWQC is not necessary, Intalco plans to submit separate documentation to the Agencies regarding how some or all of these requirements under Chapter 173-201A WAC may be utilized.

Under MTCA as discussed below, a mixing zone would be established for any point source discharges to surface waters at the Site (WAC 173-201A-410).

3.1.6 Federal Clean Water Act (33 USC 1251-1376)/ National Recommended Water Quality Criteria

CERCLA 121(d)(2)(B) states that remedial actions shall attain federal water quality criteria where they are relevant and appropriate under the circumstances of the release. This determination is based on the designated or potential use of the water, the media affected, the purposes for which the criteria were developed, and current information.

Federal National Recommended Water Quality Criteria (NRWQC) are developed pursuant to CWA section 304(a). The criteria include priority and non-priority pollutants. The NRWQC are not regulations, are not subject to public comment, and do not pose legally binding requirement on states. The NRWQC is published periodically by EPA and the states are given the option to consider and incorporate these criteria when promulgating state-specific water quality criteria. The most current publication of the NRWQC was issued by EPA in November 2002 (EPA 2002b).

MTCA states that criteria under the CWA section 304 should be considered in establishing potential cleanup levels for a site to the extent these criteria are relevant and appropriate for a specific surface water body or hazardous substance. The NRWQC current at the time the MTCA regulations were amended in 2001 were the 1999 NRWQC publication (EPA 1999a).

Intalco has provided legal justification and technical documentation showing that the NRWQC (1999 and 2002 publications) are not relevant and appropriate to the Holden Mine site. Intalco's justification has been presented in written correspondence with the Agencies between January and September 2003. This correspondence is part of the administrative record and is incorporated by reference into this FS. Intalco's rationale is summarized and presented in Appendix B.

Moreover, the NRWQC for iron and aluminum are not relevant or appropriate because these criteria are based upon out-dated scientific information (Hansen 2003b; Hansen 2004b). This fact has been acknowledged by EPA in its publication of the NRWQC[2] and the Agencies in their correspondence[3]. CERCLA 121(d)(2) requires that in determining the relevance and appropriateness of a requirement, consideration be given to whether the scientific basis of a potential criteria is current. Similarly, MTCA requires the scientific basis for information to be up-to-date (WAC 173-340-702(15) and (16)). The scientific basis for establishing the NRWQC for iron and aluminum dates back to 1972, and is not current (EPA, Water Quality Criteria Handbook, 1972, EPA-R3-73-033). Further, these criteria are under scrutiny by EPA.[4] A technical review of the NRWQC established for aluminum and iron are provided in Appendix B.

Intalco has submitted to the Agencies technical documentation demonstrating that the NRWQC for Site PCOCs are outdated, and/or based upon species that do not inhabit Railroad Creek or Copper Creek and thus, the NRWQC are not relevant and appropriate to the Holden Mine Site (Hansen 2003a; Hansen 2003b; Hansen 2004b).[5] A summary of Intalco's legal rationale, along with a technical review of the NRWQC established for Site PCOCs, is provided in Appendix B.

While reserving objections, including but not limited to those previously presented in correspondence between Intalco and the Agencies, Intalco has included the 2002 NRWQC and

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[2] (EPA 2002), page 26, Footnote L.

[3] (Forest Service 2003b), Attachment 1, page 17.

[4] Intalco's justification regarding iron was presented to the Agencies (Intalco 2003b), which the Agencies have yet to respond to. Regarding aluminum, it is clear that the aluminum NRWQC (chronic criteria) is out-dated and under scrutiny as EPA notes, "EPA is aware of field data indicating that many high quality waters in the U.S. contain more than 87 µg/L aluminum, when either total recoverable or dissolved is measured."

[5] (Intalco 2003a; Intalco 2003b, including Hansen 2003a/2003b; Intalco 2003c)

1999 NRWQC in the FS evaluations as required by the Agencies. These "Agency-required" potential ARARs for surface water are presented in Table 3-3b.

3.1.7 National Toxics Rule (33 USC 1251; 40 CFR 131.36(b)(1) and (d)(14); WAC 173-201A-240(5))

The federal National Toxics Rule (NTR) establishes water quality criteria for toxic substances for freshwater aquatic life and human health. The State of Washington has adopted by reference only the human-health based criteria as referenced in 40 CFR 131.36(d)(14) (WAC 173-201A-240(5)). The freshwater aquatic life criteria have not been adopted by the state of Washington and are not potentially applicable or relevant and appropriate. Only the human-health based standards specified in 40 CFR 13.36(d)(14) are potentially applicable to surface water at the Site. These human-health based ARARs are potentially relevant and appropriate to hazardous substances in groundwater that are likely to reach surface water. No human-health standards have been established under the NTR for the PCOCs in surface water or groundwater; therefore, the NTR is not considered a potential ARAR for surface water or groundwater at the Site.

3.1.8 Washington Model Toxics Control Act (RCW 70.105D, Chapter 173-340 WAC)

The Washington MTCA regulations specify criteria for setting cleanup standards for groundwater, surface water and soils. These regulations, identified below, are potentially applicable to setting cleanup standards for groundwater, surface water and soil at the Site. The MTCA Method B is the universal standard and may be used to establish cleanup standards at any Site. MTCA Method B levels for individual identified hazardous substances consider potentially applicable federal and state laws and risk equations, if applicable, as described in the regulations. Cleanup standards consider the cleanup level, point of compliance and other regulatory requirements that apply to the Site because of the type of action or location (WAC 173-340-700(3)).

3.1.8.1 Potential MTCA Surface Water Requirements

The following MTCA Method B requirements are potentially applicable to evaluating cleanup standards for Railroad Creek, Copper Creek, and Lake Chelan.

Potential Federal and State Laws. Under WAC 173-340-730(3)(b)(i), potential MTCA Method B cleanup levels will consider concentrations specified under state and federal laws. These potential laws include: SWQC specified in Chapter 173-201A WAC; NRWQC unless it can be demonstrated that such criteria are not relevant and appropriate for a specific surface water body or hazardous substance; and the NTR (40 CFR 131.36(d)(14)). These potential ARARs are discussed above and presented in Tables 3-3a and 3-3b.

Potential Environmental Effects. Under WAC 173-340-730(3)(b)(ii), where environmental effects-based concentrations have not been established under applicable federal and state law, concentrations that are estimated to result in no adverse effects on protection and propagation of wildlife, fish and other aquatic life. Potential ARARs have been established for all PCOCs, thus this requirement is not a potential ARAR for Site surface water.

Risk-Based Adjustment of Potential MTCA ARARs. Under WAC 173-340-730(5)(b), MTCA specifies that potential surface water ARARs have a human health based risk that is 1 x 10^{-5} or less for carcinogens or a hazard quotient of 1 or less for non-carcinogens. If the identified potential ARAR does not meet these standards, then the potential ARAR must be adjusted downward using the equations in Tables 730-1 and 730-2. This requirement is potentially applicable in evaluating the potential MCL ARAR for copper in surface water. The federal primary MCL for copper is potentially relevant and appropriate for surface water and is above the risk-based or hazard quotient factor. The adjusted value for the federal primary MCL for copper is provided in Tables 3-3a and 3-3b. The potential ARARs specified above for the other PCOCs in surface water meet these risk-based requirements; therefore, no adjustment is required.

Potential Human-Health Based Values. Under WAC 173-340-730(3)(b)(iii), where no federal or state standards exist for a contaminant, then the MTCA states that the preliminary cleanup standard will be the MTCA Method B levels for carcinogenic and non-carcinogenic substances. Since potential ARARs exist for the PCOCs at the Site, this requirement is not a potential ARAR. MTCA Method B levels for the PCOCs in surface water are presented in Tables 3-3a and 3-3b for illustrative purposes only.

Potential Domestic Water Supply Values. Under WAC 173-340-730(3)(b)(iv), where surface waters are designated as a potential domestic water supply use under Chapter 173-201A WAC, the potential cleanup standards for groundwater (WAC 173-340-720) may be considered. Railroad Creek, Copper Creek and Lake Chelan are generally categorized in Chapter 173-201A WAC as having a potential designated use as a domestic water supply.[6] As a result, this requirement is potentially applicable to these surface waters. Potential surface water cleanup standards identified for the PCOCs however, are more stringent and more protective than these potential groundwater cleanup levels and thus, these potential ARARs are met. These potential groundwater cleanup levels for the surface water PCOCs (federal and state primary MCLs, non-zero MCLGs, and MTCA Method B levels for groundwater) are presented in Tables 3-3a and 3-3b.

Adjustment for PQL and Background. Under WAC 173-340-730(5)(c), MTCA specifies that potential cleanup levels shall not be set below the practical quantification limit (PQL) or natural background concentrations, whichever is higher. Potential ARARs identified for the surface water PCOCs are above natural background and the PQL, with the exception of the potential Agency-required ARARs under the NRWQC for aluminum and cadmium. Available surface water quality data indicate that natural background concentrations of dissolved cadmium and total aluminum may seasonally exceed the NRWQC. Therefore, in evaluating the NRWQC for cadmium and aluminum in Site surface waters, these cleanup levels may need to be adjusted upward.

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[6] Although the Chapter 173-201A WAC generally categorizes these water bodies as potential domestic water supply uses, there is no present, planned, or intended foreseeable future use of these water bodies for drinking water as discussed above.

Conditional Point(s) of Compliance. Under WAC 173-340-730(6), MTCA specifies that the point of compliance for surface water cleanup will be the point or points at which hazardous substances are released to surface waters unless a mixing zone is established in accordance with Chapter 173-201A WAC. This requirement is potentially applicable to evaluating potential surface water cleanup standards in Railroad Creek, including the requirement that a mixing zone be established in accordance with Chapter 173-201A WAC, as discussed above.

3.1.8.2 Potential MTCA Groundwater Requirements

The following MTCA Method B requirements are potentially applicable to evaluating groundwater cleanup standards at the Site.

Potential Federal and State Laws. Under WAC 173-340-720(4)(b)(i), potential MTCA Method B levels consider concentrations specified under state and federal laws. These potential ARARs include: MCLs established under the Safe Drinking Water Act (40 CFR 141); MCLGs established under the SDWA (40 CFR 141) and MCLs established by the Washington DOH (Chapter 246-296 WAC). These potential ARARs are discussed above and are presented in Table 3-2.

Risk-Based Adjustment of Potential MTCA ARARs. Under WAC 173-340-720(7)(b), MTCA specifies that potential groundwater ARARs have a human health based risk that is 1 x 10^{-5} or less for carcinogens or a hazard quotient of 1 or less for non-carcinogens. If the potential ARAR does not meet these standards, then the potential ARAR must be adjusted downward using the equations in Tables 720-1 and 720-2. This requirement is potentially applicable in evaluating potential groundwater cleanup levels for copper. The MCL for copper that is potentially relevant and appropriate to groundwater is above the risk-based or hazard quotient factor. The adjusted MCL for copper is presented in Table 3-2.

Potential Surface Water Beneficial Use. Under WAC 173-340-720(4)(b)(ii), MTCA specifies that the potential concentrations established in accordance with the methods specified in WAC 173-340-730 (for surface water described above) may be applicable to groundwater cleanup where it is determined that the hazardous substances in the groundwater are likely to reach surface water. This requirement is potentially applicable to groundwater in the West Area and underneath the tailings piles that flow into Railroad Creek. These potential ARARs are presented for the surface water PCOCs in Tables 3-3a and 3-3b.

Potential Human-Health Based Values. Under WAC 173-340-720(4)(b)(iii), where no federal or state standards exist for a contaminant, then the MTCA states that the preliminary cleanup standard will be the MTCA Method B levels for carcinogenic and non-carcinogenic substances. Potential ARARs exist for all of the groundwater PCOCs at the Site except manganese and zinc for which MTCA Method B values are established. This potential ARAR is presented in Table 3-2 along with the potential MTCA Method B levels for other PCOCs, which are presented for illustrative purposes.

Adjustment for PQL and Background. Under WAC 173-340-720(7)(c), MTCA requires that cleanup levels shall not be set below the PQL or natural background concentrations, whichever is higher.

Conditional Point(s) of Compliance. Under WAC 173-340-720(8)(d), MTCA specifies that a conditional point of compliance may be established for groundwater cleanup at sites where it is not practicable to meet potential chemical-specific ARARs within groundwater under portions of the Site. The conditional point of compliance may be established in surface water at the point where groundwater enters surface water based upon the following criteria:

- The groundwater cleanup level is based on protection of surface water beneficial uses,
- Impacted groundwater must be entering the surface water and will continue to enter the surface water even after implementation of the selected cleanup action,
- It is not practicable to meet the cleanup level at a point within the groundwater before entering the surface water, within a reasonable restoration time frame,
- A mixing zone to demonstrate compliance with the surface water cleanup level(s) is not allowed,
- Groundwater discharges shall be provided with all known available and reasonable methods of treatment (AKART) before being released to surface water,
- Groundwater discharges shall not result in violations of sediment quality values (Chapter 173-204 WAC),
- Monitoring of groundwater and surface water must be conducted to assess the long-term performance of the selected cleanup action including potential bioaccumulation problems resulting from surface water concentrations below method detection limits, and
- Before approving a conditional point of compliance (CPOC), notice must be given to the natural resource trustees, Washington State Department of Natural Resources and the U.S. Army Corps of Engineers.

This provision is potentially applicable to establishing groundwater cleanup standards at the Site. Justification for establishing a CPOC for groundwater is provided in this FS.

3.1.8.3 Potential MTCA Soil Requirements

The following MTCA Method B requirements are potentially applicable to evaluating soil cleanup standards at the Site. These requirements are not potential ARARs for tailings piles and waste rock piles which will be addressed under the Solid Waste Management Handling regulations (Chapter 173-351 WAC) as described below.

Potential Federal and State Laws. Under WAC 173-340-740(3)(b)(i), potential MTCA Method B levels are to consider concentrations specified under federal and state laws. No potential federal or state ARARs specify standards for soils.

Potential Human-Health Based Values. Under WAC 173-340-740(5)(b), MTCA specifies that potential ARARs have a human health based risk that is 1×10^{-5} or less for carcinogens or a hazard quotient of 1 or less for non-carcinogens. If the identified potential ARARs do not meet these standards, then the potential ARAR must be adjusted. Since no potential ARARs exist for soils under federal or state environmental laws, this requirement is not a potential ARAR for the Site.

No Significant Adverse Terrestrial Ecological Risk. Under WAC 173-340-740(3)(b)(ii), MTCA requires that concentrations of hazardous substances result in no significant adverse effects on the protection and propagation of terrestrial ecological receptors unless it is determined that establishing such soil concentration is not necessary. A site-specific Ecological Risk Assessment (ERA) was performed during the RI and presented in the revised DRI report. The Agency-approved ERA demonstrates that there is no risk to most animals, plants and soil biota throughout a majority of the Site and only a low potential risk to select plants, soil biota and wildlife in limited Site areas. In areas where the ERA determined there was no risk, no further evaluation is required under MTCA and potential soil values based upon terrestrial ecological receptors are not potentially applicable to these areas.

In addition, MTCA provides exemptions from calculating potential soil concentrations based upon terrestrial ecological receptors under the following conditions:

- Soils contaminated with hazardous substances are, or will be, located below the point of compliance. This exemption is potentially applicable to the Site.

- Soils contaminated with hazardous substances are, or will be, covered by buildings, paved roads, pavement or other physical barriers that will prevent plants or wildlife from being exposed. This exemption is potentially applicable to Site areas, including but not limited to the lagoon area, maintenance yard, mill building, and former surface water retention area where potential soil values based upon terrestrial ecological receptors are not required because all of the proposed remedial alternatives will eliminate the potential exposure pathways to terrestrial ecological receptors, thereby meeting the requirements of WAC 173-340-7491(a) and (b).

- Land use at the site and surrounding area makes substantial wildlife exposure unlikely. This exemption is potentially applicable to the maintenance yard, mill building and Holden Village as described in the ERA.

- No potential exposure pathway from soil contamination to soil biota, plants or wildlife exists. For instance for areas with industrial uses, there would not be an exposure pathway for plants or soil biota, only potential exposure pathways to wildlife. Likewise, in instances where man-made physical barriers exist, there is an incomplete pathway for plants, soil biota and wildlife. This exemption is potentially applicable to the maintenance yard, mill building and Holden Village.

- The site includes less than 1.5 acres of contiguous undeveloped land on the site or within 500 feet of any area of the site. (WAC 173-340-7491(1) and WAC 173-340-7492(2)). This exemption is potentially applicable to the Holden Village which constitutes a separate Site due to its unique characteristics and activities unrelated to mining activities.

As noted above, previous correspondence with the Agencies and as described in the Agency-approved ERA, the Site is exempt from establishing potential soil cleanup levels for terrestrial ecological receptors.[7] As such, the establishment of potential values is unnecessary.

While reserving objections, included but not limited to those previously presented in correspondence between Intalco and the Agencies, Intalco has included preliminary cleanup values for soils based upon terrestrial ecological exposures as an "Agency-required" potential ARAR in this FS. These Agency-required potential ARARs are presented in Table 3-4b.

Potential Human-Health Based Values for Groundwater Protection. Under WAC 173-340-740(3)(b)(iii) and WAC 173-340-747, where no federal or state standards exist for a contaminant, then the MTCA states that the preliminary cleanup standard will be a concentration that protects human health as determined by evaluating pathways for groundwater and dermal contact. Human-health based values for dermal contact are discussed below. For groundwater, the regulation requires that PCOCs in soil will not cause contamination of groundwater at levels that exceed the human-health based groundwater cleanup levels using the methods specified in WAC 173-340-747. Low, conservative soil values were calculated using the three-phase partitioning model under WAC 173-340-747 for the potential human-health based groundwater ARARs identified in Table 3-2. These potential screening values are presented in Tables 3-4a and 3-4b, including the value for cadmium which is well below natural background.

These potential human-health based values for the protection of groundwater do not apply in areas where hydraulic containment is provided via downgradient groundwater interception and collection systems as part of the proposed remedial alternatives.[8] These potential values are considered screening levels only for those areas where the containment and collection of hazardous substances in groundwater will not occur as part of the proposed remedial alternatives (such as downgradient of groundwater collection systems in the West Area). These potential screening values will be used as a tool to identify those areas where CPOCs under WAC 173-340-740(6)(f) will be met or where additional evaluation is needed during the remedial design. During the remedial design, potential human-health based soil ARARs for the protection of groundwater would be established, if necessary based upon the remedy selected, using other, alternative methods outlined under WAC 173-340-747.

Potential Human Health-Based Dermal Contact Values. Concentrations of PCOCs measured in Site soils are below values estimated to result in no acute or chronic non-carcinogenic toxic effects on humans using a hazard quotient of 1 and an upper bound estimated excess cancer risk less than or equal to 1×10^{-6}. WAC 173-340-740 specifies that the equations provided in Tables 740-1 and 740-2 be used as default equations for calculating dermal contact values. The MTCA Method B soils values calculated for the direct contact pathway are potentially applicable and are provided on Tables 3-4a and 3-4b.

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[7] (Intalco, June 4, 2003); (Intalco, August 27, 2003)

[8] (Forest Service, September 11, 2003), page 2

General Potential Soil Requirement. Under WAC 173-340-740(1)(d), MTCA generally specifies that potential soil cleanup levels will be established at concentrations that do not directly or indirectly cause violations of surface water cleanup standards established under MTCA and state and federal laws. MTCA does not require that potential numerical ARARs be established for the soil to surface water pathway or for any non-human health based purpose, and thus, no potential numerical chemical-specific ARAR for this pathway is included in Tables 3-4a and 3-4b. The loadings analysis presented in Sections 2 and 7 will evaluate how source control, groundwater containment, collection, and treatment actions, monitored natural attenuation, as applicable under the proposed remedial alternatives, would address areas of concern where soil may be contributing this pathway and thus, meet this general MTCA requirement.

Potential Cleanup Levels for Petroleum Mixtures. Under WAC 173-340-740(4)(b)(iii)(B)(III), MTCA specifies the establishment of potential concentrations for petroleum mixtures in soil where no federal or state standards exist for the contaminant. The total petroleum hydrocarbon cleanup level is calculated taking into account the additive effects of the petroleum fractions and volatile organic compounds present in the mixture using equation in Table 740-3. For other non-carcinogens and known or suspected carcinogens within the petroleum mixture, the regulation specifies equations in Tables 740-4 and 740-5. The potential MTCA B cleanup values for gasoline, diesel, and motor oil are presented in Tables 3-4a and 3-4b.

Adjustment for PQL and Background. Under WAC 173-340-740(5)(c), MTCA specifies that cleanup levels need to be adjusted so that they are not set below the PQL or natural background concentrations, whichever is higher. Site-specific background soil data collected during the RI were used to establish natural background levels for the Site PCOCs. These values are presented in Table 3-4. This requirement is potentially applicable in evaluating soil cleanup levels for cadmium. The potential MTCA Method B screening level for cadmium for the protection of groundwater is below background and needs to be adjusted upward. The natural background level for cadmium is presented in Tables 3-4a and 3-4b and represents the potential ARAR for this PCOC.

Conditional Point(s) of Compliance. Under WAC 173-340-740(6) and WAC 173-340-7490(4), MTCA specifies points of compliance for soils which are based upon protection of groundwater, protection from vapors, and human exposure via direct contact or other exposure pathways, based upon ecological considerations or conditional point of compliance. Conditional points of compliance will be proposed for the remedial alternatives that involve containment of hazardous substances.

Under WAC 173-340-740(6), MTCA acknowledges that where the cleanup action involves containment of hazardous substances the soil cleanup levels will typically not be met at the standard points of compliance. Conditional points of compliance are allowed under the following conditions:

- Proposed remedial alternative is permanent to the maximum extent practicable.

- The proposed remedial alternative is protective of human health. For this condition, Ecology may require a human health risk assessment (HHRA) be completed. A HHRA was completed for the Site as part of the RI (URS 1999) and has been approved by the Agencies.

- The proposed remedial alternative is protective of terrestrial ecological receptors.

- Institutional controls are put in place that prohibit or limit activities that could interfere with long-term integrity of the containment system.

- Compliance monitoring and periodic reviews are designed to ensure long-term integrity of the containment system.

- The types, levels and amount of hazardous substances remaining on-site and the measures that will be used to prevent migration and contact with those substances are addressed in the final decision document.

Similarly, WAC 173-340-700(4)(c) and –355(2) specifies that where a cleanup action involves containment of soils with hazardous substances above cleanup levels, the cleanup action may be determined to comply with cleanup standards, provided the compliance monitoring program is designed to ensure the long-term integrity of the containment system and the other requirements for containment in this chapter are met. This requirement is potentially applicable to setting point(s) of compliance in those areas on the Site where soils above potential cleanup levels or potential screening values will be left in place and covered.

Conditional Point(s) of Compliance for Terrestrial Ecological Receptors. Under WAC 173-340-7490(4), at sites with institutional controls that prevent excavation of deeper soils, a CPOC for terrestrial ecological receptors may be set at the biologically active zone. MTCA assumes the biologically active zone is six feet. A site-specific depth may be established at the extent of the biologically active zone based upon depths to which soil biota occur, animals are expected to burrow, or depth to which plant roots are likely to extend. The ERA concluded that there were no risks to mammals at the Site, and thus no risks to burrowing animals. A CPOC based on the biologically active zone for worms could be established in the top six inches where soils exceeded a potential cleanup level, once established.

Based upon the results of the ERA, there are no significant adverse effects to terrestrial ecological receptors in most areas of the Holden Mine Site. For those areas where limited risk to receptors was identified, MTCA provides for exemptions from establishing a potential soil cleanup level. As discussed previously, for the Agency-required potential ARARs where such values have been established, the provisions discussed above are potentially applicable to establishing the points of compliance for such soil values.

3.2 POTENTIAL LOCATION-SPECIFIC ARARS

Potential location-specific ARARs are restrictions placed on the concentration of hazardous substances or the conduct of activities solely because the substances occur or activities are conducted in specified locations. These requirements may limit the type of potential remedial action that can be implemented or may impose additional constraints on remedial alternatives. Potential location-specific ARARs are identified and discussed in Table 3-5. These potential location-specific ARARs will continue to be evaluated and refined as the selected remedy is developed and finalized.

3.3 POTENTIAL ACTION-SPECIFIC ARARS

Potential action-specific ARARs are usually technology- or activity-based requirements or restrictions on actions taken with respect to hazardous substance(s). These potential requirements are triggered by the particular remedial alternative and set performance, design or other standards that will be used to implement the proposed remedial action. Potential action-specific ARARs are discussed below and summarized in Table 3-6. These potential ARARs are a starting point in evaluating the proposed remedial alternatives described in this FS. These potential action-specific ARARs will continue to be evaluated and refined as the selected remedy is developed and finalized.

3.3.1 Washington MTCA (RCW 70.105D, WAC 173-340)

The MTCA implementing regulations specify requirements that potentially affect implementation of a remedial design/remedial action (RD/RA) at a site. These regulations, identified below, are potentially applicable requirements to implementation of the selected remedy at the Site.

Monitored Natural Attenuation. WAC 173-340-370(7) provides that monitored natural attenuation (MNA) is expected to be appropriate at a site where:

- Source control (including removal and/or treatment of hazardous substances) has been conducted to the maximum extent practicable.
- Leaving contaminants on-site during the restoration time frame does not pose an unacceptable threat to human health or the environment.
- There is evidence that biodegradation or chemical degradation is occurring and will continue to occur at a reasonable rate at the site.

Appropriate monitoring requirements are conducted to ensure that the natural attenuation process is taking place and the human health and the environment are protected.

Natural attenuation is and will continue to occur at the Holden Mine Site. These MTCA requirements are potentially applicable to the proposed remedial alternatives presented in the FS. This FS will evaluate how the proposed remedial alternatives conform to these expectations for remedies that include natural attenuation.

Reasonable Restoration Timeframe. Under WAC 173-340-360(6), MTCA requires that the cleanup provide for a reasonable restoration time frame to meet the cleanup level identified in the final decision document and identifies factors to be considered when establishing that time frame, including the following:

- Potential risks posed by the site to human health and the environment.
- Practicability of achieving a shorter restoration time frame.
- Current use of the site, surrounding areas, and associated resources that are, or may be, affected by releases from the site.
- Potential future use of the site, surrounding areas, and associated resources that are, or may be, affected by releases from the site.
- Availability of alternative water supplies.
- Likely effectiveness and reliability of institutional controls.
- Ability to control and monitor migration of hazardous substances from the site.
- Toxicity of the hazardous substances at the site.
- Natural processes that reduce concentrations of hazardous substances have been documented to occur at the site or under similar site conditions.

This FS demonstrates how the proposed remedial alternatives will demonstrate conformance with this potentially applicable requirement at the Site.

Technology Screening. Under WAC 173-340-360(4), the MTCA regulations identify the order of preference of cleanup technologies, including treatment as the highest preference. This regulation is potentially applicable to the process of screening the proposed remedial alternatives and selecting the final remedy.

Institutional Controls. Under WAC 173-340-440, MTCA specifies potential requirements for institutional controls where active cleanup measures will not attain potential MTCA cleanup levels or where a cap is used to contain hazardous substances above cleanup standards. This requirement is potentially applicable to the remedial alternatives evaluated in the FS.

Compliance Monitoring. Under WAC 173-340-410, WAC 173-340-720(9), 173-340-730(7), and WAC 173-340-740(6), MTCA provides requirements for monitoring groundwater, surface water, and soil to demonstrate compliance with potential cleanup standards identified in the decision document. These requirements are potentially applicable to the proposed remedial alternatives presented in the FS. Documentation will be developed during the remedial design to address this potentially applicable requirement.

Use of an Ecology Accredited Laboratory. Under WAC 173-340-830, MTCA requires that an Ecology accredited laboratory (WAC 173-50) be used to analyze environmental samples. These requirements apply only to surface water, groundwater, sediment, sludge, and other water or water-related samples, and they are potentially applicable to investigation and response activities.

3.3.2 Minimum Standards for Construction and Maintenance of Water Wells (RCW 18.104; WAC 173-160-101, -121, -161 to –241, -261 to –341, -381)

Well construction regulations establish minimum standards for water well construction. This regulation is potentially applicable to wells constructed for groundwater withdrawal and monitoring. This regulation is also potentially applicable to decommissioning of existing or future wells.

3.3.3 Regulation and Licensing of Well Contractors and Operators (RCW 180104; WAC 173-162-020, -030)

These regulations apply to all water well contractors and operators who are providing well installation, maintenance, or abandonment services in Washington State. These regulations are potentially applicable to any well contractor or operator who installs wells at the Site.

3.3.4 Resource Conservation and Recovery Act; Dangerous Waste Act and Regulations (42 USC 6901; RCW 70.105; Chapter 173-303 WAC, select provisions)

Washington State has been authorized to implement portions of the Hazardous and Solid Waste Amendment (HSWA) and non-HSWA provisions of the Resource Conservation and Recovery Act (RCRA). In some instances, Washington state's authorized program is more stringent than the federal RCRA program. The Washington State Dangerous Waste regulations are more stringent then the federal RCRA program regarding mining wastes. Washington State did not adopt the Bevill Amendment, a provision exempting certain mining wastes from regulation under RCRA Subtitle C. Instead, Washington adopted a limited exemption from dangerous waste regulation for "mining overburden returned to the mining site." Remedial activities involving active management, treatment and disposition of soils, tailings or other solid wastes must consider applicability of the dangerous waste regulations. The potential applicability of these requirements is triggered only when the materials are actively managed; for instance, soils are excavated and located at a different area of the Site. The following are potentially applicable requirements that may need to be considered during the remedial design for the selected remedial alternative.

- **Solid Waste Identification and Exclusions.** Under WAC 173-303-016, -070, -071, and –090 through 104, the regulation specifies requirements for identifying if a waste is a solid waste and thus, subject to other provisions of the regulation; for designating dangerous wastes, for identifying wastes that are excluded from the dangerous waste regulations, including samples sent for analysis, mine overburden returned to the mine site, and waste water discharges subject to National Pollutant Discharge Elimination System (NPDES) permits; and for identifying criteria for dangerous waste characteristics which includes the federal ignitability, corrosivity, reactivity and toxicity criteria as well as Washington State specific designations.

- **Dangerous Waste Designation.** Under WAC 173-303-170, the Dangerous Waste regulations specify requirements for generators to follow including responsibility for designating dangerous and extremely hazardous waste, and an allowance for treating dangerous waste in tanks or containers without triggering permit requirements.

- **Dangerous Waste Accumulation.** Under WAC 173-303-200, the Dangerous Waste regulations specify requirements for accumulating dangerous waste on site. The substantive requirements of this regulation are potentially applicable to accumulation of containers and tanks storing dangerous waste on site; except that the provision limiting accumulation for 90-days is an administrative requirement and therefore, not an ARAR.

- **Container Requirements.** Under WAC 173-303-630, the Dangerous Waste regulations specify standards for the use and management of containers. Substantive provisions of this regulation may be potentially applicable to the storage or treatment of dangerous waste on site in containers. The specific requirements would be identified, if necessary, during the remedial design.

- **Tank Requirements.** Under WAC 173-303-640, the Dangerous Waste regulations specify requirements for the design, construction and management of tanks that store dangerous waste. These standards may be potentially applicable if the remedial alternative includes storing or treating in tanks. The specific requirements would be identified, if necessary, during the remedial design.

- **Corrective Action Management Units.** Under WAC 173-303-646(4), (5) and (8), the Dangerous Waste regulations allow development of corrective action management units for the management and consolidation of dangerous waste. This requirement is potentially applicable to soils that are determined to be characteristic wastes after being actively managed (i.e. excavated and moved to another contaminated area on site) and require treatment prior to disposition in an engineered containment area on site. Ex situ treatment in a container, tank or staging pile and placement in a corrective action management unit does not trigger land disposal restrictions.

The following dangerous waste requirements are not ARARs but may be applicable if dangerous or hazardous waste is transported off site:

- Notification numbers for generator, transporter and disposal facilities under WAC 173-303- 060.

- Land disposal restrictions under WAC 173-303-140.

- Treatment, storage and disposal of dangerous waste under WAC 173-303-141.

- Manifest for off site transport of dangerous waste under WAC 173-303-180.

- Preparation of waste for shipment, including labeling, marking, packaging, placarding under WAC 173-303-190.

- Generator record keeping and reporting under WAC 173-303-210 and –220.
- Dangerous waste transportation off site under WAC 173-303-240.

3.3.5 Construction in State Waters, Hydraulic Code Rules (RCW 75.20.100; WAC 220-110-040, -050, -070, -080, -120, -130, -150, -170, -190)

Hydraulic project approval and associated requirements for construction projects in state waters have been established for the protection of fish and shellfish. Any form of work that uses, diverts, obstructs, or changes the natural flow or bed of any fresh water or saltwater of the state, requires a Hydraulic Project Approval (HPA) from the Washington Department of Fish and Wildlife (WDFW). Compliance with this requirement is determined after WDFW is consulted for the appropriate mitigation measures applicable to this project. Technical provisions and timing restrictions, "fish windows", are established by the WDFW after consultation. Substantive requirements of this potential ARAR are potentially applicable to alternatives involving construction activities in Railroad or Copper Creeks, installation of culverts, and/or Railroad Creek diversion.

3.3.6 Clean Water Act National Pollutant Discharge Elimination System Regulations. (40 CFR 122.29, 122.41, 122.43 to 122.45, 122.48, 122.26)

The CWA regulates the discharge of pollutants from point sources into waters of the United States. The EPA maintains responsibility for implementing the National Pollutant Discharge Elimination System (NPDES) permit program for federal agencies. The NPDES program provides conditions for authorizing direct point source discharges to surface waters and specifies point source standards for such discharges into waters of the state. A discharge is defined as "any addition of any pollutant to navigable waters from any point source." A "point source is defined as "any discernible, confined and discrete conveyance, including but not limited to any pipe, ditch, channel, tunnel, conduit, well, discrete fissure, container, rolling stock…from which pollutants are or may be discharged." CERCLA 121(e) requires that only the substantive provisions of a permit requirement be complied with for on site discharges.

Substantive requirements include technology-based effluent controls, effluent limitations, and compliance with SWQC, including establishment of a mixing zone. The CWA specifies different standards depending upon if the source is a new or existing source, and whether the pollutant is conventional, toxic, or non-conventional, non-toxic. Existing sources of toxic discharges were initially required to achieve best practicable technology (BPT) and later to achieve best available technology (BAT) that is economically achievable. Conventional pollutants are subject to best conventional technology (BCT) controls that are economically achievable. New sources are subject to new source performance standards (NSPS). These substantive NPDES treatment requirements will be developed and finalized in the selection of the remedy.

The NPDES requirements are potentially applicable to remedial alternatives involving treatment and/or point source discharges. Since these discharges would occur on site, no permit would be required and only substantive compliance with this potential ARAR would be required. The substantive requirements are established through consultation with EPA, and would include establishment of a mixing zone for any point source discharge of treated effluent.

The CWA also specifies requirements for the management of storm water on construction Sites greater than 5 acres (40 CFR 122.26). EPA has developed a general permitting system that specifies requirements for the identification of sources of potential stormwater contamination, development of Stormwater Pollution Prevention Plan and implementation of Best Management Practices. The substantive provisions of 40 CFR 122.26 are potentially applicable to remedial actions involving grading and earthwork impacting more than 5 acres.

3.3.7 Washington State Water Quality Standards for Surface Waters – Mixing Zones (RCW 90.48; WAC 173-201A-410)

Washington State allows establishment of a mixing zone. The criteria for establishing the size and location of the mixing zone is described in Washington's Water Quality Standards regulations. This requirement is potentially applicable to establishing a mixing zone for those remedial alternatives, which would require substantive compliance with NPDES permit requirements.

3.3.8 Construction of Wastewater Facilities (RCW 90.48; 173-240-110 to –150, -180)

This regulation establishes requirements for Ecology to review plans, specifications, and engineering reports, review and approve proposed methods for operation and maintenance of industrial wastewater facilities, and approve construction modifications. "Industrial wastewater" is "water or liquid that carries waste from industrial or commercial processes, as distinct from domestic wastewater. These wastewaters may result from any process or activity of industry, manufacture, trade or business from development of any natural resource…and includes contaminated stormwater and leachate from solid waste facilities." Substantive compliance with the requirements of this requirement is met through consultation with Ecology. The substantive provisions of this requirement are potentially applicable to remedial alternatives involving construction of wastewater treatment systems.

3.3.9 Clean Water Act Section 404 (33 USC 1344(a) – (d); 40 CFR 230 and 330)

Section 404 of the CWA requires a permit for the discharge of dredged or fill material into waters of the United States, including filling or construction activities in navigable waters and wetlands. Substantive compliance with Section 404 permit requirements would be determined in consultation with the Army Corps of Engineers, EPA, U.S. Fish and Wildlife Service (USFWS), and WDFW. The potentially applicable substantive requirements are specified in EPA and US Army Corps regulations at 40 CFR 230 and 33 CFR 320 and 330. These requirements are potentially applicable to selected alternatives involving diversion, construction, and installation of culverts and riprap, dredging and filling of streams, creeks or wetlands. Nationwide permits exist for some of these activities. Since these discharges would occur on site, no permit would be required and only substantive compliance with this potential ARAR would be required.

3.3.10 Federal Clean Water Act Water Quality Certification (33 USC 1341(a) and (d); WAC 173-225-010)

Section 401 of the Federal Water Pollution Control Act (FWPOCA) requires that applicants for a license or permit from the federal government relating to any activity which may result in any discharge into the navigable waters obtain a certification from the state that the water quality standards will be met. Although a certification is not required for on-site CERCLA activities, substantive compliance with 401 Certification is required if a federal permit requirement is identified as ARAR. This requirement is potentially applicable to remedial alternatives involving dredge and fill requiring Section 404 permit equivalency, or point source discharge under an NPDES permit equivalency.

3.3.11 Temporary Modification of Water Quality Criteria and Other Requirements to Modify Water Quality Criteria (RCW 90.48; WAC 173-201A-410 through –450)

Chapters 173-201A-400 through -450 specify requirements for modifying SWQC on a site-specific basis. These requirements include establishment of short-term water quality modification, variance, site-specific water criteria, and water quality offsets. Construction activity in or adjacent to surface waters that will unavoidably cause violations of the Washington Surface Water Quality Criteria may obtain a Short-term Water Quality Modification. For CERCLA actions, the substantive provisions of this requirement are met through consultation with Ecology. This requirement is potentially applicable to remedial alternatives involving dredging, filling, and construction in, or adjacent to, wetlands and streams on the Site.

3.3.12 State Aquatic Lands Management (RCW 79.90455; WAC 332-30-100, -110, -163(1) to (5), (7), and (9))

The State Aquatic Lands Management Laws specify criteria for the management of aquatic lands. These lands are deemed "a finite natural resource of great value and an irreplaceable public heritage" and will be managed to "provide a balance of public benefits for all citizens of the state. State-owned aquatic lands will be managed to meet the following management goals: foster water-dependent uses; ensure environmental protection, encourage direct public use and access, promote production on a continuing basis of renewable resources, allow suitable state aquatic lands to be used for mineral and material production, and generate income from use of aquatic lands in a manner consistent with the above goals." The regulations specify criteria for management of rivers, including stream relocation, and bank stabilization. The substantive provisions of this regulation are potentially applicable to remedial alternatives involving activities in, or diversion of, Railroad or Copper Creeks.

3.3.13 Surface and Groundwater Removal (RCW 90.03.250, .340 and 90.44.050 to .060, .100)

These laws specify requirements for withdrawing groundwater and surface water for beneficial use. A water rights permit is required for the removal of groundwater at a rate greater than 5,000 gallons per day. Any removal of surface water requires a water rights permit. For CERCLA actions, only the substantive provisions of these requirements would be potentially applicable to alternatives involving withdrawal of groundwater above the threshold amount, or withdrawal or diversion of surface water. Substantive requirements are identified through consultation with Ecology.

3.3.14 Criteria for the Classification of Solid Waste Disposal Facilities and Practices (40 CFR 257); Washington State Standards for Solid Waste Handling (RCW 70.95; WAC 173-350-400(3)(e)(i)(A) through (H),), -400(7)(a), -710(7)(a) and –)

Subtitle D of RCRA establishes a framework for controlling the management of nonhazardous solid waste. The federal regulations establish guidelines under which states develop regulations for solid waste landfills. Washington State has established regulations that meet or exceed the federal solid waste disposal design criteria. These regulations set minimum performance standards for the handling of solid waste and limited purpose landfills.

The tailings piles, waste rock piles, and former surface water retention area at the Site do not constitute landfills as tailings and rock were not considered a solid waste when placed on the land in these areas. Moreover, even if considered landfills, these areas were closed prior to the applicable date of these regulations, February 10, 2003. Closure of these areas occurred when the operations ceased and subsequently, when the Forest Service implemented reclamation activities to grade, cover and vegetate the tailings piles. For these reasons, these requirements are not applicable. However, limited provisions of Chapter 173-350 WAC are potentially relevant and appropriate to the reclamation of these areas.

For proposed remedial alternatives that include consolidation of tailings and soils from other parts of the Site onto the existing tailings, such activity does not constitute disposal in a landfill since under CERCLA movement of soils and materials within an area of contamination does not constitute disposal.

The following requirements related to limited purpose landfills are potentially relevant and appropriate to the remedial activities for the tailings and waste rock piles. The specific relevance and appropriateness of these requirements will be further evaluated during the remedial design.

- The closure system design should prevent exposure of waste, minimize infiltration, prevent erosion from wind and water, be capable of sustaining native vegetation, address anticipated settlement with a goal of no less than two to five percent slope, provide sufficient stability and mechanical strength and address potential freeze-thaw and desiccation, provide for the management of run-on and run-off preventing erosion or otherwise damaging the closure cover, and minimizes the need for post-closure maintenance (WAC 173-350-400(3)(e)(i)(A) through (H)).

- The presumptive final closure cover for limited purpose landfills is presumed to meet the performance goals specified above. An alternative final closure cover may be used when the nature of the waste, the disposal site or other factors are incompatible with the presumptive final closure cover system.   The presumptive cover includes an anti-erosion layer consisting of a minimum of two feet of earthen material of which at least twelve inches of the uppermost layer is capable of sustaining native vegetation, seeded with grass or other shallow rooted vegetation, and a geomembrane with a minimum of thirty mil thickness or a greater thickness that is commensurate with the ability to join the geomembrane material and site characteristics such as slope, overlaying component foundation. (WAC 173-340-400(3)(e)(ii)) This provision is relevant and appropriate only to those proposed remedial alternatives that include an engineered cover (i.e., Alternative 7 and 8). For all other proposed remedial alternatives, this provision is not relevant or appropriate or in the alternative, a variance from the final cover requirements will apply.

- Post-closure requirements to allow for continued facility maintenance and monitoring of air, land, and water for a period of twenty years, or as long as necessary for the landfill to stabilize and to protect human health and the environment. Post-closure care includes maintaining the integrity and effectiveness of any final closure cover, including making repairs to the cover as necessary to correct the effects of settlement, subsidence, erosion or other events; maintaining the vegetative cover; preventing run-on and run-off from eroding or otherwise damaging the final closure cover; general maintenance of the facility and structures; and performing appropriate monitoring 173-350-400(7)(a).

The variance provisions under WAC 173-350-710(7)(a) are potentially relevant and appropriate to proposed remedial alternatives where capping would not occur, or where potentially relevant and appropriate requirements cannot be met at the Site. The variance requirements are expected to be demonstrated during the remedial design, and include showing that the proposed remedial design or location do not endanger public health, safety or the environment and that compliance with the section from which variance is sought would result in hardship without equal or greater benefits to the public.

3.3.15 Maximum Environmental Noise Levels (WAC 173-60-030 to-050, -080)

These regulations establish noise levels that cannot legally be exceeded. Permissible noise levels established by this regulation vary depending on the source of noise (residential, commercial, industrial), and receptor of the noise. The regulation also specifies the process for obtaining a variance, if necessary, from these requirements. These requirements are potentially applicable during implementation of the remedial actions involving on site work.

3.3.16 General Regulations for Air Contaminant Sources (RCW 70.94; WAC 173-400-040(8))

The Washington Clean Air regulations require that owners and operators of fugitive dust source take reasonable precautions to prevent fugitive dust from becoming airborne and to maintain and operate the source to minimize emissions. Other provisions of the air regulations establish permitting and emissions limits for sources that emit pollutants above threshold quantities; only the substantive provisions of such permit requirements would apply to a CERCLA on site activity. These other provisions may be potentially applicable to alternatives that may involve operation of equipment. These potential ARARs will be defined during the remedial design.

3.4 ITEMS TO BE CONSIDERED (TBCs)

Items to be considered (TBCs) are non-promulgated advisories or guidance issued by federal or state government that are not legally binding and do not have the status of potential ARARs. The following potential TBCs would be considered along with ARARs identified above.

3.4.1 Washington Department of Ecology Background Soil Concentrations (Yakima Basin). Publication #94-115, October 1994

This document provides general background metal concentrations for regions in the State of Washington. The values for the Yakima Basin may be a potential TBC if specific natural background soils data is not available for the Site.

3.4.2 Executive Order 11990, "Protection of Wetlands"

Requires consideration of impacts to wetlands in order to minimize their destruction, loss or degradation and to preserve/enhance wetland values. Executive Order 11990 requires that impacts occur only when no practicable alternative exists, requires consideration of impacts to wetlands such that impacts are minimized and provides for the preservation/enhancement of wetland values. Activities that involve construction must include all practicable means of minimizing harm to wetlands. This document contains provisions that are potential TBC for any alternatives involving dredging within Railroad Creek or Site wetlands. The specific provisions that may be TBC would be further delineated in the decision document.

3.4.3 Executive Order 11988, "Protection of Floodplains"

This Executive Order requires consideration of impacts to floodplain areas in order to reduce flood loss risks, minimize flood impacts on human health, safety and welfare and preserve/ restore floodplain values. This document contains provisions that are potential TBC for activities within 100-year floodplain on the Site. Specific provisions that may be TBC would be further delineated in the decision document

3.4.4 Superfund Remedial Design and Remedial Action Guidance (USEPA OSWER Directive 9355.0-4A, June, 1986)

This guidance is TBC during implementation of the RD/RA. It suggests a process for design initiation, reviews and approvals. It also provides guidance for compliance with permitting requirements and community relations. Since a Record of Decision (ROD) has not been signed, the project has not yet entered into the RD/RA phase. However, aspects of the guidance relating to design initiation and reviews would be during the remedial design.

3.4.5 Land and Resource Management Plan for Wenatchee National Forest (Forest Service 1990)

This plan specifies how the Wenatchee National Forest lands will be managed, including land and resource management. Provisions in this document related to the Holden Mine Site will need to be considered during the remedial design.

Table 3-1
Potentially Applicable Relevant and Appropriate Requirements
Chemical-specific Summary

Requirement	Citation	Description	Evaluation
Safe Drinking Water Act and National Primary Drinking Water Regulations	42 USC 300; 40 CFR 141.61(a) and (c), 141.62(b)	Establish maximum contaminant levels (MCLs) for drinking water in public water systems.	Primary MCLs are potentially relevant and appropriate to groundwater and surface water. Primary MCLs are achieved in surface water.
Safe Drinking Water Act and National Maximum Contaminant Level Goals	42 USC 300; 40 CFR 141.50(b); 40 CFR 141.51(b)	Non-enforceable health goals for public water systems. Only the non-zero MCLGs are potentially relevant and appropriate under CERCLA.	All non-zero MCLGs are equal to MCLS for the PCOCs in groundwater and surface water. Therefore, non-zero MCLGs are not potentially relevant and appropriate.
Washington State Department of Health Drinking Water Standards	RCW 70.19A; WAC 246-290-310(3) and (8)	Establish primary MCLs for drinking water in public water systems. Those state standards that are more stringent then the federal MCLs are potentially relevant and appropriate.	Potentially relevant and appropriate to groundwater and surface water. Nickel is the only state primary MCL that is more stringent than the federal primary MCL. State primary MCL for Nickel is achieved in surface water.
Safe Drinking Water Act and National/State Secondary Drinking Water Standards	42 USC 300; 40 CFR 143.3; RCW 70.19A, WAC 246-290-310(3)	Establish non-health based secondary MCLs for public water systems.	Secondary MCLs are not potential ARARs for site groundwater and surface water.
State Water Quality Criteria	RCW 90.48; WAC 173-201A-240(3) and (5), -400 through –450, and –600.	State of Washington has identified general and specific designated uses for state waters and adopted state water quality criteria for protection of human health and aquatic life.	Railroad Creek, Copper Creek and Lake Chelan are generally identified as having designated uses for domestic water supply (i.e., human health) and aquatic life. The SWQC are potentially applicable to Railroad Creek and to groundwater that is likely to impact surface water quality.

Table 3-1
Potentially Applicable Relevant and Appropriate Requirements
Chemical-specific Summary

Requirement	Citation	Description	Evaluation
Federal Clean Water Act/National Recommended Water Quality Criteria	33 USC 1251 – 1376	The CWA establishes NRWQC as guidance to the states for use in establishing state water quality criteria. Under MTCA and CERCLA, the NRWQC should be considered in developing potential ARARs for surface water and groundwater to the extent the NRWQC are relevant and appropriate.	The NRWQC are not relevant and appropriate to Site surface water and groundwater. However, the NRWQC are evaluated in the DFFS as requested by the Agencies.
National Toxics Rule	33 USC 1251; 40 CFR 131.36(b)(1) and (d)(14); WAC 173-201A-240(5)	The federal NTR establish water quality criteria in fresh water for aquatic life and human health. Washington adopted the human-health based NTR only in WAC 173-201A-240(5).	The human-health based NTR are potentially applicable to surface water and potentially relevant and appropriate to groundwater that is likely to impact surface water quality.
MTCA Standard Method B Surface Water Cleanup Levels	WAC 173-304-730(3)(b), -730(5)(b) and (c); -730(6)	MTCA identifies methods for establishing potential cleanup standards for surface water, adjustments to these potential cleanup standards, and points of compliance.	These MTCA provisions are potentially applicable to surface water and groundwater that is likely to impact surface water.
MTCA Standard Method B Potable Groundwater Cleanup Levels	WAC 173-304-720(4)(b),720(7)(b) and (c), -720(8)(d)	MTCA identified methods for establishing potential cleanup standards for groundwater, adjustments to these potential cleanup standards, and conditional points of compliance.	These MTCA provisions are potentially applicable to groundwater and surface water.
MTCA Method B Soil Cleanup Levels for unrestricted Land Use	WAC 173-304-740(3)(b), -, -740(5)(b) and (c), -740(6), -700(4), -747, -7490, -7491, -7492, -355(2)	MTCA identifies methods for establishing potential cleanup standards for soils, adjustments to these potential cleanup standards, and conditional points of compliance.	These MTCA provisions are potentially applicable to soils at the Site.

Table 3-2
Summary of Potential Chemical-specific ARARs for Groundwater

Potential Compounds of Concern (PCOCs)	Background Groundwater Quality (HV-3) [1]	Federal/State MCLs/Non-Zero MCLGs [2]	Adjusted MCL [3]	MTCA Method B Groundwater [4]	Laboratory PQL [5]
Metals, (ug/L)					
Cadmium	< 0.2	5	NA	8	0.2
Copper	< 2 - 3.2	1,300 at tap	592	592	0.5
Lead	< 1- 2.6	15	NA	NE	1
Manganese	0.7 - 2	NE	NA	747	1
Nickel	< 0.5 - 0.6	100	NA	320	0.5
Zinc	< 6 - 7	NE	NA	4,800	6

NE - Not Established NA - Not Applicable

1 - Range of results collected in June and September 1997, November 2001, June 2002, and October 2003.

2- MCLs and non-zero MCLGs, Drinking Water Standards and Health Advisories, Office of Water, US EPA, Summer 2000, EPA-822-B-00-001. Washington State Department of Health (WDOH) Drinking Water Standards (RCW 70.19A; WAC 246-290-310(3)). Based on Total Metals. The non-zero MCLGs for these constituents are equal to the MCLs. The MCL for nickel is based on WDOH criteria as no federal criteria exists.

3 - The MCLs were adjusted based on a HQ = 1 or cancer risk of 1×10^{-5} as appropriate using MTCA Method B equations (WAC173-340-720(7)(b)).

4 - Cleanup Levels and Risk Calculations under the Model Toxic Control Act Cleanup Regulation (CLARC) Version 3.1, updated November 2001.

5 - PQLs based on standard EPA methods used by laboratory conducting RI and supplemental analytical support (Analytical Resources Inc.).

Table 3-3A
Summary of Potential Chemical-specific ARARs for Surface Water

Potential Compounds of Concern (PCOCs)	Area Background Value [1] (Total/Dissolved)	Protection of Aquatic Life: Chapter 173-201A-240(3) WAC [2] Acute	Chapter 173-201A-240(3) WAC [2] Chronic	MTCA Method B Surface Water Standards [3]	Protection of Human Health: Federal/State MCLs/Non-Zero MCLGs [4]	Adjusted MCLs [5]	MTCA Method B Groundwater Standards[6]
Metals, (ug/L)							
Cadmium	0.10 / 0.07 [a]	0.24 - 1.0 [b]	0.16 - 0.43 [b]	20.3	5	NA	8
Copper	1.83 / 1.06 [a]	1.6 - 5.6 [b]	1.3 - 4.2 [b]	2,660	1,300 at tap	592	592
Zinc	5 / 7.81 [a]	13 - 42 [b]	12 - 39 [b]	16,500	NE	NA	4,800

a - If water hardness values decrease below a certain level, these background values may exceed regulatory criteria.
b - These metals require hardness correction specific to the sample data. Criteria shown are based on the range of hardness values (8 - 31 mg/l) calculated in Railroad Creek for 1997. Criteria is based on dissolved metals concentrations.
NE - Not Established NA - Not Applicable
1 - Values are the calculated 90th percentile using data collected from Railroad Creek upstream stations, Holden Creek, Big Creek, Copper Creek upstream stations, Tenmile Creek, South Fork Agnes Creek, and Company Creek. Source: DRI (Dames & Moore, July 1999) Section 5.3.
2 - Chapter 173-201A-240(3) WAC, Water Quality Standards for Surface Waters of the State of Washington, last amendment 7-01-03.
3 - Cleanup Levels and Risk Calculations under the Model Toxics Control Act Cleanup Regulation (CLARC) Version 3.1, updated November 2001.
4 - MCLs and Non-zero MCLGs, Drinking Water Standards and Health Advisories, Office of Water, US EPA, Summer 2000, EPA-822-B-00-001. Washington State Department of Health Drinking Water Standards (RCW 70.19A; WAC 246-290-310(3). Based on Total Metals. The State MCLs and non-zero MCLGs are equal to the Federal MCLs.
5 - MCL adjusted based on HQ = 1 or excess cancer risk of 1 x 10^{-5} as appropriate using MTCA Method B equations per WAC173-340-720(7)(b)
6 - Groundwater Cleanup Levels and Risk Calculations under MTCA CLARC Manual Version 3.1, updated November 2001.

Table 3-3B
Summary of Agency Required Potential Chemical-specific ARARs for Surface Water

Potential Compounds of Concern (PCOCs)	Area Background Value [1] (Total/Dissolved)	Protection of Aquatic Life: WAC 173-201A-240(3) [2] Acute	WAC 173-201A-240(3) [2] Chronic	Section 304 of the Clean Water Act (NRWQC) [3] Acute	Section 304 of the Clean Water Act (NRWQC) [3] Chronic	MTCA Method B Surface Water Standards [4]	Protection of Human Health: Federal/State MCLs/Non-Zero MCLGs [5]	Adjusted MCL [6]	MTCA Method B Groundwater Standards[7]
Metals, (ug/L)									
Aluminum	144 / 37.4	NE	NE	750	87	NE	NE	NA	NA
Cadmium	0.10 / 0.07 [a]	0.24 - 1.0 [b]	0.16 - 0.43 [b]	0.28 - 1.2 [b] [0.17 - 0.64 [b]]	0.34 - 0.94 [b] [0.04 - 0.11 [b]]	20.3	5	NA	8
Copper	1.83 / 1.06 [a]	1.6 - 5.6 [b]	1.3 - 4.2 [b]	1.2 - 4.5 [b] [1.2 - 4.5 [b]]	1.0 - 3.3 [b] [1.0 - 3.3 [b]]	2,660	1,300 at tap	592	592
Iron	177 / 40	NE	NE	NE	1,000	NE	NE	NA	NA
Zinc	5 / 7.81 [a]	13 - 42 [b]	12 - 39 [b]	14 - 43 [b] [14 - 43 [b]]	14 - 44 [b] [14 - 44 [b]]	16,500	NE	NA	4,800

a - If water hardness values decrease below a certain level, these background values may exceed regulatory criteria.
b - These metals require hardness correction specific to the sample data. Criteria shown are based on the range of hardness values (8 - 31 mg/l) calculated in Railroad Creek for 1997. Criteria is based on dissolved metals concentrations.
NE - Not Established NA - Not Applicable
1 - Values are the calculated 90th percentile using data collected from Railroad Creek upstream stations, Holden Creek, Big Creek, Copper Creek upstream stations, Tenmile Creek, South Fork Agnes Creek, and Company Creek. Source: DRI (Dames & Moore, July 1999) Section 5.3.
2 - Chapter 173-201A-240(3) WAC, Water Quality Standards for Surface Waters of the State of Washington, last amendment 7-01-03.
3 - Water quality criteria published under Section 304 of the Clean Water Act. EPA, National Recommended Water Quality Criteria - Correction, EPA 822-Z-99-001, April 1999; Results in [ ] are from EPA, National Recommended Water Quality Criteria: 2002, EPA-822-R-02-047. Intalco does not concur that NRWQC from 1999 or 2002 publications are potential ARAR for protection of aquatic life. The values are presented only to address an Agency request and do not represent an agreement to consider the criteria as potential ARAR.
4 - Cleanup Levels and Risk Calculations under the Model Toxics Control Act Cleanup Regulation (CLARC) Version 3.1, updated November 2001.
5 - MCLs and non-zero MCLGs, Drinking Water Standards and Health Advisories, Office of Water, US EPA, Summer 2000, EPA-822-B-00-001. Washington State Department of Health Drinking Water Standards (RCW 70.19A; WAC 246-290-310(3). Based on Total Metals. The State MCLs and Non-zero MCLGs are equal to the Federal MCLs.
6 - MCL adjusted based on HQ = 1 or excess cancer risk of 1 x 10^{-5} as appropriate using MTCA Method B equations per WAC173-340-720(7)(b)
7 - Groundwater Cleanup Levels and Risk Calculations under MTCA CLARC Manual Version 3.1, updated November 2001.

Table 3-4A
Summary of Potential Screening Values and Chemical-specific ARARs for Soil

Potential Compounds of Concern (PCOCs)	Area Background Value [1]	MTCA Method B Direct Contact Values [2]	MTCA Method B Protection of Groundwater Screening Levels[3]
Total Metals (mg/kg)			
Cadmium	5.4	80	0.69
Copper	57.4	2,960	263
Lead	20.6	NE	3,000
Silver	0.5	400	13.6
Zinc	253	24,000	5,970
Total Petroleum Hydrocarbons (mg/kg)			
Gasoline	NE	No Risk Indicated [4]	22 [4]
Diesel	NE	3300 [4]	344 [4]
Motor Oil	NE	4300 [4]	No Risk Indicated [4]

Notes:
1 - Area Background values based on Statistical Analysis per MTCA using data collected from the Railroad Creek drainage in 1998. Source: Revised DRI (Dames & Moore, 1999) Section 5.2.
2 - MTCA Cleanup Levels and Risk Calculation (CLARC), Version 3.1. Updated November 2001.
3 - MTCA - WAC 173-340-747 Fixed parameter three-phase partitioning model, Equation 747-1 using default entries and most stringent potential groundwater ARAR (MCL, State MCL, or MTCA B groundwater cleanup levels). These values are not potential ARARs and represent conservative screening values only.
4 - The concentrations and risks noted are based on use of the MTCA spreadsheets provided by Ecology for assessment and calculation of soil cleanup levels that are protective of the direct contact and groundwater pathways. The calculations were based on the use of highest detected concentrations, and weathered gasoline, fresh diesel, and heavy fuel oil weight percentages provided by Ecology. Copies of the spreadsheets have been provided to Ecology for review and are on file at URS.
NE - Not Established or Not Evaluated

Table 3-4B
Agency Required Potential Screening Values and Chemical-specific ARARs for Soil

Potential Compounds of Concern (PCOCs)	Area Background Value [1]	MTCA Method B Direct Contact Values [2]	MTCA Method B Protection of Groundwater Screening Levels[3]	Preliminary Values for the Protection of Terrestrial Ecological Receptors [4]		
				Plants	Soil Biota (Earthworms)	Wildlife (Robin)
Total Metals (mg/kg)						
Cadmium	5.4	80	0.69	No Risk Indicated	18	144
Copper	57.4	2,960	263	440	440	No Risk Indicated
Lead	20.6	NE	3,000	No Risk Indicated	1629	448
Silver	0.5	400	13.6	No Risk Indicated	No Risk Indicated	No Risk Indicated
Zinc	253	24,000	5,970	No Risk Indicated	514	1436
Total Petroleum Hydrocarbons (mg/kg)						
Gasoline	NE	No Risk Indicated [5]	22 [5]	NE	NE	NE
Diesel	NE	3300 [5]	344 [5]	NE	NE	NE
Motor Oil	NE	4300 [5]	No Risk Indicated [5]	NE	NE	NE

Notes:
1 - Area Background values based on Statistical Analysis per MTCA using data collected from the Railroad Creek drainage in 1998. Source: DRI (Dames & Moore, 1999) Section 5.2.
2 - MTCA Cleanup Levels and Risk Calculation (CLARC), Version 3.1. Updated November 2001.
3 - MTCA - WAC 173-340-747 Fixed parameter three-phase partitioning model, Equation 747-1 using default entries and most stringent potential groundwater ARAR (MCL, State MCL, or MTCA B groundwater cleanup levels). These values are not potential ARARs and represent conservative screening values only.
4 - Preliminary soil screening values calculated for the protection of terrestrial ecological receptors (Appendix K).
5 - The concentrations and risks noted are based on use of the MTCA spreadsheets provided by Ecology for assessment and calculation of soil cleanup levels that are protective of the direct contact and groundwater pathways. The calculations were based on the use of highest detected concentrations, and weathered gasoline, fresh diesel, and heavy fuel oil weight percentages provided by Ecology. Copies of the spreadsheets have been provided to Ecology for review and are on file at URS.
NE - Not Established or Not Evaluated

Table 3-5
Potentially Applicable Relevant and Appropriate Requirements
Location-Specific

Requirement	Citation	Description	Evaluation
National Historic Preservation Act	16 USC 470; 36 CFR 800; 36 CFR 65 and 60	The National Historic Preservation Act (NHPA) requires federal agencies to assess the impact of proposed actions on historic or culturally important sites, structures, or objects within the site of the proposed projects. It further requires federal agencies to assess all sites, buildings, and objects on the site to determine if any qualify for inclusion in the National Register of Historic Places (NRHP) or as a National Historic Landmark. Criteria for evaluation are included in 36 CFR Part 60.4. If historic properties or landmarks are eligible or included in the NRHP, and exist within the areas where remedial activity will occur, the remedial activities must be designed to minimize the effect on such properties or landmarks.	These requirements are potentially applicable to the areas of the site (Railroad Creek drainage from Lucerne to the site, Holden Village town site, Holden mill and mine complex, the Talus slope near Tenmile Creek, Honeymoon Heights, and Winston home sites) some of which are being surveyed and may be considered for inclusion on the Federal Register of Historic Places. If remedial activities may impact sites, buildings or objects listed on the Federal Register of Historic Places, the remedial activities will be designed to minimize impacts.
Historic Site, Buildings and Antiquities Act	16 USC 461-471; 40 CFR 6.301(a)	This act requires that historic sites, buildings, and objects of national significance be preserved.	If sites, buildings or objects are identified for listing or listed on the Historic Site, Buildings and Antiquities Federal Register, then these requirements are potentially applicable if remedial activities will impact such areas.
Archaeological and Historic Preservation Act	16 USC 469	This act establishes procedure to provide for the preservation of historical and archeological data that might be destroyed through alteration of terrain as a	This requirement is potentially applicable if historical or archeological data are found in

Table 3-5
Potentially Applicable Relevant and Appropriate Requirements
Location-Specific

Requirement	Citation	Description	Evaluation
		result of a federally licensed activity or program. Presence or absence of such data on the site must be verified. If historic or archaeological artifacts are present in the area where the remedial activity will occur, the remedial activity must be designed to minimize adverse effects on the artifacts.	areas of the site potentially disturbed during remedy implementation.
Native American Graves Protection and Repatriation Act	25 USC 3001 et. seq; 43 CFR 10.1, 10.4, and 10.5	This act protects Native American burial sites and funerary objects. If Native American graves are discovered within the area where the remedial activity occurs, the US Department of Interior and the Indian tribe with ownership must be notified of the inadvertent discovery. And the activity must cease until a reasonable effort is taken to protect the discovered items	This requirement is potentially applicable to land disturbing activities implemented during the remedial action if Native American burial sites or funerary objects are encountered.
Archaeological Resources Protection Act	16 USC 470aa; 43 CFR 7.1, 7.7 and 7.33;	This act and regulations specify the steps that must be taken to protect archaeological resources and sites that are on public and Native American lands and to preserve data uncovered. The presence of archeological sites should be identified before beginning any remedial activity.	This requirement is potentially applicable to land disturbing activities implemented during remedial action if archaeological resource or sites are encountered.
Fish and Wildlife Coordination Act	16 USC 661-667d	This act requires consultation with U.S. Fish and Wildlife Service and Washington Department of Fish and Game when waters of 10 acres or more will be impounded or diverted, or a channel deepened. Regulated projects will be evaluated for possible impacts to wildlife and identification of preventive or mitigation measures.	This requirement is potentially applicable to water diversion or dredging activities in Railroad Creek.

Table 3-5
Potentially Applicable Relevant and Appropriate Requirements
Location-Specific

Requirement	Citation	Description	Evaluation
Fish and Wildlife Conservation Act	16 USC 2901; 50 CFR 83	The FWCA requires federal agencies to use their authority to conserve and promote conservation of non-game fish and wildlife. Non-game fish and wildlife are defined as fish and wildlife that are not taken for food or sport, that are not endangered or threatened and that are not domesticated.	This requirement is potentially applicable to areas that contain habitat for non-game fish and wildlife. Appropriate measures would be identified through consultation with USFWS and WAF&G.
Endangered Species Act	(16 USC 1531-1543, 50 CFR 402) 50 CFR 17	This act protects fish, wildlife and plants that are threatened or endangered (T/E) with extinction. It also protects habitat designated as critical to the conservation of the species. The act requires consultation with resource agencies for remedial actions that may affect these species.	This requirement is potentially applicable if federally–listed candidate species are present in the areas impacted during remedy implementation.
Wilderness Act	16 USC 1531-666; 36 CFR 293.1-.15	National Forest Wilderness Resources are to be managed to promote, perpetuate, and where necessary restore, the Wilderness character of the land and its specific values.	This requirement is potentially applicable to assessing the remedial alternatives at the Site. The potentially applicable requirements will be identified during remedial design in consultation with the USFS.
National Forest Management Act	16 USC 1600(6)	Specifically regarding forestland and resource management, Congress enacted the National Forest Management Act of 1976 (NFMA). NFMA requires the USDA Forest Service to manage the National Forest System lands according to land and resource	This requirement is potentially applicable to assessing the remedial alternatives at the Site. The potentially applicable

Table 3-5
Potentially Applicable Relevant and Appropriate Requirements
Location-Specific

Requirement	Citation	Description	Evaluation
		management plans that provide for multiple-uses and sustained yield in accordance with MUSYA (16 U.S.C. 1604[e] and [g] [1]). In developing and maintaining these plans, NFMA calls for "integrated consideration of physical, biological, economic and other sciences." (16 U.S.C. 1604 [b]).	requirements will be identified during remedial design in consultation with the USFS.
Washington State Shoreline Management Act and Federal Coastal Zone Management Act	(16 USC 1451-1464; RCW 90.58; WAC 173-27-060 15 CFR 923-930)	The Shoreline Management Act requires a permit for any development or activity valued at $2500 or more that is located on the water or shoreline area. "Shorelines" are lakes, including reservoirs, of 20 acres or greater; streams with a mean annual flow of 20 cubic feet per second or greater; marine waters; plus an area landward for 200 feet measured on a horizontal plane from the ordinary high water mark; and all associated marshes, bogs, swamps, and river deltas. Floodplains and floodways incorporated into local shoreline master programs are also included. Federal agency action that is reasonably likely to affect use of shorelines must be consistent with approved coastal zone management plan to the maximum extent practicable subject to limitations set forth in the Coastal Zone Management Act. Federal agencies are not required to obtain permits for shoreline development, but must conduct a Coastal Zone Consistency Determination which includes a project description, a brief assessment of the impacts, and a statement that the project complies with the Coastal Zone Management Program.	Railroad Creek, except portions running through federal lands, and Lake Chelan are identified as shorelines subject to the Shoreline Management Act. State Shoreline Management Act, which includes demonstrating consistency with the federal CZMA requirements are potentially applicable to remedial actions involving work in and within 200 feet of Railroad Creek and Lake Chelan, except portions running through federal lands. The CZMA requirements are potentially applicable to remedial activities impacting Railroad Creek which runs through federal lands. The substantive provisions of the CZMA will met though consultation with the USFS and EPA.

Table 3-6
Potentially Applicable Relevant and Appropriate Requirements
Action-Specific

Requirement	Citation	Description	Evaluation
Washington MTCA	RCW 70.105D; WAC 173-340-360(4), -440, -410, -720(9), -730(7), -740(6), -360(6), -370(7), -830.	The MTCA specifies requirements that affect the implementation of remedial action at a site. These regulations specify requirements for choosing technologies; establishing institutional controls; conducting compliance monitoring for groundwater, surface water, and soil; providing for a reasonable restoration time frame to meet the cleanup level; determining the appropriateness of monitored natural attenuation; and using an Ecology-accredited laboratory to analyze environmental samples.	These MTCA provisions are potentially applicable to remedial action selection and implementation.
Minimum Standards for Construction and Maintenance of Water Wells	RCW 18.104; WAC 173-160-101, -121, -161 to -241, -261 to -341, -381.	Well construction regulations establish minimum standards for water well construction and decommissioning.	These provisions are potentially applicable to wells constructed for groundwater withdrawal and monitoring and decommissioning of existing or future wells.
Regulation and Licensing of Well Contractors and Operators	RCW 180104; WAC 173-162-020, -030	These regulations apply to all water well contractors and operators who are providing well installation, maintenance, or abandonment services in Washington State.	Potentially applicable to contractors or operators who install wells at the Site.
Resource Conservation and Recovery Act; Dangerous Waste Act and Regulations	42 USC 6901; RCW 70.105; WAC 173-303- 016, -070, -071, -090 to 104, -170, -200, -630, -640, -646(4), (5) and (8)	The Washington State Dangerous waste regulations establish requirements for characterizing, managing, treating, and establishing a corrective action management unit for the disposition of remediation waste.	Potentially applicable to alternatives involving the active management of soils and tailings that are determined to be characteristic dangerous waste.

Table 3-6
Potentially Applicable Relevant and Appropriate Requirements
Action-Specific

Requirement	Citation	Description	Evaluation
Resource Conservation and Recovery Act; Dangerous Waste Act and Regulations	42 USC 6901; RCW 70.105; WAC 173-303-016, -070, -071, -170, -200, -630, -646(4), (5) and (8), -060, -140, -141, -180, -190, -210, -220, and -240	The dangerous waste regulations establish criteria for the identification, designation, accumulation, management, consolidation, transportation and off-site disposal of dangerous waste.	These provisions are potentially applicable to the on-site accumulation, management and consolidation of designated dangerous waste. These regulations must be fully complied with for any off site disposal of waste determined to be characteristically hazardous.
Hydraulic Project Approval	RCW 75.20.100; WAC 220-110-040, -050, -070, -080, -120, -130, -150, -170, and -190	Construction activity below the ordinary high water mark that uses, diverts, obstructs or changes the natural flow or bed of any waters of the state requires a hydraulic project approval (HPA) from the Washington State Department of Fish and Wildlife.	Substantive provisions of this potential ARAR are potentially applicable to remedial alternatives that include diversion of or placement of a culvert in Railroad Creek or Copper Creek. The potential applicability will depend upon the activities associated with a specific remedial alternative.
Clean Water Act National Pollutant Discharge Elimination System Regulations	40 CFR 122.29, 122.41, 122.43 to 122.45, 122.48, 122.26	The CWA regulates the discharge of pollutants from point sources into waters of the United States. The NPDES regulations establish requirements for discharges of wastewater, including technology and effluent discharge limits, and for the discharge of storm water from construction activities greater than 5 acres.	These requirements are potentially applicable to alternatives involving treatment and discharge of groundwater, and portal drainage. The stormwater provisions are potentially applicable to activities involving disturbance of greater than 5 acres.

Table 3-6
Potentially Applicable Relevant and Appropriate Requirements
Action-Specific

Requirement	Citation	Description	Evaluation
Washington State Water Quality Standards for Surface Waters – Mixing Zone	RCW 90.48; WAC 173-201A-410	This Washington State regulation allows establishment of a mixing zone. The criteria for establishing the size and location of the mixing zone is described in Washington's Water Quality Standards regulations.	Establishment of a mixing zone is potentially applicable to remedial alternatives, which would require substantive compliance with NPDES permit requirements.
Construction of Wastewater Facilities	RCW 90.48; 173-240-110 to –150, -180	This regulation establishes requirements for Ecology to review plans, specifications, and engineering reports, review and approve proposed methods for operation and maintenance of industrial wastewater facilities, and approve construction modifications.	Substantive compliance with this requirement is potentially applicable to remedial alternatives involving construction of wastewater treatment systems and will be met through consultation with Ecology.
Clean Water Act Section 404	33 USC 1344(a) – (d); 33 CFR 230 and 330	Filling or construction that occurs in waters of the United States requires a Section 404 Permit from the US Army Corps of Engineers.	The substantive provisions of this requirement are potentially applicable to selected alternatives involving diversion, construction, and installation of culverts and riprap, dredging and filling of streams, creeks or wetlands. Substantive compliance would be met through consultation with the Army Corps of Engineers.

Table 3-6
Potentially Applicable Relevant and Appropriate Requirements
Action-Specific

Requirement	Citation	Description	Evaluation
Federal Clean Water Act Water Quality Certification	33 USC 1341(a) and (d); WAC 173-225-010	Section 401 of the Federal Water Pollution Control Act (FWPCA) provides that applicants for a license or permit from the federal government relating to any activity which may result in any discharge into the navigable waters shall obtain a certification from the state that the water quality standards will be met. The 401 Certification is required before obtaining a section 404 permit equivalency.	No formal certification would be required for on-site work. Substantive compliance with this requirement would be potentially applicable to alternatives where substantive compliance with a federal permit equivalency (i.e., NPDES or Section 404 permit) would be required.
Temporary Modification of Water Quality Criteria and Other Requirements to Modify Water Quality Criteria	RCW 90.48; WAC 173-201A-410 through -450	Construction activity in or adjacent to surface waters that will unavoidably cause violations of the State of Washington's Surface Water Quality Criteria requires a Short-term Water Quality Modification. The regulations also have provisions for obtaining a variance, obtaining site-specific water quality criteria and applying for water offsets.	Substantive provisions of requirements allowing for short-term modification of potential chemical-specific ARARs in surface water would be potentially applicable to remedial alternatives involving dredging, filling, and construction in, or adjacent to, wetlands and streams on the Site. Substantive provisions of the regulations relating to obtaining a variance from SWQC, obtaining a site-specific water quality criteria and applying for offsets may be applicable to on-site activities impacting surface water.

Table 3-6
Potentially Applicable Relevant and Appropriate Requirements
Action-Specific

Requirement	Citation	Description	Evaluation
State Aquatic Lands Management	RCW 79.90455; WAC 332-30-100, -110, -163(1) to (5), (7), and (9)).	The State Aquatic Lands Management Laws specify criteria for the management of aquatic lands. State-owned aquatic lands will be managed to meet the management goals. The regulations specify criteria for management of rivers, including stream relocation, and bank stabilization.	Potentially applicable to remedial alternatives involving activities in, or diversion of, Railroad Creek or Copper Creek.
Surface and Groundwater Removal	RCW 90.03.250, .340 and 90.44.050 to .060, .100	These laws specify requirements for withdrawing groundwater and surface water for beneficial use. A water rights permit is required for the removal of groundwater at a rate greater than 5,000 gallons per day. Any removal of surface water requires a water rights permit.	Substantive compliance with these requirements is potentially applicable to alternatives involving withdrawal of groundwater above the threshold amount, or withdrawal or diversion of surface water.
Criteria for the Classification of Solid Waste Disposal Facilities and Practices; Washington State Standards for Solid Waste Handling	40 CFR 257; RCW 70.95; WAC 173--350-400(3)(e)(i)(A through (H), -400(6)(a), -400(7)(a), and –710(5).	Subtitle D of RCRA establishes a framework for controlling the management of nonhazardous solid waste. The federal regulations establish guidelines under which states develop regulations for solid waste landfills. Washington State has established regulations that meet or exceed the federal solid waste disposal design criteria. This regulation specifies the requirements for minimizing liquids into the landfill by providing a cover, prohibiting placement of materials with free liquids, minimizing run-on and run-off and providing for a soil or alternative artificial liner covers, grading, and final topsoil cover. Variance from provisions in the regulations is also provided.	Tailings piles and waste rock piles are not landfills. Consolidation of tailings and soils on existing tailings does not constitute disposal. Limited provisions of these regulations, including the variance provisions, are potentially relevant and appropriate to remedial activities for the tailings and waste rock piles.

Table 3-6
Potentially Applicable Relevant and Appropriate Requirements
Action-Specific

Requirement	Citation	Description	Evaluation
Maximum Environmental Noise Levels	WAC 173-60-030 to-050, -080	These regulations establish noise levels that cannot legally be exceeded. Permissible noise levels established by this regulation vary depending on the source of noise (residential, commercial, industrial), and receptor of the noise. The regulation also specifies the process for obtaining a variance, if necessary, from these requirements.	Potentially applicable during implementation of the remedial actions involving on site work.
General Regulations for Air Contaminant Sources	(RCW 70.94; WAC 173-400-040(8)).	The Washington Clean Air regulations require that owners and operators of fugitive dust source take reasonable precautions to prevent fugitive dust from becoming airborne and to maintain and operate the source to minimize emissions. Other provisions of the air regulations establish permitting and limits for emissions for sources that emit pollutants above threshold quantities.	Fugitive emissions requirements are potentially applicable activities involving soil and tailings management. Other potential air regulations may be potentially applicable to alternatives where equipment will be used. These requirements will be identified during the remedial design.

4.0 IDENTIFICATION OF REMEDIAL ACTION OBJECTIVES

The site-specific remedial action objectives (RAOs) describe the requirements that must be met by the selected site remedy. The RAOs are designed to guide the development of candidate alternatives appropriate for site remediation, and indicate the contaminants and media of concern, and exposure routes and potential receptors. Acceptable concentration limits or ranges for each PCOC by media, exposure routes, and receptors is incorporated by reference to applicable state and federal standard.

The following three RAOs for the Holden Mine Site were developed by the Agencies and Intalco:

- Protect human health and the environment within a reasonable timeframe for:

  - Groundwater quality to meet State groundwater quality standards,
  - Surface water quality to meet State water quality standards,
  - Surface soil quality to protect human health and the environment, and
  - Sediment quality to protect human health and the environment.

- Perform appropriate natural resource damage assessment activities as agreed by the Parties consistent with 43 CFR Part 11 in order to evaluate the potential for coordinated remedial and natural resource restoration activities.

- Implement the remedial action in a manner that protects human health and the environment, including the Holden Village residential community during and after construction.

A further description of these site-specific RAOs is provided in the following subsections.

4.1 PROTECTION OF HUMAN HEALTH AND THE ENVIRONMENT WITHIN A REASONABLE TIME FRAME

An objective of the selected remedial action at the Site would be to protect human health and the environment within a reasonable timeframe for:

- Groundwater quality to meet State groundwater quality standards,
- Surface water quality to meet State water quality standards,
- Surface soil quality to protect human health and the environment, and
- Sediment quality to protect human health and the environment.

State groundwater and surface water quality standards, and other rules and regulations based on human and ecological risk assessment results are identified and discussed in Section 3.1. The objective of selected remedial actions for groundwater and surface water would be to protect human health and the environment within a reasonable timeframe by meeting these requirements.

Similarly, the objective of selected remedial actions for surface soil would be to protect human health and the environment within a reasonable timeframe by meeting surface soil quality standards. These standards are identified in Section 3.1 and include MTCA Method B cleanup requirements and ecological and human-health risk-based standards.

No applicable laws and regulations currently exist for establishing protection requirements for sediment, therefore, the objective of the selected remedial action would be to protect human health and the environment by meeting ecological and human-health risk-based standards for sediment. Results presented in the revised DRI indicate that the concentrations of metals in Railroad Creek sediments do not present a potential for adverse effects to aquatic organisms based on Ecology guidance values. Similarly, the results of bioassays conducted in December 2002 on sediment in Lake Chelan at the mouth of Railroad Creek indicate that metals concentrations at this location also do not present a potential for adverse affects to aquatic organisms.

4.2 NATURAL RESOURCE RESTORATION

The Parties have agreed and are performing appropriate natural resource damage assessment activities consistent with 43 CFR Part 11. As described in Section 2, a draft Injury Determination Report has been prepared for the Site, and negotiations related to potential natural resource restoration activities are ongoing between Intalco and the appropriate natural resource Trustees. The second RAO established for the Site is to evaluate and coordinate natural resource restoration activities with the remedial action to the extent feasible. The extent to which remedial action alternatives achieve natural resource restoration is evaluated in the detailed analysis of alternatives (Section 7) as an additional criterion. This evaluation will allow the parties to assess the potential for coordination between natural resource restoration activities and remedial activities.

4.3 REMEDIAL ACTION IMPLEMENTATION

The final RAO for the Site is to implement the remedial action in a manner that protects human health and the environment, including the Holden Village residential community and its visitors during and after construction. Action-specific ARARs are identified in Section 3.3, which specify the requirements for implementing the remedial action and setting performance-based remedial action standards that are in compliance with applicable laws and regulations. These ARARs were developed to protect human health and the environment. Implementation of the selected remedial action in accordance with these standards would meet this RAO of protecting human health and the environment, including residents at the Holden Village, during and after construction. The extent to which remedial alternatives impact human health and the environment during implementation is evaluated in the detailed analysis of alternatives (Section 7).

5.0 IDENTIFICATION AND SCREENING OF REMEDIAL TECHNOLOGIES

In this section, general response actions (GRAs) are identified for source areas, soils, surface water, and groundwater at the Site. The GRAs define sets of remedial technology types and process options that share common elements. In accordance with EPA guidance, these GRAs are specific actions selected to address the RAOs developed in Section 4, and will become the basis for remedial technology screening and development of candidate site-wide remedial alternatives.

The term *technology type* refers to general technological categories applicable under a given GRA. For example, infiltration barriers represent a technology type under the East Area physical controls GRA. The term *process option* refers to the specific remedial technologies available for consideration within a particular technology type. Vegetative soil covers and low permeability geosynthetic covers would be examples of specific process options available under the infiltration barrier technology type. The use of these terms is consistent with EPA Guidance (EPA 1988) and is maintained throughout this report.

As described in Section 2, the Site has been divided into two discrete areas: the West Area and the East Area. The West and East Area designations are based on the unique surface water and groundwater chemical characteristics and the physical conditions exhibited in each area as documented during the RI process. West Area features include the underground mine, Honeymoon Heights, east and west waste rock piles, mill building, maintenance yard, lagoon area, and former surface water retention area located downgradient from the 1500-level ventilator portal. The East Area includes the three tailings piles. A more detailed description of site characteristics is provided in Section 2.

The initial identification of GRAs and potentially applicable technology types and process options is documented in Section 5.1. To identify a comprehensive list of potential technology types and process options, a review was conducted of remedial actions implemented or evaluated at other mining sites using literature and internet searches, other resources from engineering consultants and vendors, and existing published technology databases. The GRAs and remedial technologies were further developed and refined through a collaborative process with the Agencies from 1998 through 2003.

Identified technologies and process options were screened in accordance with EPA Guidance, (EPA 1988). The initial screening for the West and East Areas is described in Section 5.2. During the initial screening process, remedial technologies judged technically feasible and generally applicable to site conditions were retained for further analysis. A secondary evaluation was then performed on retained technology types and process options. Section 5.3 documents the technology evaluation and selection step, in which technologies were evaluated on the basis of their effectiveness, technical implementability, and cost. Technology types and process options remaining after the final screening were subsequently assembled into the set of candidate site-wide remedial alternatives presented in Section 6.

Consistent with the CERCLA process and EPA Guidance described above, the FS process under MTCA includes the identification and preliminary screening of potentially applicable remedial alternatives or remedial components (i.e. technologies). The objective of this step is to reduce the number of alternatives or components that are carried through to the detailed analysis. Under MTCA, an alternative or component can be eliminated if: 1) the remedial component does not meet the minimum MTCA requirements under 173-340-360(2), including components with costs that are clearly disproportionate (WAC 173-340-360(3)); and 2) the remedial component is technically not possible at the site. Although the identified technologies and process options were screened using CERCLA criteria and terminology consistent with EPA Guidance (EPA 1988), the MTCA requirements were considered and this technology screening process is consistent with the MTCA FS process. Technologies not anticipated to meet the minimum criteria under MTCA, or determined not to be technically possible to implement, were eliminated from further consideration in the initial screening process (Section 5.2). The remaining MTCA criteria and disproportionate costs were considered in the subsequent technology evaluation step documented in Section 5.3.

As previously presented, this Draft Final FS report provides the basis for setting a conditional point of compliance in groundwater and surface water, including information to demonstrate that Site groundwater would be provided with all known available and reasonable methods of treatment (AKART) prior to discharge to Railroad Creek. This section presents the first step of the AKART demonstration through the identification and screening of groundwater collection and treatment technologies for the East and West Areas.

5.1 IDENTIFICATION OF GENERAL RESPONSE ACTIONS AND REMEDIAL TECHNOLOGIES

GRAs were developed to describe categories of remedial technologies that could potentially meet the RAOs identified in Section 4. GRAs and associated technologies and process options that were identified to address source areas, groundwater, and surface water in the East and West Areas are described in the following subsections.

5.1.1 West Area GRAs and Technology Identification

This section presents GRAs and associated technology types and process options identified as potentially applicable for impacted media in the West Area. The following subsections present GRAs identified to address West Area sources and reduce metals loading to groundwater and surface water to meet RAOs.

5.1.1.1 GRAs and Technology Identification for West Area Sources and Soils

The following GRAs have been identified for West Area sources, including the underground mine, and materials and/or soils located in the mill building, maintenance yard, lagoon area, and former surface water retention area. The GRAs were selected in the context of estimated material volumes, PCOCs, and estimated metals loadings presented in Section 2.6.

- No Action – Evaluation of the No Action GRA is required by the NCP.

- Institutional Controls and Physical Restrictions – Includes physical and legal controls implemented to prevent access to underground mine workings and the abandoned mill building. Legal access controls would also be used to prevent future development or land use that would potentially interfere with implemented remedial actions.

- Monitoring – Includes environmental monitoring, sampling, and analyses, performed to evaluate site conditions during construction and implementation of the selected remedial action, and the effectiveness of the remedial action in meeting RAOs.

- Physical Controls – Includes technology types designed to reduce water infiltration and control and/or divert surface and near surface water away from mine residuals for the purpose of reducing PCOC mobility and metals loading to Railroad Creek and groundwater. Several of these actions would simultaneously reduce potential exposure to terrestrial biota. Physical controls also include the installation of bulkheads in mine portals to control the flow of air and water through underground mine workings and improve portal drainage characteristics over time.

- Source Material/Soil Treatment – Includes monitored natural attenuation (MNA), and ex-situ and in-situ treatment technologies designed to reduce the volume, mobility and/or toxicity of PCOCs in West Area source materials and soils.

- Source Material/Soil Removal – Source material removal technology types include excavation, transportation, and disposal options for West Area sources and soils. These actions are designed to reduce exposure to environmental receptors by reducing the volume of PCOCs available for exposure and transport.

The following list of potentially applicable technology types and process options for West Area Sources/Soils GRAs has been identified for initial screening as summarized in Section 5.2. Descriptions of each of the process options listed below are provided in Table 5-1.

<u>No Action</u>

<u>Institutional Controls and Physical Restrictions</u>

- Physical Access Controls
  - Physical restrictions to underground mine workings
  - Physical restrictions to aboveground mine features
- Legal Access Controls
  - Use Restrictions
  - Modification of Wenatchee National Forest Land and Resource Management Plan

<u>Monitoring</u>

- Environmental Monitoring
  - Surface water monitoring
  - Groundwater monitoring
  - Cover monitoring

Physical Controls

- Closure of Underground Mine Portals
  - Air-flow restrictions
  - Hydrostatic bulkheads – 1500 Level
  - Hydrostatic bulkheads – 1100 Level
  - Sealing of drill holes
- Underground Mine Backfilling
  - Backfill stopes with tailings
- In-mine Water Controls
  - Mine drawdown
  - In-mine water storage
  - Selective in-mine water diversion
- Residual Reworking
  - Regrading
- Infiltration Barriers
  - Vegetative soil covers
  - Low permeability clay covers
  - Low permeability geosynthetic covers
  - Capillary barriers
  - Oxygen consuming covers
  - Revegetation
  - Asphalt/concrete covers

Source Material/Soil Treatment

- Monitored Natural Attenuation
- Ex-situ Treatment
  - Ex-situ chemical treatment
  - Ex-situ thermal treatment
  - Ex-situ stabilization
- In-situ Treatment
  - In-situ stabilization

Source Material/Soil Removal

- Excavation and Disposal
  - Off-site disposal
  - Relocation on site

5.1.1.2 West Area Groundwater and Surface Water GRAs and Technology Identification

The following GRAs were identified for West Area groundwater and surface water including the portal drainage, West Area seeps/groundwater, and the Copper Creek diversion. The GRAs were selected in the context of the estimated flow rates, inflow and recharge rates, PCOCs, and metals loading presented in Section 2.6.

- **Institutional Controls –** Include legal access controls implemented to prevent future development that would potentially interfere with remedial actions and to reduce potential future exposure to PCOCs in site groundwater and surface water.

- **Monitoring –** Includes environmental sampling and analyses, performed to monitor site conditions during construction and implementation of the selected remedial alternative, and to evaluate the effectiveness of the remedial action in meeting RAOs.

- **Physical Controls –** Include technology types designed to control and/or divert surface water and groundwater away from mine residuals for the purpose of reducing metals loading to groundwater and Railroad Creek.

- **Water Treatment –** Includes technology types designed to treat groundwater, seeps, and the portal drainage. Technology types under this GRA include physical, chemical, and biological treatment options designed to improve water quality, and reduce metals loading to groundwater and Railroad Creek.

- **In-mine Treatment –** Includes physical, chemical, and biological treatment options implemented in the mine and designed to improve portal drainage water quality and reduce metals loading to groundwater and Railroad Creek.

The following list of potentially applicable technology types and process options for West Area Groundwater and Surface Water GRAs has been identified for initial screening as summarized in Section 5.2. Descriptions of each of the process options listed below are provided in Table 5-1.

<u>No Action</u>

<u>Institutional Controls and Physical Restrictions</u>

- Legal Access Controls
  - Use Restrictions
  - Modification of the Wenatchee National Forest Land and Resource Management Plan

<u>Monitoring</u>

- Environmental Monitoring
  - Surface water monitoring
  - Groundwater monitoring

<u>Physical Controls</u>

- Surface-water Controls
  - Upgradient overland flow diversions
  - Copper Creek Diversion culvert
- Upgradient Groundwater Controls
  - Groundwater barrier walls
  - Extraction wells
  - Diversion trenches

- Downgradient Groundwater Controls
  - Groundwater barrier walls
  - Extraction wells
  - Collection trenches, basins, French drains, or pipes

Water Treatment

- Physical/Chemical Treatment
  - Chemical addition and precipitation
  - Aeration
  - Filtration/clarification
  - Membrane separation
  - High density sludge systems
  - High rate clarification
  - Evaporation
  - Ion exchange
  - Molecular recognition technology
  - Nanoporous adsorbents
  - Electrocoagulation
  - Electrolytic recovery
  - Biopolymer beads
  - Anoxic limestone drains
  - Open limestone channels
  - Permeable reactive barriers
- Physical/Chemical/Biological Treatment
  - Aerobic wetland treatment
  - Anaerobic wetland treatment

In-mine Treatment

- Physical and Chemical Treatment
  - In-mine chemical addition and precipitation
  - In-mine filtration/clarification
- Physical, Chemical, and Biological Treatment
  - Anaerobic in-mine treatment

5.1.2 East Area GRAs and Technology Identification

This section presents GRAs and associated technology types and process options identified as potentially applicable for impacted media in the East Area. The following subsections present GRAs identified to address East Area source materials, tailings pile slope stability concerns, and reduce metals loading to groundwater and surface water to meet RAOs.

5.1.2.1 East Area GRAs and Technology Identification

The following GRAs have been identified for East Area sources, including Tailings Piles 1, 2, and 3. The GRAs were selected in the context of estimated material volumes, PCOCs, and metals loadings presented in Section 2.6.

- No Action – Evaluation of the No Action GRA is required by the NCP.

- Institutional Controls – Includes legal access controls implemented to prevent future development that would potentially interfere with implemented remedial actions.

- Monitoring – Includes environmental sampling and analyses performed to monitor site conditions during construction and implementation of the selected remedial alternative, and to evaluate the effectiveness of the remedial action in meeting RAOs. Activities also include stability monitoring performed to verify the stability of the tailings piles side slopes and monitoring the condition of engineered covers.

- Physical Controls – Includes technology types designed to reduce infiltration and control and/or divert surface and near surface water away from tailings materials for the purpose of reducing PCOC mobility and metals loading to groundwater and Railroad Creek.

- Source Material Treatment – Includes MNA, and ex-situ and in-situ treatment technologies designed to reduce PCOC volumes, mobility and/or toxicity in the tailings. Several of these actions would simultaneously reduce potential exposure to terrestrial biota.

- Source Material Removal – Includes excavation, transportation, and disposal options for the tailings. Disposal options include off-site, on-site, and in-mine disposal. These actions are designed to reduce threats to environmental receptors by reducing the volume of PCOCs available for exposure and transport.

- Source Material Consolidation – Includes consolidation of tailings piles 1, 2, and 3 to reduce the overall surface area and footprint of the material. The purpose of consolidation would be to reduce the volume of material in direct contact with surface water and groundwater to reduce metals loading to groundwater and Railroad Creek.

The following list of potentially applicable technology types and process options for East Area Source GRAs has been identified for initial screening as summarized in Section 5.2. Descriptions of each of the process options listed below are provided in Table 5-2.

<u>No Action</u>

Institutional Controls

- Legal Access Controls
  - Use Restrictions
  - Modification of the Wenatchee National Forest Land and Resource Management Plan

Monitoring

- Environmental Monitoring
  - Surface water monitoring
  - Groundwater monitoring
  - Cover monitoring
  - Slope stability monitoring

Physical Controls

- Infiltration Barriers
  - Vegetative soil covers
  - Low permeability clay covers
  - Low permeability geosynthetic covers
  - Capillary barriers
  - Oxygen consuming covers
  - SRB covers
  - Revegetation
  - Lime application
  - Asphalt/concrete covers

Source Material Treatment

- Monitored Natural Attenuation
- Ex-situ Treatment of Tailings
  - Ex-situ chemical treatment
  - Reprocessing
  - Ex-situ stabilization
- In-situ Treatment of Tailings
  - In-situ stabilization
  - In-situ biological treatment
  - Biocide treatment

Source Material Removal

- Excavation and Disposal
  - Off-site disposal
  - Relocation on site
  - In-mine disposal

Source Material Consolidation

- Tailings Pile Consolidation
  - Consolidation of tailings piles 1, 2 and 3

5.1.2.2 East Area Groundwater and Surface Water GRAs and Technology Identification

The following GRAs were identified for East Area groundwater and surface water. The GRAs were selected in the context of the estimated flow rates, inflow and recharge rates, PCOCs, and metals loading presented in Section 2.6.

- Institutional Controls – Includes legal access controls implemented to prevent future development or land use that would potentially interfere with remedial actions and to reduce potential future exposure to PCOCs in site groundwater and surface water.

- Monitoring – Includes environmental sampling and analyses, performed to monitor site conditions during construction and implementation of the selected remedial alternative, and to evaluate the effectiveness of the remedial action in meeting RAOs.

- Physical Controls – Includes technology types designed to control and/or divert surface water and groundwater water away from tailings materials for the purpose of reducing PCOC mobility and metals loading to Railroad Creek and groundwater. Downgradient collection technology types are also included.

- Water Treatment – Includes technology types designed to treat groundwater and seeps. Technology types under this GRA include physical, chemical, and biological treatment options designed to improve water quality, and reduce metals loading to groundwater and Railroad Creek.

The following list of potentially applicable technology types and process options for East Area Groundwater and Surface Water GRAs has been identified for initial screening as summarized in Section 5.2. Descriptions of each of the process options listed below are provided in Table 5-2.

No Action

Institutional Controls

- Legal Access Controls
  - Deed restrictions

Monitoring

- Environmental Monitoring
  - Surface water monitoring
  - Groundwater monitoring

Physical Controls

- Upgradient Surface-water Controls
  - Upgradient overland flow diversion
  - Regrading
  - Decant tower closure
  - Re-route railroad creek
  - Copper creek culvert
- Upgradient Groundwater Controls
  - Groundwater barrier walls
  - Extraction wells
  - Diversion trenches
- Downgradient Groundwater Controls
  - Groundwater barrier walls
  - Extraction wells
  - Collection trenches, French drains, or pipes

Water Treatment

- Physical and Chemical Treatment
  - Chemical addition and precipitation
  - Aeration
  - Filtration/clarification
  - Membrane separation
  - High density sludge systems
  - High rate clarification
  - Evaporation
  - Ion exchange
  - Molecular recognition technology
  - Nanoporous adsorbents
  - Electrocoagulation
  - Electrolytic recovery
  - Biopolymer beads
  - Anoxic limestone drains
  - Open limestone channels
  - Permeable reactive barriers
- Physical, Chemical, and Biological Treatment
  - Aerobic wetland treatment
  - Anaerobic wetland treatment

5.1.2.3 East Area Slope Stability GRAs and Technology Identification

The following GRAs have been identified to address concerns regarding tailings pile slope stability and the potential for a release of tailings to Railroad Creek or Copper Creek. The GRAs were selected in the context of estimated material volumes, evaluated slope stability, and the proximity to surface water bodies.

- No Action – Evaluation of the No Action GRA is required by the NCP.

- Monitoring – Includes the periodic assessment of tailings pile slope stability during construction and implementation of the selected remedial alternative.

- Containment – Includes erosion control and stability enhancement measures designed to mitigate wind and surface water erosion, and reduce undercutting and scouring of the tailings piles side slopes during high stream flows in Railroad Creek. Containment technologies also include regrading, buttressing, and the installation of gabion walls to contain and increase the stability of the piles and reduce the potential for a release of tailings to Railroad Creek.

The following list of potentially applicable technology types and process options for East Area Slope Stability GRAs has been identified for initial screening as summarized in Section 5.2. Descriptions of each of the process options listed below are provided in Table 5-2.

<u>No Action</u>

<u>Monitoring</u>
- Stability Monitoring
  - Tailings pile slope stability monitoring

<u>Containment</u>
- Erosion Controls
  - Enhancement of existing riprap
  - Low rockfill buttress
  - Geosynthetic matting
  - Organic matting
  - Revegetation
- Stability Enhancement
  - Regrading
  - Gabion walls
  - Geo-grid reinforced soil buttress
  - Geo-web reinforced soil buttress

<u>Stream Control</u>
- Diversion
  - Re-route Railroad Creek
  - Copper Creek culvert

<u>Partial Source Removal</u>
- Partial Tailings Pile Excavation and Disposal
  - Off-site disposal
  - Relocation on site
  - In-mine disposal

5.2 INITIAL TECHNOLOGY SCREENING

The objective of the initial screening process is to assemble a subset of technically feasible and potentially applicable process options from the larger set of identified technology types. Technology types and process options retained during the initial screening step are further evaluated in Section 5.3.

In accordance with EPA Guidance (EPA 1988), the technical feasibility and general applicability of each process option is evaluated during the initial screening based on the following factors:

- Applicability to the specific site conditions,
- Applicability to the PCOCs present, and
- Anticipated effectiveness based on PCOC concentrations and site conditions.

Although CERCLA terminology is used throughout this section, the initial screening step was performed consistent with the MTCA FS process. Technologies (or remedial components) determined not to be technically possible or not anticipated to meet the threshold requirements under CERCLA and minimum requirements under MTCA were screened from further consideration. The initial screening of technologies was performed in collaboration with the Agencies and is based on site characterization data presented in the revised DRI and summarized in Section 2 of this report. As required by the NCP, the No Action GRA is retained for further consideration to provide a baseline against which all other GRAs and technologies are compared.

5.2.1 Initial Screening of West Area Technologies

This section summarizes the results of the initial screening process for each of the West Area GRAs. A brief description of each process option and the results of the initial screening are provided on Table 5-1. The identified process options in Table 5-1 are grouped into West Area Source Actions and West Area Groundwater and Surface Water Actions. General West Area Actions, including No Action, Institutional Controls, Physical Access Restrictions, and Monitoring, are listed together in the first part of the table.

Process options retained for further analysis are carried forward to the final technology evaluation presented in Section 5.3.

5.2.1.1 Institutional Controls, Physical Access Restrictions and Monitoring

All identified process options under the Institutional Controls, Physical Access Restrictions, and Monitoring GRAs were retained for further evaluation.

5.2.1.2 Initial Screening of West Area Source/Soil Actions

This section provides a summary of process options identified for West Area Sources/Soils that were screened from further consideration in the initial screening step. Brief descriptions of all the identified process options are provided in Table 5-1.

Physical Controls

All identified process options included under the Physical Controls GRA were retained for further evaluation for one or all of the West Area sources with the exception of three cover options: low permeability clay covers, capillary barriers, and oxygen consuming covers. These options were eliminated from further consideration for West Area sources including the waste rock piles, mill building, maintenance yard, lagoon area, and former surface water retention area based on the following:

- Waste Rock Piles – Clay covers, capillary barriers and oxygen consuming covers are not applicable for installation on waste rock pile side slopes as a result of physical constraints resulting from the severe slope angles. In addition, the large quantities of materials required for construction, lack of local material sources, and limited site access preclude the construction of these covers on the flat surfaces at the top of each pile. Other more technically feasible options for reducing metals loading from the waste rock piles, including low permeability geosynthetic covers placed on the top surfaces of each pile, and methods of upgradient and downgradient water controls have been retained for further evaluation.

- Mill Building – Clay covers, capillary barriers, and oxygen consuming covers are not applicable for construction over isolated materials located in the former mill building, including material in the concentrate tanks and ore bins. Results of the loading analysis indicate that the primary transport pathway for metals loading from the mill building is surface water runoff, which is currently directed to the lagoon area through a drain located in the maintenance yard. A concrete foundation already covers a majority of the soils beneath the mill building, reducing infiltration to the subsurface. Other options for reducing metals loading from this area, including soil covers, methods of upgradient and downgradient water diversion/collection, and material excavation and relocation on site have been retained for further evaluation.

- Maintenance Yard – Clay covers, capillary barriers, and oxygen consuming covers are not applicable for installation in this area due to ongoing use by the Village for heavy equipment and vehicle maintenance and storage. Other options for reducing the potential migration of PCOCs from this area, including asphalt/concrete covers and methods of upgradient and downgradient water diversion/collection have been retained for further evaluation.

- Lagoon Area – Clay covers, capillary barriers, and oxygen consuming covers are not applicable due to fluctuating groundwater levels in this area and saturated conditions during the spring. Other options for reducing potential metals loading from the materials present in this area, including excavation and relocation on site have been retained for further evaluation.

- Former Surface Water Retention Area – Clay covers, capillary barriers, and oxygen consuming covers are not applicable due to the large quantities of material required for construction, lack of local material sources, and limited access to this area. Other options for reducing potential metals loading from the materials present in this area, including vegetative soil covers, and excavation and relocation on site have been retained for further evaluation.

As indicated above, in all cases, process options with similar effectiveness were retained for further consideration in the FS.

Source Material/Soil Treatment

Monitored natural attenuation and all ex-situ and in-situ treatment technologies were retained for further evaluation with the exception of thermal treatment. While effective for treating materials with elevated concentrations of organic constituents, thermal treatment technologies are not effective in treating materials with elevated metals concentrations. Therefore, this technology type would not be effective in addressing PCOCs present in West Area sources and waters.

Source Material/Soil Removal

All West Area source material removal options, including both off-site disposal and on-site relocation, were retained for further analysis.

5.2.1.3 Initial Screening of West Area Groundwater and Surface Water Actions

This section provides a summary of process options identified for West Area groundwater and surface water that were screened from further consideration in the initial screening step. Brief descriptions of all the identified process options are provided in Table 5-1.

Physical Controls

All process options identified under the Physical Controls GRA for West Area waters were retained for further evaluation in Section 5.3. Retained technology types include surface water controls, and upgradient and downgradient groundwater controls.

Water Treatment

All identified options under the Water Treatment GRA were retained, with the exception of the following:

- Evaporation,
- Nanoporous adsorbents,
- Electrocoagulation,
- Electrolytic recovery,
- Biopolymer beads,
- Open limestone channels, and
- Permeable reactive barriers.

In all cases, process options with similar effectiveness were retained for further consideration in the FS.

Two types of evaporation were considered, mechanical evaporation and evaporation ponds. Mechanical evaporation uses steam or electrical power to evaporate the influent flow and produce recovered water with low concentrations of PCOCs. For liquids with a high potential for salting or scaling, evaporators that do not depend on boiling to induce circulation are typically used. An example of this type of evaporator is a submerged tube forced circulation system. Mechanical evaporators, including the submerged tube forced circulation systems, typically produce a final waste stream with a total solids content of less than approximately five percent. Additional processing equipment, such as filters and/or dryers, is typically used to thicken the final sludge which is then stabilized, as needed, for disposal. Additionally, large amounts of energy are required to evaporate, condense, and cool the evaporated water prior to discharge to Railroad Creek. Assuming an efficiency of 80 percent, the evaporation of one gallon of water would require approximately 3.5 kw hr. As a result, mechanical evaporation was eliminated from consideration due to the large volumes and variable flow rates for West Area waters, high operation and maintenance requirements, and the resulting concentrated waste stream requiring further treatment and disposal.

Evaporation ponds are effective in appropriate climates where sufficient land area is available to completely evaporate flows being treated. Evaporation ponds were eliminated from consideration for the Holden Mine site due to the low anticipated effectiveness for site conditions, including seasonal fluctuations in water flows, local climatic conditions (cold winters with heavy snowfall and wet spring conditions), and limited land area available for pond construction.

Nanoporous adsorbents, such as self-assembled monolayers on mesoporous support (SAMMS), remove metals from the water column through various adsorption processes. The adsorbants are placed in contact with the influent water stream in a fixed bed, batch tank, or fluidized bed application. Metals are adsorbed onto active sites on the adsorbent materials, which are chemically tailored to bind with select metals constituents, and the resulting product is removed from the water column and disposed. Nanoporous adsorbents were eliminated due to the chemical complexities of the portal drainage and West Area seeps and groundwater, and the innovative status of this technology. The development of multiple types of sorbents, formulated to selectively bind the various PCOCs, may be required to effectively treat West Area waters and it is uncertain if this technology would be able to achieve potential discharge requirements. There are currently no full-scale systems using this technology in operation.

Electrocoagulation induces the oxidation of metals constituents in water passed between two metal plates charged with a direct electrical current. A portion of each plate is also consumed in the process. The oxidized metals are then removed through precipitation and clarification. This technology is typically applied to low-volume industrial waste streams with flows less than 500 gpm and consistent influent chemistry. Due to the innovative status of this technology, electrocoagulation systems have not been applied to flows greater than 1000 gpm. This technology is not applicable to site conditions due to the high seasonal flows, and the complexity and variability of the portal drainage, groundwater, and seep water chemistry, which would significantly impact system performance. Therefore, electrocoagulation was eliminated from further consideration.

Electrolytic recovery uses conductive electrodes to promote oxidation reactions, and the recovery of metals constituents from influent waters. This technology was eliminated due to low anticipated effectiveness for providing reliable treatment of complex West Area waters under remote and isolated site conditions.

Biopolymer beads, such as sodium alginate, have been demonstrated to bind with metals constituents in acid mine drainage. However, research related to the full-scale application of this technology and the potential for bead regeneration is ongoing, and currently no full-scale systems using this technology are in operation. Therefore, this technology was eliminated from further consideration for application at this site.

Open limestone channels provide alkalinity to enhance the precipitation of metals constituents as water flows through the channel by gravity. Limestone channels were eliminated from further consideration due to significant land and limestone requirements and low demonstrated effectiveness in treating West Area waters during the implementation of Forest Service actions in the 1990's. During the work completed by the Forest Service in 1990, limestone was placed within the portal drainage channel to increase alkalinity and reduce dissolved metals loading to Railroad Creek. Precipitation of aluminum and other metal oxyhydroxides resulted in armoring of the limestone surfaces and limited the effectiveness of this action.

Permeable reactive barriers (PRBs) contain or create a subsurface reactive treatment zone designed to intercept and passively remediate impacted groundwater by physical, chemical, or biological processes. PRBs are installed as permanent or semi-permanent units across the impacted flow path. Reactive media used in PRBs include zero-valent iron, sorbents (such as activated carbon and zeolites), ion-exchange resins, compost (containing sulfate-reducing microbes), and limestone. PRBs utilizing a combination of compost and pea gravel have been used at a limited number of mine sites to address metals, such as cadmium, copper, and zinc in groundwater. This technology utilizes sulfate-reducing bacteria to produce hydrogen sulfide, which then reacts with metals to form insoluble metal sulfides. Anoxic limestone barriers, similar to anoxic limestone drains, have also been used at a limited number of mining-related sites for iron removal.

Cold water temperatures have been documented to adversely impact the effectiveness of PRBs, such as the compost pea gravel technology, particularly in shallow groundwater bodies. This is because the cold water temperatures affect the activity of the sulfate-reducing bacteria. Additionally, both the compost barrier and anoxic limestone barriers must be maintained in an anaerobic condition. Observed water level fluctuations at the Site would likely reduce the ability to maintain anaerobic conditions and result in lower efficiencies. Elevated concentrations of aluminum, which is present in Site groundwater, have also been documented to significantly impact the performance of anoxic limestone barriers due to the precipitation and subsequent plugging of reactive surfaces within the media. PRBs were eliminated from further consideration for the West Area due to the cold winter and spring temperatures, water level fluctuations, and elevated concentrations of aluminum, which would significantly impact the efficiency of this technology.

In-mine Treatment

All identified options under the In-mine Treatment GRA, including in-mine chemical addition, precipitation, clarification, and anaerobic in-mine treatment, were retained for further evaluation.

5.2.2 Initial Screening of East Area Technologies

This section summarizes the results of the initial screening process for each of the East Area GRAs. A brief description of each process option and the results of the initial screening of East Area technologies are provided on Table 5-2. The identified process options in Table 5-2 are grouped into East Area Source Actions, East Area Groundwater and Surface Water Actions, and East Area Slope Stability Actions. General East Area Actions, including No Action, Institutional Controls, and Monitoring, are listed together in the first part of the table.

Process options retained for further analysis are carried forward to the final technology evaluation presented in Section 5.3.

5.2.2.1 Institutional Controls and Monitoring

All identified process options under the Institutional Controls and Monitoring GRAs, including legal access controls and environmental monitoring options, were retained for further evaluation.

5.2.2.2 Initial Screening of East Area Source Actions

This section provides a summary of process options identified to reduce metals loading from Tailings Piles 1, 2, and 3 that were screened from further consideration in the initial screening step. Brief descriptions of all the identified process options are provided in Table 5-2.

Physical Controls

All identified process options included under the Physical Controls GRA were retained for further evaluation with the exception of low permeability clay covers. Placement of a low permeability clay cover was not considered to be feasible due to the large quantities of clay and other materials required for construction of the approximately 90-acre cover (greater than approximately 200,000 cubic yards of compacted clay), and the lack of a local clay source. Other cover options with similar anticipated effectiveness were retained for further evaluation.

Source Material Treatment

Monitored natural attenuation and all identified ex-situ treatment options under the Source Material Treatment GRA, including treatment, reprocessing, and stabilization of the tailings were retained for further evaluation.

In-situ treatment options, including in-situ stabilization, biological treatment, and biocide treatment were screened from further consideration. In-situ stabilization, which involves the injection and mixing of stabilization chemicals with the materials to be treated in place, was eliminated due to the technical infeasibility of achieving consistent mixing deep in the piles, and the potential for in-situ acidic conditions to interfere with stabilizing reactions. In-situ biological treatment and biocide treatment were eliminated based on the innovative nature of these technologies for large-scale application, and uncertain effectiveness for the existing site conditions and tailings pile chemistry. Full-scale application of in-situ biological treatment has currently not been implemented. Additionally, biocide treatment has not proven effective in controlling acid production in materials that are already generating acid drainage.

Source Material Removal

All identified process options under the Source Material Removal GRA, including off-site disposal, relocation on site, and in-mine disposal, have been retained for further evaluation.

Source Material Consolidation

The consolidation of tailings piles 1, 2, and 3 was retained for further evaluation in Section 5.3.

5.2.2.3 Initial Screening of East Area Groundwater and Surface Water Actions

This section provides a summary of process options identified for East Area groundwater and surface water that were screened from further consideration in the initial screening step. Brief descriptions of all the identified process options are provided in Table 5-1.

Physical Controls

All process options identified under the Physical Controls GRA for East Area waters were retained for further evaluation in Section 5.3. Retained technology types include upgradient surface water controls, upgradient groundwater controls, and downgradient groundwater controls.

Water Treatment

All identified options under the Water Treatment GRA were retained with the exception of the following:

- Membrane separation,
- Evaporation,
- Ion exchange,
- Nanoporous adsorbents,
- Electrocoagulation,
- Electrolytic recovery,
- Biopolymer beads, and
- Permeable reactive barriers.

In all cases, process options with similar effectiveness were retained for further evaluation in Section 5.3.

Membrane separation was screened from consideration due the high concentrations of aluminum, iron, and manganese present in the East Area waters. As described for ion exchange, the precipitation of these metals under oxidizing conditions within the filter media has been documented to impact system performance.

Two types of evaporation options were considered, mechanical evaporation and evaporation ponds. Mechanical evaporation uses steam or electrical power to evaporate the influent flow and produce recovered water with low concentrations of PCOCs for discharge. For liquids with a high potential for salting or scaling, evaporators that do not depend on boiling to induce circulation are typically used. An example of this type of evaporator is a submerged tube forced circulation system. Mechanical evaporators, including submerged tube forced circulation systems, typically produce a final waste stream with a total solids content of less than approximately five percent. Additional processing equipment, such as filters and/or dryers is typically used to thicken the final sludge which is then stabilized, as needed, for disposal. Additionally, large amounts of energy are required to evaporate, condense, and cool the evaporated water. Assuming an efficiency of 80 percent, the evaporation of one gallon of water would require approximately 3.5 kw hr. As a result, mechanical evaporation was eliminated from consideration due to the large volumes and variable flow rates for East Area waters, high operation and maintenance requirements, and the resulting concentrated waste stream requiring further treatment and disposal.

Evaporation ponds are effective in appropriate climates, where sufficient land area is available to completely evaporate flows being treated. Evaporation ponds were eliminated from consideration for the Holden Mine site due to low anticipated effectiveness for site conditions including seasonal fluctuations in water flows, local climatic conditions (cold winters with heavy snowfall and wet spring conditions), and limited land area available for pond construction.

Ion exchange utilizes reactive resin materials to selectively remove metals from solution. Ion exchange was eliminated due to the high concentrations of metals such as aluminum, iron and manganese present in East Area seeps and groundwater. Precipitation of these metals under oxidizing conditions within the ion exchange columns has been documented to significantly impact system performance.

As described for the West Area, nanoporous adsorbents, such as SAMMS, remove metals from the water column through various adsorption processes. This technology was eliminated due to the chemical complexities of the portal drainage and East Area seeps and groundwater, and the innovative status of this technology. Multiple types of sorbents, formulated to bind to the various PCOCs, may be required to effectively treat East Area waters and it is uncertain if this technology would be able to achieve potential discharge requirements. There are currently no full-scale systems using this technology in operation.

Electrocoagulation induces the oxidation of metals constituents in water passed between two metal plates charged with a direct electrical current. A portion of each plate is consumed in the process. The oxidized metals are then removed through precipitation and clarification. This technology is typically applied to low-volume industrial waste streams with flows less than 500 gpm and consistent influent chemistry. Due to the innovative status of this technology, electrocoagulation systems have not been applied to flows greater than 1000 gpm. This technology is not applicable due to the high seasonal flows, high concentrations of metals such as iron, aluminum, and manganese, and the complexity and variability of the East Area groundwater, and seep water chemistry, which would significantly impact system performance. Therefore, electrocoagulation was screened from further consideration for East Area waters.

Electrolytic recovery uses conductive electrodes to promote oxidation reactions, and the recovery of metals constituents from influent waters. This technology was eliminated due to low anticipated effectiveness for providing reliable treatment of complex East Area waters under remote and isolated site conditions.

Biopolymer beads, such as sodium alginate, have been demonstrated to bind with metals constituents in acid mine drainage. However, research related to the full-scale application of this technology and the potential for regeneration of the biopolymer beads is still ongoing, and there are currently no full-scale systems using this technology in operation. Therefore, this technology was eliminated from further consideration for application at this site.

Permeable reactive barriers (PRBs) contain or create a subsurface reactive treatment zone designed to intercept and passively remediate impacted groundwater by physical, chemical, or biological processes. PRBs are installed as permanent or semi-permanent units across the impacted flow path. Reactive media used in PRBs include zero-valent iron, sorbents (such as activated carbon and zeolites), ion-exchange resins, compost (containing sulfate-reducing microbes), and limestone. PRBs utilizing a combination of compost and pea gravel have been used at a limited number of mine sites to address metals, such as Cd, Cu, and Zn in groundwater. This technology utilizes sulfate-reducing bacteria to produce hydrogen sulfide, which then reacts with metals to form insoluble metal sulfides. Anoxic limestone barriers, similar to anoxic limestone drains, have also been used at a limited number of mining-related sites for iron removal.

As described for the West Area, PRBs were eliminated from further consideration for the East Area due to the cold winter and spring temperatures, water level fluctuations, and elevated concentrations of aluminum, which would significantly impact the efficiency of this technology. Cold water temperatures have been documented to adversely impact the effectiveness of PRBs, such as the compost pea gravel technology, particularly in shallow groundwater bodies. (Cold water temperatures affect the activity of the sulfate-reducing bacteria.) Additionally, both the compost barrier and anoxic limestone barriers must be maintained in an anaerobic condition. Observed water level fluctuations would likely reduce the ability to maintain anaerobic condition and result in lower efficiencies. Elevated concentrations of aluminum also have been documented to significantly impact the performance of anoxic limestone barriers due to the precipitation and subsequent plugging of reactive surfaces within the media.

5.2.2.4 Initial Screening of East Area Slope Stability Actions

All options identified for the East Area tailings pile slopes were retained based on their technical feasibility and potential effectiveness in reducing the potential for a release of tailings to Railroad Creek or Copper Creek. Containment options, including erosion control and stability enhancement options, were retained based on their anticipated effectiveness in preventing tailings transport to site surface waters. Options under the Stream Control and Partial Source Removal GRAs were also retained based on their potential effectiveness for reducing tailings pile erosion and the potential for a tailings release to surface water.

5.3 EVALUATION AND SELECTION OF REPRESENTATIVE TECHNOLOGIES

Technology types and process options passing the initial screening summarized in Section 5.2 were further evaluated based on effectiveness, implementability, and cost to obtain a list of process options for use in the development of candidate remedial alternatives. Results of the technology evaluation and selection process are summarized in Tables 5-3 and 5-4.

In accordance with EPA guidance (EPA 1988), technologies and process options were evaluated with respect to the following screening criteria:

- Effectiveness – For the purposes of this evaluation, the primary measure of effectiveness is the degree to which a process option would potentially provide for protection of human health and the environment and contribute toward attainment of RAOs for the Site. According to EPA Guidance, the effectiveness of a potentially applicable process option at this level of screening includes engineering judgments regarding (1) the technology's capacity to handle the estimated areas or volumes of media to be remediated; (2) its potential impacts to human health and the environment during the construction and implementation phase; and (3) its demonstrated reliability with respect to the contaminants and anticipated conditions at the Site. Process options are also evaluated on the basis of effectiveness relative to other options within the same technology type.

- Implementability – Technologies determined to be technically infeasible were eliminated from further consideration during the initial screening process. However, during this final screening step, process options are further evaluated with respect to their technical and administrative feasibility. In this final evaluation step, the administrative feasibility of potential options is emphasized (EPA 1988). Administrative aspects of a technology's implementability considered during this step include:
  - Anticipated public acceptance;
  - Ability to obtain permits for off-site actions;
  - Availability of treatment, storage, and disposal facilities; and
  - Availability of resources, specialized equipment, and skilled workers to implement the technology.

- Cost – The cost analysis performed for the technology evaluation and selection step is based on engineering judgment as directed by EPA guidance (EPA 1988). Capital and operation and maintenance (O&M) costs were evaluated relative to other process options in the same technology type and are assigned a cost rating of high, moderate, or low in lieu of more detailed estimates. Where applicable, the volume and area estimates for the Site were considered in estimating the anticipated costs of each process option. At this evaluation level, process options providing similar effectiveness at significantly higher relative costs were eliminated from further consideration. Similarly, options that provide a lower level of effectiveness and/or implementability at a similar relative cost may also be eliminated.

Although this secondary technology evaluation and screening process was completed using CERCLA criteria and terminology, the process is consistent with the MTCA FS process. Through this evaluation and screening process, technologies not anticipated to meet the "threshold" requirements under CERCLA and minimum requirements under MTCA were eliminated from further consideration. Process options providing similar effectiveness at significantly higher relative costs were also eliminated from further consideration, which is also consistent with the MTCA provision allowing the screening of technologies for which costs are clearly disproportionate.

As requested by the Agencies, detailed summaries of the evaluation and screening of three process options identified for the East and West Areas, including underground mine backfilling, tailings reprocessing, and on-site tailings relocation are provided in the following subsections. These sections are followed by summaries of the evaluation and selection of representative technologies for the West and East Areas.

5.3.1 Evaluation of Mine Backfilling

Underground mine backfilling was identified as a potential West Area process option to reduce the potential for subsidence of open mine stopes located close to the ground surface. Backfilling was also evaluated as a means to dispose of a portion of the tailings placed in tailings piles 1, 2, and 3, to reduce metals loading from these materials and provide additional space for the construction of groundwater collection and treatment systems.

5.3.1.1 Mine Backfilling - Introduction

As described in Section 2 and in the DRI report, the removal of ore materials from the mine resulted in the formation of underground voids, called stopes, as well as other tunnels and openings to allow human access, ore and equipment transport, and ventilation. During operations, a large portion of the workings created below the 1500 level of the mine were backfilled with tailings material. Approximately 1.5 million cubic yards of tailings were reportedly backfilled in the mine over the period of operation. However, stopes present above the 1500 level were not backfilled. A number of the stopes have been documented to be within 50 feet of the ground surface. Therefore, the Agencies have requested an evaluation of mine backfill as a possible means to reduce the potential for subsidence of these upper stopes, which could result in increased surface water infiltration and airflow into the mine.

An initial assessment completed as part of the RI indicated there was a potential for subsidence within the mine. Due to the relatively large size of the underground stopes, measures to mitigate the potential for future subsidence are limited. At other abandoned and active mine sites, tailings have been used with varying degrees of success to backfill underground openings with the intent to mitigate potential subsidence. The use of tailings as backfill was evaluated for the Site as a means of reducing the potential for subsidence, and reducing the volume of tailings outside the mine that currently provide a source of metals loading to surface water and groundwater. A detailed discussion of mine backfilling is provided in Appendix C.

5.3.1.2 Mine Backfilling – Screening Evaluation

There are three backfilling methods currently employed by the mining industry:

- Dry backfill - Dry solids, such as tailings, are placed into open voids using haul trucks or various types of belt conveyance systems.

- Hydraulic backfill - A tailings slurry thickened to a viscous liquid is pumped into the open voids.

- Paste backfill – A thickened mixture of tailings and cement or fly ash is pumped into the open voids.

Dry backfill was not considered for the Site due to the high degree of uncertainty regarding the ability to effectively place dry tailings within the non-uniformly shaped void spaces to prevent future settlement and provide structural support to mitigate the potential for subsidence.

A detailed evaluation of hydraulic and paste backfilling techniques is provided in Appendix C. Results of this evaluation indicate that although the use of hydraulic or paste backfill has advantages over the placement of dry tailings, significant uncertainties remain with respect to the effectiveness of these options in mitigating the potential for subsidence. This is due to future settlement of the backfilled material, and technical difficulties in achieving complete fill of the void spaces. The analysis also indicates that the use of hydraulic or paste backfilling techniques may achieve the relocation of only approximately 30 percent of the total volume of tailings present in tailings piles 1, 2, and 3.

In addition to the uncertainties related to the effectiveness of this technology in achieving the objectives stated above, results of the evaluation also indicate the following concerns related to potential impacts to human health and the environment during implementation, the technical and administrative implementability of this option, and cost:

- Mine backfilling would have an unknown effect on mine water quantity and quality. The backfilled tailings could generate significant quantities of acidic mine water that would flow from the portal or elsewhere.

- Significant power requirements are associated with the use of large capacity pumps to convey paste or hydraulic backfill to the top of the open stopes. As a result, implementation of this option would require the construction of a conventional fuel-based power generation facility at the Site.

- A large processing facility would be required to screen the tailings materials to achieve proper grain size distributions for either paste or hydraulic backfilling techniques. The lack of homogeneity of the tailings materials would adversely impact pumping efficiencies for both techniques as tailings properties change. The implementation of hydraulic backfill would require the materials to be free-draining, which would involve the removal of fine-grained materials. Operation of a processing facility would be required for several seasons, and may disrupt operations of the Village during that time.

- The net gain in elevation between the tailings piles and input points may be as much as 1,500 vertical feet, resulting in a complex, staged, pumping process.

- The existing pumping distance and elevation gain from the tailings piles to the potential input points is greater than current known backfilling operations.

- Significant safety concerns exist related to the need for workers to enter and work deep within the underground mine workings to ensure backfill penetration.

- Assuming a backfill rate of 200 tons per hour, 8 hours per day, and 300 days per year, backfilling would take 6.5 years.

- There are significant risks of pipeline breaks and tailings spills during the backfilling operation.

- The amount of water necessary for backfilling will be significant. Depending in part on the type of backfill utilized, water requirements are estimated to range between 1 percent and 20 percent of average flow in Railroad Creek, and between about 4 percent and 40 percent of base flow in the creek.

- A large capital expenditure (greater than $50 million) would be required for implementation of this option. These costs are clearly disproportionate to the benefits achieved when compared to other retained East Area options, including natural attenuation, infiltration barriers, and groundwater collection and treatment.

Based on the above-mentioned findings, backfilling of the tailings into the underground mine was not carried through to the detailed analysis.

5.3.2 Evaluation of Tailings Reprocessing

Reprocessing was identified as an East Area process option to potentially reduce the reactivity of the tailings and subsequent metals loading to East Area groundwater and Railroad Creek.

5.3.2.1 Tailings Reprocessing - Introduction

The three tailings piles consist of the remains of the ore milling process for the extraction of economic metal sulfide minerals. Metals that were recovered during mining operations included copper, zinc, gold, and silver and the efficiency of extraction/recovery process varied for each metal. As a result, the tailings contain varying concentrations of both economic metal sulfide minerals and iron sulfides.

Tailings reprocessing was evaluated for the potential to: 1) reduce metal sulfide concentrations, thereby reducing the acid-generating characteristics of the tailings; and 2) recover economic metal sulfides and associated precious metals (gold and silver) to potentially offset the costs of reprocessing and site remediation. A detailed evaluation of tailings reprocessing is provided in Appendix C.

5.3.2.2 Tailings Reprocessing – Screening Evaluation

Results of the screening evaluation indicate that reprocessing would likely remove a portion of the acid generating sulfide minerals from the tailings. However, not all of the acid generating potential would be removed from the tailings due to the large concentrations of iron sulfides. Additionally, a large volume of highly reactive pyrite solids would be produced as a byproduct of the process, and this material would require further treatment prior to disposal. Reprocessing would not provide a net reduction in the total volume of tailings, and the reprocessed tailings would still require handling and transportation prior to disposal at an on-site or off-site location.

A cost analysis was performed for this option based on current metal prices. The results indicate a net cost between $112 million to $120 million above any revenue that may be generated from the recovery of economic minerals. Additionally, preliminary analyses indicate that some of the gold and silver present in the tailings may be contained in minerals such as silica, which are not recoverable through reprocessing technologies. This may further reduce the potential revenue generated through reprocessing, as these two minerals represent a large portion of estimated potential revenues. Based on this evaluation, the costs associated with reprocessing are clearly disproportionate to the benefits achieved when compared to other retained East Area options, including natural attenuation, infiltration barriers, and groundwater collection and treatment

In addition to the uncertainties related to the effectiveness of reprocessing to significantly reduce tailings reactivity and the substantial cost of implementation, results of the evaluation also indicate the following concerns related to potential impacts to human health and the environment during implementation and technical and administrative implementability:

- The construction and operation of a large reprocessing facility on site. The reprocessing plant would require significant power for operation, and the power requirements may necessitate the construction of a conventional fuel-based power plant due to the limited power supply that could be derived through hydroelectric means on a year-round basis. This would also involve the construction of additional roads and bridges, and clearing of a suitable area for facility construction.

- The transportation of large volumes of chemical reagents to the Site would be required. These chemicals would need to be transported from Chelan via barge, increasing the potential for accidental release to Lake Chelan.

- The process would take approximately 7 years to complete. This would delay other efforts to remedy site conditions and may cause disruption to Village operations for an extended period of time.

Based on the above-mentioned findings, tailings reprocessing was not carried through the detailed analysis.

5.3.3 Evaluation of Tailings Relocation On Site

Tailings relocation within the Railroad Creek drainage was identified as an East Area process option to reduce impacts to groundwater and Railroad Creek resulting from tailings pile drainage, and to reduce the potential for a release of tailings due to slope failure or high stream flow.

5.3.3.1 Tailings Relocation On Site – Introduction

There are approximately 230,500,000 cubic feet (8,500,000 cubic yards) of tailings contained in three piles located along Railroad Creek. Based on the review of aerial photographs, five sites (Areas A through E) were identified as potentially suitable for tailings relocation within the Railroad Creek watershed, excluding the Glacier Peak Wilderness Area. The sites were identified based on topography and size, and all of the identified sites have a relatively flat to gently sloping topography and an area estimated to be greater than 15 acres. Figures providing the locations of Areas A through E are provided in Appendix C.

5.3.3.2 On-site Tailings Relocation – Screening Evaluation

Based on the analysis provided in Appendix C, three of the five areas evaluated (Areas A, C, and E) would not be of sufficient size to contain all the tailings material, even with the three areas combined, and were therefore eliminated from further consideration. Of the two remaining identified areas that could accommodate the total volume of tailings, one is located approximately 8 miles east of the Site (Area D), and one is located across Railroad Creek, just east of tailings pile 3 (Area B). These sites were not retained for further consideration due to the following:

- Relocation of the tailings to a new undisturbed location within the Railroad Creek watershed would not reduce the overall volume of tailings requiring long-term management in the valley.
- To relocate the tailings to Area B, located across Railroad Creek immediately east of tailings pile 3, it would take a fleet of ten 40-cubic yard scrapers more than seven construction seasons to complete, approximately 213,000 round trips, and 213,000 gallons of diesel fuel.
- To relocate the tailings to Area D, located approximately eight miles east of the Site, it would take a fleet of thirty 15-cubic yard haul trucks more than 13 construction seasons to complete, approximately 567,000 round trips, and 189,000 gallons of diesel fuel.
- The exposure of unoxidized tailings during excavation and relocation would potentially cause the generation of additional acid rock drainage.

- During relocation, multiple water treatment systems may be required to mitigate acidic run-off from the new and current locations.

- Relocation would cause the disruption to the Village over an extended period of time, and may result in a higher risk to inhabitants and visitors due to increased exposure to dust from tailings during transport.

- The cost of relocating the tailings to Area B is estimated to be approximately $155,000,000 and the cost of relocating the tailings to Area D is estimated to be approximately $183,000,000. These costs are clearly disproportionate to the benefits achieved when compared to other retained East Area options, including natural attenuation, infiltration barriers, and groundwater collection and treatment

Based on the above-mentioned findings, the on-site relocation of tailings was not carried through to the detailed analysis.

5.3.4 Evaluation and Selection of West Area Technologies

The following subsections summarize the results of the screening process for West Area sources and soils, surface water, and groundwater. West Area sources and soils, as identified in the DRI, include the underground mine, waste rock piles, and soils and materials in the mill building, maintenance yard, lagoon area, and former surface water retention area. Results of the evaluation and selection process for West Area technologies are summarized in Table 5-3. Process options retained during the final evaluation were carried forward to develop candidate remedial alternatives, as described in Section 6.

During the evaluation, several process options were retained as *Secondary Options* for implementation on a limited basis, as determined during the design phase of the project. Secondary options are not developed or evaluated independently in the detailed analysis of alternatives presented in Section 7. However, they are retained for possible consideration during the remedial design.

5.3.4.1 No Action, Institutional Controls, Physical Access Restriction, and Monitoring

All process options evaluated under the No Action, Institutional Controls, Physical Access Restrictions, and Monitoring GRAs were retained for remedial alternative development:

<u>No Action</u>

<u>Institutional Controls and Physical Restrictions</u>

- Physical Access Controls
  - Physical restrictions to underground mine workings
  - Physical restrictions to aboveground mine features
- Legal Access Controls
  - Use Restrictions
  - Modification of Wenatchee National Forest Land and Resource Management Plan

Monitoring

- Environmental Monitoring
  - Surface water monitoring
  - Groundwater monitoring
  - Cover monitoring

5.3.4.2 Evaluation and Selection of Actions for West Area Sources and Soils

Process options retained for incorporation into remedial alternatives for one or more of the West Area sources or soils include:

Physical Controls

- Closure of Underground Mine Portals
  - Airflow restrictions
  - Hydrostatic bulkheads – 1500 level
  - Hydrostatic bulkheads – 1100 level (secondary option)
  - Sealing of drill holes (secondary option)
- In-mine Water Control
  - Mine drawdown (secondary option)
  - In-mine water storage
  - Selective in-mine water diversion (secondary option)
- Residual Reworking
  - Regrading
- Infiltration Barriers
  - Vegetative soil covers
  - Low permeability geosynthetic covers
  - Revegetation
  - Asphalt/concrete covers

Source Material/Soils Treatment

- Monitored Natural Attenuation
- Ex-situ Treatment
  - Ex-situ chemical treatment (secondary option)
  - Ex-situ stabilization (secondary option)

Source Material/Soils Removal

- Excavation and Disposal
  - Off-site disposal (secondary option)
  - Relocation on Site

The following subsections provide summaries of the technology evaluation and selection process for each of the West Area Source/Soils GRAs:

Physical Controls

Technology types included under the Physical Controls GRA include underground mine closure, underground mine backfilling, in-mine water controls, residual reworking, and infiltration barriers.

Closure of Underground Mine Portals

Airflow restrictions were retained for open portals on and above the 1500 level to reduce the flow of oxygen through underground mine workings and improve water quality characteristics over time. Airflow restrictions installed in the 1500-level main portal would be designed to allow drainage to continue from the mine.

Hydrostatic bulkheads were retained for the 1500-level main portal and ventilator portal to control portal drainage flow rates for treatment, provide surge storage, and control airflow through the mine. The installation of a low-head hydrostatic bulkhead was also retained as a secondary option for the 1100 level to prevent the seasonal low-flow discharge observed from the 1100-level portal.

Due to difficulties associated with identifying all drill holes completed during mine development (the average diameter of the drill holes is less than approximately three inches), the sealing of drill holes was retained as a secondary option for use in conjunction with other technologies. Drill holes would be closed on an opportunistic basis if found to contribute air or water flow to the underground mine.

Underground Mine Backfilling

As described in Section 5.3.1 backfilling of the underground mine with tailings was not retained for further evaluation due to uncertain effectiveness, environmental and health and safety risks during and after implementation, and the availability of other options with more certain effectiveness for reducing metals loading from the underground mine. In addition, the costs associated with mine backfilling are clearly disproportionate to the benefits achieved in comparison with other lower-cost options.

In-mine Water Controls

The mine drawdown option was retained as a secondary option for use in conjunction with other technologies as applicable during the remedial design to provide additional storage capacity below the 1500 level if hydrostatic bulkheads prove not to be feasible. Mine drawdown was not retained as a primary option due to the potential for mobilization of additional metals into the portal drainage from the exposure of surfaces below the 1500 level to oxidizing conditions; lower implementability for the installation and maintenance of an effective pumping system; and depth constraints related to the use of siphons. Additionally, mine drawdown presents potential structural complications related to dewatering adjacent to areas where sand/tailings backfill has occurred.

In-mine water storage was retained for use in conjunction with hydrostatic bulkheads to control portal drainage flows and provide surge storage within the mine. Selective in-mine water diversion was also retained for evaluation of the potential effectiveness of in-mine mixing of high-acidity drainage from the upper mine workings with the moderately alkaline drainage observed upwelling from the lower mine workings. A potential option for evaluation includes the installation of a discharge pipe deep into the number 2 shaft and the placement of hydrostatic bulkheads in the 1500-level portals to allow the discharge of mine water from the number 2 shaft. This option has the potential to promote mixing and increased detention times for higher acidity water from the upper stopes.

Residual Reworking

The regrading process option was retained for use on the flat tops of the east and west waste rock piles to enhance runoff and reduce infiltration of precipitation and snowmelt. Regrading was also retained to mitigate the potential physical hazard associated with an isolated portion of the west waste rock pile located on the west side of the portal museum. Regrading was not retained as a primary option for use in the lagoon area, maintenance yard, mill building, or former surface water retention area, due to the anticipated low effectiveness in reducing water infiltration in these areas as a stand-alone option relative to other retained technologies.

Infiltration Barriers

Vegetative soil covers, revegetation, and low permeability geosynthetic covers were retained for potential use in the former surface water retention area and select areas within the mill building, where removal of mineralized materials is difficult.

Low permeability geosynthetic covers and asphalt/concrete covers were retained for use on the flat top surfaces of the waste rock piles. Due to the large surface area and lack of local material sources, vegetative soil covers were determined to have lower implementability and higher costs for this area relative to geosynthetic or asphalt/concrete covers. Revegetation as a stand-alone option is anticipated to have low effectiveness without the placement of a growth medium on top of the waste rock material.

Asphalt/concrete covers were retained for use in the maintenance yard, to reduce infiltration and increase surface water runoff from the area. Installation of an asphalt/concrete cover system would allow continued use of the area for equipment/vehicle maintenance and storage by the Village. Maintenance of other cover systems would interfere with these ongoing activities.

Due to elevated groundwater levels observed in the lagoon area during the spring season, no infiltration barrier options were retained for this area based on lower anticipated effectiveness relative to other source removal options.

Source Material/Soils Treatment

Monitored natural attenuation was retained as an option for the underground mine and waste rock piles. Geochemical analyses completed for these source areas indicate that natural attenuation is occurring, and that over time, the release of PCOCs to groundwater and Railroad

Creek will decline through natural geochemical processes. The geochemical analyses performed for the Holden Mine site are presented in Section 7 and Appendix E.

Ex-situ treatment technologies, including chemical treatment and stabilization were retained as secondary options for the treatment of limited quantities of unanticipated materials prior to disposal. These options were not retained as primary treatment options due to the high cost and uncertain effectiveness in mitigating long-term acid generation and reducing PCOC mobility within variable West Area source materials on a large scale relative to other available technologies.

In-situ stabilization was eliminated from further consideration due to low predicted effectiveness relative to other retained technologies for the waste rock, and materials in the mill building, maintenance yard, and former surface water retention area given the variable material characteristics, limited access, and topography. In-situ stabilization was also not retained for use in the lagoon area due to seasonal groundwater fluctuations and saturated conditions that would reduce the anticipated long-term integrity of the stabilized materials.

Source Material/Soils Removal

Off-site disposal was retained as a secondary option for limited quantities of currently unanticipated materials that would not be suitable for relocation on site. Off-site disposal was not retained as a primary option due to the large volumes of waste rock and other materials requiring handling and transportation, and permitting requirements for transportation and disposal at a suitable off-site location. Excavation, transportation and relocation on site were retained for further evaluation.

5.3.4.3 Evaluation and Selection of West Area Groundwater and Surface Water Actions

Process options retained for incorporation into remedial alternatives for West Area groundwater and surface water include:

Physical Controls

- Surface Water Controls
  - Upgradient overland flow diversion
  - Copper Creek diversion culvert
- Upgradient Groundwater Controls
  - Diversion trenches
- Downgradient Groundwater Controls
  - Groundwater barrier walls
  - Collection trenches, basins, French drains, and pipes

Water Treatment

- Physical/Chemical Treatment
  - Chemical addition and precipitation
  - Aeration
  - Filtration/clarification

- High density sludge systems
    - High rate clarification (secondary option)
- Physical/Chemical/Biological Treatment
    - Aerobic wetland treatment

<u>In-mine Treatment</u>

- Physical/Chemical Treatment
    - In-mine chemical addition and precipitation (secondary option)
    - In-mine filtration/clarification (secondary option)

Physical Controls

Technology types included under the Physical Controls GRA for West Area groundwater and surface water include surface water controls, upgradient groundwater controls, and downgradient groundwater controls.

Surface Water Controls

Surface water controls including the diversion upgradient overland flow around potential source areas and placement of the Copper Creek diversion in a culvert were retained for further development and evaluation.

Upgradient Groundwater Controls

Upgradient groundwater controls including the installation of barrier walls and groundwater extraction wells were not retained due to the uncertain degree of effectiveness associated with the installation and use of these technologies on the steep hillside above the West Area in heterogeneous subsurface materials. Implementability concerns related to these two technologies include limited access and land area, variable depth to the dense till and/or bedrock, and full-time energy requirements for pumping systems. The estimated energy required to operate an array of pumping wells in the West Area would likely exceed potential hydroelectric generation capabilities on Copper Creek. Therefore, a conventional power generation facility (such as a diesel generator) would likely be required to operate the system. Upgradient diversion trenches or French drains were retained for further consideration due to greater anticipated effectiveness and implementability, and lower costs relative to barrier walls or extraction pumps.

Downgradient Groundwater Controls

Extraction wells were not retained for the collection of water downgradient of potential West Area sources due to the moderate anticipated effectiveness in successfully capturing groundwater flow given the heterogeneous subsurface conditions and the presence of an old Railroad Creek stream channel running through the area. A large number of wells would likely be required to capture a majority of the groundwater flow in this area. Access and power concerns further lower the implementability of this technology relative to other more effective and less costly technologies, such as groundwater barrier walls, collection trenches, basins and French drains.

Water Treatment

Chemical addition and precipitation, aeration, filtration/clarification, high-density sludge systems, high rate clarification (secondary option) and aerobic wetland treatment were retained for West Area waters.

Ion exchange and membrane separation technologies were not retained as viable process options during the technology evaluation process. Ion exchange and membrane separation technologies are considered to be reliable and highly effective in removing metals from water. However, these technologies are typically viewed as advanced treatment techniques for specialized applications such as softening, tertiary polishing, deionization, or ultrapurification of water. These technologies are typically not used for the treatment of water with elevated concentrations of metals including iron or aluminum. If the water being treated has high metals concentrations or contains any amount of dissolved oxygen, there is a risk of fouling the ion exchange resin/filter membrane and clogging the system. In addition, ion exchange and membrane separation technologies produce concentrated residual waste streams that would require further processing and disposal.

Molecular recognition technology (MRT) was not retained due to uncertain effectiveness in reliably treating the complex and variable West Area flows, and lower implementability due to equipment complexity, resin regeneration, power requirements, and treatment and disposal requirements for regenerant solutions. Metals removed in the process are transferred to an acidic regenerant waste stream requiring additional treatment and disposal.

Anoxic limestone drains (ALDs) and anaerobic wetland treatment systems were not retained as primary options due to uncertain effectiveness and implementability, and the availability of more reliable and less costly process options. ALDs are considered to be effective for the removal of metals from mine waters under reducing conditions. However, the measured dissolved oxygen concentrations, oxidation reduction potential (ORP), and aluminum concentration data indicate West Area surface water chemistry would significantly reduce ALD treatment effectiveness. Anaerobic wetland treatment was retained as a secondary option for use in isolated areas as determined during the final design.

In-mine Treatment

In-mine chemical addition and precipitation were retained as secondary options for temporary or periodic use, as appropriate. Due to lower implementability, limited space, safety concerns, and uncertain reliability relative to treatment options implemented outside the mine, a continuously operating system was not retained for further consideration. In-mine filtration/clarification using existing features or bulkheads to enhance precipitation and clarification was retained for further evaluation. However, the conventional use of filtration and settling equipment within the mine was not retained. Locations suitable for construction of filtration equipment or cells, such as former hoist rooms or mechanical rooms, are located deep within the mine and are not readily accessible due to safety concerns. As a result, these technologies would be more implementable outside the mine.

Anaerobic in-mine treatment was also not retained for use at this site, as it has not been demonstrated to provide long-term treatment for higher flow rates, and due to uncertain reliability associated with the inability to control flows through the biological system and provide effective treatment.

5.3.5 Evaluation and Selection of East Area Technologies

The following subsections summarize the results of the screening process for East Area sources (tailings), surface water and groundwater, and tailings pile slope stability actions. As described for the West Area, several process options were retained as *Secondary Options* for implementation on a limited basis, as determined during the design phase of the project. These options are not developed or evaluated independently in the detailed analysis of alternatives presented in Section 7. Results of the evaluation and selection process for East Area technologies are summarized in Table 5-4. Process options retained during the final evaluation were carried forward to develop candidate remedial alternatives, as presented in Section 6.

5.3.5.1 No Action, Institutional Controls, and Monitoring

All process options evaluated under the East Area No Action, Institutional Controls, and Monitoring GRAs were retained for remedial alternative development:

<u>No Action</u>

<u>Institutional Controls</u>

- Legal Access Controls
  - Use Restrictions
  - Modification of Wenatchee National Forest Land and Resource Management Plan

<u>Monitoring</u>

- Environmental Monitoring
  - Surface water monitoring
  - Groundwater monitoring
  - Cover monitoring
  - Stability monitoring

5.3.5.2 Evaluation and Selection of East Area Source Actions

This section summarizes the results of the final screening process for each of the East Area Source GRAs. East Area sources include tailings piles 1, 2, and 3, situated on the south side of Railroad Creek to the east of the mill building and waste rock piles. Process options retained for incorporation into remedial alternatives for East Area sources include:

Physical Controls

- Infiltration Barriers
  - Low permeability geosynthetic covers
  - Revegetation
  - Lime application

Source Material Treatment

- Monitored Natural Attenuation

Source Material Consolidation

- Tailings Pile Consolidation
  - Consolidation of tailings piles 1, 2 and 3

Physical Controls

Low-permeability geosynthetic covers and revegetation were retained for further evaluation related to reducing surface water infiltration into the tailings piles. Lime application was retained as a secondary option to improve conditions for revegetation. Other identified infiltration barrier options, including vegetative soil covers, capillary barriers, oxygen consuming covers, SRB covers, and asphalt/concrete covers were eliminated due to higher relative costs, lower implementability, and similar or lower effectiveness in reducing infiltration relative to the retained technologies. The implementation of geosynthetic covers or enhanced revegetation is anticipated to be effective in reducing infiltration as discussed in Section 7.

Source Material Treatment

Monitored natural attenuation was retained as an option for the tailings piles 1, 2, and 3. Geochemical analyses completed for the tailings indicate that natural attenuation is occurring, and that over time, the release of PCOCs to groundwater and Railroad Creek will decline through natural geochemical processes. The geochemical analyses performed for the Holden Mine site are presented in Section 7 and Appendix E.

No ex-situ source material treatment technologies were retained for the development of candidate remedial alternatives. As described in Section 5.3.2 the reprocessing of tailings, using either hydrometallurgical or pyrometallurgical techniques, was eliminated from further consideration based on the infeasibility and impracticality of large-scale excavation, reprocessing, and re-depositing tailings materials. Minimal reductions in source material volume would be achieved during reprocessing and the high costs of recovering residual metal values from the source material would significantly exceed the value of potentially recovered metals. Ex-situ chemical treatment and ex-situ stabilization of tailings were also eliminated due to uncertain effectiveness in mitigating long-term acid generation within the tailings given the chemical characteristics and the implementability constraints of large-scale excavation and treatment of the approximately 9 million cubic yards of material. The costs associated with ex-situ treatment are clearly disproportionate to the benefits achieved when compared to other East Area process options.

Source Removal

No source removal technologies were retained for further evaluation. As described in Section 5.3.1, excavation and in-mine disposal was eliminated due to volume limitations within underground mine stopes available to store the tailings, and significant implementability concerns. Due to the location and configuration of the underground stopes, as well as significant power, equipment, and water requirements, implementation of this option would not be technically feasible and would likely pose significant risks to human health and the environment during implementation.

As discussed in Section 5.3.3, excavation and on-site disposal within the Railroad Creek valley was eliminated from further consideration due to the potential for source material releases during construction, long-term impacts to the selected disposal location, and implementation concerns. Similarly, excavation and off-site disposal was eliminated due to the potential for increased metals loading and accidental release to Railroad Creek and/or Lake Chelan during excavation and transportation, and the implementability concerns associated with the lack of infrastructure, including constructing and maintaining suitable access roads and bridges at the remote site. Additionally, the selected off-site disposal location would require long-term management to prevent impacts to environmental receptors at that location.

To transport the approximately 8.5 to 9 million cubic yards of tailings off site, approximately 600,000 trips from the Site to Lucerne would be required by haul trucks with carrying capacities of approximately 15 cubic yards. Greater than approximately 200,000 barge trips would then be required to transport the material to Chelan. The significant material handling requirements would increase the risk of short-term environmental impacts due to accidents and the release of materials during transport. This option would also require the transport of significant quantities of fuel and increase the potential for additional risk to workers and the local community from injury-causing accidents. Therefore, the costs associated with removal of the tailings piles were determined to be clearly disproportionate to other lower-cost options.

Source Material Consolidation

Tailings consolidation was retained for further evaluation. Consolidation would reduce the overall surface area material in contact with Site surface water and groundwater and may provide greater access and land area for the installation of downgradient collection and treatment systems.

5.3.5.3 Evaluation and Selection of East Area Surface Water and Groundwater Actions

This section summarizes the results of the final screening process for each of the East Area Surface Water and Groundwater GRAs. Process options retained for incorporation into remedial alternatives for East Area waters include:

Physical Controls

- Upgradient Surface-water Controls
  - Upgradient overland flow diversion
  - Regrading
  - Decant tower closure
  - Re-route Railroad Creek
  - Copper Creek culvert
- Upgradient Groundwater Controls
  - Diversion trenches
- Downgradient Groundwater Controls
  - Groundwater barrier walls
  - Collection trenches and pipes

Groundwater Treatment

- Physical and Chemical Treatment
  - Low-energy chemical addition and precipitation
  - Low-energy Aeration
  - Low-energy Filtration/clarification
  - Anoxic limestone drains (secondary option)
  - Open limestone channels (secondary option)
- Physical, Chemical, and Biological Treatment
  - Aerobic wetland treatment
  - Anaerobic wetland treatment (secondary option)

Physical Controls

Technology types included under the East Area Physical Controls GRA for groundwater and surface water include surface water controls, upgradient groundwater controls, and downgradient groundwater controls.

Surface Water Controls

All surface water control options identified under the Physical Controls GRA, including upgradient overland flow diversion, regrading, decant tower closure, re-routing Railroad Creek, and the placement of a portion of Copper Creek in a culvert, were retained for further evaluation. These technologies were retained based on their potential to mitigate the infiltration of unimpacted surface and near-surface water through the tailings, and to reduce contact with Railroad Creek and Copper Creek.

Upgradient Groundwater Controls

Upgradient groundwater controls, including the installation of cutoff walls and groundwater extraction wells, were not retained due to the uncertain degree of effectiveness associated with the implementation of these technologies on the steep hillside above the East Area in heterogeneous subsurface materials. Technical concerns related to the implementation of these two technologies include limited access and land area, variable depth to the dense till and/or bedrock, and full-time energy requirements for pumping systems. The estimated energy required to operate an array of pumping wells in the West Area would likely exceed potential hydroelectric generation capabilities on Copper Creek. Therefore, a conventional power generation facility (such as diesel generators) would likely be required to operate the system. As a result, upgradient diversion trenches and French drains were retained for further consideration due to greater anticipated effectiveness and implementability, and lower costs relative to barrier walls or extraction pumps. The costs associated with barrier walls and extraction pumps are clearly disproportionate to installation of diversion trenches or French drains.

Downgradient Groundwater Controls

Extraction wells were not retained for the collection of groundwater and seeps in the East Area due to the moderate anticipated effectiveness in reliably capturing groundwater flow in the heterogeneous subsurface conditions. The high iron content and acidic nature of the East Area groundwater would significantly increase operation and maintenance requirements and reduce system performance. A large number of wells would be required to capture a majority of the groundwater flow in this area, and therefore concerns related to power generation further lower the implementability of this technology relative to groundwater barrier walls and collection trenches, basins or French drains.

Groundwater Treatment

Mechanical water treatment technologies, including chemical addition/precipitation, filtration/ clarification, high density sludge systems, and high rate clarification processes were eliminated during the final technology screening process. These mechanical options were not retained due to reliability concerns related to remote operations, variable influent flows and water chemistry, increased power and maintenance requirements, and the availability of lower-energy gravity flow systems that utilize drop structures and settling ponds to provide similar treatment efficiencies for the iron-rich groundwater and seeps. Chemical addition and precipitation, and low-energy methods of aeration and filtration/clarification were retained for further evaluation.

Aerobic wetland treatment was also retained for the removal of metals from seeps and groundwater in the East Area. As most aerobic wetlands systems include anaerobic zones where sulfate reduction may occur, anaerobic wetland treatment was retained as a secondary technology for evaluation during the remedial design. Similarly, ALDs were retained as a secondary option for further evaluation during the remedial design for alkalinity addition. Open limestone channels were also retained as a secondary option for providing alkalinity to acidic groundwater and seeps in the East Area. However, other alkalinity-adding methods, such as lime addition, would likely be more reliable and cost-effective.

5.3.5.4 Evaluation and Selection of East Area Slope Stability Actions

This section summarizes the results of the final screening process for East Area Slope Stability GRAs. Process options retained for incorporation into remedial alternatives for East Area tailings pile slopes include:

Containment

- Erosion Controls
  - Enhancement of existing riprap
  - Low rockfill buttress (secondary option)
  - Geosynthetic matting (secondary option)
  - Organic matting (secondary option)
  - Revegetation (secondary option)
- Stability Enhancement
  - Regrading

Stream Control

- Diversion
  - Re-route Railroad Creek
  - Copper Creek culvert

Containment

All the erosion control technologies evaluated for the tailings pile slopes, including enhancement of existing riprap, low rockfill buttress, geosynthetic matting, organic matting, and revegetation, were retained for further analysis as primary or secondary options based on their potential effectiveness in reducing surface erosion and/or containing material in the event of a release.

Stability enhancement technologies including gabion walls, geogrid reinforced soil buttress, and geoweb reinforced soil buttress were eliminated from further consideration based on the significant material requirements, lack of local sources, and complexity of construction that lower the implementability of these options relative to regrading. Regrading the tailings side slopes was retained for evaluation in conjunction with the retained containment technologies described above, based on their combined potential effectiveness to enhance slope stability and prevent a release of tailings to site surface waters.

Stream Control

Stream control technologies, including rerouting Railroad Creek to the north and the containment of Copper Creek in a culvert, were retained based on their potential effectiveness in mitigating undercutting, erosion, and scouring of the tailings pile side slopes and limiting contact with tailings and groundwater seepage.

Table 5-1
Initial Screening of Remediation Technologies and Process Options for the West Area

General Response Action	Technology Types	Process Options	Description	Screening Comments
No Action	None	Not Applicable	No remedial action implemented.	Required for consideration by the NCP
Institutional Controls & Physical Access Restrictions	Physical Access Controls	Physical Restrictions to Underground Mine Workings	Installation of access restrictions and warning signes in open mine portals. Access restrictions could include locking gates, doors, or bulkheads.	Potentially applicable
		Physical Restrictions to Aboveground Mine Features	Maintain existing fencing and signage around the abandoned mill building and the placement of fences or signs around other potential physical hazards associated with historical mining activities, as needed.	Potentially applicable
	Legal Access Controls	Use Restrictions	Implementation of use restrictions to prevent future development and land use that may interfere with implementation of selected remedy or increase potential exposure to human or ecological receptors.	Potentially applicable
		Modification of the Wenatchee National Forest Land & Resource Management Plan	The Wenatchee National Forest Land and Resource Management Plan would be modified to provide the ability to enforce use restrictions that run with the land.	Potentially applicable
Monitoring	Environmental Monitoring	Surface Water Monitoring	Periodic surface water sampling from designated stations in Railroad Creek to verify remedial action effectiveness.	Potentially applicable
		Groundwater Monitoring	Periodic groundwater sampling from designated monitoring wells during construction and implementation of selected remedy.	Potentially applicable

Table 5-1
Initial Screening of Remediation Technologies and Process Options for the West Area

General Response Action	Technology Types	Process Options	Description	Screening Comments
		Cover Monitoring	Periodic monitoring to verify the integrety of engineered covers and identify potential maintenance and repair requirements. Typically consists of visual observations and/or site surveys.	Potentially applicable
		West Area Source/Soil Actions		
Physical Controls	Closure of Underground Mine Portals	Air-flow Restrictions	The 1500-level main portal, ventilator tunnel, and open portals above the 1500-level are sealed to reduce air flow through the mine. Earthen, concrete or steel bulkheads of various designs are installed to reduce oxygen flow through open mine workings and improve water quality characteristics over time.	Potentially applicable
		Hydrostatic Bulkheads - 1500 Level	Hydrostatic bulkheads are installed in the 1500-level main and ventilator portals. Available storage capactity within the mine is used to control and equalize portal drainage flows for reducing seasonal discharge spikes and/or treatment.	Potentially applicable
		Hydrostatic Bulkheads - 1100 Level	A low-head hydrostatic bulkhead is placed in the 1100-level portal to prevent the seasonal low-flow discharge observed at this location.	Potentially applicable
		Sealing of Drill Holes	Open drill holes identified during the RI are sealed to reduce the flow of oxygen and water through underground mine workings.	Potentially applicable

Table 5-1
Initial Screening of Remediation Technologies and Process Options for the West Area

General Response Action	Technology Types	Process Options	Description	Screening Comments
	Underground Mine Backfilling	Backfill Stopes with Tailings	Mine stopes are backfilled with tailings through upper mine workings using hydraulic or paste backfilling techniques. Typically performed by creating a slurry of tailings or tailings/grout mixture which is pumped into underground void spaces to reduce aie and water flow.	Potentially applicable
	In-mine water controls	Mine Drawdown	The exiting water level within the underground mine (1500-level) is lowered using siphons or pumps. The resulting additional storage capacity is utilized to control and equalize portal drainage flows for reducing seasonal discharge spikes and/or treatment.	Potentially applicable
		In-mine Water Storage	Available storage capacity within the mine is used to control and equalize portal drainage flows for reducing seasonal discharge spikes and/or treatment. Used in conjunction with hydrostatic bulkheads.	Potentially applicable
		Selective In-mine Water Diversion	Drainage from upper mine workings (characterized by low alkalinity and concentrations of cadmium, copper, and zinc) are mixed with mine water from lower workings (characterized by moderate alkalinity and elevated iron concentrations). Water is redirected by installing drainage pipes and bulkheads within the 1500-level and possibly the #2 shaft to facilitate metals removal underground.	Potentially applicable

Table 5-1
Initial Screening of Remediation Technologies and Process Options for the West Area

General Response Action	Technology Types	Process Options	Description	Screening Comments
	Residual reworking	Regrading	Regrading waste rock piles and soils in the mill building, maintenance yard and/or lagoon area using conventional equipment to reduce physical hazards (isolated portion of a west waste rock pile), water infiltration and mobility of PCOCs.	Potentially applicable
	Infiltration Barriers	Vegetative Soil Covers	A layer of lightly compacted top soils approx 12 to 24 in. thick is placed on top of the waste-rick piles, select locations within the mill building, maintenance yard and/or lagoon area. The soil is placed to obtain permeabilities in the range of 1 x 10^{-3} to 1 x 10^{-4} cm/s, a suitable medium for plant growth, and moisture retention. The cover promotes evapotranspiration, prevents surface erosion, and retards infiltration.	Potentially applicable
		Low Permeability Clay Covers	A layer of compacted clay soil approx 12 to 24 in thick is placed on top of the waste-rock piles, select locations within the mill building, maintenance yard, and/or lagoon area to retard the downward migration of water through the tailings. A cover of shallow-rooted native plants is typicall placed on top of the clay layer to provide erosion protection.	Not applicable to west area sources due to quantity of materials required, source material characteristics and topography.
		Low Permeability Geosynthetic Covers	Typical construction of a geosynthetic barrier includes placement of a two-sided geocomposite seepage control laye on top of the impacted materials, followed by a low density geomembrane, and a second two-sided geocomposite infiltration collection layer. The geocomposite/ geomembrane system is then typically covered with approximately 18 inches of soil and a 6-in topsoil/vegetative layer.	Potentially applicable

Table 5-1
Initial Screening of Remediation Technologies and Process Options for the West Area

General Response Action	Technology Types	Process Options	Description	Screening Comments
		Capillary Barriers	A layer of coarse gravel 8 to 12 in. thick is placed on top of waste rock piles, select locations wtihin the mill building, maintenance yard and/or lagoon. Approx 1.5 to 3 ft of soil is then placed and compacted on top of the gravel layer. The top soil layer is typically vegetated with shallow-rooted native plants. The gravel layer provides a "capillary break" which enhances the water storage capacity of the soil by breaking the normal downward suction forces and allowing water to be held in the upper soil layer by capillary tension.	Not applicable to west area source materials due to quantity of materials required for construction, material characteristics and topography.
		Oxygen Consuming Covers	An organic layer with high biological oxygen demand (BOD) is placed below a vegetative soil cover. The organics remove oxygen from water infiltration through the cover, resulting in anoxic conditions underneath the cover. This reduces chemical reactions that increase the mobility of metals within mine residuals. Naturally occurring soil bacteria also consume the oxygen in the soil as they degrade the organic matter.	Not applicable to west area source materials due to quantity of materials required for construction, material characteristics and topography.
		Revegetation	Sod or vegetative growth media and seed are placed on top of mining residuals and/or impacted soils to promote evapotranspiration and prevent surface erosion.	Potentially applicable

Table 5-1
Initial Screening of Remediation Technologies and Process Options for the West Area

General Response Action	Technology Types	Process Options	Description	Screening Comments
		Asphalt/Concrete Covers	A layer of asphalt is placed on top of the materials to minimize infiltration of water into the tailings piles and reduce surface erosion.	Potentially applicable
Source Material/Soil Treatment	Monitored Natural Attenuation	Geochemical Processes	Natural attenuation (NA) is described by the EPA as "…a variety of physical, chemical, or biological processes that, under favorable conditions, act without human intervention to reduce the mass, toxicity, mobility, volume, or concentration of contaminants in soil or groundwater." This definition is also consistent with the 2001 MTCA. Geochemical analyses performed for the Site indicate NA is occuring, and that over time, the release of PCOCs from West Area sources will decline through natural geochemical processes. (Appendix E)	Potentially applicable
	Ex-situ Treatment	Ex-situ Chemical Treatment	Alkaline chemicals such as lime are mixed with all or a portion of acid generating waste to neutralize the acidity and control or stop acid generation processes.	Potentially applicable
		Ex-situ Thermal Treatment	Soils from the maintenance yard and/or mill building are processed using thermal treatment units to destroy organic consituents.	Not applicable for treatment of soils containing metals constituents.
		Ex-situ Stabilization	Mine residuals and/or impacted soils are excavated, treated with stabilization agents in a processing system, and redeposited as inert, monolithic blocks.	Potentially applicable for select materials in the mill building, maintenance yard, and lagoon area. Not applicable to waste rock.

Table 5-1
Initial Screening of Remediation Technologies and Process Options for the West Area

General Response Action	Technology Types	Process Options	Description	Screening Comments
	In-situ Treatment	In-situ Stabilization	Pozzolonic materials are mixed with mine residuals or soils in-place to solidify materials and reduce PCOC mobility.	Potentially applicable for lagoon area soils. Not applicable to waste rock or materials in the mill building or maintenance yard.
Source Material/Soil Removal	Excavation and Disposal	Off-site Disposal	Mine residuals and/or impacted soils are excavated using conventional equipment and transported by trucks to Lucerne. From Lucerne, materials are transported by barge to Chelan, and by truck and/or rail car to a licensed disposal facility.	Potentially applicable
		Relocation On-site	Mine residuals and/or impacted soils are excavated using conventional equipment and transported by truck for consolidation on the tailings piles.	Potentially applicable
		West Area Groundwater and Surface Water Actions		
Physical Controls	Surface Water Controls	Upgradient Overland Flow Diversion	Upslope run-on in the form of overland flow is diverted around source areas using upgradient rock-lined ditches constructed using conventional equipment to a depth of approximately 5-10 ft. Captured water would be diverted toward Copper Creek or Railroad Creek upstream of waste rock piles and the lagoon area.	Potentially applicable
		Copper Creek Diversion Culvert	Copper Creek diversion water, currently in contact with Tailings Pile 1, is placed in concrete, plastic, or steel culvert to minimize contact with PCOCs and tailings pile erosion.	Potentially applicable

Table 5-1
Initial Screening of Remediation Technologies and Process Options for the West Area

General Response Action	Technology Types	Process Options	Description	Screening Comments
	Upgradient Groundwater Controls	Groundwater Barrier Walls	Sheet pilings or trenches filled with low permeability materials are installed to create a subsurface flow barrier. Barrier walls may be used to divert flows of shallow groundwater around waste materials to reduce metals loading to Railroad Creek.	Potentially applicable
		Extraction Wells	Groundwater extraction wells are installed to reduce metals loading to Railroad Creek by creating artificial groundwater sinks to lower the piezometric surface and minimize subsurface flows through mine residuals and/or impacted soils.	Potentially applicable
		Diversion Trenches	Upslope run-on in the form of near surface groundwater flow is diverted around source areas using upgradient rock-lined ditches constructed using conventional equipment to a depth of approximately 5-10 ft. Captured water would be diverted toward Copper Creek or Railroad Creek upstream of waste rock piles and the lagoon area.	Potentially applicable
	Downgradient Groundwater Controls	Groundwater Barrier Walls	Sheet pilings or trenches filled with low-permeability materials are installed to create a subsurface flow barrier between potential West Area sources and Railroad Creek. Barrier walls may be used to divert flows of shallow groundwater into collection and treatment systems prior to discharge to the creek.	Potentially applicable
		Extraction Wells	Groundwater extraction wells are installed to capture groundwater downgradient of potential West Area sources for treatment prior to discharge to Railroad Creek.	Potentially applicable

Table 5-1
Initial Screening of Remediation Technologies and Process Options for the West Area

General Response Action	Technology Types	Process Options	Description	Screening Comments
		Collection Trenches, Basins, French Drains, or Pipes	The 1500-level portal drainage, impacted groundwater and seeps are collected and diverted for treatment using trenches, french drains, collection basins, and pipes as appropriate. The 1500-level portal drainage would be placed within a pipe from the 1500-level main portal entrance.	Potentially applicable
Water Treatment	Physical/ Chemical Treatment	Chemical Addition and Precipitation	Chemical reagents (e.g. caustic soda, soda ash, hydrated lime, or limestone) are added to the portal drainage and captured groundwater/seeps to add alkalinity and promote metal precipitation. Chemical addition may occur at various locations within a treatment system.	Potentially applicable
		Aeration	Air (oxygen) is added to collected West Area water through cascading flows, bubble diffusers, or agitators to oxidize metals and promote precipitation. Typically used in conjunction with alkalinity adding process options for the removal of cadmium, copper, and/or zinc.	Potentially applicable
		Filtration/Clarification	Collected West Area water is filtered and/or clarified to remove suspended and dissolved solids including metals. Typically used in conjunction with chemical addition and precipitation to enhance removal efficiency.	Potentially applicable

Table 5-1
Initial Screening of Remediation Technologies and Process Options for the West Area

General Response Action	Technology Types	Process Options	Description	Screening Comments
		Membrane Separation	Collected West Area water is passed through a membrane system such as reverse osmosis, microfiltration, or ultrafiltration, at varying pressures for the removal of specific concentrations of dissolved solids including, metals, anions, and cations.	Potentially applicable
		High Density Sludge (HDS) Systems	The HDS process removes metals through chemical addition, precipitation, and clarification. Removal is enhanced through co-precipitation with iron on the surfaces of sludge particles recycled through the system. The precipitate is more geochemically stable when there is high iron to total metals in the plant feed. Air is typically sparged into the reactor to enhance oxidation and flocculant may also be added to improve clarification.	Potentially applicable
		High Rate Clarification (HRC) Processes	The HRC process removes metals through chemical addition, precipitation, and clarification. Removal is enhanced through the use of microsand as a seed to enhance flocculation and increase settling rates. This results in the ability to handle higher overflow rates (smaller footprint) and variable hydraulic loading. The microsand is spearated from the resulting sludge in a hydrocyclone and re-injected into the process.	Potentially applicable

Table 5-1
Initial Screening of Remediation Technologies and Process Options for the West Area

General Response Action	Technology Types	Process Options	Description	Screening Comments
		Evaporation	Collected West Area water is evaporated using mechanical evaporation equipment or evaporation ponds. Mechanical evaporators require either steam or electrical power to operate and produce recovered water with low metals concentrations for discharge. Evaporator ponds do not require a power source and would result in zero discharge from the system.	Not applicable due to high water volumes, local climatic conditions, and land area/power requirements.
		Ion Exchange	Collected West Area water is passed through a column of resins that selectively remove metals from solution. Spent resins may be regenerated on site or off site and potentially reused, although eventual disposal would be required.	Potentially applicable
		Molecular Recognition Technology (MRT)	Collected West Area water is passed through a fixed-bed column loaded with a proprietary resin. Target metals are selectively complexed with reactive sites on the MRT product. The columns are periodically eluted in dilute acid, and the highly concentrated waste stream is treated and disposed.	Potentially applicable
		Nanoporous Adsorbents	Collected West Area water is contacted with self-assembled monolayers on mesoporous supports (SAMMS) sorbents in a fixed-bed, batch tank, or fluidized bed application. Target metals are irreversibly adsorbed onto the SAMMS materials. The resulting product is removed from the water column and disposed.	Not applicable due to the chemical complexities of West Area water, the innovative status of the technology, and the availablity of other effective treatment technologies.

Table 5-1
Initial Screening of Remediation Technologies and Process Options for the West Area

General Response Action	Technology Types	Process Options	Description	Screening Comments
		Electrocoagulation	Collected West Area water is passed between two metal plates charged with a direct electrical current, inducing oxidation of metal constituents for removal through precipitation and clarification. A portion of the plate material is typically consumed to enhance the coagulation process.	Not applicable due to high water volumes, innovative nature of the technology, and the availability of other effective treatment technologies.
		Electrolytic Recovery	Conductive electrodes promote oxidation/reduction reactions to take place under an applied electric potential. Elemental metal can then be recovered from the cathode.	Not applicable due to the chemical complexity of water to be treated, and availability of other effective treatment techniques.
		Biopolymer Beads	Collected West Area water is contacted with biopolymer beads (such as sodium alginate) which bind and remove the metals from solution. The beads are then regenerated on site for reuse.	Not applicable due to the chemical complexity of West Area waters, the technology's innovative status, and the availability of other effective treatment technologies.
		Anoxic Limestone Drains (ALD)	Collected West Area water flows though a subsurface limestone-filled trench capped with a composite geomembrane and soil cover to add alkalinity. Typically used in conjunction with aerobic settling ponds or wetlands to provide detention time for precipitation and removal of metal constituents.	Potentially applicable
		Open Limestone Channels	Portal drainage and seep water flows by gravity through an open limestone-filled trench to add alkalinity. Typically used in conjunction with aerobic settling ponds to promote metal precipitation and removal.	Not applicable due to significant land and limestone requirements and the potential for blinding of the limestone surfaces.

Table 5-1
Initial Screening of Remediation Technologies and Process Options for the West Area

General Response Action	Technology Types	Process Options	Description	Screening Comments
		Permeable Reactive Barriers (PRBs)	PRBs contain or create a subsurface reactive zone to intercept and passively treat impacted groundwater by physical, chemical, or biological processes. PRBs are installed as permanent or semi-permanent units across the impacted flow path. Reactive media used in PRBs include zero-valent iron, sorbents (such as activated carbon), ion-exchange resins, compost (containing sulfate-reducing microbes), and limestone. PRBs using compost and pea gravel have been used at limited sites to promote the removal of metals, such as Cd, Cu, and Zn in groundwater as insoluble metal sulfides. Anoxic limestone barriers, similar to anoxic limestone drains, have also been used at a limited number of sites for Fe removal.	Not applicable due to cold temperatures, fluctuating groundwater levels in the West Area and elevated aluminum concentrations.
	Physical/ Chemical/ Biological Treatment	Aerobic Wetland Treatment	Aerobic wetlands typically include features such as deep or shallow water zones, ecosystems consisting of hydric soils and aquatic plants, drop structures, rock filters, and water level control structures. Aerobic wetlands facilitate both abiotic and biologically-enhanced processes resulting in the oxidation and precipitation of dissolved metals. Typically used in conjunction with alkalinity adding process options.	Potentially applicable

Table 5-1
Initial Screening of Remediation Technologies and Process Options for the West Area

General Response Action	Technology Types	Process Options	Description	Screening Comments
		Anaerobic Wetland Treatment	Anaerobic systems combine ALD technology with biological sulfate reduction to generate alkalinity and facilitate metals removal under anaerobic conditions. Dissolved metals are precipitated in the anaerobic system as insoluble sulfide complexes. Anaerobic treatment systems typically include deep water ponds, organic substrate, limestone and hydraulic controls.	Potentially applicable
In-mine Treatment	Physical/ Chemical Treatment	In-mine Chemical Addition and Precipitation	Alkalinity adding chemicals, such as lime, are added to mine waters underground to promote precipitation and removal of metals constituents. Used in conjunction with hydrostatic bulkheads. Chemicals would be added from accessable mine workings above the 1500 level, such as the 1100 or 300 levels.	Potentially applicable
		In-mine Precipitation/ Clarification	Additional detention time is provided for mine water underground through the installation of full or partial bulkheads to promote precipitation/clarification and removal of metal constituents.	Potentially applicable
	Physical/ Chemical/ Biological Treatment	Anaerobic In-mine Treatment	Flow-through cells containing organic matter and sulfate-reducing microorganisms are installed within underground mine workings to promote the precipitation and removal of metals constituents underground. Dissolved metals are precipitated in the anaerobic system as insoluble sulfide complexes. Anaerobic treatment systems typically include deep water ponds, organic substrate, limestone and hydraulic controls.	Potentially applicable

Table 5-2
Initial Screening of Remediation Technologies and Process Options for the East Area

General Response Action	Technology Types	Process Options	Description	Screening Comments
No Action	None	Not Applicable	No remedial action implemented.	Required for consideration by NCP
Institutional Controls	Legal Access Controls	Use Restrictions	Implementation of use restrictions to prevent future development and land use that may interfere with implementation of selected remedy or increase potential exposure to human or ecological receptors.	Potentially applicable
		Modification of the Wenatchee National Forest Land & Resource Management Plan	The Wenatchee National Forest Land and Resource Management Plan would be modified to provide the ability to enforce use restrictions that run with the land.	Potentially applicable
Monitoring	Environmental Monitoring	Surface Water Monitoring	Periodic surface water sampling from designated stations in Railroad Creek to verify remedial action effectiveness.	Potentially applicable
		Groundwater Monitoring	Periodic groundwater sampling from designated monitoring wells during construction and implementation of selected remedy.	Potentially applicable
		Cover Monitoring	Periodic monitoring to verify the integrety of engineered covers and identify potential maintenance/repair requirements. Typically consists of visual observations and/or site surveys.	Potentially applicable
		Slope Stability Monitoring	Periodic monitoring of tailings pile slope stability during construction and implementation of the selected remedy.	Potentially applicable

Table 5-2
Initial Screening of Remediation Technologies and Process Options for the East Area

General Response Action	Technology Types	Process Options	Description	Screening Comments
		East Area Source Actions		
Physical Controls	Infiltration Barriers	Vegetative Soil Covers	A layer of lightly compacted top soils approx 12 to 24 in. thick is placed on top of the tailings piles. The soil is placed to obtain permeabilities in the range of 1 x 10^{-3} to 1 x 10^{-4} cm/s, a suitable medium for plant growth, and moisture retention. The cover promotes evapotranspiration, prevents surface erosion, and retards infiltration.	Potentially applicable
		Low Permeability Clay Covers	A layer of compacted clay soil approx 12 to 24 in thick is placed on top of the tailings piles to retard the downward migration of water through the tailings. A cover of shallow-rooted native plants is typicall placed on top of the clay layer to provide erosion protection.	Not applicable due to material requirements and lack of local source of clay.
		Low Permeability Geosynthetic Covers	Typical construction of a geosynthetic barrier includes placement of a two-sided geocomposite seepage control layer on top of the regraded tailings, followed by a low density geomembrane, and a second two-sided geocomposite infiltration collection layer. The geocomposite/geomembrane system is then typically covered with approximately 18 inches of soil and a 6-in topsoil/vegetative layer.	Potentially applicable

Table 5-2
Initial Screening of Remediation Technologies and Process Options for the East Area

General Response Action	Technology Types	Process Options	Description	Screening Comments
		Capillary Barriers	A layer of coarse gravel 8 to 12 in. thick is placed on the tailings piles, and approx 1.5 to 3 ft of soil is then placed and compacted on top of the gravel layer. The top soil layer is typically vegetated with shallow-rooted native plants. The gravel layer provides a "capillary break" which enhances the water storage capacity of the soil by breaking the normal downward suction forces and allowing water to be held in the upper soil layer by capillary tension.	Potentially applicable
		Oxygen Consuming Covers	An organic layer with high biological oxygen demand (BOD) is placed below a vegetative soil cover. The organics remove oxygen from water infiltration through the cover, resulting in anoxic conditions underneath the cover. This reduces chemical reactions that increase the mobility of metals within mine residuals. Naturally occurring soil bacteria also consume the oxygen in the soil as they degrade the organic matter.	Potentially applicable
		SRB Covers	SRB Covers are constructed by applying a biodegradable organic substance, such as molasses waste or other high BOD substance on the surface of the tailings piles to provide a carbon source for sulfate reducing bacteria.	Potentially applicable
		Revegetation	Sod or vegetative growth media and seed are placed on tailings piles to promote evapotranspiration and prevent surface erosion.	Potentially applicable

Table 5-2
Initial Screening of Remediation Technologies and Process Options for the East Area

General Response Action	Technology Types	Process Options	Description	Screening Comments
		Lime Application	Soil ammendments, such as dolomitic lime are applied to surface tailings to improve conditions for revegetation.	Potentially applicable
		Asphalt/Concrete Covers	A layer of asphalt is placed on top of the tailings to minimize infiltration of water into the tailings piles and reduce surface erosion.	Potentially applicable
Source Material/Soil Treatment	Monitored Natural Attenuation	Geochemical Processes	Natural attenuation (NA) is described by the EPA as "…a variety of physical, chemical, or biological processes that, under favorable conditions, act without human intervention to reduce the mass, toxicity, mobility, volume, or concentration of contaminants in soil or groundwater." This definition is also consistent with the 2001 MTCA. Geochemical analyses performed for the Site indicate NA is occuring, and that over time, the release of PCOCs from the tailings piles will decline through natural geochemical processes. (Appendix E)	Potentially applicable
	Ex-situ Treatment of Tailings	Ex-situ Chemical Treatment	Alkaline chemicals such as lime are mixed with all or a portion of the acid generating tailings materials to neutralize the acidity and control or stop acid generation processes.	Potentially applicable
		Reprocessing	Hydrometallurgical and/or pyrometallurgical techniques are used to extract metal values and generate a more inert residual material. Residuals may be disposed in original tailings pile locations, or within mine shafts.	Potentially applicable

Table 5-2
Initial Screening of Remediation Technologies and Process Options for the East Area

General Response Action	Technology Types	Process Options	Description	Screening Comments
		Ex-situ Stabilization	Tailings are excavated, treated with stabilization agents in a processing system, and redeposited as inert, monolithic blocks.	Potentially applicable
	In-situ Treatment of Tailings	In-situ Stabilization	Pozzolonic materials are mixed with the tailings in-place to solidify the tailings and mitigate leaching of metals.	Not applicable because thorough mixing in the deep tailings piles would be technically infeasible and existing acidic conditions may interfere with stabilizing reactions.
		In-situ Biological Treatment	Microbial agents are injected into tailings piles to immobilize metals and control acid production. Native bacteria selected through bioaugmentation are used to reduce metal leaching within the tailings piles.	Not applicable due to the uncertain effectiveness of this technology. No full-scale systems currently installed or evaluated.
		Biocide Treatment	Chemical agents are applied to the surface of tailings materials to mitigate the onset of biological activity which results in increased metals mobility in mine wastes.	Not applicable because biocide treatment has not proven effective in controlling acid generation.
Source Material Removal	Excavation and Disposal	Off-site Disposal	Tailings are excavated using conventional equipment and transported by trucks to Lucerne. From Lucerne, materials are transported by barge to Chelan, and by truck and/or rail car to a licensed disposal facility in Idaho, Oregon, or Washington.	Potentially applicable

Table 5-2
Initial Screening of Remediation Technologies and Process Options for the East Area

General Response Action	Technology Types	Process Options	Description	Screening Comments
		Relocation On-site	Tailings are excavated using conventional equipment and transported by truck to another location within the valley situated farther away from Railroad Creek and Copper Creek. The selected disposal site would be engineered with a liner and leachage collection system to reduce impacts to surface and groundwater.	Potentially applicable
		In-mine Disposal	Mine stopes are backfilled with tailings through the upper mine workings using hydraulic or paste backfilling techniques to reduce the volume of tailings remaining in potential contact with surface water and groundwater. Typically performed by creating a slurry of tailings or tailings/grout mixture which is pumped into underground void spaces.	Potentially applicable
Source Material Consolidation	Tailings Pile Consolidation	Consolidation of Tailings Piles 1, 2 and 3	Tailings are excavated using conventional equipment and consolidated into one pile to reduce the volume of materials in direct contact with surface water and groundwater.	Potentially applicable
East Area Groundwater and Surface Water Actions				
Physical Controls	Upgradient Surface Water Controls	Upgradient Overland Flow Diversions	Upslope run-on in the form of overland flow is diverted around source areas using upgradient rock-lined ditches constructed using conventional equipment to a depth of approximately 5-10 ft. Captured water would be diverted toward Copper Creek or Railroad Creek upstream of waste rock piles and the lagoon area.	Potentially applicable

Table 5-2
Initial Screening of Remediation Technologies and Process Options for the East Area

General Response Action	Technology Types	Process Options	Description	Screening Comments
		Regrading	Tailings pile surfaces are regraded using conventional equipment to enhance runoff and reduce infiltration into the piles.	Potentially applicable
		Decant Tower Closure	The open decant tower located on tailings pile 1 would be filled with grout to reduce observed surface water transport through subsurface tailings.	Potentially applicable
		Re-route Railroad Creek	Select segments of Railroad Creek are relocated to the north to reduce contact with tailings materials and seepage, and increase available surface area for seep/groundwater collection and treatment.	Potentially applicable
		Copper Creek Culvert	Copper Creek is placed within a culvert between tailings piles 1 and 2 to to reduce potential contact with tailings materials and innundation of east area treatment systems.	Potentially applicable
	Upgradient Groundwater Controls	Groundwater Barrier Walls	Sheet pilings or trenches filled with low permeability materials are installed to create a subsurface flow barrier. Barrier walls may be used to divert flows of shallow groundwater around tailings to reduce metals loading to Railroad Creek.	Potentially applicable
		Extraction Wells	Groundwater extraction wells are installed and operated to reduce metals loading to Railroad Creek by creating artificial groundwater sinks to lower the piezometric surface and minimize subsurface flows through tailings.	Potentially applicable

Table 5-2
Initial Screening of Remediation Technologies and Process Options for the East Area

General Response Action	Technology Types	Process Options	Description	Screening Comments
		Diversion Trenches	Upslope run-on in the form of near/surface groundwater flow is diverted around tailings piles using upgradient rock-lined ditches constructed using conventional equipment to a depth of approximately 5-10 ft. Captured water would be diverted toward Copper Creek or Railroad Creek downstream of the tailings piles.	Potentially applicable
	Downgradient Groundwater Controls	Groundwater Barrier Walls	Sheet pilings or trenches filled with low permeability materials are installed to create a subsurface flow barrier between the tailings piles and Railroad Creek. Barrier walls may be used to divert groundwater and seeps into collection and treatment systems prior to discharge to the creek.	Potentially applicable
		Extraction Wells	Groundwater extraction wells are installed and operated within the tailings piles to collect impacted groundwater for treatment.	Potentially applicable
		Collection Trenches, French Drains, or Pipes.	Groundwater and seeps are collected and diverted for treatment using trenches, french drains, and/or pipes as appropriate. Groundwater/seep collection systems can be used in conjunction with slurry walls or other barrier walls to enhance collection efficiencies.	Potentially applicable
Water Treatment	Physical/ Chemical Treatment	Chemical Addition and Precipitation	Chemical reagents (e.g. caustic soda, soda ash, hydrated lime, or limestone) are added to seep/groundwater to increase alkalinity and promote metal precipitation. Chemical addition may occur at various locations within the treatment system.	Potentially applicable

Table 5-2
Initial Screening of Remediation Technologies and Process Options for the East Area

General Response Action	Technology Types	Process Options	Description	Screening Comments
		Aeration	Seep/groundwater is aerated through drop structures and cascading flows or in tanks using bubble diffusers or agitators to oxidize metals and promote precipitation. Typically used in conjunction with alkalinity adding process options for the removal of cadmium, copper, iron, and zinc.	Potentially applicable
		Filtration/Clarification	Seep/groundwater is filtered (using sand or other media) and/or clarified to remove suspended and dissolved solids including metals. Typically used in conjunction with chemical addition and precipitation to enhance removal efficiency.	Potentially applicable
		Membrane Separation	Seep/groundwater is passed through a membrane system such as, reverse osmosis, microfiltration, or ultrafiltration, at varying pressures for the removal of specific concentrations of dissolved solids including, metals, anions, and cations.	Not applicable due to high concentrations of metals such as iron, aluminum and manganese, which would significantly impact system performance.
		High Density Sludge (HDS) Systems	HDS systems remove metals through chemical addition, precipitation, and clarification. Removal is enhanced through co-precipitation with iron on the surfaces of sludge particles recycled through the clarifier. Typically, air is sparged into the reactor to enhance oxidation processes, and flocculant may also be added to further improve clarification.	Potentially applicable

Table 5-2
Initial Screening of Remediation Technologies and Process Options for the East Area

General Response Action	Technology Types	Process Options	Description	Screening Comments
		High Rate Clarification (HRC) Process	HRC systems remove metals through chemical addition, precipitation, and clarification. Removal is enhanced through the use of microsand as a seed to improve flocculation and settling rates. This allows treatment of higher overflow rates and variable hydraulic loading. The microsand is separated from teh resulting sludge in a hydrocyclone and re-injected to the process.	Potentially applicable
		Evaporation	Seep/groundwater is evaporated using mechanical evaporation equipment or evaporation ponds. Mechanical evaporators require either steam or electrical power to operate and produce recovered water with low concentrations of metals for discharge. Evaporation ponds do not require a power source and would result in zero discharge from the system.	Not applicable due to high water volumes, local climatic conditions and land area/power requirements.
		Ion Exchange	Seep/groundwater is passed through a column of resins that selectively remove metals from solution. Spent resins may be regenerated on site or off site and potentially reused, although eventual disposal would be required.	Not applicable due to the precipitation of metals (such as iron, aluminum and manganese, present in high concentrations in seeps & groundwater originating from the tailings piles), which would significantly impact system performance.

Table 5-2
Initial Screening of Remediation Technologies and Process Options for the East Area

General Response Action	Technology Types	Process Options	Description	Screening Comments
		Molecular Recognition Technology (MRT)	Collected seep and groundwater is passed through a fixed-bed column loaded with a proprietary product. Target metals are selectively complexed with reactive sites on the MRT product and removed from solution. The column is periodically eluted with dilite acid and the highly concentrated waste stream is treated and disposed.	Potentially applicable
		Nanoporous Adsorbents	Collected seeps and groundwater is contacted with self-assembled monolayers on mesoporous supports (SAMMS) sorbents in a fixed-bed, batch tank, or fluidized bed application. Target metals are irreversibly adsorbed onto the SAMMS materials. The resulting product is removed from the water column and disposed.	Not applicable due to the chemical complexity of East Area waters, the innovative status of the technology, and the availability of other effective treatment technologies.
		Electrocoagulation	Collected seeps and groundwater is passed between two metal plates charged with a direct electrical current, inducing oxidation of metal constituents for removal through precipitation and clarification. A portion of the plate material is typically consumed to enhance the coagulation process.	Not applicable due to high and variable water flows and high concentrations of metals such as iron, aluminum, and magnesium, which would significantly impact system performance.
		Electrolytic Recovery	Conductive electrodes promote oxidation/reduction reactions to take place under an applied electric potential. Elemental metal can then be recovered from the cathode.	Not applicable due to the chemical complexity of water to be treated, and availability of other effective treatment techniques.

Table 5-2
Initial Screening of Remediation Technologies and Process Options for the East Area

General Response Action	Technology Types	Process Options	Description	Screening Comments
		Biopolymer Beads	Collected West Area water is contacted with biopolymer beads (such as socium alginate) which bind and remove the metals from solution. The beads are then regenerated on site for reuse.	Not applicable due to the chemical complexity of East Area waters, the innovative status of the technology, and the availability of other effective treatment technologies.
		Anoxic Limestone Drains (ALD)	Seep/groundwater flows by though a subsurface limestone-filled trench capped with a composite geomembrane and soil cover for the addition of alkalinity. Typically used in conjunction with aerobic settling ponds or wetlands for metals precipitation and removal.	Potentially applicable
		Open Limestone Channels	Seep water flows by gravity through an open limestone-filled trench to add alkalinity. Typically used in conjunction with aerobic settling ponds to promote metal precipitation and removal.	Potentially applicable

Table 5-2
Initial Screening of Remediation Technologies and Process Options for the East Area

General Response Action	Technology Types	Process Options	Description	Screening Comments
		Permeable Reactive Barriers (PRBs)	PRBs contain or create a subsurface reactive zone to intercept and passively treat impacted groundwater by physical, chemical, or biological processes. PRBs are installed as permanent or semi-permanent units across the impacted flow path. Reactive media used in PRBs include zero-valent iron, sorbents (such as activated carbon), ion-exchange resins, compost (containing sulfate-reducing microbes), and limestone. PRBs using compost and pea gravel have been used at limited sites to promote the removal of metals, such as Cd, Cu, and Zn in groundwater as insoluble metal sulfides. Anoxic limestone barriers, similar to anoxic limestone drains, have also been used at a limited number of sites for Fe removal.	Not applicable due to cold winter temperatures, fluctuating groundwater levels in the East Area, and elevated aluminum concentrations.
	Physical/ Chemical/ Biological Treatment	Aerobic Wetland Treatment	Aerobic wetlands typically include features such as deep or shallow water zones, ecosystems consisting of hydric soils and aquatic plants, drop structures, rock filters, and water level control structures. Aerobic wetlands facilitate both abiotic and biologically-enhanced processes resulting in the oxidation and precipitation of dissolved metals. Typically used in conjunction with alkalinity adding process options.	Potentially applicable
		Anaerobic Wetland Treatment	Anaerobic wetlands systems combine ALD technology with biological sulfate reduction to generate alkalinity and facilitate metals removal under anaerobic conditions. Dissolved metals are precipitated in the anaerobic system as insoluble sulfide complexes. Anaerobic treatment systems typically include deep water ponds, organic substrate, limestone and hydraulic controls.	Potentially applicable

Table 5-2
Initial Screening of Remediation Technologies and Process Options for the East Area

General Response Action	Technology Types	Process Options	Description	Screening Comments
		East Area Slope Stability Actions		
Containment	Erosion Controls	Enhancement of Existing Rip-rap	Rip-rap obtained from a local source is placed along Railroad Creek stream banks to limit undercutting, erosion, and scouring of tailings piles.	Potentially applicable
		Low Rockfill Buttress	Rock is placed along base of tailings piles to contain tailings material transported downslope through erosion and sloughing.	Potentially applicable
		Geosynthetic Matting	Geosynthetic mats are placed on the tailings slopes to enhance erosion control and aid in vegetation growth. May be implemented in conjunction with regrading of over-steepened side-slopes.	Potentially applicable
		Organic Matting	Organic matting with grass seed is placed over the side slopes of the tailings piles adjacent to streams to enhance erosion protection and aid in vegetation growth. May be implemented in conjunction with regrading of over-steepened side-slopes.	Potentially applicable
		Revegetation	Sod or other vegetative growth media and seed are placed on top and over the side slopes of tailings piles to promote evapotranspiration and mitigate surface erosion of the tailings piles. Implemented in conjunction with regrading of over-steepened side slopes not suitable for vegetation in current configuration.	Potentially applicable

Table 5-2
Initial Screening of Remediation Technologies and Process Options for the East Area

General Response Action	Technology Types	Process Options	Description	Screening Comments
	Stability Enhancement	Regrading	Tailings pile side slopes are regraded using conventional equipment to reduce existing slope angles to increase stability and promote revegetation.	Potentially applicable
		Gabion Walls	Wire mesh boxes are filled with cobble-sized rock (10 - 20 cm diam) that are stacked to form a gabion wall. The walls are constructed to reduce sloughing and erosion by river scour.	Potentially applicable
		Geogrid Reinforced Soil Buttress	Synthetic soil reinforcement materials (geogrids) are used to reinforce soil buttressing at the base of tailings pile slopes to enhance slope stability and contain tailings transport due to erosion and sloughing.	Potentially applicable
		Geoweb Reinforced Soil Buttress	Synthetic geoweb materials are used to reinforce soil buttressing at the base of tailings pile slopes to enhance slope stability and contain tailings transport due to erosion and sloughing.	Potentially applicable
Stream Control	Diversion	Re-route Railroad Creek	Select reaches of Railroad Creek are diverted to the north and away from the tailings piles. Stream diversion structures include all available methods of collecting and transporting surface waters in an open channel.	Potentially applicable
		Copper Creek Culvert	Copper Creek is directed through concrete, plastic, or steel culverts to minimize contact with tailings piles 1 and 2, surface water impacts and the potental for tailings transport to surface water.	Potentially applicable

Table 5-2
Initial Screening of Remediation Technologies and Process Options for the East Area

General Response Action	Technology Types	Process Options	Description	Screening Comments
Partial Source Removal	Partial Tailings Pile Excavation and Disposal	Offsite Disposal	Portions of the tailings pile side slopes are excavated to provide more room at the base using conventional equipment and are transported for off-site disposal. Material would be transported by truck to Lucerne, barge transport to Chelan, and truck or rail transport to a permitted disposal facility.	Potentially applicable
		Relocation On-site	Portions of tailings pile slopes are excavated using conventional equipment and transported by truck to another location within the valley situated farther away from Railroad Creek and Copper Creek. The selected disposal site would be engineered with a liner and leachage collection system to reduce impacts to surface and groundwater.	Potentially applicable
		In-mine Disposal	Mine stopes are backfilled with tailings through the upper mine workings using hydraulic or paste backfilling techniques to reduce the volume of tailings remaining in potential contact with surface water and groundwater. Typically performed by creating a slurry of tailings or tailings/grout mixture which is pumped into underground void spaces.	Potentially applicable

Table 5-3
Evaluation and Selection of Remediation Technologies and Process Options for the West Area

General Response Action	Technology Types	Process Options	Effectiveness	Implementability	Relative Cost[1]	Comment[2]
No Action	None	Not Applicable	Not effective in reducing risk to human health or the environment.	Implementable. Subject to regulatory approval and public comment.	None	Retained as required by the NCP.
Institutional Controls & Physical Access Restrictions	Physical Access Controls	Physical Restrictions to Underground Mine Workings	Effective in restricting access and minimizing potential physical hazards related to the underground mine workings.	Implementable. Commercial materials and methods readily available.	Low Capital, Low O&M	Retained
		Physical Restrictions to Aboveground Mine Features	Effective in restricting access and promoting awareness of potential physical hazards related to the abandoned mill building and other aboveground physical hazards associated with historic mining activities.	Implementable. Commercial materials and methods readily available.	Low Capital, Low O&M	Retained
	Legal Access Controls	Use Restrictions	Effective in restricting present or future development which may potentially impact implementation of remedial actions or increase exposure to impacted media. Not effective in reducing risk to the environment from current levels.	Implementable. Commercial materials and methods available.	Low Capital, Low O&M	Retained
		Modification of the Wenatchee National Forest Land & Resource Management Plan	Effective in enforcing use restrictions and reducing potential future exposure to impacted media. Not effective in reducing risk to the environment from current levels.	Implementable. Commercial materials and methods available.	Low Capital, Low O&M	Retained
Monitoring	Environmental Monitoring	Surface Water Monitoring	Effective for monitoring PCOC concentrations in surface waters. Not effective in reducing risk to human health or the environment.	Implementable. Commercial materials and methods readily available.	Low O&M	Retained
		Groundwater Monitoring	Effective for monitoring PCOC concentrations in groundwater. Not effective in reducing risk to human health or the environment.	Implementable. Commercial materials and methods readily available.	Low O&M	Retained

Table 5-3
Evaluation and Selection of Remediation Technologies and Process Options for the West Area

General Response Action	Technology Types	Process Options	Effectiveness	Implementability	Relative Cost[1]	Comment[2]
		Cover Monitoring	Effective for identifying potential maintenance and repair requirements to insure the integrity and effectiveness of engineered covers.	Implementable. Commercial materials and methods readily available.	Low O&M	Retained
			West Area Source/Soils Actions			
Physical Controls	Closure of Underground Mine Portals	Air Flow Restrictions	Uncertain effectivness for reducing air flow through underground mine workings to mitigate oxidizing conditions and improve portal drainage water quality characteristics over time. Low effectiveness in controlling water flow and reducing the potential for a sudden release of mine water if implemented in the 1500-level main portal or ventilator shaft.	Implementable. Commercial materials and methods available.	Medium Capital, Low O&M	Retained for open portals above the 1500-level.
		Hydrostatic Bulkheads-1500 Level	Effective in equalizing and controlling portal drainge flowrates, providing surge storage, and controlling air flow. Uncertain effectiveness for improving long-term water quality characteristics. May result in water quality degradation during bulkhead construction and initial implementation.	Implementable. Commercial materials and methods available.	Medium Capital, Low O&M	Retained for the 1500-level main and ventilator portals.
		Hydrostatic Bulkheads-1100 Level	Effective in preventing seasonal low-flow water discharge from this location into the 1100-level waste rock pile and drainage that potentially contributes to seep SP-23.	Implementable. Commercial materials and methods available.	Low Capital, Low O&M	Retained as a secondary option for the 1100-level portal.
		Sealing of Drill Holes	Low to moderate effectiveness in reducing the air and water flow through underground mine workings to mitigate oxidizing conditions, due to the potential number and accessibility of drill holes.	Low implementability due to limited accessibility and ability to effectively locate drill holes. Commercial materials and methods readily available.	Medium Capital, Low O&M	Retained as a secondary option for use in conjunction with other technologies on a limited, opportunistic basis.

Table 5-3
Evaluation and Selection of Remediation Technologies and Process Options for the West Area

General Response Action	Technology Types	Process Options	Effectiveness	Implementability	Relative Cost[1]	Comment[2]
	Underground Mine Backfilling	Backfill Stopes with Tailings	Uncertain effectiveness for improving the 1500-level portal drainage water quality due to potential mobilization of additional metals from the backfilled tailings. Uncertain effectiveness in reducing the flow of air and water through underground workings. Increased potential for accidental tailings release if disposed on, or above, the 1500 level. Uncertain effectiveness in preventing subsidence of open stopes. May result in adverse impacts to air quality and Railroad Creek water quality during implementation.	Low implementability due to the location of stopes high above the valley floor, water management issues related to backfilling below the 1500-level, the required construction of bulkheads and other control systems deep within the mine, and the complexity of a tailings processing and delivery system. Presents physical safety hazards to workers during implementation.	Very High Capital, Medium O&M	Not retained due to uncertain effectiveness, environmental risks, and heath and safety risks associated with implementation. Options with more certain effectiveness are available, such as treatment options for the portal drainage, and water-tight and air-tight bulkheads.
	In-Mine Water Controls	Mine Drawdown	Potentially effective for providing water-storage capacity below the 1500 level. Uncertain effectiveness for reducing contact between mine water and exposed mine workings. Would increase surface area within mine workings exposed to oxidizing conditions. Potential for release of tailings stored below the 1500 level. May result in temporary degradation of water quality during discharge of initial drawdown volume. Presents risks of uncontrolled release during high spring runoff periods.	Low to moderate implementability due to the required installation of pumps or siphons to accomplish drawdown and stability issues related to the change in hydrostatic conditions on existing concrete bulkheads located below the 1500 level. Presents physical hazards to workers during implementation. Commercial materials and methods readily available.	Medium Capital, High O&M	Retained as a secondary option for use as part of a combined remedy, as applicable.

Table 5-3
Evaluation and Selection of Remediation Technologies and Process Options for the West Area

General Response Action	Technology Types	Process Options	Effectiveness	Implementability	Relative Cost[1]	Comment[2]
		In-Mine Water Storage	Effective for temporary water storage. Potentially effective in mitigating oxidizing conditions within flooded portions of the mine over time. However, uncertain effectiveness in improving short-term water quality due to the flushing of previously dry and oxidized workings. Would require implementation in conjunction with water-tight bulkheads. May result in water quality degradation during bulkhead construction and initial operation.	Implementable. Storage volume available in the mine up to the 1100-level. Low implementability above the 1100 level due to the presence of drill holes and workings near the ground surface. Commercial materials and methods available.	Medium Capital, Low O&M	Retained for implementation as required to provide storage and flow equalization of mine water for treatment.
		Selective In-Mine Water Diversion	Uncertain effectiveness in improving water quality by mixing high-acidity drainage from upper mine workings with moderate alkalinity water upwelling from the lower workings.	Low implementability for widespread use due to accessibility, the extent of underground mine workings. Moderately implementable on a limited basis. Commercial materials and methods available.	High Capital, Medium O&M	Retained as a secondary option for use on an limited basis in conjunction with water-tight bulkheads or other technologies as appropriate.
	Residual Reworking	Regrading	Low effectiveness in mitigating infiltration of surface water through waste rock pile side slopes, maintenance yard soils, materials in the mill building, and lagoon area soils due to topograpy and material characteristics. Potentially effective in enhancing runoff from top waste rock pile surfaces and reducing potential physical hazard associated with a portion of the west wast rock pile near the portal museum.	Implementable. Commercial materials and methods available.	Low Capital, Low O&M	Retained for use on top waste rock pile surfaces to enhance surface water runoff and for an isolated portion of the west waste rock pile to reduce potential physical hazard.

Table 5-3
Evaluation and Selection of Remediation Technologies and Process Options for the West Area

General Response Action	Technology Types	Process Options	Effectiveness	Implementability	Relative Cost[1]	Comment[2]
	Infiltration Barriers	Vegetative Soil Covers	Effective in mitigating infiltration through select residuals located in the mill building and abandoned surface water retention area. Would not effectively address infiltration through waste rock piles, or impacted soils in the lagoon area, maintenance yard, or material in the mill building concentrate tank or ore bin due to material characteristics and topography.	Moderately implementable in the mill and lagoon areas due to the quantity of materials required for cap construction, steep slopes, and difficult access. Low implementability for soils in the maintenance yard due to use of the area by Holden Village. Low implementability for waste rock pile side slopes due to material characteristics and topography.	Medium Capital, Low O&M	Retained for the abandoned surface water retention area and select materials in the mill area.
		Low Permeability Geosynthetic Covers	Effective in mitigating infiltration through top waste rock pile surfaces and residuals located in select areas within the mill building if properly maintained to prevent growth of native deep-rooted plants. Low effectiveness in addressing infiltration through other west area sources due to material characteristics and topography.	Moderately implementable for tops of waste rock piles and select areas within the mill building due to the quantity of materials required for cap construction, topography, and difficult access. Low implementability for other west area sources due to steep slopes, saturated ground surface (lagoon area), limited accessibility, and O&M requirements.	High Capital, Low O&M	Retained for use on the top waste rock pile surfaces and select areas within the mill building.
		Revegetation	Moderately effective in mitigating infiltration through residuals located in the mill building and abandoned surface water retention area. Low effectiveness in reducing infiltration through other west area sources due to material characteristics and topography.	Moderately implementable in the mill area given the chemical characteristics of the residuals. Low implementability for other west area sources due to chemical and physical characteristics of materials and topograpy.	Low Capital, Low O&M	Retained for the abandoned surface water retention area and select materials in the mill area.
		Asphalt/Concrete Cover	Effective in mitigating infiltration through the tops of the waste rock piles and impacted soils in the maintenance area if properly maintained. Low effectiveness for other west area sources due to topography and material characteristics.	Implementable on level surfaces, such as the maintenance yard and top portions of the waste rock piles. Low implementability for other west area sources due to the quantity of materials required, steep slopes, saturated ground surface (lagoon area), limited accessibility, and O&M requirements.	High Capital, Low O&M	Retained for use in the maintenance yard and tops of waste rock piles.

Table 5-3
Evaluation and Selection of Remediation Technologies and Process Options for the West Area

General Response Action	Technology Types	Process Options	Effectiveness	Implementability	Relative Cost[(1)]	Comment[(2)]
Source Material Treatment	Monitored Natural Attenuation	Geochemical Processes	Geochemical analyses completed for the Site indicate NA will be effective in reducing the release of PCOCs from the tailings piles over the long-term.	Implementable	Low Capital, Low O&M	Retained
	Ex Situ Treatment	Ex Situ Chemical Treatment	Uncertain effectiveness in mitigating long-term acid generation within mill residuals, waste rock and lagoon soils on a large scale given waste characteristics. Low effectiveness in addressing hydrocarbon concentrations in maintenance area soils. Potentially effective in reducing reactivity of low volumes of materials excavated from the mill building, maintenance yard, and lagoon area determined to be characteristic waste prior to disposal.	Low implementability for use on a large scale given material handling requirements, the source material physical and chemical characteristics, chemical requirements, and limited accessibility within the mill area.	High Capital, Low O&M	Retained as a secondary option for the treatment of limited quantities of unanticipated materials prior to disposal.
		Ex-situ Stabilization	Uncertain effectiveness in reducing PCOC mobility in waste rock due to coarse material grain size and within other west area source materials and soils due to variability in material characteristics and ability to stabilize PCOCs with long-term integrity.	Low implementability on a large scale given material handling requirements for successful batch plant operation, quantity of stabilizing agent required, limited accessibility within the mill area, and required disposal techniques to maintain a solidified product.	High Capital, Low O&M	Retained as a secondary option for the treatment of limited quantities of unanticipated materials prior to disposal.
	In-situ Treatment	In-situ Stabilization	Unpredictable effectiveness for waste rock, mill building, and maintenance yard due to material characteristics and topography. Uncertain effectiveness in the lagoon area due to seasonal groundwater fluctuations and saturated conditions in the lagoon area.	Low implementability due to difficulties in achieving thorough mixing in-place and homogeneous stabilization. Commercial methods and materials available.	High Capitol, Low O&M	Not retained due to lower effectiveness and implementability relative to other process options.

Table 5-3
Evaluation and Selection of Remediation Technologies and Process Options for the West Area

General Response Action	Technology Types	Process Options	Effectiveness	Implementability	Relative Cost[1]	Comment[2]
Source Materials/Soils Removal	Excavation and Disposal	Off-site Disposal	Effective in reducing impacts to Railroad Creek, subsurface soils, and groundwater. The selected site would require installing and maintaining infiltration management facilities.	Low implementability due to large volumes of material requiring handling and transportation, and permitting requirements for disposal at a suitable off-site location. Commercial methods available.	High Capital, Low O&M	Retained as a secondary option for the disposal of limited quantities of unanticipated materials, as applicable. Not retained as a primary option due to lower implementability relative to other process options.
		Relocation On Site	Effective in relocating materials to reduce impacts to Railroad Creek, subsurface soils, and groundwater. Excavated materials would be disposed in a designed containment area and require management of water infiltration.	Low implementability for wide-scale use in maintenance yard due to use of the area by the Holden Village. Moderately implementable for other west area sources due to material handling and transportation requirements for disposal at a suitable on-site location. Would require disposal in a contained repository at the selected location. Commercial methods available.	Medium Capital, Low O&M	Retained
West Area Groundwater and Surface Water Actions						
Physical Controls	Surface Water Controls	Upgradient Overland Flow Diversion	Effective in reducing upslope overland runon to west area sources. Low effectiveness in reducing infiltration of direct precipitation. Uncertain effectiveness in reducing impacts to surface water and groundwater.	Low to moderate implementability due to limited accessibility for equipment, limited available land area, and the potential depths required for trenches. Commercial materials and methods available.	Medium Capital, Low O&M	Retained
		Copper Creek Diversion Culvert	Effective in reducing impacts to Copper Creek diversion water due to contact with tailings materials and West Area soils.	Implementable. Commercial materials and methods available.	Low Capital, Low O&M	Retained

Table 5-3
Evaluation and Selection of Remediation Technologies and Process Options for the West Area

General Response Action	Technology Types	Process Options	Effectiveness	Implementability	Relative Cost[(1)]	Comment[(2)]
	Upgradient Groundwater Controls	Groundwater Barrier Walls	Uncertain effectiveness in reducing groundwater and near surface flows through the mill area, waste rock piles, and lagoon area due to heterogeneous localized subsurface conditions. May require implementation in conjunction with other process options to mitigate infiltration contributions.	Low to moderate implementability due to limited access and land area available upgradient of the site, and the depth to bedrock. Commercial materials and methods readily available.	High Capital, Low O&M	Not retained due to low anticipated effectiveness and implementability.
		Extraction Wells	Moderately effective in reducing groundwater and near surface flows through the mill area, waste rock piles, and lagoon area. Wells would provide limited ability to divert groundwater. May require implementation in conjunction with other process options to reduce infiltration.	Low implementability due to the large number of extraction wells required, accessibility for system installation, and full-time energy requirements for pump systems.	High Capital, High O&M	Not retained due to lower effectiveness, installation concerns, and power requirements.
		Diversion Trenches	Effective in reducing upslope, near surface groundwater flow through west area sources.	Low to moderate implementability due to limited accessibility and available land area upgradient of the site, and the potential depths required for trenches. Commercial materials and methods available.	Medium Capital, Low O&M	Retained
	Downgradient Groundwater Controls	Groundwater Barrier Walls	Effective in creating a subsurface flow barrier between West Area sources and Railroad Creek. Would reqire implementation in conjunction with other collection technologies. Uncertain effectiveness in collecting West Area groundwater due to the downstream component of groundwater flow and the presence of a former Railroad Creek channel.	Low to moderate implementability due to heterogeneous subsurface conditions and limited access upstream of the portal drainage.	High Capital, Low O&M	Retained

Table 5-3
Evaluation and Selection of Remediation Technologies and Process Options for the West Area

General Response Action	Technology Types	Process Options	Effectiveness	Implementability	Relative Cost[1]	Comment[2]
		Extraction Wells	Moderately effective in collecting West Area groundwater due to heterogeneous subsurface conditions and the presence of a former Railroad Creek channel.	Low implementability due to the heterogeneous subsurface conditions and limited access upstream of the portal drainage.	High Capital, High O&M	Not retained due to moderate effectiveness, lower implementability, and higher costs relative to other collection technologies.
		Collection Trenches, Basins, French Drains or Pipes	Effective in collecting impacted groundwater and seeps located downstream of the waste rock piles and mill area, and in reducing metals loading to Railroad Creek. Would require implementation in conjunction with other treatment process options.	Implementable. Commercial materials and methods available.	Medium Capital, Low O&M	Retained
Water Treatment	Physical/Chemical Treatment	Chemical Addition and Precipitation	Effective in removing acidity and precipitating dissolved metals from the portal drainage, and collected seeps and groundwater. May be used with other treatment technologies to enhance metals removal.	Moderately implementable as a conventional treatment system component. More readily implemented in combination with settling ponds and aerobic wetlands polishing. Sludge production will require disposal. Commercial methods and materials available.	Medium Capital, High O&M	Retained
		Aeration	Moderately effective in enhancing oxidation and precipitation of metal constituents. Lower effectiveness for treating low pH waters and for removing zinc, cadmium, and copper. Would require use in conjunction with other alkalinity adding treatment options.	Cascading flows to provide aeration would be readily implementable. Lower implementability for use of mechanical adjetators or bublers due to O&M, power requirements, and complexity of equipment. Commercial materials and methods available.	Medium Capital, Medium O&M	Retained for use in conjunction with other treatment options.

Table 5-3
Evaluation and Selection of Remediation Technologies and Process Options for the West Area

General Response Action	Technology Types	Process Options	Effectiveness	Implementability	Relative Cost[1]	Comment[2]
		Filtration/Clarification	Effective for removing metal precipitates. Would require implementation in conjunction with other alkalinity adding process options.	The use of gravity flow sand filters would be moderately implementable due to O&M requirements. The use of mechanical filtration would have lower implementability due to equipment complexities, power, and O&M requirements. Commercial materials and methods available.	Medium to High Capital, Medium O&M	Retained
		Membrane Separation	Effective for dissolved metals removal. However, metals are transferred to a concentrated waste stream requiring further treatment and/or disposal.	Low implementability at this site due to equipment complexity (pressure vessels, piping & instrumentation, pumps, and membranes), high power requirements, treatment/disposal requirements for concentrated waste stream.	High Capital, High O&M.	Not retained for use at this site due to equipment complexity, O&M requirements, and the generation of a concentrated waste stream requiring further treatment and/or disposal. Effectiveness is similar to chemical addition and filtration/clarification.
		High Density Sludge (HDS) Systems	Effective for enhancing precipitation and clarification processes in mechanical treatment facilities. Would require implementation in conjunction with chemical addition/precipitation.	Low implementability due to equipment complexity, and power and O&M requirements. Commercial materials and methods available.	High Capital, High O&M.	Retained
		High Rate Clarification (HRC) Process	Effective for enhancing clarification processes in mechanical treatment facilities. Would require implementation in conjunction with chemical addition/precipitation.	Low implementability due to equipment complexity, and increased power, materials (microsand), and O&M requirements. Commercial materials and methods available.	High Capital, High O&M.	Retained as a secondary option for potential use with other mechanical treatment options such as chemical addition and precipitation.

Table 5-3
Evaluation and Selection of Remediation Technologies and Process Options for the West Area

General Response Action	Technology Types	Process Options	Effectiveness	Implementability	Relative Cost[1]	Comment[2]
		Ion Exchange	Effective for dissolved metals removal. However, metals are transferred to a regenerant waste stream requiring further treatment and disposal.	Low implementability due to equipment complexity (reactor vessels, piping & instrumentation, pumps, and resin materials), resin regeneration, power requirements, treatment/disposal requirements for regenerant solution, and extensive O&M activities.	High Capital, High O&M.	Not retained due to equipment complexity, O&M requirements, and the generation of a concentrated waste stream requiring further treatment and/or disposal. Effectiveness is similar to chemical addition and filtration/clarification.
		Molecular Recognition Technology (MRT)	Uncertain effectiveness in treating the complex and variable West Area flows. Metals are transferred to an acidic regenerant waste stream requiring further treatment and disposal.	Low implementability due to equipment complexity (reactor vessels, piping, instrumentation, pumps, resin, and eluant materials), treatment and disposal requirements for regenerant solutions, and extensive O&M requirements.	High Capital, High O&M.	Not retained due to uncertain effectiveness, equipment complexity, O&M requirements, and generation of an acidic and concentrationed waste stream requiring further disposal.
		Anoxic Limestone Drains (ALD)	Low effectiveness for treating mine waters with elevated DO, ferric iron, and aluminum, resulting in armoring of the limestone surface. Effective for pH neutralization and alkalinity addition to anoxic waters.	Moderately implementable due to the large land area, organic matter, and limestone requirements for the combined West Area seep drainage.	High Capital, Medium O&M	Not retained because West Area waters are generally oxygenated, resulting in lower effectiveness and implementability relative to other physical/ chemical treatment options.
	Physical/Chemical/ Biological Treatment	Aerobic Wetland Treatment	Effective in removing most dissolved metals. Lower effectiveness as a primary process option for the removal of zinc, cadmium, or acidity. May require implementation in conjunction with an alkalinity adding system to improve water quality.	Moderately implementable due to the large land area and surge capacity requirements. Commercial materials and equipment available. Sludge management and disposal issues reduce implementability.	Medium Capital, Medium O&M	Retained

Table 5-3
Evaluation and Selection of Remediation Technologies and Process Options for the West Area

General Response Action	Technology Types	Process Options	Effectiveness	Implementability	Relative Cost[1]	Comment[2]
		Anaerobic Treatment	Moderately effective in precipitating some dissolved metals and adding alkalinity to mine waters as a stand-alone process option. Lower effectiveness as a primary process option for the removal of zinc and cadmium. Typically used in conjunction with aerobic basins for enhanced precipitate removal.	Low implementability due to the significant land area, depth of excavation, and volume of organic substrate required. Anaerobic basins are typically constructed to a depth of 3 - 4 m (10-13 ft). Construction and implementation at this depth would be difficult due to the shallow ground water in the location available at the site for system construction. Commercial materials and equipment available.	High Capital, Medium O&M	Not retained as a primary option due to lower effectiveness and implementability relative to other process options such as aerobic wetlands, chemical addition/ precipitation, and filtration/clarification.
In-Mine Treatment	Physical/Chemical Treatment	In-Mine Chemical Addition and Precipitation	Potentially effective under certain conditions for removing acidity and enhancement of metals precipitation within the mine. Less effective for long-term treatment than chemical addition and precipitation outside of the mine. Uncertain reliability due to chemical distribution and process control concerns related to implementation within the mine.	Low implementability at the Holden Mine due to limited accessibility and insufficient space within the mine for system construction and operation, power requirements, chemical delivery requirements, and sludge management and disposal issues. Presents physical hazards to workers during implementation. Commercial materials and methods available.	High Capital, High O&M	Retained as a secondary option for temporary or periodic use as appropriate. A continuously operating system is not retained due to lower implementability, safety concerns, and uncertain reliability relative to treatment options implemented outside the mine.

Table 5-3
Evaluation and Selection of Remediation Technologies and Process Options for the West Area

General Response Action	Technology Types	Process Options	Effectiveness	Implementability	Relative Cost[1]	Comment[2]
		In-Mine Filtration/ Clarification	Potentially effective for removing metal precipitates. Would require being combined with other alkalinity adding process options. Uncertain long-term reliability due to process control concerns related to implementation within the mine.	Low to moderate implementability as an actively managed system due to insufficient space within the mine for system construction and operation (12' x 12' tunnel), and due to sludge management and disposal issues. May present physical hazards to workers during implementation. However, the use of existing features (such as open stopes) or bulkheads to provide additional storage capacity and clarification would be implementable. Commercial materials and methods available.	High Capital, Medium O&M	Utilizing existing features to promote clarification is retained. Conventional use of settling and filtration equipment within the mine is not retained as a primary option due to lower implementability, safety concerns, and uncertain reliability relative to filtration/ clarification options implemented outside of the mine.
	Physical/Chemical/ Biological Treatment	Anaerobic In-Mine Treatment	Currently not demonstrated to provide long-term treatment for higher flows. Moderately effective in precipitating dissolved metals and adding alkalinity to mine waters on a small scale. Uncertain reliability due to the inability to control flows through the biological system, and provide effective treatment. Environmental and health & safety risks associated with the placement of large quantities of organic substrate within mine workings during system construction and operation. Accidental blockage within the mine may result in uncontrolled releases from the portal.	Low implementability for an actively managed system due to insufficient space within the mine portal for system construction and operation (12' x 12' tunnel). Requires significant volumes of organic substrate. Commercial materials and equipment available. Presents physical hazards to workers during implementation. The periodic enhancement of naturally occuring biological processes through organics/chemical addition would be moderately implementable.	High Capital, Medium O&M	Not retained due to undemonstrated effectiveness for high flows, environmental and safety risks, and lower effectiveness and implementability relative to anaerobic treatment options implemented outside of the mine.

(1) Using engineering judgment, process option costs are qualitatively assessed as very high, high, medium, or low, relative to other process options.
(2) Secondary process options are retained for implementation on a limited basis, as determined during the design phase of the project.

Table 5-4
Evaluation and Selection of Remediation Technologies and Process Options for the East Area

General Response Action	Technology Types	Process Options	Effectiveness	Implementability	Relative Cost[1]	Comment[2]
No Action	None	Not Applicable	Not effective in reducing risk to human health or the environment.	Implementable. Subject to regulatory approval and public comment.	None	Retained as required by the NCP.
Institutional Controls	Legal Access Controls	Use Restrictions	Effective in restricting present or future development which may potentially impact implementation of remedial actions or increase exposure to impacted media. Not effective in reducing risk to the environment from current levels.	Implementable. Commercial materials and methods available.	Low Capital, Low O&M	Retained
		Modification of the Wenatchee National Forest Land & Resource Management Plan	Effective in enforcing use restrictions and reducing potential future exposure to impacted media. Not effective in reducing risk to the environment from current levels.	Implementable. Commercial materials and methods available.	Low Capital, Low O&M	Retained
Monitoring	Environmental Monitoring	Surface Water Monitoring	Effective for monitoring PCOC concentrations in surface waters. Not effective in reducing risk to human health or the environment.	Implementable. Commercial materials and methods available.	Low O&M	Retained
		Groundwater Monitoring	Effective for monitoring PCOC concentrations in groundwater. Not effective in reducing risk to human health or the environment.	Implementable. Commercial materials and methods readily available.	Low O&M	Retained
		Cover Monitoring	Effective for identifying potential maintenance and repair requirements to insure the integrity and effectiveness of engineered covers.	Implementable. Commercial materials and methods readily available.	Low O&M	Retained
		Stability Monitoring	Effective in verifying stability of tailings pile side slopes. Not effective in reducing risk to human health or the environment.	Implementable. Commercial materials and methods available.	Low O&M	Retained

Table 5-4
Evaluation and Selection of Remediation Technologies and Process Options for the East Area

General Response Action	Technology Types	Process Options	Effectiveness	Implementability	Relative Cost[1]	Comment[2]
			Source Area Actions			
Physical Controls	Infiltration Barriers	Vegetative Soil Cover	Effective in reducing water infiltration through tailings and reducing acid generation.	Low to moderate implementability due to the quantity of soil required for cap construction, and limited sources available locally.	High Capital, Low O&M	Not retained as a primary option due to lower implementability and similar long-term effectiveness in reducing infiltration relative to other options. Retained as a secondary option for limited use as applicable.
		Low Permeability Geosynthetic Cover	Effective in reducing water infiltration through tailings and reducing acid generation if properly maintained to prevent the growth of deep-rooted native plants.	Low to moderate implementability due to the quantity of material required for cap construction, limited local material sources, and O&M requirements to limit growth of natural vegetation.	High Capital, Low O&M	Retained
		Capillary Barriers	Effective in reducing water infiltration through tailings and reducing acid generation if properly maintained to prevent the growth of deep-rooted native plants.	Low implementability due to the quantity of material required for cap construction, limited local material sources, and O&M requirements to limit growth of natural vegetation.	High Capital, Low O&M	Not retained due to lower implementability and similar effectiveness in reducing infiltration relative to other options.
		Oxygen Consuming Cover	Uncertain effectiveness in reducing water infiltration under local climate conditions.	Low implementability due to the quantity of material required for cap construction, limited local material sources, and O&M requirements to limit growth of natural vegetation.	High Capital, Low O&M	Not retained due to lower implementability and similar effectiveness in reducing infiltration relative to other options.
		SRB Covers	Uncertain effectiveness in mitigating oxidizing conditions within the piles and reducing metals loading to Railroad Creek. An innivative technology, not yet proven on a full-scale.	Low implementability due to the quantity of organic material (such as molasses) required for implementation, and high O&M requirements to maintain viable populations of sulfate-reducing bacteria and prevent disruption of the cover by local wildlife.	High Capital, Medium O&M	Not retained due to lower effectiveness in reducing metals loadings ro railroad creek and lower implementability relative to other options.

Table 5-4
Evaluation and Selection of Remediation Technologies and Process Options for the East Area

General Response Action	Technology Types	Process Options	Effectiveness	Implementability	Relative Cost[1]	Comment[2]
		Revegetation	Moderate effectiveness in reducing infiltration of water through tailings and reducing acid generation once vegetation is established. Meets visual objectives as established by the USDA Forest Service.	Implementability has been demonstrated by USDA Forest Service Laboratory work at the site. May require implementation in conjunction with soil amendments and an irrigation system. Commercial materials and methods available.	Medium Capital, Low O&M	Retained
		Lime Application	Moderate effectiveness in improving conditions for revegetation. Low effectiveness in reducing the acidity of East Area seeps and groundwater.	Implementable for select locations on the tailings pile surfaces. Lower implementability for complete coverage due to the large quantities of lime required and lack of a local source.	Medium Capital, Medium O&M	Retained as a secondary option to enhance revegetation.
		Asphalt/Concrete Cover	Effective in mitigating infiltration of water through tailings and providing erosion protection for other cover technologies if regularly maintained.	Low implementability due to quantity of asphalt/concrete required for cap construction, limited local materials sources, and high O&M requirements.	High Capital, High O&M	Not retained due to lower implementability relative to other options with similar or greater effectiveness.
Source Material Treatment	Monitored Natural Attenuation	Geochemical Processes	Geochemical analyses completed for the Site indicate NA will be effective in reducing the release of PCOCs from the underground mine and waste rock piles over the long-term.	Implementable	Low Capital, Low O&M	Retained
	Ex-situ Treatment of Tailings	Ex-situ Chemical Treatment	Uncertain effectiveness in mitigating long-term acid generation within tailings piles given waste characteristics. Would result in an increase in material volumes. May result in adverse impacts to air and water quality during implementation.	Low implementability given material handling requirements, volume of tailings, and replacement of the increased total volume of treated material.	Very High Capital, Low O&M	Not retained due to uncertain effectiveness and low implementability.
		Reprocessing	Uncertain effectiveness for either hydrometallurgical or pyrometallurgical techniques to recover significant metal values. Minimal reduction in the volume of material requiring disposal. May result in adverse impacts to air and water quality during implementation.	Low implementability given material handling requirements for reprocessing, construction of a complex processing facility, the nature of the tailings, and disposal requirements for residual materials.	Very High Capital, High O&M	Not retained due to uncertain effectiveness and low implementability.

Table 5-4
Evaluation and Selection of Remediation Technologies and Process Options for the East Area

General Response Action	Technology Types	Process Options	Effectiveness	Implementability	Relative Cost[1]	Comment[2]
		Ex Situ Stabilization	Uncertain effectiveness in mitigating long-term acid generation within tailings given waste characteristics. May result in adverse impacts to air and water quality during implementation.	Low implementability given material handling requirements, stabilization agent requirements, and disposal issues related to the increase in volume following stabilization.	Very High Capital, High O&M	Not retained due to uncertain effectiveness and low implementability. .
Source Removal	Excavation and Disposal	Off-site Disposal	Effective for mitigating long term impacts on groundwater and surface water. Uncertain effectiveness in reducing short-term impacts to Railroad Creek due to the potential for increased metals loading and accidental release during excavation and transportation. The selected disposal site would require installing and maintaining infiltration management facilities. May result in adverse impacts to air and water quality during implementation.	Low implementability due to material handling and transportation requirements, identification of a suitable off-site disposal location, and potential for accidental release during transport. Would require the construction of improved haul roads and/or bridges within the village, and would increase heavy-equipment traffic through the area.	Very High Capital, Low to Medium O&M	Not retained due to uncertain effectiveness, material handling requirements, and lack of a suitable disposal location.
		Relocation On site	Uncertain effectiveness in reducing long-term impacts to surface and groundwater by relocating all or a portion of the tailings to an alternative location on-site. Would cause physical impacts to the relocation site, and suitable locations may not exist. Installation of water controls at the selected site(s) would be required. Implementation may result in short-term and long-term adverse impacts to air and water quality as a result of the exposure of tailings previously contained within a reducing environment.	Low implementability due to material handling and transportation requirements, the installation of controls at the selected location, and the lack of a suitable on-site disposal location. Would require the construction of improved haul roads and/or bridges, and would increase heavy-equipment traffic through the area.	Very High Capital, Medium O&M	Not retained due to uncertain effectiveness and implementability concerns.

Table 5-4
Evaluation and Selection of Remediation Technologies and Process Options for the East Area

General Response Action	Technology Types	Process Options	Effectiveness	Implementability	Relative Cost[1]	Comment[2]
		In-Mine Disposal	Low effectiveness in reducing impacts from acid generation within the tailings piles due to volume limitations within the mine. Potential for accidental release of tailings from the mine if placed on, or above, the 1500 level. Potential impacts from the release of iron and acidic drainage through the 1500-level main portal. May result in adverse impacts to air and water quality during implementation.	Low implementability due to the location of open stopes high above the valley floor. Lower implementability due to equipment and power requirements, water management issues related to backfilling below the 1500-level, the construction of bulkheads and other control systems deep within the mine, and the complexity of a tailings processing and delivery system. Presents physical hazards to workers during implementation.	Very High Capital, Low O&M	Not retained due to the environmental and health & safety risks associated with implementation. Incremental benefit in reducing the volume of tailing that would require further mitigation efforts outside the mine.
Source Material Consolidation	Tailings Pile Consolidation	Consolidation of Tailings Piles 1, 2, & 3	Potential effectiveness in reducing long-term impacts to Railroad Creek by reducing the surface area and footprint of the materials and increasing teh area available for downgradient collection and treatment. Implementation may result in impacts to air during construction and to water quality by exposing tailings previously contained within a reducing environment.	Low to moderate implementability due to material handling and transportation requirements for the large volume of tailings.	Very High Capital, Medium O&M	Retained
East Area Groundwater and Surface Water						
Physical Controls	Surface Water Controls	Upgradient Overland Flow Diversion	Effective in mitigating the infiltration of unimpacted surface and near-surface water through tailings material to reduce impacts to Railroad Creek.	Implementable. Commercial materials and methods available.	Medium Capital, Low O&M	Retained
		Regrading	Effective in mitigating surface water infiltration through the tailings piles by enhancing surface water drainage.	Moderately implementable due to the large volume of materials requiring movement. Commercial materials and methods available.	Medium Capital, Low O&M	Retained
		Decant Tower Closure	Effective in minimizing the introduction of surface and atmospheric water through the decant tower into Tailings Pile 1.	Implementable. Commercial materials and methods available.	Low Capital, Low O&M	Retained

Table 5-4
Evaluation and Selection of Remediation Technologies and Process Options for the East Area

General Response Action	Technology Types	Process Options	Effectiveness	Implementability	Relative Cost[1]	Comment[2]
		Re-route Railroad Creek	Potentially effective in reducing contact with tailings materials and seepage and increasing the surface area available for impacted groundwater/seep collection.	Moderately implementable due to the complexity of the option. Commercial materials and methods available.	High Capital, Low O&M	Retained for segments of Railroad Creek located along the base of the tailings piles.
		Copper Creek Culvert	Potentially effectiveness in reducing baseflow losses from Copper Creek through the tailings piles and reducing potential contact with tailings materials.	Moderately implementable due to the complexity of the option. Commercial materials and methods available.	High Capital, Low O&M	Retained
	Upgradient Groundwater Controls	Groundwater Barrier Walls	Uncertain effectiveness in reducing infiltration of unimpacted groundwater through tailings due to heterogeneous localized subsurface conditions.	Low to moderate implementability due to access and installation concerns. The depth to bedrock and localized heterogeneous subsurface conditions (large boulders, etc) result in constructability issues related to the installation of an effective barrier wall. Commercial materials and methods available.	High Capital, Low O&M	Not retained due to uncertain effectiveness and low implementability due to localized non-uniform subsurface conditions.
		Extraction Wells	Low effectiveness in reducing unimpacted groundwater flow through tailings. Wells would provide limited ability to divert groundwater.	Low implementability due to the large number of extraction wells required, accessibility for system installation, and full-time energy requirements for the pump system.	High Capital, High O&M	Not retained due to lower effectiveness, and concerns related to installation and O&M requirements.
		Diversion Trenches	Potentially effective in reducing the infiltration of unimpacted near surface groundwater through tailings to reduce impacts to Railroad Creek.	Low to moderate implementability due to access and installation concerns. Commercial materials and methods available.	Medium Capital, Low O&M	Retained
	Downgradient Groundwater Controls	Groundwater Barrier Walls	Effective in creating a subsurface flow barrier between the tailings piles and the creek. Would require implementation in conjunction with other collection processes.	Low implementability due to heterogeneous subsurface conditions, variable depth to dense till or bedrock, and proximity to Railroad Creek.	High Capital, Low O&M	Retained

Table 5-4
Evaluation and Selection of Remediation Technologies and Process Options for the East Area

General Response Action	Technology Types	Process Options	Effectiveness	Implementability	Relative Cost(1)	Comment(2)
		Collection Trenches and Pipes	Moderately effective in the collection of impacted groundwater and seeps for treatment prior to discharge to Railroad Creek. Iron precipitate formation in drain pipes would significantly reduce the effectiveness of this technology in the East Area.	Low to moderate implementability due to access, installation, and maintenance concerns, and difficulties associated with preventing baseflow losses from Railroad Creek into the drain.	High Capital, Medium O&M	Retained
		Extraction Wells	Low to moderate effectiveness in the collection of impacted groundwater for treatment prior to discharge to Railroad Creek. Would require implementation with cut-off walls to prevent an increase in baseflow losses from Railroad Creek under the tailings piles.	Low implementability due to the large number of extraction wells required, accessibility for system installation, significant energy requirements for the pump system, and difficulties associated with preventing baseflow losses from Railroad Creek.	High Capital, High O&M	Not retained due to lower effectiveness and implementability, and higher costs relative to other collection systems.
Groundwater Treatment	Physical/Chemical Treatment	Chemical Addition and Precipitation	Effective in removing acidity and dissolved metals from collected water may be used with other mechanical or low-energy treatment technologies.	Implementable as a gravity flow pond system. Low implementability as a conventional treatment system component on a remote site for water containing high metal concentrations due to site constraints for operating and maintaining complex equipment. Commercial methods and materials available.	Medium Capital, Medium O&M	Low-energy process retained
		Aeration	Effective for iron removal. Lower effectiveness in treating low pH waters. Would require use in conjunction with other alkalinity adding process options.	Implementable in the form of drop structures and cascading flows. Low to moderately implementable as a mechanical system depending on power requirements and complexity of equipment. Commercial materials and methods available.	Medium Capital, Medium O&M	Low-energy systems retained for use with other alkalinity adding treatment options.

Table 5-4
Evaluation and Selection of Remediation Technologies and Process Options for the East Area

General Response Action	Technology Types	Process Options	Effectiveness	Implementability	Relative Cost[(1)]	Comment[(2)]
		Filtration/Clarification	Effective for removing metal precipitates. Would require implementation in conjunction with other aeration and alkalinity adding or generating process options.	Implementable as a gravity flow pond system. Low to moderate implementability as a mechanical system for waters containing high metals (i.e. iron) concentrations due to high power requirements.	Medium to High Capital, Medium O&M	Low-energy systems retained for use with other alkalinity adding treatment options.
		High Density Sludge (HDS) System	Effective for enhancing precipitation and clarification processes.	Low implementabilty for the East Area due to the extensive O&M and power requirements. Commercial materials and methods available.	High Capital, High O&M	Not retained due to lower implementability and higher costs relative to other available technologies with similar effectiveness in treating iron-rich groundwater and seeps.
		High Rate Clarification (HRC) Process	Effective for enhancing precipitation and clarification processes.	Low implementability due to equipment complexity, and increased power, materials (microsand), and O&M requirements. Commercial materials and methods available	High Capital, High O&M	Not retained due to lower implementability and higher costs relative to other available technologies with similar effectiveness in treating iron-rich groundwater and seeps.
		Molecular Recognition Technology (MRT)	Uncertain effectiveness in treating the complex and variable East Area flows. Metals are transferred to an acidic regenerant waste stream requiring further treatment and disposal.	Low implementability due to equipment complexity (reactor vessels, piping, instrumentation, pumps, resin, and eluant materials), treatment and disposal requirements for regenerant solutions, and extensive O&M requirements.	High Capital, High O&M.	Not retained due to uncertain effectiveness, equipment complexity, O&M requirements, and generation of an acidic and concentrationed waste stream requiring further disposal.
		Anoxic Limestone Drains (ALD)	Low effectiveness for treating waters containing elevated concentrations of ferric iron, aluminum and DO, resulting in armoring of the limestone. Effective for pH neutralization and alkalinity addition to anoxic waters.	Low to moderate implementability due to the large land area, organic matter, and limestone requirements. Commercial materials and methods available.	Medium Capital, Low O&M	Retained as a secondary option. Not retained as a primary option due to lower effectiveness and implementability relative to other options.

Table 5-4
Evaluation and Selection of Remediation Technologies and Process Options for the East Area

General Response Action	Technology Types	Process Options	Effectiveness	Implementability	Relative Cost[1]	Comment[2]
		Open Limestone Channels	Low effectiveness for treating waters containing elevated concentrations of ferric iron, aluminum and DO.	Low to moderate implementability due to the high land area and limestone requirements.	Medium Capital, Medium O&M	Retained as a secondary option. Not retained as a primary option due to lower effectiveness and implementability relative to other options.
	Physical/Chemical/ Biological Treatment	Aerobic Wetland Treatment	Effective in removing most dissolved metals from impacted seeps and groundwater from the East Area. Lower effectiveness for removing zinc and cadmium, and for alkalinity addition. May be used in conjunction with an alkalinity addition for complete treatment of collected water.	Moderately implementable as a primary process option due to sludge management and disposal issues, and limited land area available for system construction. Commercial materials and methods available.	Medium Capital, Medium O&M	Retained
		Anaerobic Treatment	Low effectiveness as a primary option for treating waters containing elevated concentrations of iron and aluminum.	Moderately implementable due to land available for system construction, and the required depth of excavation. Anaerobic basins are typically constructed to a depth of 3-4 m (10 - 13 ft). Construction and implementation at this depth would be difficult due to the shallow groundwater in the locations available for site construction and influences from Railroad Creek. Commercial materials and methods available. Requires significant volumes of organic substrate.	Medium to High Capital, Medium O&M	Not retained as a primary option due to lower effectiveness and implementability relative to other options.
East Area Slope Stability Actions						
Containment	Erosion Controls	Enhancement of Existing Riprap	Effective in mitigating undercutting and scouring of tailings piles during high stream flows. Limited effectiveness in increasing slope stability. Would require implementation in conjunction with other stability enhancing process options.	Implementable. Commercial materials and methods available.	Medium Capital, Low O&M	Retained

Table 5-4
Evaluation and Selection of Remediation Technologies and Process Options for the East Area

General Response Action	Technology Types	Process Options	Effectiveness	Implementability	Relative Cost[1]	Comment[2]
		Low Rockfill Buttress	Effective in mitigating undercutting and scouring of tailings piles and containing material in the event of a slope failure. Limited effectiveness in increasing slope stability. Would require implementation in conjunction with other stability enhancing process options.	Implementable. Commercial materials and methods available.	Medium Capital, Low O&M	Retained as a secondary option for use in conjunction with other technologies on a selective basis.
		Geosynthetic Matting	Effective in mitigating erosion of tailings piles due to wind and surface water runoff. Limited effectiveness in increasing slope stability or reducing undercutting, erosion, and scouring during high stream flows. Would require implementation in conjunction with other stability enhancing process options.	Moderately implementable due to the large quantity of geotextile material required to be transported to the site. Commercial materials and methods available	Low to Medium Capital, Low O&M	Retained as a secondary option for use in conjunction with other technologies on a selective basis.
		Organic Matting	Shown to be effective in mitigating erosion, and enhancing revegetation of tailings pile slopes at the site through Forest Science Laboratory research. Limited effectiveness in increasing slope stability or reducing undercutting, erosion, and scouring during high stream flows. Would require implementation in conjunction with other stability enhancing process options.	Moderate to low implementability due to the large quantity of material required to be transported to the site. Commercial materials and methods available	Medium Capital, Low O&M	Retained as a secondary option for use in conjunction with other technologies on a selective basis.
		Revegetation	Effective in mitigating erosion of tailings piles due to wind and surface water runoff. Limited effectiveness in increasing slope stability or reducing undercutting, erosion, and scouring during high stream flows. Would require implementation in conjunction with other stability enhancing process options.	Moderately implementable given the chemical characteristics of the tailings materials and steep top slopes. Commercial materials and methods available.	Low to Medium Capital, Low O&M	Retained as a secondary option for use in conjunction with other technologies on a selective basis.

Table 5-4
Evaluation and Selection of Remediation Technologies and Process Options for the East Area

General Response Action	Technology Types	Process Options	Effectiveness	Implementability	Relative Cost[(1)]	Comment[(2)]
	Stability Enhancement	Regrading	Effective in increasing the stability of the tailings piles. Limited effectiveness in reducing undercutting, erosion and scouring during high stream flows. May be implemented in conjunction with other erosion control options. May result in air and water quality degradation during construction activities.	Moderately implementable given steep top slopes and the volume of material requiring handling. May require use in conjunction with other process options to reduce regrading requirements. Commercial materials and methods available.	High Capital, Low O&M	Retained
		Gabion Walls	Effective in increasing stability of select reaches of the tailings piles.	Low implementability due to complexity of construction, material requirements, and limited area available between tailings piles and Railroad Creek.	High Capital, Low O&M	Not retained due to low implementability relative to other process options.
		Geogrid Reinforced Soil Buttress	Effective in increasing stability of select reaches of the tailings piles.	Low implementability due to complexity of construction, material requirements, and limited area available between tailings piles and Railroad Creek.	High Capital, Low O&M	Not retained due to low implementability relative to other process options.
		Geo-Web Reinforced Soil Buttress	Effective in increasing stability of the tailings piles.	Low implementability due to complexity of construction, material requirements, and limited area available between tailings piles and Railroad Creek.	High Capital, Low O&M	Not retained due to low implementability relative to other process options.
Stream Control	Diversion Structures	Re-routing Railroad Creek	Effective in mitigating undercutting, erosion, and scouring of side slopes and reducing potential tailings transport to surface water.	Moderately implementable due to complexity of construction methods required to divert Railroad Creek. Commercial materials and methods readily available.	High Capital, Low O&M	Retained

Table 5-4
Evaluation and Selection of Remediation Technologies and Process Options for the East Area

General Response Action	Technology Types	Process Options	Effectiveness	Implementability	Relative Cost(1)	Comment(2)
		Copper Creek Culvert	Moderately effective in mitigating undercutting, erosion, and scouring of tailings piles. Effective in reducing potential tailings transport to Copper Creek.	Moderately implementable. Commercial materials and methods readily available.	High Capital, Low O&M	Retained
Partial Source Removal	Partial Tailings Pile Excavation and Disposal	Excavation, Transportation, and Disposal Off-Site	Effective in reducing long-term impacts to Railroad Creek related to slope stability issues. Would require the construction of improved haul roads and/or bridges, and would increase the heavy-equipment traffic through the area. May result in adverse impacts to air and water quality during implementation.	Low implementability due to material handling and transportation requirements, the location of a suitable off-site disposal location and the potential for an accidental release during transport.	Very High Capital, Medium O&M	Not retained due to lower implementability and similar effectiveness relative to other stability enhancing process options.
		Excavation, Transportation, and On-site Disposal	Effective in reducing long-term impacts related to slope stability issues. May cause physical and chemical impacts to the relocation site, and a site, or sites, of suitable size may not exist. May result in adverse impacts to air and water quality during implementation.	Low implementability due to material handling and transportation requirements and the lack of a suitable on-site disposal location. Would require the construction of improved haul roads and/or bridges, and would increase heavy-equipment traffic through the area.	Very High Capital, Medium O&M	Not retained due to lower implementability and similar effectiveness relative to other stability enhancing process options.
		Excavation and In-Mine Disposal	Moderately effective in improving slope stability by relocating a portion of the tailings within the mine. However, volume constraints within the mine lower the effectiveness of this option. Potential for accidental release of tailings from the mine if disposed on, or above, the 1500 level. Potential to liberate iron into the 1500-level main portal. May result in adverse impacts to air and water quality during implementation.	Low implementability due to the complexity related to effective delivery of tailings, providing for uniform backfill of stopes, and placement of bulkheads and other control systems deep within the mine. Presents physical risks to workers during implementation.	Very High Capital, Low O&M	Not retained due to environmental and health & safety risks associated with implementation. Similar effectiveness in achieving slope stability relative to regrading or buttressing.

(1) Using engineering judgment, process option costs are qualitatively assessed as very high, high, medium, or low, relative to other process options.

(2) Secondary process options are retained for implementation on a limited basis, as determined during the design phase of the project. Secondary options will not undergo a detailed evaluation in the FS.

6.0 DEVELOPMENT OF CANDIDATE SITE-WIDE REMEDIAL ALTERNATIVES

Based on the results of the technology evaluation, and through a collaborative process with the Agencies, eight candidate site-wide remedial alternatives have been identified to address site RAOs. The following subsections describe the alternative development process and provide descriptions of the eight alternatives developed for detailed analysis in Section 7.

6.1 ALTERNATIVE DEVELOPMENT PROCESS

Eight candidate site-wide remedial alternatives have been identified for addressing site environmental conditions described in the DRI. As described previously, for purposes of the FS, the Site has been divided into two areas based on the unique surface water and groundwater chemical characteristics exhibited in the east and west areas (Figure 6-1). Figure 6-2 provides seep and surface water sampling locations used to delineate the specific characteristics of the two areas.

West area features include Honeymoon Heights, abandoned surface water retention area, east and west waste rock piles, the underground mine, mill building, maintenance yard, and lagoon area. The east area includes the three tailings piles and associated seasonal seeps and shallow groundwater beneath the tailings piles.

6.1.1 Site PCOCs and Affected Media

A discussion of Site PCOCs for surface water, groundwater, and soils are provided in the following subsections.

6.1.1.1 Surface Water

As described in Section 2, available surface water chemistry data from Railroad Creek indicate seasonal exceedances of the SWQC established for dissolved copper, cadmium, and zinc. Exceedances of dissolved copper and zinc were measured during the spring high-flow periods from Railroad Creek monitoring station RC-4, which is located downstream of the point where the portal drainage enters Railroad Creek (station P-5), to the mouth of Railroad Creek (station RC-3). Dissolved cadmium exceedances during the spring high-flow period were observed from station RC-4 to station RC-10. During low-flow periods, dissolved zinc concentrations above the SWQC were detected from immediately downstream of the tailings piles (station RC-2) to station RC-5, located less than approximately one mile downstream of the Site. No other exceedances of the SWQC were measured during the fall/winter low-flow periods.

As required by the Agencies, available surface water chemistry data from Railroad Creek were also compared to the federal NRWQC published in 1999 and 2002[1]. Based on this comparison, seasonal concentrations of dissolved cadmium, copper, and zinc in Railroad Creek exceed the 1999 and 2002 NRWQC established for freshwater aquatic life. The 1999 and 2002 NRWQC chronic criteria for total aluminum and iron were also exceeded seasonally. The 2002 NRWQC are lower than either the 1999 NRWQC or SWQC for dissolved copper and cadmium. As a result, seasonal exceedances of the 2002 NRWQC were measured for dissolved cadmium in Railroad Creek from upstream monitoring station RC-6 to station RC-3. During spring high-flow periods, exceedances of the NRWQC for copper and zinc were measured from station RC-4 to station RC-3. During the low-flow periods in the fall/winter, slight exceedances of the 2002 NRWQC were measured for copper at station RC-4. Zinc exceedances were not observed during the low-flow periods.

Concentrations of total aluminum and iron were also observed to seasonally exceed the 1999/2002 chronic NRWQC in Railroad Creek. During high flow periods in the spring, aluminum concentrations greater than the calculated area background value and the chronic NRWQC were measured in Railroad Creek from background station RC-6 to downstream station RC-3. During low-flow conditions in Railroad Creek, aluminum concentrations were below the NRWQC and/or area background. During spring high-flow conditions, available water quality data indicate no exceedances of the NRWQC for iron. During low-flow conditions, however, exceedances of the NRWQC for iron were measured from station RC-7 to station RC-5.

No exceedances of potential ARARs were measured in Copper Creek or Lake Chelan at the mouth of Railroad Creek as part of the DRI or subsequent sampling programs. Additionally, no exceedances of federal or state MCLs, or other applicable surface water quality criteria were recorded in Railroad Creek.

Aquatic Biota

Results of aquatic studies performed for the RI suggest reduced fish and benthic macroinvertebrates populations in Railroad Creek resulting from site discharges. Data presented in the RI indicate the reduced populations may be due to a combination of chemical and physical effects. Physical effects observed at the Site include the presence of iron oxy-hydroxide precipitates (flocculent) and limited areas of ferricrete formation in the Railroad Creek streambed. Based on fish surveys conducted during the RI, reduced fish populations were observed in Railroad Creek adjacent to the Site from monitoring station RC-7 to approximately three miles downstream of the Site. Reduced benthic macroinvertebrate populations were observed from adjacent to the Site at RC-9 to the mouth of Railroad Creek at Lucerne (station RC-3).

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[1] Intalco has provided legal justification and technical documentation showing that the NRWQC (1999 and 2002 publications) are not relevant and appropriate to the Holden Mine site. Intalco's justification has been provided in written correspondence with the Agencies between January and September 2003. This correspondence is part of the administrative record and is incorporated into this FS. Intalco's rationale is also summarized and presented in Section 3 and Appendix B.

6.1.1.2 Groundwater

Cadmium, copper, lead, manganese, and zinc were detected above potential groundwater ARARs in one or more west area seeps or groundwater monitoring locations. Sampling results indicate exceedances of potential groundwater ARARs for cadmium, copper, manganese, nickel, and zinc beneath various portions of tailings pile 1, 2, and 3. Exceedances of the SWQC and 1999/2002 NRWQC for copper, cadmium, and zinc were measured in Site seeps and groundwater discharging directly into Railroad Creek. The NRWQC for aluminum and/or iron were also exceeded in a number of seeps discharging to Railroad Creek from the east and west areas. However, a majority of the seeps do not flow (are dry) from the late summer through the early spring.

6.1.1.3 Soils

Cadmium, copper, and TPH were detected above potential ARARs or screening levels calculated for the protection of groundwater in maintenance yard soils. Cadmium, copper, silver, zinc, and TPH were detected above potential ARARs or screening levels for the protection of groundwater in the lagoon area, and exceedances of these levels were measured for cadmium, copper, and zinc in the former surface water retention area. Soil samples were not collected from the mill building during the RI. However, seep samples collected from this area indicate the mill building provides a source of metals loading to groundwater and Railroad Creek.

6.1.2 Summary of Baseline Loading Analysis and Potential Source Areas

Results of the site-wide loading analysis presented in Section 2.6 indicate that aluminum, cadmium, copper, iron and zinc loading is highest during the spring snowmelt, when flows from the portal drainage and seeps are the highest, and when groundwater levels are highest in the wells beneath the tailings piles. During the high-flow period, the data indicate that the portal drainage and seep SP-23 contribute a majority of the measured cadmium, copper, and zinc load at station RC-2. Available data indicate that a majority of the iron and aluminum enters Railroad Creek adjacent to the three tailings piles, between stations RC-4 and RC-2. Tailings pile 1 appears to individually contribute significantly more aluminum and iron than tailings piles 2 and 3 combined.

Groundwater and seeps entering the creek adjacent to tailings pile 1 also contain concentrations of cadmium, copper and zinc, which may be due to the presence of a paleo-channel extending from upstream of the lagoon area to a location near the eastern toe of tailings pile 1. RI data indicate that this paleo-channel may provide a preferential pathway for PCOCs from the West Area to Railroad Creek.

During the seasonal low flow period, represented for purposes of the FS analysis by September 1997 sampling data, a majority of the seeps were observed to be dry and the portal drainage accounted for only a small percentage of the measured aluminum, cadmium, copper, iron, and zinc load at RC-2. During this period, a majority of the metal loading appears to enter the creek through groundwater baseflow in the west and east areas. September 1997 data also indicate that groundwater baseflow from the tailings piles continues to contribute a majority of the aluminum and iron to Railroad Creek, with baseflow from tailings pile 1 contributing most of the loading from the east area.

6.1.3 Candidate Site-wide Remedial Alternatives

Technology types and process options that were carried forward from the screening evaluation described in Section 5 were assembled into eight candidate site-wide remedial alternatives to address the impacted media and source areas described above, and the RAOs presented in Section 4. The eight alternatives were assembled through a collaborative process with the Agencies, and in accordance with CERCLA, the NCP, EPA guidance, and MTCA to provide a range of alternatives that represent potentially applicable approaches to addressing the site-specific RAOs. The significant components of each of the eight alternatives are summarized in Table 6-1.

Consistent with the NCP, the No Action/Institutional Controls alternative will be retained throughout the detailed analysis of alternatives described in Section 7. Descriptions of the following eight candidate site-wide alternatives, and associated subalternatives, are provided in this section:

Alternative 1: No Action/Institutional Controls

Alternative 2: Water Management
- Alternative 2a: Water management (open portal)
- Alternative 2b: Water management (hydrostatic bulkhead)

Alternative 3: Water Management and Low-Energy West Area Treatment
- Alternative 3a: Water management and low-energy West Area treatment (open portal)
- Alternative 3b: Water management and low-energy West Area treatment (hydrostatic bulkheads)

Alternative 4: Water Management and East Area Collection and Treatment
- Alternative 4a: Water management and partial East Area collection and treatment
- Alternative 4b: Water management and extended East Area collection and treatment
- Alternative 4c: Water management, extended Railroad Creek relocation, and extended East Area collection and treatment

Alternative 5: Water Management and East/West Area Treatment (Low Energy WTP)
- Alternative 5a: Water management, partial East Area collection, and East/West Area treatment (low-energy WTP)
- Alternative 5b: Water management, extended East Area collection, and East/West area treatment (low-energy WTP)
- Alternative 5c: Water management, extended Railroad Creek relocation, and East/West Area treatment (low-energy WTP)
- Alternative 5d: Water management, secondary West Area collection, extended Railroad Creek relocation, and East/West Area treatment (low-energy WTP)

Alternative 6: Water Management, Extended Railroad Creek Relocation, and East/West Area Treatment (Mechanical WTP)

- Alternative 6a: Water management, extended secondary West Area collection, extended Railroad Creek relocation, and East/West Area treatment (mechanical WTP with open portal)
- Alternative 6b: Water management, extended secondary West Area collection extended Railroad Creek relocation, and East/West Area treatment (mechanical WTP with bulkhead)

Alternative 7: Capping, Consolidation, Water Management, and West Area Treatment

Alternative 8: Source Control and East/West Area Treatment

6.2 ALTERNATIVE 1: NO ACTION/INSTITUTIONAL CONTROLS

While consideration of this alternative is required by the NCP, the No Action/Institutional Controls alternative is also intended to represent a baseline alternative for comparison with all other candidate alternatives. No engineering controls would be provided under the No Action alternative. The portal drainage and Site surface water, groundwater, and seasonal seeps would continue to flow into Railroad Creek without control or treatment, and source materials and impacted soils would remain in place. However, the following actions would be implemented under Alternative 1:

- Institutional controls and physical access restrictions,
- Environmental and slope stability monitoring,
- Limited mine actions.

Under this alternative, tailings pile revegetation would continue naturally by migration of both native plant species and existing plants placed as part of previous Forest Service revegetation programs. Actions included under Alternative 1 are described in the following subsections.

6.2.1 Institutional Controls and Physical Access Restrictions

The results of the technology identification and screening process presented in Section 5 indicate that potentially hazardous substances would remain on site under all of the candidate remedial alternatives. CERCLA and the NCP indicate preferences for site remedies that reduce the toxicity, mobility, and/or volume of affected media through the use of treatment or resource recovery techniques. Similarly, MTCA requires that alternatives use permanent solutions to the maximum extent practicable. Results of the technology evaluation and screening process indicate such remedies would be impractical for all media at this Site due to the large volume, low toxicity, and low concentrations of hazardous substances in remaining materials.

The NCP recognizes the appropriateness of institutional controls (ICs) under certain conditions at CERCLA sites (EPA 1990). EPA further recognizes that ICs play an important role in site remedies. Often, ICs are a critical component of the cleanup process and are used by the site manager to ensure both the short- and long-term protection of human health and the environment

(EPA 2000). Specifically, the NCP states that ICs may be considered as a remedial alternative to prevent or limit exposures to hazardous substances when active measures such as treatment or containment are determined to be impractical [40 CFR 300.430 (a)(1)(iii)].

Similarly, MTCA recognizes the importance of ICs in the development of cleanup action alternatives. Under circumstances where it is not technically possible to implement a permanent cleanup action for all or a portion of a site, MTCA allows the cleanup actions to rely primarily on ICs and monitoring where it is technically not possible to implement a more permanent cleanup. Institutional controls are to assure both continued protection of human health and the environment and the integrity of a cleanup action when hazardous substances will remain on-site at concentrations that exceed potentially applicable ARARs or when a conditional point of compliance is established (WAC 173-340-440(1)(4)).

The use of ICs at the Site would, therefore, be appropriate as components of candidate site-wide remedial alternatives where hazardous substances remain on site above potentially applicable ARARs or for circumstances where conditional point(s) of compliance are established. Although results of the human health risk assessment indicate risks are acceptable for both residents and visitors to the Site based on reasonable maximum exposure scenarios, ICs would be implemented to limit potential future exposures to human and ecological receptors from source materials and PCOCs remaining on site.

ICs for Alternatives 1 through 8 would include land use restrictions to prevent the use of a resource or area that would be inconsistent with the remedy, or require pre-approval for certain activities; security devices to limit access; and informational devices to notify users about potential risks. The ICs implemented on patented claims, such as near the 1500-level main portal, may be maintained through the use of deed notices. The ICs would be implemented to address potential risks associated with groundwater, soils within certain areas of the Site, and underground mine areas. The objectives of the ICs would include:

- Prevent the potential future human use or consumption of groundwater beneath the Site until human-health based criteria (i.e., potential groundwater ARARs identified in Section 3) are met;
- Prevent undue exposure to hazardous substances or physical hazards remaining on site; and
- Limit or prevent activities that would interfere with the remedial activity at the Site.

To meet the objectives stated above, ICs would be implemented for each media as described in the following subsections. Existing physical access restrictions would also be maintained to provide protection for residents and visitors from potential physical hazards associated with several site features, as described in Section 6.2.1.3 below.

6.2.1.1 Institutional Controls for Groundwater

To prevent potential future consumption and uses of groundwater, land use restrictions would be implemented that prevent the construction of water supply wells, except current or future monitoring wells or wells that may be needed for future remedial actions throughout the Site. Restrictions would be implemented for groundwater on the south side of Railroad Creek in the West Area (east of the 1500-level ventilator portal and SP-26), East Area, and immediately downgradient of the Site at the approximate locations of monitoring wells DS-1 and D-2. This prohibition on groundwater use would be implemented until such time as groundwater quality complies with applicable health-based criteria (i.e., potential groundwater ARARs identified in Section 3).

A combination of mechanisms would potentially be used to meet this objective, including:

- Recording the boundaries of the contaminated groundwater in the Washington State aquifer register;

- Providing notification to the land users (i.e., Holden Village and Forest Service) through signs and pamphlets;

- Implementing deed notices, which would require notice to Ecology prior to the installation of water supply wells or other groundwater uses for areas within the patented claims; and

- Providing for enforceable use restrictions that run with the land by modifying the Wenatchee National Forest Land and Resource Management Plan (Forest Service, 1990).

In addition, unnecessary monitoring wells would be closed in accordance with Washington State well closure standards.

6.2.1.2 Institutional Controls for Construction and Maintenance Activities

The Wenatchee National Forest Land and Resource Management Plan would be modified to require pre-approval from the Forest Service prior to initiating any activities that would potentially interfere with or compromise long-term monitoring, effectiveness of a remedy (i.e., installed engineered cover), or other remedial activities at the Site. The activity would require notification to the Forest Service so that potential future short- and long-term risks could be evaluated prior to approving such activities. This restriction would apply to specific areas (i.e., tailings piles, lagoon area, mill building, waste rock piles) to be defined in the Wenatchee Land and Resource Management Plan.

In addition, notice would be posted near any remedial component, limiting access to the area to prevent compromising the remedy or structure.

6.2.1.3 Existing Physical Access Restrictions

Existing physical access restrictions would be maintained to provide protection for residents and visitors from potential physical hazardous associated with certain site features. Security fences installed around the mill building, access restrictions to the 300- and 1000-level portals, and locking steel door located on the 1500-level main portal would be maintained. Informational and/or access restricting signage (i.e., “No Trespassing”) would be posted along with information related to the potential risks. Any reports of trespassers would be reported to the Forest Service for possible investigation and evaluation.

6.2.1.4 Institutional Control Management Plan

ICs would be more specifically developed during the RD/RA, during which an Institutional Control Management Plan (ICMP) would be developed. The ICMP would:

- Identify the areas subject to each of the ICs, including the conditions and boundaries of the sites subject to land use controls and the terms and conditions of such land use control;
- Identify the purpose and objectives of the ICs;
- Specify the anticipated time frames that ICs are to remain in effect;
- Identify a contact for implementing, maintaining, and monitoring ICs;
- Identify a process for notifying EPA and Ecology if a change in land use is anticipated;
- Identify criteria regarding what would be considered inconsistent with the ICs objectives or protectiveness criteria;
- Identify current land users and uses; and
- Identify monitoring requirements to ensure that ICs are protective.

The ICMP would be referenced in the Wenatchee Land and Resource Management Plan.

6.2.1.5 Institutional Control Administration and Monitoring

The Forest Service would administer the ICs in conjunction with residents of Holden Village for as long as the Forest Service administers U.S. government-owned lands. In the event of property transfer, it would be necessary to include deed or land use restrictions to implement the ICs. Deed restrictions cannot be placed on the property until transfer of the property. Upon transfer of the property, notification of the history of the site would be attached to any property transfer, which would be to meet the requirements of CERCLA 120(h). Deed restrictions would address any limits to remain in effect after the time of transfer to restrict land use, restrict the use of groundwater, and manage excavation. The deed covenants would also include provisions addressing the continued operation, maintenance, and monitoring of the selected remedy.

Long-term monitoring would be conducted in accordance with the ICMP. Monitoring requirements would be developed during and after the remedial design phase. Monitoring of the ICs would be performed to determine the effectiveness and protectiveness. In addition, ongoing implementation of the ICs would be periodically reported to EPA and Ecology.

6.2.2 Environmental and Slope Stability Monitoring

Under the No Action alternative, surface water and groundwater quality monitoring would be performed during spring high flow periods and low-flow periods in the late summer or fall to monitor environmental site conditions and assess remedy performance. The specific groundwater and surface-water monitoring locations will be determined during the RD/RA and described in the Site Operation and Maintenance Monitoring Plan (OMMP), which is also developed during the RD/RA.

Surface water monitoring points would include Railroad Creek stations upstream, adjacent to, and downstream of the Site as determined during the RD/RA. While specific monitoring locations would be determined during the RD/RA, it is assumed for purposes of the FS that surface water monitoring would be performed at locations RC-6 (background), RC-4 (adjacent to the west area), and a station downstream of the tailings piles (e.g., RC-13) under Alternative 1 (Figure 6-2).

For groundwater, a conditional point of compliance (CPOC) would need to be established for the selected remedy. As described in Section 3, MTCA allows the establishment of a CPOC for groundwater at sites where it is not practicable to meet potential ARARs within groundwater throughout the site within a reasonable restoration timeframe (WAC 173-340-720(8)(d)). The CPOC(s) may be established in surface water at the point(s) where groundwater enters surface water if the requirements specified under WAC 173-340-720(8)(d) are met. Justification for establishing a CPOC for groundwater in surface water is provided in this FS. A final determination of the specific monitoring locations within surface water to assess remedy performance would be determined and refined during the RD/RA.

While the specific monitoring points would be determined during the RD/RA, the following approximate locations are being considered for purposes of the FS:

- Background well HV-3 located in the northwest corner of the Holden Village,
- A point in Railroad Creek adjacent to the west area in the vicinity of station RC-4,
- A point in Railroad Creek adjacent to the east area in the vicinity of seep SP-2, and
- A point in Railroad Creek downstream of the Site in the vicinity of station RC-13.

These CPOCs would likely be located between the centerline and south bank of Railroad Creek. Groundwater and surface-water parameters would include dissolved metals and previously monitored water quality characteristics consistent with RI sampling requirements. The quality and quantity of the monitoring data collected would be sufficient to perform statistical analyses as stipulated under MTCA requirements [WAC 173-340-720 and WAC 173-340-730]. For purposes of the FS, it is assumed that biannual surface water and groundwater sampling would be performed for the first five years. Following the fifth year, the frequency of monitoring would be evaluated and adjusted appropriately based on Agency review.

Annual stability monitoring of tailings pile side slopes would be performed in the spring to evaluate the potential for slope failure and accidental release of tailings to Railroad Creek. Monitoring would potentially consist of visual assessments documenting any observed changes in the condition of the side slopes. Existing riprap integrity would also be visually assessed and documented concurrently.

As discussed in Section 6.2.1, ICs would be monitored as specified in the ICMP. For Alternative 1, periodic monitoring would be conducted to ensure that the ICs for groundwater have been implemented; ICs to prevent construction in restricted areas is being complied with, and physical access restrictions to the 300-, 1100-, and 1500-levels of the underground mine are maintained.

6.2.3 Limited Mine Actions

Limited mine actions would be conducted under Alternative 1 to maintain the 1500-level main portal supports installed by Intalco during rehabilitation of the portal in fall 2000. Steel and timber support sets were installed in the initial approximately 100 feet of the 1500-level main tunnel to allow access into the mine through the formerly collapsed portal. The supports would be inspected annually in the spring and repaired as needed to maintain an acceptable factor of safety and minimize the potential for a surge release from the mine in the event of a portal collapse or blockage. Additionally, debris (such as railroad ties) and metal precipitates (slimes) remaining within accessible portions of the 1500 level would also be removed and disposed of on site to reduce the potential for accidental release. Miscellaneous objects or pieces of abandoned equipment removed from the 1500 level during these activities would be disposed of at a suitable location on site or taken off site to an appropriate disposal facility.

6.3 REMEDIATION COMPONENTS COMMON TO ALTERNATIVES 2 THROUGH 8

Several remediation components are common to all the candidate site-wide alternatives with the exception of Alternative 1 (No Action). These components include a combination of engineering actions and institutional controls designed to protect Holden Village residents and visitors from potential physical and chemical hazards associated with site features, and reduce metals loading to groundwater and surface water. To avoid repetition, the following common components are described in this section:

- Institutional controls and physical access restrictions,
- Environmental and slope stability monitoring,
- Limited mine actions,
- Mill building actions,
- Maintenance yard actions,
- Lagoon area actions,
- Former surface water retention area actions,
- Copper Creek channel modifications between tailings piles 1 and 2,
- Copper Creek diversion culvert,
- Riprap source development, and
- Railroad Creek bank protection in the West Area.

The areas listed above are depicted on Figures 6-3, 6-4, 6-5, and 6-6, and are described in the following subsections.

6.3.1 Institutional Controls and Physical Access Restrictions

As described for Alternative 1, the results of the technology identification and screening process presented in Section 5 indicate that potentially hazardous substances would remain on site under all of the alternatives. Although results of the human health risk assessment indicate that risks are acceptable for both residents and visitors to the Site based on reasonable maximum exposure scenarios, ICs would be implemented to limit potential future exposures to human and ecological receptors from source materials and PCOCs remaining on site. These ICs are described in Section 6.2.1.

Existing physical access restrictions, including the security fence installed around the mill building, access restrictions in the 300, 1100, and 1500 levels, and signage would also be maintained under all of the alternatives. The access restrictions would be maintained to provide protection for residents and visitors from potential physical hazards associated with these site features.

6.3.2 Environmental and Slope Stability Monitoring

The continued monitoring of surface water, groundwater, and tailings pile side slopes would be performed under all of the candidate alternatives. Confirmatory soil sampling would also be conducted where soil removal actions are performed (e.g., in the lagoon area and mill building) to ensure remedial objectives have been achieved. Additional monitoring of specific remedial components, such as engineered covers and institutional controls, would also be conducted as applicable. Environmental and slope stability monitoring activities are discussed in the following subsections.

6.3.2.1 Surface Water Monitoring

Under all the candidate remedial alternatives, surface-water quality monitoring would be performed during the spring flush and under low flow conditions in the late summer/fall to monitor site conditions, confirm adequate protection of human health and the environment, and assess performance of the selected remedy over time. The exact locations of the groundwater and surface-water monitoring points would be determined during the RD/RA and specified in the Site Operation and Maintenance and Monitoring Plan (OMMP). Surface water monitoring points would include Railroad Creek stations upstream, adjacent to, and downstream of the Site at locations determined during the RD/RA.

As described in Section 3, MTCA specifies that the point of compliance for surface water cleanup will be the point or points at which hazardous substances are released to surface waters unless a mixing zone is established in accordance with WAC 173-201A-400 (WAC 173-340-730(6)). For those alternatives that include the discharge of treatment system effluent or other point sources to Railroad Creek, mixing zone(s) would be established under WAC 173-201A-400, and surface-water monitoring would occur at the boundaries of the mixing zone(s). The specific size and location of the mixing zones and associated effluent limits would be established in accordance with WAC 173-201A-400 during the RD/RA.

While actual surface water monitoring points would be determined during the RD/RA, and would depend on the specific components of the final selected remedy, the following approximate locations are being considered for purposes of the FS (Figure 6-2):

- Alternatives that do not include the collection and treatment of groundwater, seeps or the portal drainage would include surface water monitoring at monitoring station RC-6 (background), station RC-4 (adjacent to the west area), and a station downstream of the tailings piles (e.g., station RC-13).

- Alternatives providing collection and treatment of West Area groundwater and the portal drainage, but not collection and treatment in the East Area, would include monitoring at station RC-6, at the downstream edge of a mixing zone (as allowed under WAC 173-201A-400) for the West Area treatment system discharge, and at a station downstream of the tailings piles (e.g., RC-13).

- Alternatives that include the collection and treatment of East Area groundwater and seeps, but not collection and treatment in the West Area would include monitoring at station RC-6, station RC-4, the downstream edge of a mixing zone for discharge from the East Area treatment system, and a station downstream of the tailings piles (e.g., station RC-13), unless there are no expected discharges from the Site downstream from the edge of the mixing zone.

- Alternatives that include the collection and treatment of groundwater and seeps from both East and West Areas and the portal drainage would include monitoring at station RC-6, the downstream edge of a mixing zone for discharge(s) from the East and West Area treatment systems, and a station downstream of the tailings piles (e.g., station RC-13) unless there are not expected discharges from the Site downstream from the edge of the mixing zone.

Surface water monitoring points at other locations, or in addition to those listed above, may be identified in the ROD for the selected remedy. Water quality analyses would include dissolved metals and routine water quality characteristics consistent with RI sampling requirements, and the quality and quantity of the monitoring data collected would be sufficient to perform statistical analyses as stipulated under MTCA requirements (WAC 173-340-730).

6.3.2.2 Groundwater Monitoring

For all the remedial alternatives, groundwater quality monitoring would also be performed during the spring flush and low flow conditions in the late summer/fall to monitor site conditions, confirm adequate protection of human health and the environment, and assess performance of the selected remedy over time. As described for surface water, the exact locations of the groundwater and surface-water monitoring points would be determined in the ROD and/or the RD/RA, and specified in the Site OMMP.

For groundwater, a CPOC would be established. As described in Section 3 and for Alternative 1, MTCA allows for the establishment of a CPOC for groundwater at sites where it is not practicable to meet potential ARARs within groundwater throughout the Site within a reasonable restoration timeframe (WAC 173-340-720(8)(d)). The CPOC(s) may be established in surface water at the point(s) where groundwater enters surface water if the requirements specified under WAC 173-340-720(8)(d) are met. Justification for establishing a CPOC for groundwater in surface water is provided in this FS, as appropriate for the specific alternatives. Specific monitoring locations would be determined in the ROD and potentially refined during the RD/RA.

While specific groundwater monitoring points would be determined during the RD/RA, and would depend on the specific components of the final selected remedy, the following approximate locations are being considered for purposes of the FS (Figure 6-2):

- Background well HV-3 located in the northwest corner of the Holden Village,
- A point in Railroad Creek adjacent to the West Area in the vicinity of station RC-4,
- A point in Railroad Creek adjacent to the East Area in the vicinity of seep SP-2, and
- A point in Railroad Creek downstream of the Site in the vicinity of station RC-13.

These CPOCs would likely be located between the centerline and south bank of Railroad Creek Groundwater quality analyses would include dissolved metals and routine water quality characteristics consistent with RI sampling requirements, and the quality and quantity of the monitoring data collected would be sufficient to perform statistical analyses as stipulated under MTCA requirements (WAC 173-340-720).

6.3.2.3 Soil Sampling

Under each of the candidate remedial alternatives, confirmatory sampling would be performed where soil removal actions are conducted (e.g., in the lagoon area and mill building) to demonstrate compliance with potential ARARs. These requirements would be identified in the ROD and/or during the RD/RA, and specified in the OMMP. Soil removal actions in these areas are discussed further in Sections 6.3.4 and 6.3.6.

6.3.2.4 Cover and Slope Stability Monitoring

In addition to the environmental monitoring described above, annual monitoring of source area covers would be conducted, as applicable, to monitor cover integrity and identify potential maintenance requirements (e.g., in the maintenance yard). Cover monitoring would likely be performed following the spring thaw, and would include visual assessments and/or engineering surveys. These requirements would be specifically developed in the ROD and/or during the RD/RA and identified in the OMMP.

Annual stability monitoring of tailings pile side slopes would also be performed to evaluate the potential for slope failure and accidental release of tailings to Railroad Creek. As described for Alternative 1, monitoring would include a visual assessment, and observed changes in slope conditions would be documented. Riprap integrity at the base of the tailings piles would be visually assessed and documented concurrently.

6.3.2.5 Monitoring of Institutional Controls

As discussed in Section 6.2.2, ICs would be monitored as specified in the ICMP. Under all of the remedial alternatives, periodic monitoring would be conducted to ensure that the ICs for groundwater have been implemented; ICs to prevent construction in restricted areas is being complied with; and physical access restrictions to the 300-, 1100-, and 1500-levels of the underground mine are maintained.

6.3.3 Limited Mine Actions

The following limited mine actions would be conducted under each of the candidate alternatives:

- Maintenance of the 1500-level main portal supports and debris removal from the 1500-level main tunnel.

- Installation of airflow restrictions within open portals on and above the 1500 level.

6.3.3.1 Maintenance of 1500-Level Main Portal Supports and Debris Removal

In the fall of 2000, Intalco installed steel and timber support sets in the initial approximately 100 feet of the 1500-level main tunnel to allow access into the mine through the formerly collapsed portal. The supports would be inspected annually in the spring and would be replaced or repaired as needed to maintain an acceptable factor of safety and minimize the potential for a surge release from the mine in the event of a portal collapse or blockage.

Debris and metal precipitates (slimes) remaining within accessible portions of the 1500 level would be removed and disposed of at a suitable on site location (e.g., tailings pile 1) to minimize the potential for accidental release.

6.3.3.2 Installation of Airflow Restrictions above the 1500 Level

Airflow restrictions would be placed within open portals on and above the 1500 level (Figure 6-3). Potentially open drill holes would also be sealed on an opportunistic basis if located. Data collected during the RI indicate that the oxidation of mineralized surfaces within underground stopes and mine workings is the primary process resulting in the generation and transport of metals constituents to the portal drainage. The installation of airflow restrictions would be intended to reduce oxygen-dependent reactions, and thereby improve water quality over time.

Preliminary geochemical analyses performed by SRK indicate that successful restriction of airflow through the workings (greater than 99 percent) would likely limit the oxygen supply to less than that needed to sustain current estimated oxidation rates. The analyses performed by SRK are provided in Appendix E. Based on observed airflow velocities in the 300, 1100, and 1500 levels of the mine, it is anticipated that reductions greater than 99 percent may potentially be achieved through the installation of airtight bulkheads, if the airflow through potential drill holes or other unidentified openings is not significant.

Airflow restrictions would be designed to prevent physical access into underground mine workings, and allow unrestricted portal drainage flow from the 1500 level for alternatives that do not include the installation of hydrostatic bulkheads at this location.

6.3.4 Mill Building Actions

Drip water samples collected by the U.S. Geologic Survey (USGS) in 1995 and 1996 indicate the potential for residual materials and soils located in the mill building to contain metals concentrations above potential clean-up criteria. Due to safety concerns, no soil samples were collected from this area during the RI. The building is located on a steep hillside below the 1500-level main portal and encompasses approximately 1 acre (Figure 6-4). Data collected during the RI indicate surface water runoff and seeps associated with the mill building (SP-7 and SP-22) contribute loading of cadmium, copper, and zinc to groundwater during the spring.

To reduce potential risks to ecological receptors and reduce surface water infiltration and PCOC mobility in this area, soils and residuals in the mill building with metals concentrations above the potential cleanup criteria provided in Section 3.0 would be excavated and relocated to a containment area on site or covered in place. Residuals contained in the former concentrate tank and ore bin would likely be excavated and relocated to an on-site containment area due to the impracticability of installing an effective cover on these features. The disposition of other materials within the building would be evaluated during the RD/RA phase.

Although not anticipated, excavated materials determined to be characteristic hazardous wastes would be stabilized or treated as appropriate prior to disposal. Excavation techniques used in this area would vary depending on location, and would likely include a combination of hand excavation and the use of small equipment. Vegetative soil covers would be installed over soils and residual materials that are not removed. Removal of limited portions of the former mill structure would be completed as necessary to provide safe access to work areas.

6.3.5 Maintenance Yard Actions

The Holden Village currently uses this area, which is approximately 1 acre in size, for vehicle maintenance, and storage. A new maintenance building was recently constructed in the area for equipment and vehicle maintenance and to house the Village's drinking water treatment system. The area is also used by the Village to access a composting system and combustible waste incinerator. The new maintenance building was constructed with a concrete foundation placed over soils with measured concentrations of metals and petroleum hydrocarbons above clean-up levels.

To reduce potential exposure to human and ecological receptors and metals transport to surface water and groundwater, an asphalt or concrete cover would be placed over soils in the maintenance yard area with metals and/or petroleum hydrocarbon concentrations exceeding the potential clean-up criteria provided in Section 3. The use of a concrete or asphalt cover would allow continued use of the area by Village residents. Soils that cannot be effectively covered would be excavated and relocated to a suitable containment area on site (e.g., tailings pile 1). Although not anticipated, excavated materials determined to be characteristic hazardous wastes would be stabilized or treated as appropriate prior to disposal. Figure 6-4 depicts the approximate extent of the areas to be covered and/or excavated. The actual extent will be confirmed during the RD/RA.

6.3.6 Lagoon Area Actions

To reduce potential exposure to human and ecological receptors and metals loading to the subsurface, soils within the footprint of the lagoon containing constituent concentrations above potential ARARs would be excavated and relocated to a suitable on-site containment area (e.g., tailings pile 1). Although not anticipated, excavated materials identified as characteristic hazardous wastes would be stabilized or treated as appropriate prior to disposal. Based on soil sampling data obtained during the RI, it is assumed that approximately 9,000 cubic yards of impacted soils would be excavated from this area. However, the actual volume of soils requiring removal would be evaluated during the RD/RA and through confirmatory sampling.

6.3.7 Former Surface Water Retention Area Actions

As described in Section 2, a former surface water retention area, located downgradient from the 1500-level ventilator portal, was observed during the RI (Figure 6-3). The area encompasses approximately 400 square yards and is located hydraulically upgradient of seep SP-26. The area is located in a remote portion of the Site that is not accessible by road or hiking trail. Under each of the alternatives, small track-mounted equipment, such as a front-end loader, would be used to remove or cover the feature with approximately 2-feet of clean soil obtained from surrounding areas. The specific action would be determined during the RD/RA. If the materials are covered, the cover would be compacted and revegetated to provide a suitable cover to reduce surface water infiltration and PCOC mobility. The area would then be graded to direct surface water around the feature and reduce potential erosion of the soil cover. As described in Section 3, the remedy would comply with the relevant and appropriate provisions for limited purpose landfills under WAC 173-350-400.

The use of a geosynthetic cover in this area would also be evaluated during the RD/RA under Alternatives 7 and 8, where such covers are evaluated for other site features.

6.3.8 Copper Creek Channel Modifications between Tailings Piles 1 and 2

Copper Creek is confined by bedrock on either side of its channel down to the elevation of the Forest Service hiking trail located above tailings piles 1 and 2. Once the channel is no longer confined, there is a break in slope where an alluvial fan has formed. Previous stabilization efforts conducted by the Forest Service between 1989 and 1991 modified this fan and attempted to direct Copper Creek into one main channel and one overflow channel. Water within these channels flows through separate culverts under the access road located at the top of tailings pile 1.

Because the alluvial fan between tailings pile 1 and 2 was formed by the deposition of debris at the lowest points on the fan, over the years, the Copper Creek has moved move back and forth across the fan as the elevation changes. As described in Section 2.2.5, during the high-flow event that occurred in October 2003, Copper Creek flowed outside of the two channels constructed during the remedial activities conducted in 1989 through 1991. As a result, portions of the creek flowed onto tailings piles 1 and 2. This was partly due to the deposition of debris that altered the elevation within the two channels.

Over the long term Copper Creek will continue to build an alluvial fan in this area, and potentially migrate across the tailings, unless the channel is artificially steepened. A steeper channel would allow the sediment carried by the creek to be conveyed directly down to Railroad Creek. The channel would be designed to mitigate the potential for logjams to create breaks in slope that temporarily store sediment and create channel migration conditions. The channel would need to be relatively straight and protected along the sides. Alternatively, the construction of a debris trap upgradient of tailings piles 1 and 2 would be evaluated during the RD/RA.

Modification of the Copper Creek channel between tailings piles 1 and 2, and an evaluation of the two existing culverts beneath the access road, would be performed under all of the candidate alternatives to create a steeper channel and mitigate the potential for future channel migration. The methods used to protect the channel (e.g., riprap, culverts, etc.) would depend on the individual remedial action as described in the following sections for Alternatives 2 through 8.

6.3.9 Copper Creek Diversion Culvert

The Holden Village currently diverts a portion of Copper Creek upstream of the Site for drinking water and generation of hydroelectric power (Copper Creek diversion). During the fall and winter, the entire creek is diverted by the Village. Discharge from the hydroelectric plant flows in an open channel over the western edge of tailings pile 1 and discharges to Railroad Creek (Figure 6-3). The drainage channel also receives surface water runoff from a drainage ditch constructed by the Forest Service on tailings pile 1 (SP-19). Results of the RI indicate an increase in surface water PCOC concentrations in the Copper Creek diversion, possibly as a result of contact with tailings pile 1 and/or groundwater flow from the west area. The metals concentrations in Copper Creek meet all potential chemical-specific ARARs. However, to reduce the direct transport of metals to Railroad Creek, the Copper Creek diversion would be placed in a lined channel or culvert from the hydroelectric plant discharge to the confluence with Railroad Creek. The open channel or culvert would be constructed of concrete or high-density polyethylene (HDPE).

6.3.10 Riprap Source Development

A source of large-diameter rock for use as riprap or in the construction of other remedial features (e.g., low energy treatment systems) will be needed under all of the candidate alternatives. As described in Section 2, the Forest Service placed riprap along the south bank of Railroad Creek adjacent to tailings piles 1, 2, and 3 during Site reclamation efforts completed between 1989 and 1991. The riprap placed by the Forest Service originated from an existing rock quarry developed near Dan's Camp, at a site called "Lightning Ridge" located approximately 8 miles east of the Site.

An assessment of potential riprap sources within the Railroad Creek watershed was performed as part of the RI. The assessment concluded that the Lightning Ridge source used by the Forest Service does not contain sufficient quantities of competent bedrock for use as a future source of riprap. A second potential borrow source area identified by the Forest Service and evaluated in the RI consists of talus rock slopes located approximately one mile east of Holden Village, near Tenmile Creek (Figure 6-5). The talus slopes consist mostly of boulder-sized fragments of relatively competent quartz monzonite bedrock that originates from an upslope outcrop. Visits to the Site by URS geologists in 2003 indicated that obtaining riprap from both the talus and nearby outcrop sources may be feasible in this area (Figures 6-5 and 6-6). The following subsections describe additional exploration and testing that would be needed during the remedial design prior to selecting a riprap source, and the potential methods that may be used to develop the talus and outcrop sources.

6.3.10.1 Exploration and Testing Program

Primary considerations for riprap source evaluation are the location, quality, and quantity of materials proximal to the project site. A memorandum by the Forest Service (Holden Riprap Sources, December 1988) describes the presence of two talus slopes and bedrock exposures near the point where Tenmile Creek empties into Railroad Creek. However, the quality of these potential materials sources was not quantified in the Forest Service memorandum.

Site reconnaissance during the remedial design by an engineering geologist would be an initial step to examine the variability in rock types, site access, and materials-handling issues. The geologist would layout a full-scale exploration and testing program to verify the quality and quantity of riprap available from talus and bedrock sources. Potential rock fall hazards during quarry operation would also be evaluated.

For potential sources from talus materials, the depth of the talus and the variation of size with depth could be evaluated using equipment such as a track hoe. For rock outcrops, a core-drilling rig would be needed to provide samples for testing and to assist in the evaluation of blasting design. Field rock core logging would include logging of rock strength and calculation of Rock Quality Designation (RQD). Logging of discontinuities would also be needed to assess the size of materials that can be quarried.

Surface and core samples from the areas of interest would be needed to calculate a Durability Index, test for resistance to abrasion, and determine if minerals that might accelerate decomposition of the rock are present. Based on the results of this testing, other tests may be required. Tests for rock chemical composition may also be needed to further verify the suitability of these materials for placement in contact with river water.

6.3.10.2 Talus Source

During the work conducted in 1988, the Forest Service assessed the talus slopes located near Tenmile Creek and concluded that the talus materials were suitable for use as riprap. An initial petrographic examination of five samples collected by a URS engineering geologist in 2003 indicated that the rock is likely to be found suitable as a riprap source when further testing is undertaken.

Removal of material from this location could potentially result in physical hazards (in the form of rock falls) to work crews and the road leading from Lucerne to the Holden Village.

Additionally, a hiking trail parallel to the slope has recently been constructed by the Forest Service between this potential borrow source site and the road.

To safely develop the talus source for remedial action implementation, safety measures, such as rock berms or gabion walls would be constructed between the borrow source site and the road. Temporary rerouting of the Forest Service hiking trail would also be required during construction. To evaluate appropriate measures to mitigate physical hazards associated with a potential rockfall, existing USGS topography for the Site would be used in conjunction with evaluation tools, such as the Colorado Rockfall Simulation Program (CRSP), during the RD/RA. A program such as the CRSP would be used to model two-dimensional representations of the most probable rockfall path, providing the following output:

- Rockfall velocity,
- Impact force, and
- Bounce height characteristics.

In the event a gabion wall approach is determined to be appropriate for riprap development, the following guidelines may be used during design:

- *Naval Facilities Engineering Command, Design Manual 7.02* for Foundations and Earth Structures, dated September 1, 1986.

- *Forest Service Specifications for construction of Roads and Bridges,* dated August 1996.

- *Standard Specifications for Construction of Roads and Bridges on Federal Highway Projects*, FP-96, U.S. Department of Transportation, Federal Highway Administration, dated 1996.

- *Washington State Department of Transportation Design Manual*, dated February 2002.

As described above, a test-pit excavation program at this source would be necessary to ensure that sufficient quantities of rock are present at this location for remedy implementation. In the event sufficient rock cannot be removed safely from this location, competent rock from nearby outcrop sources would be evaluated.

6.3.10.3 Outcrop Sources

One of the potential sources identified by the Forest Service, during the work conducted from 1989 to 1991, had both talus and bedrock materials available (Figure 6-6). The Forest Service assessed this potential source and concluded that both the talus and bedrock materials were likely suitable for use as riprap. A subsurface exploration and testing program as described above would be needed to further verify this conclusion for the required use. An initial petrographic examination of one sample collected by a URS engineering geologist in 2003 indicated that the rock is likely to be found suitable as a riprap source when further testing is undertaken.

Should the talus source or the talus and outcrop source prove infeasible for the quantity, size range and quality needed, alternative sources may need to be evaluated. In 2003, a URS geologist identified another potential outcrop source in the field during a brief reconnaissance visit. This potential source is the closest identified source to the Holden Village (Figure 6-6) and has the advantage that existing vegetation could screen the quarry from view and the topography makes it less susceptible to rockfall hazards to the road below. A gently sloping area immediately south of the rock exposures could serve as a staging area for rock quarry development. As bedrock sources require blasting, an evaluation of the potential effects of blasting on the Holden Village community would be required if development of this area is anticipated. A subsurface exploration and testing program as described above would also be needed to further quantify the suitability of this potential source area.

6.3.11 Railroad Creek South Bank Protection in the West Area

Under Alternative 2, the condition of the south bank of Railroad Creek in the West Area would be assessed during the RD/RA, and riprap or other means of stream bank protection would be placed to mitigate the potential for erosion, as needed. Observations made during the fall of 2003 indicate that the meander pattern being formed by Railroad Creek may result in the potential erosion of the south bank near the current locations of the vehicle and pedestrian bridges in the West Area (Figure 6-7). Under this alternative, stream bank protection would be placed in along the south bank of Railroad Creek in the West Area, as needed, to minimize the potential for future release PCOCs or impacts to remedial features.

6.4 ALTERNATIVE 2: WATER MANAGEMENT

Alternative 2 would include the common remediation components described under Section 6.3 with the addition of:

- Diversion of upgradient surface and near-surface water around East and West Area features,
- Closure of tailings pile 1 decant tower,
- Regrading and enhanced revegetation of the tailings piles,
- Tailings pile slope actions, and
- Monitored natural attenuation in the East and West Areas.

Specific remediation components of Alternative 2 are provided in the following subsections. Two subalternatives (2a and 2b) that provide different approaches to portal drainage control were developed under this alternative. Under Alternative 2a, discharge from the 1500-level main portal would flow unrestricted to Railroad Creek. Under Alternative 2b, surge storage and control of the portal discharge would be provided by placing hydrostatic bulkheads in the 1500-level main and ventilator portals or through the use of an equalization basin constructed on tailings pile 1. Remediation components included under Alternative 2 are summarized on Table 6-1 and are discussed in the following subsections.

6.4.1 Diversion of Upgradient Surface and Near-Surface Water

Under Alternative 2, upgradient water diversion would be implemented to reduce metals loading to surface water and shallow groundwater from impacted materials in the mill building, maintenance yard, waste rock piles, lagoon area, and tailings piles. Upgradient water would be diverted using shallow rock-filled trenches or French drains installed upslope of mine features at the approximate locations shown on Figures 6-7 and 6-8.

The diversion trenches would be constructed using a new access road placed into the adjacent hillside and installing a trench or drain along the upslope edge of the road. In the West Area, the diversion trench would be installed immediately upslope from the 1500-level main portal, waste rock piles, and mill building. Alternatively, construction of the diversion system at the base of the hill slope above the waste rock piles and mill may be evaluated during the RD/RA. Diverted water would be directed to Railroad Creek through a new channel constructed adjacent to the current portal drainage channel and to Copper Creek. In the East Area, an abandoned road located upslope of the tailings piles would be reestablished to provide access for trench construction. Diverted flow in the East Area would be directed to Copper Creek and to Railroad Creek east of tailings pile 3.

The trenches would be constructed to capture and divert as much subsurface flow as practicable while minimizing the disturbance of soils and vegetation currently present on the steep hillside above the Site. Measures would be taken to provide sufficient grade to promote runoff and reduce re-infiltration of the collected water. However, some re-infiltration would be expected. Following construction, routine debris clearance would be conducted annually to maintain suitable drainage.

6.4.2 Closure of Tailings Pile 1 Decant Tower

During spring conditions, surface water runoff from tailings pile 1 is observed to flow into a partially open decant tower constructed during mining operations on the southern edge of tailings pile 1 (Figure 6-8). Under Alternative 2, the open decant tower would be filled with grout or other inert material and abandoned to minimize the flow of water and oxygen to subsurface tailings.

6.4.3 Regrading and Enhanced Revegetation of the Tailings Piles

Alternative 2 would include select regrading and enhanced revegetation of the top portions of the tailings piles to reduce surface water infiltration and contact with surface and subsurface tailings containing soluble metals. As described in Section 6.3.8, modification of the Copper Creek channel between tailings piles 1 and 2 would be performed under this alternative to mitigate the potential for future channel migration.

Observations made during the RI indicate that the drainage ditches and regrading efforts completed by the Forest Service in 1989 to 1991 resulted in improved surface water runoff from the tailings pile surfaces. However, during the spring freshet, continued ponding of snowmelt and upslope surface water runon has been observed to cover approximately 5 to 10 percent of the surface of tailings piles 2 and 3. Under this alternative, the top surfaces of the three piles would be regraded as necessary to minimize surface water ponding and infiltration.

Alternative 2 would also include continuing and enhancing revegetation efforts undertaken by the US Bureau of Mines and the Forest Service from the mid-1960s through the early 1990s to establish a successful plant community on the three piles. Revegetation efforts would be conducted to mitigate wind and surface erosion of the tailings, and to increase evapotranspiration rates. Studies conducted by the Forest Service indicate that the six-inch gravel cover placed on the tailings piles in 1990 to 1991 provides enhanced protection from wind erosion and has facilitated the successful establishment of a combination of planted and volunteer plant species. In addition, volunteer tree species have been found growing along the steep side slopes 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 and on top of the piles near existing water diversion ditches. Various grasses, forbs, and sedges currently cover approximately 5 to 10 percent of the tops of the tailings piles.

Following regrading efforts, the six-inch gravel layer would be replaced, along with available woody debris and clean soil generated during the construction of the upgradient water diversions. A combination of seeding and planting of seedlings would then be conducted. Soil amendments, such as plant nutrients or lime, would also be utilized as necessary for further establishment of the successful plant communities initiated by the Forest Service.

Periodic maintenance would be required following remedy implementation to maintain the new vegetation and surface drainage features. For purposes of the FS it is assumed that approximately 5 to 10 years of active revegetation efforts would be conducted following remedy implementation.

As described in Section 6.3.8, the Copper Creek channel would be modified between tailings piles 1 and 2 to prevent the deposition of debris and sediment through this reach. Under Alternative 2, additional riprap and geotextile materials would be placed within the modified Copper Creek channel to provide protection of the creek banks and mitigate the potential erosion of tailings piles 1 and 2 within this reach. A portion of the riprap and geotextiles placed in this area by the Forest Service during the remedial activities conducted in 1989 through 1990 were displaced during the October 2003 high-flow event described in Section 2 and would need to be replaced. Additional materials may also be needed along the creek banks within this reach as determined during the RD/RA.

6.4.4 Tailings Pile Slope Actions

Under Alternative 2, a combination of actions would be completed to enhance tailings pile slope stability and reduce the potential release of tailings to Railroad Creek:

- Slope regrading,
- Constructing low rockfill buttresses at locations along the base of the tailings, and
- Enhancing existing riprap at the base of tailing piles 1, 2, and 3.

6.4.4.1 Slope Regrading

Results of the slope stability analyses conducted as part of the RI indicate the top portions of tailings pile 1 slopes located adjacent to Railroad Creek are marginally stable with factors of safety between 1.0 and 1.2. Factors of safety greater than 1.2 indicate a suitably stable slope, while factors of safety at or below 1.0 indicate impending failure of the slope. Results of the RI indicate the top approximately 3 to 15 feet of tailings pile 1 slopes have slope angles greater than approximately 60 degrees and are marginally stable under static conditions in their current configuration. To increase the factor of safety and reduce the potential for a release of tailings to Railroad Creek, portions of these slopes with slope angles steeper than the angle of repose (estimated to be approximately 34 degrees or 1.5H to 1V), would be regraded. The top approximately 3 to 15 feet of tailings pile 1 represented by segments 1-B East through 1-F on Figure 6-9, would be regraded to final configuration of approximately 1.5H to 1V.

The slope stability analysis performed on cross-sections developed for tailings pile 2 indicates a minimum static factor of safety between 1.0 and 1.2, with the lowest factors of safety for relatively shallow failures extending 10 to 15 feet below the face of the slope at the deepest point. The erosion potential for tailings pile 2 side slopes was indicated to vary between moderate to high (Figure 6-9). To increase the factor of safety and reduce the potential for erosion and transport of tailings to Railroad Creek, tailings pile 2 slopes represented by sections 2-B through 2-F East on Figure 6-9 would be regraded to a final configuration of approximately 2H to 1V. Portions of tailings pile 2 represented approximately by sections 2-A South and 2-A North would also potentially be regraded to a final configuration of 1.5H to 1V to promote revegetation.

Using cross-sections developed for the tailings piles 1 and 2 side slopes, approximately 250,000 cubic yards of tailings are estimated to require relocation under this alternative. Tailings pulled back from the side slopes would likely be relocated to the western portion of tailings pile 3, along the existing tailings pile 2 slope. Relocated oxidized (orange) tailings would be stockpiled separately for placement on top of unoxidized (gray) tailings at the new location. The relocated tailings would be compacted and regraded to reduce surface water infiltration.

Erosion control measures would be conducted to minimize material transport during construction and following completion of regrading efforts. Final slope configurations would allow successful revegetation of tailings pile side slopes adjacent to Railroad Creek, and allow most of the mature vegetation and trees currently growing on the surface and slopes of tailings piles 1 and 3 to remain in place.

6.4.4.2 Low Rockfill Buttresses

The top portions of limited segments of tailings pile 3 side slopes are also steeper than the estimated angle of repose. Slope angles of the top portions of sections 3A and 3B on Figure 6-9 are steeper than approximately 42 degrees. However, the findings of the RI indicate these slopes appear to be stable in their current configuration. The tailings pile 3 slopes would not be disturbed under this alternative, allowing the mature vegetation and trees on the upper-most portions of these slopes to remain in place. To contain tailings potentially transported downslope due to sloughing or slope failure, low rock-fill buttresses would be constructed at the base, as needed.

6.4.4.3 Enhance Existing Rip-Rap

Existing riprap placed at the base of the three tailings piles during site reclamation efforts completed by the Forest Service between 1989 and 1991 and by URS during the emergency response activities conducted in the fall of 2003 would be enhanced under this alternative. An assessment of riprap condition was conducted as part of the RI in 1997. The results indicate that the existing riprap has weathered in a majority of the reaches adjacent to the three piles. Subsequent to the RI investigation, a portion of the riprap placed along the toe of tailings pile 2 was eroded during the high flow event that occurred in October 2003. As discussed in Section 2, competent rock was replaced along the affected reach during the emergency response actions completed by URS in November 2003.

Under Alternative 2, competent riprap would be obtained from a local source as discussed in Section 6.3.10 and placed along portions of the south stream bank, as needed, to reduce future erosion and scouring of the tailings under high flow conditions.

6.4.5 Monitored Natural Attenuation in the East and West Areas

Natural attenuation is defined by the EPA as "…a variety of physical, chemical, or biological processes that, under favorable conditions, act without human intervention to reduce the mass, toxicity, mobility, volume or concentration of contaminants in soil or groundwater. These in situ processes include biodegradation; dispersion; dilution; sorption; volatilization; radioactive decay; and chemical or biological stabilization, transformation, or destruction of contaminants." (EPA 1999) Monitored natural attenuation (MNA) relies on natural attenuation processes to achieve site-specific remediation objectives within a time frame that is reasonable compared to that offered by other more active methods.

MNA is beneficial for several reasons as described by EPA, including but not limited to the following:

- As an in situ process, MNA generates less volume of remediation wastes, reduces potential for cross-media transfer of contaminants, reduces risk of human exposure to contaminants, and contaminated media, and reduces risks to ecological receptors due to exposure to contaminants and contaminated media;
- Natural attenuation processes result in in-situ destruction of contaminants;
- MNA results in less intrusion as few surface disturbances and structures are required;
- MNA is flexible and is potentially applicable to all or part of a site, depending upon the site conditions and RAOs;

- MNA can be used in conjunction with other more active remedial measures; and
- MNA is results in lower overall remediation costs than those associated with more active remediation.

This description is consistent with the definition of natural attenuation under MTCA (WAC 13-340-200). MTCA, under WAC 173-340-370(7), specifies the following expectations regarding natural attenuation and the appropriateness at sites:

- Source control (including removal and/or treatment of hazardous substances) has been conducted to the maximum extent practicable;
- Leaving contaminants on-site during the restoration time frame does not pose an unacceptable threat to human health or the environment;
- There is evidence that biodegradation or chemical degradation is occurring and will continue to occur at a reasonable rate at the site; and
- Appropriate monitoring requirements are conducted to ensure that the natural attenuation process is taking place and the human health and the environment are protected.

If these MTCA natural attenuation expectations are demonstrated, then remedial action alternatives that rely on natural attenuation for achievement of potential ARARs can be considered active remedial measures.

Geochemical analyses conducted for the Site document that natural attenuation is occurring, and the release of PCOCs from the underground mine workings, waste rock piles, and tailings piles will continue to decline over time under this alternative. These geochemical analyses and predictions of trends in chemical loading from Site source areas are provided in Appendix E. Monitored natural attenuation, in conjunction with the actions provided under Alternative 2, including: source control and removal actions described in Section 6.3; diversion of upgradient water around potential source areas; closure of the tailings pile 1 decant tower; and tailings pile regrading and revegetation are expected to significantly reduce the release of PCOCs over time.

Descriptions of the natural attenuation processes and an evaluation of the achievement of MTCA expectations for natural attenuation are provided in Section 7. Groundwater and surface water monitoring for natural attenuation are generally described in Section 6.2.2 and would be specified in the OMMP.

6.4.6 Alternative 2a – Open Portal

Under Alternative 2a, airflow restrictions would be placed within the 1500-level main portal, allowing unrestricted water flow from the mine. The water level within the mine would remain unchanged from current conditions and the existing drainage alignment from the portal to Railroad Creek would not be modified.

6.4.7 Alternative 2b – Hydrostatic Bulkhead

Under Alternative 2b, the 1500-level main portal discharge would be controlled and equalized through the placement of hydrostatic bulkheads within the 1500-level main portal and ventilator tunnel or through the use of a lined equalization basin constructed outside of the mine on tailings pile 1. Portal drainage control would be used to provide surge storage and reduce seasonal loading spikes to Railroad Creek to the extent possible.

Under the hydrostatic bulkhead option, two or more hydrostatic bulkheads would be installed in strategic locations within the 1500-level main portal and ventilator tunnel to control water flow rates from the underground mine. Available volume between the 1500 and 1100 levels would be used for water storage as needed. Based on analyses conducted during the RI and underground mine investigations, the storage of water above the 1100 level would likely not be feasible, due to the proximity of stopes and mine workings to the ground surface.

As discussed below, access into the 1500-level ventilator tunnel was not possible during the 2001 underground investigation due to the partially collapsed nature of the area and associated safety concerns. While initial observations of the mine geology indicate that construction of a bulkhead would likely be feasible at some location within the tunnel, in the event that it is determined during the RD/RA that this action is less feasible, less cost-effective, or would significantly increase potential risks to workers, the construction of an equalization basin outside of the mine would be considered.

The following subsections describe evaluations related to the installation of hydrostatic bulkheads, portal drainage discharge rates, in-mine flow controls, the potential installation of a lined equalization basin, and actions related to the 1100 level portal and seep SP-23 under Alternative 2b.

6.4.7.1 Bulkhead Feasibility

The underground investigation conducted in the spring of 2001 included an evaluation of the integrity of the bedrock within the mine for the installation of hydrostatic bulkheads within the 1500-level main and ventilator tunnels. The underground investigations confirmed that the integrity of the bedrock within 1500-level main tunnel is sufficient to allow for the installation of a hydrostatic bulkhead within that portion of the mine. Due to the partially collapsed condition of the ventilator tunnel in the immediate vicinity of the No. 2 shaft, access was not possible during the investigation. Access is also not currently possible to the tunnel through the ventilator portal at the surface. However, initial observations of the mine geology within the immediate vicinity of the No. 2 shaft indicate construction of a bulkhead would likely be feasible at some location within the ventilator tunnel and practical access to the tunnel can be gained.

As described in Section 2, the results of the underground investigations also confirmed the presence of two primary faults within the mine that will need to be considered in terms of the specific bulkhead locations. The two faults appear to intersect both the 1500-level main and ventilator tunnels. However, the following observations indicate that the hydrostatic bulkheads would be feasible if placed on the 1500 level between the locations of the two faults:

- The faults plunge relatively steeply downward, and were not observed to daylight at the surface below the 1100 level of the mine.
- The relatively "tight" nature of the bedrock. (Relatively minor amounts of seepage were observed entering the mine at the intersection with the faults.)
- The lack of evidence suggesting recent movement.
- The presence of relatively low-permeability glacial till overlying the bedrock below the 1100 level.

Figure 6-10 provides a plan view of the 1500-level and potential tunnel segments that would be further evaluated for bulkhead installation during the RD/RA.

6.4.7.2 In-mine Storage Volumes

An evaluation of stope volumes between the 1500 and 1100 levels of the mine was conducted by URS in 1999. An existing profile map (Howe Sound Co. 1957) was used to estimate the height of the stopes. Available cross-sections obtained from Howe Sound Co. mine assay plans were then used to evaluate the cross-sectional area for each of the stopes. Where a stope intersected two or more mine levels, cross-sectional areas between adjacent levels were averaged, and the volume of the stope was calculated by multiplying the average by the height between levels. Where the stope intercepted only one level, the stope was assumed to be rectangular in cross-section, and the volume was calculated by multiplying the single cross-sectional area by the height of the stope.

Using the method described above, the total volume of open stope between the 1500 and 1100 levels was estimated to be approximately 25,658,000 cubic feet (191,907,000 gallons). Assuming approximately three miles of tunnel established on the 1500 level with an average cross-section of approximately 64 square feet, an additional volume of approximately 1,014,000 cubic feet was estimated for a total of 26,672,000 cubic feet (199,491,000 gallons). Using portal drainage discharge data obtained with the pressure transducer/data logger (Troll) installed at the portal at location P-1 over the two-year period from November 1997 through October 1999, the annual discharge volume (from November 1 through October 31) was approximately 8,510,000 and 10,480,000 cubic feet per year. Based on these calculations, it is anticipated that there would be between approximately 2.5 to 3.1 years of total storage volume available between these two levels.

6.4.7.3 Portal Drainage Discharge Rates

If hydrostatic bulkheads are used to control portal drainage discharge rates, the bulkheads would be designed to allow the water level within the mine to be raised up to approximately the 1100 level (400 feet above the 1500 level) to provide additional water storage as required during remedy implementation. However, for purposes of the FS, it is assumed that the total water inflow to the mine would be discharged on an annual basis. The mine water would be metered out over the year in proportion to seasonal discharge rates in Railroad Creek.

The calculation of estimated portal drainage discharge rates was performed based on portal discharge data obtained using the pressure transducer installed at P-1 over the period from November 1, 1997 to October 31, 1999. Data collected during subsequent years were either incomplete due to periods when the transducer was off line, or indicated lower annual discharge rates. Based on these calculations, discharge rates of approximately 70 to 90 gpm (0.15 to 0.2 cfs) during low flow periods between September and March and approximately 135 to 270 gpm (0.3 and 0.6 cfs) over the five-month period between April and August would allow complete drainage of the mine each year (Table 6-2). Actual flowrates would be determined during the RD/RA and adjusted during operations.

Based on the 1997 to 1999 flow data, and the volume and location of open stopes estimated between the 1500 and 1100 levels, these drainage rates would result in maximum water heights of less than approximately 10 feet behind the bulkhead.

6.4.7.4 In-mine Water Controls

As described above, the installation of bulkheads in the 1500-level portals under Alternative 2b would provide storage capacity to equalize and control portal drainage discharge rates. Actual discharge rates and the potential height of the pooled water underground would be evaluated during the RD/RA to provide optimal mixing and detention time for the combined high-acidity water draining from the upper mine workings and near-neutral/elevated alkalinity water upwelling from the lower workings

Other in-mine water controls that would be evaluated during the RD/RA include the circulation of drainage from the upper mine workings through the lower workings prior to discharge from the 1500-level main portal. This would potentially be accomplished by drawing-off the mine water from the bottom of the number 2 shaft through a discharge pipe, combined with the installation of hydrostatic bulkheads in the 1500-level main and ventilator portals. The hydrostatic bulkhead installed in the 1500-level main portal would be designed with the capability to discharge water solely from the number 2 shaft discharge pipe, or directly from the 1500-level tunnel. This option would be expected to provide similar in-mine water diversion to the placement of a siphon or an active pumping system in the lower mine workings.

Figure 6-11 provides a conceptual diagrammatic cross-section illustrating potential in-mine water controls that would be further evaluated during the RD/RA.

6.4.7.5 Lined Equalization Basin

During the RD/RA, the construction of a lined equalization basin on top of tailings pile 1 would be evaluated in the event that installation of hydrostatic bulkheads within the underground workings is not feasible. The basin would be sized to provide surge storage and reduce seasonal loading spikes to Railroad Creek to the extent possible. Using the portal drainage discharge rates described above in Section 6.4.7.3, an equalization basin, approximately 4 acres in size with a depth of 10 feet (approximately 13 million gallons) would likely be sufficient to provide equivalent flow control as described above for the hydrostatic bulkheads (Table 6-3). However, additional volume may be needed for water storage during an extended period of treatment system maintenance or repair, and a larger basin may be required. Final pond sizing would be determined based on anticipated future peak flows during the RD/RA, as applicable.

6.4.7.6 1100-level Portal

Under Alternative 2b, a low-head hydrostatic bulkhead (less than approximately 10 feet of water) would be installed in the 1100-level portal to mitigate the seasonal low-flow discharge observed from this location and re-direct the water back into the underground mine.

6.4.7.7 Seep 23

Under Alternative 2b, the feasibility of diverting Seep 23 into the underground mine workings above the elevation of the 1500-level ventilator portal would be evaluated during the RD/RA. Depending on the elevation at which SP-23 could be diverted, the entry point into the mine would possibly require a back-flow prevention system if hydrostatic bulkheads are installed on the 1500-level.

6.5 ALTERNATIVE 3: WATER MANAGEMENT AND LOW-ENERGY WEST AREA TREATMENT

Alternative 3 would include the common remediation components described for the East and West Areas under Section 6.3 and actions described under Alternative 2 with the addition of:

- Downgradient collection of the portal drainage and West Area seeps.
- Barrier wall and collection system for shallow groundwater downgradient of the east and west waste rock piles, maintenance yard, and mill building.
- Low-energy physical/chemical treatment of collected West Area water.
- Monitored natural attenuation in the East and West Area.

Specific actions included under this alternative are shown on Table 6-1 and Figures 6-3, 6-8, and 6-12 through 6-14. As described for Alternative 2, there are two subalternatives under Alternative 3 (designated as 3a and 3b) providing varying degrees of 1500-level main portal drainage control. These two subalternatives include no portal drainage flow control (3a) and the placement of hydrostatic bulkheads in the 1500-level (3b). The following subsections provide descriptions of the downgradient collection of West Area waters and specific water treatment components under Alternatives 3a and 3b.

6.5.1 Downgradient Collection of West Area Water

Alternative 3 includes collection and treatment of the following west area waters (Figures 6-12 and 6-14):

- The portal drainage at station P-1;
- Seeps associated with Honeymoon Heights (SP-23 and SP-12);
- Seeps associated with the mill building, maintenance yard, and east and west waste rock piles (SP-6, SP-7, SP-8, SP-15W, SP-15E, and SP-19); and
- Shallow groundwater downgradient of the mill building, maintenance yard, and east and west waste rock piles.

The portal drainage would be placed within a culvert at the 1500-level main portal (P-1) and directed to a treatment building for chemical addition. The culvert would be sized to handle the maximum anticipated spring discharge, which is estimated to be approximately 1200 gpm for purposes of the FS. Portal drainage flows are assumed to decrease to approximately 100 gpm for the remainder of the year.

Seeps SP-23 and SP-12 would be captured using collection basins installed within the native soils. The captured seep flow would then be directed to the West Area treatment system within a culvert or pipe. Surface water runoff from the mill building (referred to as SP-7) would be intercepted at the northern edge of the building and directed to the treatment system in a pipe or lined channel. Seeps SP-6, SP-8, SP-15E, SP-15W, and SP-19, associated with the waste rock piles, mill building and maintenance yard, would be intercepted using collection basins or sumps and directed into a barrier wall/collection trench system completed along the base of the waste rock piles and north side of the maintenance building or directly to the treatment system.

Flow measurements collected during the RI field program in 1997 indicate a total estimated flow of approximately 360 gpm from the collected West Area seeps during the spring flush (assuming an average collection efficiency of approximately 90 percent). The seep flows were observed to peak over a period of approximately one to two months and were not observed to flow during the remainder of the year, except during isolated storm events.

Shallow groundwater downgradient of the mill building, maintenance yard, and east and west waste rock piles would be collected using a barrier wall/groundwater collection system installed downgradient of these source areas. The barrier wall, referred to as the “upper West Area barrier wall” on Figure 6-12, would be completed down to the low-permeability till or bedrock interface to enhance groundwater collection. As described in Section 2, data collected between 1997 and 2003 from seismic refraction surveys, geological borings, and groundwater monitoring wells indicate that the subsurface of the West Area is composed of a thin to moderate layer of permeable material overlying low-permeability till or bedrock. The material overlying the dense till or bedrock becomes thinner in steeper portions of the site and was estimated to be variable and approximately 15 to 20 feet thick along the proposed upper West Area barrier wall alignment. Water collected in these systems would be conveyed to the West Area treatment system by gravity, using existing topography as possible.

Available groundwater and surface water monitoring data indicate a strong seasonal trend in groundwater flows at the Site. Approximately 510 gpm of groundwater is assumed to be captured in the spring through installation of the upper West Area collection system, and an average of approximately 290 gpm during the remainder of the year. Groundwater collection estimates assume interception of approximately 0.23 gpm per linear foot of collection system (spring flush) and 0.13 gpm per linear foot (baseline flow) along approximately 2,450 feet of collection trench with a collection efficiently of approximately 90 percent. Groundwater collection assumptions are described in Section 7.2.1.3. Seasonal groundwater flows will vary from year to year, based on annual precipitation/snowfall and winter temperatures, and the flows captured could potentially exceed the values estimated for purposes of the FS. Additional hydrogeologic data would be required during the RD/RA, as appropriate for sizing of the collection and treatment systems and determination of potential flow equalization measures.

It should be noted that the additional groundwater, not intercepted or collected directly through the upgradient diversion trenches or downgradient collection systems, would be expected to be intercepted or treated indirectly through the use of unlined treatment ponds as described in the following section.

Table 6-4 provides a summary of the estimated flows and metals concentrations for collected West Area seeps, groundwater, and portal drainage in the spring and fall. As possible, the collection systems would be constructed to minimize interference with Holden Village operations.

6.5.2 Alternative 3a – Water Management and West Area Treatment (Open Portal)

Under Alternative 3a, airflow restrictions would be installed within the 1500-level main portal, allowing unrestricted flow of water from the mine. As a result, the West Area water collection and treatment system would need to be sized to handle seasonal fluctuations in portal drainage and seep/groundwater flow.

6.5.2.1 Low-Energy West Area Treatment (Open Portal)

This section provides a description of the energy-efficient conventional alkaline neutralization and precipitation system, termed the “low-energy” treatment system in this FS, for collected West Area waters, including conceptual hydraulic and chemical influent parameters, treatment system unit processes, and expected system performance.

Conceptual Hydraulic and Chemical Influent Parameters

Table 6-4 provides a summary of the conceptual hydraulic and chemical influent parameters assumed for the low-energy West Area treatment system. As summarized on Table 6-4, a nominal peak flow of approximately 2,050 gpm was used to size the treatment system components for Alternative 3a. This includes flow from the portal drainage (1200 gpm), seeps (360 gpm) and groundwater (510 gpm). During the fall, or low-flow period, the average influent flow was estimated to be approximately 380 gpm.

Dissolved metals concentrations observed in the portal drainage vary seasonally. For example, dissolved copper values observed in 1997 varied from 0.08 mg/L in the fall to 5.8 mg/L during the spring flush. The measured concentrations of other dissolved metals follow the same trend. Therefore, metals concentrations in the blended influent stream to the West Area treatment plant was estimated for both the spring and fall periods. For the spring flush period, the blended concentration was calculated based on estimated flows and concentrations in the portal drainage, seeps, and groundwater (Table 6-4). Following the spring flush, West Area seeps are not observed to flow; therefore, the blended concentrations for the portal drainage and groundwater were assumed to be representative of the influent concentrations to the treatment system. Because limited groundwater quality data is available for the area upgradient of the barrier wall and collection trench, metals concentrations in collected groundwater were assumed to be similar to the blended seep concentrations estimated for spring conditions.

Low-Energy Treatment System Unit Processes

The most common technology for treating mine-related drainage is chemical addition, followed by alkaline precipitation and clarification. This technology is widely used and accepted as providing successful treatment of acidic waters containing elevated concentrations of dissolved metals. Alternative 3a includes a low-energy alkaline precipitation and clarification system designed to remove metals constituents in the portal drainage and captured West Area seeps and groundwater. A conceptual process flow diagram, providing the low-energy unit processes identified for the treatment of collected West Area waters is provided on Figure 6-13. As shown on Figure 6-13, the unit processes included in the low-energy system are equivalent to those included in typical mechanical systems that involve significantly higher energy usage. The primary difference between the low-energy system under Alternative 3a and a mechanical alkaline precipitation system is related to the geometry of the facilities and the energy usage.

Conceptual process sizing, including estimated chemical dosage rates are provided in Table 6-5. Figure 6-12 provides a diagrammatic plan view of the West Area water collection and treatment system components included under Alternative 3a. Specific unit processes include the following:

- **Chemical Addition.** An alkalinity adding chemical, such as hydrated lime ($Ca(OH)_2$), caustic (NaOH), or soda ash (Na_2CO_3) would be added to raise the pH of the collected waters to between 9 and 10 to promote the precipitation of dissolved metals including cadmium, copper, iron, and zinc. Conceptual process sizing, including estimated chemical dosage rates are provided in Table 6-5. The average chemical dosage rate was estimated based on hydrated lime dosing rates determined during the June 2000 treatability study described in Section 2.7. The actual treatment chemical and dosage rates would be determined during the RD/RA, in consideration of factors including pH control, solubility, sludge generation, cost, and chemical handling/transportation considerations. Chemical dosing would be adjusted during operation based on influent flow rates and pH. For purposes of the FS, it was assumed the chemical would be stored in a hopper and added in solid form. However, the addition of alkalinity in slurry form would be evaluated during the RD/RA.

- **Cascading Aeration.** Aeration is performed to promote the transfer of oxygen and the oxidation of metals into insoluble metal oxides. Data collected during the RI indicate that the portal drainage and West Area seeps are relatively oxygenated. However, under this alternative, additional aeration would be performed using a series of drop structures to provide mixing as well as oxygen transfer.

- **Flocculent Addition (if needed).** The addition of a polymer would be evaluated during the RD/RA for its ability to enhance flocculation and promote settling of the oxidized metals constituents.

- **Clarification/Sedimentation.** Two unlined settling ponds would be constructed in the vicinity of the lagoon area to take advantage of existing topography and allow flow through the system by gravity. Conceptual unit sizing of the ponds is provided on Table 6-5 and Figure 6-12, and is based on the estimated annual production of treatment residue. For purposes of the FS, it was assumed that residue removal would be performed annually by letting the pond dry (diverting the flow through the second pond) and physically removing the dry residue. The total residue production was estimated based on the total estimated volume of influent water, total metals and sulfate concentrations, and hydrated lime dosing rates. Treatment residue would be disposed on site in a containment area designed for compliance with action specific ARARs.

- **Filtration.** A gravity media filter would be used to promote further removal of metal precipitates and other suspended solids from the water column. The cells would be unlined, and would be cleaned on an annual basis by allowing each filter to drain, and removing and replacing the top layer of media, as needed. Alternatively, filtration would be provided in a wetlands polishing system constructed to provide similar physical processes.

As indicated above, the system would rely on gravity flow, to reduce power requirements as possible. The sizing of the process components would be robust, thus providing for the ability to handle variable hydraulic and chemical loading rates. During the RD/RA and system operation, operating parameters, including the types and quantities of chemicals added and sludge removal rates, may be adjusted to improve effluent quality, as needed.

Use of unlined treatment ponds and filter cells would also be expected to intercept additional West Area groundwater that is not diverted or collected though the upgradient or downgradient diversion/collection systems. During the spring, when groundwater elevations are high, untreated groundwater would likely infiltrate into the unlined treatment ponds. During periods when the groundwater table is low, treated water (with high alkalinity) would be expected to seep into the subsurface from the treatment ponds, providing treatment of uncollected groundwater in the area.

Low-Energy Treatment System Performance

A review of the following information was performed to assess effluent water quality expected for the low-energy treatment system described above:

- The results of bench-scale testing conducted on samples of the 1500-level main portal discharge (URS 2001). Results of the bench-scale testing are summarized in Table 2-10 in Section 2.7.

- Available performance data from a number of pilot- and full-scale acid drainage treatment systems. Average influent and effluent concentrations reported for the constituents of interest from twelve acid drainage treatment systems are provided on Table 6-6. More complete summaries of the primary treatment components and available influent and effluent data for a select number of these systems, determined to be more applicable to the Holden Mine site, are provided in Appendix F.

- An assessment of acid drainage treatment performance conducted by Hart Crowser (Hart Crowser 2003).

- An independent assessment of acid drainage treatment performance by Elbow Creek Engineering (Elbow Creek 2004). The results of this assessment are provided as attachment F-1 to Appendix F.

Available performance data reported for two low-energy precipitation systems (Appendix F) indicate that equivalent effluent quality for Site PCOCs would be achievable by a low-energy system. The two systems include a low-energy system using automated hydrated lime addition/mixing with flocculant addition and removal of suspended solids in two 3-million gallon settling ponds (baffled) and a system utilizing an Aquafix chemical addition system followed by aeration and precipitation. The low-energy treatment system included under Alternative 3a is more closely represented by the first of these two treatment systems. The bench-scale data provided in Section 2.7 and Appendix F suggest the following effluent concentrations would be generally achievable:

- Aluminum – 130 µg/L
- Cadmium – 5 µg/L
- Copper – 24 µg/L
- Iron – 200 µg/L
- Zinc – 240 µg/L

The effluent concentration assumed for aluminum is based on the results of Tests 1 and 2 of the June 2000 bench-scale treatability study (Section 2.7). The effluent concentrations assumed for copper and zinc were proposed by the Agencies for a mechanical water treatment system (Hart Crowser 2003), and the assumed cadmium and iron concentrations are based on engineering judgment and the information provided in Appendix F. A testing program would be required during the RD/RA to determine achievable effluent characteristics and potential variability due to operational considerations for a full-scale water treatment plant at the Site.

Under Alternative 3a, system reliability would be influenced by variable influent volumes and chemistry. The low-energy treatment system would be robust and sized to handle variable hydraulic loading rates. An important factor in providing consistent treatment efficiencies would be the ability to control chemical addition rates in response to the rapid changes in water quality and flow expected under this alternative.

6.5.3 Alternative 3b – Water Management and West Area Treatment (Hydrostatic Bulkheads)

Under Alternative 3b, two or more hydrostatic bulkheads would be installed in strategic locations within the 1500-level main portal and ventilator tunnel to control discharge rates from the underground mine. Portal drainage control would be used to provide surge storage and reduce seasonal discharge and loading spikes for enhanced treatment efficiencies and system reliability. The installation of hydrostatic bulkheads would also provide an opportunity to provide in-mine water controls as described in Section 6.4.7.4. Alternatively, flow equalization would be provided by equalization basins outside the mine.

6.5.3.1 West Area Flow Retention and Equalization (Hydrostatic Bulkheads)

As described under Alternative 2b, the hydrostatic bulkheads would be designed to allow the water level within the mine to be raised up to approximately the 1100 level to provide additional water storage and flow equalization as required during remedy implementation. However, under this alternative, it is assumed that the total water inflow to the mine would be discharged on an annual basis. The mine water would be metered out over the year in proportion to seasonal discharge rates in Railroad Creek.

Based on the calculations described in Section 6.4.7.3, discharge rates of approximately 70 to 90 gpm (0.15 to 0.2 cfs) during low flow periods between September and March and 135 to 270 gpm (0.3 to 0.6 cfs) over the five-month period between April and August would allow complete drainage of the mine each year (Table 6-2). Actual flowrates would be determined during the RD/RA and could be adjusted during operations.

During the RD/RA, the feasibility of constructing a lined detention pond on top of tailings pile 1 would be evaluated in the event that installation of hydrostatic bulkheads is not feasible. The pond would be sized to handle approximately two weeks of portal drainage flow in the event the treatment system must be shut down for unexpected maintenance or repair. Data obtained from the pressure transducer installed at P-1 over the period from October 1997 through October 2003 were used to estimate the highest total volume of drainage measured from the portal over a two-week period (Table 6-7). Based on this historical data, a detention pond sized to hold approximately 13 million gallons would likely be sufficient to handle approximately two-weeks of spring flow. This would require a foot print of approximately 4 acres for a pond constructed with an average depth of 10 feet.

6.5.3.2 West Area Low-Energy Treatment (Hydrostatic Bulkheads)

This section provides a description of the low-energy treatment system for collected West Area waters, including conceptual hydraulic and chemical influent parameters, treatment system unit processes, and expected system performance.

Conceptual Hydraulic and Chemical Influent Parameters

Table 6-4 provides a summary of the conceptual hydraulic and chemical influent parameters assumed for the low-energy West Area treatment system. As summarized on Table 6-4, a nominal peak flow of approximately 1,150 gpm (occurring during one month the spring flush) was used to size the treatment system components. An average flow of approximately 380 gpm was assumed for the remainder of the year. Influent flowrates for Alternative 3b were estimated based on the portal drainage discharge calculations summarized in Table 6-2 and the estimated seep and groundwater flowrates described previously under Alternative 3a and summarized in Table 6-4.

Portal drainage water quality would likely be altered through the installation of hydrostatic bulkheads in the underground mine. In the short-term, metals concentrations in the portal drainage would potentially increase through increased contact of the pooled water with metal sulfates present on the surfaces of exposed mine workings. The supporting geochemical evaluations provided in Appendix E (SRK 2004a) provides a summary of the potential short- and long-term effects of in-mine water storage, based on site data collected during the RI and underground mine investigations, and data from other sites where mine flooding has been performed. The data presented in Appendix E indicate the following metals concentrations are possible in the portal drainage in the short-term:

- Aluminum – 17 mg/L
- Cadmium – 0.1 mg/L
- Copper – 12 mg/L
- Iron – 2 mg/L
- Zinc – 21 mg/L

The actual effects of in-mine water storage will depend on the height the water level is raised within the mine, as well as potential beneficial effects of other remedial actions, such as air-tight bulkheads, and in-mine water diversion.

Low-Energy Treatment System Unit Processes

The same low-energy unit processes described for the West Area under Alternative 3a (Section 6.5.2.1) for low energy alkaline precipitation and clarification would be implemented under Alternative 3b. A conceptual process flow diagram, providing the specific low-energy unit processes identified for the treatment of collected West Area waters, is provided on Figure 6-13. Conceptual process sizing, including estimated chemical dosage rates are provided in Table 6-5.

Process sizing for Alternative 3b was adjusted based on the lower estimated hydraulic loading and higher chemical loading as described above. Because the settling ponds would be sized to accommodate an annual production of treatment residue, the ponds would be larger under Alternative 3b than estimated under Alternative 3a. However, sizing of the other treatment units, including drop structures and media filters would be reduced based on the reduction in the expected peak flows.

A diagrammatic plan view of West Area water collection and treatment system components included under Alternative 3b is provided on Figure 6-14.

Low-Energy Treatment System Performance

The low-energy treatment system described for the West Area under Alternative 3b is assumed to produce the same effluent concentrations as described for Alternative 3a:

- Aluminum – 130 µg/L
- Cadmium – 5 µg/L
- Copper – 24 µg/L
- Iron – 200 µg/L
- Zinc – 240 µg/L

The increased chemical loading predicted for this alternative is not anticipated to adversely impact system performance. The potential increase in the concentrations of select metals, such as iron, would be expected to improve system performance by promoting co-precipitation with other metals such as cadmium, copper, and zinc. As described previously, a summary of the treatment system performance data compiled for various alkaline precipitation systems is provided in Table 6-6 and Appendix F.

Under this alternative, system reliability would be enhanced through the flow equalization provided by the installation of hydrostatic bulkheads in the 1500 level. The bulkheads would allow the in-mine storage of water in the event the treatment system is pulled off-line for unexpected equipment maintenance and repair, and would reduce the variations in water chemistry and discharge rates that are currently observed in the portal drainage. Alternatively, flow equalization would be provided by equalization basins outside the mine. This would simplify the control of chemical dosing rates and provide more reliable system operation than for a system without flow equalization capability.

6.5.4 Monitored Natural Attenuation in the East and West Areas

Under alternative 3, MNA would be implemented in the East Area in conjunction with the remedial measures included under Alternative 3 to reduce the release of PCOCs from the tailings piles over time. Additionally, MNA would be implemented in the portions of the West Area located downgradient of groundwater collection or treatment systems.

Geochemical analyses conducted for the Site document that natural attenuation is occurring, and the release of PCOCs from waste rock, the underground mine, and tailings piles would continue to decline over time under this alternative. These geochemical analyses and predictions of the attenuation of chemical loading from Site source areas are provided in Appendix E (SRK 2004). Additionally, following the removal of lagoon area soils (the only identified potential source area located downgradient of collection systems) from the West Area, PCOCs potentially remaining in soils and groundwater would be expected to flush out over time.

Based on the results of these analyses, MNA, in conjunction with the East and West Area actions provided under Alternative 3 are expected to significantly reduce the release of PCOCs to groundwater and surface water over time. Descriptions of the natural attenuation processes and an evaluation of the achievement of MTCA expectations for natural attenuation are provided in Section 7. Groundwater and surface water monitoring for natural attenuation are generally described in Section 6.2.2 and would be specified in the OMMP.

6.6 ALTERNATIVE 4: WATER MANAGEMENT AND EAST AREA COLLECTION AND TREATMENT

Alternative 4 would include the common remediation components described for the East and West Areas under Section 6.3 and actions described under Alternative 2b (Water Management with Hydrostatic Bulkheads) with the addition of:

- Downgradient collection of East Area seeps and groundwater;
- Low-energy chemical/physical treatment of collected East Area water;
- Rehabilitation of select reaches of Railroad Creek to remove ferricrete and enhance aquatic and terrestrial habitat along the stream corridor; and
- MNA in the East (Alternative 4a only) and West Areas.

Remediation components included under Alternative 4 would be designed to divert upgradient surface water and shallow groundwater around identified source areas and collect downgradient groundwater and seepage from the tailings piles in the East Area. The collection and treatment of East Area waters would be performed to reduce the loading of iron and other PCOCs from the tailings piles and improve aquatic habitat in Railroad Creek. Alternative 4 does not include the collection and treatment of West Area waters. Specific actions included under this alternative are summarized on Table 6-1, and depicted on Figures 6-7, and 6-15 through 6-29. There are three subalternatives under Alternative 4 (designated as 4a, 4b, and 4c) that vary the method and extent of East Area water collection and treatment. These three subalternatives include:

- Alternative 4a – Partial East Area collection and treatment;
- Alternative 4b **–** Extended East Area collection and treatment; and
- Alternative 4c **–** Extended relocation of Railroad Creek and East Area collection and treatment.

The following subsections provide descriptions of the specific East Area water collection and treatment components included under Alternatives 4a through 4c.

6.6.1 Subalternative 4a – Partial East Area Collection and Treatment

Alternative 4a would include the partial relocation of Railroad Creek between tailings piles 1 and 2 to provide additional area for construction of downgradient collection and treatment systems. Under Alternative 4a, two collection trenches, each approximately 1100 feet long, would be constructed at the northeast corners of tailings piles 1 and 3 (Figure 6-15). The collection systems would be constructed to intercept seepage and groundwater naturally flowing toward these areas for physical/chemical treatment prior to discharge to Railroad Creek. As described in Section 6.5 for the West Area, collected East Area water would be treated through chemical addition and precipitation for the removal of iron and other PCOCs. The following subsections describe partial Railroad Creek relocation, Copper Creek culvert, and the collection and treatment system components included under Alternative 4a.

6.6.1.1 Partial Relocation of Railroad Creek

Alternative 4a includes relocating a portion of Railroad Creek to the north to provide additional area for construction of a collection and treatment system. Approximately 1,000 to 1,300 lineal feet of Railroad Creek would be relocated from its current location as shown on Figure 6-15. The new alignment would also remove the creek from direct contact with the portion of tailings pile 2 having the steepest existing slope configurations, highest erosion potential and lowest factors of safety. The relocated alignment would be designed to establish a stable channel, improve aquatic habitat, and provide hydraulic capacity for transport of high flows and incoming sediment loads. The banks of the new channel would be revegetated and/or protected with large boulders, as required to create stable channel conditions under high flow conditions. A conceptual channel cross section for the relocated stream segment is provided on Figure 6-16. Large diameter logs and rock recovered from the excavation would be utilized as part of the enhancement of aquatic habitat within the new reach.

6.6.1.2 Copper Creek Culvert

As described in Section 6.3, the Copper Creek channel would be modified between tailings piles 1 and 2 to prevent the deposition of debris and sediment through this reach. Under Alternative 4, the segment of Copper Creek adjacent to tailings piles 1 and 2 would also be placed within a large-diameter culvert to prevent interference with the collection and treatment systems (Figure 6-15). The culvert would be designed to meet appropriate design and safety standards and sized to handle high flow conditions. Grates may also be placed at the culvert intake to minimize potential plugging. Periodic maintenance would be required following the spring flush to remove debris, as necessary, and maintain unrestricted flow through the culvert.

6.6.1.3 Partial East Area Collection

Under Alternative 4a, two groundwater collection systems, consisting of open collection trenches and barrier walls approximately 1,100 feet long, would be constructed at the northeast corners of tailings piles 1 and 3 (Figure 6-15). The collection systems would be constructed to intercept seepage and groundwater naturally flowing toward these areas for physical/chemical treatment prior to discharge to Railroad Creek. The partial collection system would include the following components:

- Access road and work platform along the base of tailings piles 1, 2, and 3;
- Open groundwater collection trenches; and
- Barrier walls.

Under this alternative, a road would be constructed at the base of tailings piles 1 and 3 to provide access for vehicles and construction equipment to the collection and treatment areas. Construction of the access road would be performed in conjunction with the tailings pile slope regrading activities described previously under Alternative 2.

Open collection trenches, each approximately 1,100 feet in length, would be installed along the base of the northeastern corners of tailings piles 1 and 3, as shown on Figure 6-15. The collection trenches would be constructed using conventional excavation equipment in locations with sufficient area to allow installation without significant tailings regrading. Conceptual cross-sectional views of trench construction are provided on Figures 6-17 and 6-18. As shown on the cross sections, limited additional regrading of the northeastern corners of tailings piles 1 and 3 may be needed for collection system construction. Tailings pulled back from the slopes would likely be relocated to the western portion of tailings pile 3, along the eastern slope of tailings pile 2. Intercepted seeps and groundwater would flow by gravity in open rock-filled channels to small treatment buildings located at the northeast corners of tailings piles 1 and 3.

To enhance groundwater collection efficiencies and minimize losses from Railroad Creek to the collection trenches, barrier walls would be installed to a depth of several feet into the dense till (or to the top of bedrock if low-permeability till is not present) between the creek and collection systems. For purposes of the FS, depths between approximately 60 and 80 feet were assumed for barrier wall construction under this alternative.

Data collected during the RI indicate that the native materials beneath the tailings piles are heterogeneous in nature, and likely contain large cobbles, timbers and granitic boulders. Under Alternative 4a, the barrier walls would likely be constructed with backhoes and rock chisels using soil-bentonite backfill. Excavated materials would be processed to remove cobbles and boulders prior to mixing with bentonite to produce the barrier wall backfill. However, due to the structural considerations related to trench construction at the base of the large tailings piles, the barrier walls in this area may need to be constructed in panels using a cement/bentonite mix to reduce the potential for slurry losses and provide greater structural stability. Clamshell excavation techniques would then be required. Additional data related to subsurface conditions in this area would be required during the RD/RA to support the design and construction of the East Area groundwater collection systems.

The estimated groundwater flows captured by the partial collection and treatment systems are summarized on Tables 6-8 through 6-11. The collection system installed at the northeast corner of tailings pile 1 is estimated to capture approximately 230 gpm during the spring flush and an average of 140 gpm for the remainder of the year. The collection system installed at the northeast corner of tailings pile 3 is estimated to capture approximately 1,100 gpm during the spring flush and an average of 180 gpm for the remainder of the year. Seep SP-21 accounts for a majority (approximately 830 gpm) of the estimated flow captured in the spring by the system installed at the toe of tailings pile 3. It should be noted that the volume and metals concentrations associated with seep SP-23 may be reduced following remedy implementation through the improvement of upgradient water diversions.

Groundwater capture was estimated based on the flow tube analysis summarized on Tables 6-8 through 6-11 and in Section 2.6, and the down-valley deep groundwater component assumed to be intercepted by the barrier wall installed at the northeast corner of tailings pile 3. Significant losses of Railroad Creek water to the collection system are not anticipated under this alternative due to barrier wall installation on the north side of the collection trenches. Figures 6-19 through 6-22 provide a plan view of the groundwater flow nets developed for wells completed in tailings and native materials below the tailings piles, using groundwater monitoring data collected in the spring and fall of 1997. As described for the site-wide baseline loading analysis in Section 2.6, the flow nets represent the shallow portion of the groundwater aquifer, and therefore a majority of the metals loading that is currently intercepted by Railroad Creek in the East Area. A discussion of groundwater collection assumptions is provided in Section 7.2.1.3.

For purposes of the FS, the groundwater collection systems were assumed to have collection efficiencies ranging from approximately 80 to 90 percent, as summarized on Tables 6-8 through 6-11. Intercepted seeps and groundwater would flow by gravity in open rock-filled channels to treatment facilities located at the northeast corners of tailings piles 1 and 3 (Figure 6-15).

6.6.1.4 East Area Treatment (Partial Collection)

This section provides a description of low-energy treatment system for collected East Area waters, including conceptual hydraulic and chemical influent parameters, treatment system unit processes, and expected system performance.

Conceptual Hydraulic and Chemical Influent Parameters

Tables 6-8 through 6-11 provide summaries of the conceptual hydraulic and chemical influent parameters assumed for the East Area low-energy treatment systems (for spring and fall conditions) and Table 6-12 provides conceptual treatment process sizing information. Blended metals concentrations were calculated based on the estimated flow and metals concentrations for each flow tube intercepted, and for the deep groundwater flow component. The average metals concentrations measured in monitoring wells DS-3D and DS-4D, located downgradient of Railroad Creek monitoring station RC-2, were assumed to be representative of concentrations within the down-valley deep groundwater component.

As summarized on Table 6-12, a nominal peak flow of approximately 230 gpm was used to size the treatment system components located east of tailings pile 1 and approximately 1,100 gpm was estimated for the system located east of tailings pile 3. Due to the limited space available at the toe of tailings piles 1, 2, and 3, water storage and flow equalization would likely not be possible. As a result, the East Area treatment systems would need to be designed to handle seasonal variations in hydraulic and chemical loading. While the estimated flows and water quality are anticipated to vary seasonally in the East Area, the fluctuations are not expected to be as severe as observed in the portal drainage in the West Area.

East Area Low-Energy Treatment System Unit Processes (Partial Collection)

As described previously for the West Area, the most common technology for treating mine-related drainage is chemical addition, followed by alkaline precipitation and clarification. Based on the technology screening summarized in Section 5, this technology was also selected for treatment in the East Area. The primary difference between the low-energy treatment system described for the West Area under Alternative 3 and the system described for the East Area are the high concentrations of select metals such as iron in the collected seeps and groundwater and the inability to provide significant flow equalization due to the relatively flat grade and space constraints. The elevated concentrations of iron would be expected to increase treatment efficiencies for the removal of other metals such as cadmium, copper, and zinc through co-precipitation processes and would therefore likely reduce the potential need for flocculent addition.

A conceptual process flow diagram, providing the low-energy unit processes identified for the treatment of collected East Area waters, is provided on Figure 6-23. The East Area system would be similar to the low-energy Aquafix treatment system described in Appendix F. However, the feasibility of adding alkalinity in slurry form, and providing enhanced control of chemical addition rates and mixing would be evaluated during the RD/RA. Conceptual process sizing, including estimated chemical dosage rates are provided in Table 6-12. Figure 6-15 provides a diagrammatic plan view of the partial collection and treatment system components under Alternative 4a. Specific unit processes include the following:

- **Chemical Addition.** An alkalinity adding chemical, such as hydrated lime ($Ca(OH)_2$), caustic (NaOH), or soda ash (Na_2CO_3) would be added to raise the pH of the collected waters to near neutral (pH of approximately 7) to promote the precipitation of metals including cadmium, copper, iron, and zinc. Conceptual process sizing, including estimated chemical dosage rates are provided in Table 6-12. The average chemical dosage rate was estimated based on hydrated lime dosing rates determined during the bench-scale testing conducted in June 2000 and described in Section 2.7. Actual treatment chemical and dosage rates would be determined during the RD/RA, in consideration of factors including pH control, solubility, sludge generation, cost, and chemical handling/transportation considerations. Chemical dosing would be adjusted during operation based on influent flow rates and pH. For purposes of the FS, it was assumed the chemical would be stored in a hopper and added in solid form. However, the addition of alkalinity in slurry form would be evaluated during the RD/RA.

- **Cascading Aeration.** Aeration is performed to promote the transfer of oxygen and the oxidation of metals into insoluble metal oxides. The precipitation of iron occurs at a pH above approximately 4.0 under oxidizing conditions. Under this alternative, aeration would be accomplished using a series of drop structures to provide mixing as well as oxygen transfer.

- **Clarification/Sedimentation.** Two unlined settling ponds would be constructed at the base of tailings piles 1 and 3 as shown on Figure 6-15. Conceptual unit sizing of the ponds is provided on Table 6-12 and Figure 6-23, and is based on the estimated annual production of treatment residue. For purposes of the FS, it was assumed that residue removal would be performed annually by letting the pond dry (diverting the flow through the second pond) and physically removing the dry residue. The total residue production was estimated based on the total estimated volume of influent water, total metals and sulfate concentrations, and hydrated lime dosing rates. Treatment residue would be disposed on site in a containment area designed for compliance with action specific ARARs.

- **Filtration.** A gravity media filter would be used to promote further removal of metal precipitates and other suspended solids from the water column. The cells would be unlined, and would be cleaned on an annual basis by allowing each filter to drain, and removing and replacing the top layer of media, as needed. Alternatively, filtration would be provided in a wetlands polishing system constructed to provide similar physical processes.

The system would rely on gravity flow, to reduce power requirements as possible. As described for the West Area, the sizing of the process components would be robust, thus providing for the ability to handle variable hydraulic and chemical loading rates. The unlined treatment ponds and filter cells would be expected to intercept additional East Area groundwater that is not diverted or collected directly though the upgradient or downgradient diversion/collection systems. During the spring, when groundwater elevations are high, untreated groundwater would likely infiltrate into the unlined treatment ponds. During periods when the groundwater table is low, treated water (with high alkalinity) would be expected to seep into the subsurface from the treatment ponds, providing treatment of uncollected groundwater in the area.

Low-Energy Treatment System Performance (Partial Collection)

As described for the low-energy alkaline precipitation system included under Alternative 3, a review of the results of bench-scale testing conducted on samples of the portal drainage discharge (URS, 2001) and available data from a number of pilot and full-scale acid drainage treatment systems was conducted to assess effluent water quality expected for the East Area low-energy treatment systems described above. A summary of the treatment system performance data compiled for various alkaline precipitation systems is provided in Table 6-6 and Appendix F. As described previously, the East Area low-energy system would be similar to the low-energy Aquafix system described in Appendix F. However, the feasibility of providing alkalinity in slurry form, and the enhanced control of chemical addition rates and mixing would be evaluated during the RD/RA.

Available performance data reported for two low-energy precipitation systems (Appendix F) and the results of the June 2000 bench-scale treatability study (Section 2.7) suggest that the following effluent concentrations would be generally achievable:

- Aluminum – 130 μg/L
- Cadmium – 5 μg/L
- Copper – 35 μg/L
- Iron – 200 μg/L
- Zinc – 350 μg/L

The effluent concentrations provided above for copper and zinc are slightly higher than assumed for the West Area low-energy system due to the anticipated difficulties associated with providing flow equalization for East Area groundwater, and the resulting seasonal variations in influent volumes and PCOC concentrations. The effluent concentration assumed for aluminum is based on the results of Tests 1 and 2 of the June 2000 bench-scale treatability study (Section 2.7). The assumed effluent concentrations for copper and zinc were proposed by the Agencies (Hart Crowser 2003), and the assumed cadmium and iron concentrations are based on engineering judgment and the information provided in Appendix F. A testing program would be required during the RD/RA to determine actual achievable effluent characteristics and potential variability due to operational considerations for a full-scale water treatment plant at the Site.

During the RD/RA and system operation, operating parameters, including the types and quantities of chemicals added and sludge removal rates, may be adjusted to improve effluent quality, as needed.

Under this alternative, system reliability would be influenced by the feasibility of constructing and maintaining groundwater collection and treatment systems. The low-energy treatment system would be robust and sized to handle variable hydraulic loading rates. An important factor in providing consistent treatment efficiencies would be the ability to control chemical addition rates in response to the seasonal changes in water quality expected under this alternative. Additionally, due to the limited space available at the toe of the tailings piles for flow storage and equalization, the storage of collected flows during periods of unanticipated maintenance or repair would not be possible.

6.6.2 Alternative 4b – Extended East Area Collection and Treatment

Alternative 4b includes the same components as described for Alternative 4a with the extended collection and treatment of East Area seeps and groundwater. Actions included under this alternative are shown on Figures 6-7 and 6-24. As described for Alternative 4a, Alternative 4b would also include the partial relocation of Railroad Creek between tailings piles 1 and 2 and the placement of Copper Creek in a culvert to provide additional area for construction of the extended downgradient collection and treatment systems.

Under this alternative, a groundwater collection trench and barrier wall would be installed along the northern toe of the three tailings piles to intercept seepage and groundwater for physical/chemical treatment prior to discharge to Railroad Creek (Figure 6-24). Collected water would be treated through chemical addition and aeration to promote the precipitation and removal of iron, and co-precipitation of other PCOCs. The following subsections describe the specific collection and treatment system components included under Alternative 4b.

6.6.2.1 Extended East Area Collection

Under Alternative 4b, a barrier wall and collection trench would be installed along the entire length of tailings piles 1, 2, and 3 (Figure 6-24). The collection systems would be constructed to intercept seepage and groundwater for physical/chemical treatment prior to discharge to Railroad Creek. The extended collection system would include the following components:

- Partial relocation of Railroad Creek;
- Placement of Copper Creek in a culvert;
- Regrading tailings piles 1, 2, and 3 to provide sufficient working area;
- Barrier wall; and
- Collection trenches.

The partial relocation of Railroad Creek and placement of Copper Creek in a culvert would be completed as described under Alternative 4a (Sections 6.6.1.1 and 6.6.1.2). Additionally, to accommodate the parallel trench construction, a minimum working area of approximately 30 to 40 feet would be required at the base of the tailings piles. Therefore, under this alternative, the north side-slopes of the three tailings piles would be regraded to provide approximately 30 to 40 feet at the base with a final side slope of 2H to 1V. Conceptual cross-sections of collection system construction and regrading requirements are provided on Figures 6-25 though 6-27.

Based on cross-sections developed for tailings pile side slopes using topographic information provided by the Forest Service during the RI, approximately 750,000 to 1,000,000 cubic yards of tailings would require handling under this alternative. Tailings pulled back from the side slopes would be placed on the western portion of tailings pile 3 as described under Alternative 4a. Surface water runoff and erosion control measures would also be conducted to minimize the potential transport of PCOCs and tailings during construction and following completion of regrading efforts. Final slope configurations would allow the revegetation of slopes adjacent to Railroad Creek.

To enhance groundwater collection, and reduce losses of Railroad Creek water into the collection and treatment systems, a barrier wall would be installed along the base of the piles to a depth of several feet into the dense till. For purposes of the FS, depths between approximately 60 and 80 feet were assumed for barrier wall construction. The wall would be installed as described for Alternative 4a. Due to the extent and depth of barrier wall construction, a berm would be constructed at the outside edge of the work area and a minimum buffer of approximately 20 feet would be maintained between the trench and Railroad Creek to prevent slurry losses to the creek and reduce hydraulic gradients from the creek toward the excavation.

The collection trench would be constructed on the south side of the barrier wall, with a minimum 12-inch diameter collection pipe installed with clean-outs for system maintenance. Conceptual cross-sectional views of the barrier wall and intercept trench construction at the base of tailings piles 1, 2, and 3 are provided on Figures 6-25 through 6-27. The total length of the collection system would be about 5800 lineal feet. The collection trenches would direct the intercepted seeps and groundwater by gravity flow to the treatment ponds.

The barrier wall and collection trench would be expected to intercept a majority of the groundwater baseflow and seeps with an initial collection efficiency ranging from approximately 80 to 90 percent, as summarized in Tables 6-8 through 6-11. As described in Section 7, the collection efficiency for this system would likely decline over time due to system fouling. The estimated groundwater flows captured by the extended collection system are summarized on Tables 6-8 through 6-11. The collection system installed along the base of tailings pile 1 is estimated to capture approximately 330 gpm during the spring flush and an average of approximately 170 gpm for the remainder of the year. The collection system installed along the base of tailings pile 3 is estimated to capture approximately 1,300 gpm during the spring flush and an average of 120 gpm for the remainder of the year. As described for Alternative 4a, Seep SP-21 accounts for a majority (approximately 830 gpm) of the estimated flow captured in the spring by the system installed at the toe of tailings pile 3.

The seeps and groundwater volumes assumed to be interecepted under Alternative 4b are based on the flow tube analysis described in Section 2.6 and summarized on Tables 6-8 through 6-11. The deep down-valley groundwater component was assumed to be effectively diverted around the collection system by the barrier wall installed on the west side of tailings pile 1. Similarly, it was assumed that the extended barrier wall would effectively minimize losses from Railroad Creek into the collection system. Therefore, it was assumed that only the shallow groundwater component described by the flow tube analysis would be intercepted by the system. Additional discussion of groundwater collection assumptions is provided in Section 7.2.1.3.

Intercepted seeps and groundwater would flow by gravity to treatment facilities located at the northeast corners of tailings piles 1 and 3 (Figure 6-24).

6.6.2.2 East Area Treatment (Extended Collection)

This section provides a description of the low-energy treatment systems for collected East Area waters, including conceptual hydraulic and chemical influent parameters, treatment system unit processes, and expected system performance.

Conceptual Hydraulic and Chemical Influent Parameters

Tables 6-8 through 6-11 provides a summary of the conceptual hydraulic and chemical influent parameters assumed for the low-energy East Area treatment systems with extended collection and treatment. Table 6-12 provides a summary of the conceptual process sizing, including chemical dosing. As summarized on Table 6-12, nominal peak flows of approximately 330 gpm and 1,300 gpm were used to size the treatment system components located east of tailings piles 1 and 3 respectively. Blended metals concentrations, summarized on Tables 6-8 through 6-11 were estimated based on the anticipated flow and total metals loading that would be intercepted by the East Area collection and treatment systems.

As described for Alternative 4a, water storage and flow equalization would likely not be possible under this alternative. As a result, the East Area treatment systems would need to be designed to handle seasonal variations in hydraulic and chemical loading. While the estimated flows and water quality are anticipated to vary seasonally in the East Area, the fluctuations are not expected to be as severe as observed in the portal drainage in the West Area.

Low-Energy Treatment System Unit Processes (Extended Collection)

The same unit processes described under Alternative 4a for low-energy alkaline precipitation and clarification would be implemented under Alternative 4b. A conceptual process flow diagram, providing the specific low-energy unit processes identified for the treatment of collected East Area waters, is provided on Figure 6-23. Conceptual process sizing, including estimated chemical dosage rates are provided in Table 6-12.

Process sizing for Alternative 4b was adjusted based on the higher estimated hydraulic and chemical loading as described above. Because the settling ponds would be sized to accommodate an annual production of treatment residue, the ponds would be larger under Alternative 4b than estimated under Alternative 4a. A diagrammatic plan view of the West Area water collection and treatment system components included under Alternative 4b is provided on Figure 6-24.

Low-Energy Treatment System Performance (Extended Collection)

The low-energy treatment system described under Alternative 4b is assumed to produce the same effluent concentrations as described for Alternative 4a:

- Aluminum – 130 µg/L
- Cadmium – 5 µg/L
- Copper – 35 µg/L
- Iron – 200 µg/L
- Zinc – 350 µg/L

A testing program would be required during the RD/RA to determine actual achievable effluent characteristics and potential variability due to operational considerations for a full-scale water treatment plant at the Site.

Under this alternative, system reliability would depend on the ability to adequately construct and maintain the groundwater collection systems. The precipitation of metals such as aluminum, iron, and manganese has been documented to substantially reduce collection efficiencies achieved over the long term in subsurface collection systems. Additionally, due to the limited space available at the toe of the tailings piles for flow storage and equalization, the storage of collected flows during periods of unanticipated maintenance or repair would not be possible. Long-term treatment efficiencies would depend on the ability to control chemical addition rates in response to seasonal changes in water quality.

6.6.3 Alternative 4c – Extended Railroad Creek Relocation and East Area Collection and Treatment

Alternative 4c includes the extended relocation of Railroad Creek and collection and treatment of East Area groundwater and seeps. Under this alternative, an extended segment of Railroad Creek would be relocated to the north and the current channel bed would be enhanced for collection and treatment of tailings pile seeps and groundwater. As described for Alternatives 4a and 4b, intercepted water would be treated through chemical addition and aeration to promote precipitation and removal of iron and other PCOCs. The following subsections describe the extended Railroad Creek relocation and collection and treatment system components included under Alternative 4c.

6.6.3.1 Extended Railroad Creek Relocation

Under Alternative 4c, the existing Railroad Creek channel located adjacent to the tailings piles would be used for collection and treatment of East Area groundwater and seeps. This approach requires the construction of a replacement channel approximately 4,500 lineal feet long as shown on Figure 6-27. The creek alignment would be shifted to the north away from the tailings piles, and would rejoin the current creek alignment downstream of the wetlands area located to the east of tailings pile 3. Where space is limited between the tailings piles and the Holden Village road, such as reaches adjacent to tailings pile 2, the new creek corridor would overlap somewhat with the current corridor and structural measures may be required to stabilize the hillslope.

The relocated channel would be constructed to meet the following objectives:

- Provide hydraulic capacity for reasonably expected high flows,
- Maintain stream power through the reach to transport incoming sediment loads (and prevent aggradation),
- Establish a stable channel, and
- Provide improved aquatic habitat.

To meet the first objective, a channel would be constructed at an appropriate gradient to convey the 100-year flow. The second objective would be achieved by modifying the channel geometry (narrower, deeper sections) in lower gradient reaches to maintain stream power. To meet the third objective, various bank reinforcing materials and additional channel roughness would be used, depending on the bank orientation (outside of bends) and anticipated velocities. The fourth objective would be achieved by providing a stable base-flow channel within the overall cross-section.

A conceptual channel cross-section is shown on Figure 6-16. Dimensions shown are based on the average existing channel gradient, estimated as 1.1 percent. At this gradient, preliminary analyses indicate that a typical trapezoidal channel cross-section with a bottom width of 40 feet (2H to 1V side slopes) and a depth of 8 feet would be adequate for conveying the 100-year flow, with a 1-foot freeboard. Channel gradient and cross-section geometry would likely be somewhat varied along the reach in order to create habitat complexity, maintain stream power, and accommodate corridor restrictions. The final configuration would be determined during the RD/RA.

The aquatic habitat channel would be configured to convey base flows within its cross-section and would confine smaller flows to provide more complex fish habitat (i.e., pools and riffles). The aquatic habitat channel would have a gravel bed, and would include lines of flow constricting boulder deflectors, spaced approximately every 50 to 100 feet. These boulder deflectors would provide roughness and confinement to maintain adequate depths during low flow periods. Large timbers (most of which may be salvaged from the new channel alignment) would be anchored to increase roughness and improve habitat. The aquatic habitat channel would meander to the extent practical within the high flow cross-section (pool/riffle) and would create some of the additional sinuosity that may have been present prior to the reconfiguration of the valley by the mining activities.

Outside the aquatic habitat channel, banks would be revegetated and/or protected with large boulders to provide a stable channel under high-flow conditions. Preliminary analyses indicate that during higher flows, the channel may be at or near supercritical flow. To maintain a stable channel under these conditions, the outside banks of bends may need to be protected with large rock (3 to 4-foot diameter boulders) to prevent erosion and channel migration.

Construction of the new channel alignment would require extensive excavation. Channel relocation along the eastern section of tailings pile 2 would likely require structural measures to stabilize the hillside due to high slopes and limited space between the tailings pile and Holden Village road.

To construct the new channel, some temporary dewatering of the portion of the creek between tailings piles 2 and 3 and the road may be needed, most likely through use of a coffer dam.

Areas disturbed during construction would be reclaimed to provide riparian habitat along the new channel alignment. Maintenance of the new channel banks and riparian habitat would be required under this alternative. For purposes of the FS, it is assumed that periodic maintenance activities would be performed for a period of approximately 5 years following construction.

6.6.3.2 East Area Collection (Extended Railroad Creek Relocation)

Under Alternative 4c, the existing Railroad Creek channel would be enhanced for collection and treatment of tailings pile seeps and groundwater (Figures 6-28 and 6-29). An open collection trench would be constructed within the existing railroad creek channel to intercept seepage and groundwater for physical/chemical treatment prior to discharge by gravity to Railroad Creek.

The extended collection system would include the following components:

- Placement of Copper Creek in a culvert;
- Completion of an access road along the base of tailings piles 1, 2, and 3; and
- Installation of open interceptor drain trenches with possible culvert conveyance in constricted reaches adjacent to tailings pile 2.

The placement of Copper Creek in a culvert would be completed as described for Alternatives 4a and 4b. To provide access for construction of the collection and treatment systems, a road would be constructed at the base of the tailings piles following creek relocation.

The relocation of Railroad Creek would provide additional space at the base of the tailings piles to allow the containment of material in the event of a slope failure, thereby reducing the potential for release. As a result, it is anticipated that the magnitude of slope-stability regrading required under this alternative would be reduced to a limited reach along tailings pile 2, where the available area between the road and Railroad Creek would likely limit the distance the creek could be relocated to the north (Figure 6-28). Tailings potentially transported to the collection and treatment system in the event of a slope failure would be removed as a maintenance activity. The new Railroad Creek channel alignment, the conveyance method for collected groundwater in the restricted area adjacent to tailings pile 2, and slope regrading requirements would be determined during the RD/RA should this alternative be selected.

To enhance groundwater collection, an open interceptor trench would be constructed to an assumed depth of approximately 5 to 10 feet below the existing creek bottom. Deeper excavation would be employed to intercept additional water as permitted by existing grades and depth to the dense till. A conceptual cross-section of the collection system is provided on Figure 6-29.

Available subsurface data indicate variable thicknesses of alluvial material and glacial drift beneath the tailings piles and creek channel. As a result, the final alignment for the collection trench under Alternative 5c would be determined during the RD/RA. Groundwater collected in the restricted area adjacent to tailings pile 2 may need to be conveyed past this section in a culvert due to the limited area available to install an open drain trench system in this reach. A culvert may also be considered in this reach to limit the seepage of clean water from the relocated stream to the open drain trench. Use of a culvert for groundwater transport in this reach instead of the open interceptor drain trench would be further examined in the RD/RA should this alternative be selected.

As possible, the relocated Railroad Creek alignment would be constructed to maintain a higher elevation relative bottom of the interceptor drain trench. This would maintain groundwater gradients in the direction of the collection system and would likely result in the loss of water from Railroad Creek into the collection and treatment system.

A partial barrier wall would be installed to a depth of several feet into the dense till or bedrock on the south side of new Railroad Creek channel near the toe of tailings pile 3 to enhance groundwater collection near the east end of the Site (Figure 6-28). As described for Alternatives 4a and 4b, data collected during the RI indicate that the native materials beneath the tailings piles are heterogeneous in nature, and likely contain large cobbles, timbers and granitic boulders. Due to the increased distance between the tailings piles and barrier wall alignment under Alternative 4c, the barrier walls would likely be constructed with backhoes and rock chisels using soil-bentonite backfill. The structural considerations, related to trench construction at the base of the tailings piles, would be mitigated under this alternative since the barrier wall would be further away from the steep tailing pile slopes.

Alternative options for reducing the potential influx of Railroad Creek water into the collection and treatment systems would be evaluated during the RD/RA. Potential options for further evaluation include the installation of a partial or "hanging" barrier wall in the upper portion of the subsurface between the collection systems and creek channel, or techniques for reducing the permeability, and therefore water loss, from the bottom and sides of the relocated channel. Additional data related to subsurface conditions in this area would be required and collected during the RD/RA to support the design and construction of the East Area groundwater collection systems.

Tables 6-8 through 6-11 provide a summary of the estimated groundwater flows that would be intercepted by the Alternative 4c collection and treatment systems. The open collection trench would be expected to intercept a majority of the shallow aquifer currently intercepted by Railroad Creek, represented by the flow net analysis described in Sections 2.6, with a collection efficiency ranging from approximately 80 to 90 percent. There is also a potential for losses of Railroad Creek water from the relocated channel into the collection system, most notably in the narrow reach adjacent to tailings pile 2, where the distance between the relocated channel and collection system is reduced.

The portion of the collection system installed along the base of tailings pile 1 is estimated to collect approximately 660 gpm during the spring flush and an average of approximately 360 gpm for the remainder of the year. The collection system installed along the base of tailings pile 3 is estimated to capture approximately 2,100 gpm during the spring flush and an average of 640 gpm for the remainder of the year. As described for Alternative 4a, Seep SP-21 accounts for a portion (approximately 830 gpm) of the estimated flow captured in the spring by the system installed at the toe of tailings pile 3.

The seep and groundwater volumes assumed to be intercepted under Alternative 4c were based on the flow tube analysis described in Section 2.6 and summarized on Tables 6-8 through 6-11; the estimated down-valley deep groundwater component; and estimated losses from the relocated Railroad Creek channel. Additional discussion of groundwater collection assumptions is provided in Section 7.2.1.3.

6.6.3.3 East Area Treatment (Extended Railroad Creek Relocation)

Under Alternative 4c, the abandoned Railroad Creek stream channel would be enhanced to provide drop structures and ponds in suitable areas along the length of the tailings piles. Two larger treatment pond systems would also be constructed at the northeastern corners of tailings piles 1 and 3 to provide additional detention time for the removal of iron and other metals from intercepted seeps and groundwater (Figure 6-28). This section provides a description of the low-energy treatment systems for collected East Area waters, including conceptual hydraulic and chemical influent parameters, treatment system unit processes, and expected system performance.

Conceptual Hydraulic and Chemical Influent Parameters

Tables 6-8 through 6-11 provides a summary of the conceptual hydraulic and chemical influent parameters assumed for the low-energy East Area treatment system included under

Alternative 4c. Table 6-12 provides a summary of the conceptual process sizing, including chemical dosing. As summarized on Table 6-12, nominal peak flows of approximately 660 gpm and 2,100 gpm were used to size treatment system components located east of tailings piles 1 and 3 respectively. Blended metals concentrations were calculated based on the estimated flow and metals concentrations for each flow tube intercepted, estimated water influx from the relocated Railroad Creek Channel, and deep groundwater flow component. The average metals concentrations measured in monitoring wells DS-3D and DS-4D, located downgradient of Railroad Creek monitoring station RC-2, were assumed to be representative of concentrations within the deep groundwater component. The estimated post-remediation concentrations at monitoring station RC-4 were assumed for the estimated influx from the Railroad Creek channel.

As described for Alternatives 4a and 4b, water storage and flow equalization would not be possible under this alternative. As a result, the East Area treatment systems would need to be designed to handle seasonal variations in hydraulic and chemical loading.

Low-Energy Treatment System Unit Processes (Extended Collection)

The same unit processes described under Alternatives 4a and 4b for low energy alkaline precipitation and clarification would be implemented under Alternative 4c. A conceptual process flow diagram, providing the specific low-energy unit processes identified for the treatment of collected East Area waters, is provided on Figure 6-23. As described previously, additional drop structures and ponds would also be constructed within the former Railroad Creek channel at locations determined during the RD/RA. Conceptual process sizing, including estimated chemical dosage rates, for the pond systems constructed east of tailings piles 1 and 3 are provided in Table 6-12.

Process sizing for Alternative 4c was adjusted based on the higher estimated collection efficiencies achieved by this alternative in comparison to Alternative 4b, and the associated higher hydraulic and chemical loading rates. Because the settling ponds would be sized to accommodate an annual production of treatment residue, the total required volume would be larger under Alternative 4c than estimated under Alternative 4b. A diagrammatic plan view of East Area water collection and treatment system components included under Alternative 4c is provided on Figure 6-28.

Low-Energy Treatment System Performance (Extended Collection)

The low-energy treatment system described under Alternative 4c is assumed to produce the same effluent concentrations as described for Alternatives 4a and 4b:

- Aluminum – 130 μg/L
- Cadmium – 5 μg/L
- Copper – 35 μg/L
- Iron – 200 μg/L
- Zinc – 350 μg/L

A testing program would be required during the RD/RA to determine actual achievable effluent characteristics and potential variability due to operational considerations for a full-scale water treatment plant at the Site.

As described for Alternatives 4a and 4b, system reliability would depend on the ability to adequately construct and maintain the groundwater collection systems, and control chemical feed rates in response to seasonal variations hydraulic and chemical loading. Additionally, due to the limited space available at the toe of the tailings piles for flow storage and equalization, the storage of collected flows during periods of unanticipated maintenance or repair would not be possible.

6.6.4 Railroad Creek Rehabilitation

Under Alternatives 4a, 4b, and 4c, select reaches of Railroad Creek would be rehabilitated to enhance aquatic habitat. The portions of Railroad Creek addressed by rehabilitation efforts would vary depending on the selected alternative, and would include ferricrete removal and habitat enhancement features, such as the placement of boulders and logs as appropriate.

6.6.5 Monitored Natural Attenuation in the East and West Areas

As described for Alternative 2, natural attenuation can be considered an active remedial measure for achievement of potential ARARs if the MTCA and EPA expectations related to natural attenuation are met. Under alternative 4, MNA would be implemented in the East (Alternative 4a) and West Areas in conjunction with the remedial measures described in Sections 6.3 (Common Remedial Components) and 6.4 (Alternative 2) to reduce the release of PCOCs over time.

Geochemical analyses conducted for the Site document that natural attenuation is occurring, and the release of PCOCs from the tailings piles, underground mine, and waste rock piles would continue to decline over time under Alternatives 4a through 4c. The geochemical analyses and predictions of trends in chemical loading from source areas are provided in Appendix E. Based on the results of these analyses, MNA, in conjunction with the East and West Area actions provided under these alternatives, are expected to significantly reduce the release of PCOCs to groundwater and surface water over time. Treatment requirements for the East Area under Alternatives 4a through 4c are also expected to be reduced in the long-term.

Descriptions of the natural attenuation processes and an evaluation of the achievement of MTCA expectations for natural attenuation are provided in Section 7. Groundwater and surface water monitoring for natural attenuation are generally described in Section 6.2.2 and would be specified in the OMMP.

6.7 ALTERNATIVE 5: WATER MANAGEMENT AND WEST/EAST AREA COLLECTION AND TREATMENT (LOW-ENERGY TREATMENT)

Alternative 5 would include the common remediation components described for the East and West Areas in Section 6.3 and combine the additional components included under

Alternatives 3b (Water Management and West Area Treatment - Hydrostatic Bulkhead) and 4 (Water Management and East Area Treatment).

Actions included under Alternative 5 would be designed to divert upgradient surface water and shallow groundwater around source areas and collect downgradient groundwater and seepage in the East and West Areas. Collection and treatment of East and West Area waters would be performed as described in Sections 6.5 and 6.6 to reduce the loading of aluminum, cadmium, copper, iron, and zinc to groundwater and surface water, and improve aquatic habitat in Railroad Creek. Specific actions included under this alternative are summarized on Table 6-1. There are four subalternatives under Alternative 5 (designated as 5a, 5b, 5c and 5d) that vary the method and extent of East and West Area water collection and treatment. These four subalternatives include:

- Alternative 5a – Partial East Area collection, upper West Area collection, and East/West Area treatment;
- Alternative 5b – Extended East Area collection, upper West Area collection, and East/West Area treatment;
- Alternative 5c – Extended relocation of Railroad Creek, upper West Area collection, and East/West Area treatment; and
- Alternative 5d – Extended relocation of Railroad Creek, upper and lower (secondary) West Area collection, and East/West Area treatment.

During the RD/RA, diverting treated flow from the West Area water treatment system to the East Area treatment system to provide alkalinity addition and pH control would be evaluated. The following subsections provide summaries of West Area collection and treatment and specific East Area water collection and treatment components under Alternatives 5a through 5d.

6.7.1 Alternatives 5a, 5b, 5c, and 5d - West Area Collection and Treatment (Hydrostatic Bulkhead)

Under Alternative 5a, 5b, and 5c, the collection and treatment of West Area waters would be performed as described for Alternative 3b (West Area Treatment with Hydrostatic Bulkhead) in Section 6.5. Alternative 5d would also include the same collection and treatment components described for Alternative 3b, and add the installation of a secondary groundwater collection system in the lower West Area adjacent to Railroad Creek. Figure 6-14 provides a conceptual plan view of the West Area actions included under Alternatives 5a, 5b, and 5c. Figure 6-30 provides a conceptual plan view of these same actions with the additional lower West Area barrier wall and collection trench included under Alternative 5d.

Under Alternative 5d, the secondary barrier wall and collection trench would be installed to collect groundwater resulting from the infiltration of precipitation in the West Area and groundwater potentially bypassing the upper West Area collection system. To enhance groundwater collection efficiencies and minimize losses from Railroad Creek to the lower collection trench, a barrier wall would be installed to a depth of several feet into the dense till (or to the top of bedrock if low-permeability till is not present) between the creek and collection system. For purposes of the FS, a depth of approximately 55 feet is assumed for the lower West Area barrier wall construction. A conceptual cross-section depicting assumed barrier wall and collection trench construction is provided on Figure 6-31.

Subsurface data collected from geotechnical borings and monitoring wells completed in the West Area in 2003 indicate that the subsurface is heterogeneous in nature, and likely contains large cobbles, timbers and granitic boulders. Under Alternative 5d, the lower West Area barrier wall would likely be constructed with backhoes and rock chisels using soil-bentonite backfill. Excavated materials would be processed to remove cobbles and boulders prior to mixing with bentonite to produce the barrier wall backfill. Additional data related to subsurface conditions in this area would be required during the RD/RA to support the design and construction of the East Area groundwater collection systems.

Under all of the Alternative 5 subalternatives, treated overflow from the West Area settling ponds would potentially be directed from the lagoon area to the tailings pile 1 groundwater and seep collection system to provide alkalinity and reduce chemical addition rates in the East Area treatment systems. Portal drainage and West Area seep and groundwater flows assumed to be collected under Alternatives 5a, 5b, 5c, and 5d are summarized on Table 6-4. For Alternative 5d, groundwater collected in the lower West Area collection system would be directed to the East Area for treatment and is therefore accounted for on Tables 6-8 and 6-9. The additional groundwater flow captured by the lower West Area collection system is estimated to be approximately 50 gpm during the spring flush and an average of approximately 30 gpm for the remainder of the year.

Figure 6-13 provides a conceptual process flow diagram for the West Area treatment system included under all of the subalternatives under Alternative 5. A detailed description of the conceptual hydraulic and chemical influent parameters and low-energy treatment system unit processes is provided in Section 6.5.2.1. Because groundwater collected in the lower West Area collection trench under Alternative 5d would be diverted into the East Area collection system for treatment, the West Area treatment system component sizing for Alternative 5d would be equivalent to Alternatives 5a, 5b, and 5c. However, due to the lower West Area collection trench and barrier wall, it is assumed that the treatment ponds included under Alternative 5d would be lined to avoid high alkalinity water from plugging the collection system. Alternatively, open collection systems and unlined ponds would be evaluated during the RD/RA.

Table 6-4 provides conceptual hydraulic and chemical influent parameters estimated for the West Area treatment system. Table 6-5 provides conceptual process sizing, with chemical dosing rates. The low-energy treatment system described under Alternative 5 for the West Area is assumed to produce the same effluent concentrations as described for Alternative 3:

- Aluminum – 130 ug/L
- Cadmium – 5 µg/L
- Copper – 24 µg/L
- Iron – 200 µg/L
- Zinc – 240 µg/L

6.7.2 Alternative 5a –Partial East Area Collection and Treatment

A detailed discussion of the partial East Area collection and treatment system is provided under Alternative 4a in Section 6.6.1. As described under Alternative 4a, two open collection trenches, each approximately 1,100 feet long, would be constructed at the northeast corners of tailings piles 1 and 3 (Figures 6-15 through 6-18). The collection systems would be constructed to intercept seepage and groundwater naturally flowing toward these areas for physical/chemical treatment.

Two barrier walls installed to the depth of the dense till or bedrock would be included along the length of the collection trenches for increased collection efficiency (Figure 6-15). The collection efficiencies of the barrier wall/collection trench systems are estimated to range from approximately 80 to 90 percent. Collected water would be treated through chemical addition, aeration, and alkaline precipitation to promote the removal of iron, and co-precipitation of other PCOCs.

Under Alternative 5a, treated overflow from the West Area would potentially be combined with intercepted water adjacent to tailings pile 1 for alkalinity addition and pH adjustment. Tables 6-8 through 6-11 provide conceptual hydraulic and chemical influent parameters estimated for the East Area treatment system under Alternative 5a. Table 6-12 provides conceptual process sizing, with chemical dosing rates, and Figures 6-15 and 6-23 provide a conceptual process flow diagram and plan view of East Area actions included under Alternative 5a.

The low-energy treatment system described under Alternative 5a for the East Area would be expected to produce the same effluent concentrations as described for Alternative 4:

- Aluminum – 130 µg/L
- Cadmium – 5 µg/L
- Copper – 35 µg/L
- Iron – 200 µg/L
- Zinc – 350 µg/L

Detailed discussion of the collection and treatment system components is provided under Alternative 4a in Section 6.6.1.

6.7.3 Alternative 5b – Extended East Area Collection and Treatment

Under Alternative 5b, a groundwater intercept drain and barrier wall about 5,800 feet long would be installed along the northern toe of the three tailings piles as described under Alternative 4b and shown on Figures 6-23 through 6-27. As described for Alternative 4b, the collection systems would be constructed to intercept a majority of the seepage and groundwater flow from the three tailings piles for physical/chemical treatment. The collection efficiency of the intercept drain/barrier wall system is estimated to be approximately 80 percent.

As described under alternative 5a, treated overflow from the West Area would potentially be combined with intercepted water adjacent to tailings pile 1 for alkalinity addition and pH adjustment. The East Area treatment system(s) would include chemical addition, aeration, and alkaline precipitation as described under Alternative 5a (Section 6.7.2).

Tables 6-8 through 6-11 provide conceptual hydraulic and chemical influent parameters estimated for the East Area treatment system under Alternative 5b. Table 6-12 provides conceptual process sizing, with chemical dosing rates, and Figures 6-23 and 6-24 provide a conceptual process flow diagram and plan view of East Area actions included under Alternative 5b. The low-energy treatment system included under Alternative 5b for the East Area would be expected to produce the same effluent concentrations as described for Alternative 5a.

6.7.4 Alternatives 5c and 5d – Extended Railroad Creek Relocation and East Area Treatment

Under Alternatives 5c and 5d, an extended segment of Railroad Creek would be relocated to the north and the current channel bed would be used for the collection and treatment of tailings pile seeps and groundwater (Figures 6-28 and 6-29). Following stream relocation, the existing channel would be enhanced to intercept seepage and groundwater from the three tailings piles for physical/chemical treatment prior to gravity discharge to Railroad Creek.

Intercepted water would be treated through chemical addition and aeration to promote precipitation and removal of iron and other PCOCs as described under Alternative 4c (Section 6.6.3). However, as described previously for Alternatives 5a and 5b, treated flow from the West Area would potentially be combined with groundwater water intercepted adjacent to tailings pile 1 for alkalinity addition and pH adjustment. Under Alternative 5d, flow captured by the lower West Area barrier wall and collection trench would also be directed into the east area collection system for treatment.

A detailed description of extended Railroad Creek relocation and East Area collection and treatment is provided under Alternative 4c in Section 6.6.3. Tables 6-8 through 6-11 provide conceptual hydraulic and chemical influent parameters estimated for the East Area treatment system under Alternatives 5c and 5d. The open collection trench would be expected to intercept a majority of the shallow aquifer currently intercepted by Railroad Creek, represented by the flow net described in Sections 2.2 and 6.6.1.3, with an average collection efficiency of approximately 80 percent. Table 6-12 provides conceptual process sizing, with chemical dosing rates, and Figures 6-23 and 6-28 provide a conceptual process flow diagram and plan view of East Area actions included under Alternatives 5c and 5d.

The low-energy treatment system included under Alternatives 5c and 5d for the East Area would be expected to produce the same effluent quality as described for Alternatives 5a and 5b.

6.7.5 Alternatives 5a, 5b, and 5c - Monitored Natural Attenuation

As described previously, natural attenuation can be considered an active remedial measure for achievement of potential ARARs if the MTCA and EPA expectations related to natural attenuation are demonstrated. Under alternatives 5a, 5b, and 5c, MNA would be implemented in the portions of the East (Alternative 5a only) and West Areas located downgradient of groundwater collection or treatment systems. Following the removal of lagoon area soils (the only identified potential source area located downgradient of collection systems) from the West Area, potentially remaining PCOCs in soils and groundwater would be expected to flush out over time. MNA, in conjunction with the upper West Area collection system and other West Area actions provided under this alternative are expected to significantly reduce the release of PCOCs to groundwater and surface water from these areas over a reasonable restoration time frame.

The geochemical analyses provided in Appendix E document that natural attenuation is occurring in the East and West Areas and is expected to reduce metals loading from waste rock, the underground mine, and tailings piles over time. Treatment requirements for the East and West Areas are therefore expected to be reduced in the long-term.

Descriptions of the natural attenuation processes and an evaluation of the achievement of MTCA expectations for natural attenuation are provided in Section 7. Groundwater and surface water monitoring for natural attenuation are generally described in Section 6.2.2 and would be specified in the OMMP.

6.8 ALTERNATIVE 6: WATER MANAGEMENT AND WEST/EAST AREA COLLECTION AND TREATMENT (MECHANICAL TREATMENT)

Alternative 6 was proposed for inclusion in the FS by the Agencies in a transmittal dated January 2, 2003 (Hart Crowser 2003). Alternative 6 would combine the remedial components included under Alternative 3 (Water Management and West Area Treatment) and 4c (Water Management and Extended Railroad Creek Relocation and East Area Treatment) and add the following:

- Mechanical water treatment facility in the West Area; and
- Barrier wall and collection trench system extending approximately 3,500 linear feet west of tailings pile 1 on the south side of Railroad Creek.

Actions included under Alternative 6 would be designed to divert upgradient surface water and shallow groundwater around source areas and maximize the collection and treatment of downgradient groundwater and seepage to reduce the loading of aluminum, cadmium, copper, iron, and zinc to groundwater and surface water, and improve aquatic habitat in Railroad Creek. Specific actions included under this alternative are summarized on Table 6-1.

As described for Alternative 3, there are two subalternatives under Alternative 6 (designated as 6a and 6b) providing varying degrees of 1500-level main portal drainage control. These two subalternatives include no portal drainage flow control (6a) and the placement of hydrostatic bulkheads in the 1500-level (6b). The following subsections provide descriptions of the downgradient collection of West Area waters, specific mechanical water treatment components included for the West Area under Alternatives 6a and 6b, and East Area collection and treatment.

6.8.1 West Area Downgradient Collection

Alternative 6 would include the collection of the portal drainage, seeps, and shallow groundwater associated with the mill building, waste rock piles, and maintenance yard as described under Alternatives 3 and 5. In addition, this alternative would include the installation of an extended barrier wall and collection drain from the upstream site boundary on the south side of Railroad Creek to the upstream side of Tailings Pile 1. These actions are discussed in the following subsections.

6.8.1.1 Upper West Area Collection

Alternative 6 includes collection and treatment of the portal drainage, shallow groundwater, and seeps associated with the mill building, waste rock piles, and maintenance yard (SP-6, SP-7, SP-8, SP-15W, SP-15E, and SP-19) as described for Alternative 3 in Section 6.5.1. Figure 6-32 provides a conceptual plan view of the West Area remedial components included under this alternative.

As described for Alternative 3, the portal drainage would be placed within a culvert at the 1500-level main portal (P-1) and directed to a treatment building for chemical addition. The culvert would be sized to handle the maximum anticipated spring discharge, which is estimated to be approximately 1200 gpm for purposes of the FS.

Seeps SP-23 and SP-12 would be captured using collection basins installed within the native soils. The captured seep flows would then be directed to the West Area treatment system within a culvert or pipe. Surface water runoff from the mill building (referred to as SP-7) would be intercepted at the northern edge of the building and directed to the treatment system in a pipe or lined channel. Seeps SP-6, SP-8, SP-15E, SP-15W, and SP-19, associated with the waste rock piles, mill building and maintenance yard, would be intercepted using rock-filled collection basins or sumps and directed into a barrier wall/collection trench system completed along the base of the waste rock piles and north side of the maintenance building or directly to the treatment system (Figure 6-32).

The approximately 2,450 foot long barrier wall would be completed down to the dense till or bedrock interface to enhance the collection of surface and subsurface flow from these potential source areas. For purposes of the FS, an average depth of approximately 25 feet was assumed for the upper West Area barrier wall construction. However, actual depths may vary depending on the thickness of the materials overlying the low-permeability till or bedrock. Collected water would be conveyed to the West Area treatment system by gravity, using existing topography as possible.

6.8.1.2 Extended Lower West Area Collection System

Under Alternatives 6a and 6b, the lower West Area collection system described under Alternative 5d would be extended upstream (west) to the approximate location of SP-26 (Figure 6-32). The lower barrier wall and collection trench would extend approximately 3,500 feet upstream of the western edge of tailings pile 1 to collect groundwater resulting from the infiltration of precipitation in the lagoon area and additional groundwater not intercepted by the upper West Area collection system.

To enhance groundwater collection efficiencies and minimize losses from Railroad Creek to the lower collection trench, a barrier wall would be installed to a depth of several feet into the dense till (or to the top of bedrock if low-permeability till is not present) between the creek and collection system. Figures 6-31 through 6-33 provide a conceptual plan view and diagrammatic cross-sections of the West Area downgradient collection systems included under Alternative 6.

The collected groundwater would be directed through the collection trench and piping system to a sump where it would be pumped to a mechanical treatment facility located in the vicinity of the current lagoon area. Groundwater collected to the east of the sump would be transferred to the East collection system. A new access road would be required to reach the westernmost areas of construction and serve as a work platform for construction equipment.

The work pad/access road needed for construction of the extended collection system would likely have a minimum width of approximately 30 feet, and would be constructed to provide an average grade of about 2 percent falling from the west to the east. A 5-foot wide berm would be constructed on the creekside edge of the work platform to reduce environmental exposure to the creek. The barrier wall would be installed through the native soils to depth of several feet into the dense till or bedrock, which based on available geophysical data and geological borings was assumed to average approximately 20 feet below the top of the access road along the alignment west of P-5, and average approximately 55 feet below grade from P-5 to the west side of Tailings Pile 1. The excavation for the interceptor drain trench was assumed to be approximately 5 feet in the steeper reaches west of P-5 (Figure 6-33) and approximately 8 feet deep in the flatter reaches east of P-5 (Figure 6-31).

About 1,700 feet along the west portion of the barrier alignment would require special access work due to the steep slopes adjacent to the creek. It was assumed that access would be gained by excavating a cut/fill road near the base of the slope at least 5 feet above the creek high water mark. The height of the access road above the creek would vary depending on the grades needed to provide an even slope for the work platform. The road would serve as a work platform for excavation of both the barrier and collection trenches.

For the purposes of the FS, it was assumed that conventional slurry trench excavation and soil/bentonite backfill would be used to construct the barrier trench. Due to narrow access (limited to minimize disturbance to the area as possible), several pieces of equipment would potentially be required to perform the trench work, including a grade all, backhoes, dump trucks, and conveyor system.

The groundwater collection trench would likely be installed after the barrier wall is in place and the barrier trench backfilled. To reduce the excavation depth of the drain trench, the collection trench would be a parallel trench excavated on the inboard side of the access road. For purposes of the FS, it is assumed that the maximum depth necessary to excavate the interceptor drain is 6 feet. A geotextile will be placed around the perimeter of the trench to provide a filter. Flexible polyethylene pipe would be laid in the trench from above and the trench will be backfilled with gravel produced in the crushing operations.

Following construction, select areas would be restored as required to meet action- and site-specific ARARs. However, under this alternative, the road would need to be maintained to allow future access for operation and maintenance activities.

The Upper West Area barrier wall and collection trench would be installed as described under Alternative 3.

6.8.1.3 West Area Flow Captured

Available seep flow measurements and hydrogeologic data for the Site indicate that the upper West Area collection system would collect approximately 870 gpm of groundwater and seep flow during the one-month spring flush and an average of approximately 290 gpm during the remainder of the year (assuming 90 percent collection efficiency). The extended lower West Area collection system is estimated to collect an additional 350 gpm of seep and groundwater flow during the spring flush and approximately 190 gpm of additional flow during the remainder of the year. This assumes a collection efficiency of approximately 80 percent upstream (west) of P-5 and approximately 90 percent in the flat area downstream (east) of P-5. A majority of the additional groundwater collected is accounted for by seep SP-26 and groundwater upgradient of the portal drainage channel (P-5).

Table 6-4 provides a summary of the estimated flows and metals concentrations for collected West Area seeps, groundwater, and portal drainage in the spring and fall that would be treated in the West Area treatment system (for purposes of the FS groundwater collected by the lower West Area collection system is assumed to be conveyed to the East Area for treatment). As possible, the collection systems would be constructed to minimize interference with Holden Village operations.

6.8.2 Alternative 6a – West Area Mechanical Treatment (Open Portal)

Under Alternative 6a, airflow restrictions would be installed within the 1500-level main portal, allowing unrestricted flow of water from the mine. As a result, the West Area water collection and treatment system would need to be sized to handle seasonal fluctuations in the portal drainage and seep/groundwater flow.

6.8.2.1 Mechanical West Area Treatment (Open Portal)

This section provides a description of the mechanical treatment system for collected West Area waters, including conceptual hydraulic and chemical influent parameters, treatment system unit processes, and expected system performance.

Conceptual Hydraulic and Chemical Influent Parameters

Table 6-4 provides a summary of the conceptual hydraulic and chemical influent parameters assumed for the mechanical West Area treatment system. Table 6-5 provides conceptual process unit sizing. As summarized on Table 6-5, a nominal peak flow of approximately 2,050 gpm (occurring during the spring flush) was used to size the treatment system components under Alternative 6a. During the fall, or low-flow period, the influent flow was estimated to be approximately 380 gpm.

Blended metals concentrations estimated for the spring (high-flow) and fall (low-flow) are summarized on Table 6-4. Dissolved metals concentration in the influent stream to the West Area treatment plant during the spring flush period were estimated based on measured flows and concentrations in the portal drainage and west area seeps. Following the spring flush, West Area seeps were not observed to flow; therefore, the blended concentrations for the portal drainage and groundwater were assumed to be representative of the influent concentrations to the treatment system. Because limited groundwater quality data is available for the area upgradient of the barrier wall and collection trench system, metals concentrations in collected groundwater were assumed to be similar to the blended seep concentrations estimated for spring conditions.

Mechanical Treatment System Unit Processes

A high density sludge (HDS) system was assumed for the mechanical treatment of collected West Area waters. A conceptual process flow diagram, providing the unit processes identified for the mechanical treatment system, is provided on Figure 6-34. Conceptual process sizing, including estimated chemical dosage rates are provided in Table 6-5. Figure 6-32 provides a diagrammatic plan view of the West Area water collection and treatment system components under Alternative 6a. Specific unit processes and components include the following:

- **Pump station.** A pump station would be located on the south bank of Railroad Creek to transfer groundwater from the barrier wall/collection system to the treatment building.

- **Chemical Addition.** An alkalinity adding chemical, such as hydrated lime ($Ca(OH)_2$), caustic (NaOH), or soda ash (Na_2CO_3) would be added to raise the pH of the collected waters to between 9 and 10 to promote the precipitation of metals including cadmium, copper, iron, and zinc. Conceptual process sizing, including estimated chemical dosage rates are provided in Table 6-5. The average chemical dosage rate was estimated based on hydrated lime dosing rates determined during bench-scale testing completed on samples of the portal drainage in June 2000 (Section 2.7). The actual treatment chemical and dosage rates would be determined during the RD/RA, in consideration of factors including pH control, solubility, sludge generation, cost, and chemical handling/transportation considerations. Chemical dosing would also be adjusted during operation based on influent flow rates and pH.

- **Aeration.** Under this alternative, aeration would be provided using a mechanical blower following chemical addition.

- **Flocculent Addition (If needed).** The addition of a polymer would be evaluated during the RD/RA for its ability to enhance flocculation and increase settling rates for the oxidized metals constituents.

- **Clarification/Sedimentation.** A mechanical clarifier with sludge recycle would be used for the precipitation and removal of metal constituents. Residue would be mechanically removed from the clarifier using flights.

- **Sludge Dewatering.** Treatment residue would be dewatered using a filter press prior to disposal. Residue would be disposed on site in a containment area designed for compliance with action specific ARARs. Actual dewatering components would be determined during the RD/RA.

- **Filtration.** A gravity media filter would be used to promote removal of metal precipitates and other suspended solids from the water following gravity settling in the clarifier. The filter would be periodically backwashed using treated water from the system.

- **Power Generation Facility.** The energy requirements of the mechanical treatment system would exceed the hydroelectric generation capacity available at the Site. As a result, the system would require on-site power generation capabilities. Preliminary calculations indicate approximately 140 to 190 kW of power would need to be generated to operate a 2000 gpm mechanical system (assuming 95 percent motor efficiency and a power factor of 0.8).

- **Diesel Storage Facility.** A power consumption rate between 140 and 190 kW translates to a diesel fuel consumption rate between 95,000 and 125,000 gallons per year. This would require a storage tank of approximately 50,000 gallons to ensure uninterrupted operation during the winter months when access to the village is limited.

Because the system would be designed for peak hydraulic and chemical loading occurring during the spring flush, it would only be expected to operate at its maximum capacity for a portion of the year.

Mechanical Treatment System Performance

As described for the low-energy alkaline precipitation system included under Alternatives 3, 4 and 5, a review of the results of bench-scale testing conducted on samples of the portal drainage discharge (URS, 2001) and available data from a number of pilot and full-scale acid drainage treatment systems was conducted to assess effluent water quality expected for the West Area mechanical treatment systems described above. A summary of the treatment system performance data compiled for various alkaline precipitation systems is provided in Table 6-6 and Appendix F.

The available treatment system performance data provided in Appendix F for mechanical ARD treatment systems and the results of the June 2000 bench-scale treatability study (Section 2.7) indicate the following effluent concentrations would likely be achieved by the West Area treatment system described above:

- Aluminum – 130 µg/L
- Cadmium – 5 µg/L
- Copper – 24 µg/L
- Iron – 200 µg/L
- Zinc – 240 µg/L

The assumed effluent concentration for aluminum is based on the results of Tests 1 and 2 of the June 2000 bench-scale treatability study (Section 2.7). The effluent concentrations assumed for copper and zinc were proposed by the Agencies for the West Area mechanical water treatment system (Hart Crowser 2003), and the assumed cadmium and iron concentrations are based on engineering judgment and the information provided in Appendix F. A testing program would be required during the RD/RA to determine actual achievable effluent characteristics and potential variability due to operational considerations for a full-scale water treatment plant at the Site.

During the RD/RA and system operation, operating parameters, including the types and quantities of chemicals added (e.g., polymers) and sludge recycle rates, may be adjusted to improve effluent quality, as needed. The operating parameters and/or configuration of some unit processes, such as the media filters, could also potentially be adjusted, if needed, to improve effluent quality. However, the addition of new process options, such as reverse osmosis units or other mechanical systems, would not be practicable.

Under this alternative, system reliability would be influenced by seasonal variations in influent volumes and chemistry. The mechanical treatment system would be oversized for the hydraulic and chemical loadings expected for a majority of the year. However, treatment efficiencies would depend on the ability to control chemical addition rates in response to the rapid changes in water quality expected under this alternative.

6.8.3 Alternative 6b –West Area Mechanical Treatment (Hydrostatic Bulkheads)

Under Alternative 6b, two or more hydrostatic bulkheads would be installed in strategic locations within the 1500-level main portal and ventilator tunnel to control discharge rates from the underground mine. Portal drainage control would be used to provide surge storage and reduce seasonal discharge and loading spikes for enhanced treatment efficiencies and system reliability. The installation of hydrostatic bulkheads would also provide an opportunity to provide in-mine water controls as described in Section 6.4.7.4

6.8.3.1 West Area Flow Retention and Equalization (Hydrostatic Bulkheads)

As described under Alternative 3b, it is assumed that the total water inflow to the mine would be discharged on an annual basis, and would be metered out over the year in proportion to seasonal discharge rates in Railroad Creek. Based on the calculations described in Section 6.4.7.3, discharge rates of approximately 70 to 90 gpm (0.15 to 0.2 cfs) during low flow periods between September and March and 135 to 270 gpm (0.3 and 0.6 cfs) over the five-month period between April and August would allow complete drainage of the mine each year (Table 6-3). Actual flowrates would be determined during the RD/RA and could be adjusted during operations.

During the RD/RA, the feasibility of constructing a lined detention pond on top of tailings pile 1 would be evaluated in the event that installation of hydrostatic bulkheads is not feasible. The pond would be sized to handle approximately two weeks of portal drainage flow in the event the treatment system must be shut down for unexpected maintenance or repair. Data obtained from the pressure transducer installed at P-1 over the period from October 1997 through October 2003 were used to estimate the highest total volume of drainage measured from the portal over a two-week period (Table 6-7). Based on this historical data, a detention pond sized to hold approximately 13 million gallons would likely be sufficient to handle approximately two-weeks of spring flow. This would require a foot print of approximately 4 acres for a pond constructed with an average depth of 10 feet.

6.8.3.2 West Area Mechanical Treatment (Hydrostatic Bulkheads)

This section provides a description of the mechanical treatment system for collected West Area waters with the installation of hydrostatic bulkheads in the 1500 level, including conceptual hydraulic and chemical influent parameters, treatment system unit processes, and expected system performance.

Conceptual Hydraulic and Chemical Influent Parameters (Hydrostatic Bulkhead)

Table 6-4 provides a summary of the conceptual hydraulic and chemical influent parameters assumed for the mechanical West Area treatment system. Table 6-5 provides a summary of conceptual process sizing. As summarized on Table 6-5, a nominal peak flow of approximately 1,100 gpm (occurring during the spring flush) was used to size the treatment system components. During the low-flow period in the late summer through early spring, the influent flow was estimated to be approximately 380 gpm.

Influent flowrates for Alternative 6b were estimated based on the portal drainage discharge calculations summarized in Table 6-2 and the estimated seep and groundwater flowrates described previously under Alternative 6a. A maximum portal drainage discharge rate of approximately 270 gpm was assumed for this alternative, based on the calculations described above.

As described under Alternative 3b, portal drainage water quality would likely be altered through the installation of hydrostatic bulkheads in the underground mine. In the short-term, metals concentrations in the portal drainage would likely increase through increased contact of the pooled water with metal sulfates present on the surfaces of exposed mine workings. Appendix E provides a summary of the potential short- and long-term effects of in-mine water storage, based on Site data collected during the RI and underground mine investigations, and data from other sites where mine flooding has been performed. The data presented in Appendix E indicate the following metals concentrations are possible in the portal drainage in the short-term:

- Aluminum – 17 mg/L
- Cadmium – 0.1 mg/L
- Copper – 12 mg/L
- Iron – 2 mg/L
- Zinc – 21 mg/L

The actual effects of in-mine water storage will depend on the height the water level is raised within the mine, as well as potential beneficial effects of other remedial actions, such as air-tight bulkheads, and in-mine water diversion.

Mechanical Treatment System Unit Processes (Hydrostatic Bulkhead)

The same unit processes described under Alternative 6a for an HDS treatment system would be implemented under Alternative 6b. A conceptual process flow diagram, providing the specific low-energy unit processes identified for the treatment of collected West Area waters under Alternative 6, is provided on Figure 6-34. Conceptual process sizing, including estimated chemical dosage rates are provided in Table 6-5.

Process sizing for Alternative 6b was adjusted based on the lower estimated hydraulic loading and higher chemical loading as described above. A diagrammatic plan view of the West Area water collection and treatment system components included under Alternative 6b is provided on Figure 6-32.

Although the sizing of the mechanical treatment system under Alternative 6b would be generally smaller than under Alternative 6a, the energy requirements would exceed the hydroelectric generation capacity available at the Site. Preliminary calculations indicate approximately 90 to 120 kW of power would need to be generated to operate a 1100 gpm mechanical system (assuming a 95 percent motor efficiency and a power factor of 0.8). This power consumption rate translates into a diesel fuel consumption rate between 60,000 and 80,000 per year.

Mechanical Treatment System Performance (Hydrostatic Bulkhead)

The mechanical treatment system described under Alternative 6b would be expected to produce the same effluent concentrations as described for Alternative 6a:

- Aluminum – 130 µg/L
- Cadmium – 5 µg/L
- Copper – 24 µg/L
- Iron – 200 µg/L
- Zinc – 240 µg/L

As described for Alternative 3, the increased chemical loading predicted for this alternative is not anticipated to adversely impact system performance. An increase in the concentrations of select metals, such as iron, would potentially improve system performance by promoting co-precipitation with other metals such as cadmium, copper, and zinc. A summary of the treatment system performance data compiled for various alkaline precipitation systems is provided in Table 6-6 and Appendix F.

Under this alternative, system reliability would be enhanced through the flow equalization provided by the installation of hydrostatic bulkheads in the 1500 level. The bulkheads would allow the in-mine storage of water in the event the treatment system is pulled off-line for equipment maintenance and repair, and would reduce the variations in water chemistry and discharge rates that are currently observed in the portal drainage. This would simplify the control of chemical dosing rates and provide more reliable system operation.

6.8.4 Extended Railroad Creek Relocation and East Area Collection and Treatment

The East Area collection and low-energy treatment systems described under Alternatives 5c and 5d would be implemented under Alternative 6. Due to the high concentrations of select metals such as iron, which promotes effective co-precipitation of other metals such as copper and zinc, a low-energy system including chemical addition, aeration, and alkaline precipitation was selected for this area.

Under both Alternatives 6a and 6b, an extended segment of Railroad Creek would be relocated to the north and the current channel bed would be used for collection and treatment of tailings pile seeps and groundwater (Figures 6-28 and 6-29). Following stream relocation, the existing channel would be enhanced to intercept seepage and groundwater from the three tailings piles for physical/chemical treatment prior to gravity discharge to Railroad Creek. The collection efficiency of the groundwater collection system is estimated to range from approximately 80 to 90 percent. As described for Alternatives 5c and 5d, intercepted water would be treated through chemical addition and aeration to promote precipitation and removal of iron and other PCOCs. Treated flow from the West Area would be potentially combined with intercepted water adjacent to tailings pile 1 for alkalinity addition and pH adjustment.

Tables 6-8 through 6-11 provide conceptual hydraulic and chemical influent parameters estimated for the East Area treatment system under Alternative 6. Table 6-12 provides conceptual process sizing, with chemical dosing rates, and Figures 6-23, and 6-28 provide a conceptual process flow diagram and plan view of East Area actions included under Alternative 6.

The low-energy treatment system described under Alternative 6 for the East Area would be expected to produce the same effluent concentrations as described for Alternatives 4 and 5 above.

- Aluminum – 130 µg/L
- Cadmium – 5 µg/L
- Copper – 35 µg/L
- Iron – 200 µg/L
- Zinc – 350 µg/L

6.9 ALTERNATIVE 7: CAPPING, CONSOLIDATION, WATER MANAGEMENT AND WEST AREA TREATMENT

Alternative 7 would combine the actions included under Alternative 3b (Water Management and West Area Treatment), with the addition of:

- Consolidation of tailings pile 1, 2, and 3;
- Placement of a low-permeability cover on the consolidated tailings pile (CTP); and

- Placement of a low-permeability cover on the top surfaces of the east and west waste rock piles.

Actions included under Alternative 7 would be designed to divert upgradient surface and near-surface water around source areas and collect West Area downgradient groundwater and seepage to reduce the loading of aluminum, cadmium, copper, iron, and zinc to groundwater and surface water, and improve aquatic habitat in Railroad Creek.

Tailings pile consolidation would be performed to reduce contact between tailings materials and surface water and groundwater by reducing the overall surface area and footprint of the pile. A low-permeability cover would be installed on the CTP to reduce surface water infiltration. Under this alternative, Railroad Creek would not be relocated and riprap would be placed along the banks of Railroad Creek to reduce the potential for contact with the consolidated pile during high stream flows.

No East Area collection or treatment is included under Alternative 7, due to the expected long-term reductions in metals loading from the tailings piles resulting from consolidation and cover installation. Remediation components included under Alternative 7 are summarized on Table 6-1. The following subsections provide descriptions of the downgradient West Area collection and treatment, tailings consolidation, low-permeability cover system, and MNA included under this alternative.

6.9.1 Downgradient West Area Collection and Treatment (Hydrostatic Bulkhead)

Under Alternative 7, the collection and treatment of West Area waters would be performed as described under Alternative 3b in Section 6.3. Table 6-4 provides conceptual hydraulic and chemical influent parameters estimated for the West Area treatment system. Table 6-5 provides conceptual process sizing with chemical dosing rates, and Figures 6-13 and 6-35 provide a conceptual process flow diagram and plan view of West Area actions included under Alternative 7.

The low-energy treatment system included under Alternative 7 would be expected to produce the same effluent concentrations as described for Alternative 3:

- Aluminum – 130 µg/L
- Cadmium – 5 µg/L
- Copper – 24 µg/L
- Iron – 200 µg/L
- Zinc – 240 µg/L

6.9.2 Tailings Pile Consolidation

Tailings pile consolidation would be performed under Alternative 7 to reduce contact between tailings materials and surface water and groundwater by reducing the overall surface area and footprint of the pile. Tailings pile 1, and a portion of tailings pile 3 would be consolidated onto the existing footprint of tailings pile 2, and the pile would be reconfigured to provide finished side slopes of 2H to 1V. A buffer of approximately 50 feet would be provided between the creek and the consolidated pile (Figure 6-36).

The volumes of tailings piles 1 and 3 were estimated based on an evaluation of the areal extent of footprint of each pile, and geologic cross-sections provided in the revised DRI. The volumes of tailings piles 1 and 3 were estimated to be approximately 1.4 and 1.6 million cubic yards, respectively. The volume of tailing from tailings pile 2 that would require movement to provide a 50-foot buffer and finished side slopes of 2H to 1V was estimated to be approximately 1 million cubic yards. This was based on cross-sections developed using an existing base map provided by the Forest Service and Washington State Department of Natural Resources (DNR).

Based on the estimated volumes described above, a total of approximately 4 million cubic yards of tailings would require excavation and/or regrading to construct the consolidated tailings pile. Assuming a final footprint of approximately 1,620 feet by 1,000 feet and side slopes of 2H to 1V, the height of the consolidated pile would be approximately 180 to 190 ft (Figures 6-36 and 6-37). Consolidation would be performed using conventional earthmoving equipment, such as scrapers, bulldozers, backhoes, and haul trucks.

6.9.3 Low-permeability Cover

Under Alternative 7, the current revegetation efforts undertaken by the Forest Service would be suspended, and a low-permeability cover would be installed on the CTP (Figure 6-36). Cover installation, along with the diversion of upgradient surface and near-surface water, would be expected to further reduce water infiltration through the tailings pile than that achieved by regrading activities alone. By reducing water infiltration, the cover would be expected to reduce the primary source of metals mobility over the long term.

For cover installation, remaining vegetation on the tailings pile would be removed, and the top surface would be regraded to a minimum grade of two to three percent. Tailings pile side slopes would be regraded to provide a maximum slope angle of approximately 26.6 degrees (2H to 1V). Additional regrading may be required to provide a lower slope angle or benches as determined during the RD/RA. Materials consolidated from tailings pile 1 and 2 side slopes could be used to crest the top surface of the piles, creating a center ridgeline. The tailings could then be regraded back to the slope crest to achieve an appropriate grade.

The CTP cover would consist of the following cross-section:

- Topsoil/vegetative layer – 6 inches thick
- Cover soil layer – 18 inches thick
- Infiltration collection layer - two-sided geocomposite
- Barrier layer – 60-mil thick, linear low density (LLDPE) geomembrane, textured on both sides

- Seepage control layer – two-sided geocomposite
- Graded tailings subgrade

The textured geomembrane represents the barrier to infiltration of surface water from precipitation. The geocomposite layers above and below the geomembrane collect and divert surface infiltration of stormwater and seepage water from the slope, respectively. A reinforced layer, consisting of a geogrid or high-strength woven geotextile, would also likely be needed on the tailings pile side slopes to prevent overstressing of the geomembrane and sliding of the cover soils at the geomembrane/geocomposite interface.

Under Alternative 7, a cover system would also be installed on the top surfaces of the east and west waste rock piles. Cover systems that would be evaluated during the RD/RA include geosynthetic covers as described above, and an asphalt/concrete cover. In addition to the steps outlined above, additional preparation of the waste rock pile surfaces would be required to proved an adequate subgrade for cover placement.

Appropriate measures to manage and control stormwater runoff during construction and after cover installation would be required under this alternative. Cover system maintenance would include periodic inspection for damage or erosion, and maintenance of a good vegetative layer of shallow-rooted plants. The establishment of deep-rooted plants and trees would compromise the cover integrity.

6.9.4 Monitored Natural Attenuation for the East and West Areas

Under alternative 7, MNA would be implemented in the East Area in conjunction with upgradient water controls and capping to reduce the release of PCOCs from the tailings piles over time. Additionally, MNA would be implemented in the portions of the West Area located downgradient of groundwater collection or treatment systems.

Natural attenuation would be implemented in the East Area during the time required for water present within the tailings at the time of consolidation to drain down through the consolidated pile. This time frame was estimated to be approximately 15 to 30 years (Section 7.2.1.3). Geochemical analyses conducted for the Site indicate that natural attenuation is occurring, and the release of PCOCs from the tailings piles would significantly decline over time under the consolidation and capping scenario. The analyses indicate that following complete draindown, the release of PCOCs from the consolidated tailings pile would be reduced. The geochemical analyses and predictions of trends in chemical loading from source areas are provided in Appendix E.

Natural attenuation would also be implemented under Alternative 7 for soils and groundwater located downgradient of West Area collection systems. Following the removal of lagoon area soils (the only identified potential source area located downgradient of collection systems) from the West Area, potentially remaining PCOCs in soils and groundwater would be expected to flush out over time.

Descriptions of the natural attenuation processes and an evaluation of the achievement of MTCA expectations for natural attenuation are provided in Section 7. Groundwater and surface water monitoring for natural attenuation are generally described in Section 6.2.2 and would be specified in the OMMP.

6.10 ALTERNATIVE 8: CAPPING, CONSOLIDATION, WATER MANAGEMENT AND TREATMENT

Alternative 8 would include actions described under Alternative 7 (Capping, Consolidation, Water Management and West Area Treatment) with the addition of:

- Relocation of the east and west waste rock piles onto the consolidated tailings pile; and
- Extended East Area collection and treatment.

Actions included under this alternative are designed to provide full containment of source materials to the extent possible. Following consolidation of waste rock and tailings materials, the consolidated pile would be covered, and an extended barrier wall/groundwater intercept drain system installed downgradient of the CTP. Collected East Area groundwater would be diverted to a low-energy treatment system located to the east of the CTP for physical/chemical treatment. The collection and treatment of West Area waters would be performed as described under Alternative 3b.

Remediation components included under Alternative 8 are summarized on Table 6-1. The following subsections provide descriptions of the East and West Area collection and treatment systems.

6.10.1 Water Management and West Area Treatment (Hydrostatic Bulkhead)

Under Alternative 8, the collection and treatment of the portal drainage and seeps SP-23 and SP-12 would be performed as described under Alternative 3b. However, a majority of the loading associated with the waste rock piles would be eliminated through relocation to the CTP. Therefore, seeps SP-6, SP-8, SP-15W, SP-15E, and SP-19 would likely not need to be collected and the upper West Area collection system described under Alternative 7 would not likely be installed.

Table 6-4 provides conceptual hydraulic and chemical influent parameters estimated for the West Area treatment system. Table 6-5 provides conceptual process sizing with chemical dosing rates, and Figures 6-13 and 6-38 provide a conceptual process flow diagram and plan view of West Area collection and treatment actions included under Alternative 8. For purposes of the FS, equipment sizing was assumed to be the same as described for Alternative 3b.

The low-energy treatment system described for the West Area under Alternative 8 would be expected to produce the same effluent concentrations as described for Alternatives 3, 5, and 7:

- Aluminum – 130 µg/L
- Cadmium – 5 µg/L
- Copper – 24 µg/L
- Iron – 200 µg/L
- Zinc – 240 µg/L

The system would be designed to allow the portal discharge rates to be varied based on the water level of the mine pool, chemical dosage requirements in the East and West Areas, and seasonal discharge rates in Railroad Creek. The system would be constructed with the flexibility to allow bypass of the treatment ponds located in the lagoon area during the late fall and winter months when the West Area seeps are observed to be dry. During these periods, the portal drainage could be dosed with chemical in the maintenance yard, and all or a portion of the flow would be transferred directly to the East Area through a culvert.

6.10.2 Water Management and Extended East Area Treatment

A groundwater collection trench and barrier wall would be installed along the northern toe of the CTP as described under Alternative 4b and shown on Figures 6-39 and Figures 6-24 through 6-27 (diagrammatic cross-sections). The collection systems would be about 3,500 feet in length and constructed to intercept a majority of the seepage and groundwater flow from the CTP for physical/chemical treatment prior to discharge to Railroad Creek. The initial collection efficiency of the intercept drain/barrier wall system is estimated to be approximately 80 to 90 percent. Collected water would be treated through chemical addition, aeration, and alkaline precipitation as described under Alternative 4b in Section 6.6.2. Under Alternative 8, treated flow from the West Area may be combined with intercepted water adjacent to tailings pile 1 for alkalinity addition and pH adjustment.

Table 6-13 provides conceptual hydraulic and chemical influent parameters estimated for the East Area treatment system under Alternative 8. It is anticipated that metals loading from the consolidated pile would not be immediately reduced, due to the expected length of time for existing water present in the tailings to drain down through the system. Additionally, due to the significant movement and reoxidation of tailings that would be required to implement this alternative, short-term water quality may be degraded, and the treatment system would need to be sized accordingly. Based on the flow net analysis described in Section 6.6.1, flow tubes TP1 through TP13 and S7 through S15 would continue to contact the CTP in the spring and flow tubes TP1 through TP13 and S7 through S15 would continue to flow beneath the pile in the fall (Table 6-13). Based on this analysis a nominal peak flow of 1,400 gpm was assumed for treatment system sizing.

Table 6-12 provides conceptual process sizing, with chemical dosing rates. Figure 6-23 provides a conceptual process flow diagram for the East Area treatment system. The sizing of the processes options was based on the estimated hydraulic and chemical loading.

The low-energy treatment system described under Alternative 8 for the East Area would be expected to produce the same effluent concentrations as described for Alternatives 4, 5, and 6:

- Aluminum – 130 µg/L
- Cadmium – 5 µg/L
- Copper – 35 µg/L
- Iron – 200 µg/L
- Zinc – 350 µg/L

6.10.3 Monitored Natural Attenuation in the West Area

Under alternative 8, MNA would be implemented in the West Area for areas located outside the influence of groundwater collection systems. Because Alternative 8 includes the relocation of the east and west waste rock piles to the consolidated tailings pile, a groundwater collection system as described for Alternative 7 would not be installed in the West Area. Residual PCOCs remaining in groundwater and soils in this area would be expected to flush out over time.

The geochemical analyses provided in Appendix E indicate that natural attenuation is occurring in the East and West Areas and is expected to reduce metals loading from waste rock, the underground mine, and tailings piles over time. Treatment requirements for the East and West Areas are therefore expected to be reduced in the long-term.

Descriptions of the natural attenuation processes and an evaluation of the achievement of MTCA expectations for natural attenuation are provided in Section 7. Groundwater and surface water monitoring for natural attenuation are generally described in Section 6.2.3 and would be specified in the OMMP.

Table 6-1
Candidate Site-wide Remedial Alternative Summary Matrix

No.	Site-Wide Alternative	Institutional Controls/Physical Access Restrictions	Physical Access Restrictions	Deed Restrictions	Monitoring	Surface/Groundwater Quality Monitoring	Tailings Pile Slope Stability Monitoring	Cover Monitoring	Natural Attenuation	Natural Attenuation - East Area	Natural Attenuation - West Area	Mine Actions	Access/Air-flow Restrictions In Adits	1500-level Hydrostatic Bulkheads	Collection & Treatment of Portal Drainage	Mill Building/Maint Yard Actions	Upgradient Water Diversion	Engineered Cover for Impacted Soils	Excavate Impacted Soils & Onsite Relocation	Downgradient Water Collection & Treatment	Waste Rock Pile Actions	Upgradient Water Diversion	Downgradient Water Collection & Treatment	Low Permeability Cover	Relocate to Consolidated Tailings Pile	Lagoon Soil Actions	Excavate Impacted Soils & Onsite Relocation	Downgradient Water Collection & Treatment	Secondary West Area Collection System	Lower West Area Collection System	Extended Lower West Area Collection System	West Area Treatment System	Low-energy Alkaline Precipitation System	Mechanical HDS Treatment System	Tailings Actions	Revegetation	Upgradient Water Diversion	Extended Copper Creek Culvert	Slope Stability Actions	Develop Rip-rap Source	Enhance Rip-rap at Toe of Tailings	Partial Seep/Groundwater Collection & Treat	Extended Seep/Groundwater Collect & Treat	Low-permeability Cover	Tailings Pile Consolidation	Railroad Creek Actions	Partial Relocation of Railroad Creek	Extended Relocation of Railroad Creek
1	1 - No Action/Institutional Controls		●	●		●	●																																									
2	2a - Water Management (Open Portal):		●	●		●	●	●		●	●		●				●	●	●			●					●									●	●		●	●	●							
	2b - Water Management (Hydrostatic Bulkheads):		●	●		●	●	●		●	●		●	●			●	●	●			●					●									●	●		●	●	●							
3	3a - Water Management and Low-Energy West Area Treatment (Open Portal):		●	●		●	●	●		●	●		●		●		●	●	●	●		●	●				●						●			●	●		●	●	●							
	3b - Water Management and Low-Energy West Area Treatment (Hydrostatic Bulkheads):		●	●		●	●	●		●	●		●	●	●		●	●	●	●		●	●				●						●			●	●		●	●	●							
4	4a - Water Management, and Partial East Area Collection and Treatment:		●	●		●	●	●		●	●		●	●			●	●	●			●					●									●	●	●	●	●	●	●					●	
	4b - Water Management, and Extended East Area Collection and Treatment:		●	●		●	●	●			●		●	●			●	●	●			●					●									●	●	●	●	●	●		●				●	
	4c - Water Management, Extended Railroad Creek Relocation, and Extended East Area Collection and Treatment:		●	●		●	●	●			●		●	●			●	●	●			●					●									●	●	●	●	●			●					●
5	5a - Water Management, Partial East Area Collection, and East/West Area Treatment (Low-Energy WTP):		●	●		●	●	●		●	●		●	●	●		●	●	●	●		●	●				●						●			●	●	●	●	●	●	●					●	
	5b - Water Management, Extended East Area Collection, and East/West Area Treat. (Low-Energy WTP):		●	●		●	●	●			●		●	●	●		●	●	●	●		●	●				●						●			●	●	●	●	●	●		●				●	
	5c - Water Management, Extended Railroad Creek Relocation, and East/West Area Treat (Low-Energy WTP):		●	●		●	●	●			●		●	●	●		●	●	●	●		●	●				●						●			●	●	●	●	●			●					●
	5d - Water Management, Secondary West Area Collection, Extended Railroad Creek Relocation, and East/West Area Treat (Low-Energy WTP):		●	●		●	●	●					●	●	●		●	●	●	●		●	●				●	●		●			●			●	●	●	●	●			●					●

Table 6-1
Candidate Site-wide Remedial Alternative Summary Matrix

No.	Site-Wide Alternative	***Institutional Controls/Physical Access Restrictions***	Physical Access Restrictions	Deed Restrictions	***Monitoring***	Surface/Groundwater Quality Monitoring	Tailings Pile Slope Stability Monitoring	Cover Monitoring	***Natural Attenuation***	Natural Attenuation - East Area	Natural Attenuation - West Area	***Mine Actions***	Access/Air-flow Restrictions In Adits	1500-level Hydrostatic Bulkheads	Collection & Treatment of Portal Drainage	***Mill Building/Maint Yard Actions***	Upgradient Water Diversion	Engineered Cover for Impacted Soils	Excavate Impacted Soils & Onsite Relocation	Downgradient Water Collection & Treatment	***Waste Rock Pile Actions***	Upgradient Water Diversion	Downgradient Water Collection & Treatment	Low Permeability Cover	Relocate to Consolidated Tailings Pile	***Lagoon Soil Actions***	Excavate Impacted Soils & Onsite Relocation	Downgradient Water Collection & Treatment	***Secondary West Area Collection System***	Lower West Area Collection System	Extended Lower West Area Collection System	***West Area Treatment System***	Low-energy Alkaline Precipitation System	Mechanical HDS Treatment System	***Tailings Actions***	Revegetation	Upgradient Water Diversion	Extended Copper Creek Culvert	Slope Stability Actions	Develop Rip-rap Source	Enhance Rip-rap at Toe of Tailings	Partial Seep/Groundwater Collection & Treat	Extended Seep/Groundwater Collect & Treat	Low-permeability Cover	Tailings Pile Consolidation	***Railroad Creek Actions***	Partial Relocation of Railroad Creek	Extended Relocation of Railroad Creek
6	**6a - Water Management, Extended Secondary West Area Collection, Extended Railroad Creek Relocation, and East/West Area Treatment (Mechanical West Area WTP):**		●	●		●	●	●					●		●		●	●	●	●		●	●				●	●			●			●		●	●	●	●	●			●					●
	6b - Water Management, Extended Secondary West Area Barrier Wall, Extended Railroad Creek Relocation, and East/West Area Treat (Mechanical West Area WTP with Bulkhead):		●	●		●	●	●					●	●	●		●	●	●	●		●	●				●	●			●			●		●	●	●	●	●			●					●
7	**7 - Capping, Consolidation, Water Management, and West Area Treatment (Low-Energy WTP):**		●	●		●	●	●		●	●		●	●	●		●	●	●	●		●	●	●			●										●		●	●	●			●	●			
8	**8 - Source Control and East/West Area Treatment (Low-Energy WTP):**		●	●		●	●	●			●		●	●	●		●	●	●	●		●			●		●	●					●				●	●	●	●	●		●	●	●			

Table 6-2
Portal Drainage and Water Height Calculation Summary
November 1997 - October 1999

Dates		Portal P-1 Transducer Data (1)		12-Month Discharge			
		Total Monthly Portal Discharge from Portal (ft^3)	Average Portal Flow (cfs)	Hydrostatic Bulkhead Status	Discharge Setting on Hydrostatic Bulkhead (cfs)	Total Monthly Discharge from Bulkhead (ft^3)	Volume of Water in the Mine Above the 1500-Level Portal (2) (ft^3)
1997	Nov 1 - Nov 30	897,124	0.35	Low Flow	0.15	388,800	508,324
	Dec 1 - Dec 31	393,746	0.16			401,760	500,310
1998	Jan 1 - Jan 31	137,578	0.05			401,760	236,128
	Feb 1 - Feb 28	184,311	0.08			362,880	57,559
	Mar 1 - Mar 31	120,732	0.04			401,760	0
	Apr 1 - Apr 30	1,416,116	0.67	Ramp Up	0.3	777,600	638,516
	May 1 - May 31	2,231,685	1.01	High Flow Condition	0.6	1,607,040	1,263,161
	Jun 1 - Jun 30	1,324,666	0.51			1,555,200	1,032,628
	Jul 1 - Jul 31	717,055	0.27			1,607,040	142,642
	Aug 1 - Aug 31	464,022	0.17	Ramp Down	0.3	803,520	0
	Sept 1 - Sept 30	334,848	0.13	Low Flow	0.15	388,800	0
	Oct 1 - Oct 31	288,255	0.11			401,760	0
	Nov 1 - Nov 30	324,688	0.13			388,800	0
	Dec 1 - Dec 31	529,537	0.20			401,760	127,777
1999	Jan 1 - Jan 31	694,670	0.26			401,760	420,687
	Feb 1 - Feb 28	544,174	0.23			362,880	601,981
	Mar 1 - Mar 31	390,416	0.15			401,760	590,637
	Apr 1 - Apr 30	654,308	0.25	Ramp Up	0.4	1,036,800	208,145
	May 1 - May 31	1,907,420	0.71	High Flow Condition	0.6	1,660,608	454,958
	Jun 1 - Jun 30	2,714,136	1.05			1,607,040	1,562,053
	Jul 1 - Jul 31	1,227,722	0.46			1,660,608	1,129,168
	Aug 1 - Aug 31	704,909	0.26	Ramp Down	0.4	1,178,496	655,581
	Sept 1 - Sept 30	480,803	0.19	Bulkhead set at low flow	0.2	518,400	617,984
	Oct 1 - Oct 31	307,383	0.11			535,680	389,687

(1) Calculations based on measurements recorded by the Troll at portal station P-1
(2) Volume of water stored in mine behind the bulkhead

Table 6-3
Portal Drainage and Detention Pond Footprint Summary
November 1997 - October 1999

Dates	Portal P-1 Transducer Data (1)		12-Month Discharge				
	Total Monthly Portal Discharge from Portal (ft^3)	Average Portal Flow (cfs)	Detention Pond Outflow Status	Detention Pond Outlet Discharge Setting (cfs)	Total Monthly Discharge from Detention Pond (ft^3)	Volume of Water in Detention Pond (ft^3)	Minimum Footprint of 10' Deep Detention Pond (acres)
1997 Nov 1 - Nov 30	897,124	0.35	Low Flow	0.15	388,800	508,324	1.2
Dec 1 - Dec 31	393,746	0.16			401,760	500,310	1.1
1998 Jan 1 - Jan 31	137,578	0.05			401,760	236,128	0.5
Feb 1 - Feb 28	184,311	0.08			362,880	57,559	0.1
Mar 1 - Mar 31	120,732	0.04			401,760	0	0.0
Apr 1 - Apr 30	1,416,116	0.67	Ramp Up	0.3	777,600	638,516	1.5
May 1 - May 31	2,231,685	1.01	High Flow Condition	0.6	1,607,040	1,263,161	2.9
Jun 1 - Jun 30	1,324,666	0.51			1,555,200	1,032,628	2.4
Jul 1 - Jul 31	717,055	0.27			1,607,040	142,642	0.3
Aug 1 - Aug 31	464,022	0.17	Ramp Down	0.3	803,520	0	0.0
Sept 1 - Sept 30	334,848	0.13	Low Flow	0.15	388,800	0	0.0
Oct 1 - Oct 31	288,255	0.11			401,760	0	0.0
Nov 1 - Nov 30	324,688	0.13			388,800	0	0.0
Dec 1 - Dec 31	529,537	0.20			401,760	127,777	0.3
1999 Jan 1 - Jan 31	694,670	0.26			401,760	420,687	1.0
Feb 1 - Feb 28	544,174	0.23			362,880	601,981	1.4
Mar 1 - Mar 31	390,416	0.15			401,760	590,637	1.4
Apr 1 - Apr 30	654,308	0.25	Ramp Up	0.4	1,036,800	208,145	0.5
May 1 - May 31	1,907,420	0.71	High Flow Condition	0.6	1,660,608	454,958	1.0
Jun 1 - Jun 30	2,714,136	1.05			1,607,040	1,562,053	3.6
Jul 1 - Jul 31	1,227,722	0.46			1,660,608	1,129,168	2.6
Aug 1 - Aug 31	704,909	0.26	Ramp Down	0.4	1,178,496	655,581	1.5
Sept 1 - Sept 30	480,803	0.19	Bulkhead set at low flow	0.2	518,400	617,984	1.4
Oct 1 - Oct 31	307,383	0.11			535,680	389,687	0.9

(1) Calculations based on measurements recorded by the Troll at portal station P-1

Table 6-4
Conceptual West Area Hydraulic and Chemical Influent Parameters

Source Area	Spring Data								Fall Data							
	Peak Flow[a,b] (gpm)	Dissolved Metals Concentrations[c,d] Al (mg/L)	Cd (mg/L)	Cu (mg/L)	Fe (mg/L)	Mg (mg/L)	Zn (mg/L)	Sulfate (mg/L)	Flow[a,b] (gpm)	Dissolved Metals Concentrations[c,d] Al (mg/L)	Cd (mg/L)	Cu (mg/L)	Fe (mg/L)	Mg (mg/L)	Zn (mg/L)	Sulfate (mg/L)
1500 Main Portal (No Bulkhead)	1180	13.2	0.08	5.8	0.24	10.7	14.9	270	95	0.02	0.008	0.08	0.11	9.8	3.28	310
1500 Main Portal (With Bulkhead)	270	17	0.10	12	2	26	21	720	90	17	0.10	12	2	26	21	720
Alternative 3 Seeps[e]										-	-	-	-	-	-	-
SP-23	201	7.89	0.04	6.9	0.01	5.1	5.0	130	0	-	-	-	-	-	-	-
SP-23B	27	5.25	0.03	4.9	0.01	3.9	3.6	100	0	-	-	-	-	-	-	-
SP-12	27	1.38	0.01	2.0	0.01	1.5	2.2	45	0	-	-	-	-	-	-	-
SP-6	6	14.6	0.17	12.7	0.03	15	22	600	0	-	-	-	-	-	-	-
SP-7	61	0.19	0.03	2.8	0.12	4.8	4.3	79	0[i]	-	-	-	-	-	-	-
SP-8	9	9.6	0.09	7.9	0.03	5.4	11	240	0	-	-	-	-	-	-	-
SP-15W	30	0.03	0.01	0.2	0.01	2.6	2.3	78	0	-	-	-	-	-	-	-
Total Seep Flow/Blended Conc	359	5.4	0.036	5.3	0.029	4.6	4.8	118	0	-	-	-	-	-	-	-
W. Area GW Collection (Alts 3, 5a/b/c/d, 6, 7)[f]	507								285							
Total Flow/Blended Conc (Alternative 3a, 6a)[g]	**2050**	**9.9**	**0.06**	**5.6**	**0.15**	**8.1**	**10.6**	**205**	**380**	**4.1**	**0.03**	**4.0**	**0.05**	**5.9**	**4.4**	**166**
Total Flow/Blended Conc (Alternatives 3b, 5a/b/c/d, 6b,7)[g]	**1140**	**8.1**	**0.05**	**6.8**	**0.50**	**9.7**	**8.6**	**261**	**380**	**8.1**	**0.05**	**6.8**	**0.50**	**9.6**	**8.5**	**259**
Total Flow/Blended Conc (Alternative 8)[h]	**580**	**10.9**	**0.06**	**8.5**	**0.94**	**14.5**	**12.1**	**392**	**90**	**17**	**0.10**	**12.0**	**2.00**	**26**	**21**	**720**

a. 1500-level Main Portal (no bulkhead) and seep flows obtained from 1997 flow data presented in Appendix A and adjusted to account for collection efficiencies.
b. 1500-level Main Portal (with bulkhead) flow obtained from high flow conditions calculations presented in Table 6-3.
c. 1500-level Main Portal and seeps metal concentrations obtained from May 1997 and September 1997 data presented in Appendix A.
d. 1500 Main Portal (with bulkhead) metals concentrations obtained from geochemical calculations presented in Appendix B.
e. Seep flows are adjusted by a collection efficiency factor of 90%
f. Estimated downgradient groundwater collection (upper barrier wall @ 90% collection efficiency) is assumed to equal 507 gpm (spring) and 285 gpm (fall).
g. Total flows/blended concentrations = Portal flow, seeps & collected groundwater. Blended seep (spring) concentrations assumed for collected groundwater concentrations.
h. Total flows/blended concentrations = Portal flow & collected seeps. Alternative 8 assumes collection of portal discharge and seeps SP-23, SP-23B, SP-12, and SP-7 only. No groundwater collection is assumed for Alternative 8.
i. Flow from seep SP-7 reported as "very low" for September 1997. Contribution of flow/metals to treatment plant influent from SP-7 assumed to be negligible.

Table 6-5
Conceptual Process Sizing - West Area Treatment

Process	Parameter	Units	Low Energy Treatment System			Mechanical Treatment System	
			Open 1500-Level Portal (Alt 3a)	1500-Level Hydrostatic Bulkheads (Alts 3b, 5a, 5b, 5c, 5d, & 7)	1500-Level Hydrostatic Bulkheads (Alt 8)	Open 1500-Level Portal (Alt 6a)	1500-Level Hydrostatic Bulkheads (Alt 6b)
System	Peak Capacity[a]	gpm	2,050	1,140	580	2,050	1,140
	Annual Water Treated[b]	MG	300	300	120	300	300
Chemical Addition	Annual Usage[c]	ton	57	57	22	57	57
	Hopper Size	gallon	4,000	4,000	1,600	4,000	4,000
Clarification / Sedimentation	Annual Dry Sludge Production[d]	ton	300	450	310	300	450
	Annual Wet Sludge Production[e]	yd^3	18,000	27,000	18,000	18,000	27,000
	Total Capacity[f]	MG	3.5	5.3	3.6	0.29	0.16
	Surface Area	ft^2	40,000	61,000	42,000	2,900	1,600
	Hydraulic Detention Time[g]	min	-	-	-	140	140
	Basin Depth	ft	12	12	12	13	13
	Overflow Rate	gpd/ft^2	73	27	20	1,000	1,000
Filtration	Total Surface Area	ft^2	20,000	11,000	5,800	4,100	2,300
	Depth of Media	ft	5	5	5	4	4
	Overflow Rate	gpm/ft^2	0.1	0.1	0.1	0.5	0.5

a. Peak capacity assumed to peak flow, data presented in Table 6-4.
b. Annual portal flow data from 1999 portal transducer data (Table 6-2). Annual seep & groundwater flows based on data presented in Table 6-4.
High-flow (spring) seep and groundwater flow assumed for 3 months, Low-flow (fall) seep and groundwater flow assumed for 9 months.
c. Assumes a chemical dosage of 45 mg/L, dosage required to raise pH to 9, June 2000 treatability results.
d. Assumes precipitation of total metals, sulfate, and dosed chemical.
e. Estimated using concentration of 2% solids.
f. Low energy system sized for annual cleanout of sludge. Mechanical system for detention time at peak flow.
g. For low energy system this value will vary depending on flow and volume of sludge in settling pond (sized for annual sludge cleanout).

Table 6-6
Summary of Ten Alkaline Precipitation Treatment Systems

Site, Location	General Treatment Type	Primary System Components	Flow (gpm)		Influent (mg/l)	Effluent (mg/l)	Years of Operation	Reference
LOW ENERGY SYSTEMS								
Crystal Mine, Montana	Aquafix (low-energy chemical addition)	Quicklime neutralization with AquaFix feeder followed by aeration in riprap lined channels and suspended solids removal in settling ponds.	20 - 100	pH	3.04	11.41	2 Yr Period	MSE 1998; Elbow Creek Engineering 2004
				Sulfate	--	--		
				Fe	50	0.02		
				Zn	65	0.4		
				Cu	14.7	0.04		
				Cd	0.86	0.005		
Elbow Creek Site 4, North America	Alkaline precipitation and clarification (Low-energy plant)	Automated hydrated lime feed/neutralization with flocculant addition and removal of suspended solids in two 3-million gallon settling ponds	200 - 6,000	pH	5 - 6	7 - 8	Mid 1990's to Present	Elbow Creek Engineering 2004
				Sulfate	--	--		
				Fe	30.8	0.29		
				Zn	0.90	0.05		
				Cu	0.30	0.004		
				Cd	0.015	0.0003		
St Salvy Mine, France	Alkaline precipitation and clarification (Low-energy plant)	Lime neutralization Polymer addition Clarification (lamellar settling) Polishing in anaerobic/aerobic wetland Centrifugation (sludge dewatering)	32-476	pH	6.5	7.1	1997 to Present	SRK 1995a; SRK 1996
				Sulfate	1460	234		
				Fe	7.2	0.43		
				Zn	72.8	0.28		
				Cu	--	--		
				Cd	0.4	0.002		
Ynysarwed, South Wales, UK	Alkaline precipitation and clarification (Low-energy plant)	Lime neutralization Aeration - Mechanical Polymer addition Clarification (lamellar settling) Aerobic wetland Centrifugation (sludge dewatering)	571	pH	4.5	8	2000 to Present	Ranson, Reynolds & Smith 1998; SRK 1994a
				Sulfate	--	--		
				Fe	200	< 1		
				Zn	--	--		
				Cu	--	--		
				Cd	--	--		
Whitworth #1	Anaerobic/aerobic wetland treatment	Two anaerobic wetland treatment cells Two aerobic wetland treatment cells	48	pH	6	6.1	1995 to Present	Dey, Bowell, Williams, & Rees 2001; Ranson, Reynolds & Smith 1998; Rees Bowell & Wildman 2002; SRK 1994b; SRK 1995b
				Sulfate	--	--		
				Fe	24.2	4.3		
				Zn	--	--		
				Cu	--	--		
				Cd	--	--		

Table 6-6
Summary of Ten Alkaline Precipitation Treatment Systems

Site, Location	General Treatment Type	Primary System Components	Flow (gpm)		Influent (mg/l)	Effluent (mg/l)	Years of Operation	Reference
MECHANICAL SYSTEMS								
Elbow Creek Site 2, North America	High density sludge (HDS) with sulfide precipitation	HDS system Sulfide injection Clarification Filtration	5,000 - 15,000	pH	5.5	9.8	1998 - 2001	Elbow Creek Engineering 2004
				Sulfate	2273	2106		
				Fe	9.3	0.21		
				Zn	265	0.06		
				Cu	0.087	0.002		
				Cd	2.71	0.003		
Elbow Creek Site 1, North America	HDS	HDS system Clarification	3,800	pH	3.98	9.22	1992 - 2001	Elbow Creek Engineering 2004
				Sulfate	2050	1876		
				Fe	190	0.02		
				Zn	40	0.02		
				Cu	0.18	0.008		
				Cd	0.075	< 0.002		
Elbow Creek Site 3, North America	Alkaline precipitation with sludge recycle	Alkaline precipitation Sludge recycle Clarification	1,000	pH	3.18	8.87	1999 - 2001	Elbow Creek Engineering 2004
				Sulfate	--	--		
				Fe	135	0.19		
				Zn	13	0.05		
				Cu	32	0.07		
				Cd	--	--		
Wheal Jane Mine, Baldu, Cornwall, UK	HDS	HDS system Aeration Clarification	4000	pH	3.8	9	2001 to Present	Coulton, Bullen, Dolan, Hallet, Wright & Marsden 2002; Hyder Engineering 2000; Environment Agency 2002
				Sulfate	520	465		
				Fe	1.59	1.3		
				Zn	44	0.4		
				Cu	0.4	<0.1		
				Cd	0.056	<0.001		
Woolley, West Yorkshire, UK	HDS	HDS system Aeration Settling ponds Flow-through settling lagoons Aerobic wetland	2600	pH	--	--	2000 to Present	Birse Construction 2000; Ranson, Reynolds & Smith 1998; SRK 1994a
				Sulfate	--	--		
				Fe	16	0.3		
				Zn	--	--		
				Cu	--	--		
				Cd	--	--		

-- = not available or above the APA assumed effluent water quality

References:
Coulton, et al. 2002; Dey, et al. 2001; ECE 2004; EA 2002; HE 2000; Ranson, et al. 1998; Rees, et al. 2001; Rees, et al. 2002; SRK 1994a; SRK 1994b; SRK 1995a; SRK 1995b; SRK 1996.

Table 6-7
Summary of Historical Two-week Portal Drainage Volumes

Two-week Period Ending --------	Total Portal Discharge (Gallons)	Total Portal Discharge (Cubic Feet)	Footprint Area of 10' Deep Pond to Contain 2 Weeks Discharge (Acres)
6/7/2002	11,353,901	1,517,901	3.5
6/8/2002	11,344,501	1,516,645	3.5
6/3/2002	11,298,989	1,510,560	3.5
6/6/2002	11,298,430	1,510,485	3.5
6/7/1999	11,276,615	1,507,569	3.5
6/8/1999	11,263,639	1,505,834	3.5
6/4/2002	11,248,622	1,503,826	3.5
6/5/2002	11,235,066	1,502,014	3.4
6/9/2002	11,217,184	1,499,624	3.4
6/2/2002	11,184,072	1,495,197	3.4
6/9/1999	10,963,664	1,465,730	3.4
6/10/2002	10,953,053	1,464,312	3.4
6/6/1999	10,926,851	1,460,809	3.4
6/1/2002	10,915,365	1,459,273	3.4
6/10/1999	10,706,387	1,431,335	3.3
5/21/1998	10,681,676	1,428,032	3.3
6/11/2002	10,539,415	1,409,013	3.2
6/19/1999	10,529,170	1,407,643	3.2
5/31/2002	10,520,010	1,406,418	3.2
6/11/1999	10,519,796	1,406,390	3.2
6/18/1999	10,474,341	1,400,313	3.2
6/5/1999	10,467,821	1,399,441	3.2
6/20/1999	10,461,132	1,398,547	3.2
6/21/1999	10,321,843	1,379,926	3.2
6/12/1999	10,318,310	1,379,453	3.2
6/17/1999	10,296,704	1,376,565	3.2
6/22/1999	10,157,926	1,358,011	3.1
6/13/1999	10,135,380	1,354,997	3.1
6/16/1999	10,135,224	1,354,976	3.1
5/22/1998	10,109,079	1,351,481	3.1
6/15/1999	10,075,220	1,346,954	3.1
6/4/1999	10,070,754	1,346,358	3.1
6/23/1999	10,042,997	1,342,647	3.1
6/14/1999	10,041,883	1,342,498	3.1
5/30/2002	10,001,972	1,337,162	3.1
6/12/2002	9,996,322	1,336,407	3.1
6/24/1999	9,986,205	1,335,054	3.1
6/25/1999	9,964,442	1,332,145	3.1
6/26/1999	9,924,182	1,326,762	3.0
6/27/1999	9,855,041	1,317,519	3.0

Calculations are based on available portal transducer data for October 1997 - October 2003.

Table 6-8
Partial and Extended Groundwater and Seep Collection - Spring 1997 Data
System Constructed East of Tailings Pile 1

Flow Tube Designation	Referenced Wells & Seeps	Estimated Flow (gpm)	Estimated Flow Capture (a): Partial Collection (gpm)	Extended collection (gpm)	Ext. w/ RRC Relocation (gpm)			Al	Al: Partial Collection (kg/day)	Extended Collection (kg/day)	Ext. w/ RRC Relocation (kg/day)			Cd	Cd: Partial Collection (kg/day)	Extended Collection (kg/day)	Ext. w/ RRC Relocation (kg/day)			Cu	Cu: Partial Collection (kg/day)	Extended Collection (kg/day)	Ext. w/ RRC Relocation (kg/day)		
			Alts 4a, 5a	Alts 4b, 5b	Alts 4c, 5c	Alt 5d	Alts 6a, 6b	(mg/L)	Alts 4a, 5a	Alts 4b, 5b	Alts 4c, 5c	Alt 5d	Alts 6a, 6b	(mg/L)	Alts 4a, 5a	Alts 4b, 5b	Alts 4c, 5c	Alt 5d	Alts 6a, 6b	(mg/L)	Alts 4a, 5a	Alts 4b, 5b	Alts 4c, 5c	Alt 5d	Alts 6a, 6b
SP-1	SP-1	15	0	12	12	12	12	27	0	1.8	1.8	1.8	1.8	0.023	0	0.001	0.001	0.001	0.001	0.70	0	0.046	0.046	0.046	0.046
Tailings (b)	SP-1, SP-2	16	3.3	13	13	13	13	61	1.1	4.4	4.4	4.4	4.4	0.023	0	0.002	0.002	0.002	0.002	0.81	0.015	0.058	0.058	0.058	0.058
SP-2	SP-2	15	12	12	12	12	12	95	6.2	6.2	6.2	6.2	6.2	0.023	0.001	0.001	0.001	0.001	0.001	0.91	0.060	0.060	0.060	0.060	0.060
S2	TP1-6A	27	0	22	22	22	22	46	0	5.5	5.5	5.5	5.5	0.10	0	0.012	0.012	0.012	0.012	1.10	0	0.13	0.13	0.13	0.13
S3	TP1-2A	28	22	22	22	22	22	7.1	0	0.86	0.86	0.86	0.86	0.0003	0.000	0.000	0.000	0.000	0.000	0.001	0.000	0.000	0.000	0.000	0.000
S4	TP1-2A, TP1-3A	55	44	44	44	44	44	4.6	0	1.1	1.1	1.1	1.1	0.001	0.000	0.000	0.000	0.000	0.000	0.001	0.000	0.000	0.000	0.000	0.000
S5	TP1-5A	34	28	28	28	28	28	103	16	16	16	16	16	0.010	0.002	0.002	0.002	0.002	0.002	0.20	0.030	0.030	0.030	0.030	0.030
S6	TP1-5A	56	45	45	45	45	45	103	25	25	25	25	25	0.010	0.002	0.002	0.002	0.002	0.002	0.20	0.048	0.048	0.048	0.048	0.048
S7	TP2-11	75	0	60	60	60	60	0.33	0	0.11	0.11	0.11	0.11	0.002	0	0.001	0.001	0.001	0.001	0.010	0	0.003	0.003	0.003	0.003
S8	TP2-11	63	0	51	51	51	51	0.33	0	0.092	0.09	0.09	0.09	0.002	0	0.000	0.000	0.000	0.000	0.010	0	0.003	0.003	0.003	0.003
S9	TP2-11	21	0	16	16	16	16	0.33	0	0.030	0.030	0.030	0.030	0.002	0	0.000	0.000	0.000	0.000	0.010	0	0.001	0.001	0.001	0.001
TP1	SP-3	1.6	0	1.3	1.3	1.3	1.3	33	0	0.23	0.23	0.23	0.23	0.040	0	0.000	0.000	0.000	0.000	1.3	0	0.009	0.009	0.009	0.009
TP2	SP-3	2.7	0	2.2	2.2	2.2	2.2	33	0	0.40	0.40	0.40	0.40	0.040	0	0.000	0.000	0.000	0.000	1.3	0	0.015	0.015	0.015	0.015
TP3	SP-3	2.9	0	2.3	2.3	2.3	2.3	33	0	0.42	0.42	0.42	0.42	0.040	0	0.001	0.001	0.001	0.001	1.3	0	0.016	0.016	0.016	0.016
Deep GW and/or GW from N Side Old RRC (c)			72	-	332	332	332	-	0.21	-	0.02	0.02	0.02	-	0.00	-	0.00	0.000	0.000	-	0.00	-	0.00	0.00	0.00
Collected GW from W Area (Alts 5d, 6a, 6b) (d)			-	-	-	52	351	-	-	-	-	0.01	0.06	-	-	-	-	1.50	1.51	-	-	-	-	0.01	0.01
Unaccounted loading (e)								-	-	-	-	-	-	-	0.005	0.019	0.019	0.019	0.019	-	-	-	-	-	-
TOTAL:		**412**	**225**	**330**	**661**	**713**	**1013**	**-**	**48**	**62**	**62**	**62**	**62**	**-**	**0.011**	**0.042**	**0.042**	**1.540**	**1.554**	**-**	**0.15**	**0.42**	**0.42**	**0.43**	**0.43**
BLENDED CONC (mg/L)								**-**	**39**	**34**	**17**	**16**	**11**	**-**	**0.009**	**0.023**	**0.012**	**0.394**	**0.280**	**-**	**0.12**	**0.23**	**0.12**	**0.11**	**0.08**

Notes:

Source: Site-wide loading analysis Table A-3 and Figures A-7 and A-8

(a) Captured flow was estimated by multiplying the estimated flow by the appropriate expected collection efficiency (E[CE]) for source area. Expected collection efficiencies for each source area are presented on Tables D1-5 & D1-8 (partial collection), D1-6 & D1-9 (extended collection), and D1-7, D1-10, D1-10a, D1-11, & D1-12 (extended collection + RRC relocation) of the Draft Final FS Report.

Source Area	Partial	Extended	RRC Relocation
TP-1 Seeps & Flow Tubes	80%	80%	80%
TP-2 Seeps & Flow Tubes (Upstream of RC-7)	0%	80%	80%
TP2/3 Seeps & Flow Tubes (Downstream of RC-7)	80%	80%	80%
Unaccounted Load - East Area	20%	80%	80%
Loading downstream of RC-2 (SP-21)	95%	95%	95%
Loading Downstream of RC-2 (Flow Tubes)	90%	90%	90%

(b) Assumes 25% of groundwater in the tailings unit captured with a 80% collection efficiency for partial East Area collection. For extended East Area collection, 100% of the groundwater in the tailings unit is assumed to be captured with a collection efficiency of 80% for extended collection and extended collection + RRC relocation.

(c) Water quality for collected deep groundwater assumed to equal average of measured concentrations from wells DS-3D and DS-4D. Water quality for groundwater from the north side of former RRC channel assumed to equal Fall 1997 water quality in RRC at station RC-4.

(d) Collected groundwater from lower W Area barrier walls is conveyed to the E Area for Alts 5d, 6a, & 6b. Water quality for water intercepted by the lower barrier wall from RC-4 to P-5 assumed to equal total seep/flow blended concentration for W Area (see Table 6-4). Water quality of groundwater collected by lower barrier wall from P-5 to SP-26 assumed to equal backgoround concentrations (from well HV-3). Note that for Alts 6a & 6b seep SP-26 is also collected and conveyed to the E Area treatment systyem.

(e) Unaccounted loading based on loading analysis provided in Appendix A. If unaccounted loading was positive, captured unaccounted loading was estimated by multiplying baseline unaccounted loading by estimated collection efficiency (E[CE]) and the ratio of RRC banklength from RC-4 to the end of the wetland east of TP-1 (2,200 ft) divided by the RRC banklength from RC-4 to RC-2 (5,000 ft). If baseline unaccounted loading was negative, the captured unaccounted loading was assumed to be zero.

Table 6-8
Partial and Extended Groundwater and Seep Collection - Spring 1997 Data
System Constructed East of Tailings Pile 1

Flow Tube Designation	Referenced Wells & Seeps	Estimated Flow (gpm)	Estimated Flow Capture (a): Partial Collection (gpm)	Extended collection (gpm)	Ext. w/ RRC Relocation (gpm)			Fe (mg/L)	Fe: Partial Collection (kg/day)	Extended Collection (kg/day)	Ext. w/ RRC Relocation (kg/day)		
			Alts 4a, 5a	Alts 4b, 5b	Alts 4c, 5c	Alt 5d	Alts 6a, 6b		Alts 4a, 5a	Alts 4b, 5b	Alts 4c, 5c	Alt 5d	Alts 6a, 6b
SP-1	SP-1	15	0	12	12	12	12	542	0	35	35	35	35
Tailings (b)	SP-1, SP-2	16	3.3	13	13	13	13	515	9	37	37	37	37
SP-2	SP-2	15	12	12	12	12	12	487	32	32	32	32	32
S2	TP1-6A	27	0	22	22	22	22	145	0	17	17	17	17
S3	TP1-2A	28	22	22	22	22	22	321	39	39	39	39	39
S4	TP1-2A, TP1-3A	55	44	44	44	44	44	333	80	80	80	80	80
S5	TP1-5A	34	28	28	28	28	28	246	37	37	37	37	37
S6	TP1-5A	56	45	45	45	45	45	246	60	60	60	60	60
S7	TP2-11	75	0	60	60	60	60	0.01	0	0.003	0.003	0.003	0.003
S8	TP2-11	63	0	51	51	51	51	0.01	0	0.003	0.003	0.003	0.003
S9	TP2-11	21	0	16	16	16	16	0.01	0	0.001	0.001	0.001	0.001
TP1	SP-3	1.6	0	1.3	1.3	1.3	1.3	154	0	1.1	1.1	1.1	1.1
TP2	SP-3	2.7	0	2.2	2.2	2.2	2.2	154	0	1.8	1.8	1.8	1.8
TP3	SP-3	2.9	0	2.3	2.3	2.3	2.3	154	0	1.9	1.9	1.9	1.9
Deep GW and/or GW from N Side Old RRC (c)			72	-	332	332	332	-	0.01	-	0.07	0.07	0.07
Collected GW from W Area (Alts 5d, 6a, 6b) (d)			-	-	-	52	351	-	-	-	-	1.32	1.39
Unaccounted loading (e)								-	-	-	-	-	-
TOTAL:		**412**	**225**	**330**	**661**	**713**	**1013**	**-**	**257**	**343**	**343**	**344**	**344**
BLENDED CONC (mg/L)								**-**	**209**	**190**	**95**	**88**	**62**

Flow Tube Designation	Mg (mg/L)	Mg: Partial Collection (kg/day)	Extended Collection (kg/day)	Ext. w/ RRC Relocation (kg/day)			Zn (mg/L)	Zn: Partial Collection (kg/day)	Extended Collection (kg/day)	Ext. w/ RRC Relocation (kg/day)		
		Alts 4a, 5a	Alts 4b, 5b	Alts 4c, 5c	Alt 5d	Alts 6a, 6b		Alts 4a, 5a	Alts 4b, 5b	Alts 4c, 5c	Alt 5d	Alts 6a, 6b
SP-1	54	0.000	3.5	3.5	3.5	3.5	3.5	0	0.23	0.23	0.23	0.23
Tailings (b)	75	1.4	5.4	5.4	5.4	5.4	4.5	0.082	0.33	0.33	0.33	0.33
SP-2	97	6.3	6.3	6.3	6.3	6.3	5.6	0.37	0.37	0.37	0.37	0.37
S2	29	0	3.5	3.5	3.5	3.5	11	0	1.3	1.3	1.3	1.3
S3	33	4	4.0	4.0	4.0	4.0	2.3	0.3	0.27	0.27	0.27	0.27
S4	45	11	11	11	11	11	3.7	0.9	0.88	0.88	0.88	0.88
S5	78	12	12	12	12	12	9.8	1.5	1.5	1.5	1.5	1.5
S6	78	19	19	19	19	19	9.8	2.4	2.4	2.4	2.4	2.4
S7	4.9	0	1.6	1.6	1.6	1.6	0.17	0	0.055	0.055	0.055	0.055
S8	4.9	0	1.4	1.4	1.4	1.4	0.17	0	0.047	0.047	0.047	0.047
S9	4.9	0	0.44	0.44	0.44	0.44	0.17	0	0.015	0.015	0.015	0.015
TP1	48	0	0.33	0.33	0.33	0.33	4.0	0	0.028	0.028	0.028	0.028
TP2	48	0	0.57	0.57	0.57	0.57	4.0	0	0.048	0.048	0.048	0.048
TP3	48	0	0.60	0.60	0.60	0.60	4.0	0	0.050	0.050	0.050	0.050
Deep GW and/or GW from N Side Old RRC (c)	-	1.22	-	0.67	0.67	0.67	-	0.03	-	0.02	0.02	0.02
Collected GW from W Area (Alts 5d, 6a, 6b) (d)	-	-	-	-	1.36	4.40	-	-	-	-	33.78	37.11
Unaccounted loading (e)	-	2.3	9.4	9.4	9.4	9.4	-	0.27	1.07	1.07	1.07	1.07
TOTAL:	**-**	**57**	**79**	**79**	**81**	**84**	**-**	**5.8**	**8.6**	**8.6**	**42.4**	**45.8**
BLENDED CONC (mg/L)	**-**	**46**	**44**	**22**	**21**	**15**	**-**	**4.7**	**4.8**	**2.4**	**10.9**	**8.3**

Notes:

Source: Site-wide loading analysis Table A-3 and Figures A-7 and A-8

(a) Captured flow was estimated by multiplying the estimated flow by the apporpriate expected collection efficiency (E[CE]) for source area. Expected collection efficiencies for each source area are presented on Tables D1-5 & D1-8 (partial collection), D1-6 & D1-9 (extended collection), and D1-7, D1-10, D1-10a, D1-11, & D1-12 (extended collection + RRC relocation) of the Draft Final FS Report.

Source Area	Partial	Extended	RRC Relocation
TP-1 Seeps & Flow Tubes	80%	80%	80%
TP-2 Seeps & Flow Tubes (Upstream of RC-7)	0%	80%	80%
TP2/3 Seeps & Flow Tubes (Downstream of RC-7)	80%	80%	80%
Unaccounted Load - East Area	20%	80%	80%
Loading downstream of RC-2 (SP-21)	95%	95%	95%
Loading Downstream of RC-2 (Flow Tubes)	90%	90%	90%

(b) Assumes 25% of groundwater in the tailings unit captured with a 80% collection efficiency for partial East Area collection. For extended East Area collection, 100% of the groundwater in the tailings unit is assumed to be captured with a collection efficiency of 80% for extended collection and extended collection + RRC relocation.

(c) Water quality for collected deep groundwater assumed to equal average of measured concentrations from wells DS-3D and DS-4D. Water quality for groundwater from the north side of former RRC channel assumed to equal Fall 1997 water quality in RRC at station RC-4.

(d) Collected groundwater from lower W Area barrier walls is conveyed to the E Area for Alts 5d, 6a, & 6b. Water quality for water intercepted by the lower barrier wall from RC-4 to P-5 assumed to equal total seep/flow blended concentration for W Area (see Table 6-4). Water quality of groundwater collected by lower barrier wall from P-5 to SP-26 assumed to equal backgoround concentrations (from well HV-3). Note that for Alts 6a & 6b seep SP-26 is also collected and conveyed to the E Area treatment systyem.

(e) Unaccounted loading based on loading analysis provided in Appendix A. If unaccounted loading was positive, captured unaccounted loading was estimated by multiplying baseline unaccounted loading by estimated collection efficiency (E[CE]) and the ratio of RRC banklength from RC-4 to the end of the wetland east of TP-1 (2,200 ft) divided by the RRC banklength from RC-4 to RC-2 (5,000 ft). If baseline unaccounted loading was negative, the captured unaccounted loading was assumed to be zero.

Table 6-8
Partial and Extended Groundwater and Seep Collection - Spring 1997 Data
System Constructed East of Tailings Pile 1

Flow Tube Designation	Referenced Wells & Seeps	Estimated Flow (gpm)	Estimated Flow Capture (a): Partial Collection (gpm)	Extended collection (gpm)	Ext. w/ RRC Relocation (gpm)			Sulfate (mg/L)	Partial Collection (kg/day)	Extended Collection (kg/day)	Ext. w/ RRC Relocation (kg/day)		
			Alts 4a, 5a	Alts 4b, 5b	Alts 4c, 5c	Alt 5d	Alts 6a, 6b		Alts 4a, 5a	Alts 4b, 5b	Alts 4c, 5c	Alt 5d	Alts 6a, 6b
SP-1	SP-1	15	0	12	12	12	12	1700	0	111	111	111	111
Tailings (b)	SP-1, SP-2	16	3.3	13	13	13	13	1900	34	137	137	137	137
SP-2	SP-2	15	12	12	12	12	12	2100	137	137	137	137	137
S2	TP1-6A	27	0	22	22	22	22	850	0	101	101	101	101
S3	TP1-2A	28	22	22	22	22	22	1000	121	121	121	121	121
S4	TP1-2A, TP1-3A	55	44	44	44	44	44	1250	301	301	301	301	301
S5	TP1-5A	34	28	28	28	28	28	1700	257	257	257	257	257
S6	TP1-5A	56	45	45	45	45	45	1700	416	416	416	416	416
S7	TP2-11	75	0	60	60	60	60	150	0	49	49	49	49
S8	TP2-11	63	0	51	51	51	51	150	0	42	42	42	42
S9	TP2-11	21	0	16	16	16	16	150	0	14	14	14	14
TP1	SP-3	1.6	0	1.3	1.3	1.3	1.3	880	0	6	6	6	6
TP2	SP-3	2.7	0	2.2	2.2	2.2	2.2	880	0	10	10	10	10
TP3	SP-3	2.9	0	2.3	2.3	2.3	2.3	880	0	11	11	11	11
Deep GW and/or GW from N Side Old RRC (c)			72	-	332	332	332	-	25	-	7	7	7
Collected GW from W Area (Alts 5d, 6a, 6b) (d)			-	-	-	52	351	-	-	-	-	0	0
Unaccounted loading (e)								-	-	-	-	-	-
TOTAL:		**412**	**225**	**330**	**661**	**713**	**1013**	**-**	**1292**	**1713**	**1720**	**1720**	**1720**
BLENDED CONC (mg/L)								**-**	**1048**	**949**	**475**	**441**	**310**

Notes:
Source: Site-wide loading analysis Table A-3 and Figures A-7 and A-8
(a) Captured flow was estimated by multiplying the estimated flow by the apporpriate expected collection efficiency (E[CE]) for source area. Expected collection efficiencies for each source area are presented on Tables D1-5 & D1-8 (partial collection), D1-6 & D1-9 (extended collection), and D1-7, D1-10, D1-10a, D1-11, & D1-12 (extended collection + RRC relocation) of the Draft Final FS Report.

Source Area	Partial	Extended	RRC Relocation
TP-1 Seeps & Flow Tubes	80%	80%	80%
TP-2 Seeps & Flow Tubes (Upstream of RC-7)	0%	80%	80%
TP2/3 Seeps & Flow Tubes (Downstream of RC-7)	80%	80%	80%
Unaccounted Load - East Area	20%	80%	80%
Loading downstream of RC-2 (SP-21)	95%	95%	95%
Loading Downstream of RC-2 (Flow Tubes)	90%	90%	90%

(b) Assumes 25% of groundwater in the tailings unit captured with a 80% collection efficiency for partial East Area collection. For extended East Area collection, 100% of the groundwater in the tailings unit is assumed to be captured with a collection efficiency of 80% for extended collection and extended collection + RRC relocation.
(c) Water quality for collected deep groundwater assumed to equal average of measured concentrations from wells DS-3D and DS-4D. Water quality for groundwater from the north side of former RRC channel assumed to equal Fall 1997 water quality in RRC at station RC-4.
(d) Collected groundwater from lower W Area barrier walls is conveyed to the E Area for Alts 5d, 6a, & 6b. Water quality for water intercepted by the lower barrier wall from RC-4 to P-5 assumed to equal total seep/flow blended concentration for W Area (see Table 6-4). Water quality of groundwater collected by lower barrier wall from P-5 to SP-26 assumed to equal backgoround concentrations (from well HV-3). Note that for Alts 6a & 6b seep SP-26 is also collected and conveyed to the E Area treatment systyem.
(e) Unaccounted loading based on loading analysis provided in Appendix A. If unaccounted loading was positive, captured unaccounted loading was estimated by multiplying baseline unaccounted loading by estimated collection efficiency (E[CE]) and the ratio of RRC banklength from RC-4 to the end of the wetland east of TP-1 (2,200 ft) divided by the RRC banklength from RC-4 to RC-2 (5,000 ft). If baseline unaccounted loading was negative, the captured unaccounted loading was assumed to be zero.

Table 6-9
Partial and Extended Groundwater and Seep Collection - Fall 1997 Data
System Constructed East of Tailings Pile 1

			Estimated Flow Capture (a)					Al						Cd						Cu					
		Estimated Flow	Partial Collection (gpm)	Extended collection (gpm)	Ext. w/ RRC Relocation (gpm)				Partial Collection (kg/day)	Extended Collection (kg/day)	Ext. w/ RRC Relocation (kg/day)				Partial Collection (kg/day)	Extended Collection (kg/day)	Ext. w/ RRC Relocation (kg/day)				Partial Collection (kg/day)	Extended Collection (kg/day)	Ext. w/ RRC Relocation (kg/day)		
Flow Tube Designation	Referenced Wells & Seeps	(gpm)	Alts 4a, 5a	Alts 4b, 5b	Alts 4c, 5c	Alt 5d	Alts 6a, 6b	(mg/L)	Alts 4a, 5a	Alts 4b, 5b	Alts 4c, 5c	Alt 5d	Alts 6a, 6b	(mg/L)	Alts 4a, 5a	Alts 4b, 5b	Alts 4c, 5c	Alt 5d	Alts 6a, 6b	(mg/L)	Alts 4a, 5a	Alts 4b, 5b	Alts 4c, 5c	Alt 5d	Alts 6a, 6b
SP-1	SP-1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Tailings (b)	SP-2	14.19	2.8	11.4	11.4	11.4	11.4	68	1.055	4.22	4.22	4.22	4.22	0.004	0.000	0.000	0.000	0.000	0.000	0.10	0.002	0.006	0.006	0.006	0.006
SP-2	SP-2	1.6	1.3	1.3	1.3	1.3	1.3	68	0.47	0.47	0.47	0.47	0.47	0.004	0.000	0.000	0.000	0.000	0.000	0.10	0.001	0.001	0.001	0.001	0.001
S1	HBKG-1, TP1-6A	35	0	28	28	28	28	7.8	0	1.19	1.19	1.19	1.19	0.034	0	0.005	0.005	0.005	0.005	1.6	0	0.24	0.24	0.24	0.24
S2	TP1-2A, TP1-3A	19	15	15	15	15	15	5.5	0.45	0.45	0.45	0.45	0.45	0.001	0.000	0.000	0.000	0.000	0.000	0.005	0.000	0.000	0.000	0.000	0.000
S3	TP1-5A	56	45	45	45	45	45	26	6.29	6.3	6.3	6.3	6.3	0.002	0.000	0.000	0.000	0.000	0.000	0.048	0.012	0.012	0.012	0.012	0.012
S4	TP2-11A	72	0	57	57	57	57	0.44	0	0.14	0.14	0.14	0.14	0.003	0	0.001	0.001	0.001	0.001	0.010	0	0.003	0.003	0.003	0.003
S5	TP2-11A	9	0	7.3	7.3	7.3	7.3	0.44	0	0.02	0.02	0.02	0.02	0.003	0	0.000	0.000	0.000	0.000	0.010	0	0.000	0.000	0.000	0.000
TP1	SP-3	7.1	0	5.7	5.7	5.7	5.7	3.9	0	0.12	0.12	0.12	0.12	0.002	0	0.000	0.000	0.000	0.000	0.090	0	0.003	0.003	0.003	0.003
TP2	SP-3	1.7	0	1.4	1.4	1.4	1.4	3.9	0	0.03	0.03	0.03	0.03	0.002	0	0.000	0.000	0.000	0.000	0.090	0	0.001	0.001	0.001	0.001
TP3	SP-3	2.5	0	2.0	2.0	2.0	2.0	3.9	0	0.04	0.04	0.04	0.04	0.002	0	0.000	0.000	0.000	0.000	0.090	0	0.001	0.001	0.001	0.001
Deep GW and/or GW from N Side Old RRC (c)			72	-	189	189	189	-	0.21	-	0.01	0.01	0.01	-	0.00	-	0.00	0.00	0.00	-	0.00	-	0.00	0.00	0.00
Collected GW from W Area (Alts 5d, 6a, 6b) (d)			-	-	-	30	194	-	-	-	-	0.01	0.04	-	-	-	-	0.86	0.86	-	-	-	-	0.00	0.01
Unaccounted loading (e)								-	-	-	-	-	-	-	0.000	0.001	0.001	0.001	0.001	-	-	-	-	-	-
TOTAL:		**218**	**136**	**174**	**364**	**394**	**558**	**-**	**8**	**13**	**13**	**13**	**13**	**-**	**0.001**	**0.008**	**0.008**	**0.871**	**0.871**	**-**	**0.02**	**0.27**	**0.27**	**0.28**	**0.28**
BLENDED CONC (mg/L)								**-**	**11**	**14**	**7**	**7**	**5**	**-**	**0.001**	**0.009**	**0.004**	**0.497**	**0.329**	**-**	**0.02**	**0.28**	**0.14**	**0.16**	**0.11**

Notes:

Source: Site-wide loading analysis Table A-4 and Figures A-9 and A-10

(a) Captured flow was estimated by multiplying the estimated flow by the apporpriate expected collection efficiency (E[CE]) for source area. Expected collection efficiencies for each source area are presented on Tables D1-5 & D1-8 (partial collection), D1-6 & D1-9 (extended collection), and D1-7, D1-10, D1-10a, D1-11, & D1-12 (extended collection + RRC relocation) of the Draft Final FS Report.

Source Area	Partial	Extended	RRC Relocation
TP-1 Seeps & Flow Tubes	80%	80%	80%
TP-2 Seeps & Flow Tubes (Upstream of RC-7)	0%	80%	80%
TP2/3 Seeps & Flow Tubes (Downstream of RC-7)	80%	80%	80%
Unaccounted Load - East Area	20%	80%	80%
Loading downstream of RC-2 (SP-21)	95%	95%	95%
Loading Downstream of RC-2 (Flow Tubes)	90%	90%	90%

(b) Assumes 25% of groundwater in the tailings unit captured with a 80% collection efficiency for partial East Area collection. For extended East Area collection, 100% of the groundwater in the tailings unit is assumed to be captured with a collection efficiency of 80% for extended collection and extended collection + RRC relocation.

(c) Water quality for collected deep groundwater assumed to equal average of measured concentrations from wells DS-3D and DS-4D. Water quality for groundwater from the north side of former RRC channel assumed to equal Fall 1997 water quality in RRC at station RC-4.

(d) Collected groundwater from lower W Area barrier walls is conveyed to the E Area for Alts 5d, 6a, & 6b. Water quality for water intercepted by the lower barrier wall from RC-4 to P-5 assumed to equal total seep/flow blended concentration for W Area (see Table 6-4). Water quality of groundwater collected by lower barrier wall from P-5 to SP-26 assumed to equal backgoround concentrations (from well HV-3). Note that for Alts 6a & 6b seep SP-26 is also collected and conveyed to the E Area treatment systyem.

(e) Unaccounted loading based on loading analysis provided in Appendix A. If unaccounted loading was positive, captured unaccounted loading was estimated by multiplying baseline unaccounted loading by estimated collection efficiency (E[CE]) and the ratio of RRC banklength from RC-4 to the end of the wetland east of TP-1 (2,200 ft) divided by the RRC banklength from RC-4 to RC-2 (5,000 ft). If baseline unaccounted loading was negative, the captured unaccounted loading was assumed to be zero.

Table 6-9
Partial and Extended Groundwater and Seep Collection - Fall 1997 Data
System Constructed East of Tailings Pile 1

Flow Tube Designation	Referenced Wells & Seeps	Estimated Flow (gpm)	Estimated Flow Capture (a)					Fe						Mg						Zn					
			Partial Collection (gpm)	Extended collection (gpm)	Ext. w/ RRC Relocation (gpm)				Partial Collection (kg/day)	Extended Collection (kg/day)	Ext. w/ RRC Relocation (kg/day)				Partial Collection (kg/day)	Extended Collection (kg/day)	Ext. w/ RRC Relocation (kg/day)				Partial Collection (kg/day)	Extended Collection (kg/day)	Ext. w/ RRC Relocation (kg/day)		
			Alts 4a, 5a	Alts 4b, 5b	Alts 4c, 5c	Alt 5d	Alts 6a, 6b	(mg/L)	Alts 4a, 5a	Alts 4b, 5b	Alts 4c, 5c	Alt 5d	Alts 6a, 6b	(mg/L)	Alts 4a, 5a	Alts 4b, 5b	Alts 4c, 5c	Alt 5d	Alts 6a, 6b	(mg/L)	Alts 4a, 5a	Alts 4b, 5b	Alts 4c, 5c	Alt 5d	Alts 6a, 6b
SP-1	SP-1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Tailings (b)	SP-2	14.19	2.8	11.4	11.4	11.4	11.4	685	10.64	42.6	42.6	42.6	42.6	94	1.46	5.85	5.85	5.85	5.85	5.7	0.089	0.354	0.354	0.354	0.354
SP-2	SP-2	1.6	1.3	1.3	1.3	1.3	1.3	685	4.7	4.7	4.7	4.7	4.7	94	0.65	0.65	0.65	0.65	0.65	5.7	0.039	0.039	0.039	0.039	0.039
S1	HBKG-1, TP1-6A	35	0	28	28	28	28	40	0	6.1	6.1	6.1	6.1	9.9	0	1.5	1.5	1.5	1.5	4.3	0	0.65	0.65	0.65	0.65
S2	TP1-2A, TP1-3A	19	15	15	15	15	15	1605	132	132	132	132	132	136	11	11	11	11	11	4.6	0.38	0.38	0.38	0.38	0.38
S3	TP1-5A	56	45	45	45	45	45	413	102	102	102	102	102	46	11	11	11	11	11	2.7	0.67	0.67	0.67	0.67	0.67
S4	TP2-11A	72	0	57	57	57	57	0.10	0	0.03	0.03	0.03	0.03	13	0	4.0	4.0	4.0	4.0	0.31	0	0.097	0.10	0.10	0.10
S5	TP2-11A	9	0	7.3	7.3	7.3	7.3	0.10	0	0.00	0.00	0.00	0.00	13	0	0.51	0.51	0.51	0.51	0.31	0	0.012	0.012	0.012	0.012
TP1	SP-3	7.1	0	5.7	5.7	5.7	5.7	251	0	7.8	7.8	7.8	7.8	62	0	1.9	1.9	1.9	1.9	0.61	0	0.019	0.019	0.019	0.019
TP2	SP-3	1.7	0	1.4	1.4	1.4	1.4	251	0	1.9	1.9	1.9	1.9	62	0	0.47	0.47	0.47	0.47	0.61	0	0.005	0.005	0.005	0.005
TP3	SP-3	2.5	0	2.0	2.0	2.0	2.0	251	0	2.8	2.8	2.8	2.8	62	0	0.69	0.69	0.69	0.69	0.61	0	0.007	0.007	0.007	0.007
Deep GW and/or GW from N Side Old RRC (c)			72	-	189	189	189	-	0.02	-	0.04	0.04	0.04	-	0.14	-	0.38	0.38	0.38	-	0.00	-	0.01	0.01	0.01
Collected GW from W Area (Alts 5d, 6a, 6b) (d)			-	-	-	30	194	-	-	-	-	0.76	0.79	-	-	-	-	0.78	2.50	-	-	-	-	19.45	19.46
Unaccounted loading (e)								-	-	-	-	-	-	-	0.00	0.0	0.0	0.0	0.0	-	0.12	0.49	0.49	0.49	0.49
TOTAL:		**218**	**136**	**174**	**364**	**394**	**558**	**-**	**249**	**300**	**300**	**301**	**301**	**-**	**25**	**38**	**39**	**39**	**41**	**-**	**1.3**	**2.7**	**2.7**	**22.2**	**22.2**
BLENDED CONC (mg/L)								**-**	**336**	**314**	**151**	**172**	**113**	**-**	**33**	**40**	**19**	**22**	**15**	**-**	**1.8**	**2.9**	**1.4**	**12.7**	**8.4**

Notes:
Source: Site-wide loading analysis Table A-4 and Figures A-9 and A-10
(a) Captured flow was estimated by multiplying the estimated flow by the apporpriate expected collection efficiency (E[CE]) for source area. Expected collection efficiencies for each source area are presented on Tables D1-5 & D1-8 (partial collection), D1-6 & D1-9 (extended collection), and D1-7, D1-10, D1-10a, D1-11, & D1-12 (extended collection + RRC relocation) of the Draft Final FS Report.

Source Area	Partial	Extended	RRC Relocation
TP-1 Seeps & Flow Tubes	80%	80%	80%
TP-2 Seeps & Flow Tubes (Upstream of RC-7)	0%	80%	80%
TP2/3 Seeps & Flow Tubes (Downstream of RC-7)	80%	80%	80%
Unaccounted Load - East Area	20%	80%	80%
Loading downstream of RC-2 (SP-21)	95%	95%	95%
Loading Downstream of RC-2 (Flow Tubes)	90%	90%	90%

(b) Assumes 25% of groundwater in the tailings unit captured with a 80% collection efficiency for partial East Area collection. For extended East Area collection, 100% of the groundwater in the tailings unit is assumed to be captured with a collection efficiency of 80% for extended collection and extended collection + RRC relocation.
(c) Water quality for collected deep groundwater assumed to equal average of measured concentrations from wells DS-3D and DS-4D. Water quality for groundwater from the north side of former RRC channel assumed to equal Fall 1997 water quality in RRC at station RC-4.
(d) Collected groundwater from lower W Area barrier walls is conveyed to the E Area for Alts 5d, 6a, & 6b. Water quality for water intercepted by the lower barrier wall from RC-4 to P-5 assumed to equal total seep/flow blended concentration for W Area (see Table 6-4). Water quality of groundwater collected by lower barrier wall from P-5 to SP-26 assumed to equal backgoround concentrations (from well HV-3). Note that for Alts 6a & 6b seep SP-26 is also collected and conveyed to the E Area treatment systyem.
(e) Unaccounted loading based on loading analysis provided in Appendix A. If unaccounted loading was positive, captured unaccounted loading was estimated by multiplying baseline unaccounted loading by estimated collection efficiency (E[CE]) and the ratio of RRC banklength from RC-4 to the end of the wetland east of TP-1 (2,200 ft) divided by the RRC banklength from RC-4 to RC-2 (5,000 ft). If baseline unaccounted loading was negative, the captured unaccounted loading was assumed to be zero.

Table 6-9
Partial and Extended Groundwater and Seep Collection - Fall 1997 Data
System Constructed East of Tailings Pile 1

Flow Tube Designation	Referenced Wells & Seeps	Estimated Flow (gpm)	Estimated Flow Capture (a): Partial Collection (gpm)	Extended collection (gpm)	Ext. w/ RRC Relocation (gpm)			Sulfate	Partial Collection (kg/day)	Extended Collection (kg/day)	Ext. w/ RRC Relocation (kg/day)		
			Alts 4a, 5a	Alts 4b, 5b	Alts 4c, 5c	Alt 5d	Alts 6a, 6b	(mg/L)	Alts 4a, 5a	Alts 4b, 5b	Alts 4c, 5c	Alt 5d	Alts 6a, 6b
SP-1	SP-1	0	0	0	0	0	0	0	0	0	0	0	0
Tailings (b)	SP-2	14.19	2.8	11.4	11.4	11.4	11.4	2200	34	137	137	137	137
SP-2	SP-2	1.6	1.3	1.3	1.3	1.3	1.3	2200	15	15	15	15	15
S1	HBKG-1, TP1-6A	35	0	28	28	28	28	240	0	37	37	37	37
S2	TP1-2A, TP1-3A	19	15	15	15	15	15	3750	309	309	309	309	309
S3	TP1-5A	56	45	45	45	45	45	1000	247	247	247	247	247
S4	TP2-11A	72	0	57	57	57	57	390	0	122	122	122	122
S5	TP2-11A	9	0	7.3	7.3	7.3	7.3	390	0	16	16	16	16
TP1	SP-3	7.1	0	5.7	5.7	5.7	5.7	1300	0	40	40	40	40
TP2	SP-3	1.7	0	1.4	1.4	1.4	1.4	1300	0	9.9	10	10	10
TP3	SP-3	2.5	0	2.0	2.0	2.0	2.0	1300	0	14	14	14	14
Deep GW and/or GW from N Side Old RRC (c)			72	-	189	189	189	-	25.26	-	1.57	1.57	1.57
Collected GW from W Area (Alts 5d, 6a, 6b) (d)			-	-	-	30	194	-	-	-	-	0.00	4.76
Unaccounted loading (e)								-	-	-	-	-	-
TOTAL:		**218**	**136**	**174**	**364**	**394**	**558**	**-**	**630**	**946**	**948**	**948**	**953**
BLENDED CONC (mg/L)								**-**	**848**	**992**	**476**	**541**	**359**

Notes:
Source: Site-wide loading analysis Table A-4 and Figures A-9 and A-10
(a) Captured flow was estimated by multiplying the estimated flow by the apporpriate expected collection efficiency (E[CE]) for source area. Expected collection efficiencies for each source area are presented on Tables D1-5 & D1-8 (partial collection), D1-6 & D1-9 (extended collection), and D1-7, D1-10, D1-10a, D1-11, & D1-12 (extended collection + RRC relocation) of the Draft Final FS Report.

Source Area	Partial	Extended	RRC Relocation
TP-1 Seeps & Flow Tubes	80%	80%	80%
TP-2 Seeps & Flow Tubes (Upstream of RC-7)	0%	80%	80%
TP2/3 Seeps & Flow Tubes (Downstream of RC-7)	80%	80%	80%
Unaccounted Load - East Area	20%	80%	80%
Loading downstream of RC-2 (SP-21)	95%	95%	95%
Loading Downstream of RC-2 (Flow Tubes)	90%	90%	90%

(b) Assumes 25% of groundwater in the tailings unit captured with a 80% collection efficiency for partial East Area collection. For extended East Area collection, 100% of the groundwater in the tailings unit is assumed to be captured with a collection efficiency of 80% for extended collection and extended collection + RRC relocation.
(c) Water quality for collected deep groundwater assumed to equal average of measured concentrations from wells DS-3D and DS-4D. Water quality for groundwater from the north side of former RRC channel assumed to equal Fall 1997 water quality in RRC at station RC-4.
(d) Collected groundwater from lower W Area barrier walls is conveyed to the E Area for Alts 5d, 6a, & 6b. Water quality for water intercepted by the lower barrier wall from RC-4 to P-5 assumed to equal total seep/flow blended concentration for W Area (see Table 6-4). Water quality of groundwater collected by lower barrier wall from P-5 to SP-26 assumed to equal backgoround concentrations (from well HV-3). Note that for Alts 6a & 6b seep SP-26 is also collected and conveyed to the E Area treatment systyem.
(e) Unaccounted loading based on loading analysis provided in Appendix A. If unaccounted loading was positive, captured unaccounted loading was estimated by multiplying baseline unaccounted loading by estimated collection efficiency (E[CE]) and the ratio of RRC banklength from RC-4 to the end of the wetland east of TP-1 (2,200 ft) divided by the RRC banklength from RC-4 to RC-2 (5,000 ft). If baseline unaccounted loading was negative, the captured unaccounted loading was assumed to be zero.

Table 6-10
Partial and Extended Groundwater and Seep Collection - Spring 1997 Data
System Constructed East of Tailings Pile 3

Flow Tube Designation	Referenced Wells & Seeps	Estimated Flow (gpm)	Estimated Flow Capture (a)			Al				Cd				Cu				Fe			
			Partial Collection (gpm)	Extended collection (gpm)	Ext. w/ RRC Relocation (gpm)	(mg/L)	Partial Collection (kg/day)	Extended Collection (kg/day)	Ext. w/ RRC Relocation (kg/day)	(mg/L)	Partial Collection (kg/day)	Extended Collection (kg/day)	Ext. w/ RRC Relocation (kg/day)	(mg/L)	Partial Collection (kg/day)	Extended Collection (kg/day)	Ext. w/ RRC Relocation (kg/day)	(mg/L)	Partial Collection (kg/day)	Extended Collection (kg/day)	Ext. w/ RRC Relocation (kg/day)
			Alts 4a, 5a	Alts 4b, 5b	Alts 4c, 5c, 5d, 6a, 6b		Alts 4a, 5a	Alts 4b, 5b	Alts 4c, 5c, 5d, 6a, 6b		Alts 4a, 5a	Alts 4b, 5b	Alts 4c, 5c, 5d, 6a, 6b		Alts 4a, 5a	Alts 4b, 5b	Alts 4c, 5c, 5d, 6a, 6b		Alts 4a, 5a	Alts 4b, 5b	Alts 4c, 5c, 5d, 6a, 6b
S10	PZ-3A	43	0	34	34	0.01	0	0.002	0.002	0.002	0	0.000	0.000	0.001	0	0.000	0.000	5.7	0	1.07	1.07
S11	PZ3-A	40	0	32	32	0.01	0	0.002	0.002	0.002	0	0.000	0.000	0.001	0	0.000	0.000	5.7	0	0.98	0.98
S12	TP2-4A	22	0	17	17	0.01	0	0.001	0.001	0.002	0	0.000	0.000	0.003	0	0.000	0.000	7.0	0	0.66	0.66
S13	TP2-4A	19	0	15	15	0.01	0	0.001	0.001	0.002	0	0.000	0.000	0.003	0	0.000	0.000	7.0	0	0.59	0.59
S14	TP3-8A	29	0	23	23	0.12	0	0.015	0.015	0.000	0	0.000	0.000	0.001	0	0.000	0.000	55	0	7.05	7.05
S15	TP3-8A	8	0	6	6	0.12	0	0.004	0.004	0.000	0	0.000	0.000	0.001	0	0.000	0.000	55	0	1.89	1.89
S16	TP3-8A	19	0	15	15	0.12	0	0.010	0.010	0.000	0	0.000	0.000	0.001	0	0.000	0.000	55	0	4.55	4.55
S17	TP3-10	31	24	24	24	0.29	0.039	0.039	0.039	0.001	0.000	0.000	0.000	0.013	0.002	0.002	0.002	0.07	0.01	0.01	0.01
S18	TP3-10	30	24	24	24	0.29	0.038	0.038	0.038	0.001	0.000	0.000	0.000	0.013	0.002	0.002	0.002	0.07	0.01	0.01	0.01
S19	TP3-10	49	39	39	39	0.29	0.062	0.062	0.062	0.001	0.000	0.000	0.000	0.013	0.003	0.003	0.003	0.07	0.01	0.01	0.01
SP-3	SP-3	75	0	60	60	33	0	10.925	10.925	0.040	0	0.013	0.013	1.3	0	0.419	0.419	154	0	50.38	50.38
TP4	SP-3	3	0	2	2	33	0	0.397	0.397	0.040	0	0.000	0.000	1.3	0	0.015	0.015	154	0	1.83	1.83
TP5	SP-3	2	0	2	2	33	0	0.311	0.311	0.000	0	0.000	0.000	1.3	0	0.012	0.012	154	0	1.43	1.43
TP6	SP-3	3	0	2	2	33	0	0.398	0.398	0.040	0	0.000	0.000	1.3	0	0.015	0.015	154	0	1.83	1.83
TP7	SP-3	4	0	3	3	33	0	0.584	0.584	0.040	0	0.001	0.001	1.3	0	0.022	0.022	154	0	2.69	2.69
SP-4	SP-4	224	0	179	179	19	0	18.645	18.645	0.007	0	0.007	0.007	0.67	0	0.657	0.657	75	0	73.50	73.50
TP8	SP-3, SP-4	3	0	2	2	26	0	0.311	0.311	0.024	0	0.000	0.000	0.98	0	0.012	0.012	114	0	1.36	1.36
TP9	SP-3, SP-4	1	0	1	1	26	0	0.125	0.125	0.024	0	0.000	0.000	0.98	0	0.005	0.005	114	0	0.54	0.54
TP10	SP-4	1	0	1	1	19	0	0.111	0.111	0.007	0	0.000	0.000	0.67	0	0.004	0.004	75	0	0.44	0.44
TP11	SP-4	3	0	2	2	19	0	0.218	0.218	0.007	0	0.000	0.000	0.67	0	0.008	0.008	75	0	0.86	0.86
TP12	SP-4	2	0	1	1	19	0	0.142	0.142	0.007	0	0.000	0.000	0.67	0	0.005	0.005	75	0	0.56	0.56
TP13	SP-4, PZ-6A	2	0	2	2	9.5	0	0.089	0.089	0.005	0	0.000	0.000	0.34	0	0.003	0.003	67	0	0.62	0.62
TP14	PZ-6A	2	2	2	2	0.01	0.000	0.000	0.000	0.002	0.000	0.000	0.000	0.001	0.000	0.000	0.000	58	0.62	0.62	0.62
TP15	PZ-6A	3	3	3	3	0.01	0.000	0.000	0.000	0.002	0.000	0.000	0.000	0.001	0.000	0.000	0.000	58	0.86	0.86	0.86
TP16	PZ-6A	1	1	1	1	0.01	0.000	0.000	0.000	0.002	0.000	0.000	0.000	0.001	0.000	0.000	0.000	58	0.37	0.37	0.37
SP-21 (b)	SP-21	876	833	833	833	1.5	6.833	6.833	6.833	0.000	0.000	0.000	0.000	0.052	0.236	0.236	0.236	1.0	4.56	4.56	4.56
Deep GW and/or GW from N Side Old RRC (c)			143	NA	805	-	0.428	-	0.461	0.00	0.001	-	0.001	-	0.002	-	0.008	-	0.02	-	0.16
Unaccounted loading (d)						-	-	-	-	-	0.006	0.024	0.024	-	-	-	-	-	-	-	-
TOTAL:		**1494**	**1069**	**1327**	**2132**	**-**	**7**	**39**	**40**	**-**	**0.007**	**0.049**	**0.050**	**-**	**0.24**	**1.42**	**1.43**	**-**	**6**	**159**	**159**
TOTAL BLENDED CONC (mg/L)						**-**	**1.3**	**5.4**	**3.4**	**-**	**0.001**	**0.007**	**0.004**	**-**	**0.04**	**0.20**	**0.12**	**-**	**1.1**	**21.9**	**13.7**

Notes:
Source: Site-wide loading analysis Table A-3 and Figures A-7 and A-8
(a) Captured flow was estimated by multiplying the estimated flow by the apporpriate expected collection efficiency (E[CE]) for source area. Expected collection efficiencies for each source area are presented on Tables D1-5 & D1-8 (partial collection), D1-6 & D1-9 (extended collection), and D1-7, D1-10, D1-10a, D1-11, & D1-12 (extended collection + RRC relocation) of the Draft Final FS Report.

Source Area	Partial	Extended	Extended w/ RRC Relocation
TP-1 Seeps & Flow Tubes	80%	80%	80%
TP-2 Seeps & Flow Tubes (Upstream of RC-7)	0%	80%	80%
TP2/3 Seeps & Flow Tubes (Downstream of RC-7)	80%	80%	80%
Unaccounted Load - East Area	20%	80%	80%
Loading downstream of RC-2 (SP-21)	95%	95%	95%
Loading Downstream of RC-2 (Flow Tubes)	90%	90%	90%

(b) SP-21 would be conveyed directly to the treatment pond and would not be intercepted by the collection system.
(c) Water quality for collected deep groundwater assumed to equal average of measured concentrations from wells DS-3D and DS-4D. Water quality for groundwater from the north side of former RRC channel assumed to equal Fall 1997 water quality in RRC at station RC-4.
(d) Unaccounted loading based on loading analysis provided in Appendix A. If unaccounted loading was positive, captured unaccounted loading was estimated by multiplying baseline unaccounted loading by estimated collection efficiency (E[CE]) and the ratio of RRC banklength from the end of the wetland east of TP-1 to station RC-2 (2,800 ft) divided by the RRC banklength from RC-4 to RC-2 (5,000 ft). If baseline unaccounted loading was negative, the captured unaccounted loading was assumed to be zero.

Table 6-10
Partial and Extended Groundwater and Seep Collection - Spring 1997 Data
System Constructed East of Tailings Pile 3

Flow Tube Designation	Referenced Wells & Seeps	Estimated Flow (gpm)	Estimated Flow Capture (a) Partial Collection (gpm)	Extended collection (gpm)	Ext. w/ RRC Relocation (gpm)	Mg (mg/L)	Mg Partial Collection (kg/day)	Mg Extended Collection (kg/day)	Mg Ext. w/ RRC Relocation (kg/day)	Zn (mg/L)	Zn Partial Collection (kg/day)	Zn Extended Collection (kg/day)	Zn Ext. w/ RRC Relocation (kg/day)	Sulfate (mg/L)	Sulfate Partial Collection (kg/day)	Sulfate Extended Collection (kg/day)	Sulfate Ext. w/ RRC Relocation (kg/day)
			Alts 4a, 5a	Alts 4b, 5b	Alts 4c, 5c, 5d, 6a, 6b		Alts 4a, 5a	Alts 4b, 5b	Alts 4c, 5c, 5d, 6a, 6b		Alts 4a, 5a	Alts 4b, 5b	Alts 4c, 5c, 5d, 6a, 6b		Alts 4a, 5a	Alts 4b, 5b	Alts 4c, 5c, 5d, 6a, 6b
S10	PZ-3A	43	0	34	34	24	0	4.55	4.55	0.003	0	0.000	0.000	670	0	126	126
S11	PZ3-A	40	0	32	32	24	0	4.17	4.17	0.003	0	0.000	0.000	670	0	116	116
S12	TP2-4A	22	0	17	17	27	0	2.58	2.58	0.006	0	0.001	0.001	720	0	68	68
S13	TP2-4A	19	0	15	15	27	0	2.28	2.28	0.006	0	0.000	0.000	720	0	60	60
S14	TP3-8A	29	0	23	23	17	0	2.21	2.21	0.058	0	0.007	0.007	340	0	43	43
S15	TP3-8A	8	0	6	6	17	0	0.59	0.59	0.058	0	0.002	0.002	340	0	12	12
S16	TP3-8A	19	0	15	15	17	0	1.43	1.43	0.058	0	0.005	0.005	340	0	28	28
S17	TP3-10	31	24	24	24	3.6	0.48	0.48	0.48	0.068	0.009	0.009	0.009	100	13	13	13
S18	TP3-10	30	24	24	24	3.6	0.47	0.47	0.47	0.068	0.009	0.009	0.009	100	13	13	13
S19	TP3-10	49	39	39	39	3.6	0.77	0.77	0.77	0.068	0.0146	0.015	0.015	100	22	22	22
SP-3	SP-3	75	0	60	60	48	0	15.67	15.67	4.0	0	1.318	1.318	880	0	288	288
TP4	SP-3	3	0	2	2	48	0	0.57	0.57	4.0	0	0.048	0.048	880	0	10	10
TP5	SP-3	2	0	2	2	48	0	0.45	0.45	4.0	0	0.038	0.038	880	0	8	8
TP6	SP-3	3	0	2	2	48	0	0.57	0.57	4.0	0	0.048	0.048	880	0	10	10
TP7	SP-3	4	0	3	3	48	0	0.84	0.84	4.0	0	0.070	0.070	880	0	15	15
SP-4	SP-4	224	0	179	179	36	0	35.62	35.62	0.90	0	0.887	0.887	660	0	648	648
TP8	SP-3, SP-4	3	0	2	2	42	0	0.50	0.50	2.5	0	0.029	0.029	770	0	9	9
TP9	SP-3, SP-4	1	0	1	1	42	0	0.20	0.20	2.5	0	0.012	0.012	770	0	4	4
TP10	SP-4	1	0	1	1	36	0	0.21	0.21	0.90	0	0.005	0.005	660	0	4	4
TP11	SP-4	3	0	2	2	36	0	0.42	0.42	0.90	0	0.010	0.010	660	0	8	8
TP12	SP-4	2	0	1	1	36	0	0.27	0.27	0.90	0	0.007	0.007	660	0	5	5
TP13	SP-4, PZ-6A	2	0	2	2	51	0	0.47	0.47	0.46	0	0.004	0.004	1080	0	10	10
TP14	PZ-6A	2	2	2	2	65	0.70	0.70	0.70	0.015	0.000	0.000	0.000	1500	16	16	16
TP15	PZ-6A	3	3	3	3	65	0.96	0.96	0.96	0.015	0.000	0.000	0.000	1500	22	22	22
TP16	PZ-6A	1	1	1	1	65	0.42	0.42	0.42	0.015	0.000	0.000	0.000	1500	10	10	10
SP-21 (b)	SP-21	876	833	833	833	3.8	17.40	17.40	17.40	0.11	0.497	0.497	0.497	84	383	383	383
Deep GW and/or GW from N Side Old RRC (c)			143	NA	805	-	2.45	-	3.77	-	0.067	-	0.107	-	51	-	15
Unaccounted loading (d)						-	2.99	11.96	11.96	-	0.341	1.364	1.364	-	-	-	-
TOTAL:		**1494**	**1069**	**1327**	**2132**	**-**	**27**	**107**	**111**	**-**	**0.9**	**4.4**	**4.5**	**-**	**529**	**1951**	**1965**
TOTAL BLENDED CONC (mg/L)						**-**	**4.6**	**14.7**	**9.5**	**-**	**0.2**	**0.6**	**0.4**	**-**	**90**	**269**	**168**

Notes:
Source: Site-wide loading analysis Table A-3 and Figures A-7 and A-8
(a) Captured flow was estimated by multiplying the estimated flow by the apporpriate expected collection efficiency (E[CE]) for source area. Expected collection efficiencies for each source area are presented on Tables D1-5 & D1-8 (partial collection), D1-6 & D1-9 (extended collection), and D1-7, D1-10, D1-10a, D1-11, & D1-12 (extended collection + RRC relocation) of the Draft Final FS Report.

Source Area	Partial	Extended	Extended w/ RRC Relocation
TP-1 Seeps & Flow Tubes	80%	80%	80%
TP-2 Seeps & Flow Tubes (Upstream of RC-7)	0%	80%	80%
TP2/3 Seeps & Flow Tubes (Downstream of RC-7)	80%	80%	80%
Unaccounted Load - East Area	20%	80%	80%
Loading downstream of RC-2 (SP-21)	95%	95%	95%
Loading Downstream of RC-2 (Flow Tubes)	90%	90%	90%

(b) SP-21 would be conveyed directly to the treatment pond and would not be intercepted by the collection system.
(c) Water quality for collected deep groundwater assumed to equal average of measured concentrations from wells DS-3D and DS-4D. Water quality for groundwater from the north side of former RRC channel assumed to equal Fall 1997 water quality in RRC at station RC-4.
(d) Unaccounted loading based on loading analysis provided in Appendix A. If unaccounted loading was positive, captured unaccounted loading was estimated by multiplying baseline unaccounted loading by estimated collection efficiency (E[CE]) and the ratio of RRC banklength from the end of the wetland east of TP-1 to station RC-2 (2,800 ft) divided by the RRC banklength from RC-4 to RC-2 (5,000 ft). If baseline unaccounted loading was negative, the captured unaccounted loading was assumed to be zero.

Table 6-11
Partial and Extended Groundwater and Seep Collection - Fall 1997 Data
System Constructed East of Tailings Pile 3

Flow Tube Designation	Referenced Wells & Seeps	Estimated Flow (gpm)	Estimated Flow Capture (a): Partial Collection (gpm) Alts 4a, 5a	Estimated Flow Capture (a): Extended collection (gpm) Alts 4b, 5b	Estimated Flow Capture (a): Ext. w/ RRC Relocation (gpm) Alts 4c, 5c, 5d, 6a, 6b	Al (mg/L)	Al Partial Collection (kg/day) Alts 4a, 5a	Al Extended Collection (kg/day) Alts 4b, 5b	Al Ext. w/ RRC Relocation (kg/day) Alts 4c, 5c, 5d, 6a, 6b	Cd (mg/L)	Cd Partial Collection (kg/day) Alts 4a, 5a	Cd Extended Collection (kg/day) Alts 4b, 5b	Cd Ext. w/ RRC Relocation (kg/day) Alts 4c, 5c, 5d, 6a, 6b	Cu (mg/L)	Cu Partial Collection (kg/day) Alts 4a, 5a	Cu Extended Collection (kg/day) Alts 4b, 5b	Cu Ext. w/ RRC Relocation (kg/day) Alts 4c, 5c, 5d, 6a, 6b	Fe (mg/L)	Fe Partial Collection (kg/day) Alts 4a, 5a	Fe Extended Collection (kg/day) Alts 4b, 5b	Fe Ext. w/ RRC Relocation (kg/day) Alts 4c, 5c, 5d, 6a, 6b	Mg (mg/L)	Mg Partial Collection (kg/day) Alts 4a, 5a	Mg Extended Collection (kg/day) Alts 4b, 5b	Mg Ext. w/ RRC Relocation (kg/day) Alts 4c, 5c, 5d, 6a, 6b
S6	TP2-11A, PZ-3A	43.8	0	35.1	35.1	0.23	0	0.043	0.043	0.002	0	0.000	0.000	0.006	0	0.001	0.001	2.9	0	0.56	0.56	18	0	3.4	3.4
S7	TP2-4A	40.1	0	32.1	32.1	0.010	0	0.002	0.002	0.000	0	0.000	0.000	0.001	0	0.000	0.000	5.6	0	0.99	0.99	30	0	5.2	5.2
S8 in (b)	TP2-4A	5.5	0	4.4	4.4	0.010	0	0.000	0.000	0.000	0	0.000	0.000	0.001	0	0.000	0.000	5.6	0	0.13	0.13	30	0	0.7	0.7
S8 out (b)	DS-1, TP3-9	19.7	17.8	17.8	17.8	5.0	0.483	0.483	0.483	0.002	0.000	0	0	0.045	0.004	0	0	63	6.07	6.07	6.07	23	2.3	2.3	2.3
SL1 (b)	DS-1, TP3-9	0	0	0	0	5.0	0	0	0	0.002	0	0	0	0.045	0	0	0	63	0	0	0	23	0	0	0
SL2 (b)	DS-1	0	0	0	0	0.25	0	0	0	0.001	0	0	0	0.039	0	0	0	0.010	0	0	0	5.0	0	0	0
SL3 (b)	DS-1	0	0	0	0	0.25	0	0	0	0.001	0	0	0	0.039	0	0	0	0.010	0	0	0	5.0	0	0	0
SL4 (b)	TP3-9	4.9	4.4	4.4	4.4	9.7	0.232	0.232	0.232	0.004	0.000	0.000	0.000	0.051	0.001	0.001	0.001	125	2.99	2.99	2.99	41	1.0	1.0	1.0
SL5 (b)	TP3-9	6.1	5.5	5.5	5.5	9.7	0.293	0.293	0.293	0.004	0.000	0.000	0.000	0.051	0.002	0.002	0.002	125	3.78	3.78	3.78	41	1.3	1.3	1.3
SP-3	SP-3	6.3	0	5.1	5.1	3.9	0	0.108	0.108	0.002	0	0.000	0.000	0.090	0	0.002	0.002	251	0	6.94	6.94	62	0	1.7	1.7
TP4	PZ-1B	2.6	0	2.1	2.1	3.9	0	0.044	0.044	0.002	0	0.000	0.000	0.090	0	0.001	0.001	251	0	2.85	2.85	62	0	0.7	0.7
TP5	SP-3	1.5	0	1.2	1.2	3.9	0	0.025	0.025	0.002	0	0.000	0.000	0.090	0	0.001	0.001	251	0	1.61	1.61	62	0	0.4	0.4
TP6	SP-3	2.9	0	2.3	2.3	3.9	0	0.050	0.050	0.002	0	0.000	0.000	0.090	0	0.001	0.001	251	0	3.22	3.22	62	0	0.8	0.8
SP-4	SP-4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TP7	SP-3	0.9	0	0.7	0.7	3.9	0	0.015	0.015	0.002	0	0.000	0.000	0.090	0	0.000	0.000	251	0	0.94	0.94	62	0	0.2	0.2
TP8	SP-3	2.3	0	1.8	1.8	3.9	0	0.040	0.040	0.002	0	0.000	0.000	0.090	0	0.001	0.001	251	0	2.54	2.54	62	0	0.6	0.6
TP9	SP-3	2.4	0	1.9	1.9	3.9	0	0.041	0.041	0.002	0	0.000	0.000	0.090	0	0.001	0.001	251	0	2.63	2.63	62	0	0.7	0.7
TP10	SP-3	3.1	0	2.5	2.5	3.9	0	0.053	0.053	0.002	0	0.000	0.000	0.090	0	0.001	0.001	251	0	3.38	3.38	62	0	0.8	0.8
TP11	SP-3, PZ-6A	0.3	0	0.3	0.3	2.0	0	0.003	0.003	0.001	0	0.000	0.000	0.046	0	0.000	0.000	163	0	0.23	0.23	73	0	0.1	0.1
TP12	PZ-6A	0.4	0	0.4	0.4	0.020	0	0.000	0.000	0.000	0	0.000	0.000	0.002	0	0.000	0.000	76	0	0.15	0.15	83	0	0.2	0.2
TP13	PZ-6A	1.0	0	0.8	0.8	0.020	0	0.000	0.000	0.000	0	0.000	0.000	0.002	0	0.000	0.000	76	0	0.33	0.33	83	0	0.4	0.4
TP14	PZ-6A	1.6	1.3	1.3	1.3	0.020	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.002	0.000	0.000	0.000	76	0.54	0.54	0.54	83	0.6	0.6	0.6
TP15	PZ-6A	2.0	1.6	1.6	1.6	0.020	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.002	0.000	0.000	0.000	76	0.65	0.65	0.65	83	0.7	0.7	0.7
SP-21 (c)	SP-21	1.5	1.4	1.4	1.4	1.8	0.014	0.014	0.014	0.001	0.000	0.000	0.000	0.034	0.000	0.000	0.000	1.5	0.01	0.01	0.01	7.6	0.1	0.1	0.1
Deep GW and/or GW from N Side Old RRC (d)			143	NA	521	-	0.428	-	0.446	-	0.001	-	0.001	-	0.002	-	0.005	-	0.02	-	0.10	-	2.4	-	3.2
Unaccounted loading (e)						-	-	-	-	-	0.000	0.002	0.002	-	-	-	-	-	-	-	-	-	0.0	0.0	0.0
TOTAL:		**149**	**175**	**122**	**643**	**-**	**1.45**	**1.45**	**1.89**	**-**	**0.001**	**0.003**	**0.003**	**-**	**0.009**	**0.017**	**0.023**	**-**	**14.1**	**40.5**	**40.6**	**-**	**8.3**	**22**	**25**
TOTAL BLENDED CONC (mg/L)						**-**	**1.5**	**2.2**	**0.5**	**-**	**0.001**	**0.004**	**0.001**	**-**	**0.01**	**0.03**	**0.01**	**-**	**14.7**	**60.5**	**11.5**	**-**	**8.7**	**32.4**	**7.1**

Notes:

Source: Site-wide loading analysis Table A-4 and Figures A-9 and A-10

(a) Captured flow was estimated by multiplying the estimated flow by the apporpriate expected collection efficiency (E[CE]) for source area. Expected collection efficiencies for each source area are presented on Tables D1-5 & D1-8 (partial collection), D1-6 & D1-9 (extended collection), and D1-7, D1-10, D1-10a, D1-11, & D1-12 (extended collection + RRC relocation) of the Draft Final FS Report.

Source Area	Partial	Extended	Extended w/ RRC Relocation
TP-1 Seeps & Flow Tubes	80%	80%	80%
TP-2 Seeps & Flow Tubes (Upstream of RC-7)	0%	80%	80%
TP2/3 Seeps & Flow Tubes (Downstream of RC-7)	80%	80%	80%
Unaccounted Load - East Area	20%	80%	80%
Loading downstream of RC-2 (SP-21)	95%	95%	95%
Loading Downstream of RC-2 (Flow Tubes)	90%	90%	90%

(b) S8(in) indicates portion of flowtube S8 flowing to the Creek; S8(out), SL1, SL2 and SL3 indicate groundwater flow from the Creek into tailings material at the east end of Tailings Pile 3 (see loading analysis Figure A-10). Flow of water from RRC into the collection was assumed to be zero based on system design.

(c) SP-21 would be conveyed directly to the treatment pond and would not be intercepted by the collection system.

(d) Water quality for collected deep groundwater assumed to equal average of measured concentrations from wells DS-3D and DS-4D. Water quality for groundwater from the north side of former RRC channel assumed to equal Fall 1997 water quality in RRC at station RC-4.

(e) Unaccounted loading based on loading analysis provided in Appendix A. If unaccounted loading was positive, captured unaccounted loading was estimated by multiplying baseline unaccounted loading by estimated collection efficiency (E[CE]) and the ratio of RRC banklength from the end of the wetland east of TP-1 to station RC-2 (2,800 ft) divided by the RRC banklength from RC-4 to RC-2 (5,000 ft). If baseline unaccounted loading was negative, the captured unaccounted loading was assumed to be zero.

Table 6-11
Partial and Extended Groundwater and Seep Collection - Fall 1997 Data
System Constructed East of Tailings Pile 3

Flow Tube Designation	Referenced Wells & Seeps	Estimated Flow (gpm)	Estimated Flow Capture (a)			Zn				Sulfate			
			Partial Collection (gpm)	Extended collection (gpm)	Ext. w/ RRC Relocation (gpm)	(mg/L)	Partial Collection (kg/day)	Extended Collection (kg/day)	Ext. w/ RRC Relocation (kg/day)	(mg/L)	Partial Collection (kg/day)	Extended Collection (kg/day)	Ext. w/ RRC Relocation (kg/day)
			Alts 4a, 5a	Alts 4b, 5b	Alts 4c, 5c, 5d, 6a, 6b		Alts 4a, 5a	Alts 4b, 5b	Alts 4c, 5c, 5d, 6a, 6b		Alts 4a, 5a	Alts 4b, 5b	Alts 4c, 5c, 5d, 6a, 6b
S6	TP2-11A, PZ-3A	43.8	0	35.1	35.1	0.16	0	0.030	0.030	450	0	86.3	86.3
S7	TP2-4A	40.1	0	32.1	32.1	0.007	0	0.001	0.001	570	0	100.1	100.1
S8 in (b)	TP2-4A	5.5	0	4.4	4.4	0.007	0	0.000	0.000	570	0	13.6	13.6
S8 out (b)	DS-1, TP3-9	19.7	17.8	17.8	17.8	0.24	0.023	0.023	0.023	0.61	0	0.1	0.1
SL1 (b)	DS-1, TP3-9	0	0	0	0	0.24	0	0	0	0.61	0	0	0
SL2 (b)	DS-1	0	0	0	0	0.079	0	0	0	0.12	0	0	0
SL3 (b)	DS-1	0	0	0	0	0.079	0	0	0	0.12	0	0	0
SL4 (b)	TP3-9	4.9	4.4	4.4	4.4	0.40	0.010	0.010	0.010	1.1	0.0	0.0	0.0
SL5 (b)	TP3-9	6.1	5.5	5.5	5.5	0.40	0.012	0.012	0.012	1.1	0.0	0.0	0.0
SP-3	SP-3	6.3	0	5.1	5.1	0.61	0	0.017	0.017	1300	0	35.9	35.9
TP4	PZ-1B	2.6	0	2.1	2.1	0.61	0	0.007	0.007	1300	0	14.7	14.7
TP5	SP-3	1.5	0	1.2	1.2	0.61	0	0.004	0.004	1300	0	8.3	8.3
TP6	SP-3	2.9	0	2.3	2.3	0.61	0	0.008	0.008	1300	0	16.7	16.7
SP-4	SP-4	0	0	0	0	0	0	0	0	0	0	0	0
TP7	SP-3	0.9	0	0.7	0.7	0.61	0	0.002	0.002	1300	0	4.9	4.9
TP8	SP-3	2.3	0	1.8	1.8	0.61	0	0.006	0.006	1300	0	13.2	13.2
TP9	SP-3	2.4	0	1.9	1.9	0.61	0	0.006	0.006	1300	0	13.6	13.6
TP10	SP-3	3.1	0	2.5	2.5	0.61	0	0.008	0.008	1300	0	17.5	17.5
TP11	SP-3, PZ-6A	0.3	0	0.3	0.3	0.32	0	0.000	0.000	1500	0	2.1	2.1
TP12	PZ-6A	0.4	0	0.4	0.4	0.025	0	0.000	0.000	1700	0	3.3	3.3
TP13	PZ-6A	1.0	0	0.8	0.8	0.025	0	0.000	0.000	1700	0	7.4	7.4
TP14	PZ-6A	1.6	1.3	1.3	1.3	0.025	0.000	0.000	0.000	1700	12	12.2	12.2
TP15	PZ-6A	2.0	1.6	1.6	1.6	0.025	0.000	0.000	0.000	1700	15	14.6	14.6
SP-21 (c)	SP-21	1.5	1.4	1.4	1.4	0.13	0.001	0.001	0.001	140	1.1	1.1	1.1
Deep GW and/or GW from N Side Old RRC (d)			143	NA	521	-	0.067	-	0.089	-	50.5	-	58.4
Unaccounted loading (e)						-	0.157	0.628	0.628	-	-	-	-
TOTAL:		**149**	**175**	**122**	**643**	**-**	**0.3**	**0.8**	**0.9**	**-**	**79**	**366**	**424**
TOTAL BLENDED CONC (mg/L)						**-**	**0.3**	**1.1**	**0.2**	**-**	**82**	**546**	**120**

Notes:
Source: Site-wide loading analysis Table A-4 and Figures A-9 and A-10
(a) Captured flow was estimated by multiplying the estimated flow by the apporpriate expected collection efficiency (E[CE]) for source area. Expected collection efficiencies for each source area are presented on Tables D1-5 & D1-8 (partial collection), D1-6 & D1-9 (extended collection), and D1-7, D1-10, D1-10a, D1-11, & D1-12 (extended collection + RRC relocation) of the Draft Final FS Report.

Source Area	Partial	Extended	Extended w/ RRC Relocation
TP-1 Seeps & Flow Tubes	80%	80%	80%
TP-2 Seeps & Flow Tubes (Upstream of RC-7)	0%	80%	80%
TP2/3 Seeps & Flow Tubes (Downstream of RC-7)	80%	80%	80%
Unaccounted Load - East Area	20%	80%	80%
Loading downstream of RC-2 (SP-21)	95%	95%	95%
Loading Downstream of RC-2 (Flow Tubes)	90%	90%	90%

(b) S8(in) indicates portion of flowtube S8 flowing to the Creek; S8(out), SL1, SL2 and SL3 indicate groundwater flow from the Creek into tailings material at the east end of Tailings Pile 3 (see loading analysis Figure A-10). Flow of water from RRC into the collection was assumed to be zero based on system design.
(c) SP-21 would be conveyed directly to the treatment pond and would not be intercepted by the collection system.
(d) Water quality for collected deep groundwater assumed to equal average of measured concentrations from wells DS-3D and DS-4D. Water quality for groundwater from the north side of former RRC channel assumed to equal Fall 1997 water quality in RRC at station RC-4.
(e) Unaccounted loading based on loading analysis provided in Appendix A. If unaccounted loading was positive, captured unaccounted loading was estimated by multiplying baseline unaccounted loading by estimated collection efficiency (E[CE]) and the ratio of RRC banklength from the end of the wetland east of TP-1 to station RC-2 (2,800 ft) divided by the RRC banklength from RC-4 to RC-2 (5,000 ft). If baseline unaccounted loading was negative, the captured unaccounted loading was assumed to be zero.

Table 6-12
Conceptual Process Sizing - East Area Treatment

Process	Parameter	Units	Tailings Pile 1					Tailings Pile 3			
			Partial Collection (Alt 4a & 5a)	Extended Collection (Alt 4b & 5b)	Extended Collection w/ RRC Relocation (Alt 4c & 5c)	Extended Collection w/ RRC Relocation (Alt 5d)	Extended Collection w/ RRC Relocation (Alt 6a & 6b)	Partial Collection (Alt 4a & 5a)	Extended Collection (Alt 4b & 5b)	Extended Collection w/ RRC Rel. (Alt 4c, 5c, 5d, 6a, & 6b)	Extended Collection (Alt 8)
System	Peak Capacity[a]	gpm	230	330	660	710	1,000	1,100	1,300	2,100	1,400
	Annual Water Treated[b]	MG	82	110	230	250	350	210	220	530	240
Chemical Addition	Annual Usage[c]	ton	10	14	28	31	44	26	28	66	30
	Hopper Size	gallon	800	1,000	2,000	2,200	3,100	1,900	2,000	4,700	2,200
Clarification / Sedimentation	Annual Dry Sludge Production[d]	ton	450	620	640	650	670	110	380	440	440
	Annual Wet Sludge Production[e]	yd^3	27,000	37,000	38,000	39,000	39,000	6,700	23,000	26,000	26,000
	Total Capacity[f]	MG	5.3	7.3	7.5	7.6	7.8	1.3	4.5	5.2	5.2
	Surface Area[g]	ft^2	61,000	84,000	86,000	88,000	90,000	15,000	52,000	60,000	59,000
	Overflow Rate	gpd/ft^2	5.3	5.6	11	12	16	100	37	51	33
Filtration	Total Surface Area[h]	ft^2	2,300	3,300	6,600	7,100	10,000	11,000	13,000	21,000	14,000

a. From groundwater and seep collection Tables 6-8 through 6-11.
b. Spring flow assumed for 3 months, Fall flow assumed for 9 months.
c. Assumes chemical dosage of 30 mg/L, dosage required to raise pH to 7, June 2000 treatability results.
d. Assumes precipitation of total metals, sulfate, and dosed chemical.
e. Estimated using concentration of 2% solids.
f. Sized for annual cleanout of sludge.
g. Assumes basin depth of 12 ft.
h. Assumes media depth of 5 ft and overflow rate of 0.1 gpm/ft^2.

Table 6-13
Extended Groundwater and Seep Collection
Alternative 8
Spring 1997 Data

		Estimated			Al		Cd		Cu		Fe		Mg		Zn		Sulfate	
Flow Tube Designation	**Referenced Wells & Seeps**	**Flow (gpm)**	**Flow (l/s)**	**Flow Capture (a) (gpm)**	**(mg/L)**	**Collection (kg/day)**	**(mg/L)**	**Collection (kg/day)**	**(mg/L)**	**Collection (kg/day)**	**(mg/L)**	**Collection (kg/day)**	**(mg/L)**	**Collection (kg/day)**	**(mg/L)**	**Collection (kg/day)**	**(mg/L)**	**Collection (kg/day)**
S7	TP2-11	75	4.72	60	0.33	0.11	0.002	0.001	0.01	0.003	0.01	0.0	4.9	1.6	0.17	0.055	150	49
S8	TP2-11	63	4.02	51	0.33	0.09	0.002	0.000	0.01	0.003	0.01	0.0	4.9	1.4	0.17	0.047	150	42
S9	TP2-11	21	1.31	16	0.33	0.03	0.002	0.000	0.01	0.001	0.01	0.0	4.9	0.4	0.17	0.015	150	14
S10	PZ-3A	43	2.73	34	0.01	0.00	0.002	0.000	0.00	0.000	5.7	1.1	24	4.5	0.003	0.000	670	126
S11	PZ3-A	40	2.51	32	0.01	0.00	0.002	0.000	0.00	0.000	5.7	1.0	24	4.2	0.003	0.000	670	116
S12	TP2-4A	21.5	1.36	17.2	0.01	0.00	0.002	0.000	0.00	0.000	7.0	0.7	27	2.6	0.006	0.001	720	68
S13	TP2-4A	19.0	1.20	15.2	0.01	0.00	0.002	0.000	0.00	0.000	7.0	0.6	27	2.3	0.006	0.000	720	60
S14	TP3-8A	29	1.84	23.3	0.12	0.02	0.000	0.000	0.00	0.000	55	7.0	17	2.2	0.058	0.007	340	43
S15	TP3-8A	7.8	0.49	6.2	0.12	0.00	0.000	0.000	0.00	0.000	55	1.9	17	0.6	0.058	0.002	340	12
SP-21	SP-21	876.3	55.50	832.5	1.50	6.83	0.000	0.000	0.05	0.236	1	4.6	4	17.4	0.109	0.497	84	383
SP-3	SP-3	75	4.73	60	33.40	10.93	0.040	0.013	1.28	0.419	154	50.4	48	15.7	4.0	1.318	880	288
SP-4	SP-4	224	14.20	179	19.00	18.65	0.007	0.007	0.67	0.66	75	73.5	36	35.6	0.90	0.887	660	648
TP1	SP-3	1.6	0.10	1	33.40	0.23	0.040	0.000	1.28	0.009	154	1.1	48	0.3	4.0	0.028	880	6
TP2	SP-3	2.7	0.17	2.2	33.40	0.40	0.040	0.000	1.28	0.015	154	1.8	48	0.6	4.0	0.048	880	10
TP3	SP-3	2.9	0.18	2.3	33.40	0.42	0.040	0.001	1.28	0.016	154	1.9	48	0.6	4.0	0.050	880	11
TP4	SP-3	2.7	0.17	2.2	33.40	0.40	0.040	0.000	1.28	0.015	154	1.8	48	0.6	4.0	0.048	880	10
TP5	SP-3	2.1	0.13	1.7	33.40	0.31	0.000	0.000	1.28	0.012	154	1.4	48	0.4	4.0	0.038	880	8
TP6	SP-3	2.7	0.17	2.2	33.40	0.40	0.040	0.000	1.28	0.015	154	1.8	48	0.6	4.0	0.048	880	10
TP7	SP-3	4.0	0.25	3.2	33.40	0.58	0.040	0.001	1.28	0.022	154	2.7	48	0.8	4.0	0.070	880	15
TP8	SP-3, SP-4	2.7	0.17	2.2	26.20	0.31	0.024	0.000	0.98	0.012	114	1.4	42	0.5	2.5	0.029	770	9
TP9	SP-3, SP-4	1.1	0.07	0.87	26.20	0.12	0.024	0.000	0.98	0.005	114	0.5	42	0.2	2.5	0.012	770	4
TP10	SP-4	1.3	0.08	1.07	19.00	0.11	0.007	0.000	0.67	0.004	75	0.4	36	0.2	0.90	0.005	660	4
TP11	SP-4	2.6	0.17	2.10	19.00	0.22	0.007	0.000	0.67	0.008	75	0.9	36	0.4	0.90	0.010	660	8
TP12	SP-4	1.7	0.11	1.4	19.00	0.14	0.007	0.000	0.67	0.005	75	0.6	36	0.3	0.90	0.007	660	5
TP13	SP-4, PZ-6A	2.1	0.13	1.7	9.51	0.09	0.005	0.000	0.34	0.003	67	0.6	51	0.5	0.46	0.004	1080	10
Unaccounted loading (b)					-	-	-	0.044	-	-	-	-	-	21.4	-	2.44	-	-
TOTAL:		**1524**	**97**	**1351**	**-**	**40**	**-**	**0.070**	**-**	**1.5**	**-**	**158**	**-**	**116**	**-**	**5.7**	**-**	**1959**

	Al	Cd	Cu	Fe	Mg	Zn	Sulfate
TOTAL BLENDED CONC (mg/L)	**5**	**0.009**	**0.20**	**21**	**16**	**0.8**	**265**

Notes:
Source: Site-wide loading analysis Table A-3 and Figures A-7 and A-8
(a) Captured flow was estimated by multiplying the estimated flow by the apporpriate expected collection efficiency (E[CE]) for source area.
(b) Unaccounted loading based on loading analysis provided in Appendix A. If unaccounted loading was positive, captured unaccounted loading was estimated by multiplying baseline unaccounted loading by estimated collection efficiency (E[CE]).

Table 6-13
Extended Groundwater and Seep Collection
Alternative 8
Fall 1997 Data

Flow Tube Designation	Referenced Wells & Seeps	Estimated Flow (gpm)	Flow (l/s)	Flow Capture (a) (gpm)	Al (mg/L)	Al Collection (kg/day)	Cd (mg/L)	Cd Collection (kg/day)	Cu (mg/L)	Cu Collection (kg/day)	Fe (mg/L)	Fe Collection (kg/day)	Mg (mg/L)	Mg Collection (kg/day)	Zn (mg/L)	Zn Collection (kg/day)	Sulfate (mg/L)	Sulfate Collection (kg/day)
S4	TP2-11A	72	4.53	57	0.44	0.138	0.003	0.001	0.010	0.003	0.10	0.03	13	4.0	0.31	0.097	390	122.1
S5	TP2-11A	9	0.58	7.3	0.44	0.018	0.003	0.000	0.010	0.000	0.10	0.00	13	0.5	0.31	0.012	390	15.6
S6	TP2-11A, PZ-3A	44	2.78	35	0.23	0.043	0.002	0.000	0.006	0.001	2.9	0.56	18	3.4	0.16	0.030	450	86.3
S7	TP2-4A	40	2.54	32	0.010	0.002	0.000	0.000	0.001	0.000	5.6	0.99	30	5.2	0.01	0.001	570	100.1
S8 in (b)	TP2-4A	5.5	0.35	4	0.010	0.000	0.000	0.000	0.001	0.000	5.6	0.13	30	0.7	0.01	0.000	570	13.6
SP-21	SP-21	1.5	0.09	1	1.800	0.014	0.001	0.000	0.034	0.000	1.5	0.01	8	0.1	0.13	0.001	140	1.1
S8 out (b)	DS-1, TP3-9	0	0.000	0	5.0	0	0.002	0	0.045	0	63	0	23	0	0.24	0	0.6	0
SL1 (b)	DS-1, TP3-9	0	0.000	0	5.0	0	0.002	0	0.045	0	63	0	23	0	0.24	0	0.6	0
SL2 (b)	DS-1	0	0.000	0	0.25	0	0.001	0	0.039	0	0.01	0	5.0	0	0.08	0	0.1	0
SL3 (b)	DS-1	0	0.000	0	0.25	0	0.001	0	0.039	0	0.01	0	5.0	0	0.08	0	0.1	0
SL4 (b)	TP3-9	4.9	0.31	4.4	9.7	0.232	0.004	0.000	0.051	0.001	125	2.99	41	1.0	0.40	0.010	1.1	0.0
SL5 (b)	TP3-9	6.1	0.39	5.5	9.7	0.293	0.004	0.000	0.051	0.002	125	3.78	41	1.3	0.40	0.012	1.1	0.0
SP-3	SP-3	6.3	0.40	5.1	3.9	0.108	0.002	0.000	0.090	0.002	251	6.94	62	1.7	0.61	0.017	1300	35.9
SP-4	SP-4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TP1	SP-3	7.1	0.45	5.7	3.9	0.122	0.002	0.000	0.090	0.003	251	7.80	62	1.93	0.61	0.019	1300	40.4
TP2	SP-3	1.7	0.11	1.4	3.9	0.030	0.002	0.000	0.090	0.001	251	1.91	62	0.47	0.61	0.005	1300	9.9
TP3	SP-3	2.5	0.16	2.0	3.9	0.043	0.002	0.000	0.090	0.001	251	2.78	62	0.69	0.61	0.007	1300	14.4
TP4	PZ-1B	2.6	0.16	2	3.9	0.044	0.002	0.000	0.090	0.001	251	2.85	62	0.71	0.61	0.007	1300	14.7
TP5	SP-3	1.5	0.09	1	3.9	0.025	0.002	0.000	0.090	0.001	251	1.61	62	0.40	0.61	0.004	1300	8.3
TP6	SP-3	2.9	0.19	2	3.9	0.050	0.002	0.000	0.090	0.001	251	3.22	62	0.80	0.61	0.008	1300	16.7
TP7	SP-3	0.86	0.05	1	3.9	0.015	0.002	0.000	0.090	0.000	251	0.94	62	0.23	0.61	0.002	1300	4.9
TP8	SP-3	2.3	0.15	2	3.9	0.040	0.002	0.000	0.090	0.001	251	2.54	62	0.63	0.61	0.006	1300	13.2
TP9	SP-3	2.4	0.15	2	3.9	0.041	0.002	0.000	0.090	0.001	251	2.63	62	0.65	0.61	0.006	1300	13.6
TP10	SP-3	3.1	0.20	2	3.9	0.053	0.002	0.000	0.090	0.001	251	3.38	62	0.84	0.61	0.008	1300	17.5
TP11	SP-3, PZ-6A	0.32	0.02	0	2.0	0.003	0.001	0.000	0.046	0.000	163	0.23	73	0.10	0.32	0.000	1500	2.1
TP12	PZ-6A	0.44	0.03	0	0.020	0.000	0.000	0.000	0.002	0.000	76	0.15	83	0.16	0.03	0.000	1700	3.3
Unaccounted loading (c)					-	-	-	0.003	-	-	-	-	-	-	-	0.15	-	-
TOTAL:		**217**	**14**	**175**	**-**	**1.3**	**-**	**0.005**	**-**	**0.021**	**-**	**45**	**-**	**25**	**-**	**0.40**	**-**	**534**

	Al	Cd	Cu	Fe	Mg	Zn	Sulfate
TOTAL BLENDED CONC (mg/L)	**1.4**	**0.005**	**0.022**	**48**	**27**	**0.4**	**559**

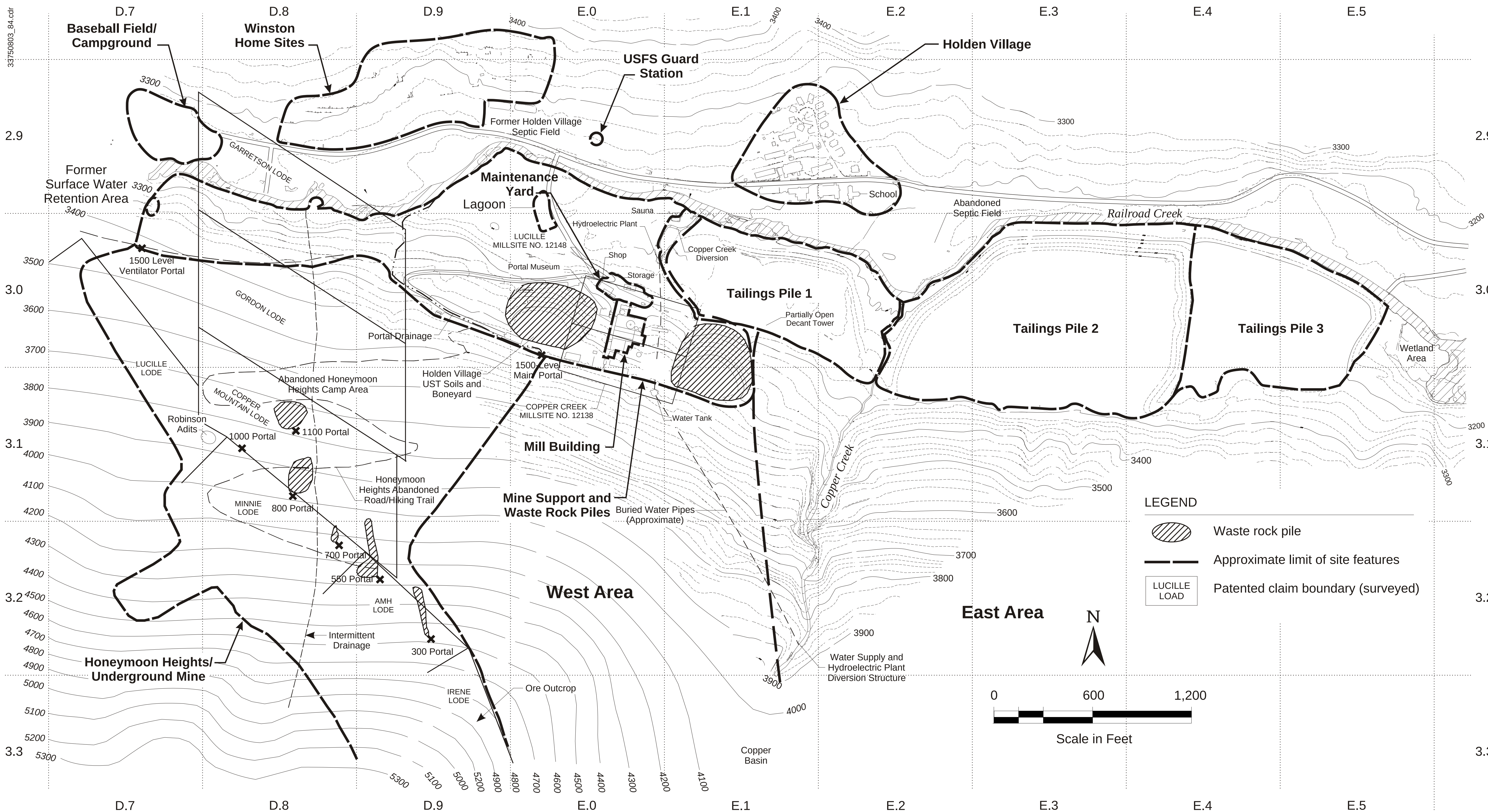
Notes:

Source: Site-wide loading analysis Table A-4 and Figures A-9 and A-10

(a) Captured flow was estimated by multiplying the estimated flow by the apporpriate expected collection efficiency (E[CE]) for source area.

(b) S8(in) indicates portion of flowtube S8 flowing to the Creek; S8(out), SL1, SL2 and SL3 indicate groundwater flow from the Creek into tailings material at the east end of Tailings Pile 3 (see loading analysis Figure A-10). Flow of water from RRC into the collection system was assumed to be zero based on system design.

(c) Unaccounted loading based on loading analysis provided in Appendix A. If unaccounted loading was positive, captured unaccounted loading was estimated by multiplying baseline unaccounted loading by estimated collection efficiency (E[CE]).



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

Figure 6-1
Holden Mine Site Map

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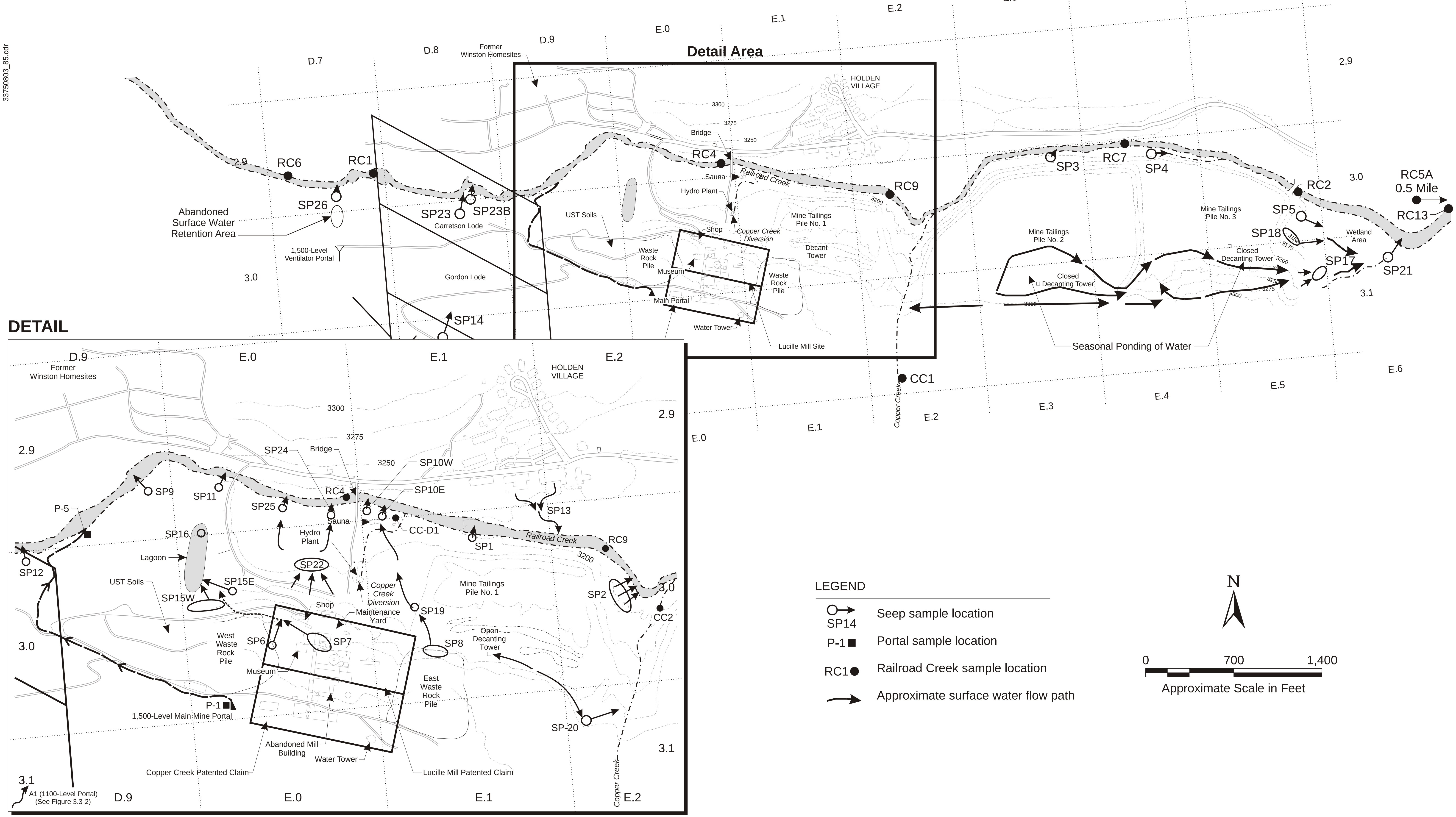

SOURCE: ORB, 1975

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Figure 6-2
Approximate Seep and Surface Water Sampling Locations

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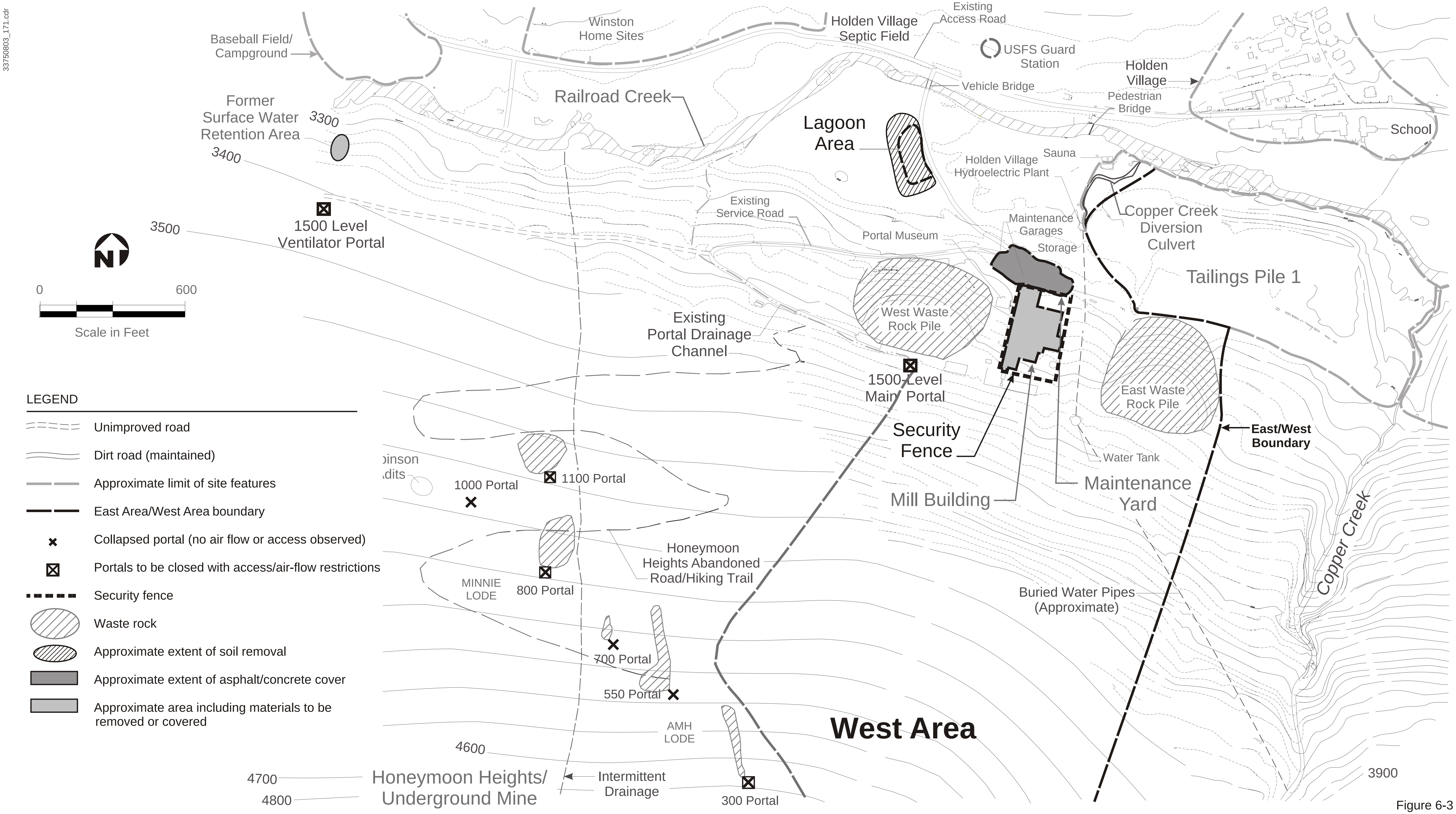

Figure 6-3

Common West Area Remediation Components Site-wide Alternatives 2-8

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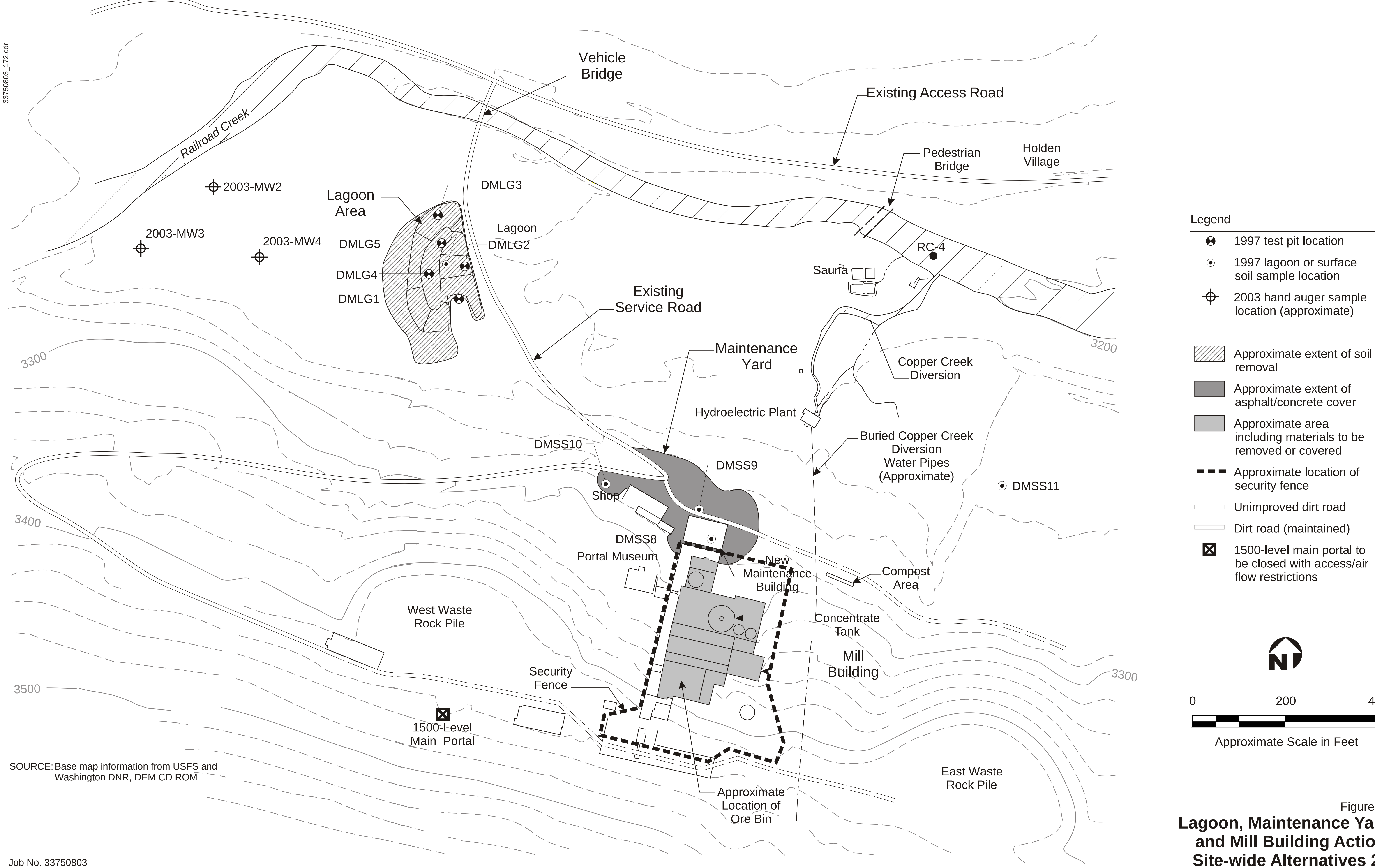

SOURCE: Base map information from USFS and Washington DNR, DEM CD ROM

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Figure 6-4
Lagoon, Maintenance Yard, and Mill Building Actions Site-wide Alternatives 2-8

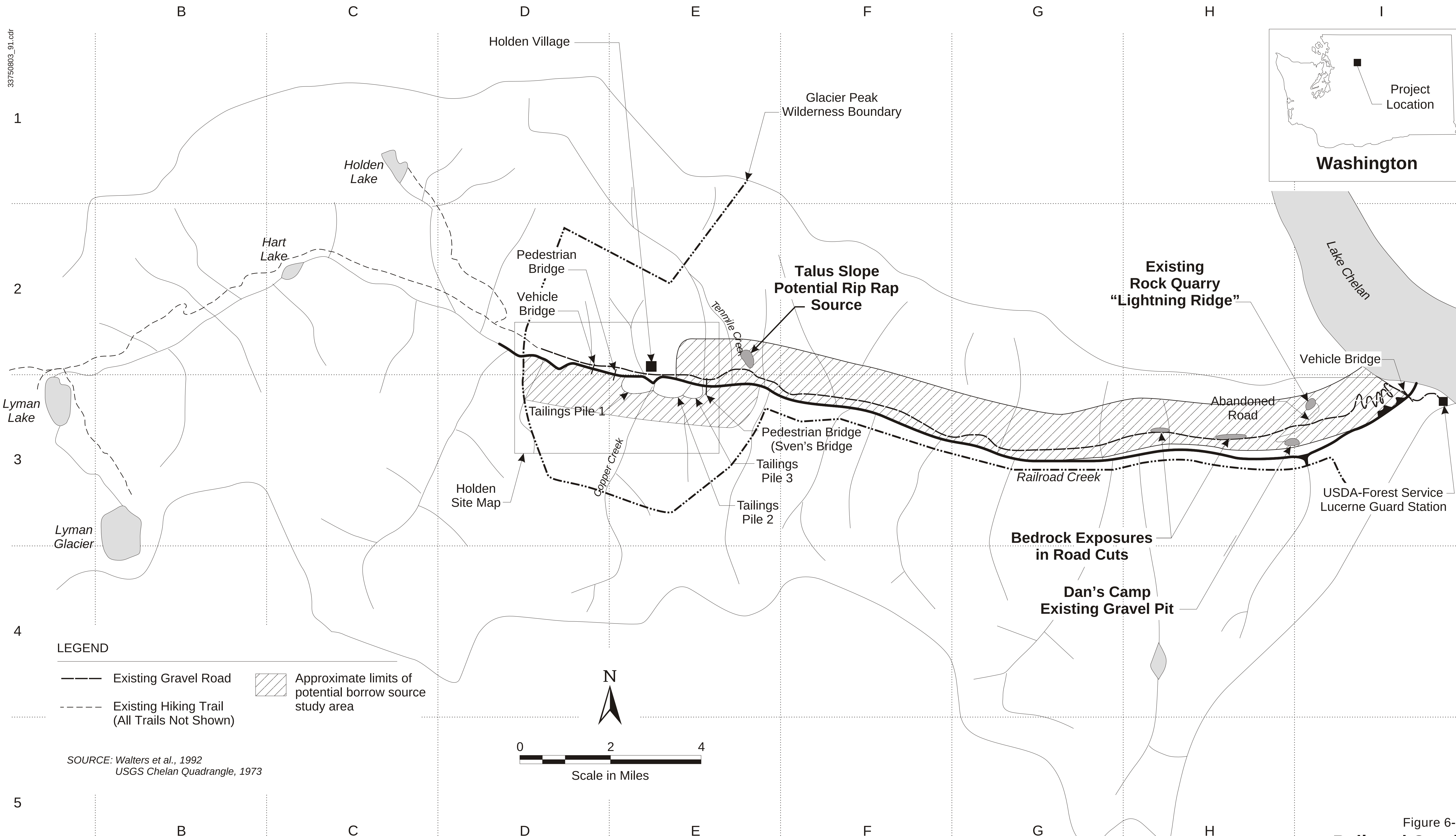

Figure 6-5
Railroad Creek
Existing and Potential
Borrow Source Study Areas

33750803_146.cdr

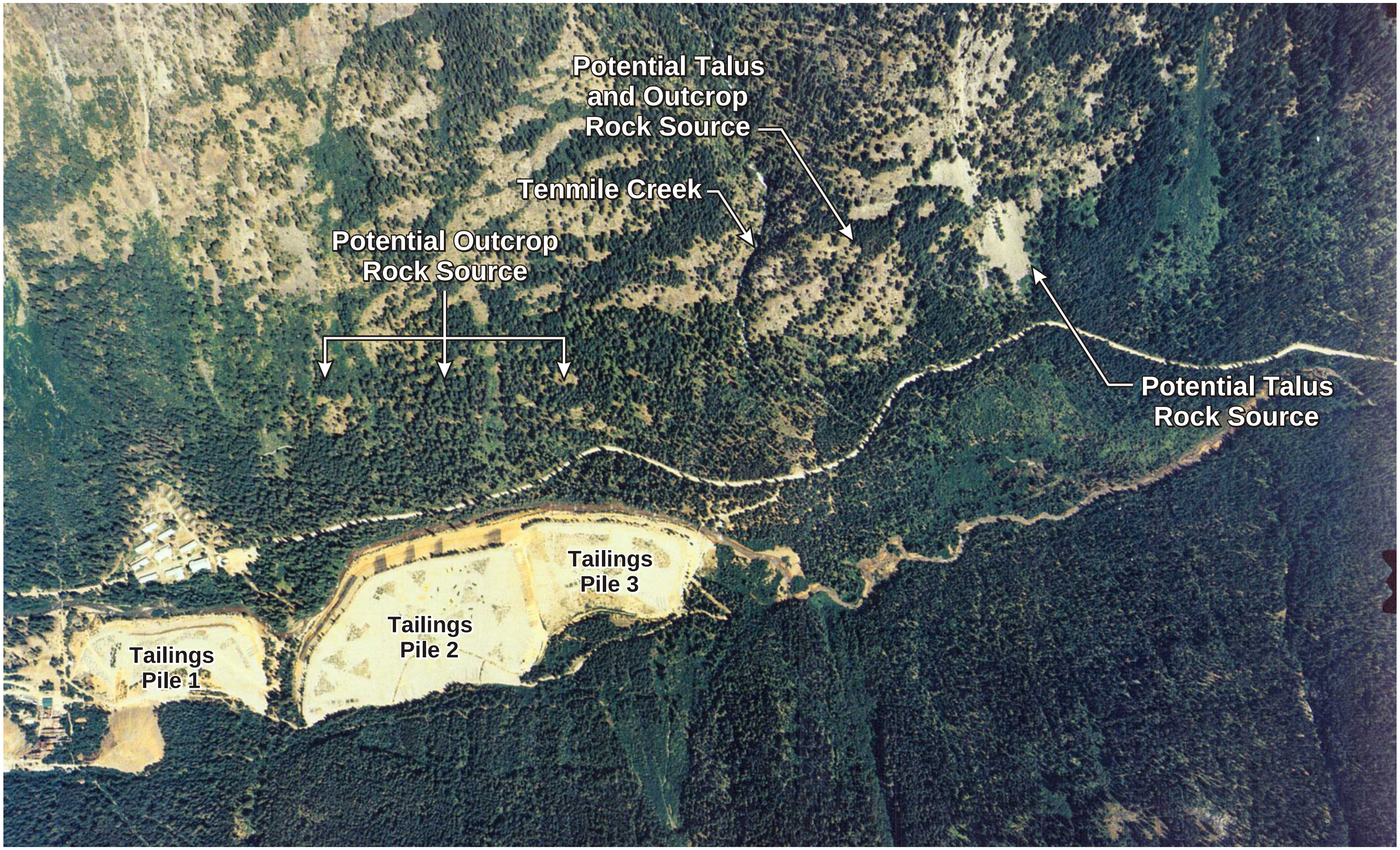

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Figure 6-6

Potential Rock Source Locations

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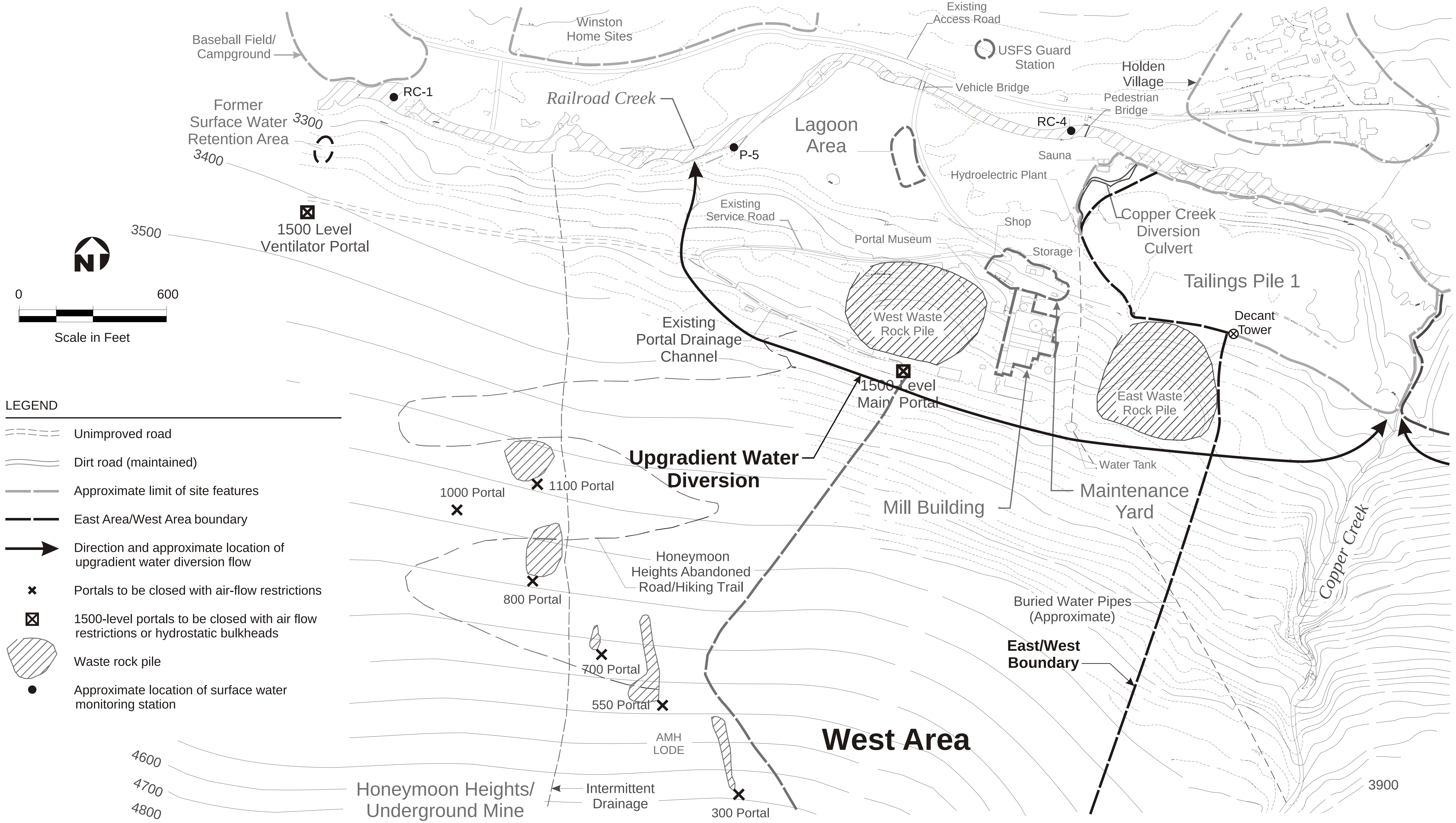

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Figure 6-7
West Area - Upgradient Water Controls
Site-wide Alternatives 2 and 4

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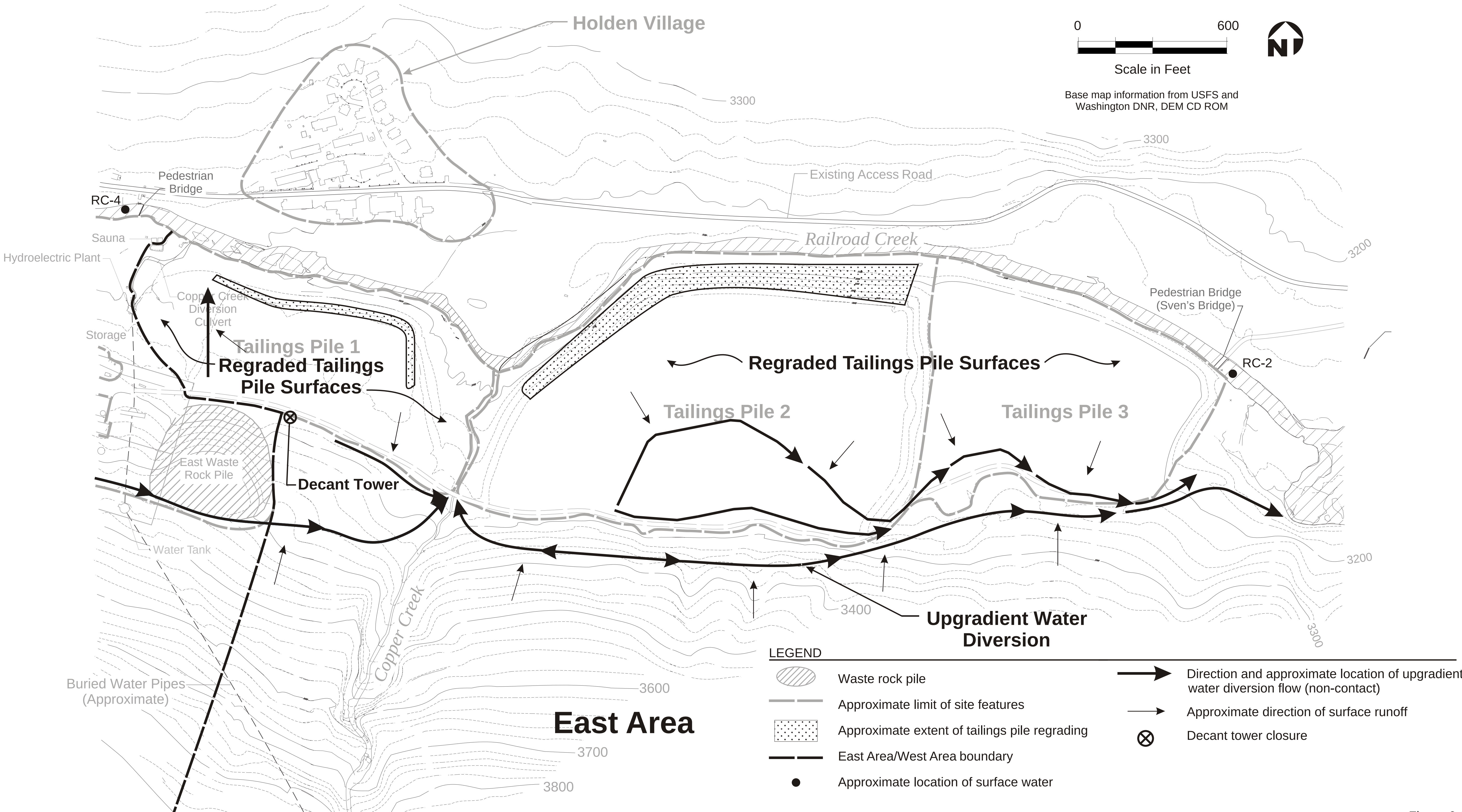

Figure 6-8
East Area - Revegetation and Upgradient Water Controls Site-wide Alternatives 2 and 3

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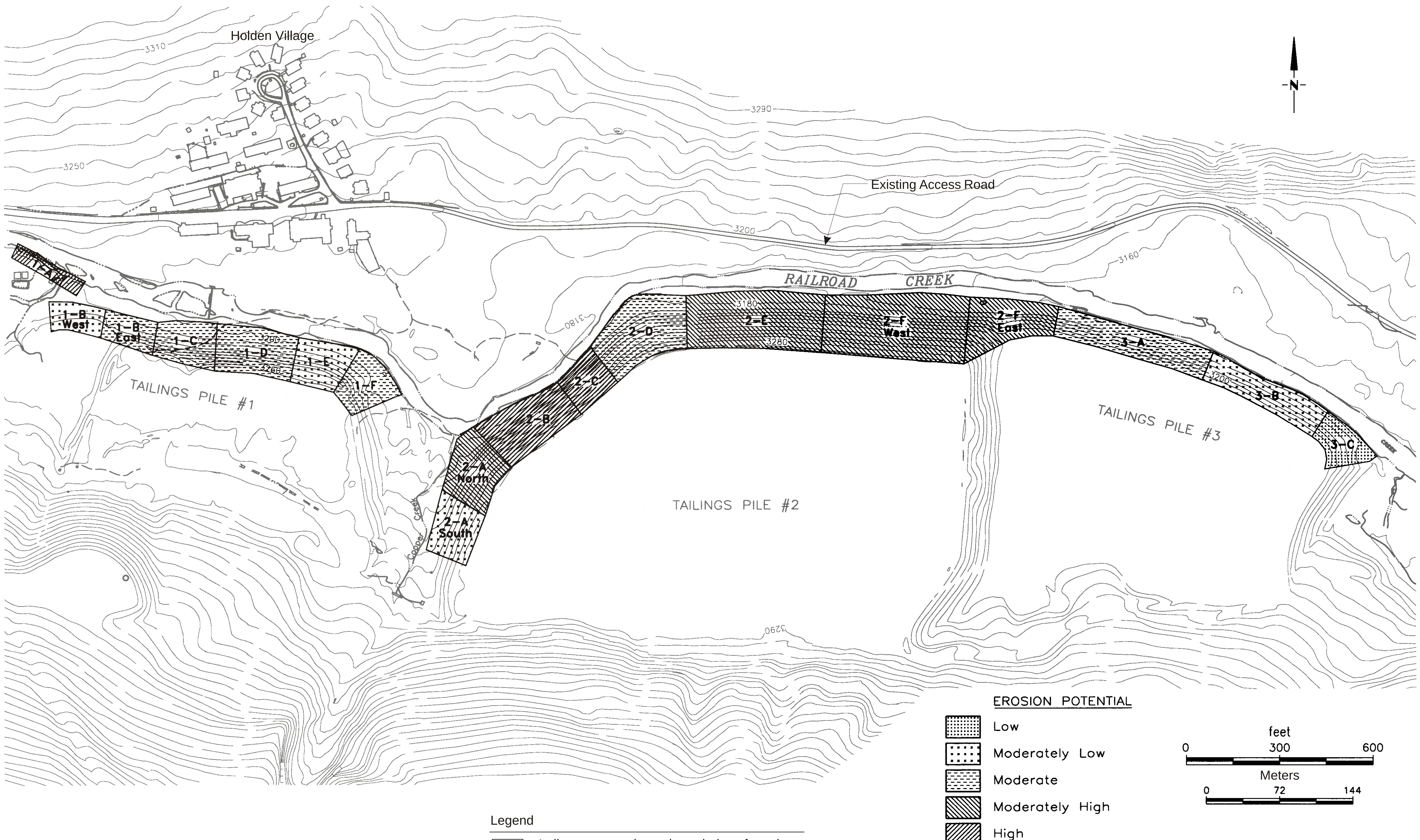

Legend

3-C Indicates approximate boundaries of erosion potential areas based on RI field observations

Figure 6-9
Tailings Pile Erosion Potential Map

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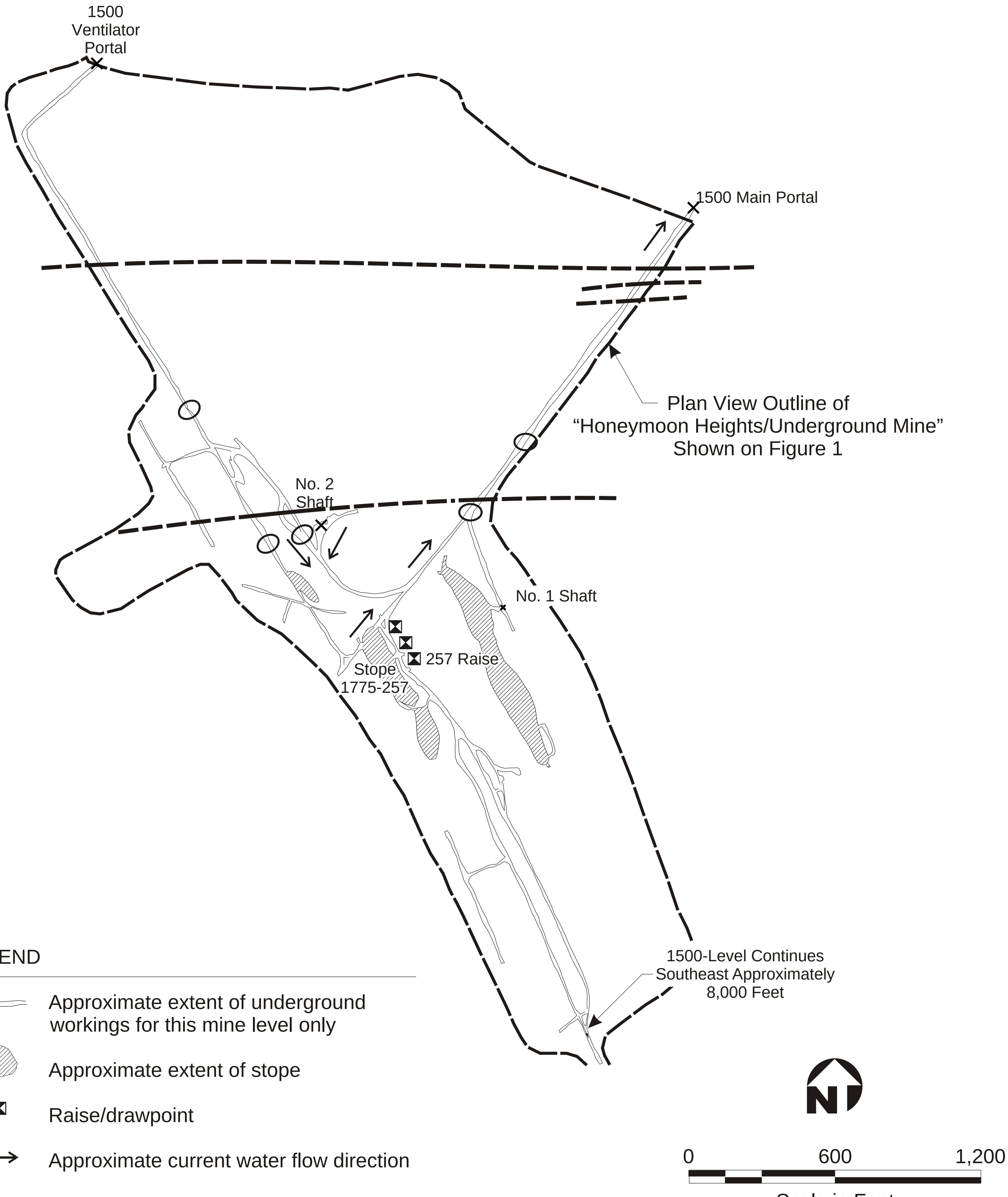

LEGEND

Approximate extent of underground workings for this mine level only

Approximate extent of stope

Raise/drawpoint

Approximate current water flow direction

Approximate location of mapped fault (dashed where inferred)

Potential tunnel segments to be evaluated for the installation of

Figure 6-10

1500-Level Plan View with Approximate Location of Primary Faults and Possible Bulkhead Placement

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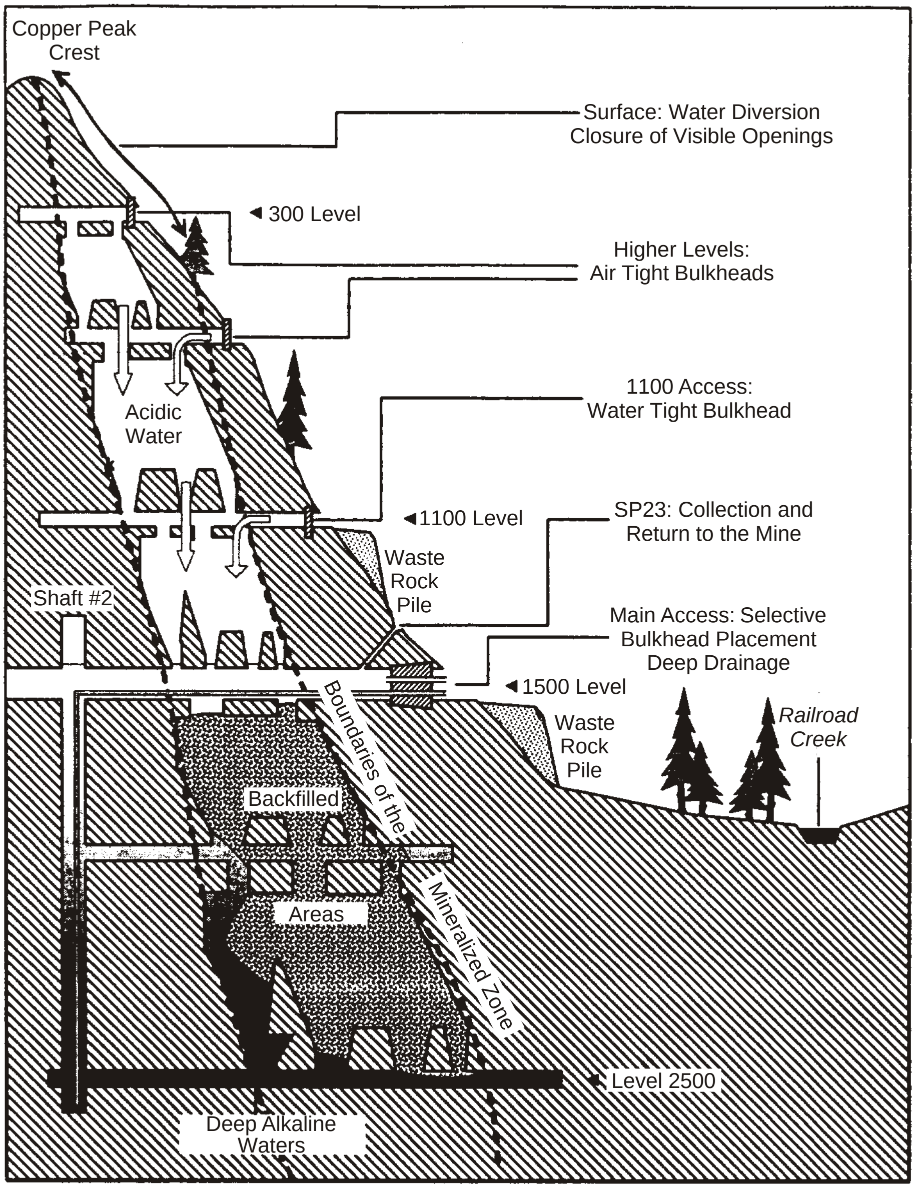


Developed by Mr. Jean-Michel Schmitt
the School of Mines, Paris, France

Figure 6-11

Conceptual Diagram of the Underground Mine and Potential In-mine Water Controls

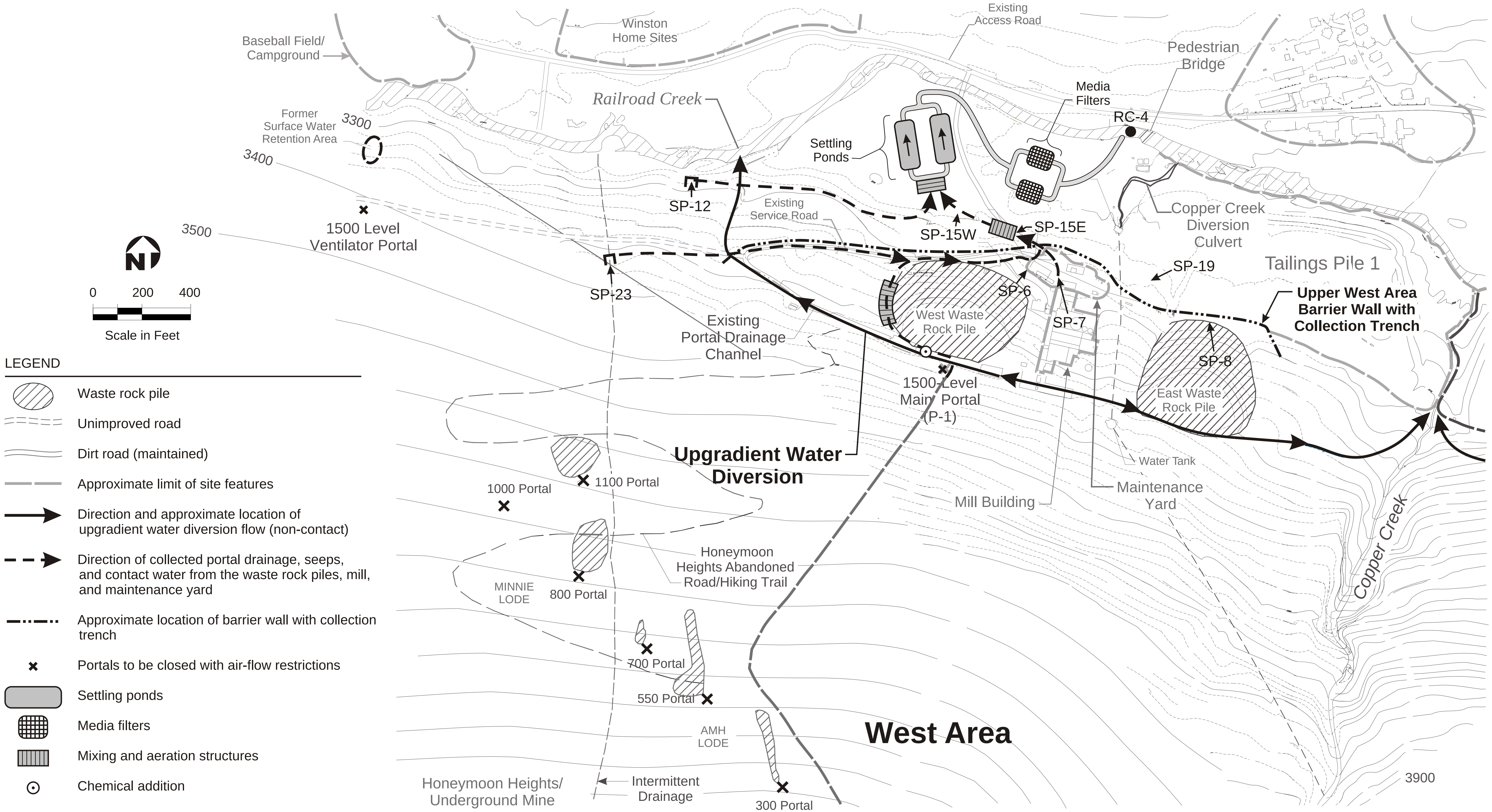
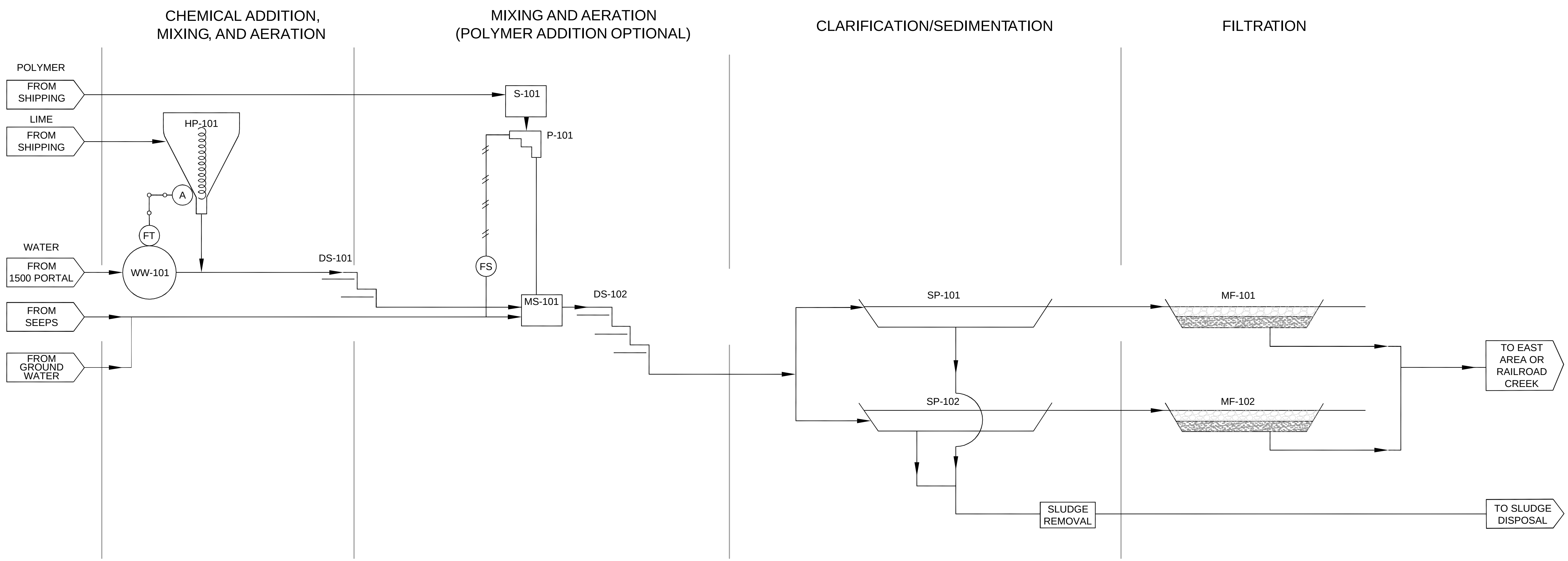


Figure 6-12
West Area
Water Collection and Treatment
Site-wide Alternative 3a (Open Portal)



LEGEND

- FT FLOW TRANSMITTER
- FS FLOW SIGNAL
- A AUGER
- PROCESS LINE
- MECHANICAL LINE
- ELECTRIC SIGNAL
- METER PUMP

	I.D.	HP-101	WW-101	DS-101	MS-101	DS-102	P-101	S-101	SP-101	SP-102	MF-101	MF-102
	DESCRIPTION	ALKALI STORAGE	CHEMICAL FEED	DROP STRUCTURE MIXING/AERATION	MIXING SUMP	DROP STRUCTURE AERATION/FLOC	POLYMER PUMP	POLYMER STORAGE	SETTLING POND	SETTLING POND	MEDIA FILTER	MEDIA FILTER
OPEN 1500-LEVEL PORTAL (ALT 3a)	**CAPACITY**	4,000 gal	50 lbs/hr	1,200 gpm	TBD	2,100 gpm	TBD	TBD	1.8 MG	1.8 MG	1,100 gpm	1,100 gpm
	SURFACE AREA	-	-	-	-	-	-	-	20,000 ft^2	20,000 ft^2	10,000 ft^2	10,000 ft^2
	HEIGHT	-	-	-	-	-	-	-	12 ft	12 ft	5 ft	5 ft
WITH 1500-LEVEL HYDROSTATIC BULKHEADS (ALTS 3b, 5a, 5b, 5c, 5d & 7)	**CAPACITY**	4,000 gal	30 lbs/hr	270 gpm	TBD	1,100 gpm	TBD	TBD	2.7 MG	2.7 MG	550 gpm	550 gpm
	SURFACE AREA	-	-	-	-	-	-	-	31,000 ft^2	31,000 ft^2	5,500 ft^2	5,500 ft^2
	HEIGHT	-	-	-	-	-	-	-	12 ft	12 ft	5 ft	5 ft
WITH 1500-LEVEL HYDROSTATIC BULKHEADS (ALT 8)	**CAPACITY**	1,600 gal	13 lbs/hr	270 gpm	TBD	580 gpm	TBD	TBD	1.8 MG	1.8 MG	290 gpm	290 gpm
	SURFACE AREA	-	-	-	-	-	-	-	21,000 ft^2	21,000 ft^2	2,900 ft^2	2,900 ft^2
	HEIGHT	-	-	-	-	-	-	-	12 ft	12 ft	5 ft	5 ft

TBD: TO BE DETERMINED DURING DESIGN

Figure 6-13

Conceptual Process Flow Diagram
West Area Low-Energy Treatment

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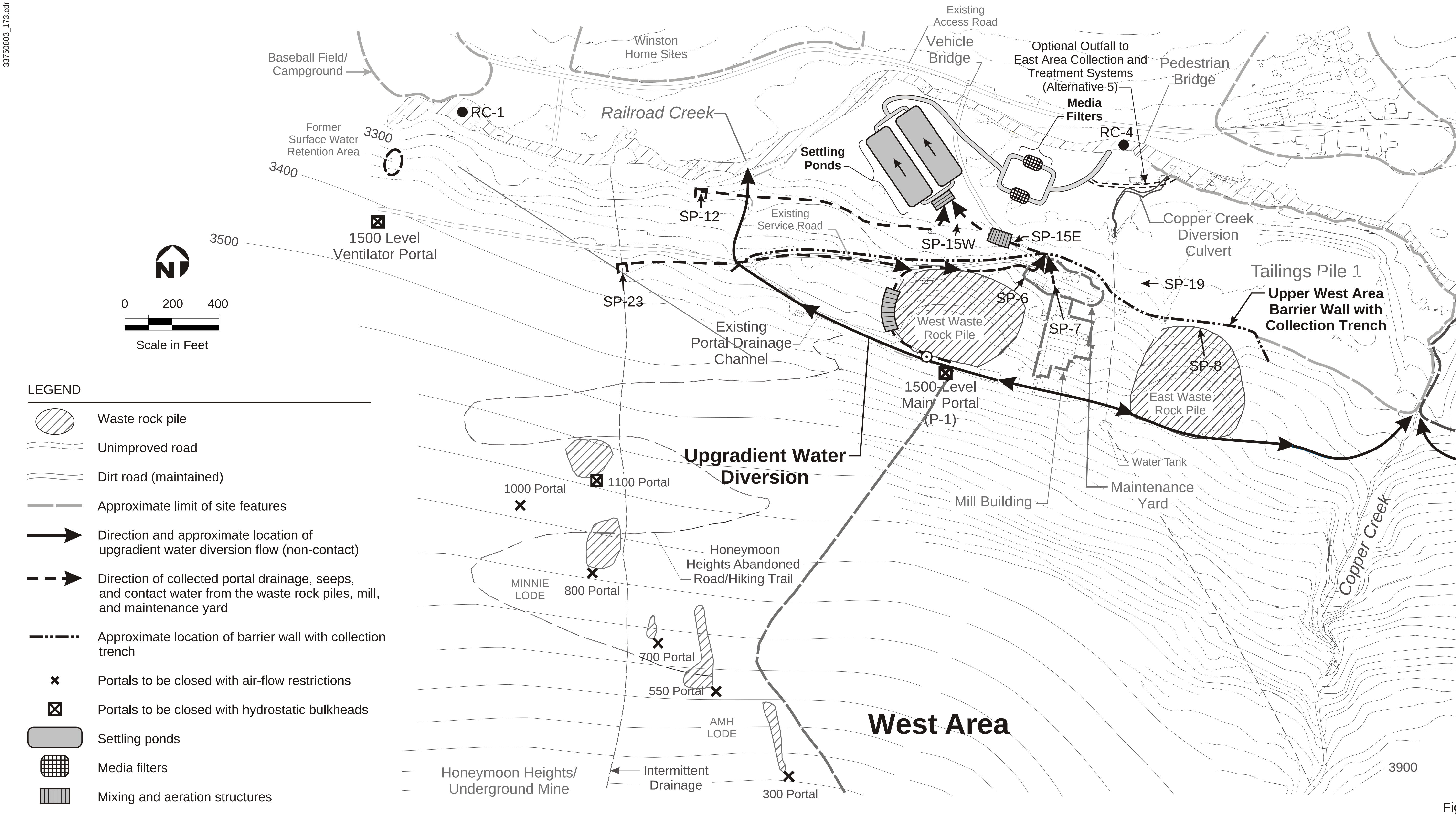

LEGEND

- Waste rock pile
- Unimproved road
- Dirt road (maintained)
- Approximate limit of site features
- Direction and approximate location of upgradient water diversion flow (non-contact)
- Direction of collected portal drainage, seeps, and contact water from the waste rock piles, mill, and maintenance yard
- Approximate location of barrier wall with collection trench
- Portals to be closed with air-flow restrictions
- Portals to be closed with hydrostatic bulkheads
- Settling ponds
- Media filters
- Mixing and aeration structures

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Figure 6-14
West Area - Water Collection and Treatment Site-wide Alternatives 3b, 5a, 5b and 5c (Hydrostatic Bulkhead)

33750803_134.cdr

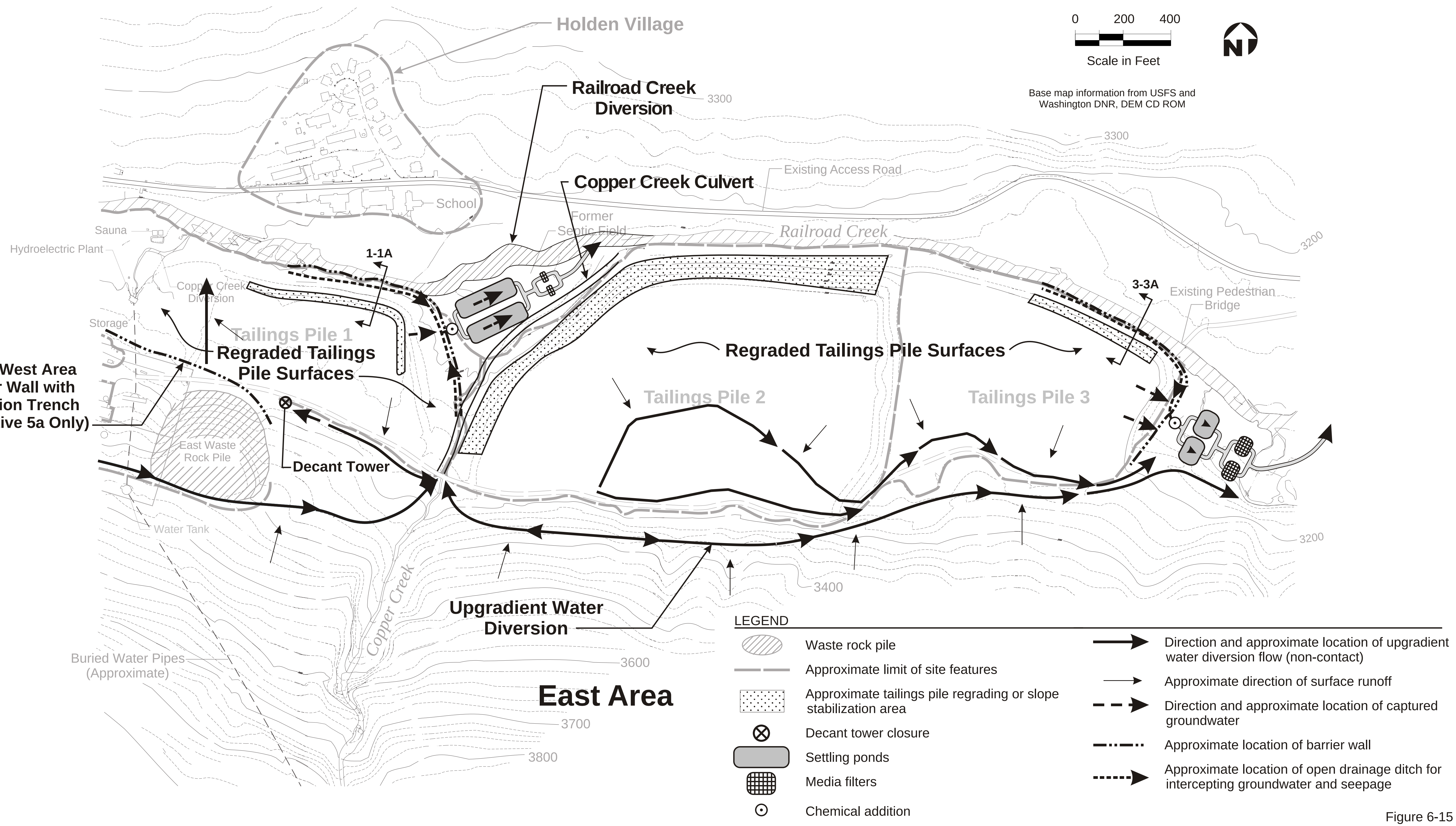

Figure 6-15

Partial East Area Collection and Treatment Site-wide Alternatives 4a and 5a

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33750803_95.cdr

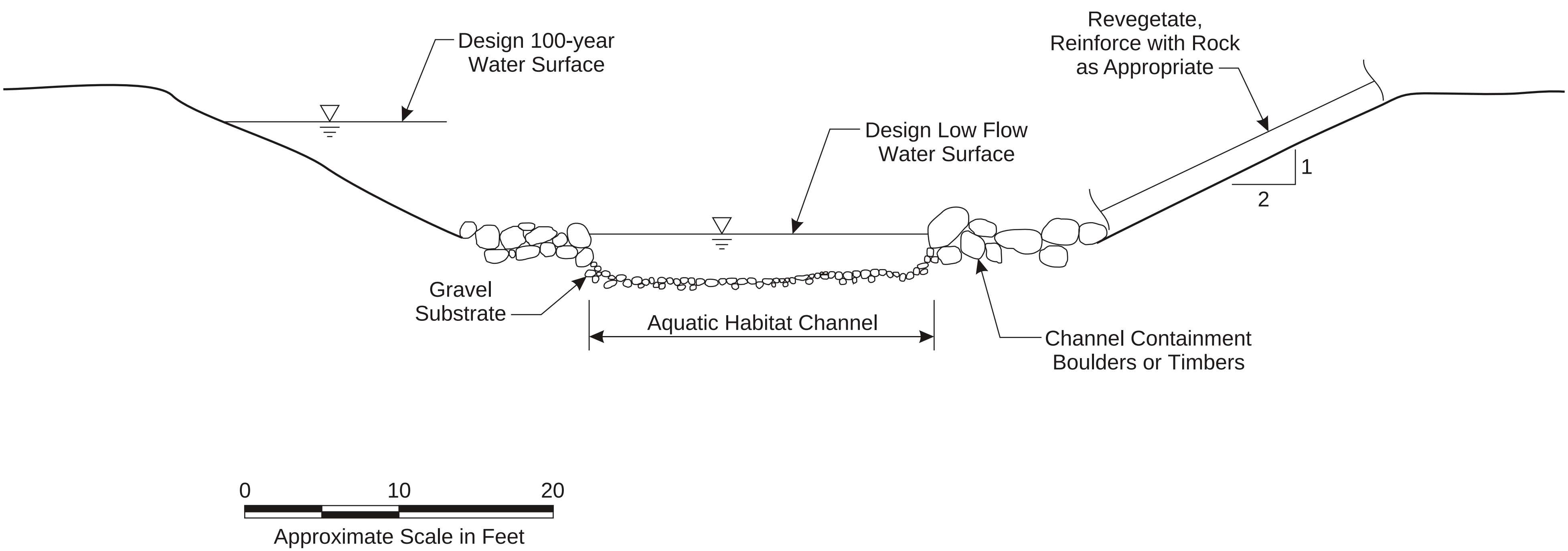

Figure 6-16
Conceptual Channel Cross Section
Railroad Creek Relocation

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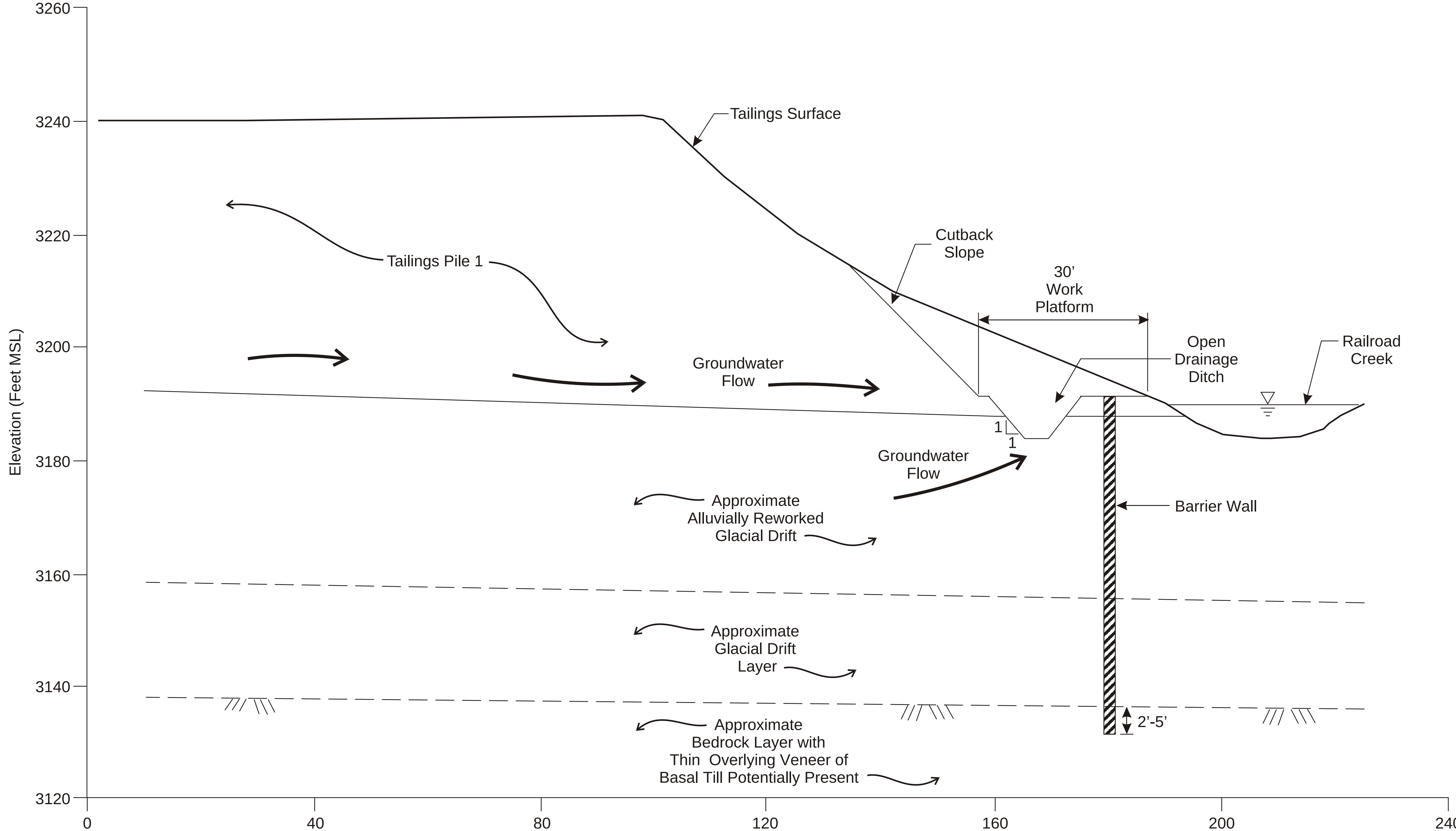

Figure 6-17
Cross-Section 1-1A

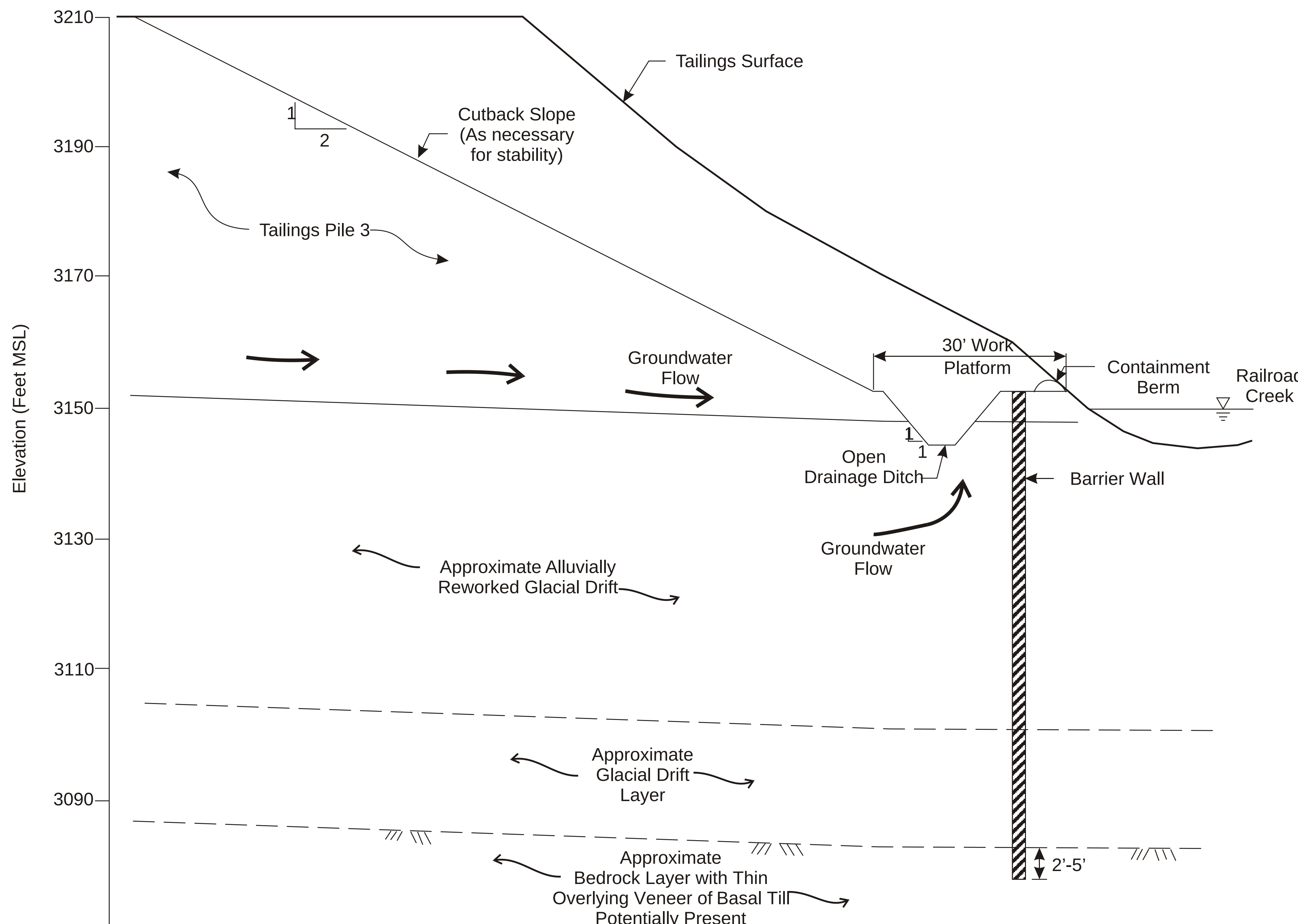

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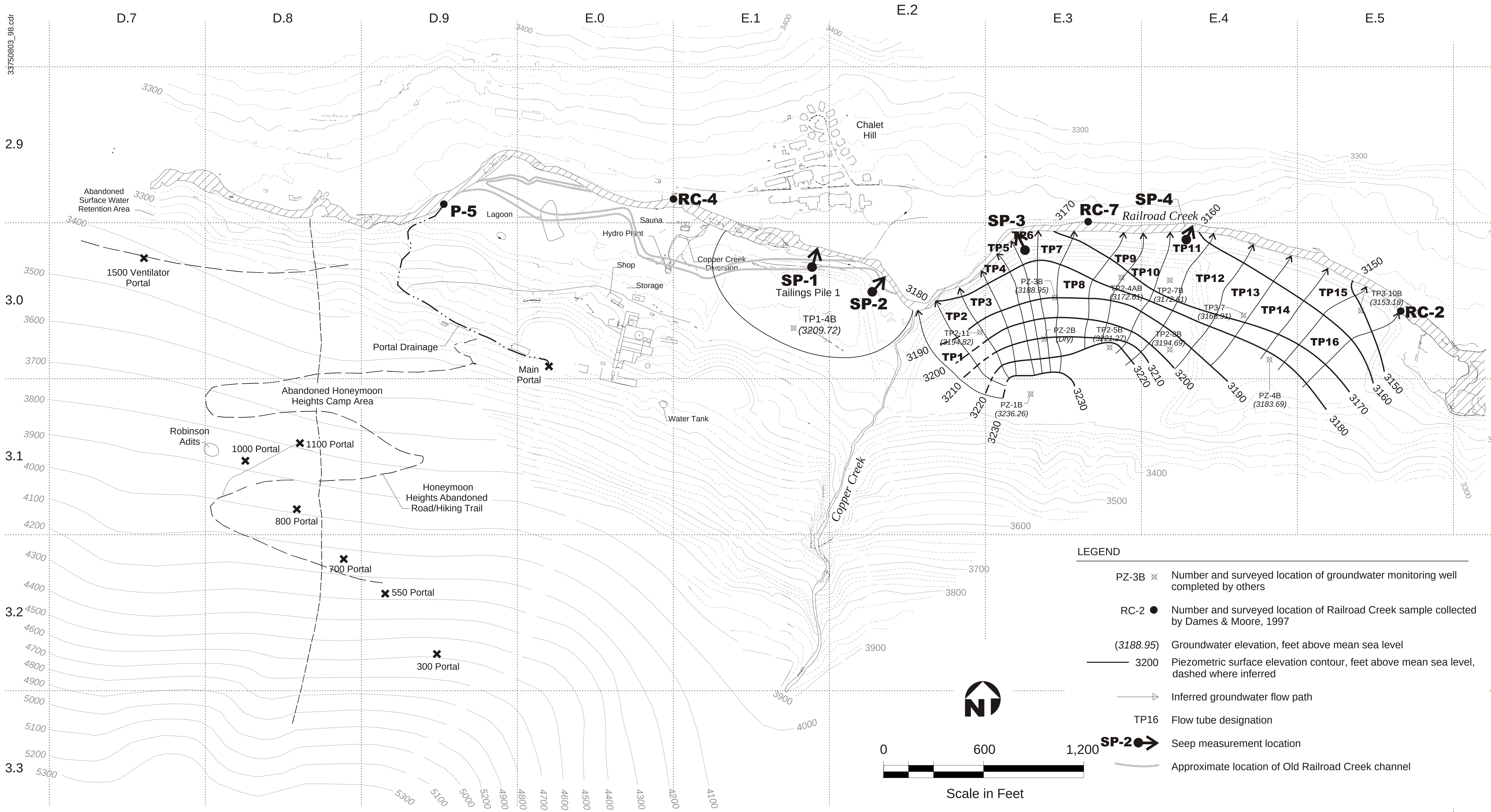
Figure 6-18
Cross-Section 3-3A

URS



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

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Figure 6-19
Flow Net for Site Wells Completed in Tailings – May 1997

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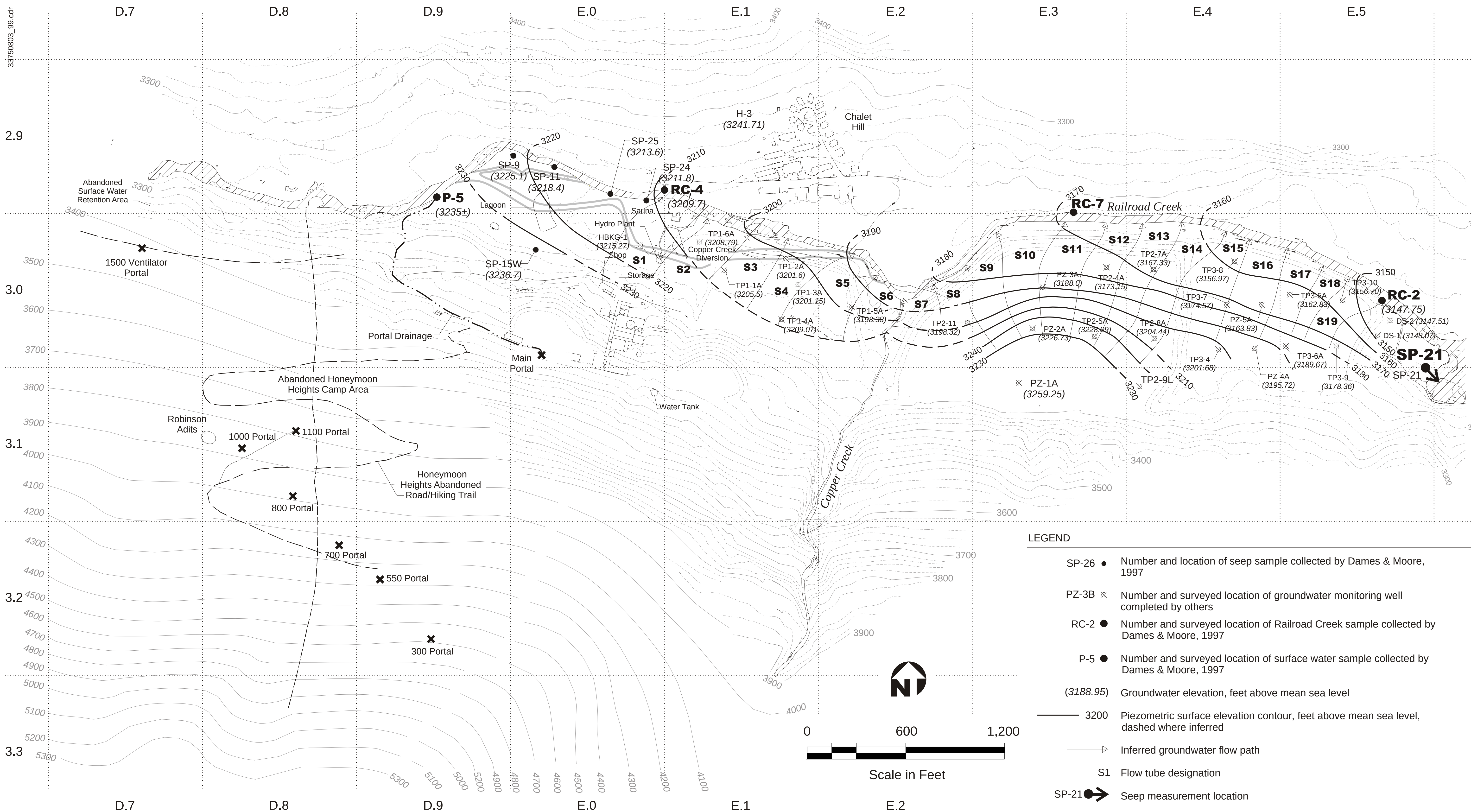

SOURCE: Base map information from USFS and Washington DNR, DEM CD ROM

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Figure 6-20

Flow Net for Site Wells Completed in Native Materials – May 1997

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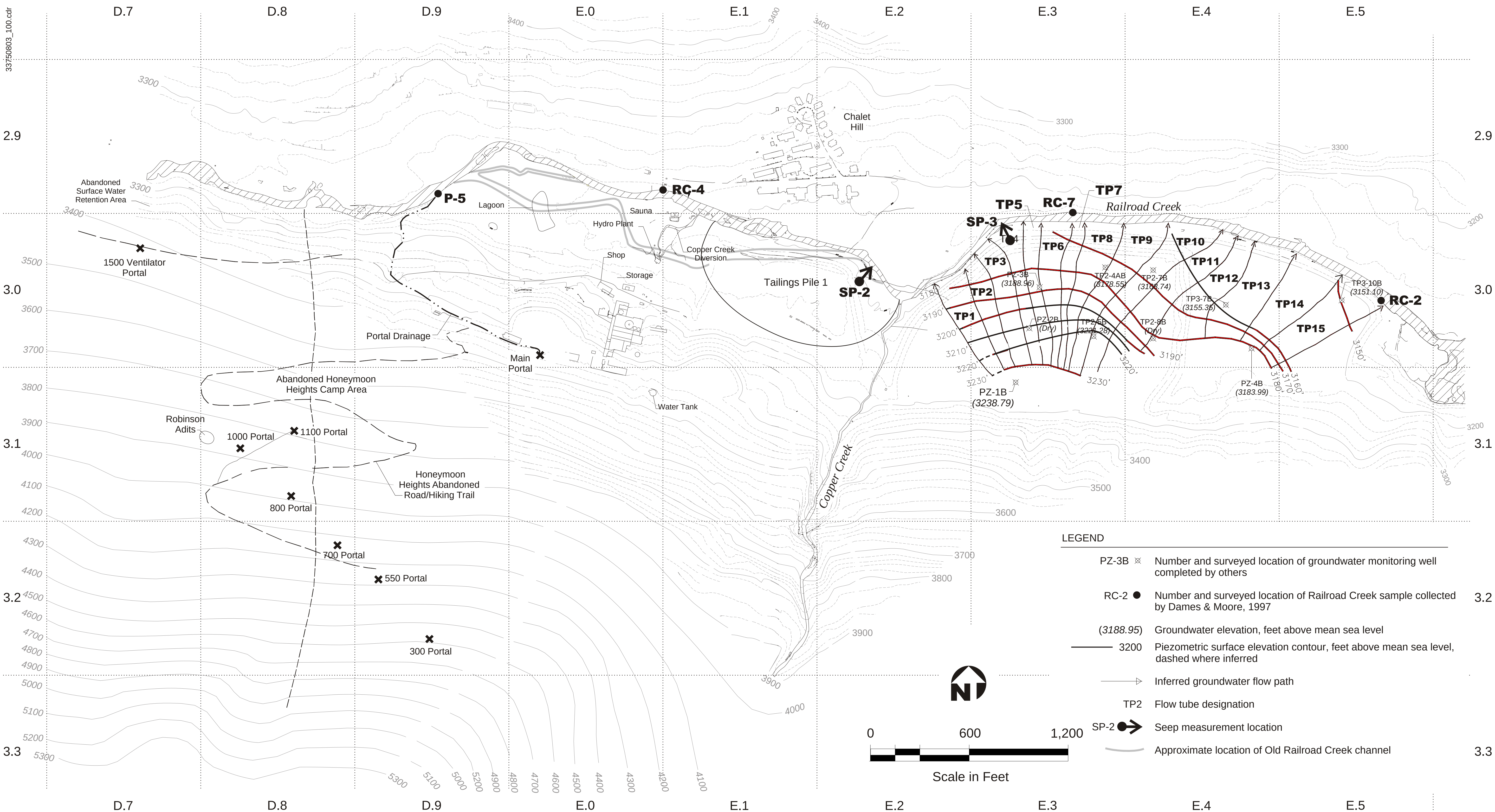


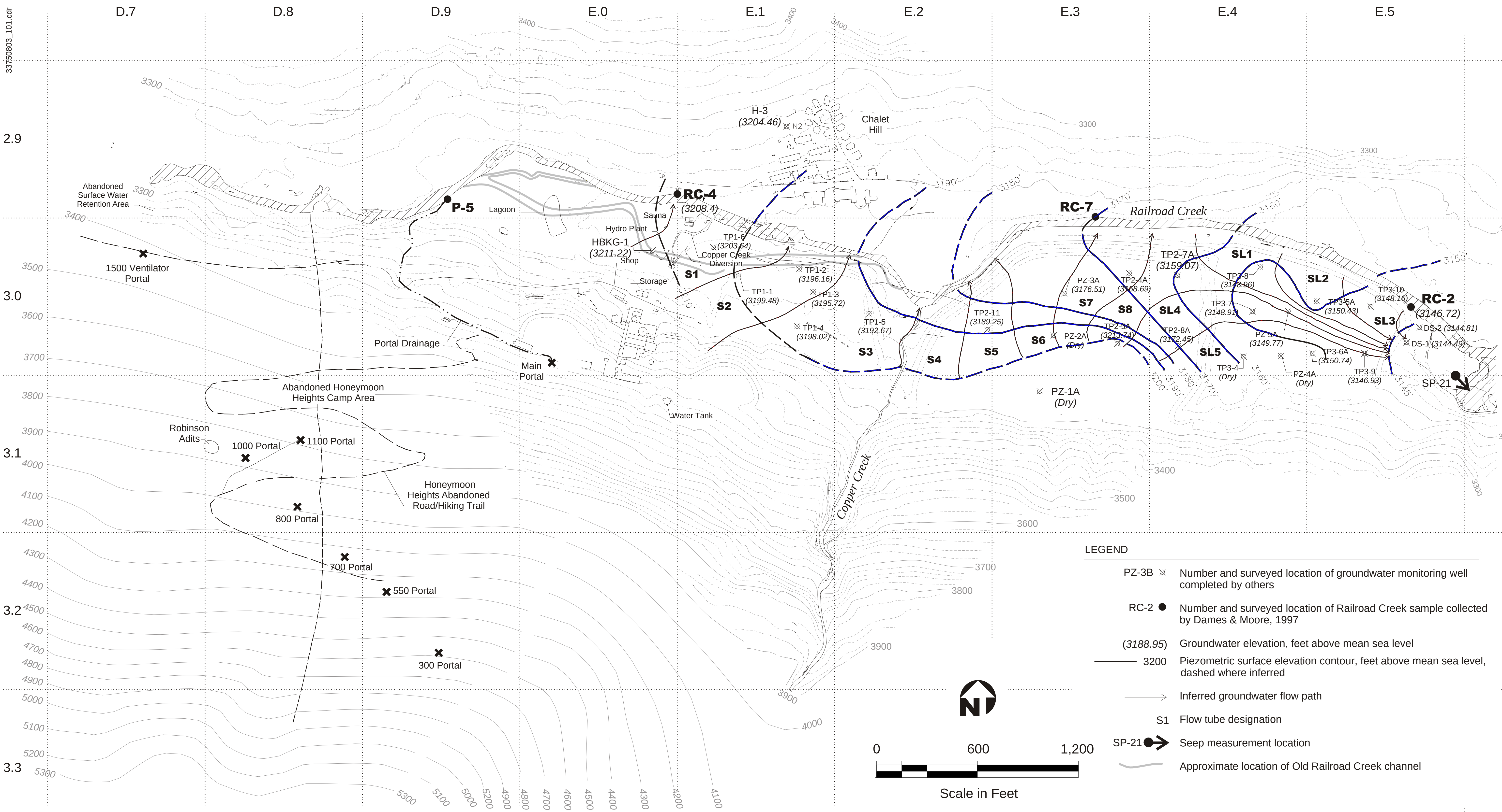
SOURCE: Base map information from USFS and Washington DNR, DEM CD ROM

Job No. 33750803

Figure 6-21

Flow Net for Site Wells Completed in Tailings – September 1997

URS



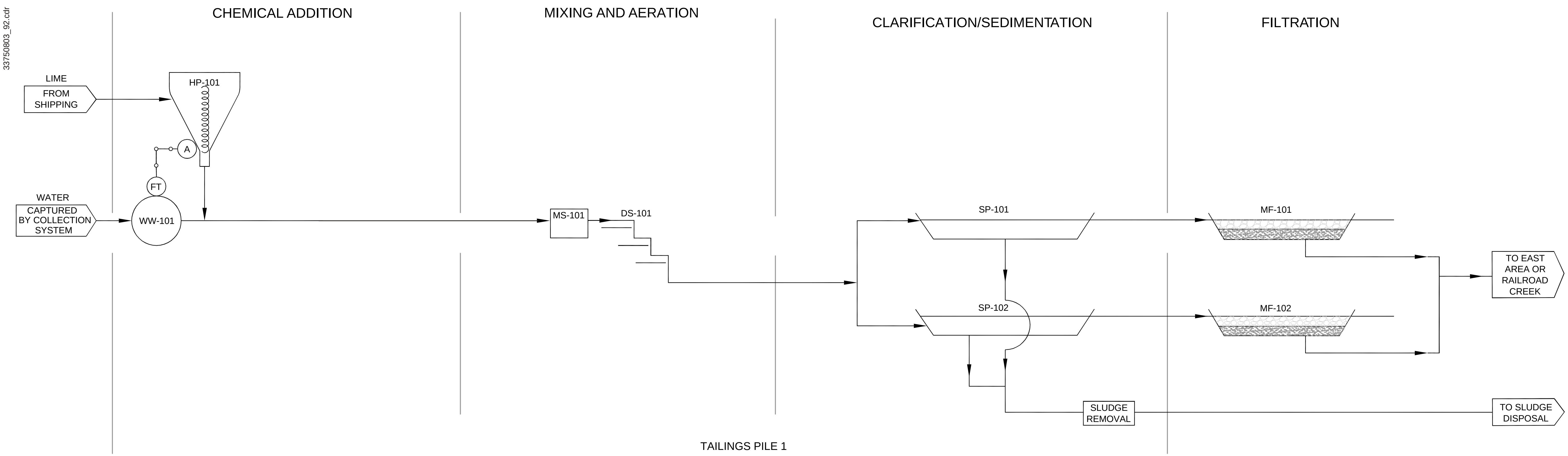
SOURCE: Base map information from USFS and Washington DNR, DEM CD ROM

Job No. 33750803

Figure 6-22

Flow Net for Site Wells Completed in Native Materials – September 1997

URS



TAILINGS PILE 1

	I.D.	HP-101	WW-101	DS-101	MS-101	SP-101	SP-102	MF-101	MF-102
	DESCRIPTION	ALKALI STORAGE	CHEMICAL FEED	DROP STRUCTURE MIXING/AERATION	MIXING SUMP	SETTLING POND	SETTLING POND	MEDIA FILTER	MEDIA FILTER
PARTIAL COLLECTION (ALTS 4a & 5a)	**CAPACITY**	800 gal	4 lb/hr	230 gpm	230 gpm	2.7 MG	2.7 MG	120 gpm	120 gpm
	SURFACE AREA	-	-	-	-	31,000 ft^2	31,000 ft^2	1,200 ft^2	1,200 ft^2
	HEIGHT	-	-	-	-	12 ft	12 ft	5 ft	5 ft
EXTENDED COLLECTION (ALTS 4b & 5b)	**CAPACITY**	1,000 gal	5 lb/hr	330 gpm	330 gpm	3.7 MG	3.7 MG	220 gpm	220 gpm
	SURFACE AREA	-	-	-	-	42,000 ft^2	42,000 ft^2	1,700 ft^2	1,700 ft^2
	HEIGHT	-	-	-	-	12 ft	12 ft	5 ft	5 ft
EXTENDED COLLECTION W/ RRC RELOCATION (ALTS 4c & 5c)	**CAPACITY**	2,000 gal	10 lb/hr	660 gpm	660 gpm	3.8 MG	3.8 MG	330 gpm	330 gpm
	SURFACE AREA	-	-	-	-	43,000 ft^2	43,000 ft^2	3,300 ft^2	3,300 ft^2
	HEIGHT	-	-	-	-	12 ft	12 ft	5 ft	5 ft
EXTENDED COLLECTION W/ RRC RELOCATION (ALT 5d)	**CAPACITY**	2,200 gal	11 lb/hr	710 gpm	710 gpm	3.8 MG	3.8 MG	360 gpm	360 gpm
	SURFACE AREA	-	-	-	-	44,000 ft^2	44,000 ft^2	36,000 ft^2	36,000 ft^2
	HEIGHT	-	-	-	-	12 ft	12 ft	5 ft	5 ft
EXTENDED COLLECTION W/ RRC RELOCATION (ALTS 6a & 6b)	**CAPACITY**	3,100 gal	15 lb/hr	1,000 gpm	1,000 gpm	3.9 MG	3.9 MG	500 gpm	500 gpm
	SURFACE AREA	-	-	-	-	45,000 ft^2	45,000 ft^2	5,000 ft^2	5,000 ft^2
	HEIGHT	-	-	-	-	12 ft	12 ft	5 ft	5 ft

TAILINGS PILE 3

	I.D.	HP-101	WW-101	DS-101	MS-101	SP-101	SP-102	MF-101	MF-102
	DESCRIPTION	ALKALI STORAGE	CHEMICAL FEED	DROP STRUCTURE MIXING/AERATION	MIXING SUMP	SETTLING POND	SETTLING POND	MEDIA FILTER	MEDIA FILTER
PARTIAL COLLECTION (ALTS 4a & 5a)	**CAPACITY**	1,900 gal	17 lb/hr	1,100 gpm	1,100 gpm	0.65 MG	0.65 MG	550 gpm	550 gpm
	SURFACE AREA	-	-	-	-	7,500 ft^2	7,500 ft^2	5,500 ft^2	5,500 ft^2
	HEIGHT	-	-	-	-	12 ft	12 ft	5 ft	5 ft
EXTENDED COLLECTION (ALTS 4b & 5b)	**CAPACITY**	2,000 gal	20 lb/hr	1,300 gpm	1,300 gpm	2.3 MG	2.3 MG	650 gpm	650 gpm
	SURFACE AREA	-	-	-	-	26,000 ft^2	26,000 ft^2	6,500 ft^2	6,500 ft^2
	HEIGHT	-	-	-	-	12 ft	12 ft	5 ft	5 ft
EXTENDED COLLECTION W/ RRC RELOCATION (ALTS 4c, 5c, 5d, 6a & 6b)	**CAPACITY**	4,700 gal	32 lb/hr	2,100 gpm	2,100 gpm	2.6 MG	2.6 MG	1,100 gpm	1,100 gpm
	SURFACE AREA	-	-	-	-	30,000 ft^2	30,000 ft^2	11,000 ft^2	11,000 ft^2
	HEIGHT	-	-	-	-	12 ft	12 ft	5 ft	5 ft
EXTENDED COLLECTION (ALT 8)	**CAPACITY**	2,200 gal	21 lb/hr	1,400 gpm	1,400 gpm	2.6 MG	2.6 MG	700 gpm	700 gpm
	SURFACE AREA	-	-	-	-	30,000 ft^2	30,000 ft^2	7,000 ft^2	7,000 ft^2
	HEIGHT	-	-	-	-	12 ft	12 ft	5 ft	5 ft

LEGEND

- FT — FLOW TRANSMITTER
- A — AUGER
- PROCESS LINE
- MECHANICAL LINE
- ELECTRIC SIGNAL
- METER PUMP

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Figure 6-23

Conceptual Process Flow Diagram East Area Low-Energy Treatment

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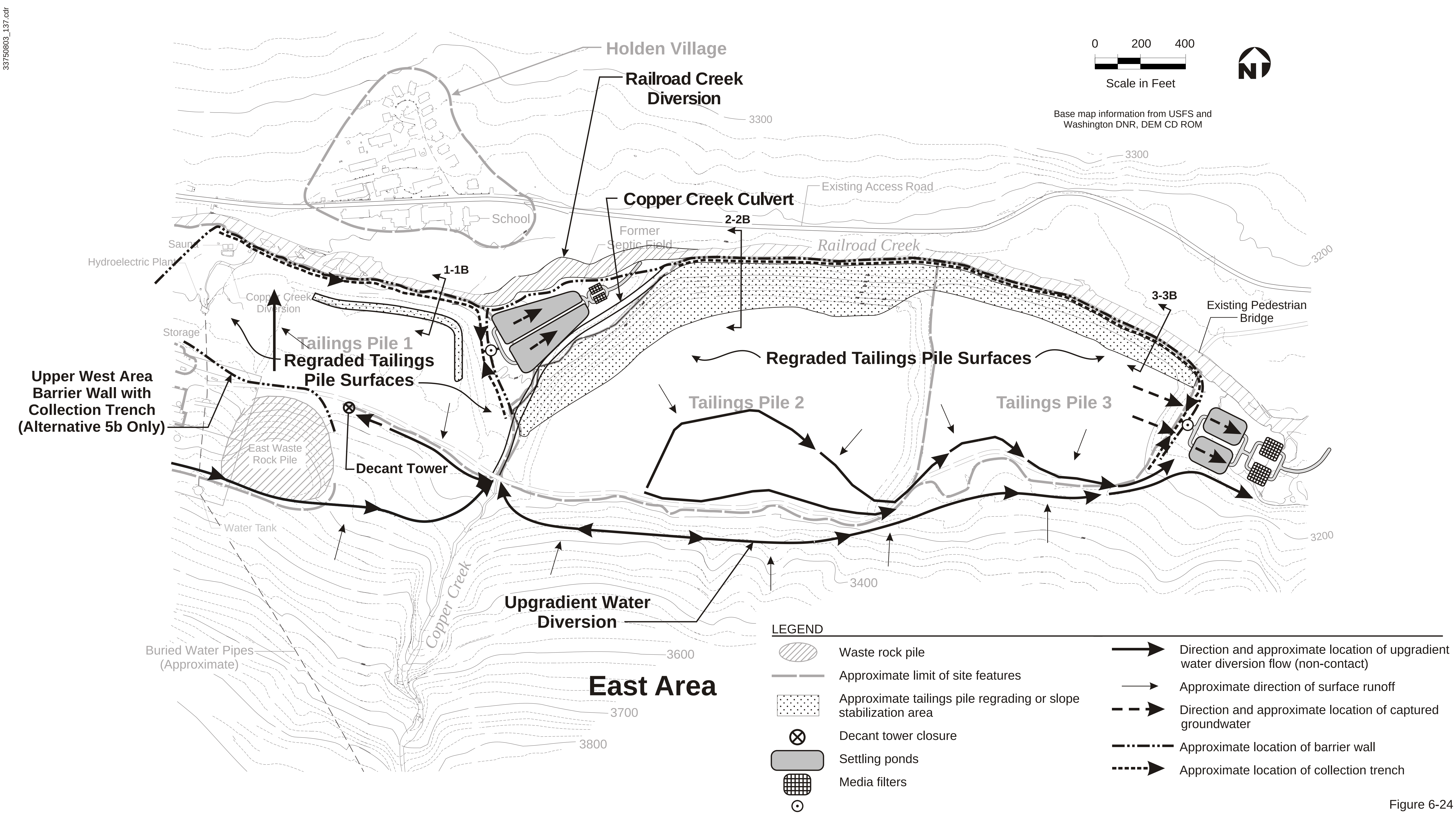

Figure 6-24
Extended East Area Collection and Treatment Site-wide Alternatives 4b and 5b

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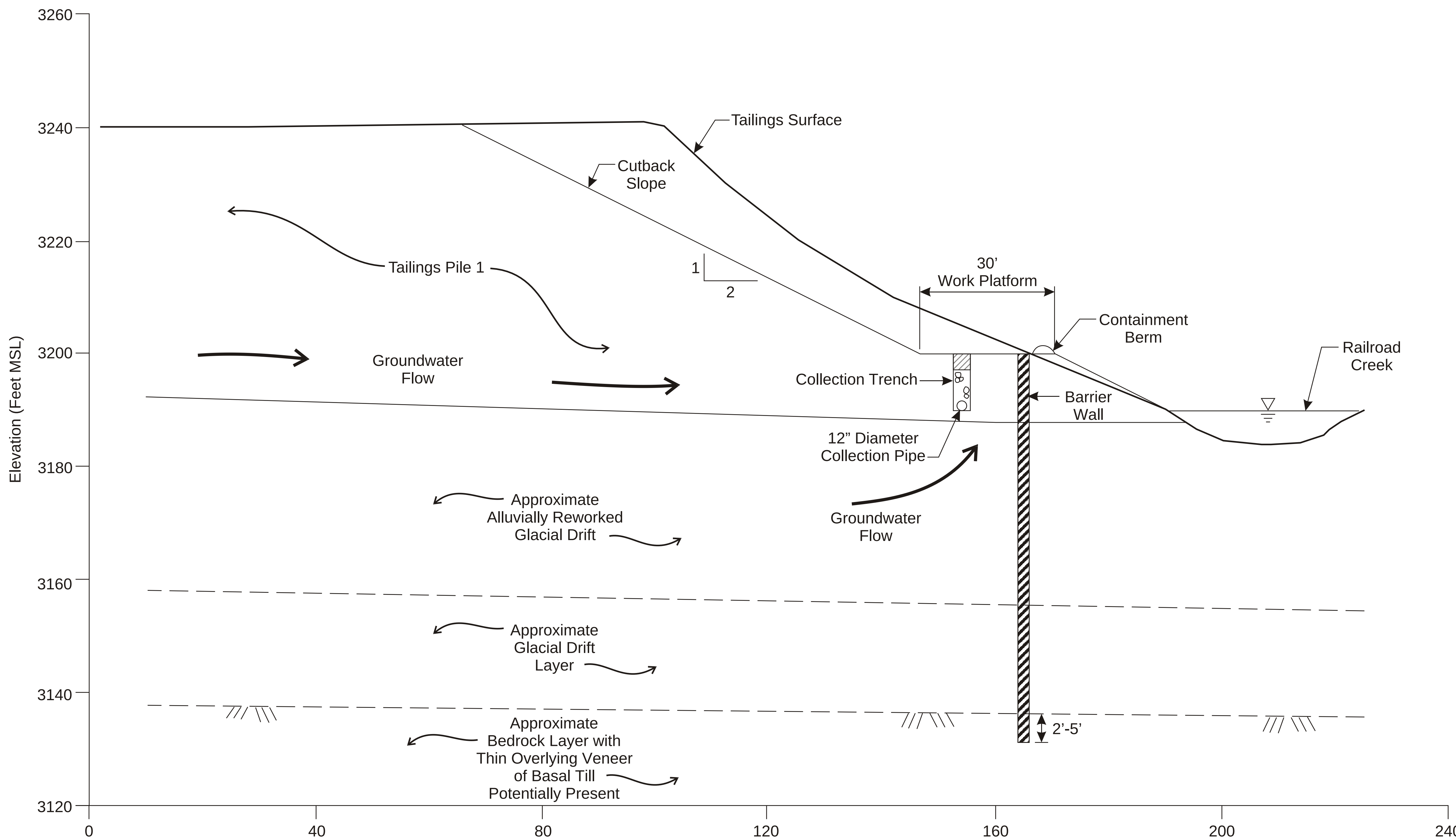

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Figure 6-25
Cross-Section 1-1B

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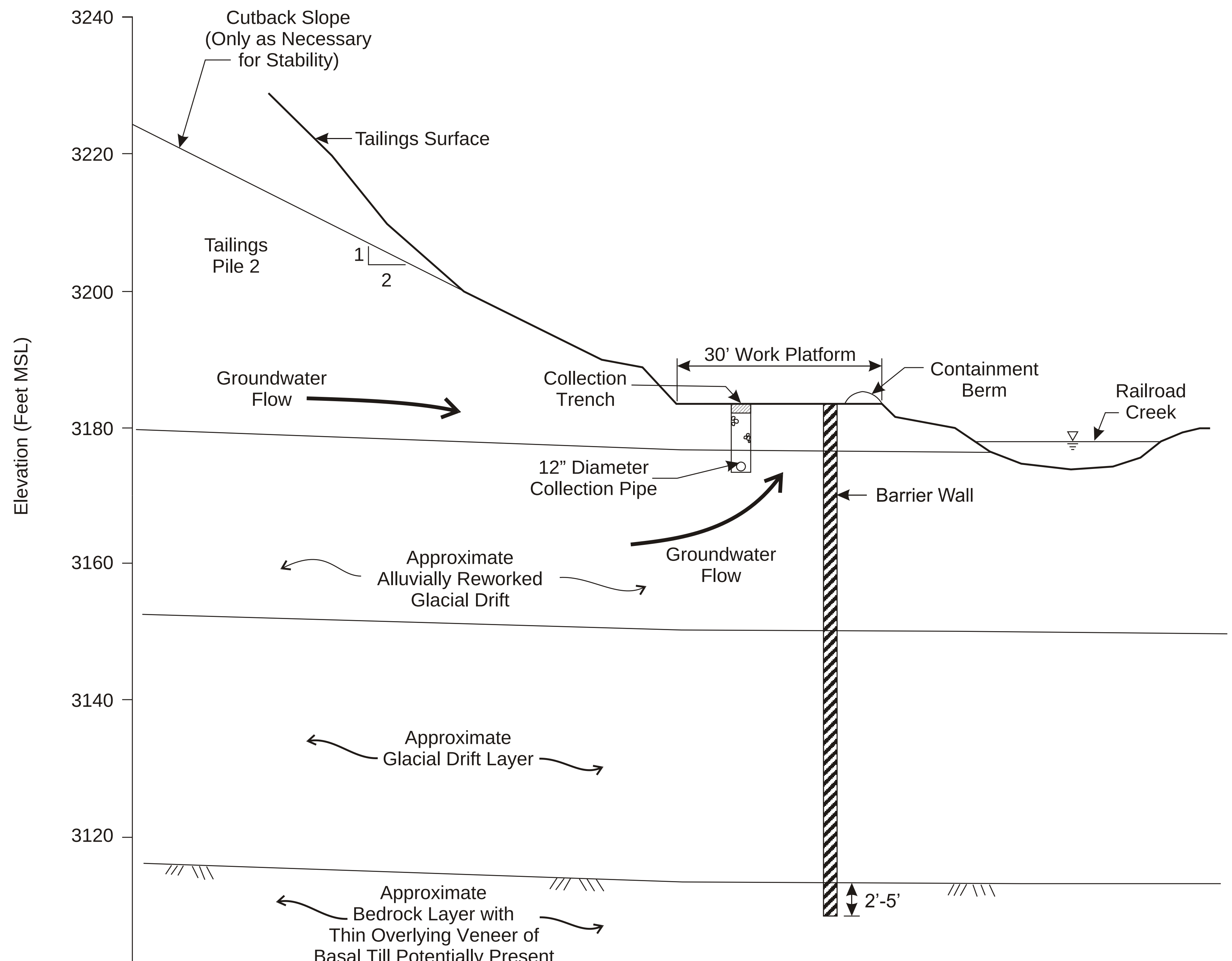

Figure 6-26
Cross-Section 2-2B

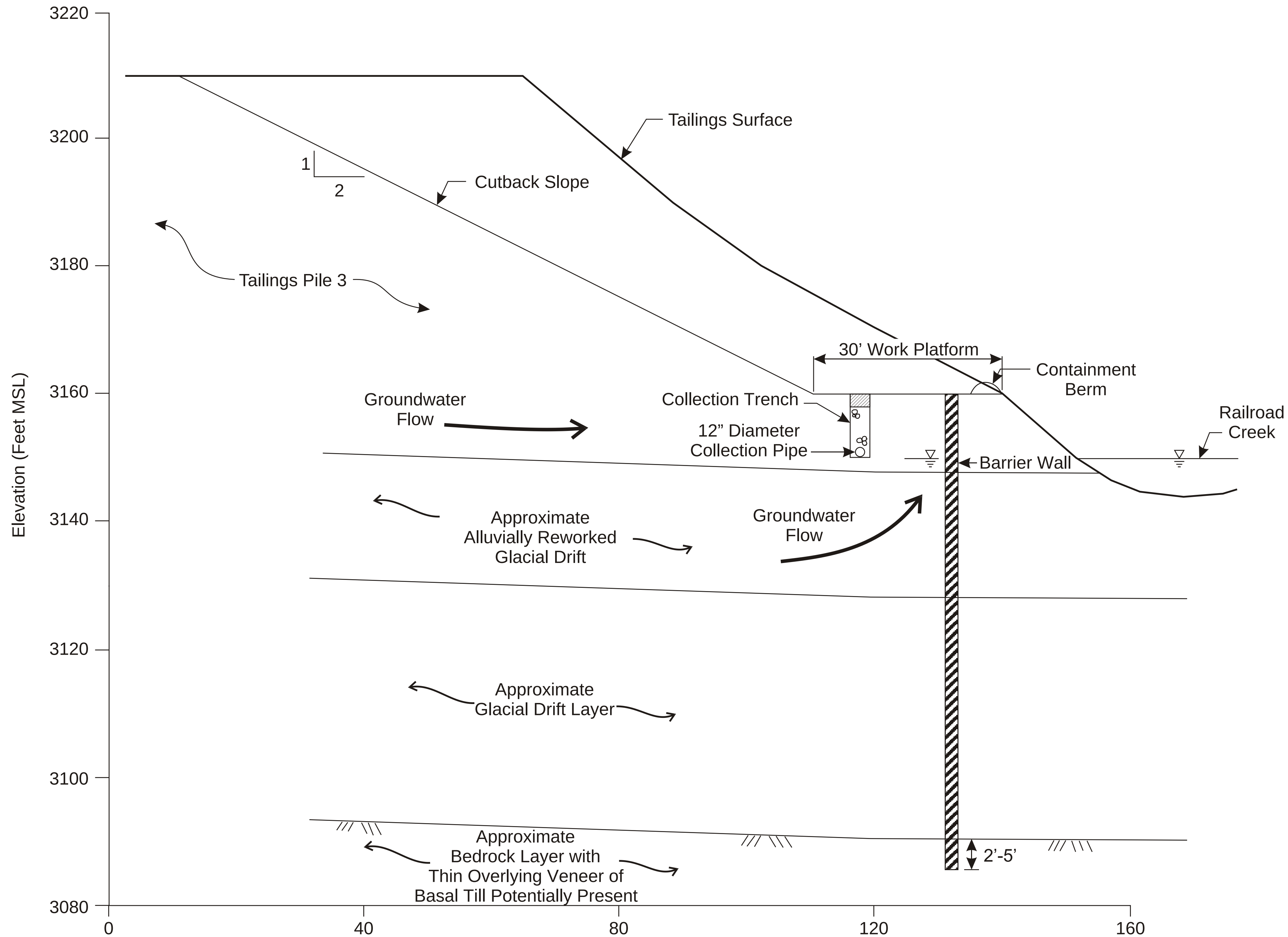

Figure 6-27
Cross-Section 3-3B

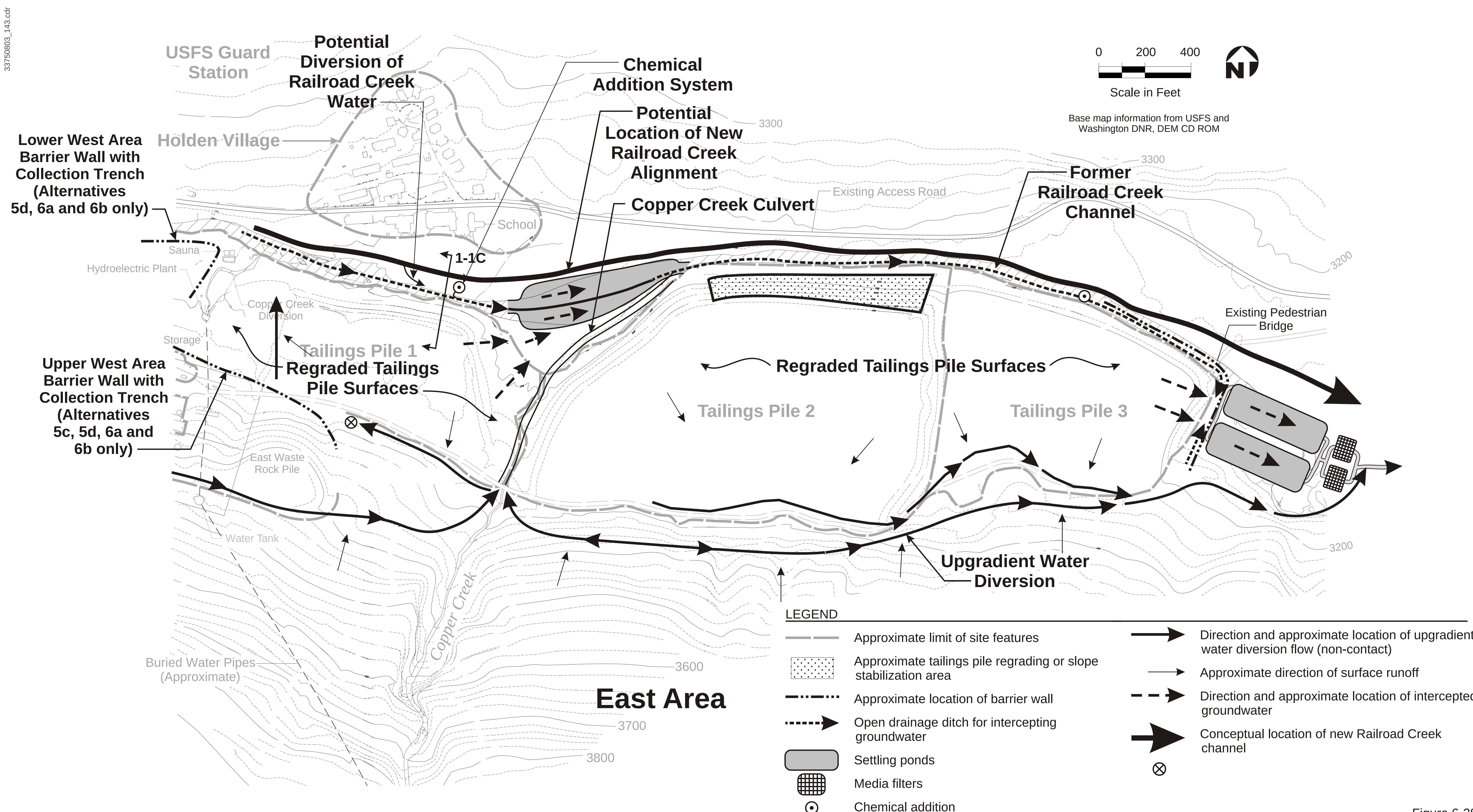

Figure 6-28

Extended Railroad Creek Relocation and East Area Treatment Site-wide Alternatives 4c, 5c, 5d, 6a and 6b

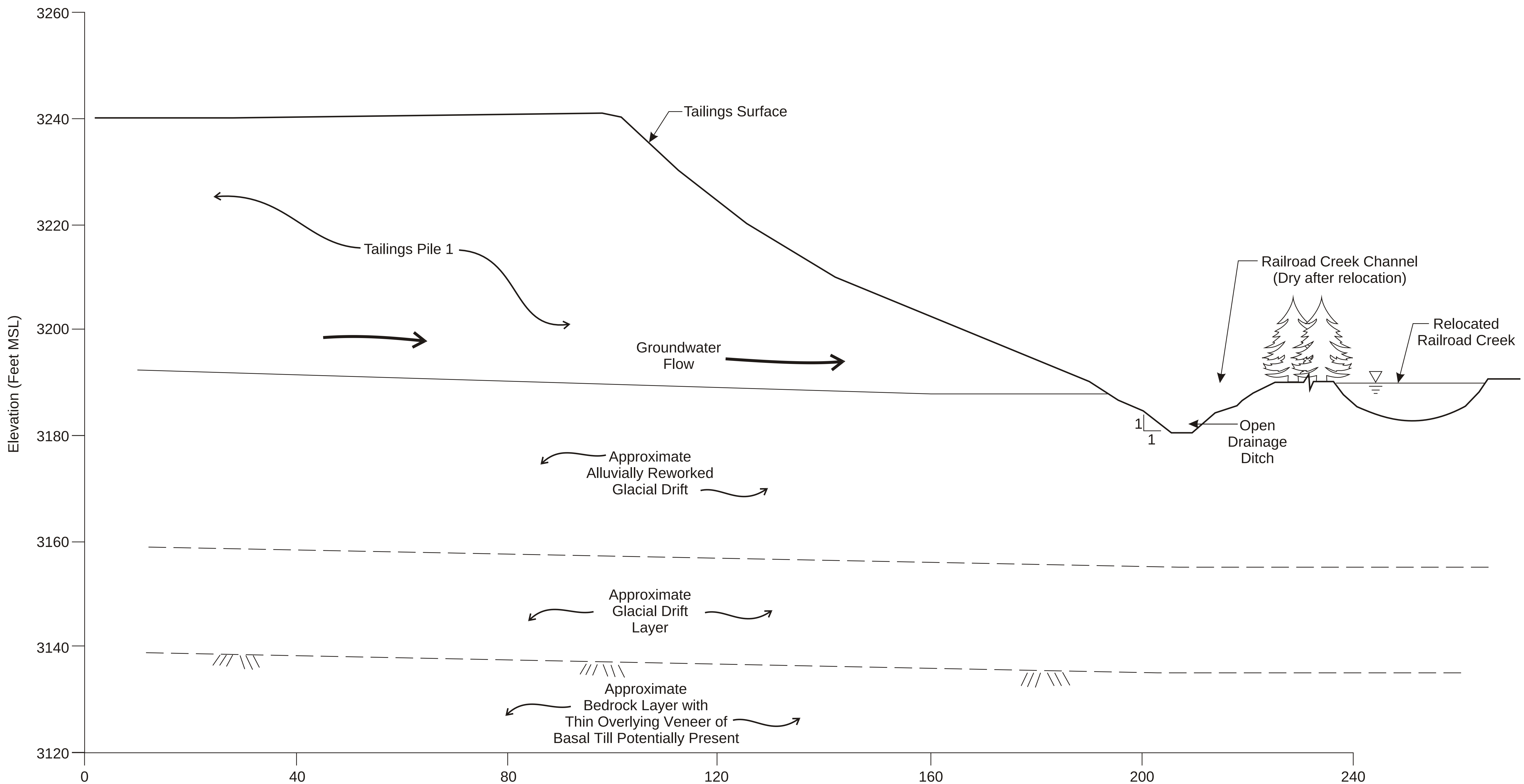

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Figure 6-29
Cross-Section 1-1C

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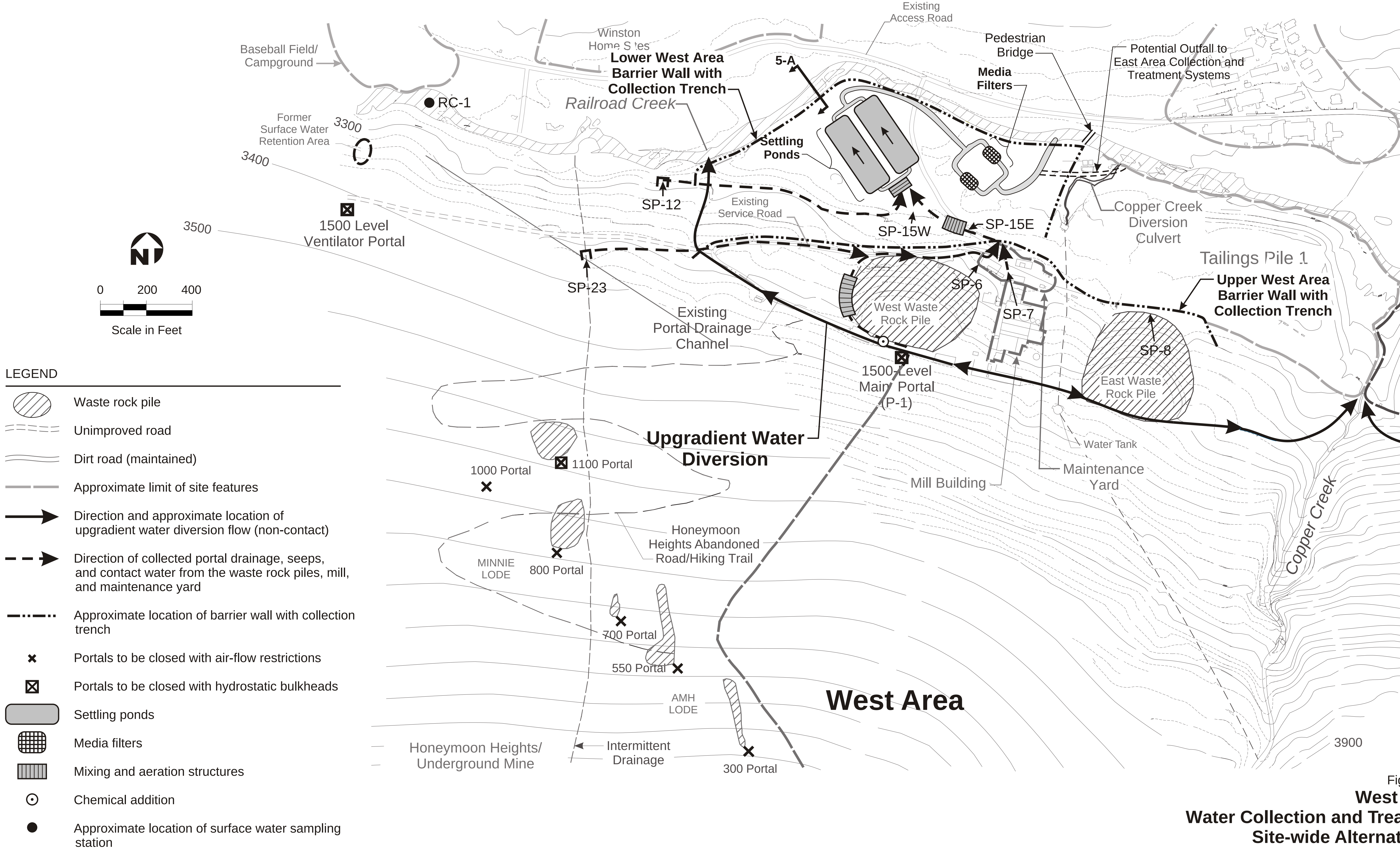

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Figure 6-30
West Area - Water Collection and Treatment Site-wide Alternative 5d (Hydrostatic Bulkhead)

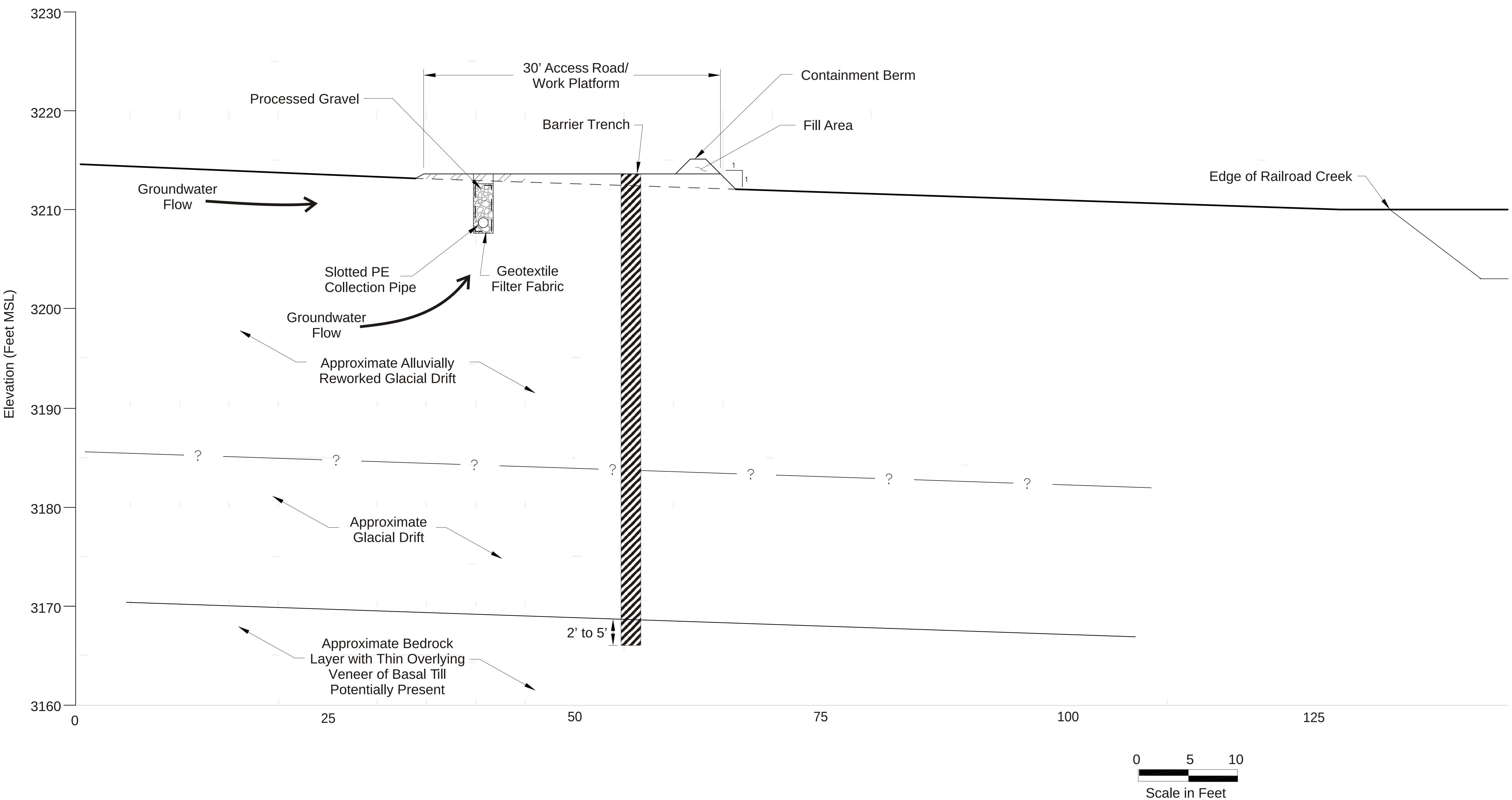

Figure 6-31
Cross Section 5-A

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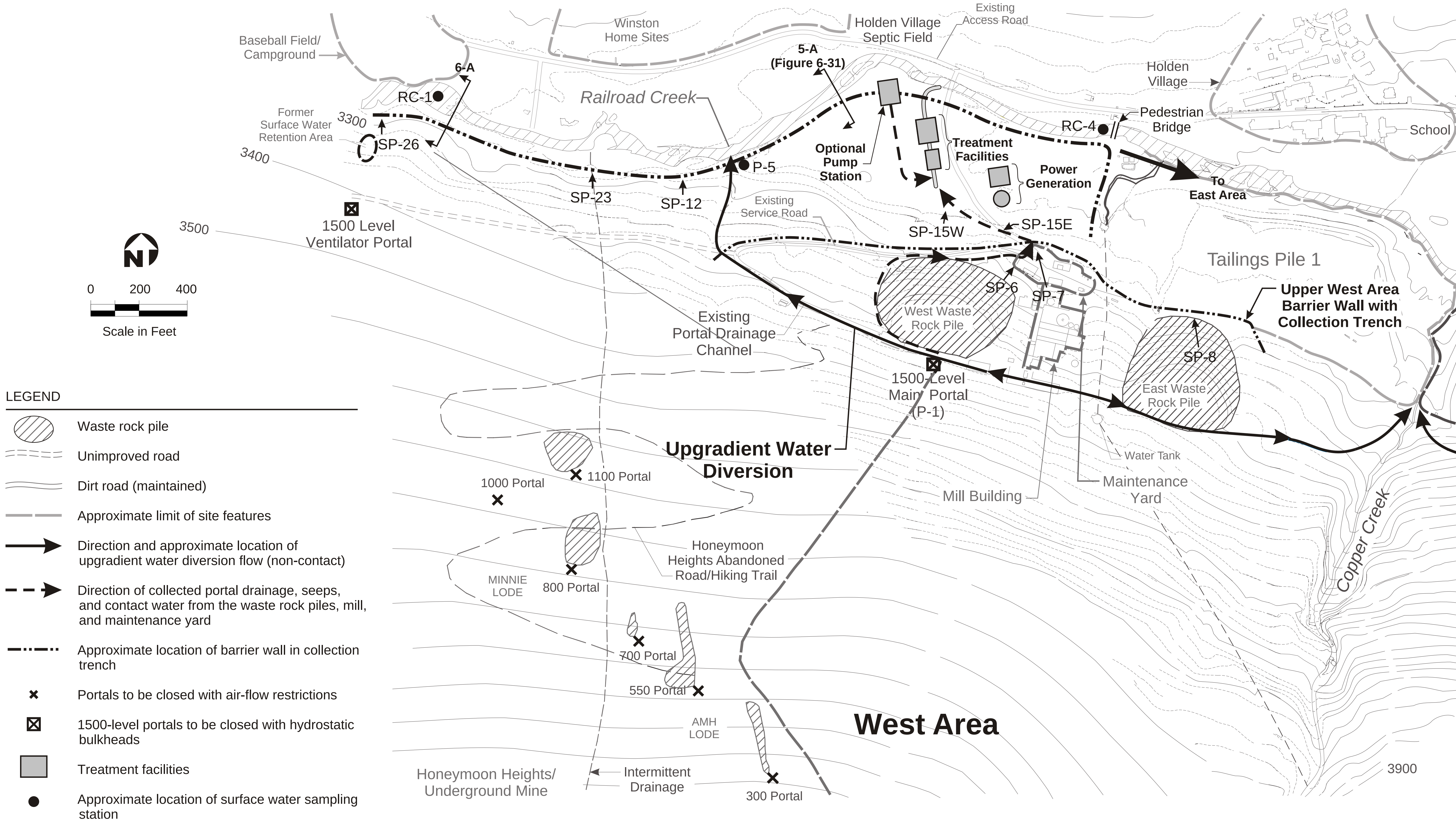

Figure 6-32
West Area -
Water Collection and Treatment
Site-Wide Alternative 6

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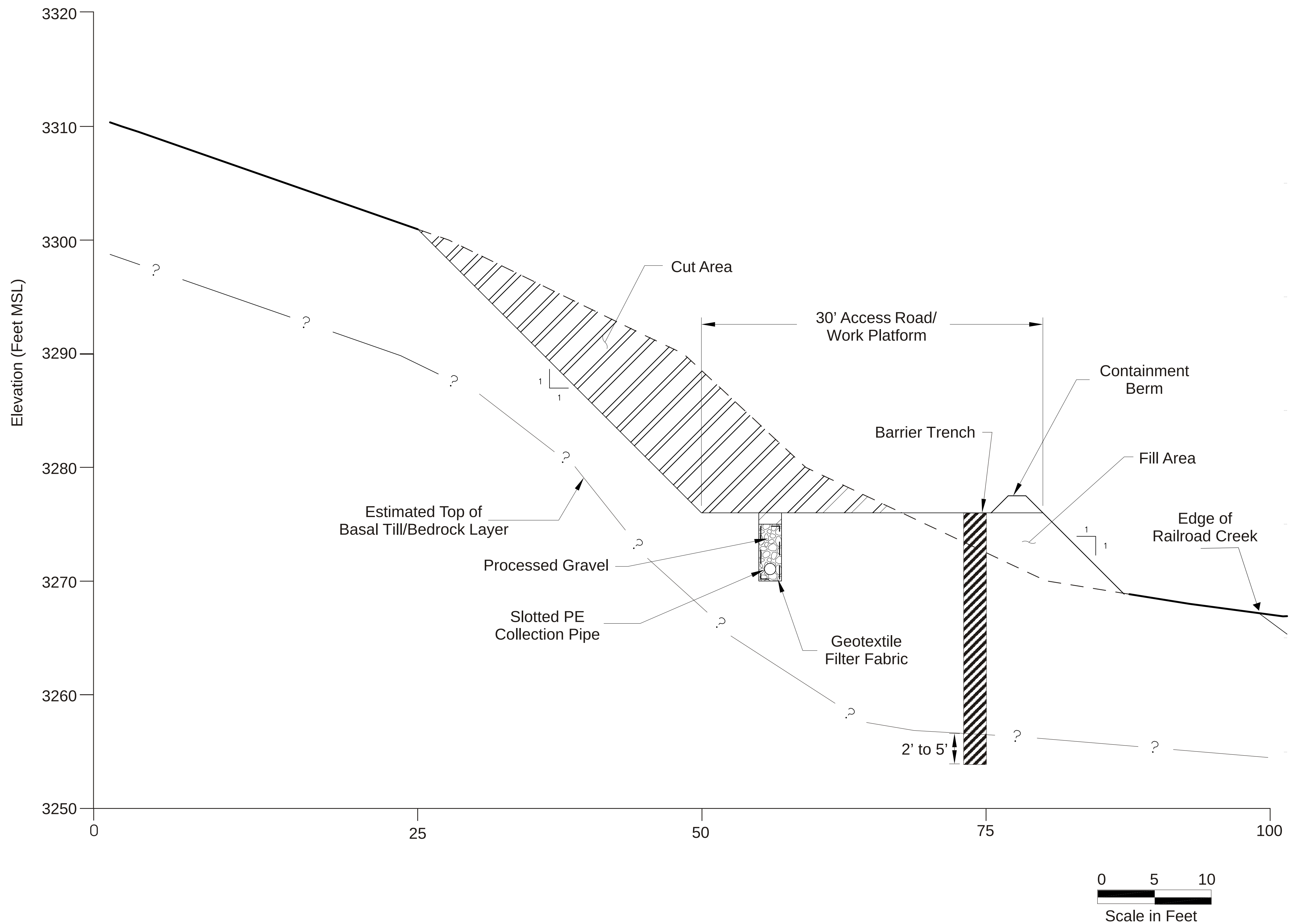

Figure 6-33
Cross-Section 6-A

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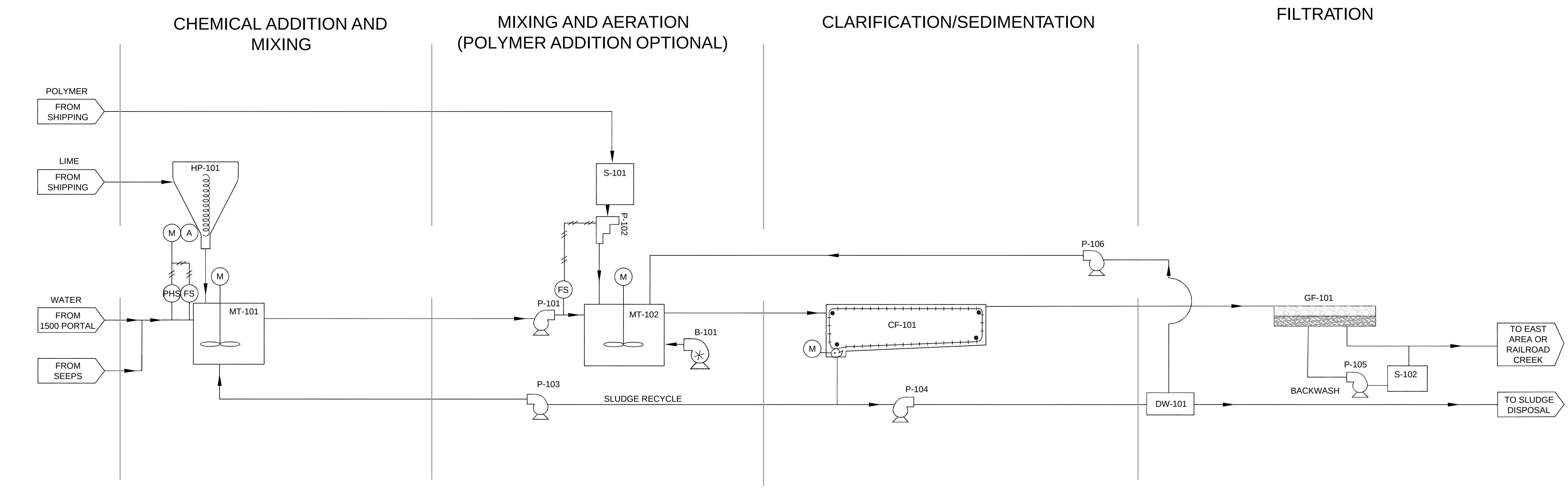

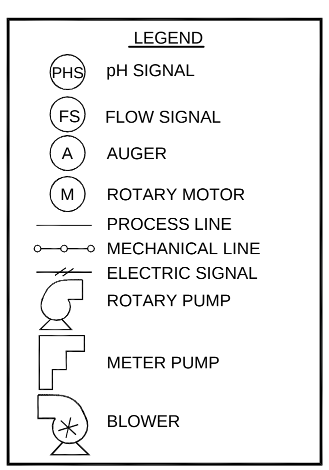

	I.D.	HP-101	MT-101	B-101	P-101	MT-102	S-101	P-102	CF-101	P-103	P-104	GF-101	P-105	S-102	DW-101	P-106
	DESCRIPTION	ALKALI STORAGE	LIME CONTACT CHAMBER	BLOWER	SLURRY PUMP	FLOCCULATION TANK	POLYMER STORAGE	POLYMER PUMP	CLARIFIER	SLURRY PUMP SLUDGE RECYCLE	SLURRY PUMP SLUDGE DISCHARGE	GRAVITY FILTER	BACKWASH PUMP	BACKWASH WATER STORAGE	SLUDGE DEWATERING	PUMP WATER RECYCLE
ALTERNATIVE 6a (OPEN PORTAL)	**CAPACITY**	4,000 gal	2,100 gpm	TBD	2,100 gpm	2,100 gpm	TBD	TBD	0.29 MG	TBD	TBD	2,100 gpm	TBD	TBD	TBD	TBD
	SURFACE AREA	-	-	-	-	-	-	-	2,900 ft^2	-	-	4,100 ft^2	-	-	-	-
	HEIGHT	-	-	-	-	-	-	-	13 ft	-	-	4 ft	-	-	-	-
ALTERNATIVE 6b (WITH HYDROSTATIC BULKHEADS)	**CAPACITY**	4,000 gal	1,100 gpm	TBD	1,100 gpm	1,100 gpm	TBD	TBD	0.16 MG	TBD	TBD	1,100 gpm	TBD	TBD	TBD	TBD
	SURFACE AREA	-	-	-	-	-	-	-	1,600 ft^2	-	-	2,300 ft^2	-	-	-	-
	HEIGHT	-	-	-	-	-	-	-	13 ft	-	-	4 ft	-	-	-	-

TBD: TO BE DETERMINED DURING DESIGN

Figure 6-34

Conceptual Process Flow Diagram
West Area Mechanical Treatment

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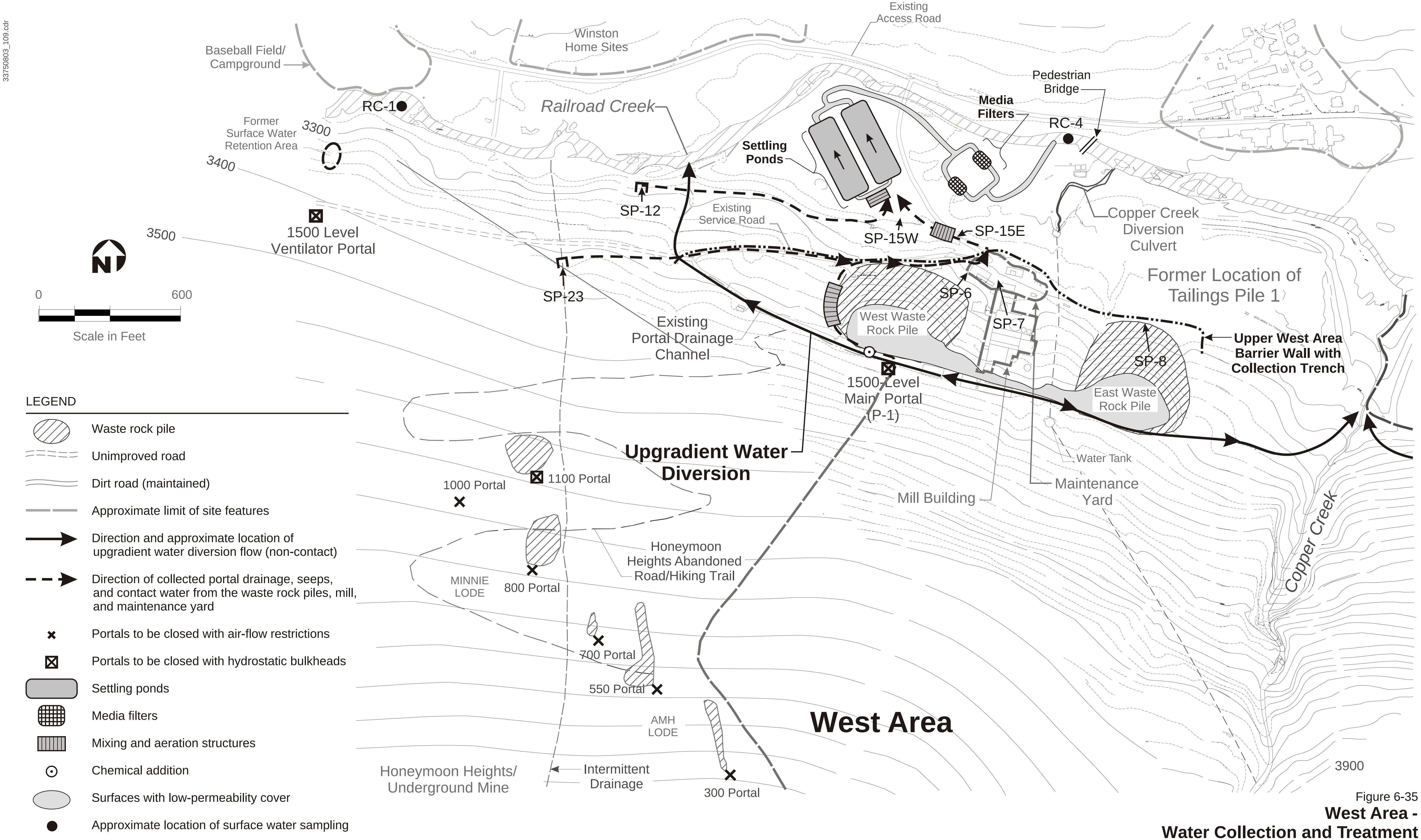

Figure 6-35
West Area -
Water Collection and Treatment
Site-wide Alternative 7

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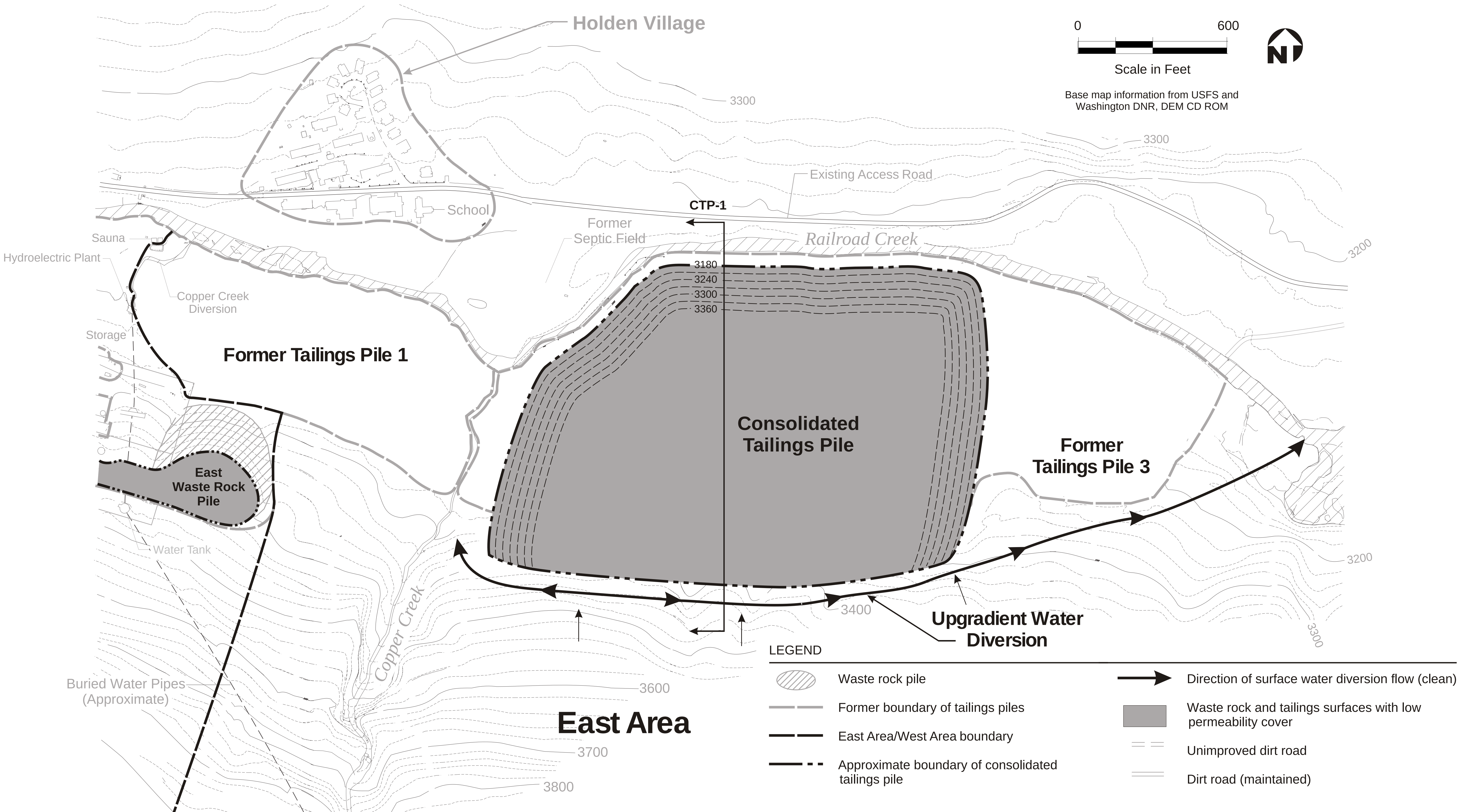

Figure 6-36
East Area - Consolidation and Low Permeability Cover Site-wide Alternative 7

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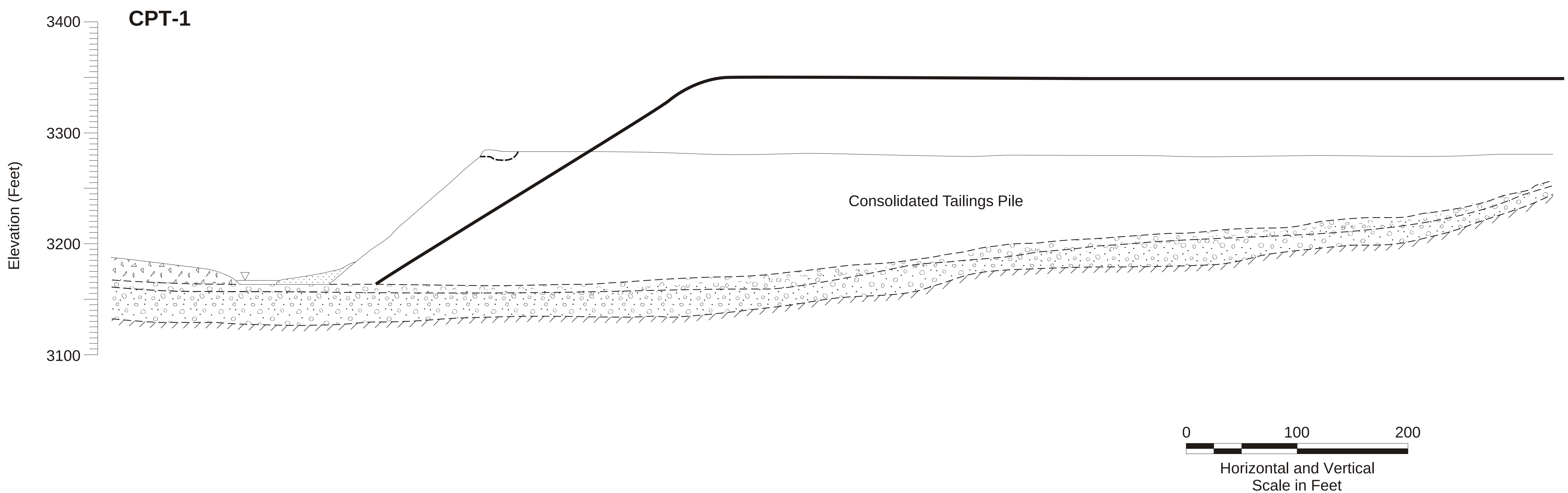

LEGEND

Colluvium

Alluvially reworked glacial drift

Glacial drift

Colluvium – tailings

Basal till/bedrock

Former Tailings Pile 2 configuration

Conceptual consolidate Tailings Pile 2 configuration

SOURCE: Northwest Geophysical Association, 1997, Seismic Line C-C', Holden Mine Geophysical Investigation

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Figure 6-37

Conceptual Consolidated Tailings Pile
Cross Section CTP-1
Site-wide Alternatives 7 and 8

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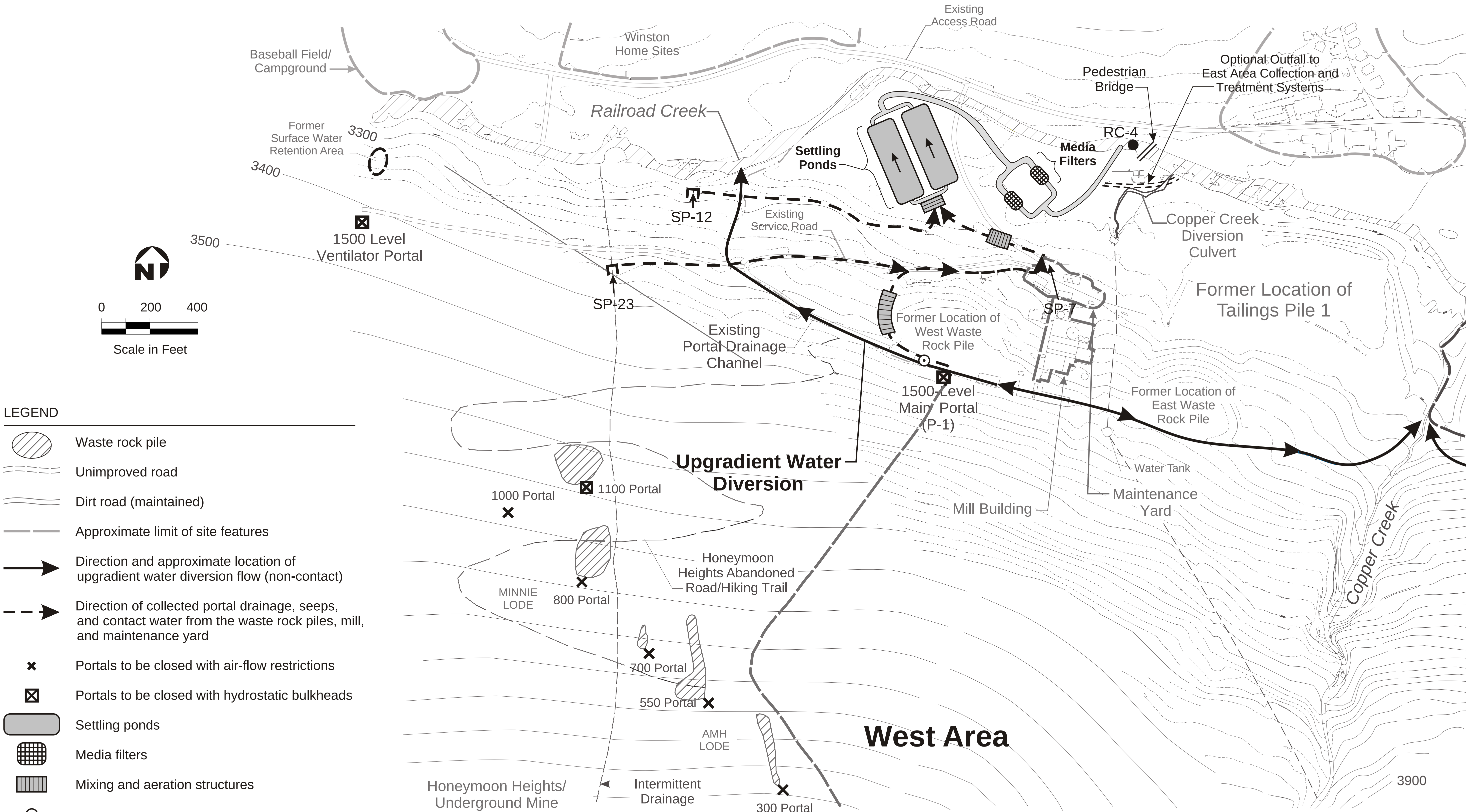

Figure 6-38
West Area -
Water Collection and Treatment
Site-wide Alternative 8

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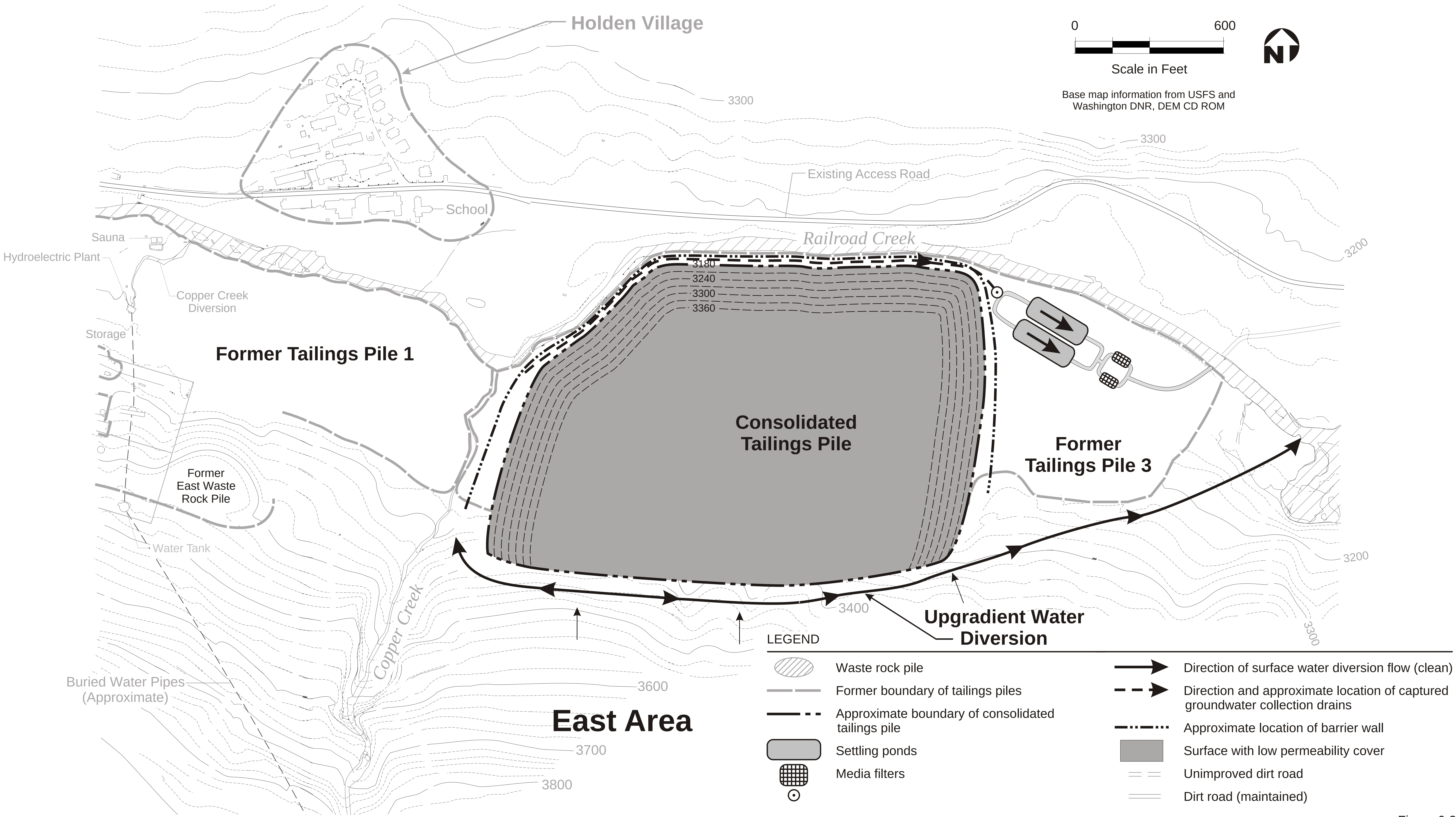

Figure 6-39
East Area - Consolidation, Low Permeability Cover and Treatment Site-wide Alternative 8

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7.0 DETAILED ANALYSIS OF ALTERNATIVES

The detailed analysis of remedial alternatives, as required by the National Contingency Plan (NCP) in 40 CFR 300.430(e)(9), is presented in this section. As described in Section 6, the following eight candidate site-wide alternatives will be evaluated in the detailed analysis:

- **Alternative 1 – No Action/Institutional Controls**
- **Alternative 2 – Water Management**
  - Alternative 2a – Water Management (Open Portal)
  - Alternative 2b – Water Management (Hydrostatic Bulkheads)
- **Alternative 3 – Water Management and Low-energy West Area Treatment**
  - Alternative 3a – Water Management and Low-energy West Area Treatment (Open Portal)
  - Alternative 3b – Water Management and Low-energy West Area Treatment (Hydrostatic Bulkhead)
- **Alternative 4 – Water Management and East Area Collection and Treatment**
  - Alternative 4a – Water Management and Partial East Area Collection and Treatment
  - Alternative 4b – Water Management and Extended East Area Collection and Treatment
  - Alternative 4c – Water Management, Extended Railroad Creek Relocation, and East Area Collection and Treatment
- **Alternative 5 – Water Management and East/West Area Treatment (Low-Energy WTP)**
  - Alternative 5a - Water Management, Partial East Area Collection, and East/West Area Treatment (Low-energy WTP)
  - Alternative 5b – Water Management, Extended East Area Collection, and East/West Area Treatment (Low-energy WTP)
  - Alternative 5c – Water Management, Extended Railroad Creek Relocation, and East/West Area Treatment (Low-energy WTP)
  - Alternative 5d – Water Management, Secondary West Area Collection, Extended Railroad Creek Relocation, and East/West Area Treatment (Low-energy WTP)

- **Alternative 6 – Water Management, Extended Secondary West Area Collection, Extended Railroad Creek Relocation, and East/West Area Treatment (Mechanical WTP)**
  - Alternative 6a – Water Management, Extended Secondary West Area Collection, Extended Railroad Creek Relocation, and East/West Area Treatment (Mechanical WTP)
  - Alternative 6b – Water Management, Extended Secondary West Area Collection, Extended Railroad Creek Relocation, and East/West Area Treatment (Mechanical WTP with Bulkhead)
- **Alternative 7 – Capping, Consolidation, Water Management and West Area Treatment**
- **Alternative 8 – Source Control and East/West Area Treatment**

The development and refinement of remedial alternatives is an iterative process. During the FS, the candidate remedial alternatives are developed based upon data collected and are presented with a sufficient level of detail for analysis and selection of the preferred remedy. However, these alternatives remain conceptual and design details and cost estimates will continue to be refined following remedy selection, up until final implementation of the remedial action.

This section presents the detailed analysis process, including associated requirements under CERCLA and MTCA, supporting engineering calculations, and the results of the detailed analysis for each candidate site-wide alternative. A comparative analysis of the eight alternatives, including the subalternatives, based on the results of the detailed analysis, is provided in Section 8.0.

7.1 THE DETAILED ANALYSIS PROCESS

This section provides an overview of the detailed analysis process, including a summary of requirements under CERCLA and MTCA and descriptions of the individual evaluation criteria.

7.1.1 Description of CERCLA and MTCA Requirements

The objective of the detailed analysis is to assess the alternatives with respect to nine evaluation criteria specified in the NCP [40 CFR 300.430(e)(9)]. This analysis provides the basis for identification of a preferred alternative and preparation of the Proposed Plan. The nine criteria are listed below and fall into three groups: threshold criteria, primary balancing criteria, and modifying criteria.

<u>Two threshold criteria including:</u>

- Overall protection of human health and the environment; and
- Compliance with applicable or relevant and appropriate requirements (ARARs).

Five primary balancing criteria including:

- Long-term effectiveness and permanence;
- Reduction of toxicity, mobility, and volume;
- Short-term effectiveness;
- Implementability; and
- Cost.

Two modifying criteria including:

- Forest Service, State and EPA acceptance; and
- Community acceptance.

The threshold and primary balancing criteria are described below. The two modifying criteria are not evaluated in the FS Report, but will be evaluated and submitted with the Record of Decision (ROD) following Forest Service, EPA, Ecology, and public comment on the FS Report and Proposed Plan. In addition to the nine CERCLA criteria discussed above, as agreed to by the Parties in the AOC, a tenth criterion is used in the detailed analysis of alternatives at the Holden Mine Site:

- Natural resource restoration**.**

In accordance with the AOC, the additional criterion was added to evaluate the extent to which each candidate remedial alternative achieves natural resource restoration.

As discussed in Section 1, the FS process for the Holden Mine site is also being completed in accordance with MTCA. The MTCA specifies general requirements for evaluating cleanup actions completed in the State of Washington (WAC 173-340-700 through 760), including:

- Protect human health and the environment;

- Comply with cleanup standards specified in WAC 173-340-700 through 760;

- Comply with applicable state and federal laws;

- Provide for compliance monitoring as specified under WAC 173-340-410 and 173-340-720 through 760;

- Use permanent solutions to the maximum extent practicable, which requires the use of a disproportionate cost analysis to compare the costs and benefits of candidate remedial alternatives;

- Provide for a reasonable restoration time frame as described in WAC 173-340-360(4); and

- Consider public concerns.

These requirements allow for some flexibility and require use of professional judgment in determining how to apply them at particular sites. The first four requirements listed above are considered to be "threshold" requirements under MTCA that the selected final remedy must meet. The remaining three requirements are considered along with the threshold requirements in the comparative analysis of remedial alternatives. The seven MTCA requirements listed above are evaluated in the detailed analysis within the discussions provided for corresponding CERCLA criteria as follows:

- Protection of human health and the environment is addressed under the CERCLA criterion for overall protection of human health and the environment.

- Compliance with MTCA cleanup standards and compliance with applicable state and federal laws are addressed under the CERCLA criterion for compliance with potential ARARs.

- Providing for compliance monitoring is addressed generally under the CERCLA criteria for short-term effectiveness and long-term effectiveness and permanence. However, the identification of specific compliance monitoring locations and frequency will be determined following preparation of the Proposed Plan.

- Use of permanent solutions to the maximum extent practicable is encompassed under several CERCLA criteria including long-term effectiveness and permanence. This criterion allows for the use of a MTCA-specified disproportionate cost analysis, which includes the evaluation of overall protectiveness of human health and the environment, permanence, cost, effectiveness over the long term, management of short-term risks, technical and administrative implementability, and consideration of public concerns. Because the disproportionate cost analysis includes components evaluated under a number of CERCLA criteria, this criterion will be discussed separately following the CERCLA criteria evaluation.

- Providing for reasonable restoration time frame is addressed separately following the CERCLA criteria evaluation to address the MTCA-specific requirements specified in WAC 173-340-360(4).

Similar to the CERCLA process, the consideration of public concerns will be addressed during the final remedy selection process, and will be evaluated following preparation of the Proposed Plan.

The following subsections provide descriptions of the individual CERCLA and MTCA criteria evaluated in the detailed analysis.

7.1.2 Threshold Criteria

The first two evaluation criteria under CERCLA are categorized as threshold criteria because, in general, a candidate alternative is required to meet these criteria in order to support the statutory determinations and declarations that must be made in the ROD. Failure to satisfy either of these criteria usually means an alternative is eliminated from further consideration; however, waivers of some requirements may be allowed under certain circumstances. Overviews of the two threshold criteria are presented below.

7.1.2.1 Overall Protection of Human Health and the Environment

The NCP requires that alternatives “be assessed to determine whether they can adequately protect human health and the environment, in both the short- and long-term, from unacceptable risks posed by hazardous substances, pollutants, or contaminants present at the site by eliminating, reducing or controlling exposure....” Evaluation of alternatives with respect to this criterion provides a final check of the degree to which each alternative addresses RAOs and reduces identified potential human health and environmental risks, thereby providing adequate protection of human health and the environment. This assessment draws upon results of the evaluation of other criteria, especially long-term effectiveness and permanence, short-term effectiveness, and compliance with potential ARARs. As stated previously, failure to satisfy the criterion of overall protectiveness generally eliminates an alternative from consideration as the preferred alternative.

To satisfy this criterion, candidate alternatives must adequately address the site-specific RAOs provided in Section 4, and demonstrate protectiveness in three ways:

- Through their ability to eliminate, reduce, or control existing and potential risks associated with completed transport/exposure pathways;

- By providing engineering controls and/or institutional controls in instances where residual materials or risks to human health and the environment will remain on site after completion of remedial actions; and

- Through prevention of unacceptable risks and/or contamination of the environment during implementation of the alternative.

This CERCLA requirement corresponds to the threshold MTCA requirement for protection of human health and the environment under WAC 173-340-360.

7.1.2.2 Compliance with Applicable or Relevant and Appropriate Requirements (ARARs)

The NCP [40 CFR 300.430(e)(9)(B)] requires that alternatives “be assessed to determine whether they attain applicable or relevant and appropriate requirements under federal environmental laws and state environmental or facility siting laws or provide grounds for invoking one of the waivers under paragraph (f)(1)(ii)(c) of this section.” The potential ARARs are identified in Section 3 of this FS and discussed below for each alternative are preliminary. The final ARARs determination will be made as part of the remedy selection.

Compliance with potential chemical-specific, location-specific, and action-specific ARARs is usually required for an alternative to be considered for selection as the preferred remedy; however, an alternative that does not meet all ARARs may still be selected if one or more of six justifications for waiving an ARAR are met. Of these six allowable waiver justifications, the following four may be considered for Holden Mine Site:

- Compliance with the requirement would result in greater risk to human health and the environment than other alternatives.

- Compliance with the requirement is technically impracticable from an engineering perspective.

- Potential state ARARs are inconsistently applied.

- The alternative will attain an equivalent standard of performance through the use of another method or approach.

Potential ARAR waivers, if necessary, would be addressed during the remedy selection process.

No ARAR waivers are specifically identified or requested in this FS report because it is Intalco's position that such ARAR waivers are not necessary. Intalco, however, is submitting to the Agencies, documentation under separate cover demonstrating how ARAR waivers and other mechanisms allowable under state and federal law may be utilized.

This CERCLA criterion corresponds to the MTCA threshold criteria for compliance with MTCA cleanup standards (specified in WAC 173-340-700 through 760) and compliance with applicable state and federal laws.

In this detailed analysis, the baseline and predicted post-remediation Railroad Creek water quality is compared to both the Washington State promulgated surface water quality criteria (SWQC) for the protection of aquatic life and the National Recommended Water Quality Criteria (NRWQC)[1]. As discussed in Section 3, Intalco has submitted technical documentation to the Agencies demonstrating that the SWQC and NRWQC are based upon sensitive species that would not naturally inhabit Railroad Creek or Copper Creek and thus, the justification for a potential future modification to address site-specific conditions and resident aquatic life.

7.1.3 Primary Balancing Criteria

The primary balancing criteria constitute the basis for evaluating remedial alternatives and provide, in part, the basis for determining an alternative's overall protectiveness. These five criteria are summarized in the following subsections.

---

[1] Intalco has provided legal justification and technical documentation showing that the NRWQC (1999 and 2002 publications) are not relevant and appropriate to the Holden Mine site. Intalco's justification has been provided in written correspondence with the Agencies between January and September 2003. This correspondence is part of the administrative record and is incorporated into this FS. Intalco's rationale is also summarized and presented in Section 3 and Appendix B.

7.1.3.1 Long-term Effectiveness and Permanence

The NCP in 40 CFR 300.430(e)(9)(C) requires that alternatives be: "...assessed for the long-term effectiveness and permanence they afford, along with the degree of certainty that the alternative will prove successful." This criterion serves as a measurement of the expected effectiveness of source controls and other measures that would be implemented to manage the risk remaining on site from untreated materials or concentrated wastes resulting from treatment. In performing this assessment, the potential long-term improvements in environmental quality are addressed for each of the alternatives. As directed by EPA Guidance (EPA, 1988a), the following factors are considered in this assessment:

- Magnitude of residual risk based on characteristics of untreated materials and concentrated wastes remaining after completion of remedial activities. Volume, toxicity, mobility, and potential for bioaccumulation of remaining hazardous materials are considered during the quantification of residual risks.

- The expected adequacy and reliability of engineering controls, including the suitability and continual effectiveness of controls used to manage the remaining materials; the need for replacement of technical components or facilities; and requirements for long-term management, monitoring, and O&M. The uncertainties of long-term effectiveness are addressed under this criterion, when appropriate.

- The potential need for future review of effectiveness**.**

This criterion corresponds to the MTCA criterion for use of permanent solutions to the maximum extent practicable, described in Section 7.1.5. The MTCA specifies the process for balancing the estimated costs and benefits of an alternative using a disproportionate cost analysis to evaluate the extent to which an alternative provides permanent solutions. The disproportionate cost analysis, which includes the evaluation of overall protectiveness of human health and the environment, permanence, cost, effectiveness over the long term , management of short-term risks, technical and administrative implementability, and consideration of public concerns. Because the disproportionate cost analysis includes components evaluated under a number of CERCLA criteria, this criterion will be addressed separately following the CERCLA criteria evaluation.

7.1.3.2 Reduction of Toxicity, Mobility, and Volume

The NCP in 40 CFR 300.430(e)(9)(D) requires that: "The degree to which alternatives employ recycling or treatment that reduces toxicity, mobility, or volume shall be assessed, including how treatment is used to address the principal threats posed by the site." Those alternatives that include treatment technologies are evaluated in this FS on a conceptual basis. Technologies that meet the statutory preference for treatment-based alternatives include actions that result in one or more of the following:

- Destruction of contaminants,
- Reduction of the total mass of contaminants,

- Irreversible reduction in contaminant mobility, and
- Reduction of total volume of contaminated materials**.**

The EPA has made the following pronouncements on the applicability of treatment technologies at mining-related CERCLA sites through OSWER Directive No. 9355.0-26 (EPA 1989c):

- Engineering controls such as containment may be more appropriate than treatment at large sites characterized by high volume/low toxicity wastes such as mine and mill wastes.

- Treatment technologies are generally more appropriate for addressing liquid, highly concentrated, and toxic compounds.

- In some instances, a combination of treatment and containment would be recognized as the most appropriate remedial approach.

The concepts contained in this directive were considered in the evaluation of this criterion.

7.1.3.3 Short-Term Effectiveness

The NCP, in 40 CFR 300.430(e)(9)(E) requires that: "The short-term impacts of alternatives shall be assessed considering the following:

- Short-term risks that might be posed to the community during implementation of an alternative,

- Potential impacts on workers during remedial action and the effectiveness and reliability of protective measures,

- Potential environmental impacts of the remedial action and the effectiveness and reliability of mitigative measures during implementation, and

- Time until protection is achieved."

The MTCA requires the assessment of short-term effectiveness as part of the disproportionate cost analysis.

7.1.3.4 Implementability

The NCP, in 40 CFR 300.430(e)(9)(F), requires that: "The ease or difficulty of implementing the alternatives shall be assessed by considering the following types of factors as appropriate:

- Technical feasibility, including technical difficulties and unknowns associated with the construction and operation of a technology, the reliability of the technology, ease of undertaking additional remedial actions, and the ability to monitor the effectiveness of the remedy.

- Administrative feasibility, including activities needed to coordinate with other offices and agencies and the ability and time required to obtain any necessary approvals and permits from other agencies (for off site actions).

- Availability of services and materials, including the availability of adequate off site treatment, storage capacity, and disposal capacity and services; the availability of necessary equipment and specialists, and provisions to ensure any necessary additional resources.

- Availability of prospective technologies."

The implementability of candidate remedial alternatives is addressed under MTCA in the disproportionate cost analysis.

7.1.3.5 Cost

The NCP in 40 CFR 300.430 (e)(9)(G) requires that: "The types of costs that shall be assessed include the following:

- Capital costs, including both direct and indirect costs;
- Annual operation and maintenance costs; and
- Net present value of capital and operation and maintenance costs."

Evaluation of the capital and operation and maintenance (O&M) costs of each alternative is performed under the cost criterion. In accordance with EPA Guidance (EPA 1988), capital costs include the following two types of expenditures:

- **Direct Capital Costs -** Costs for the purchase of equipment, labor, and materials for the implementation of the remedial actions, including:

  - Construction costs - materials, labor, and equipment;

  - Equipment costs - process and/or construction equipment necessary to complete remediation;

  - Land and site development costs - site preparation;

  - Buildings costs - costs of process and non-process buildings, utility connections, etc.; and

  - Disposal facility costs - costs of on site or off site transportation and disposal including construction of waste repositories.

- **Indirect Capital Costs -** Expenditures for services such as engineering, financing, and other items that are not specifically part of actual installation activities but are required for completion of remediation, including:

  – Engineering expenses - design, treatability testing, construction supervision, etc.;

  – Startup and shakedown costs - costs to ensure the system is operational and functional; and

  – Contingency allowances.

Annual O&M costs are incurred after completion of construction to ensure continued effectiveness of a particular remedial alternative. In accordance with EPA Guidance (EPA 1988a), O&M costs specifically applicable to the candidate alternatives may include the following:

- Labor costs associated with post-construction operations, if applicable;

- Maintenance costs including materials and labor for routine maintenance;

- Administrative costs including the costs of administering institutional controls and providing oversight to ensure proper maintenance is continued into the foreseeable future;

- Costs of long-term monitoring to assess the continued effectiveness of remedial actions;

- Insurance, taxes, licensing costs, annual or long-term fees, and reporting costs;

- Rehabilitation and/or replacement costs including maintenance and/or replacement of equipment, structures, or other physical controls which degrade over a period of time; and

- Costs of periodic site reviews - conducted at least every 5 years if wastes above health-based criteria remain at the Site.

The alternative development provided in Section 6 was performed to the level of detail necessary to perform cost estimates having an accuracy of +50 percent to -30 percent. All anticipated future expenditures were discounted to 2004 dollars based on an assumed discount rate of 7 percent over a 30-year period. Cost estimates were based on published values for construction, materials, equipment, and labor, on the prior experience of project personnel, and engineering judgment. Capital and O&M costs are summarized in Table 7-9. Cost detail sheets for each alternative are provided in Appendix I of this report.

Similarly, under MTCA, costs that should be considered include:

- Costs to implement the alternative, including the cost of construction;

- The net present value of any long-term costs, including O&M costs, monitoring costs, equipment replacement costs, and the cost of maintaining institutional controls;
- Agency oversight costs that are cost-recoverable; and
- Treatment costs, including costs associated with pretreatment, analytical, labor, water management, and replacement or repair of major treatment components (WAC 173-340-360(3)(f).

7.1.4 Natural Resource Restoration Criterion

A draft injury determination report (URS 2002) has been prepared and submitted to the identified natural resource Trustees, including the Forest Service, U.S. Department of Interior (DOI), Ecology, Washington State Department of Fish and Wildlife (WDFW), Yakima Indian Nation, and Colville Federated Tribe. The Forest Service is the Lead Administrative Trustee for the Holden Mine Site. The draft injury determination identified potentially injured resources at the Site due to the release of hazardous substances resulting from historical mining activities. Potentially injured resources at the Site include surface water, groundwater, soils, and biological resources. Additional discussion of the findings of the draft injury determination report is provided in Section 2.

Based on the information provided in the injury determination report, as well as supplemental information provided in meetings held between Intalco and the Trustees, natural resource damage negotiations are ongoing. Final settlement will be based on an evaluation of the following factors:

- Potential natural resource injuries resulting from historic mining activities at the Site;
- Predicted natural resource restoration provided by the selected remedial alternative; and
- Specific restoration projects completed on- or off-site that would be completed to compensate for potential past and future natural resource damages.

In accordance with the AOC, the second RAO identified for the Holden Mine Site requires the performance of appropriate natural resource damage assessment activities as agreed by the Parties consistent with 43 CFR Part 11 to evaluate the potential for coordinated remedial and natural resource activities. Therefore, the detailed analysis of candidate alternatives for the Holden Mine Site includes an evaluation of the extent to which alternatives would be expected to achieve natural resource restoration and the potential for coordinated remedial and natural resource restoration activities. Natural resource restoration is considered an additional primary balancing criterion for the purposes of this FS report.

7.1.5 Use of Permanent Solutions to the Maximum Extent Practicable

The MTCA (WAC 173-340-360(4)(b)) requires as a threshold criterion that the final remedy use permanent solutions to the maximum extent practicable. A disproportionate cost analysis is used to make this assessment, and includes the evaluation of predicted costs and benefits. The costs and benefits evaluated include overall protection of human health and the environment, permanence, cost, effectiveness over the long term, management of short-term risks, technical and administrative implementability, and consideration of public concerns.

7.1.6 Reasonable Restoration Time Frame

The MTCA specifies that cleanup actions provide for a reasonable restoration time frame and consideration of the following factors:

- Potential risks posed by the Site to human health and the environment;
- Practicability of achieving a shorter restoration time frame;
- Current use of the Site, surrounding areas, and associated resources that are, or may be affected by releases from the site;
- Potential future use of the Site, surrounding areas, and associated resources that are, or may be affected by releases from the Site;
- Availability of alternative water supplies;
- Likely effectiveness and reliability of institutional controls;
- Ability to control and monitor migration of hazardous substances from the site;
- Toxicity of the hazardous substances at the Site; and
- Natural processes that reduce concentrations of hazardous substances have been documented to occur at the Site or under similar site conditions.

A longer time frame may be used to achieve cleanup levels at a conditional point of compliance (CPOC) if the cleanup action selected has a greater degree of long-term effectiveness than on-site or off-site disposal, isolation, or containment options (WAC 173-340-360(4)(c)).

7.2 SUPPORTING EVALUATIONS

Subsequent to the technology screening and remedial alternative development described in Sections 5 and 6, additional evaluations were performed to support the detailed analysis of remedial alternatives:

- Post-remediation loading analysis for dissolved cadmium, copper, iron, and zinc (Appendix D and Section 7.2.1);
- Analysis and prediction of long-term attenuation of chemical loadings at the Site (Appendix E and Section 7.2.1);

- Hydrologic evaluation of landfill performance (HELP) modeling and conceptual water balance completed for the tailings piles (Appendix G);

- Evaluation of potential impacts to aquatic life in Railroad Creek after remediation due to residual metals concentrations (Appendix H);

- Evaluation of expected post-remediation concentrations of total aluminum in Railroad Creek (Section 7.2.2); and

- Evaluation of potential storm-water runoff chemistry during tailings regrading activities (Section 7.2.3).

A discussion of the post remediation loading analysis model, including the long-term loading analysis is provided in Section 7.2.1. The loading analysis output and tables summarizing key input parameters and assumptions are provided in Appendix D. An evaluation of the expected post-remediation concentrations of aluminum in Railroad Creek is provided in Section 7.2.2, and an evaluation of potential storm-water runoff chemistry during tailings regrading is provided in Section 7.2.3.

7.2.1 Post-remediation Metals Loading Analysis

The expected post-remediation concentrations of PCOCs in Railroad Creek were estimated for the candidate remedial alternatives by evaluating the reductions in metals loading expected based on each alternative's remedial components. As discussed in the following subsections, both short-term and long-term Railroad Creek water quality was evaluated in the analysis.

The expected reductions in metals loading to Railroad Creek were evaluated using the baseline loading analysis presented in Section 2 and Appendix A, performance factors estimated for each of the remedial alternatives, and modeling of long-term geochemical processes. The performance factors evaluated include:

- Loading reductions due to upgradient controls,
- Downgradient collection efficiencies, and
- Water treatment system effectiveness.

The water balance for the site was assumed to remain constant throughout the analysis (i.e., the net contribution of flow to Railroad Creek from each source area was assumed to remain constant over time).

For the short-term and long-term analyses, a reduction in metals loading due to upgradient controls (e.g., source removal, capping, etc.) was estimated for each source area by multiplying the baseline loading by an estimated loading reduction factor. The magnitude of the loading reduction factor was estimated based on the specific remedial actions included under each alternative. For the long-term analysis, an additional reduction in metals loading from each source area due to natural geochemical processes was estimated by multiplying the long-term loading (a function of baseline loading and reductions due to upgradient controls) by a time-trend loading ratio.

Under alternatives that include downgradient collection and treatment, the post-remediation metals loading for each source area was multiplied by a downgradient collection efficiency factor, as appropriate, on an alternative-by-alternative basis. Collected seep and groundwater flow to the treatment system(s), if applicable, was then calculated by summing the collected flows from each source area. Metals loading to Railroad Creek from the treatment system(s) were then evaluated as point-sources, with the loading to the creek equal to the collected flow multiplied by an assumed effluent metals concentration.

The short- and long-term loading analyses were performed for dissolved cadmium, copper, iron, and zinc. Because dissolved aluminum concentrations were measured to be at or below laboratory detection limits in samples collected from monitoring stations upstream and adjacent to the Site for a majority of the year, aluminum was not incorporated into the post-remediation analyses. A discussion of estimated post-remediation aluminum loading is provided in Section 7.2.2.

Appendix D1, Tables D1-1 through D1-14, presents the expected short-term performance factors for Alternatives 2 through 8. Expected long-term performance factors are presented in Appendix D2, Tables D2-1 through D2-14. A summary of the key assumptions used in estimating the long-term, time-trend loading ratios is provided in Appendix D4. The detailed post-remediation loading calculations are presented in Appendices D3 (short term) and D5 (long term)

The following subsections describe the expected remedial alternative performance factors, the estimated long-term changes in metals loading due to geochemical effects, as well as the post-remediation loading analysis calculation method, uncertainty analysis, and Railroad Creek water quality results.

7.2.1.1 Expected Remedial Alternative Performance Factors

Summaries of the expected performance factors for each candidate site-wide alternative are provided in Appendix D Tables D1-1 through D1-14 (short term) and Tables D2-1 through D2-14 (long term). As described above, the estimated performance factors include metals loading reductions due to upgradient controls, downgradient collection efficiencies, and treatment system effluent concentrations, as appropriate, for each alternative. The estimated effects of long-term geochemical processes as a function of time are summarized for West Area sources, the underground mine, and the tailings piles in Section 7.2.1.2 and Appendix D, Table D4. Key assumptions used in developing the short- and long-term performance factors are described below.

Loading Reductions Due to Upgradient Controls

The anticipated post-remediation reductions in metals loading for each source area due to upgradient controls were estimated based on the geochemical analyses provided in Appendix E; the estimated reduction in water infiltration based on the conceptual water balance and HELP modeling described in Section 7.2.4; and engineering judgment. Post-remediation metals loadings were calculated by multiplying the baseline concentration and flow, described in Section 2 and Appendix A, by an estimated loading reduction factor for each source area under each alternative. For example, a loading reduction factor of 15 percent would yield a post-remediation load in the respective discharge, seep or groundwater that is 85 percent of the baseline load (100% - 15% = 85%).

Short-term Metal Loading Reductions Due to Upgradient Controls

Loading reductions due to upgradient controls were estimated for the short term (assumed for purposes of the FS to take place approximately five years after remedy implementation) in order to evaluate the estimated metals loading to Railroad Creek over this timeframe. These reduction factors represent the decrease in metals loading expected to occur from source areas during the transition from current conditions to long-term post-remediation conditions at the Site.

- Seep SP-26 and Unaccounted Load Upstream of RC-1 - A 50-percent loading reduction was assumed for seep SP-26 and the unaccounted (groundwater) loading upstream of RC-1 due to a combination of removal and capping of potential source materials from this area as described for Alternatives 2 through 8 in Section 6.

- Seep SP-23/Honeymoon Heights - No short-term loading reductions were assumed for seep SP-23 under Alternatives 2 through 8.

- Underground Mine (Portal Drainage) – No short-term reduction in metals concentrations from the 1500-level main portal was assumed for Alternatives 2 through 8 due to the installation of airtight bulkheads, hydrostatic bulkheads, or the implementation of in-mine water controls. Although over the long-term these actions would be expected to reduce airflow through underground workings, and provide additional detention time and contact with lower workings and groundwater for enhanced metals removal through geochemical processes, there are significant uncertainties regarding the timeframe during which these processes may occur. Additionally, to account for the potential short-term increases in metals concentration due to the installation of hydrostatic bulkheads and raising the water level within the mine, the best estimate concentrations presented on Table 5 of the SRK's geochemical analysis presented in Appendix E (SRK 2004) were assumed in the post remediation loading calculations for both the spring and fall scenarios under those alternatives which include hydrostatic bulkheads.

- Mill Building (Seeps SP-7 and SP-22) – A 50-percent loading reduction was estimated for the mill building seeps as a result of upgradient water diversion and the removal and/or covering of a majority of the potential source materials within this area as described for Alternatives 2 through 8 in Section 6.

- Waste Rock Piles (Seeps SP-6, SP-8, SP-19, SP-15W) – No short-term loading reduction was assumed for seeps associated with the waste rock piles as a result of upgradient water diversions or capping under Alternatives 2 through 7. This assumption is based on SRK's geochemical evaluations provided in Appendix E (SRK 2004). As described in Appendix E, the estimated decrease in water infiltration to the waste rock piles under Alternatives 2 through 7 was not expected to result in significant reductions in metals loading from this source area. A loading reduction factor of 90 percent was estimated for this area under Alternative 8, to account for expected loading reductions due to consolidation and the installation of a low-permeability cap.

- Copper Creek Diversion – A 95 percent reduction in loading from the Copper Creek diversion was assumed for all the candidate remedial alternatives. The placement of Copper Creek diversion water in a lined channel or culvert from the outlet of the hydroelectric power plant to the confluence with Railroad Creek is expected to be effective in reducing contact with tailings material and potentially impacted groundwater in this area.

- West Area Seeps (SP-9, SP-11, SP-25, SP-24, SP-10W, SP-10E) and Unaccounted West Area Loading – A 25-percent reduction in metals loading from these West Area seeps and groundwater was assumed for Alternatives 2 and 4. This estimate is based on anticipated reductions in metals loading to groundwater due to the implementation of upgradient water and source controls in the West Area. The estimated loading reduction was increased to 75 percent for Alternatives 3, 5, 6, and 7 to account for the anticipated incremental reduction in loading to the lower West Area through installation of the upper West Area groundwater and seep collection and treatment system. An 80-percent reduction factor was assumed for Alternative 8 to account for the relocation of the east and west waste rock piles to the consolidated tailings pile.

- Tailings Piles 1, 2, and 3, and Unaccounted East Area Loading – No short-term reductions in metals loading was assumed for Alternatives 2 through 6, based on the results of the geochemical analyses provided in Appendix E (SRK 2004). As described in Appendix E, although long-term reductions in metals loading from the tailings piles are expected, metals loading may not decrease as a result of upgradient water diversions and regrading in the short-term. This is due to the continued flow of groundwater beneath the piles and the availability of stored metals in the form of secondary minerals (such iron carbonate) in the deeper tailings materials. Additionally, an extended period of time is predicted for residual water within the tailings to "drain-down" through the piles. A loading reduction factor of 90 percent was estimated for groundwater associated with tailings pile 1 under Alternatives 7 and 8, which include removal of tailings pile 1, and consolidation onto the current footprint of tailings piles 2 and 3.

Long-term Metal Loading Reductions Due to Upgradient Controls

Long-term loading reductions for each source area were estimated to reflect "steady-state" conditions following the long-term implementation of upgradient water controls and source removal/capping. The long-term factors were estimated to represent conditions after dissolved metals and metal oxides remaining in groundwater and soils downgradient of source controls and collection systems have been depleted. For purposes of the FS, the long-term loading reduction factors due to upgradient controls were applied after a period of approximately 30 years. It should be noted that the reduction factors described below do not incorporate the effects of long-term geochemical processes (described in Section 7.2.1.2).

- Seep SP-26 and Unaccounted Load Upstream of RC-1 – The loading reduction factor for this area was increased to 60 percent for the long-term due to the removal and/or capping of potential source materials. It was assumed that the metals loading would continue to decline as residual metals are flushed from soils and groundwater located downstream of the source controls implemented in this area.

- Seep SP-23/Honeymoon Heights - No long-term loading reduction was assumed for SP-23 based on upgradient controls.

- Underground Mine (Portal Drainage) – No long-term loading reduction factor was estimated for the portal drainage under Alternatives 2a, 3a, and 6a due to the installation of airflow restrictions in the open portals. This is a conservative assumption, based on the geochemical analyses provided in Appendix E (SRK 2004), and engineering judgment. Similarly, no loading reduction was assumed for the portal drainage under Alternatives 2b, 3b, 4, 5, 6b, 7 and 8 due to the installation of hydrostatic bulkheads or other in-mine controls. However, the placement of hydrostatic bulkheads is predicted to decrease airflow through the mine and increase detention times and the contact of mine water from the upper workings with the lower mine workings and groundwater. It was assumed that over the long-term the potentially elevated metals concentrations in the portal drainage would return to near-baseline conditions, as secondary metal sources are flushed from the underground workings. As such, long-term portal drainage concentrations for Alternatives 2b, 3b, 4, 5, 6b, 7 and 8 are assumed to equal the spring and fall baseline 1997 concentrations.

- Mill Building (Seeps SP-7 and SP-22) – The loading reduction factor for seeps associated with the mill building was increased to 60 percent for the long-term analysis, based on the depletion of secondary metals sources following the removal and/or capping of potential source materials within this area.

- Waste Rock Piles (Seeps SP-6, SP-8, SP-19 and SP-15W) – No long-term loading reduction was assumed for seeps associated with the Waste Rock piles based on upgradient controls for Alternatives 2 through 7. A 90-percent loading reduction was assumed for Alternative 8, as described for the short-term analysis.

- Copper Creek Diversion – A 95-percent reduction in loading from the Copper Creek diversion was assumed for all the candidate remedial alternatives as described for the short-term analysis. This is based on the placement of Copper Creek diversion water in a lined channel or culvert from the outlet of the hydroelectric power plant to the confluence with Railroad Creek.

- West Area Seeps (SP-9, SP-11, SP-25, SP-24, SP-10W, SP-10E) and Unaccounted West Area Loading – The loading reduction factor for these West Area seeps and groundwater was increased to 30 percent in the long-term for Alternatives 2 and 4; 85 percent for Alternatives 3, 5, 6, and 7, and 90 percent for Alternative 8. The increased reduction factors are based on the anticipated depletion of dissolved metals and metal oxides remaining in groundwater and soils located downgradient of source controls and collection systems.

- Tailings Piles 1, 2, and 3, and Unaccounted East Area Loading – Long-term reductions in metals loading from the tailings piles was evaluated based on geochemical modeling presented in Appendix E. Results of the geochemical modeling, which takes into account the estimated reductions in infiltration due to upgradient controls, indicates that the long-term loading trends vary by metal and with time. As a result, these effects are accounted for separately, and no long-term reductions in metals loading due to upgradient controls are assumed for Alternatives 2 through 6. Consistent with the short-term analysis, a loading reduction factor of 90 percent was estimated for groundwater associated with tailings pile 1 under Alternatives 7 and 8, which include the consolidation of Tailings Pile 1 onto the current footprint of tailings piles 2 and 3. Additional discussion of the estimated long-term effects of natural geochemical processes is presented in Section 7.1.2.2.

Short- and Long-term Downgradient Collection Efficiencies

The collection efficiencies presented in Appendices D1 and D2 for downgradient collection systems were based on the assumed collection method and engineering judgment. Downgradient collection efficiencies for intercepted seeps and groundwater are estimated to be the same in the short and long term. Estimated collection efficiencies and key assumptions are provided below for alternatives that include downgradient collection and treatment as described in Section 6.

- Seep SP-26 and Unaccounted Load Upstream of RC-1 - No downgradient collection is included for this area under Alternatives 2, 3, 4, 5, 7, and 8. A downgradient collection efficiency of 80 percent was estimated for Alternative 6 for this source area based on the anticipated effectiveness of a groundwater collection system installed on the steep slopes in this area.

- Seep SP-23, Mill Building (Seeps SP-7 and SP-22), and Waste Rock Piles (Seeps SP-6, SP-8, SP-19 and SP-15) – No downgradient collection is included for these areas under Alternatives 2 and 4. A downgradient collection efficiency of 90 percent was estimated under Alternatives 3, 5, 6, 7, and 8 for groundwater and seeps from these source areas based on the predicted effectiveness of the upper West Area barrier wall/collection trench system. Alternative 8 does not include the collection of waste rock pile seeps, because the waste rock piles would be consolidated with the tailings piles under this alternative.

- Underground Mine (Portal Drainage) – A downgradient collection efficiency of 97 percent was estimated under Alternatives 3, 5, 6, 7, and 8. This estimated value is based on the assumption that the portal drainage would be directed into a pipe or culvert at the 1500-level main portal for transfer to a treatment building located in the maintenance yard or lagoon area. No collection or treatment of the portal drainage is included under Alternatives 2 and 4.

- West Area Seeps (SP-9, SP-11, SP-25, SP-24, SP-10W, SP-10E) and Unaccounted West Area Loading – No downgradient collection of these seeps and groundwater in the lower West Area is included under alternatives 2, 3, 4, 5a/b/c, 7, or 8. A collection efficiency of 90 percent was estimated for this area under Alternatives 5d and 6 based the anticipated effectiveness of the lower West Area barrier wall/collection trench system in this area.

- Tailings Piles 1, 2, and 3 and Loading Downgradient of RC-2 – No collection and treatment of East Area groundwater is included under Alternatives 2, 3, or 7. Under Alternatives 4, 5, 6, and 8 the estimated collection efficiencies are based on the anticipated effectiveness for each collection method (i.e. partial collection, extended collection, extended Railroad Creek relocation). Under Alternatives 4, 5, 6, and 8, collection efficiencies of 80 percent were applied to intercepted seeps and groundwater based on the anticipated effectiveness of the barrier wall and/or collection systems. Under Alternatives 4a and 5a (partial East Area collection), the collection efficiency was only applied to those seeps or groundwater flow tubes intercepted by the barrier walls. Due to the point source nature and location of seep SP-21, this seep was assumed to be collected with an efficiency of approximately 95 percent under all the alternatives that include collection and treatment in the East Area.

- East Area Unaccounted Loading – No collection and treatment of East Area groundwater is included under Alternatives 2, 3, or 7. Therefore, no collection of the unaccounted load was assumed for these alternatives. Under Alternatives 4, 5, 6, and 8 the estimated collection efficiencies are based on the anticipated effectiveness and extent of each collection method (i.e. partial collection, extended collection, extended Railroad Creek relocation). A collection efficiency of approximately 20 percent was assumed for the unaccounted load under Alternatives 4a and 5a (partial East Area collection). This assumes approximately 25 percent of the unaccounted load (groundwater) in this area is collected with a collection efficiency of approximately 80 percent. A collection efficiency of 80 percent was assumed for the unaccounted load in the short term and long term for Alternatives 4b, 5b, and 8 (extended East Area collection). A collection efficiency of 80 percent was also estimated for the open trench system included under Alternatives 4c, 5c, 5d, and 6 (Railroad Creek relocation).

- Loading Downstream of RC-2 (Flow tubes) – A collection efficiency of 90 percent was assumed for groundwater flow downstream of RC-2 in the fall under Alternatives 4a through 8. This collection efficiency is based on the interception of the flow tubes by the East Area treatment system downstream of tailings pile 3.

Short- and Long-term Treatment System Effluent Concentrations

As described in Section 6, treatment system effluent concentrations were estimated based on comments received from the Agencies, a review of available performance data from full- and pilot-scale acid rock drainage treatment systems in North America and Europe, and the results of the May 2000 bench-scale treatability study described in Section 2. Treatment system effluent concentrations are estimated to be the same in the short and long term. Estimated treatment system effluent concentrations and key assumptions are provided below for the areas identified for collection and treatment under the candidate remedial alternatives described in Section 6.

- Low-energy and Mechanical West Area Treatment Systems – Based on a review of available treatment system performance data from other sites, the results of the bench-scale testing performed on the portal drainage, and application of equivalent unit processes, it was assumed that the low-energy and mechanical treatment systems would achieve equivalent effluent quality for West Area waters: cadmium (5 ug/L), copper (24 ug/L), iron (200 ug/L) and zinc (240 ug/L).

- Low-energy East Area Treatment System – Based on a review of available treatment system performance data from other sites and the results of the bench-scale testing performed on the portal drainage, it was assumed that the low-energy treatment systems for East Area waters would achieve the following effluent quality: cadmium (5 ug/L), copper (35 ug/L), iron (200 ug/L) and zinc (350 ug/L).

Metals loading to Railroad Creek from the East and West Area treatment systems are estimated as point-sources, with the loading to the creek equal to the collected flow multiplied by the appropriate effluent concentrations. The volumes collected and treated are estimated to vary by season and by alternative based on the specific collection and treatment system components included. A summary of the estimated volumes of water collected and treated by each alternative is provided on the post-remediation loading analysis tables included in Appendices D3 and D5 and is discussed below in Section 7.2.1.3.

7.2.1.2 Long-term Attenuation of Metals Loading due to Geochemical Processes

Long-term reductions in metals loading from Site source areas (including waste rock, the underground mine and tailings piles) due to natural geochemical processes (natural attenuation) were estimated based on the geochemical analyses presented in Appendix E (SRK 2004). The attenuation of ARD and associated metals loading is well documented in the literature. ARD is generally formed as a result of the oxidation of sulfide minerals in the presence of moisture. As the mass of available sulfide declines over time, the associated release of acidic water and metals also declines until background conditions are reached.

Assumed long-term loading reduction factors are presented in Appendix D4. A summary of the general approach and results for each type of source area is provided below. A detailed discussion of the geochemical analyses performed is provided in Appendix E.

Waste Rock

Waste Rock – Waste rock is located in Honeymoon Heights, the East and West waste rock piles, and in isolated locations within the mill building. Long-term reductions in loading from these sources were assumed to follow an exponential decay resulting from the depletion of available primary minerals as the primary sources of metals loading. The general form of the decay equation is:

$$L_{time=t} = L_{time=0}\ 10^{(k*t)}$$

where:

$L_{time=t}$ is the load at any given time "t" (in weeks)
$L_{time=0}$ is the load at time = zero, and
k is the decay constant (here with units of $weeks^{-1}$)

Based on the geochemical evaluations presented in Appendix E, a conservative decay constant (k) of -0.0001 $weeks^{-1}$ was assumed for site waste rock. For the purposes of the long-term loading analysis model, this decay constant was applied to all loading sources in the West Area that are influenced by waste rock materials (e.g., seep SP-23, waste rock pile seeps, lower west area seeps, etc.).

Underground Mine

Long-term reductions in metals loading from the underground mine were also assumed to follow an exponential decay trend based on the gradual depletion of available minerals in the underground workings. Based on the geochemical evaluations presented in Appendix E, a conservative decay constant of -0.0001 $weeks^{-1}$ was assumed for the underground mine (i.e., loading from the portal drainage).

Tailings Piles

Metals loading from tailings piles 1, 2, and 3 were modeled as a function of time based on the progression of oxidized zones and acidic zones through the tailings piles as described in Appendix E. Whereas the long-term trend for metals loading from waste rock and the underground mine were assumed to continually decrease with time, the results of the geochemical modeling performed for the finer-grained tailings predict several intermittent increases in metals loading within an overall decreasing trend.

Results of the long-term analysis of metals loading from the tailings piles are presented as loading ratios, where the loading at a given point in time was estimated to be equal to the loading at time equals zero (assumed to be year 1997) multiplied by the corresponding loading ratio. For example, a loading ratio of 0.15 would equate to an estimated loading that is 15% of the loading at time zero. A summary of the estimated loading ratios over time for each remedial alternative is provided in Appendix D4.

7.2.1.3 Post-remediation Loading Analysis Calculation Method

Overview

Post-remediation metals concentrations in Railroad Creek were calculated based on the expected post-remediation cumulative metals loading. Reductions in metals loading were estimated by estimating loading reductions due to upgradient controls, downgradient collection and treatment of seeps or groundwater, and the predicted long-term trends in metals loading from each source area. Expected post-remediation metals loading from each source area was estimated by applying one or more loading reduction factors to the baseline loading presented in the baseline loading analysis (Appendix A). When downgradient collection and treatment was included for a source area under a given alternative, post-remediation loads to Railroad Creek were calculated by applying a downgradient collection efficiency factor to the estimated post-remediation loading from each source area. Loading to Railroad Creek from treatment systems, if applicable, was calculated by multiplying the cumulative collected seep and groundwater flow by the estimated treatment system effluent concentration.

The expected loading from background (upstream), each source area, and the treatment system(s), if applicable, were summed to yield the expected cumulative loading at station RC-4 and downstream of RC-2. Expected post-remediation concentrations were then calculated by dividing the expected cumulative loading by the baseline flows in Railroad Creek at station RC-4 and downstream of RC-2. Post-remediation loading calculations for spring and fall conditions are presented on tables in Appendices D3 and D5, and a summary of the results are provided on Tables 7-1 through 7-5. Due to the size and number of tables comprising Appendices D3 and D5, these tables have been provided electronically on a compact disk included in Volume 2.

Calculation Detail

Post-remediation Loading from Source Areas

In order to evaluate short-term post-remediation metals loading, loading reduction factors were applied to the baseline load from each source area. The short-term post-remediation metals loading for seeps and groundwater were calculated by multiplying the baseline concentration and flow by one minus the estimated concentration reduction due to upgradient controls:

$$L_{source,ST} = Q_B*C_B*(1-UG)$$

where:
$L_{source,ST}$ = Short-term post-remediation loading from source area
Q_B = Baseline flow
C_B = Baseline Concentration
UG = Estimated loading reduction due to upgradient controls

For the long-term analysis, an additional loading reduction factor – the loading ratio as a function of time - is included in the post-remediation loading calculation:

$L_{source,LT} = Q_B*C_B*(1-UG)*LR_t$

where:
$L_{source,LT}$ = Long-term post-remediation loading from source area
Q_B = Baseline flow
C_B = Baseline Concentration
UG = Estimated loading reduction due to upgradient controls
LR_t = Load ratio at time = t

The load ratio as a function of time was calculated based on the assumed geochemical model that best described the source area. For waste rock-type source areas and the underground mine, the load ratio was calculated as a function of time by the equation

$LR_{t,WR} = 10^{(k_{wr}*t)}$

where:
$LR_{t,wr}$ = Loading ratio for waste rock-type sources
k_{wr} = Decay constant for waste rock-type sources = -0.0001 $weeks^{-1}$
t = Time in weeks

Loading ratios for the underground mine as a function of time were calculated with a similar equation:

$LR_{t,um} = 10^{(k_{um}*t)}$

where:
$LR_{t,um}$ = Loading ratio for the underground mine
k_{um} = Decay constant for the underground mine = -0.0001 $weeks^{-1}$
t = Time in weeks

Loading ratios for the tailings piles were estimated based on geochemical modeling. Values for the loading ratios for the tailings piles for each alternative are presented in Appendix D4.

Post-remediation Loading to Railroad Creek or Subsurface

Loading from each source area discharges either to the subsurface or to Railroad Creek. When a downgradient collection system is included, the amount of collected flow (and consequently loading) was calculated based on the assumed collection efficiency. The post-remediation loading to Railroad Creek or subsurface from each source area was calculated by multiplying the post-remediation loading from each source area by one minus the downgradient collection efficiency:

$$L_{SS\ or\ RRC} = L_{source}*(1-CE)$$

where:
$L_{SS\ or\ RRC}$ = Post-remediation loading to subsurface or Railroad Creek
L_{source} = Post-remediation loading from source area
CE = Downgradient collection efficiency

Collected Flows (Treatment System Influent)

For alternatives which include collection and treatment of seeps, groundwater, and discharges, collected water from each source area to the treatment systems was calculated by multiplying the baseline flow by the estimated collection efficiency:

$$Q_C = Q_B*(CE)$$

where:
Q_C = Collected flow from source area
Q_B = Baseline flow from source area
CE = Estimated downgradient collection efficiency

The collected flows from each source area were then summed to calculate to total collected flow conveyed to the treatment system. Under alternatives including West Area collection and treatment, the seeps associated with the mill building and the west waste rock pile, which normally discharge to the subsurface, are collected, treated and discharged to Railroad Creek. As a result, metals loading from these sources was split between the subsurface (untreated) and Railroad Creek (after treatment) based on the anticipated collection efficiencies. The contributions of flow from these sources to Railroad Creek (after treatment) were *not* added to the baseline flow for the post-remediation concentration calculations presented in the Post-Remediation Loading Analysis Tables (Appendices D3 and D5).

The volume of groundwater collected and treated under alternatives that include West Area collection and treatment (Alternatives 3, 5, 6, and 7) was estimated based on an assumed groundwater interception per length of collection system and the estimated collection efficiencies. Groundwater collection volume assumptions for each alternative are summarized on the remedial alternative performance summaries in Appendix D1. Alternative 8 includes the collection and treatment of selected West Area seeps and the portal drainage but does not include groundwater collection. Metals concentrations in the collected groundwater were estimated using available seep and groundwater sampling data. The volume and chemistry of the groundwater collected by the upper and lower West Area collection systems was estimated as follows:

<u>Upper West Area Collection System (Alternatives 3, 5, 6, 7)</u>

Groundwater collection estimates for the upper West Area collection system under Alternatives 3, 5, 6 and 7 assume interception of approximately 0.23 gallons per minute (gpm) per linear foot of collection system (spring flush) and 0.13 gpm per linear foot (baseflow) along approximately 2,450 feet of collection system with a collection efficiency of 90 percent. The groundwater interception rate was estimated based on a mean annual average groundwater flow of 0.15 gpm per linear foot for the West Area. The mean annual average groundwater flow was calculated by averaging the annualized groundwater flows estimated using the following methods:

- Collection system interception of groundwater following Darcy's Law;
- Collection system interception of groundwater at a rate equivalent to flownet analysis rates for native material at the Site; and
- Collection system interception of groundwater based on an analysis of annual precipitation infiltration for the area upgradient of the collection system.

Interception rates, calculation parameters and assumptions for each method are summarized below. For collection system interception of groundwater following Darcy's Law, groundwater is assumed to flow into the trench from the uphill face, following Darcy's Law, a standard law of groundwater flow. Darcy's law states:

$$Q = k * i * a$$

where:
Q = groundwater volume
k = hydraulic conductivity of permeable material
i = hydraulic gradient
a = area through which groundwater flows

Calculation parameters and assumptions are as follows:

- The trench is 15 feet deep based on geophysical and test pit results. Test pits completed in 2003 indicate 13 feet bgs to dense till at the west waste rock pile, and at least 17-18 feet bgs at the east waste rock pile.
- At the height of the spring snowmelt, the uphill side of the trench is fully saturated from ground surface to base (15 feet saturated thickness).
- Under low flow conditions, the trench has a saturated thickness of 0.5 feet. This value may be conservative, based on no saturated thickness observed during test pit excavation in October 2003, however a larger saturated thickness may occur during the winter due to intermittent snowmelt on days when the temperature rises above freezing at the Site.

- Groundwater gradient is a subdued reflection of topographic gradient. Topographic gradient is 0.125 ft/ft on the slope south of the trench, the groundwater gradient is assumed to be 75% of the topographic gradient.

- Groundwater levels drop 10 feet per month after spring snowmelt (based on site wells HV-3, PZ-1A, and PZ-4A).

- Material overlying dense till is silty gravel, with a hydraulic conductivity of 100 to 150 ft/day.

Based on a Darcy's Law evaluation of groundwater interception utilizing the parameters and assumptions above, the groundwater interception rate varies from 0.12 to 0.17 gpm per linear foot of trench. The variability in interception rate is related to the range of hydraulic conductivity assumed for material overlying the dense till.

The flownet analysis for native material at the Site (Attachment A1 to Appendix A) provides a best estimate value of approximately 1.491 cfs for groundwater input from native materials under spring conditions along 4,825 linear feet of stream length (0.14 gpm per linear foot) and 0.627 cfs groundwater input from 3,280 feet of stream length under fall conditions (0.08 gpm per linear foot). To estimate an annual average value, it was assumed that spring conditions last for two months, and fall conditions for 10 months. This assessment yields an average annual value of 0.09 gpm per linear foot. For the West Area Collection System analysis, it was assumed that inflow to the collection system would occur at the same rate as estimated by the flownet analysis for groundwater from native materials into Railroad Creek.

An additional method of assessing potential collection system interception of groundwater was based on analysis of annual precipitation infiltration for the area upgradient of the tailings piles. Using precipitation (60.19 in) and potential evapotranspiration (17.86 in) values from the DRI (URS 1999), and the area likely to drain onto the tailings piles (272 acres for tailings piles 2 and 3 combined; 71 acres for tailings pile 1), influent water volumes to the tailings piles are calculated as1.33 CFS for tailings piles 2 and 3 combined, 0.35 CFS for tailings pile 1. Using the lengths of the southern end of the tailings piles (2,850 ft for tailings piles 2 and 3 combined; 1,050 feet for tailings pile 1), and converting to gpm per linear foot provides annual average values of 0.15 gpm per linear foot for tailings pile 1 and 0.21 gpm per linear foot for tailings pile 2 and 3 combined. For the West Area Collection System analysis, it was assumed that inflow to the collection system would be at the same rates as groundwater flow derived from the precipitation on areas upgradient of the tailings piles.

Five annual average inflow values were derived from the methods described, as summarized below:

Method	Average Annual Inflow (gpm/linear foot)
Darcy's Law, low hydraulic conductivity	0.12
Darcy's Law, high hydraulic conductivity	0.17
Flow-net analysis	0.09
Upgradient drainage, Tailings Pile 1	0.15
Upgradient drainage, Tailings Piles 2 & 3	0.21

The groundwater interception rate chosen for use in the collection and treatment volume estimates (0.15 gpm per linear foot) is the mean of the five values calculated from the methods described.

Groundwater interception rates for the spring flush and baseflow conditions were calculated from the estimated mean annual inflow rate by assuming that flow during spring conditions (2 months of year) is 1.75 times greater than flow during baseflow conditions (10 months of year) to arrive at the 0.23 gpm per linear foot (spring) and 0.13 gpm per linear foot (baseflow). The coefficient 1.75 is derived from the ratio of spring (0.14 gpm per linear foot) to fall (0.08 gpm per linear foot) groundwater flow rates from the revised flow net analysis. For purposes of the loading analysis, groundwater intercepted by the upper West Area collection system was assumed to have metals concentrations equal to the blended West Area seep concentrations presented in Section 6 (Table 6-4).

<u>Lower West Area Collection System SP-26 to P-5 (Alternative 6)</u>

For the portion of the lower West Area collection system extending from SP-26 to P-5 under Alternative 6, the volume of groundwater intercepted per linear foot of collection system was assumed to be approximately 0.23 gpm per linear foot (spring flush) and 0.13 gpm per linear foot (baseflow) along approximately 1600 feet of collection system (as described above for the upper West Area collection system). Groundwater intercepted by the lower barrier wall from SP-26 to P-5 was assumed to be collected with a collection efficiency of 80 percent. For purposes of the loading analysis, groundwater intercepted between P-5 and SP-26 was assumed to have metals concentrations equal to the average of concentrations measured in monitoring well HV-3 (natural background concentrations) from 1997 to 2001. Groundwater collected by the lower barrier wall was assumed to be conveyed to the East Area for treatment.

<u>Lower West Area Collection System – P-5 to RC-4 (Alternatives 5d, 6)</u>

Groundwater intercepted by the lower West Area collection system between P-5 and RC-4 (Alternatives 5d and 6) was estimated to be approximately 0.039 gpm per linear foot of collection system (spring) and 0.022 gpm per linear foot (baseflow) along 1600 feet of collection system. These estimates were based on the total average annual precipitation for the Site as presented in the DRI and assuming an upgradient area (between upper and lower collection systems) of approximately 790,000 square feet. The spring flush and baseline flowrates were then estimated based on the same seasonality assumptions described above for the upper West Area collection system. The lower groundwater collection system from P-5 to RC-4 was assumed to have a collection efficiency of 90 percent. For purposes of the loading analysis, groundwater intercepted between RC-4 and P-5 was assumed to have metals concentrations equal to the blended West Area seep concentrations presented in Section 6 (Table 6-4). Groundwater collected by the lower barrier wall was assumed to be conveyed to the East Area for treatment.

Under alternatives which include East Area collection and treatment, groundwater collection systems were assumed to intercept shallow groundwater in tailings and native materials characterized by the flownet analysis (Alternatives 4, 5, 6 and 8), deep groundwater that would be intercepted by barrier wall(s) completed to the dense till or bedrock (Alternatives 4a, 4c, 5a, 5c, 5d, and 6), and/or groundwater lost from the relocated Railroad Creek channel to the collection system(s) (Alternatives 4c, 5c, 5d, and 6). Groundwater collection volume assumptions for each alternative are summarized on the remedial alternative performance summaries in Appendix D1. Collected shallow groundwater volumes from the tailings and native materials were calculated based on the estimated collection efficiencies and the estimated discharge rates for each flowtube intercepted as presented in Attachment A-1 to Appendix A (Flownet Analysis). Collection estimates for the deep groundwater and groundwater losses from the relocated creek channel were calculated based on estimated groundwater flows and assumed collection efficiencies as follows:

East Area Deep Groundwater (Alternatives 4a, 4c, 5a, 5c, 5d, 6)

Estimates of the deep groundwater component intercepted by the East Area barrier walls were assumed to be unaffected by seasonality (i.e., estimated collection volumes would be the same for spring and fall conditions). Deep groundwater flow rates were based on Darcy's law and the range of measured hydraulic conductivities for native materials described in Section 2.6 (Baseline Loading Analysis). The estimated volume of deep groundwater intercepted was calculated assuming that the hydraulic conductivity is lognormally distributed and the high and low estimates for groundwater interception represent the upper and lower bounds of a 90% confidence interval on the average intercepted volume.

Deep Groundwater Intercepted by a Barrier Wall Downstream of TP-1 (Alternatives 4a, 5a):

- hydraulic gradient = 0.014 ft/ft
- hydraulic conductivity = 0.0001 ft/sec to 0.003 ft/sec
- cross sectional area = 18,000 ft^2
- intercepted groundwater = 0.02 cfs to 0.76 cfs (expected value = 0.2 cfs)

Deep Groundwater Intercepted by a Barrier Wall downstream of TP-3 (Alternatives 4a, 4c, 5a, 5c, 5d, 6):

- hydraulic gradient = 0.014 ft/ft
- hydraulic conductivity = 0.0001 ft/sec to 0.003 ft/sec
- cross sectional area = 29,000 ft^2
- intercepted groundwater = 0.04 cfs to 1.2 cfs (expected value = 0.4 cfs)

For purposes of the loading analysis, metals concentrations in the deep East Area groundwater were assumed to equal the average of concentrations measured in monitoring wells DS-3D and DS-4D.

Note that under alternatives which include extended East Area collection without Railroad Creek relocation (Alternatives 4b and 5b), the barrier wall extends to the south upstream of tailings pile 1, effectively cutting off the down-valley deep groundwater component. As a result, deep groundwater is not assumed to be collected under these alternatives in the East Area.

Groundwater Losses from the Relocated Railroad Creek Channel (Alternatives 4c, 5c, 5d, and 6)

Groundwater losses from the relocated Railroad Creek channel to the collection system under Alternatives 4c, 5c, 5d, and 6 were also estimated based on Darcy's law. The assumed hydraulic gradient was based on a difference in head between the relocated channel and collection system of approximately 3 feet in the spring and 1.75 feet in the fall, with the distance between the former and relocated channel equal to approximately 40 feet. Groundwater intercepted from the north side of the former channel was estimated based on the following assumptions:

- hydraulic gradient = 0.075 ft/ft (spring); 0.044 ft/ft (fall)
- hydraulic conductivity = 0.0001 ft/sec to 0.003 ft/sec
- cross sectional area = 40,000 ft^2
- intercepted groundwater (spring) = 0.3 cfs to 9 cfs (expected value = 2.8 cfs)
- intercepted groundwater (fall) = 0.175 cfs to 5.2 cfs (expected value = 1.6 cfs)

For the purposes of the loading analysis, post-remediation metals concentrations for groundwater losses from the relocated Railroad Creek channel were assumed to equal the calculated post-remediation concentrations at station RC-4.

Loading to Railroad Creek from Treatment Systems

When a treatment system is included, metal loading to Railroad Creek from the system's effluent was handled as a single "point" source. Loading to Railroad Creek as treatment system effluent was calculated analogously to other source areas, using the total collected flow and the treatment system effluent as the discharge and concentration:

$$L_{TP} = Q_{Influent} * C_{Effluent}$$

where:
L_{TP} = Load to Railroad Creek from treatment plant (effluent)
$Q_{Influent}$ = Influent flow to treatment plant
$C_{Effluent}$ = Effluent metals concentration

Recalling that the influent flow to the treatment plant is the sum of the collected seep or groundwater from each source area, loading to Railroad Creek from a treatment plant may be re-written as:

$$L_{TP} = \Sigma Q_C * C_{Effluent}$$

where:
ΣQ_C = Sum of collected seep or groundwater from each source area

Portal Discharge

For the alternatives that include placement of hydrostatic bulkheads in the 1500-level portals, the portal drainage flow was assumed to be controlled to eliminate the high peaks observed under current conditions in the spring. Therefore, the post-remediation flow (Q) from the portal was assumed to equal the high-flow condition (0.6 cfs) for the spring and low-flow condition (0.15 cfs) for the fall as presented on Table 6-2. To account for the expected water quality degradation resulting from flooding the mine under these alternatives, short-term metals concentrations in the portal discharge in the spring and fall were assumed to equal the "best estimate" concentrations for flooded mine water chemistry presented in Appendix E, Table 5 (SRK 2004). Long-term portal discharge metal concentrations were assumed to be equivalent to baseline conditions for the spring and fall as presented in Appendix A. Portal drainage water quality degradation is addressed further in the post-remediation uncertainty analysis discussion.

Unaccounted Load

Post-remediation unaccounted loading at stations RC-1, RC-2 and RC-4 was calculated using the loading reduction factors provided in Appendix D1 and D2 if the baseline unaccounted loading was a positive value. If the baseline unaccounted loading was calculated to be negative, the post-remediation loading analysis model assumes that under post-remediation conditions, the attenuation that may occur between two Railroad Creek monitoring stations (if observed under baseline conditions) would be proportional to the total estimated dissolved load from sources within that segment:

$$UL_{PR} = UL_B * (L_{PR} / L_B)$$

where:

UL_{PR} = Post-remediation unaccounted load at station RC-1, RC-2 or RC-4

UL_B = Baseline unaccounted load at station RC-1, RC-2 or RC-4

L_{PR} = Calculated cumulative post-remediation loading at station RC-1, RC-2 or RC-4

L_B = Calculated baseline loading at station RC-1, RC-2 or RC-4 (without unaccounted load)

For example, if the negative unaccounted loading for iron between RC-6 and RC-1 was calculated to be 10% of the total calculated iron load from sources between upstream of RC-1 for baseline conditions in the spring, the negative unaccounted load for iron was assumed to be 10% of the total estimated post-remediation load from sources upstream of RC-1 in the post-remediation loading analysis model.

The effect of this assumption is that as the estimated post-remediation load to a segment of Railroad Creek decreases, the magnitude of the dissolved metals attenuation within that segment was reduced proportionally from observed baseline conditions. The type of precipitation and oxidation reactions (e.g. oxidation of ferrous iron and precipitation of ferric iron compounds) that are currently occurring in Railroad Creek would be expected to continue in the future, thereby affecting some attenuation of dissolved metals in Railroad Creek. This assumption is reasonable, and was applied across the board to all of the remedial alternatives evaluated; therefore, it does not affect the relative comparison of alternatives

Treatment Plant Effluent Limitations (Long-term Analysis)

When downgradient collection and treatment is included with a remedial alternative, effluent metals concentrations in the treatment plant effluent were assumed to be constant over time. As metals loading from source areas decreases over the long-term, it is possible that the metals concentration in the blended effluent will decrease below the assumed effluent concentration from the treatment plant. The long-term loading analysis accounts for this by comparing the calculated metal loading to the treatment plant at a given time to the estimated metals loading in the treatment plant effluent assuming the fixed metals concentration in the effluent. If the calculated loading to the treatment plant was greater than the estimated loading in the effluent, the load to Railroad Creek from the treatment plant was assumed to equal the collected flow multiplied by the fixed effluent concentration. If the loading to the treatment plant decreases below the treatment plant effluent (assuming fixed effluent concentrations) the load to Railroad Creek was assumed to equal the calculated metals loading to the treatment plant.

Background Loading Limitations (Long-term Analysis)

The exponential decay model for waste rock-type sources and the underground mine both predict that metals concentrations in the sources will approach zero in the very long term. Realistically, metals concentrations are more likely to approach a background value representative of natural conditions (i.e. unaltered by mining activities) in the very long term. To compensate for this, the calculated long-term loading from each source at a given time was compared against the theoretical loading from that source assuming that the metals concentration equaled the background concentration. If the calculated loading at that time was greater than the theoretical background loading, the calculated loading at the given time was used in the loading analysis. If, however, the calculated loading at a given time was less than the theoretical background loading, the theoretical background loading was used instead of the calculated loading. Average groundwater metals concentrations at monitoring well HV-3 (from 1997 to 2001) were assumed to be representative of naturally occurring background concentrations.

Consolidated Tailings Pile Drain-down Estimates

The cap placed on the consolidated tailings pile (CTP) would minimize infiltration of surface water and incident precipitation. However, prior to cap installation, a portion of the tailings would likely be saturated (e.g., the lower portion of tailings pile 2) or partially saturated (tailings from piles 1 and 3 following consolidation onto tailings pile 2). After consolidation and capping, the CTP would continue to drain by gravity until the moisture content in the tailings reaches a steady state. During this period of drain down, residual metals within the pore water would also drain from the CTP and the net metals loading from the CTP would remain approximately equal to the calculated baseline loading.

Available field measurements collected from transducers placed within tailings pile piezometers indicate that drainage from the CTP could occur over a period of 3 to 12 years. This estimate is based on the assumption there would be little or no lateral groundwater flow or precipitation infiltration to the CTP and that the water-table drop in saturated tailings would be similar to that observed during the dry season for piezometers screened in the tailings piles. During drain down, seep and groundwater flow from the tailings are assumed to remain approximately equal to baseline flow until the saturated tailings have been drained. The post-remediation loading analysis assumes that groundwater discharge and metals loading for the short term (approximately 5 years) would equal baseline conditions. Groundwater discharge from the CTP for the long-term analysis (> 30 years) is assumed to equal approximately 6% of the baseline flow.

Post-remediation Metals Concentrations

The background loading in Railroad Creek (station RC-6) and the post-remediation load to Railroad Creek from each source area were summed to yield the cumulative post-remediation metals loading ($L_{PR\ Cumulative}$). The estimated post-remediation concentrations of dissolved metals in Railroad Creek at station RC-4 or downstream of RC-2 were then calculated by dividing $L_{PR\ Cumulative}$ by the baseline flow (Q_B):

$$C_{RRC,PR} = L_{PR\ Cumulative}/Q_B$$

where:

$C_{RRC,\ PR}$ = Post-remediation dissolved metal concentration in Railroad Creek at RC-4 or downstream of RC-2

Q_B = Railroad Creek discharge at station RC-4 or downstream of RC-2

7.2.1.4 Post Remediation Uncertainty Analysis

Overview

The uncertainty associated with post-remediation metals concentrations in Railroad Creek was evaluated differently for the short-term and long-term analyses. For the short-term analysis, uncertainty was evaluated by performing a probabilistic analysis of the post-remediation loading analysis. This approach quantifies the uncertainty associated with calculated post-remediation metals concentrations as a function of the uncertainty associated with each input parameter of the model. Uncertainty estimates for the long-term analyses were accomplished by performing a sensitivity analysis on the parameters associated with the long-term model. The following subsections describe each approach in detail.

Short-term Post-remediation Uncertainty Analysis

Uncertainty associated with the short-term post-remediation water quality calculations was assessed by performing a probabilistic uncertainty analysis on the loading calculations described above and presented in Appendices D1 and D3. Uncertainty calculations for the short-term post-remediation loading analyses are included in Appendix D3 and summarized on Table 7-5.

The background theory and mathematical calculations used for the short-term post-remediation uncertainty analysis are as described for the baseline loading uncertainty analysis presented in Appendix A and described in Section 2.6. The uncertainties associated with each loading reduction factor were estimated for each source area under each alternative are summarized in

Tables D1-1 through D1-14. These levels of uncertainty (which are equal to the coefficients of variation) were then used to calculate the variance of the loading from each source. The individual variances were summed to yield the variance of the estimated post remediation cumulative loading. The coefficient of variation for the post-remediation cumulative loading was then back-calculated from the variance.

The coefficients of variation for the post-remediation metals concentrations in Railroad Creek were calculated based on the coefficients of variation for cumulative metals loading and the measured flow in Railroad Creek at station RC-4 and downstream of RC-2. The coefficient of variation for post-remediation metals concentrations is representative of the estimated uncertainty associated with the calculated post-remediation water quality value. A more detailed discussion of the background theory and relevant equations is presented in the uncertainty analysis discussion in Section 2.6.

As described for the baseline uncertainty analysis, it was assumed that flow values, concentration values and loading reduction factors are independent variables (i.e. the correlation coefficient between flow, concentration and loading reduction factor equals zero). This assumption was made based on the limited amount of data available for the Site, specifically the lack of flow and concentration data for each source over time. As such, this analysis is a first approximation of the uncertainty associated with the calculated post-remediation metals concentrations in Railroad Creek.

Coefficients of Variation

Estimated values for coefficients of variation for loading reductions due to upgradient controls (CV[UG]), downgradient collection efficiencies (CV[CE]) and treatment system effluent concentrations (CV[C_{Eff}]) are presented on the tables in Appendix D1. These values were typically estimated based on the current understanding of Site conditions, engineering judgment, and the geochemical analyses (Appendix E). When a large degree of uncertainty was expected for loading reductions due to upgradient controls for a source area, a coefficient of variation was selected to equal 1.

For remedial alternatives that include hydrostatic bulkheads, the uncertainty associated with short-term water quality degradation for the portal discharge as a result of the installation of hydrostatic bulkheads and mine flooding was estimated probabilistically. Under these alternatives, the anticipated range of metals concentrations in the discharge from the bulkhead was evaluated using a Bayesian approach to estimate a coefficient of variation that describes the possible range in metals concentrations. The estimated upper bounds were based on the worst-case scenario values for water quality degradation (Appendix E). Coefficients of variation for long-term portal drainage water quality were assumed to be equivalent to the short term. For cadmium, copper and zinc, the coefficient of variation for metals concentrations in the portal drainage (CV[C_{Portal}]) was iterated with the expected metals concentration (E[C_{Portal}]) until the upper bound of the 90% confidence interval matched the estimated upper bound for portal drainage water quality (UB[C_{Portal}]). For iron, a probability distribution with an expected concentration equal to the spring baseline (0.24 mg/L) and a practical upper bound equal to the worst-case water quality estimate (14 mg/L) was not calculable. The CV[C_{Portal}] for iron was therefore calculated based on an assumed upper bound equal to the worst-case concentration (14 mg/L) and a practical lower bound equal to the spring baseline portal drainage concentration (0.24 mg/L). The estimated upper bounds, expected values and coefficients of variations for short-term metals concentrations in the portal drainage are provided below.

- Cd $E[C_{Portal, Cd}]=0.1$ mg/L, $UB[C_{Portal, Cd}]=0.2$ mg/L, $CV[C_{Portal, Cd}]=0.5$
- Cu $E[C_{Portal, Cu}]=12$ mg/L, $UB[C_{Portal, Cu}]=20$ mg/L, $CV[C_{Portal, Cu}]=0.36$
- Fe $LB[C_{Portal, Fe}]=0.24$ mg/L, $UB[C_{Portal, Fe}]=14$ mg/L, $CV[C_{Portal, Fe}]=1.9$
- Zn $E[C_{Portal, Zn}]=21$ mg/L, $UB[C_{Portal, Zn}]=33$ mg/L, $CV[C_{Portal, Zn}]=0.31$

Calculation Detail (Short-term Uncertainty Analysis)

As described above, the post-remediation loads to Railroad Creek were calculated by multiplying the baseline flow and concentration by one minus the concentration reduction factor:

$$L_{PR} = Q_B*(1-CE)*C_B*(1-UG)$$

where:
L_{PR} = Estimated post-remediation loading
Q_B = Baseline flow
C_B = Baseline concentration
UG = Loading reduction factor due to upgradient controls
CE = Downgradient collection efficiency

As in the baseline loading uncertainty analysis, the values presented in the post-remediation loading calculations (Appendix D3) were assumed to be the expected values for L_{PR}, Q_B, C_B, UG and CE. The equation for post-remediation loading may then be re-written as:

$$E[L_{PR}] = E[Q_B]*E[(1-CE)]*E[C_B]*E[(1-UG)]$$

The coefficient of variation for the post-remediation loading is expressed as:

$$CV[L_{PR}] = \{(CV[Q_B]^2+1)*(CV[(1-CE)]^2+1)*(CV[C_B]^2+1)*(CV[(1-UG)]^2+1)-1\}^{1/2}$$

The coefficients of variation for the baseline flow and concentration are equal to those discussed in the baseline loading uncertainty analysis (Appendices A-5 and A-6), except for the portal drainage under remedial alternatives which include hydrostatic bulkheads as discussed above. The coefficient of variation for the terms (1-CE) and (1-UG) are not equal to the coefficients of variation of CE and UG, so CV[(1-CE)] and CV[(1-UG)] are rewritten as follows:

$$CV[(1-CE)] = \{CV[(CE)]*E[CE]\}/(1-E[CE])$$

and

$$CV[(1-UG)] = \{CV[(UG)]*E[UG]\}/(1-E[UG]$$

After calculating $CV[L_{PR}]$ for each source, the variance for the loading from each source area ($V[L_{PR}]$) was calculated as the square of the product of the expected value and the coefficient of variation.

$$V[L_{PR}] = (CV[L_{PR}]*E[L_{PR}])^2$$

The variance of the loading from the background and each source were summed to yield the variance for the cumulative post-remediation loading, $V[L_{PR\ Cumulative}]$. The coefficient of variation for the calculated post-remediation cumulative loading was then calculated from $V[L_{PR\ Cumulative}]$ and the expected value of the of the post-remediation cumulative loading, $E[L_{PR\ Cumulative}]$:

$$CV[L_{PR\ Cumulative}] = V[L_{PR\ Cumulative}]^{1/2} / E[L_{PR\ Cumulative}]$$

Finally, the coefficient of variation for the post-remediation dissolved metal concentration in Railroad Creek may be calculated from $CV[Q_B]$ and $CV[L_{PR\ Cumulative}]$ with the equation:

$$CV[C_{RR,\ PR}] = \{(CV[Q_B]^2+1)*(CV[L_{PR\ Cumulative}]^2+1)-1\}^{1/2}$$

The estimated values and associated uncertainties of loading reductions due to upgradient controls, collection efficiencies and treatment efficiencies were incorporated into a post remediation model that includes both an expected result ($E[C_{RR,\ PR}]$) and an expression of the uncertainty associated with the expected value ($CV[C_{RR,\ PR}]$). Results of the short-term probabilistic uncertainty analysis are presented in Table 7-5.

Long-term Post-remediation Uncertainty Analysis

The long-term post-remediation uncertainty analysis was accomplished by performing a sensitivity analysis on the input parameters of the long term model. These parameters include the loading ratios as a function of time for waste rock sources, the underground mine, and the tailings piles. Each loading ratio for the long-term analysis has a degree of uncertainty associated with it. For the loading ratios that were modeled as exponential decays (waste rock sources and the underground mine) the largest degree of uncertainty is associated with the decay constant (k). Uncertainty associated with long-term trends in loading from the tailings piles is primarily associated with the unknown depth to native materials beneath each of the tailings piles, as discussed in Appendix E.

The sensitivity analysis was performed by evaluating the effects of using “better-case” and “worse-case” inputs for these parameters on the post-remediation concentrations of metals in Railroad Creek. The results for these different scenarios illustrate the upper bounds and lower bounds bracketing the expected post-remediation metals concentrations. The sensitivity analysis presented in Appendix D6 graphically illustrates the effects of variability in the input parameters as follows:

Confidence Interval for Expected Post-Remediation Concentrations (Upper and Lower CI E[X])

Estimated variability in concentrations due to remedial performance criteria was evaluated based on the calculated uncertainty (expressed as the coefficient of variation) for the short-term, post-remediation metal concentrations in Railroad Creek downstream of RC-2. Upper and lower bounds of post-remediation metal concentrations over the long term were estimated by applying ratios calculated by dividing the upper and lower bounds of the 90 percent confidence interval for the short-term post-remediation metal concentration (presented on Table 7-5) by the expected value for the short-term post-remediation metal concentrations. These ratios were applied over time to the long-term post-remediation metal concentrations calculated in Appendix D5.

West Area Decay Geochemical Constant

Effects of the decay constant (k) for West Area sources (i.e. waste rock and underground mine) were evaluated by individually varying the assumed decay constant to –0.001 weeks^{-1} to –0.00001 weeks^{-1}. Effects are illustrated for both the underground mine and waste rock-type sources.

Tailings Loading Ratios

Variability of the long-term loading from the tailings piles was estimated based on the output of the geochemical modeling described in Appendix E. The sensitivity of the long-term loading analysis output to the loading from the tailing piles was evaluated by varying the assumed location of current conditions along the timescale provided in Figures 14, 15, and 17 in Appendix E, and adjusting the load ratios accordingly. Load ratios were re-calculated by shifting the assumed location of current conditions forward 25 years and back 15 years along the timescale.

Summary

The figures presented in Appendix D6 illustrate the relative sensitivity of the analysis to varying input parameters for the long-term post-remediation calculations. These sensitivity analyses do not quantify the uncertainty associated with estimated post-remediation metals concentrations nor do they evaluate potential results for compounding the variabilities associated with the individual input parameters.

As it is unlikely that all of the input parameters are under-estimated, or that all are over-estimated, the ranges of concentrations presented on the sensitivity analyses may be considered approximations of the concentration ranges which would be estimated by a probability-based uncertainty analysis that combines uncertainty from each input to the loading analysis model into a single uncertainty estimate. The long-term post-remediation sensitivity analyses indicate that the variability associated with long-term post-remediation metals concentrations would be similar to the uncertainty associated with the short-term post-remediation calculations. The scenarios modeled for the sensitivity analyses result in relative post-remediation concentration ranges that are comparable to the relative lower and upper bounds calculated for the short-term post-remediation concentrations.

The sensitivity analysis graphs illustrate that the long-term post-remediation concentrations of metals in Railroad Creek are not overly dependent on any single input parameter. The following general conclusions may be drawn for the sensitivities of long-term post-remediation PCOC concentrations in Railroad Creek:

- Cadmium – Long-term post-remediation cadmium concentrations are primarily affected by the underground mine decay constant (alternatives without West Area treatment) and the waste decay constant (alternatives with West Area Treatment).

- Copper – Depending on the alternative, long-term post-remediation copper concentrations are most sensitive to either the waste rock decay constant or the calculated short term post-remediation uncertainty.

- Iron – Long-term post-remediation iron concentrations are most sensitive to the calculated short term post-remediation uncertainty.

- Zinc – Long-term post-remediation zinc concentrations are most sensitive to the underground mine decay constant (for alternatives without West Area treatment) and the calculated short term post-remediation uncertainty.

7.2.1.5 Post-remediation Water Quality Results

The results of the estimated short-term and long-term post-remediation water quality calculations for Railroad Creek are summarized on Tables 7-1 through 7-5. The estimated short-term post remediation concentrations of dissolved cadmium, copper, iron, and zinc are summarized in Table 7-1 for each alternative for the spring (high-flow) and fall (low-flow) seasons. Short-term post-remediation concentrations were estimated for Railroad Creek stations RC-4 (downstream of West Area sources) and downstream of station RC-2 (immediately downstream of East Area sources). Table 7-5 includes the expected short-term post-remediation metals concentrations as well as the uncertainty (coefficient of variation) associated with the estimated value and the practical upper and lower concentrations of a 90-percent confidence interval. As shown on Table 7-1, short-term concentrations are generally expected to be higher during the spring flush period for cadmium, copper, and zinc, and higher during low-flow periods for iron. The estimated short-term post-remediation concentrations of cadmium, copper, and zinc for spring conditions, and iron for fall conditions, are compared with 90-percent confidence intervals on Figures 7-1 through 7-4.

The estimated long-term post-remediation concentrations in Railroad Creek downstream of RC-2 are summarized for approximately 50 years, 150 years, and 250 years from remedy implementation on Tables 7-2, 7-3, and 7-4, respectively. Figures 7-5 through 7-12 provide the predicted long-term concentrations of cadmium, copper, iron, and zinc downstream of RC-2 for both spring and fall conditions through the year 2300.

Tables 7-1 through 7-5 report model outputs for RC-4 and RC-2 monitoring stations for some parameters to 2 to 3 significant figures and tenths to one hundredths of parts per billion for comparison to potential ARARs which are also calculated to more than one significant figure and are often extremely low. Caution should be used when comparing small differences in predicted concentrations between alternatives. Judging differences of small relative percentages or beyond one significant figure is beyond the capability of the model to predict actual future concentrations and differences between alternatives. Also, see discussions of uncertainty in Section 7.2.1.4 and the representativeness of the loading analysis to other years and hydraulic conditions in Section 2.6.6.

7.2.2 Evaluation of Expected Post Remediation Total Aluminum Concentrations in Railroad Creek

Due to the limited data available for total aluminum in Site seeps and groundwater, the evaluation of total aluminum loading to Railroad Creek was not possible for either the baseline or the post-remediation loading analysis model. The post-remediation analysis was not completed for dissolved aluminum due to the large number of non-detects measured in Railroad Creek during the spring and fall of 1997.

Total aluminum concentrations measured in Railroad Creek adjacent to the Site in 1997 were above the NRWQC of 87 ug/L. Concentrations ranged from 90 ug/L (RC-6 and RC-1) to 230 ug/L (RC-2) in the spring, and from 50 ug/L (RC-4) to 90 ug/L (RC-2) in the fall (Tables 7-6). The following subsections provide a summary of aluminum concentrations, loadings, and an evaluation of expected reductions in aluminum loading to Railroad Creek over the long term.

7.2.2.1 Relationships between Total and Dissolved Aluminum – Baseline Conditions

Aluminum loading in Railroad Creek adjacent to the Site consists of a dissolved fraction, likely complexed in solution with hydroxides, and an undissolved fraction associated with hydroxide floc and suspended silt and clay minerals in the water column. Total and dissolved aluminum concentrations measured in Railroad Creek are summarized in Section 2, Tables 2-2 through 2-4. For most sampling events, measured total aluminum concentrations in Railroad Creek are considerably greater than the dissolved concentrations measured at each monitoring station. Dissolved aluminum concentrations in Railroad Creek adjacent to the Site are typically either not detected or detected at concentrations less than 100 ug/L, whereas total aluminum has been typically detected at concentrations ranging from 40 ug/L to 250 ug/L adjacent to the Site.

The low concentrations of dissolved aluminum measured in Railroad Creek are consistent with the documented instability of dissolved aluminum in water with a pH above 4 to 5. At the typical pH range between 5.5 and 8 observed in Railroad Creek adjacent to the Site, dissolved aluminum that enters Railroad Creek within groundwater and seeps is expected to largely precipitate once it reaches the creek. Precipitated aluminum is expected to occur primarily as colloidal aluminum, therefore the reported dissolved aluminum concentrations likely includes a component of colloidal aluminum hydroxides which can pass through a 0.45 um filter.

7.2.2.2 Aluminum Loading Sources (East Area)

Dissolved aluminum was evaluated in the baseline loading analysis described in Section 2.6 and Appendix A. As indicated previously, a quantitative baseline loading analysis for total aluminum was not performed due to the lack of available total aluminum baseline concentrations for seeps and groundwater. However, a first order approximation of baseline total aluminum loading is possible for Railroad Creek on a reach-by-reach basis through an evaluation of a mass balance of total aluminum loading in Railroad Creek calculated with the measured total aluminum concentrations and discharge measurements for Railroad Creek stations upstream and adjacent to the Site.

Total aluminum concentrations and loadings in Railroad Creek for the baseline (1997) dataset are summarized in Table 7-6. Measured total aluminum concentrations remain relatively constant between station RC-6 and RC-4, and increase by more than double between RC-4 and RC-2. For both the spring and the fall, total aluminum loading between stations RC-4 and RC-2 (i.e., groundwater and seep flow from the tailings) appears to account for a majority of the net increase in the total aluminum concentrations measured in Railroad Creek adjacent to the Site.

The analysis described above for total aluminum is consistent with the findings of the baseline loading analysis for dissolved aluminum. During the high-flow period in the spring, the net dissolved aluminum loading from East Area sources (i.e., the tailings piles) was approximately twice that measured from West Area sources (i.e., SP-26, SP-23, SP-12, the portal drainage, and West Area seeps and groundwater downstream of P-5). During the fall, measured aluminum loads from West Area sources were negligible, and the loading from East Area sources, although significantly lower than loading measured in the spring, remained at approximately 15 to 20 kg/day.

7.2.2.3 Predicted Long-term trends in Aluminum Loading from Source Areas

As described in Section 7.2.2 for cadmium, copper, iron, and zinc, aluminum loading to Railroad Creek from Site source areas is expected to decline over time due to source depletion and geochemical effects. The long-term geochemical trends for aluminum are expected to be consistent with the other four PCOCs. Aluminum loading from waste rock and the underground mine would be expected to follow an exponential decay with a decay constant of approximately -0.0001 weeks^{-1} as presented in the long-term geochemical analysis provided in Appendix E (SRK 2004). A decay constant of -0.0001 weeks^{-1} corresponds to an expected reduction in aluminum loading of 50% over the next 50 to 75 years from West Area sources.

Aluminum loading from the tailings would be expected to change over time as a function of the progression of the oxidation and acid fronts through the tailings piles. Long-term trends in dissolved aluminum loading from the tailings piles are discussed in Appendix E. While the geochemical analysis addresses dissolved aluminum only, the trends described for dissolved aluminum may be considered representative of total aluminum loading to Railroad Creek from the tailings piles. The fine-grained matrix of the tailings would be expected to inhibit the transport of particulate aluminum by acting as a filter medium. The dissolved aluminum loading trends predicted for groundwater and seeps from the tailings piles may therefore be considered to represent the total aluminum loading from the tailings piles.

Results of the geochemical modeling presented in Appendix E indicate that aluminum loading from the tailings piles in their current configuration is predicted to decrease to below 85 percent of the current loading over 50 years, and 60 percent of the current loading within the next 200 years. Despite intermittent incremental increases in aluminum due to breakthrough of the acid fronts in the various piles, aluminum loading over the very long term is expected to remain below 60 percent and eventually decrease to less than 40 percent of the current loading for the tailings piles. Therefore, aluminum loading to Railroad Creek is expected to continue to decline over the long-term.

7.2.2.4 Evaluation of Long-term Aluminum Loading in Railroad Creek

Total aluminum concentrations measured at station RC-4 are below background concentrations or the NRWQC (87 ug/L) during the low-flow periods. Aluminum concentrations at RC-4 are generally equal to, or only slightly above the NRWQC or background during the high-flow period in the spring. Based on the long-term loading assumptions described above, aluminum loading to Railroad Creek from West Area sources would be expected to decline over time through natural geochemical processes. A decay constant of 0.0001 $weeks^{-1}$, estimated for waste rock and the underground mine, corresponds to an expected reduction in aluminum loading of 50 percent over the next 50 to 75 years from West Area sources.

Additionally, for Alternatives 3, 5, 6, 7, and 8, it is assumed that the primary sources of aluminum in the West Area (i.e., seeps SP-12, SP-23 and portal drainage) would be collected at a collection efficiency of approximately 90 to 97 percent and treated prior to discharge. As a result, aluminum loading to Railroad Creek from the West Area is expected to be significantly reduced following remedy implementation, with additional reductions due to natural geochemical processes in the long-term.

As discussed above, a majority of the aluminum loading to Railroad Creek is from East Area sources. Long-term trends for aluminum loading in Railroad Creek in the vicinity of RC-2 would therefore depend primarily on reductions in aluminum loading from the tailings piles. Potential reductions of total aluminum concentrations in Railroad over time were estimated based on the measured total aluminum loadings at stations RC-4 and RC-2 presented on Table 7-6. These estimates conservatively assume that the loading from background and West Area sources remain relatively constant over time.

For spring baseline conditions, the total aluminum load measured at stations RC-4 and RC-2 are approximately 122 kg/day and 298 kg/day, respectively, indicating that the East Area of the site contributes approximately 176 kg/day of aluminum loading to Railroad Creek (Table 7-6). During fall baseline conditions, the total aluminum load at stations RC-4 and RC-2 are 15 kg/day and 30 kg/day, respectively, indicating a contribution of 15 kg/day aluminum to Railroad Creek from the East Area.

Based on the predicted reductions in aluminum loading from the tailings piles described above, aluminum loading to Railroad Creek from the East Area would be expected to decrease to 85 percent of current loadings over 50 years, and 60 percent of current conditions over the next 200 years. Loadings are expected to continue to decline to less than 40 percent over the very long term.

Additionally, alternatives that include East Area collection and treatment would be anticipated to further reduce aluminum loading to Railroad Creek by collecting East Area groundwater and seeps with efficiencies ranging from 80 percent to 95 percent.

7.2.3 Evaluation of Potential Storm-water Runoff Quality during Tailings Pile Regrading

During implementation of remedial alternatives which include regrading of tailings slope surfaces or consolidation of tailings piles, it is likely that "fresh" unoxidized tailings will be exposed prior to placement of a permanent cover over their surface. As such, any precipitation which occurs before the regraded surfaces are covered will result in the interaction of the precipitation with the unoxidized tailings. Runoff from regraded surfaces therefore may contain elevated concentrations of metals that are mobilized from the regraded surfaces of the tailings piles. It was assumed that surface runoff from the tailings during construction would be managed using best management practices to minimize potential increases in loading to Railroad Creek.

Potential short-term metals loading from regraded tailings surfaces was estimated by calculating the peak surface water discharges from exposed tailing pile surfaces during a typical storm event and evaluating estimated metals concentrations in runoff as a function of exposure time. The following subsections describe the assumptions and results for this evaluation.

7.2.3.1 Estimated Peak Surface Water Discharges from Exposed Tailing Pile Surfaces

Peak surface water discharges (runoff flows) from regraded tailings surfaces were calculated using the Natural Resources Conservation Service (NRCS) runoff curve number method and graphical peak discharge method as presented in Technical Release TR-55 Urban Hydrology for Small Watersheds (USDA 1986). TR-55 presents simplified procedures for the calculation of storm runoff volumes and peak discharges as applicable to small watersheds. Peak discharges were estimated as a function of precipitation, soil type and roughness, and site topography. The key assumptions used for peak discharge modeling include:

- A one-inch 24-hour storm event,
- An NRCS curve number of 86 for the tailings side slopes (newly graded area/soil type A);
- Sheet flow and Mannings roughness coefficient of 0.06 for storm-water flow over regraded tailings; and
- A final regraded slope of 2:1 (0.5 ft/ft).

The heights, lengths, and surface areas of regraded tailings surfaces under each alternative were calculated based on the conceptual site figures and cross sections presented in Section 6. A summary of the assumed dimensions and representative cross sections is presented on Table 7-7. Peak discharges from regraded surfaces were evaluated for five regarding scenarios, as discussed below:

1. *Regrading tailings piles 1 and 2 (Alternatives 2 & 3).* The lateral extent of regraded surfaces along tailings piles 1 and 2 was estimated based on Figure 6-8, in Section 6. The slope and height of the regraded surfaces was estimated based on cross sections Figure 7-

13 (TP-1) and Figure 7-14 (TP-2), assuming a 2:1 slope and no bench at the base of the piles.

2. *Regrading tailings piles 1, 2 and 3 with partial collection (Alternatives 4a & 5a).* The lateral extent of regraded surfaces was estimated based on Figure 6-15, in Section 6. The slopes and heights for regraded surfaces along tailings pile 2 and the section of tailings pile 1 which does not include a constructed collection system were estimated based on cross sections provided in Figure 7-13 (TP-1) and Figure 7-14 (TP-2) assuming a 2:1 slope with no bench at the base of the piles. For the portions of tailings piles 1 and 3 that include a constructed collection system, regraded surface slopes and heights were estimated based on Figures 6-17 and 6-18, in Section 6.

3. *Regrading tailings piles 1, 2 and 3 with extended collection (Alternatives 4b & 5b).* The lateral extent of regraded surfaces was estimated based on Figure 6-24, in Section 6. Slopes and heights for regraded surfaces along tailings piles 1, 2, and 3 were estimated based on Figures 6-25, 6-26, and 6-27, in Section 6.

4. *Regrading tailings pile 2 with Railroad Creek relocation (Alternatives 4c, 5c, 5d, 6a, & 6b).* Under this scenario, only tailings pile 2 would be regraded. The lateral area of regraded surface was estimated based on Figure 6-28, in Section 6. The slope and height of the regraded surface was estimated based on the cross section provided on Figure 7-14 (TP-2) assuming a 2:1 slope with no bench at the base of the pile.

5. *Consolidated Pile (Alternatives 7 & 8).* Consolidation of tailings pile 1 and 3 onto the footprint of tailings pile 2 could result in potentially large areas of regraded tailings exposed to precipitation. As the specific process for consolidation has not been determined, the following conservative assumptions were used to estimate the surface area of regraded tailings exposed during consolidation activities prior to capping: 1) 10 percent of the sloped surfaces of tailings pile 1 and 3 adjacent to Railroad Creek would be exposed at any given time, and 2) the entire sloped surface of the consolidated tailings pile would be exposed throughout the consolidation process. The lateral surface area for the consolidated tailings pile was estimated based on Figures 6-36 and 6-40, in Section 6. The sloped surface lengths of tailings pile 1 and tailings pile 3 were estimated based on Section 6 Figures 6-25 and 6-27. The slope and height of the consolidated tailings pile was estimated based on Figure 6-37, in Section 6. The surface water runoff from all regraded areas was assumed to enter Railroad Creek with the exception of runoff from the east side of the consolidated pile.

The assumptions described above were used with the TR-55 modeling to predict peak discharges from regraded tailings surfaces for each of the 5 scenarios. The results of the modeling ranged from 36 liters per second (L/sec) for regrading tailings pile 2 with relocation of Railroad Creek to 152 L/sec for the consolidated tailings pile. Results of the modeling are presented on Table 7-7. These results represent very conservative estimates of peak discharges as they do not account for any best management practices for storm water controls during construction and the entire regraded surfaces are assumed to be exposed at the same time.

7.2.3.2 Estimated Storm-water Runoff Water Quality and Metals Loading

Short-term water quality for surface water runoff from regraded tailings material was evaluated by SRK and is discussed in Appendix E (SRK 2004). Water quality was evaluated based on results from humidity cell testing and through geochemical modeling. Potential metals concentrations in runoff water were evaluated for regraded, unoxidized tailings after atmospheric exposures of one, two, three, and four months, as well as for after 6 months of being covered with snow. These approaches facilitate the evaluation of potential runoff water quality over an assumed 4-month working season (June through September) as well as for spring conditions during snowmelt.

For the evaluation of potential metals loading in storm-water runoff, the estimated metals concentrations for the worst-case scenario (4-month exposure) were assumed for the peak discharges, which could potentially enter Railroad Creek. While it is unlikely that the entire regraded surfaces of the tailings pile would remain exposed for four months, these concentrations were chosen to keep with the conservative nature of this analysis.

Metals loading to Railroad Creek from the regraded surfaces of the tailings piles was calculated by multiplying the peak discharge (L/sec) by the estimated metals concentrations in runoff after four months exposure. The calculated potential worst-case storm-water metals loadings from regraded tailings surfaces for each alternative are summarized on Table 7-8. For comparison purposes, the estimated short-term post-remediation metals loading in Railroad Creek downstream of RC-2 is also included for each alternative. The potential metals loading from regraded tailings surfaces presented on Table 7-8 represent conservative, worst-case estimates. The actual metals loading expected to potentially enter Railroad Creek from regraded tailings surfaces would be minimized through the use of best management practices developed during the design phase of remedy implementation.

7.3 ALTERNATIVE 1 - NO ACTION/INSTITUTIONAL CONTROLS

Alternative 1 consists of limited mine actions and the installation of physical access restrictions. Consideration of this alternative is required by the NCP, and is intended to represent a baseline alternative for comparison with all other alternatives.

7.3.1 Threshold Criteria

Evaluation of the two threshold criteria, including overall protection of human health and the environment and compliance with ARARs, is provided in the following subsections for Alternative 1 (No Action/Institutional Controls).

7.3.1.1 Overall Protection of Human Health and the Environment

Protection of Human Health and Terrestrial Ecological Receptors

The human health risk assessment found no existing unacceptable risk to Holden Village residents or visitors based on current reasonable maximum exposures to PCOCs within soil, surface water, groundwater, sediments, and air at the Site. The institutional controls and physical access controls prescribed under this alternative and described in Section 6 would be expected to eliminate potential future risks to human health resulting from possible land use scenarios, such as use of groundwater as a drinking water source. These controls are also expected to reduce potential physical hazards to residents and visitors associated with site features resulting from historical mining activities.

Soils with concentrations above risk-based levels presented in Section 3 for plants, earthworms, and robins would remain in the Holden Village, lagoon area, maintenance yard, and mill building under this alternative.

The RAO to implement the remedial action in a manner that is protective of human health, including the Holden Village community, during and after construction would be met under this alternative. However, the soil RAO to achieve soil quality that is protective of human health and the environment, and the RAO to implement the remedial action in a manner that is protective of the environment during and after construction would not be achieved in some areas of the Site.

Protection of Aquatic Life

Potential risks to aquatic life in Railroad Creek, including trout and macroinvertebrates, would not be addressed under Alternative 1. Although PCOC loading to Railroad Creek from Site sources, including waste rock, the underground mine, and tailings piles, is predicted to decline in the long-term, long-term seasonal exceedances of the SWQC and/or the NRWQC are expected for site PCOCs under this alternative. Based on the toxicological evaluations provided in Appendix H (Hansen 2004), these exceedances may result in a potential risk to resident aquatic species in Railroad Creek adjacent to the site.

The limited mine actions conducted under this alternative, including maintaining the 1500-level main portal and removing debris and precipitates from the 1500 level, are expected to reduce the potential for increased risks to aquatic life from uncontrolled surges of portal drainage flow in the event of a collapse within the mine.

The RAOs for groundwater and surface water quality to meet State standards within a reasonable restoration timeframe would not be achieved under Alternative 1.

Potential for Short-term Impacts

Short-term risks to the environment resulting from the release of hazardous substances from the Site are expected to remain unchanged under Alternative 1. No additional short-term risks would be created for the local community or environment as a result of this alternative.

7.3.1.2 Compliance with ARARs

Compliance with ARARs includes the evaluation of potential chemical-specific, location-specific, and action-specific ARARs identified in Section 3.

Potential Chemical-specific ARARs

The potential chemical-specific ARARs for the Site include potential requirements for surface water quality, groundwater quality and soil.

Although PCOC releases from Site sources are predicted to gradually decline through natural attenuation, long-term exceedances of potential chemical-specific ARARs for surface water, groundwater, and soils are expected under Alternative 1. The MCLs and MCLGs in Site surface water would continue to be met. However, other potential chemical-specific ARARs that specify numerical values for groundwater, surface water, soil, and portal drainage would not be met.

Potential Location-specific ARARs

No location-specific ARARs would apply under Alternative 1.

Potential Action-specific ARARs

The institutional controls, physical access restrictions, and long-term monitoring included under Alternative 1 would meet the potential action-specific requirements for establishing and maintaining institutional controls under CERCLA and MTCA. Debris and metal precipitates removed from the mine, previously determined to be non-hazardous, would be consolidated on one of the tailings piles. Other miscellaneous debris may be managed off site in compliance with solid waste regulations.

7.3.2 Primary Balancing Criteria

Evaluation of the five primary balancing criteria, including long-term effectiveness and permanence; reduction of toxicity, mobility, and volume; short-term effectiveness; implementability; and cost is provided in the following subsections for Alternative 1 (No Action/Institutional Controls).

7.3.2.1 Long-term Effectiveness and Permanence

The human health risk assessment found no existing unacceptable risk to human health at the Site based on current reasonable maximum exposures to PCOCs. Metals concentrations above state and federal MCLs are likely to remain in groundwater beneath the Site under this alternative. However, potential future risks associated with the use of groundwater as a drinking water source would be effectively eliminated through the implementation of land use restrictions (institutional controls). Alternative 1 would also reduce potential physical risks to human health through implementation of limited mine actions and physical access controls.

Potential long-term risks to aquatic life in Railroad Creek, including trout and macroinvertebrates, would not be addressed under this alternative. Although PCOC loading to Railroad Creek from Site sources, including waste rock, the underground mine, and tailings piles, is predicted to decline in the very long-term, PCOC concentrations more than an order of magnitude above the SWQC and/or the NRWQC are expected in the long-term.

Potential risks to terrestrial ecological receptors, including plants, soil invertebrates, and wildlife would remain in isolated locations in the mill building, maintenance yard, lagoon, and the Holden Village soils under this alternative.

7.3.2.2 Reduction of Toxicity, Mobility, and Volume

Over time, the mass, and therefore volume, of PCOCs released to groundwater and surface water from Site source areas would be reduced through the natural geochemical processes described in Appendix E.

7.3.2.3 Short Term Effectiveness

Short-term risks to the environment resulting from the release of hazardous substances from the Site are expected to remain unchanged under Alternative 1. No additional short-term risks would be created for the local community or environment as a result of this alternative.

The limited mine actions and physical access restrictions included under this alternative would involve performing construction work underground in the abandoned mine workings on the 300, 1100, and 1500 levels. While appropriate health and safety precautions would be implemented, these actions would present potential physical risks to workers in the event of a collapse or rock fall. The limited mine actions and physical access restrictions would likely be completed in one field season.

7.3.2.4 Implementability

The actions included under this alternative, including limited mine actions and physical access restrictions would be technically implementable. Completion of the limited mine actions, including removal of debris and precipitates from the 1500 level and maintenance of the 1500-level main portal would require specialized equipment and personnel trained to work underground. This type of specialized equipment and personnel would not be as readily available as standard construction equipment and crews.

Because no actions would be performed to reduce the release of PCOCs from the Site, this alternative would likely have lower administrative implementability.

7.3.2.5 Cost

The total estimated costs associated with Alternative 1 are approximately $2,730,000 (2004 dollars at a 7-percent discount rate). Table 7-9 provides a summary of capital and O&M costs for each of the eight candidate alternatives, and cost detail sheets are provided in Appendix I.

Capital costs associated with implementation of limited mine actions and the installation of physical access restrictions are estimated at approximately $580,000. Annual O&M costs associated with environmental and slope stability monitoring, and maintaining the 1500-level main portal are estimated to be approximately $100,000.

7.3.3 Natural Resource Restoration

Actions included under this alternative would not provide natural resource restoration on site in the short term. Over the long term, seepage and groundwater quality from the underground mine, waste rock, and tailings piles would be expected to gradually improve, thereby resulting in gradual improvements to aquatic habitat in Railroad Creek.

7.3.4 Use of Permanent Solutions to the Maximum Extent Practicable

Because Alternative 1 does not include active remedial measures, this alternative would not be expected to meet the MTCA requirements for use of permanent solutions to the maximum extent practicable. An evaluation of the use of permanent solutions to the maximum extent practicable is provided in Section 8.

7.3.5 Reasonable Restoration Time Frame

Under Alternative 1, potential risks to aquatic and terrestrial receptors may remain into the long term. Other practicable alternatives evaluated in this section are predicted to achieve RAOs within a shorter time frame. Although PCOC concentrations in surface water and groundwater will be reduced over time through natural attenuation, exceedances of potential ARARs at points of compliance are expected to persist for at least 250 years. As a result, Alternative 1 would not likely meet MTCA expectations for a reasonable restoration time frame.

7.4 ALTERNATIVE 2A - WATER MANAGEMENT (OPEN PORTAL)

The following subsections provide the detailed analysis of the remediation components included under Alternative 2a to address Site soils, surface water and groundwater.

Seasonal PCOC concentrations in Railroad Creek would be reduced under this alternative through the implementation of upgradient water diversions and source controls designed to reduce PCOC loading to Site groundwater and surface water. Additional reductions in the release of PCOCs from Site sources, including the underground mine, waste rock, and tailings piles, are predicted over time through natural attenuation. Estimated loading reductions from East and West Area sources under Alternative 2a are provided in Appendix D, Tables D1-1, D2-1, and D4. The predicted post-remediation Railroad Creek water quality for this alternative is summarized on Tables 7-1 through 7-4.

7.4.1 Threshold Criteria

Evaluation of the two threshold criteria, including overall protection of human health and the environment and compliance with ARARs, is provided in the following subsections for Alternative 2a (Water Management – Open Portal).

7.4.1.1 Overall Protection of Human Health and the Environment

Protection of Human Health and Terrestrial Ecological Receptors

The human health risk assessment found no existing unacceptable risk to Holden Village residents or visitors based on reasonable maximum exposure to PCOCs at the Site. To eliminate potential future risks associated with the use of groundwater as a drinking water source, land use restrictions would be implemented under this alternative. Alternative 2a would also reduce potential physical risks to human health through the installation and maintenance of physical access controls.

Alternative 2a would protect human health and the environment through removal, containment, and/or covering of Site soils containing PCOCs above the potential MTCA Method B human-health dermal contact values and preliminary ecological risk-based values at the point(s) or conditional point(s) of compliance as identified in Section 3. These actions would eliminate potential exposure pathways, thereby mitigating potential existing or future risks to terrestrial receptors. Soils with concentrations above the potential MTCA Method B values for the protection of groundwater, as developed during the RD/RA, would also be addressed under this alternative.

Based on the above information, the RAO to implement the remedial action in a manner that is protective of human health, including the Holden Village community, during and after construction would be met under this alternative. The soil RAO would also be achieved following remedy implementation.

Protection of Aquatic Life

Results of the post-remediation loading analysis indicate that dissolved cadmium, copper, and zinc concentrations in Railroad Creek would be reduced following remedy implementation and would continue to gradually decline over time through natural attenuation. The analysis predicts that all criteria would be met within approximately 250 years of remedy implementation (Tables 7-1 through 7-4). However, based on the toxicological evaluations provided in Appendix H (Hansen 2004), the predicted short-term PCOC concentrations may result in continued potential risks to aquatic life in Railroad Creek.

Seasonal concentrations of total aluminum and iron are predicted to remain above the potential NRWQC in the short-term under this alternative. However, an analysis of documented aluminum and iron toxicity, presented in Appendix H, indicates that the post-remediation concentrations would be protective of resident aquatic species in Railroad Creek. Over the long-term, total aluminum and iron concentrations are expected to gradually decline, approaching the NRWQC and background concentrations.

The RAOs for groundwater and surface water quality to meet state standards would not be achieved in the short term. A discussion of compliance with groundwater and surface water ARARs is provided below in Section 7.4.1.2.

Potential for Short-term Impacts

No additional short-term risks would be anticipated for the local community during or after implementation of this alternative. Appropriate health and safety, and dust control measures would be implemented to reduce potential impacts to residents and visitors during remedy implementation.

Possible short-term increases in metals loading to Railroad Creek from the tailings piles may result during regrading actions due to the exposure of previously unoxidized tailings to air and storm water (Section 7.2.3). However, measures would be taken during implementation to control storm-water runoff, reduce the volume of tailings disturbed during construction, and to place and compact materials cut back from the side slopes to minimize additional oxidation and surface water infiltration.

7.4.1.2 Compliance with ARARs

Compliance with ARARs includes the evaluation of potential chemical-specific, location-specific, and action-specific ARARs identified in Section 3.

Potential Chemical-Specific ARARs

The following subsections evaluate compliance with potential chemical-specific ARARs identified for Site media, including surface water, groundwater and soil. As described below, remedial activities included under this alternative are predicted to reduce PCOC releases to Site groundwater and surface water, and mitigate potential risks to ecological receptors due to exposure to soils in isolated locations on site.

Surface Water

Results of the post-remediation loading analysis indicate dissolved cadmium concentrations in Railroad Creek would be below the SWQC within approximately 50 years of remedy implementation under Alternative 2a. The analysis predicts that dissolved copper and zinc concentrations would be below the SWQC within approximately 250 years (Tables 7-1 through 7-4).

Dissolved cadmium, copper, and zinc concentrations are expected to be below the NRWQC within approximately 250 years (Tables 7-1 through 7-4). Although the post-remediation loading analysis could not be performed for total aluminum or iron, aluminum and iron concentrations are expected to approach the NRWQC and background concentration in the long term (i.e., within approximately 250 years).

Groundwater

Under Alternative 2a, portions of the seeps and groundwater beneath the Site are not expected to meet potential chemical-specific ARARs in the short- or long-term. Based upon a review of technologies in Section 5, it has been determined that it is not practicable to meet potential groundwater ARARs throughout the Site within a reasonable restoration time frame. Therefore, a CPOC would need to be established for both the East and West Areas for any of the proposed alternatives. Since Railroad Creek abuts the Site and potential ARARs are identified for protecting surface water beneficial uses, a CPOC that is located within the surface water at the point or points where groundwater flows into surface water may be established if the conditions described in the MTCA regulation are met.

Under Alternative 2a, the results of the post-remediation loading analysis indicate that potential ARARs would not be met in the short-term at points where groundwater flows into surface water. However, as described above for surface water, results of the loading analysis indicate potential ARARs would be achieved at points in Railroad Creek (represented by stations RC-4 and RC-2) within approximately 250 years. These stations are considered to be generally representative of water quality in Railroad Creek downstream of West and East Area sources. However, it may take longer for some locations within the creek to achieve potential ARARs.

Because active collection and treatment is not included in the West Area under Alternative 2a, the conditions for a CPOC under MTCA would likely not be met, and CPOCs for Site groundwater would not be available in the West Area unless a determination is made that West Area treatment is not practicable or reasonable under MTCA.

Natural attenuation, in conjunction with upgradient water diversion and source control actions included for the East Area under Alternative 2a are considered to be AKART and CPOCs at the points where groundwater flows into surface water would apply for this area. Based on the results of the post-remediation loading analysis, metals loading to East Area groundwater would be reduced over time through natural attenuation, and groundwater discharges would not result in exceedances of potential ARARs in the long term or cause an impact to aquatic life. Metals loadings from the West Area, not the East Area, are the cause of potential risks to aquatic life in Railroad Creek under Alternative 2a. The variable subsurface conditions, depth to low-permeability glacial till or bedrock, limited access between the tailings piles and Railroad Creek, and relatively flat grade significantly reduce the technical implementability and increase the costs associated with East Area collection and treatment. As a result, the collection and treatment of East Area groundwater and seeps is not practicable or reasonable.

Soils

Under Alternative 2a, soils and residuals in the mill building, maintenance yard and lagoon area with concentrations above the potential MTCA Method B human-health dermal contact values and/or the risk-based values developed for the protection of ecological receptors would be excavated and relocated on site or contained with an engineered cover. Soils with concentrations above screening values calculated for the protection of groundwater (Section 3) would be further evaluated during the RD/RA. This alternative would achieve the potential ARARs for soil.

Potential Location-specific ARARs

This alternative would meet all potentially applicable location-specific ARARs. The specific requirements of these ARARs would be identified through consultation with federal and state agencies during the RD/RA. The Alternative 2a actions are not expected to influence archaeological and/or historic sites of significance. Construction-related activities, including excavation or earthmoving, would consider the presence of historic or culturally important sites, structures or objects, historical and archeological data, and Native American burial sites, and if present, minimize impacts to such resources.

Construction activities would be conducted to minimize potential impacts to fish and wildlife, thereby meeting the potential ARARs associated with fish and wildlife protection. Coordination with Washington State Department of Fish and Wildlife (WDFW) and USFWS would be conducted during the remedial design to identify potentially applicable substantive requirements and incorporate mitigative measures into the design as necessary. Potential impacts to fish and wildlife, and consistency with the Forest Management Act would be addressed through consultation with USFWS and Forest Service.

Potential Action-Specific ARARs

Alternative 2a activities are expected to comply with potential action-specific ARARs through the implementation of institutional controls and monitoring as described in Section 6. Substantive compliance with CWA construction stormwater requirements, CWA section 401 water quality certification, and CWA section 404 would be addressed under this alternative. Substantive compliance with potential action-specific ARARs will be evaluated during the design through consultation with WDFW, USACOE, EPA, DNR, and Ecology. If remedial activities under Alternative 2a are determined to have temporary impacts to water quality, substantive compliance with temporary water quality modification requirements would be achieved. Best management practices would be used to comply with potential substantive stormwater construction requirements and fugitive dust requirements.

Excavated soils and tailings materials removed from the maintenance yard, mill building and lagoon are not expected to be either characteristic hazardous or dangerous waste. However, RCRA and Washington State Dangerous Waste regulations would be potentially applicable if these materials are determined to be hazardous or dangerous waste. If such a determination were made, these materials would be managed within the area of contamination, stabilized to immobilize the constituents, consolidated within a corrective management unit located on one of the tailings piles, and contained with an appropriate engineered cover.

The tailings piles and waste rock piles would meet relevant and appropriate requirements under the Washington State Requirements for Solid Waste Handling. These areas would be designed to meet the relevant and appropriate requirements for closure systems to prevent exposure of waste, minimize infiltration, prevent erosion from wind and water, be capable of sustaining native vegetation, address anticipated settlement, provide adequate drainage, provide sufficient stability and mechanical strength, address potential freeze-thaw and desiccation, provide for the management of run on and run off, prevent erosion from damaging the vegetative cover, and minimize the need for post-closure maintenance (WAC 173-350-400(3)(e)(i)(A) through (H)). Post-closure care requirements as deemed relevant and appropriate would also be met, including maintaining the vegetative cover, controlling run on and run off, and performing appropriate monitoring (173-350-400(7)(a)).

Limited purpose landfill cover requirements are not potentially applicable or relevant and appropriate to this remedial alternative, but would be potentially relevant and appropriate to those alternatives that include an engineered cover on the waste rock piles and/or tailings piles (Alternative 7 and 8).

7.4.2 Primary Balancing Criteria

Evaluation of the five primary balancing criteria, including long-term effectiveness and permanence; reduction of toxicity, mobility, and volume; short-term effectiveness; implementability; and cost is provided in the following subsections for Alternative 2a.

7.4.2.1 Long-term Effectiveness and Permanence

Long-term effectiveness and permanence includes evaluation of the magnitude of residual risk and the adequacy and reliability of controls.

Magnitude of Residual Risks

Under this alternative, a majority of the mine residuals would remain on site and mining-related PCOC concentrations would remain in groundwater beneath the Site. However, potential future risks to human health associated with the use of groundwater as a drinking water source would be effectively eliminated through the implementation of land-use restrictions. This alternative would also reduce potential physical hazards to residents and visitors associated with historical mining activities. Therefore, the magnitude of remaining human health risks would be low under Alternative 2a. The West Area source removal and containment actions are expected to be effective in achieving protection of terrestrial ecological receptors. Therefore the magnitude of remaining risks to terrestrial ecological receptors would be low under this alternative.

The implementation of upgradient water diversions, regrading and revegetating the tailings piles, and underground mine actions are expected to be effective in reducing metals loading to Site groundwater and surface water following remedy implementation. Results of the post-remediation loading analysis indicate PCOC concentrations would be below the SWQC and NRWQC in the long term. However, based on the toxicological evaluations provided in Appendix H, the predicted short-term PCOC concentrations may result in potential continued risks to aquatic life in Railroad Creek adjacent to the Site.

The limited underground mine actions and tailings pile slope stability actions included under Alternative 2a would be expected to significantly reduce the potential risk of sudden surge flows from the 1500-level main portal and the potential for release of tailings to Railroad Creek in the event of a slope failure.

Adequacy and Reliability of Controls

Land use restrictions are expected to be implementable, reliable, and adequate in providing long-term protection of human health. The installation of access restrictions around select Site features is also expected to be reliable in protecting Holden Village residents and visitors from potential physical hazards.

The removal and/or covering of impacted soils in the West Area is expected to be implementable, reliable, and adequate for mitigating potential risks to terrestrial receptors and the potential release of PCOCs from Site soils to groundwater. Upgradient water diversions and regrading and revegetation of the tailings piles are expected to further reduce surface and near-surface water contact with mining residuals and soils.

Maintaining the 1500-level main portal tunnel supports and removing remaining debris from the tunnel would be effective in reducing the potential for an uncontrolled release from the underground mine. Regrading tailings pile 2 and portions of tailings pile 1 side slopes is expected to provide a factor of safety greater than 1.2 to reduce the potential risk of a tailings release resulting from a slope failure or erosion. These actions would be implementable and have a high degree of long-term reliability.

7.4.2.2 Reduction of Toxicity, Mobility, and Volume

Over time, the mass, and therefore volume, of PCOCs released to groundwater and surface water would be reduced from site sources through the source control actions included under Alternative 2a and the natural geochemical processes described in Appendix E.

7.4.2.3 Short-term Effectiveness

Short-term effectiveness includes the protection of local communities, worker protection, short-term environmental impacts, and time required to reach remediation goals.

Protection of Local Communities

The human health risk assessment found no existing unacceptable risk to Holden Village residents or visitors based on current reasonable maximum exposures to PCOCs at the Site.

Actions included under this alternative would be implemented in such a way so as to protect Holden Village residents and visitors. A stream crossing over Railroad Creek would be constructed at the northeast corner of tailings pile 3, to allow vehicles and equipment to bypass the Village during remedy implementation. Access to the top of the tailings piles would be gained from the new stream crossing under this alternative. However, risks to the public would result from increased truck traffic on portions of the Site and the Holden Village road during construction.

Potential physical hazards to the local community related to the possible development of a rock source near Tenmile creek would be mitigated using proven engineering controls.

Worker Protection

During remedy implementation, potential risks to workers related to the possible generation of fugitive dust or exposure to metals constituents would be adequately mitigated through the use of personal protection equipment and engineering controls. Workers at construction and industrial sites are required to comply with the requirements and standards under the Occupational Safety and Health Act (OSHA) - detailed in 29 CFR 1910 et seq.

The underground mine actions and physical access restrictions included under this alternative would involve performing construction work underground in the abandoned mine workings on the 300, 1100, and 1500 levels. These actions would present potential physical risks to workers in the event of a collapse or rock fall. However, appropriate health and safety precautions, consistent with that required by the Mine Safety and Health Administration (MSHA), would be implemented to reduce potential risks under this alternative.

Development of the potential Tenmile rock source would present possible physical risks to workers due to the potential for rock fall at this location. The substantial earthmoving work required for tailings pile slope regrading would also result in potential safety risks to workers. However, appropriate health and safety precautions and engineering controls would be implemented to mitigate these potential risks.

Environmental Impacts

The potential for erosion and sediment loading to Railroad and Copper Creeks are expected to increase during tailings pile slope regrading activities. However, these potential risks would be preventable by incorporating appropriate erosion control measures into the remedial designs, such as diversion of surface-water runon and runoff, the use of silt fences, or construction of temporary sedimentation basins. Erosion and dust control measures would also be implemented to mitigate potential impacts to aquatic biota resulting from the release of tailings to surface water during and after remedy implementation.

Possible short-term increases in metals concentrations within surface runoff from the tailings piles may result during regrading actions due to the exposure of previously unoxidized tailings to air and storm water (Section 7.2.3). Measures would be taken during implementation to control storm-water runoff, reduce the volume of tailings disturbed during construction, and to place and compact materials removed from the side slopes to minimize additional oxidation and surface water infiltration.

No significant impacts to terrestrial biota are anticipated as a result of the remedial actions planned under this alternative.

Time Required to Reach Remedial Goals

Implementation of Alternative 2a is expected to occur over a one- to two-year period of time. Following implementation, the soil RAO would be met. The groundwater RAO is currently being met in monitoring wells located downgradient of the Site, but would not be expected to be met in all locations beneath the Site. Groundwater quality throughout the site is expected to improve over time, through on-going natural attenuation.

The surface-water RAO is not expected to be achieved under this alternative in the short-term. However, the results of the long-term post-remediation loading analysis indicate surface water and groundwater RAOs would be achieved in Railroad Creek within approximately 250 years.

7.4.2.4 Implementability

Implementability includes technical feasibility, administrative feasibility, and availability of services and materials.

Technical Feasibility

The proposed engineering controls are implementable. Aboveground actions included under Alternative 2a have been successfully implemented at other sites, and are based on conventional construction technologies. Completion of the underground mine actions, including removal of debris and precipitates from the 1500 level and maintenance of the 1500-level main portal would require specialized equipment and personnel trained to work underground. This type of specialized equipment and personnel would not be as readily available as standard construction equipment and crews. However, a suitably skilled work force is expected to be available in surrounding areas.

Administrative Feasibility

The Site is located adjacent to the Holden Village, which is operated under a special-use permit issued by the Forest Service, a wilderness area boundary, and Forest Service lands. As a result, coordination between many local agencies and the Holden Village will be required under Alternatives 2 through 8.

Availability of Services and Materials

The materials required to implement this alternative would be available within the Railroad Creek Valley or could be mobilized to the Site by barge. Specialized equipment and personnel for completion of underground actions is expected to be available in surrounding areas. Preliminary evaluations indicate that the development of a potential rock source near Tenmile Creek would be feasible through the use of proven engineering controls.

7.4.2.5 Cost

The total estimated costs associated with Alternative 2a are approximately $17,260,000 (2004 dollars at a 7-percent discount rate). Table 7-9 provides a summary of capital and O&M costs for each of the eight candidate alternatives, and cost detail sheets are provided in Appendix I.

Capital costs associated with implementation of Alternative 2a are estimated at approximately $10,020,000. Annual O&M costs associated with monitoring, and maintaining the 1500-level main portal and diversion channels, are estimated to be approximately $150,000.

7.4.3 Natural Resource Restoration

A summary of the extent of natural resource restoration expected under each of the candidate alternatives is provided in Appendix J. Under Alternative 2a, natural resource restoration would be achieved for soils and vegetation in the West Area and terrestrial wildlife across the Site following remedy implementation. Although the tailings piles do not represent an injured resource, the tailings pile revegetation included under this alternative would provide replacement terrestrial habitat over time for other potentially injured areas on site.

Results of the long-term loading analysis indicate gradual improvements in surface-water and groundwater quality over time. PCOC concentrations in Railroad Creek are predicted to achieve potential ARARs in the long term. The potential long-term reductions in PCOC concentrations would be expected to result in improved aquatic habitat in Railroad Creek adjacent to and downstream of the Site.

7.4.4 Use of Permanent Solutions to the Maximum Extent Practicable

The remedial actions included under Alternative 2a constitute permanent solutions since potential ARARs are expected to be achieved in the long term without further actions being required (WAC 173-340-200). The loading analysis indicates that PCOC loading to Site groundwater and surface water would be reduced over time and potential ARARs are expected to be achieved within approximately 250 years.

An evaluation of the use of permanent solutions to the maximum extent practicable is provided in Section 8 (comparative analysis of alternatives). Evaluation of the practicability of this alternative includes whether the alternative is capable of being designed, constructed, and implemented in a reliable and effective manner, including consideration of cost. In considering cost under this analysis, an alternative shall not be considered practicable if the incremental costs are disproportionate to the incremental degree of benefits provided by the alternative over other lower cost alternatives.

7.4.5 Reasonable Restoration Time Frame

Following implementation of Alternative 2a, soil RAOs are expected to be met. Actions included under Alternative 2a are also expected to be effective in eliminating potential physical hazards to Holden Village residents and visitors related to mine features and potential future risks to human health due to the possible development of groundwater as a drinking water supply.

PCOC loading to groundwater would be reduced over time under Alternative 2a through source controls and natural attenuation. Results of the post-remediation loading analysis indicate that groundwater RAOs would be achieved at CPOCs in surface water in the West Area (if applicable) and East Areas within approximately 250 years.

Results of the post-remediation loading analysis indicate that the surface water RAO would be achieved within approximately 250 years. However, based on the results of toxicological evaluations provided in Appendix H, the predicted short-term post-remediation PCOC concentrations may result in continued potential risks to aquatic life in Railroad Creek. Based on this evaluation, and because other practicable alternatives are expected to be protective of aquatic life in the short term and achieve ARARs within a shorter time frame, the remedial actions included under Alternative 2a would not likely meet MTCA requirements for a reasonable restoration time frame.

7.5 ALTERNATIVE 2B: WATER MANAGEMENT (HYDROSTATIC BULKHEADS)

Alternative 2b includes the same remediation components described for Alternative 2a, with the addition of installing hydrostatic bulkheads in the 1500 level, installing a low-head bulkhead in the 1100 level, and other potential in-mine controls. The following subsections provide an analysis of the additional components included under Alternative 2b.

Under Alternative 2b, the underground mine actions and upgradient water diversions and source controls in the East and West Areas are expected to reduce PCOC loading to the subsurface and improve groundwater quality throughout the Site. The installation of hydrostatic bulkheads and other in-mine water controls is also expected to reduce the magnitude of seasonal PCOC loading increases to Railroad Creek that result from the sharp increases in portal drainage flow observed during the spring flush. These additional actions would also likely achieve greater reductions in airflow and oxygen transport to underground workings. As a result, greater reductions in PCOC concentrations in Railroad Creek are expected in the short-term under Alternative 2b compared to Alternative 2a during the spring flush period. Estimated loading reductions from East and West Area sources under Alternative 2b are provided in Appendix D, Tables D1-2, D2-2, and D4.

Due to the assumption that portal drainage flows may be higher during the fall and winter months (the underground mine would be used for flow equalization throughout the year), the results of the post-remediation loading analysis indicate short-term PCOC concentrations may be elevated in the fall compared to Alternative 2a. However, actual portal drainage flowrates would likely be adjusted during the RD/RA to minimize impacts during low-flow periods. Estimated short- and long-term Railroad Creek water quality is summarized on Tables 7-1 through 7-4.

7.5.1 Threshold Criteria

Evaluation of the two threshold criteria, including overall protection of human health and the environment and compliance with ARARs, is provided in the following subsections for Alternative 2b.

7.5.1.1 Overall Protection of Human Health and the Environment

Protection of Human Health and Terrestrial Ecological Receptors

As described for Alternative 2a, the actions included under Alternative 2b are expected to be protective of human health and terrestrial ecological receptors at the Site. The RAO to implement the remedial action in a manner that is protective of human health, including the Holden Village community, during and after construction would be met under this alternative. The soil RAO would also be achieved following remedy implementation.

Protection of Aquatic Life

Results of the post-remediation loading analysis indicate that seasonal dissolved cadmium, copper, and zinc concentrations in Railroad Creek would be reduced following remedy implementation, and would continue to gradually decline over time through natural attenuation. The analysis predicts that dissolved cadmium concentrations in Railroad Creek would meet potential ARARs within approximately 150 years, and dissolved copper and zinc concentrations would meet potential ARARs within approximately 250 years of remedy implementation (Tables 7-1 through 7-4). However, based on the toxicological evaluations provided in Appendix H (Hansen 2004), the estimated short-term PCOC concentrations may result in continued potential risks to aquatic life in Railroad Creek.

Under Alternative 2b, seasonal concentrations of total aluminum and total iron are predicted to remain above the potential NRWQC in the short term. However, an analysis of documented aluminum and iron toxicity, presented in Appendix H, indicates that the post-remediation concentrations would be protective of resident aquatic species in Railroad Creek. Over the long term, total aluminum and iron concentrations are expected to gradually decline, approaching the NRWQC and background concentrations.

The RAOs for groundwater and surface water quality would not be achieved in the short term under Alternative 2b. A discussion of compliance with groundwater and surface water ARARs is provided below in Section 7.5.1.2.

Potential for Short-term Impacts

As described for Alternative 2a, no additional short-term risks would be anticipated for the local community during or after implementation of this alternative. Possible short-term increases in metals loading from the tailings piles may result during regrading actions due to the exposure of previously unoxidized tailings to air and storm water (Section 7.2.3). However, measures would be taken during implementation to control storm-water runoff, reduce the volume of tailings disturbed during construction, and to place and compact materials cut back from the side slopes to minimize additional oxidation and surface water infiltration. Elevated PCOC concentrations in the portal drainage may also result in the short term due to flooding of the underground mine workings. These effects have been accounted for in the loading analysis calculations and are not expected to persist into the long-term.

7.5.1.2 Compliance with ARARs

Compliance with ARARs includes the evaluation of potential chemical-specific, location-specific, and action-specific ARARs identified in Section 3.

Potential Chemical-Specific ARARs

The following subsections evaluate compliance with potential chemical-specific ARARs identified for Site media, including surface water, groundwater and soil.

Surface Water

Results of the post-remediation loading analysis indicate dissolved cadmium concentrations in Railroad Creek would be below the SWQC within approximately 50 years of remedy implementation under Alternative 2b. The analysis predicts that dissolved copper and zinc concentrations would be below the SWQC within approximately 250 years (Tables 7-1 through 7-4).

Dissolved cadmium concentrations are expected to be below the NRWQC within approximately 150 years (Tables 7-1 through 7-4) and the dissolved copper and zinc concentrations are expected to be below the NRWQC within approximately 250 years. Although the post-remediation loading analysis could not be performed for total aluminum or iron, aluminum and iron concentrations are expected to approach the NRWQC and background concentration in the long term (i.e., within approximately 250 years).

Groundwater

Portions of the seeps and groundwater beneath the Site would not likely meet potential chemical-specific ARARs in the short- or long-term under any of the alternatives. Therefore, as discussed under Alternative 2a, it is not practicable to meet potential groundwater ARARs throughout the site within a reasonable restoration time frame.

The results of the post-remediation loading analysis indicate that potential ARARs would not be met under Alternative 2b in the short term at the specific points where groundwater flows into surface water. As described above for surface water, results of the loading analysis indicate potential ARARs would be achieved at points in Railroad Creek (represented by monitoring stations RC-4 and RC-2) within approximately 250 years. These stations are considered to be generally representative of water quality in Railroad Creek downstream of West and East Area sources. However, it may take longer for some locations within the creek to achieve potential ARARs.

Because Alternative 2b does not include collection and treatment in the West Area, CPOCs for groundwater would not likely be available for the West Area unless a determination is made that West Area treatment is not practicable or reasonable under MTCA. However, as described under Alternative 2a, the East Area actions included under Alternative 2b are considered to be AKART, and CPOCs, at the points where groundwater flows into surface water would apply for this area.

Soils

As described for Alternative 2a, the potential ARARs identified for soil would be achieved under Alternative 2b.

Potential Location-specific ARARs

Compliance with potential location-specific ARARs for Alternative 2b would be the same as described for Alternative 2a in Section 7.4.1.2.

Potential Action-specific ARARs

Compliance with potential action-specific ARARs for Alternative 2b would be the same as described for Alternative 2a in Section 7.4.1.2.

7.5.2 Primary Balancing Criteria

An evaluation of the five primary balancing criteria, including long-term effectiveness and permanence; reduction of toxicity, mobility, and volume; short-term effectiveness; implementability; and cost is provided in the following subsections for Alternative 2b.

7.5.2.1 Long-term Effectiveness and Permanence

Long-term effectiveness and permanence includes evaluation of the magnitude of residual risk, and the adequacy and reliability of controls.

Magnitude of Residual Risks

As described for Alternative 2a, the actions included under Alternative 2b would be protective of human health and terrestrial ecological receptors. Therefore, the magnitude of remaining human health risks and risks to terrestrial ecological receptors would be low under this alternative.

The long-term post-remediation Railroad Creek water quality is predicted to be improved over Alternative 2a due to reductions in airflow through the mine, the ability to regulate the portal drainage discharge based on seasonal discharge rates in Railroad Creek, increased detention time in the mine, and the contact of mine water with lower mine workings. Results of the post-remediation loading analysis indicate that PCOC concentrations in Railroad Creek would be below potential ARARs in the long term. However, based on the toxicological evaluations provided in Appendix H, the predicted short-term PCOC concentrations may result in continued potential risks to aquatic life in Railroad Creek.

The magnitude of residual risks due to potential surge releases from the underground mine or tailing releases due to potential slope failure would be low under alternative 2b.

Adequacy and Reliability of Controls

As described under Alternative 2a, East and West Area actions under Alternative 2b would be expected to be implementable and reliable in providing long-term protection of human health and the environment.

7.5.2.2 Reduction of Toxicity, Mobility, and Volume

Over time, the mass, and therefore volume, of PCOCs released to groundwater and surface water would be reduced from Site sources through the source control actions included under Alternative 2b and the natural geochemical processes described in Appendix E.

7.5.2.3 Short Term Effectiveness

Short-term effectiveness includes evaluation of protection of local communities, worker protection, short-term environmental impacts, and time required to reach remediation goals.

Protection of Local Communities

As described for Alternative 2a, Alternative 2b would be protective of Holden Village residents and visitors during remedy implementation.

Worker Protection

Potential increased risks to workers related to the additional underground construction required for hydrostatic bulkhead installation and other in-mine controls may exist under Alternative 2b compared to Alternative 2a. However, as described under Alternative 2a, appropriate health and safety precautions, consistent with that required by MSHA, would be implemented to reduce potential risks under this alternative.

Environmental Impacts

In addition to the potential short-term impacts and mitigation measures related to tailings pile regrading described under Alternative 2a, possible short-term increases in portal drainage metals concentrations may result from the installation of hydrostatic bulkheads in the 1500-level. The increased concentrations may occur in the short-term due to the flushing of soluble metal salts from rock surfaces not previously exposed to large volumes of water (Appendix E). These potential effects were accounted for in the short-term post-remediation loading analysis. As described in Appendix E, concentrations would be expected to return to baseline levels in a number of years.

Time Required to Reach Remedial Goals

The installation of hydrostatic bulkheads would increase the level of effort required to implement this alternative. However, as described for Alternative 2a, implementation Alternative 2b is expected to occur over a one- to two-year period of time. Following implementation the soil RAO would be met.

The groundwater and surface-water RAOs are not expected to be achieved under this alternative in the short-term. Results of the post-remediation loading analysis indicate that surface-water and groundwater RAOs would be achieved in Railroad Creek within approximately 250 years.

7.5.2.4 Implementability

Implementability includes the evaluation of technical feasibility, administrative feasibility, and availability of materials.

Technical Feasibility

As described for Alternative 2a, the actions described under this alternative are implementable. Additional design and construction efforts would be required under Alternative 2b for installation of the hydrostatic bulkheads and other in-mine controls. However, actions included under this alternative have been successfully implemented at other sites, and are based on conventional construction technologies.

Administrative Feasibility

As described for Alternative 2a, coordination between many local agencies and the Holden Village would be required under Alternatives 2 through 8.

Availability of Services and Materials

As described for Alternative 2a, the services and materials required to implement this alternative would be available within the Railroad Creek valley or could be mobilized to the Site by barge. Specialized equipment and personnel for completion of underground actions would be available in the surrounding areas.

7.5.2.5 Cost

The total estimated costs associated with Alternative 2b are $18,760,000 (2004 dollars at a 7-percent discount rate). The increased costs estimated for this alternative compared to Alternative 2a are primarily associated with the installation of hydrostatic bulkheads. Table 7-9 provides a summary of capital and O&M costs for each of the eight candidate alternatives, and cost detail sheets are provided in Appendix I.

Capital costs associated with implementation of Alternative 2b are estimated to be approximately $11,020,000. Annual O&M costs associated with monitoring and maintaining the 1500-level main portal and diversion channels are estimated to be approximately $150,000.

7.5.3 Natural Resource Restoration

Following implementation, alternative 2b would achieve the same level of natural resource restoration as described for Alternative 2a. Additional improvements in seasonal Railroad Creek water quality would be expected over time under this alternative through the installation of hydrostatic bulkheads. Therefore, additional improvements in aquatic habitat are also expected. A summary of the extent of natural resource restoration expected under each of the candidate alternatives is provided in Appendix J.

7.5.4 Use of Permanent Solutions to the Maximum Extent Practicable

The remedial actions included under Alternative 2b constitute permanent solutions since potential ARARs are expected to be achieved in the long term without further actions being required (WAC 173-340-200). The loading analysis indicates that PCOC loading to Site groundwater and surface water would be reduced over time and potential ARARs are expected to be achieved within approximately 250 years.

An evaluation the use of permanent solutions to the maximum extent practicable is provided in Section 8 (comparative analysis of alternatives). The evaluation of the practicability of this alternative includes whether the alternative is capable of being designed, constructed, and implemented in a reliable and effective manner, including consideration of cost. In considering cost under this analysis, an alternative shall not be considered practicable if the incremental costs are disproportionate to the incremental degree of benefits provided by the alternative over other lower cost alternatives.

7.5.5 Reasonable Restoration Time Frame

Following implementation of Alternative 2b, soil RAOs would be met. Remedial actions would also be effective in eliminating potential physical hazards to Holden Village residents and visitors related to mine features and potential future risks to human health due to the possible development of groundwater as a drinking water supply.

PCOC loading to groundwater would be reduced over time under Alternative 2b through source controls and natural attenuation. Results of the post-remediation loading analysis indicate that groundwater RAOs would be achieved at CPOCs in surface water in the West Area (if applicable) and East Areas within approximately 250 years.

Results of the post-remediation loading analysis indicate that the surface water RAO would be achieved within approximately 250 years. However, based on the results of toxicological evaluations provided in Appendix H, the predicted short-term post-remediation PCOC concentrations may result in continued potential risks to aquatic life in Railroad Creek. Based on this evaluation, and because other practicable alternatives evaluated in this section are expected to be protective of aquatic life in the short term and achieve ARARs within a shorter restoration time frame, the remedial actions included under Alternative 2b would not likely meet MTCA requirements for a reasonable restoration time frame.

7.6 ALTERNATIVE 3A: WATER MANAGEMENT AND WEST AREA TREATMENT (OPEN PORTAL)

The following subsections provide detailed analysis of the remediation components included under Alternative 3a to address Site soils, surface water and groundwater. Alternative 3a includes the same remediation components described for Alternative 2a, with the addition of collection and treatment of the portal drainage and West Area seeps and shallow groundwater. To avoid repetition, the following subsections provide an analysis of the additional remediation components included under Alternatives 3a.

The collection and treatment of the portal drainage and seeps and groundwater associated with Honeymoon Heights, the waste rock piles, mill building, and maintenance yard is anticipated to further reduce PCOC loading (primarily cadmium, copper, and zinc) to Railroad Creek and Site groundwater. Estimated loading reductions from East and West Area sources under Alternative 3a are provided in Appendix D, Tables D1-3, D2-3, and D4. Additionally, the construction of unlined treatment ponds in the former lagoon area is anticipated to increase the collection efficiency of shallow groundwater in the West Area. The potential loss of treated water, containing elevated alkalinity and pH, from the unlined treatment ponds would also be expected to further improve groundwater quality in the area. The reduction in metals concentrations in West Area groundwater would also likely result in reduced PCOC concentrations in groundwater and seeps associated with the old Railroad Creek channel beneath tailings pile 1.

Results of the loading calculations indicate significant improvements in estimated Railroad Creek water quality under Alternative 3a relative to Alternative 2a. The predicted short- and long-term post-remediation Railroad Creek water quality for this alternative is summarized in Tables 7-1 through 7-4.

7.6.1 Threshold Criteria

Evaluation of the two threshold criteria, including overall protection of human health and the environment and compliance with ARARs, is provided in the following subsections for Alternative 3a.

7.6.1.1 Overall Protection of Human Health and the Environment

Protection of Human Health and Terrestrial Ecological Receptors

As described for Alternative 2a, the actions included under Alternative 3a are expected to be protective of human health and terrestrial ecological receptors at the Site. The RAO to implement the remedial action in a manner that is protective of human health, including the Holden Village community, during and after construction would be met under this alternative. The soil RAO would also be achieved following remedy implementation.

Protection of Aquatic Life

Results of the post-remediation loading analysis indicate that seasonal dissolved cadmium, copper, and zinc concentrations in Railroad Creek would be reduced following remedy implementation, and would continue to gradually decline over time through natural attenuation. The analysis predicts that the potential surface water criteria for copper would be met within approximately 50 years of remedy implementation (Tables 7-1 through 7-4). Concentrations of dissolved cadmium and zinc are expected to achieve potential criteria within approximately 250 years. However, based on the toxicological evaluations provided in Appendix H (Hansen 2004), post-remediation PCOC concentrations under Alternative 3a would be protective of resident species in Railroad Creek, including salmonids and their food supply, following remedy implementation in the short term.

Under Alternative 3a, seasonal concentrations of total aluminum and total iron are predicted to remain above the potential NRWQC in the short term. However, an analysis of documented aluminum and iron toxicity, presented in Appendix H, indicates that the post-remediation concentrations would be protective of resident aquatic species in Railroad Creek. Over the long term, total aluminum and iron concentrations are expected to gradually decline, approaching the NRWQC and/or background concentrations.

The RAOs for groundwater and surface water quality would not be achieved in the short term under Alternative 3a. However, results of the post-remediation loading analysis indicate that these RAOs would be met in the long-term as described below in Section 7.6.1.2.

Potential for Short-term Impacts

Potential short-term impacts to the environment during construction and implementation of Alternative 3a would be similar to those described under Alternative 2. However, the construction and operation of a water treatment system in the West area would potentially result in greater disturbance to soils and vegetation in this area.

7.6.1.2 Compliance with ARARs

Compliance with ARARs includes the evaluation of potential chemical-specific, location-specific, and action-specific ARARs identified in Section 3.

Potential Chemical-specific ARARs

The following subsections evaluate compliance with potential chemical-specific ARARs identified for Site media, including surface water, groundwater, and soil. The portal drainage, West Area shallow groundwater, and seeps would be treated under this alternative.

Surface Water

Results of the post-remediation loading analysis indicate dissolved cadmium concentrations in Railroad Creek would be below the SWQC following remedy implementation and dissolved copper would be below the SWQC within approximately 50 years under Alternative 3a. The analysis predicts that dissolved zinc concentrations would be below the SWQC within approximately 250 years (Tables 7-1 through 7-4). However, based on the toxicological evaluations provided in Appendix H (Hansen 2004), post-remediation PCOC concentrations under Alternative 3a would be protective of resident aquatic species in Railroad Creek following remedy implementation in the short term.

Dissolved copper concentrations are expected to be below the NRWQC within approximately 50 years, zinc concentrations are expected to be below the NRWQC within approximately 150 years, and the dissolved cadmium concentrations are expected to be below the NRWQC within approximately 250 years (Tables 7-1 through 7-4). Although the post-remediation analysis could not be performed for total aluminum or iron, concentrations are expected to approach the NRWQC and/or background in the long term, and are expected to be protective of resident aquatic species in Railroad Creek.

For the West Area, a point of compliance would be established through a mixing zone where West Area treated effluent discharges to surface water. The CPOC would be monitored at the limits of the established mixing zone.

Groundwater

Portions of the seeps and groundwater beneath the Site would not likely meet potential chemical-specific ARARs in the short or long term under any of the alternatives. Therefore, as discussed under Alternative 2a, it is not practicable to meet potential groundwater ARARs throughout the Site within a reasonable restoration time frame.

The results of the post-remediation loading analysis indicate that potential ARARs would not be met in the short term under Alternative 3a at the points where groundwater flows into surface water. As described above for surface water, results of the loading analysis indicate potential ARARs would be achieved at points in Railroad Creek (represented by stations RC-4 and RC-2) within approximately 250 years. These stations are considered to be generally representative of water quality in Railroad Creek downstream of West and East Area sources. However, it may take longer for some locations within the creek to achieve potential ARARs.

Natural attenuation, combined with upgradient water diversions, source controls, and upper West Area collection and treatment, constitute AKART for the West Area of the Site. Based on the results of the post-remediation loading analysis and the toxicological evaluations provided in Appendix H, the West Area actions included under Alternative 3a would achieve ARARs in the long term and would provide equivalent protection to aquatic life in Railroad Creek as the actions included under Alternatives 3b and 5a through 8 (Alternatives 2 and 4 do not include West Area collection and treatment). As a result, CPOCs for groundwater, at the points where groundwater flows into surface water, would apply for the West Area under this alternative.

As described for Alternative 2a, natural attenuation, in conjunction with upgradient water diversion and source control actions included under Alternative 3a for the East Area are considered to be AKART. CPOCs at the points where groundwater flows into surface water would apply for this area.

Soils

Under Alternative 3a, soils and residuals in the mill building, maintenance yard and lagoon area with concentrations above the MTCA Method B soil cleanup standards for unrestricted land use and/or the risk-based values developed for the protection of ecological receptors would be excavated and relocated on site or contained with an engineered cover.

Soils located outside of groundwater collection systems with concentrations above the screening values calculated for the protection of groundwater (Section 3) would be further evaluated during the RD/RA. This alternative would achieve the potential ARARs for soil.

Potential Location-specific ARARs

Compliance with potential location-specific ARARs for Alternative 3a would be the same as described for Alternative 2a in Section 7.4.1.2.

Potential Action-Specific ARARs

Compliance with potential action-specific ARARs for Alternative 3a would be the same as described for Alternative 2a in Section 7.4.1.2.

Substantive compliance with NPDES discharge requirements for effluent from the West Area treatment system to Railroad Creek would also be evaluated under this alternative, including establishment of a mixing zone with monitoring at the limits of the mixing zone. This will be the point of compliance for demonstrating compliance with potential surface-water ARARs.

7.6.2 Primary Balancing Criteria

Evaluation of the five primary balancing criteria, including long-term effectiveness and permanence; reduction of toxicity, mobility, and volume; short-term effectiveness; implementability; and cost is provided in the following subsections for Alternative 3a.

7.6.2.1 Long-term Effectiveness and Permanence

Long-term effectiveness and permanence includes evaluation of the magnitude of residual risk and the adequacy and reliability of controls.

Magnitude of Residual Risks

As described for Alternative 2a, the actions included under Alternative 3a would be protective of human health and ecological receptors. Therefore, the magnitude of remaining human health risks and risks to terrestrial ecological receptors would be low under this alternative.

Under Alternative 3a, the short- and long-term post-remediation Railroad Creek water quality is predicted to be significantly improved over Alternative 2a due to the collection and treatment of the portal drainage and groundwater and seeps related to Honeymoon Heights, the east and west waste rock piles, mill building, and maintenance yard. Based on the results of the short-term loading analysis and toxicological analyses provided in Appendix H, post-remediation PCOC concentrations following implementation of Alternative 3a are not expected to adversely impact the aquatic community in Railroad Creek, including salmonids and their food supply.

As described for Alternative 2a, the magnitude of residual risks due to potential surge releases from the underground mine or tailings releases due to potential slope failures would be low under Alternative 3a.

Adequacy and Reliability of Controls

East and West Area Actions are expected to be implementable and reliable in providing long-term protection of human health and the environment. Although gradual improvements in portal drainage and West Area groundwater quality are expected through the installation of airflow restrictions in open mine portals and natural attenuation, continued long-term operation and maintenance of the West Area collection and treatment systems would be required under this alternative.

The low-energy treatment system would have a high degree of implementability and would be designed to reliably treat seasonal portal drainage, seep, and groundwater flows. Chemical addition rates would be controlled based on seasonal flows and water quality, and the settling ponds and media filters would be sized to provide significant detention times and solids removal prior to discharge to Railroad Creek. An important factor in providing consistent effluent quality under Alternative 3a would be the ability to adjust chemical addition rates in response to the rapid changes in influent flows and water chemistry expected under this alternative, which does not include flow equalization.

7.6.2.2 Reduction of Toxicity, Mobility, and Volume

The alkaline precipitation process included for the West Area under Alternative 3a would reduce the mass and volume of PCOCs released to groundwater and surface water. The treatment processes would produce stable treatment residuals, and thus reduce the mobility and toxicity of PCOCs to environmental receptors. The volume of impacted materials requiring management would increase with the sludge generated from the water treatment processes.

Additionally, the mass, and therefore volume, of PCOCs released to groundwater and surface water would be reduced from Site sources over time through source control actions and the natural geochemical processes described in Appendix E.

7.6.2.3 Short-term Effectiveness

Short-term effectiveness includes evaluation of protection of local communities, worker protection, short-term environmental impacts, and time required to reach remediation goals.

Protection of Local Communities

Alternative 3a would be protective of Holden Village residents and visitors. Operation and maintenance of the West Area treatment system would require periodic deliveries of diesel fuel and treatment chemicals to the Site by barge and truck, and would result in increased traffic and equipment operations in the vicinity of the lagoon and maintenance yard during maintenance activities.

Potential physical hazards to the local community related to the possible development of a rock source near Tenmile creek would be mitigated using proven engineering controls. However, increased risks to the public would potentially result from increased truck traffic on portions of the Site and the Holden Village road during construction.

Worker Protection

Potential risks to workers related to the possible generation of fugitive dust or exposure to treatment chemicals and metal constituents during construction and implementation could be adequately mitigated with use of personal protection equipment and engineering controls. Workers at construction and industrial sites are required to comply with the requirements and standards under OSHA.

Potential risks to workers related to the limited underground mine actions, upgradient water diversions, and source controls would be mitigated through the use of appropriate health and safety practices, consistent with that required by MSHA.

Environmental Impacts

Potential short-term impacts to water quality in Railroad Creek resulting from tailings pile regrading or other excavation and construction activities conducted in the East and West Areas under this Alternative would be mitigated as described for Alternative 2a.

No significant impacts on terrestrial biota are anticipated as a result of the remedial actions planned under Alternative 3a.

Time Required to Reach Remedial Goals

Construction of the upper West Area collection system would increase the level of effort required to implement this alternative. However, as described for Alternative 2a, implementation of Alternative 3a is expected to occur over a one- to two-year period of time. Following implementation, the soil RAO would be met.

Results of the post-remediation loading analysis indicate that copper concentrations would achieve potential surface water criteria in Railroad Creek within approximately 50 years. Cadmium and zinc concentrations are predicted to achieve potential surface water criteria within approximately 250 years. However, based on the toxicological evaluations provided in Appendix H, short- and long-term post-remediation concentrations are expected to be protective of aquatic life in Railroad Creek.

As described above for surface water, the groundwater RAO would be expected to be achieved at CPOCs within surface water within approximately 250 years.

7.6.2.4 Implementability

Implementability includes the evaluation of technical feasibility, administrative feasibility, and availability of materials.

Technical Feasibility

Actions described under this alternative are implementable. Treatment of the portal drainage without flow equalization or surge control would potentially reduce treatment efficiencies and increase the size and volumes of required piping, valves, treatment ponds, chemical storage hoppers, and dosing equipment. Although chemical dosing would be controlled based on pH or flow, significant surges in discharge rates, as have been recorded by data loggers at P-1, would be difficult to control and may result in over- or under-dosing with treatment chemical.

Administrative Feasibility

As described for Alternative 2a, coordination between many local agencies and the Holden Village would be required under Alternatives 2 through 8. Additional coordination with the Holden Village would be required under alternative 3a to facilitate long-term water treatment in the West Area.

Availability of Services and Materials

As described for Alternative 2a, the materials required to implement Alternative 3a would be available within the Railroad Creek Valley or could be mobilized to the Site by barge. Specialized equipment and personnel for completion of underground actions is expected to be available in surrounding areas. Treatment system chemicals would be transported to the Site by barge and truck on a regular basis under this alternative.

7.6.2.5 Cost

The total estimated costs associated with Alternative 3a are $27,090,000 (2004 dollars at a 7-percent discount rate). The primary costs associated with this alternative include the installation of hydrostatic bulkheads, West Area treatment, tailings pile slope regrading, and riprap placement. Table 7-9 provides a summary of capital and O&M costs for each of the eight candidate alternatives, and cost detail sheets are provided in Appendix I.

Capital costs associated with implementation of Alternative 3a are estimated to be approximately $15,260,000. Annual O&M costs associated with monitoring, and maintaining the 1500-level main portal and diversion channels, are estimated to be approximately $260,000.

7.6.3 Natural Resource Restoration

Following implementation, Alternative 3a would achieve the same level of natural resource restoration for soils, vegetation, and terrestrial wildlife, as described for Alternative 2a. However, additional improvements in groundwater quality, Railroad Creek water quality, and aquatic resources are expected through West Area collection and treatment, and thus additional restoration for these resources would be achieved. A summary of the extent of natural resource restoration expected under each of the candidate alternatives is provided in Appendix J.

7.6.4 Use of Permanent Solutions to the Maximum Extent Practicable

The remedial actions included under Alternative 3a constitute permanent solutions since potential ARARs are expected to be achieved in the long term without further actions being required (WAC 173-340-200). The loading analysis indicates that PCOC loadings to Site groundwater and surface water would be reduced over time and all potential ARARs are expected to be achieved within approximately 50 to 250 years, depending on the PCOC.

An evaluation of the use of permanent solutions to the maximum extent practicable is provided in Section 8 (comparative analysis of alternatives). The evaluation of the practicability of this alternative includes whether the alternative is capable of being designed, constructed, and implemented in a reliable and effective manner, including consideration of cost. In considering cost under this analysis, an alternative shall not be considered practicable if the incremental costs are disproportionate to the incremental degree of benefits provided by the alternative over other lower cost alternatives.

7.6.5 Reasonable Restoration Time Frame

As described in Section 7.6.1, Alternative 3a would address potential risks to human health and the environment in the short term. Minimal potential future risks to human health would be addressed through removal of soils that exceed potential human health-based soil ARARs and institutional controls. Likewise, potential risks to terrestrial ecological receptors would be addressed following remedy implementation.

Results of the short-term loading analysis and toxicological evaluations (Appendix H) also indicate that surface water quality would be protective of aquatic life in Railroad Creek in the short term under Alternative 3a. However, the additional flow equalization provided under Alternative 3b is practicable and expected to provide greater reductions in short-term PCOC concentrations in Railroad Creek. As a result, the remedial actions included under Alternative 3a would not likely meet MTCA requirements for a reasonable restoration time frame.

7.7 ALTERNATIVE 3B: WATER MANAGEMENT AND WEST AREA TREATMENT (HYDROSTATIC BULKHEADS)

Alternative 3b includes the same remediation components described for Alternative 3a, with the addition of installing hydrostatic bulkheads in the 1500 level, installing a low-head bulkhead in the 1100 level, and other in-mine controls. The following subsections provide an analysis of the additional components under Alternative 3b.

The installation of hydrostatic bulkheads and other in-mine water controls achieve slightly greater reductions in PCOC loading to Railroad Creek than estimated for Alternative 3a. The ability to control portal drainage and treatment system discharge rates would also be expected to reduce seasonal loading spikes in Railroad Creek in both the short- and long-term. Estimated loading reductions from East and West Area sources under Alternative 3b are provided in Appendix D, Tables D1-4, D2-4, and D4. Results of the loading analysis indicate additional improvements in post-remediation Railroad Creek water quality relative to Alternative 3a. Estimated short- and long-term post-remediation Railroad Creek water quality for this alternative is summarized in Tables 7-1 through 7-4.

7.7.1 Threshold Criteria

Evaluation of the two threshold criteria, including overall protection of human health and the environment and compliance with ARARs, is provided in the following subsections for Alternative 3b.

7.7.1.1 Overall Protection of Human Health and the Environment

Protection of Human Health and Terrestrial Ecological Receptors

As described for Alternative 3a, the actions included under Alternative 3b are expected to be protective of human health and terrestrial ecological receptors at the Site. The RAO to implement the remedial action in a manner that is protective of human health, including the Holden Village community, during and after construction would be met under this alternative. The soil RAO would also be achieved following remedy implementation.

Protection of Aquatic Life

Results of the post-remediation loading analysis indicate that seasonal dissolved cadmium, copper, and zinc concentrations in Railroad Creek would be reduced following remedy implementation, and would continue to gradually decline over time through natural attenuation. The analysis predicts that the potential surface water criteria for cadmium and copper would be met within approximately 50 years of remedy implementation (Tables 7-1 through 7-4).

Concentrations of dissolved zinc are expected to achieve potential criteria within approximately 250 years. However, based on the toxicological evaluations provided in Appendix H, post-remediation PCOC concentrations under Alternative 3b would be protective of resident species in Railroad Creek, including salmonids and their prey, following remedy implementation in the short term.

Under Alternative 3b, seasonal concentrations of total aluminum and total iron are expected to remain above the potential NRWQC in the short term. However, an analysis of documented aluminum and iron toxicity, presented in Appendix H, indicates that the post-remediation concentrations would be protective of resident aquatic species in Railroad Creek. Over the long term, total aluminum and iron concentrations are expected to gradually decline, approaching the NRWQC and/or background concentrations.

The RAOs for groundwater and surface water quality would not be achieved in the short term under Alternative 3b. However, results of the post-remediation loading analysis indicate that these RAOs would be met in the long term as described below in Section 7.7.1.2.

Potential for Short-term Impacts

Potential short-term impacts to the environment during construction and implementation would be similar to those described under Alternative 3a.

7.7.1.2 Compliance with ARARs

Compliance with ARARs includes the evaluation of potential chemical-specific, location-specific, and action-specific ARARs identified in Section 3.

Potential Chemical-specific ARARs

The following subsections evaluate compliance with potential chemical-specific ARARs identified for Site media, including surface water, groundwater, and soil. The portal drainage, West Area shallow groundwater, and seeps would be treated under this alternative.

Surface Water

Results of the post-remediation loading analysis indicate dissolved cadmium concentrations in Railroad Creek would be below the SWQC following remedy implementation, and dissolved copper would be below the SWQC within approximately 50 years under Alternative 3b. The analysis predicts that dissolved zinc concentrations would be below the SWQC within approximately 250 years (Tables 7-1 through 7-4). However, based on the toxicological evaluations provided in Appendix H, post-remediation PCOC concentrations under Alternative 3b would be protective of resident aquatic species in Railroad Creek following remedy implementation in the short term.

Dissolved cadmium, copper and zinc concentrations are expected to be below the NRWQC within approximately 50 years (Tables 7-1 through 7-4). Although the post-remediation analysis could not be performed for total aluminum or iron, concentrations are expected to approach the

NRWQC and/or background in the long term, and are expected to be protective of resident aquatic species in Railroad Creek.

For the West Area, a point of compliance would be established through a mixing zone where West Area treated effluent discharges to surface water. The CPOC would be monitored at the limits of the established mixing zone.

Groundwater

Portions of the seeps and groundwater beneath the Site would not likely meet potential chemical-specific ARARs in the short or long term under any of the alternatives. Therefore, as discussed under Alternative 2a, it is not practicable to meet potential groundwater ARARs throughout the Site within a reasonable restoration time frame.

The results of the post-remediation loading analysis indicate that potential ARARs would not be met in the short term at the points where groundwater flows into surface water. As described above for surface water, results of the loading analysis indicate potential ARARs would be achieved at points in Railroad Creek (represented by stations RC-4 and RC-2) within approximately 250 years. These stations are considered to be generally representative of water quality in Railroad Creek downstream of West and East Area sources. However, it may take longer for some locations within the creek to achieve potential ARARs.

As described for Alternative 3a, natural attenuation, in conjunction with upgradient water diversions, source control actions, and upper West Area collection and treatment, constitute AKART for this Site. As a result, CPOCs for groundwater, where groundwater flows into surface water, would apply for the East and West Areas under Alternative 3b.

Soils

As described for Alternative 3a, the potential ARARs identified for soil would be achieved under Alternative 3b.

Potential Location-specific ARARs

Compliance with potential location-specific ARARs for Alternative 3b would be the same as described for Alternative 3a in Section 7.6.1.2.

Potential Action-Specific ARARs

Compliance with potential action-specific ARARs for Alternative 3b would be the same as described for Alternative 3a in Section 7.6.1.2.

7.7.2 Primary Balancing Criteria

Evaluation of the five primary balancing criteria, including long-term effectiveness and permanence; reduction of toxicity, mobility, and volume; short-term effectiveness; implementability; and cost is provided in the following subsections for Alternative 3b.

7.7.2.1 Long-term Effectiveness and Permanence

Long-term effectiveness and permanence includes evaluation of the magnitude of residual risk and adequacy and reliability of controls.

Magnitude of Residual Risks

As described under Alternative 2a, the actions included under Alternative 3b would be protective of human health and terrestrial ecological receptors. Therefore, the magnitude of remaining human health risks and risks to terrestrial ecological receptors would be low under this alternative.

The predicted short- and long-term post-remediation water quality in Railroad Creek under Alternative 3b is estimated to be improved over Alternative 3a due to the installation of hydrostatic bulkheads in the 1500 level and other in-mine water controls. Based on the results of the short-term loading analysis and toxicological analyses provided in Appendix H, post-remediation PCOC concentrations following implementation of Alternative 3b are not expected to adversely impact the aquatic community in Railroad Creek including salmonids and their prey.

Adequacy and Reliability of Controls

East and West Area actions would be expected to be implementable and reliable in providing long-term protection of human health and the environment. Although gradual improvements in portal drainage and West Area groundwater quality are expected through the installation of hydrostatic bulkheads, in-mine water controls, and natural attenuation, continued long-term operation and maintenance of the West Area collection and treatment systems would be required under this alternative.

The low-energy treatment system included under this alternative for the West Area would have a high degree of implementability and would be designed to reliably treat seasonal portal drainage, seep, and groundwater flows. Chemical addition rates would be controlled based on seasonal flows and water quality, and the settling ponds and media filters would be sized to provide significant detention times and solids removal prior to discharge to Railroad Creek. An important factor in providing consistent effluent quality under Alternative 3b would be the ability to adjust chemical addition rates in response to variations in influent flows and water chemistry.

7.7.2.2 Reduction of Toxicity, Mobility, and Volume

The alkaline precipitation process included for the West Area under Alternative 3b would reduce the mass and volume of PCOCs released to groundwater and surface water. The treatment processes would produce stable treatment residuals, and thus reduce the mobility and toxicity of PCOCs to environmental receptors. The volume of impacted materials requiring management would increase with the sludge generated from the water treatment processes.

Additionally, the mass, and therefore volume, of PCOCs released to groundwater and surface water would be reduced over time from Site sources through the natural geochemical processes described in Appendix E.

7.7.2.3 Short Term Effectiveness

Short-term effectiveness includes evaluation of protection of local communities, worker protection, short-term environmental impacts, and time required to reach remediation goals.

Protection of Local Communities

As described for Alternative 3a (Section 7.6.2.3), Alternative 3b would be protective of Holden Village residents and visitors.

Worker Protection

Potential increased risks to workers related to the additional underground construction required for hydrostatic bulkhead installation and other in-mine controls may exist under this alternative. However, as described under Alternative 3a, appropriate health and safety precautions, consistent with that required by MSHA, would be implemented to reduce potential risks under this alternative.

Environmental Impacts

No additional impacts to aquatic or terrestrial biota are anticipated over those described under Alternative 3a as a result of the remedial actions planned under Alternative 3b.

Time Required to Reach Remedial Goals

Although the installation of hydrostatic bulkheads would increase the level of effort required to implement this alternative, the time required to implement Alternative 3b is expected to be approximately one to two years, which is the same as described under Alternative 3a. Following implementation, the soil RAO would be met.

Results of the post-remediation loading analysis indicate that cadmium and copper concentrations would achieve potential ARARs in Railroad Creek within approximately 50 years. Zinc concentrations are predicted to achieve potential ARARs within approximately 250 years. However, based on the toxicological evaluations provided in Appendix H, short- and long-term post-remediation concentrations are expected to be protective of aquatic life in Railroad Creek.

7.7.2.4 Implementability

Implementability includes technical feasibility, administrative feasibility, and availability of materials. The implementability of Alternative 3b is expected to be the same as Alternative 3a. Additional design and construction efforts would be required under Alternative 3b for installation of hydrostatic bulkheads and other in-mine controls. However, the actions included under this alternative have been successfully implemented at other sites, and are based on conventional construction technologies. Specialized equipment and personnel for completion of underground actions would be available in the surrounding areas.

7.7.2.5 Cost

The total estimated costs associated with Alternative 3b are $28,160,000 (2004 dollars at 7-percent discount rate). The additional costs estimated for this alternative compared to Alternative 3a primarily include costs associated with the installation of hydrostatic bulkheads in the underground mine. Table 7-9 provides a summary of capital and O&M costs for each of the eight candidate alternatives, and cost detail sheets are provided in Appendix I.

Capital costs associated with implementation of Alternative 3b are estimated at approximately $15,970,000. Annual O&M costs associated with monitoring, maintaining the upgradient diversion channels, and operation and maintenance of the collection and treatment systems are estimated to be approximately $260,000.

7.7.3 Natural Resource Restoration

Following implementation, Alternative 3b would achieve the same level of natural resource restoration for soils, vegetation, and terrestrial wildlife as described for Alternative 3a. However, slight improvements in Railroad Creek water quality and aquatic resources would be expected over time through the installation of hydrostatic bulkheads and enhanced treatment of West Area waters, thus additional restoration for these resources would potentially be achieved. A summary of the extent of natural resource restoration expected under each of the candidate remedial alternatives is provided in Appendix J.

7.7.4 Use of Permanent Solutions to the Maximum Extent Practicable

As described for Alternative 3a, the remedial actions included under Alternative 3b constitute permanent solutions under MTCA since potential ARARs are expected to be achieved in the long term without further actions being required (WAC 173-340-200). The loading analysis indicates that PCOC loadings to Site groundwater and surface water would be reduced over time and all potential ARARs are expected to be achieved within approximately 50 to 250 years, depending on the PCOC.

An evaluation the use of permanent solutions to the maximum extent practicable is provided in Section 8 (comparative analysis of alternatives). The evaluation of the practicability of this alternative includes whether the alternative is capable of being designed, constructed, and implemented in a reliable and effective manner, including consideration of cost. In considering cost under this analysis, an alternative shall not be considered practicable if the incremental costs are disproportionate to the incremental degree of benefits provided by the alternative over other lower cost alternatives.

7.7.5 Reasonable Restoration Time Frame

Alternative 3b provides a reasonable restoration time frame as specified under MTCA (WAC 173-340-360(4)(b) and (c)). The factors considered under MTCA are addressed below.

As described in Section 7.7.1, this alternative would address potential risks to human health and the environment in the short term. Minimal potential future risks to human health would be addressed through the removal of soils that exceed potential human health-based ARARs and institutional controls. Likewise, potential risks to terrestrial ecological receptors would be addressed following remedy implementation.

Results of the short-term loading analysis and toxicological evaluations (Appendix H) also indicate that surface water quality would be protective of aquatic life in Railroad Creek in the short term under Alternative 3b. This is an equivalent time frame for protection as achieved by other alternatives that include West Area collection and treatment. Through a combination of source controls, collection, treatment, and natural attenuation processes, potential ARARs are predicted to be achieved in the long term (within approximately 50 to 250 years).

7.8 ALTERNATIVE 4A - WATER MANAGEMENT AND PARTIAL EAST AREA COLLECTION AND TREATMENT

The following subsections provide detailed analysis of the remediation components included under Alternative 4a to address Site soils, surface water and groundwater. Alternative 4a includes the same remediation components described for Alternative 2b, with the addition of partial collection and treatment of East Area seeps and groundwater. To avoid repetition, the following subsections provide an analysis of the additional remediation components included under Alternative 4a.

7.8.1 Threshold Criteria

Evaluation of the two threshold criteria, including overall protection of human health and the environment and compliance with ARARs, is provided in the following subsections for Alternative 4a.

Under Alternative 4a, the collection and treatment of seeps and groundwater in the East Area is anticipated to further reduce metals loading from the tailings piles (primarily copper, iron, and zinc) to Railroad Creek. As a result, greater reductions in PCOC concentrations in Railroad Creek are expected under Alternative 4a compared to Alternative 2b. Estimated loading reductions from East and West Area sources under Alternative 4b are provided in Appendix D, Tables D1-5, D2-5, and D4. The estimated short- and long-term Railroad Creek water quality for this alternative is summarized on Tables 7-1 through 7-4.

7.8.1.1 Overall Protection of Human Health and the Environment

Protection of Human Health and Terrestrial Ecological Receptors

As described for Alternative 2a, the remedial actions included under Alternative 4a are expected to be protective of human health and terrestrial ecological receptors at the Site. The RAO to implement the remedial action in a manner that is protective of human health, including the Holden Village community, during and after construction would be met under this alternative. The soil RAO would also be achieved following remedy implementation.

Protection of Aquatic Life

Results of the post-remediation loading analysis indicate that seasonal dissolved cadmium, copper, and zinc concentrations in Railroad Creek would be reduced following remedy implementation, and would continue to gradually decline over time through natural attenuation. The analysis predicts that the potential surface water criteria for cadmium would be met within approximately 150 years of remedy implementation (Tables 7-1 through 7-4). Concentrations of dissolved copper and zinc are expected to achieve potential criteria within approximately 250 years. However, based on the toxicological evaluations provided in Appendix H, the estimated short-term PCOC concentrations may result in continued potential risks to resident species in Railroad Creek.

Under Alternative 4a, seasonal concentrations of total aluminum and total iron may remain above the potential NRWQC in the short term. However, an analysis of documented aluminum and iron toxicity (Appendix H) indicates that the post-remediation concentrations would be protective of resident aquatic species in Railroad Creek. Over the long term, total aluminum and iron concentrations are expected to gradually decline, approaching the NRWQC and/or background.

The RAOs for groundwater and surface water quality would not be achieved in the short term under Alternative 4a. A discussion of compliance with groundwater and surface water ARARs is provided below in Section 7.8.1.2.

Potential for Short-term Impacts

No additional short-term risks would be anticipated for the local community during or after implementation of this alternative. As described for Alternative 2b, elevated PCOC concentrations in the portal drainage may result in the short term due to flooding of the underground mine workings. These effects have been accounted for in the loading analysis calculations and are not expected to persist into the long term.

Under Alternative 4a, possible short-term increases in metals loading from the tailings piles may result during regrading actions due to the exposure of previously unoxidized tailings to air and storm water (Section 7.2.3). However, measures would be taken during implementation to control storm-water runoff, reduce the volume of tailings disturbed during construction, and to place and compact materials cut back from the side slopes to minimize additional oxidation and surface water infiltration. There is also a potential for slurry losses to Railroad Creek during construction of the East Area partial collection and treatment system. These losses would be minimized through the use of standard engineering controls.

The partial relocation of Railroad Creek and placement of Copper Creek in a culvert may result in short-term impacts to water quality and the aquatic community during construction due to the release of fine-grained sediment after the modified channels are put into service. These impacts would be minimized as possible by exercising appropriate construction best management practices.

7.8.1.2 Compliance with ARARs

Compliance with ARARs includes the evaluation of potential chemical-specific, location-specific, and action-specific ARARs identified in Section 3.

Potential Chemical-specific ARARs

The following subsections evaluate compliance with potential chemical-specific ARARs identified for Site media, including surface water, groundwater, and soil.

Surface Water

Results of the post-remediation loading analysis indicate dissolved cadmium concentrations in Railroad Creek would be below the SWQC within approximately 50 years following implementation of Alternative 4a. The analysis predicts that dissolved copper and zinc would be below the SWQC within approximately 250 years (Tables 7-1 through 7-4).

Dissolved cadmium and zinc concentrations are expected to be below the NRWQC within approximately 150 years and dissolved copper is expected to be below the NRWQC within approximately 250 years (Tables 7-1 through 7-4). Although the post-remediation analysis could not be performed for total aluminum or iron, concentrations are expected to approach the NRWQC and/or background concentrations in the long term.

For the East Area, a point of compliance would be established through a mixing zone where East Area treated effluent discharges to surface water. The CPOC would be monitored at the limits of the established mixing zone.

Groundwater

Portions of the seeps and groundwater beneath the Site would not likely meet potential chemical-specific ARARs in the short or long term under any of the alternatives. Therefore, as discussed under Alternative 2a, it is not practicable to meet potential groundwater ARARs throughout the Site within a reasonable restoration time frame.

Under Alternative 4a, the results of the post-remediation loading analysis indicate that potential ARARs would not be met in the short term at the points where groundwater flows into surface water. As described above for surface water, results of the loading analysis indicate potential ARARs would be achieved in Railroad Creek (represented by stations RC-4 and RC-2) within approximately 250 years. These stations are considered to be generally representative of water quality in Railroad Creek downstream of West and East Area sources. However, it may take longer for some locations within the creek to achieve potential ARARs.

As described for Alternative 2a, CPOCs for Site groundwater would not likely be available for the West Area under Alternative 4a, unless a determination is made that West Area treatment is not practicable or reasonable under MTCA. However, natural attenuation, in conjunction with upgradient water diversion, source controls, and East Area collection and treatment would be more than required to achieve AKART for this area. Therefore, CPOCs at the points where groundwater flows into surface water would apply for this area.

Soils

The potential ARARs identified for soil would be achieved under Alternative 4a.

Potential Location-specific ARARs

As described for Alternative 2b, Alternative 4a would meet all potentially applicable location-specific ARARs through consultation with federal and state agencies during the RD/RA. The actions included under Alternative 4a are not expected to influence archaeological and/or historic sites of significance. Coordination with WDFW and USFWS would be conducted during the RD/RA to identify potentially applicable substantive requirements associated with fish and wildlife protection and incorporate mitigative measures into the RD.

The installation of a Copper Creek culvert and relocation of Railroad Creek (not included under Alternative 2b) would potentially impact shoreline area of the state and thus, consistency with the substantive requirements for shoreline management would evaluated during the remedial design and mitigative measures incorporated into the design. Impacts to fish and wildlife and consistency with the Forest Management Act would be addressed through consultation with USFWS and the Forest Service if necessary.

Potential Action-specific ARARs

Alternative 4a activities associated with construction, creek relocation, installation of open intercept trenches, installation of treatment system outfalls, installation of barrier cutoff walls, installation of a Copper Creek culvert, and enhancement of aquatic life habitat are expected to be in compliance with potential action-specific ARARs.

These alternatives would address action-specific ARARs through the implementation of institutional controls and monitoring. Substantive compliance with CWA construction stormwater requirements; substantive compliance with Hydraulic Project Approval, surface water removal/diversion, and CWA section 404 would be evaluated under this alternative. Substantive compliance with potential action-specific ARARs will be evaluated during the RD through consultation with WDFW, USACOE, EPA, DNR, and Ecology. If remedial activities under Alternative 4a are determined to have temporary impacts to water quality, substantive compliance with requirements for a temporary water quality modification would be achieved. Best management practices will be used to comply with potential substantive stormwater construction requirements and fugitive dust requirements.

Excavated soils and materials removed from the maintenance yard, mill building and lagoon are not expected to be either characteristic hazardous or dangerous waste. However, RCRA and Washington State Dangerous waste regulations may potentially be ARAR if these materials are determined to be hazardous or dangerous waste. These materials would be managed within the area of contamination, stabilized to immobilize the constituents, consolidated within a corrective management unit located on one of the tailings piles, and contained with an appropriate engineered cover in compliance with RCRA and Dangerous Waste regulations.

The tailings piles and waste rock piles would meet relevant and appropriate requirements under the Washington State Requirements for Solid Waste Handling. These areas would be designed to meet the relevant and appropriate requirements to prevent exposure of waste, minimize infiltration, prevent erosion from wind and water, be capable of sustaining native vegetation, address anticipated settlement, provide adequate drainage, provide sufficient stability and mechanical strength, address potential freeze-thaw and desiccation, provide for the management of run on and run off to prevent erosion, and minimize the need for post-closure maintenance (WAC 173-350-400(3)(e)(i)(A) through (H)). Post-closure care requirements as deemed relevant and appropriate would also be met, including maintaining the vegetative cover, preventing run on and run off, and performing appropriate monitoring (173-350-400(7)(a)).

Limited purpose landfill cover requirements are not potentially applicable or relevant and appropriate to this remedial alternative, but would be potentially relevant and appropriate to those alternatives that include an engineered cover on the waste rock piles and/or tailings piles (Alternative 7 and 8).

7.8.2 Primary Balancing Criteria

Evaluation of the five primary balancing criteria, including long-term effectiveness and permanence; reduction of toxicity, mobility, and volume; short-term effectiveness; implementability; and cost is provided in the following subsections for Alternative 4a.

7.8.2.1 Long-term Effectiveness and Permanence

Long-term effectiveness and permanence includes evaluation of the magnitude of residual risk, and the adequacy and reliability of controls.

Magnitude of Residual Risks

As described for Alternative 2a, the actions included under Alternative 4a would be protective of human health and terrestrial ecological receptors. Therefore, the magnitude of remaining human health risks and risks to terrestrial ecological receptors would be low under this alternative.

Following implementation, Railroad Creek water quality is predicted to be improved over Alternatives 1 through 2b due to the partial collection and treatment of East Area seeps and groundwater. Results of the post-remediation loading analysis indicate that PCOC concentrations in Railroad Creek would be below potential ARARs in the long term. However, based on the toxicological evaluations provided in Appendix H, the predicted short-term PCOC concentrations may result in continued potential risks to aquatic life in Railroad Creek.

As described for Alternative 2b, the magnitude of residual risks due to potential surge releases from the underground mine or tailing releases due to potential slope failure would be low under alternative 4a.

Adequacy and Reliability of Controls

East and West Area actions included under this alternative are expected to be moderately implementable and reliable in reducing metals loading from Site sources and providing long-term protection of human health and the environment. The partial collection system is estimated to intercept less than approximately 25 to 30 percent of East Area groundwater and seeps with an estimated collection efficiency of approximately 80 to 90 percent. The reliability of the partial collection system for interception of groundwater originating from the tailings piles while segregating clean water from Railroad Creek is uncertain. Long-term operations and maintenance of chemical addition systems, collection trenches, treatment ponds, and containment areas would be required under this alternative.

The low-energy treatment system(s) included under this alternative for the East Area would be designed to treat seasonal seep and groundwater flows. Chemical addition rates would be controlled based on seasonal flows and water quality, and the treatment ponds would be sized to provide significant detention times and solids removal prior to discharge to Railroad Creek. An important factor in providing consistent effluent quality under Alternative 4a would be the ability to adjust chemical addition rates in response to variations in influent flows and water chemistry.

7.8.2.2 Reduction of Toxicity, Mobility, and Volume

The alkaline precipitation process included for the East Area under Alternative 4a would reduce the mass and volume of PCOCs released to groundwater and surface water. The treatment process would produce stable treatment residuals, and thus reduce the mobility and toxicity of PCOCs to environmental receptors. The volume of impacted materials requiring management would increase with the sludge generated from the water treatment processes.

Additionally, the mass, and therefore volume, of PCOCs released to groundwater and surface water would be reduced over time from Site sources through the source control actions and the natural geochemical processes described in Appendix E.

7.8.2.3 Short-term Effectiveness

Short-term effectiveness includes evaluation of protection of local communities, worker protection, short-term environmental impacts, and time required to reach remediation goals.

Protection of Local Communities

Appropriate measures would be implemented under Alternative 4a to protect Holden Village residents and visitors from potential risks due to increased traffic and heavy equipment operation during remedy construction and implementation. A temporary stream crossing would be constructed over Railroad Creek at the northeast corner of tailings pile 3, to allow some of the vehicles and equipment to bypass the Village during construction. Access to the top of the tailings piles would also be gained from the new stream crossing. However, the increased heavy equipment and truck traffic on the road to the east of the Village would result in short-term impacts to the local community, including the routine Village bus and supply vehicle traffic, disruption to pedestrian use in the area, and increased noise levels.

The partial relocation of Railroad Creek would require additional heavy construction activities on the north side of Railroad Creek, in the vicinity of the Holden Village. These activities would present additional safety risks to the local community and increased noise levels in the vicinity of Holden Village buildings and lodges.

Operation and maintenance of the East Area treatment system would also require periodic deliveries of diesel fuel and treatment chemicals to the Site by barge and truck, and would result in increased traffic and equipment operations on the south side of Railroad Creek during sludge disposal and maintenance activities.

Potential physical hazards to the local community related to the possible development of a rock source located near Tenmile creek would be mitigated using proven engineering controls.

Worker Protection

Potential risks to workers related to the possible generation of fugitive dust or exposure to treatment chemicals and metal constituents during construction and implementation could be adequately mitigated with use of personal protection equipment and engineering controls. Workers at construction and industrial sites are required to comply with the requirements and standards under OSHA.

The installation of hydrostatic bulkheads and other in-mine controls would involve construction work underground in abandoned mine workings on the 300, 1100, and 1500 levels. These actions would present potential physical risks to workers in the event of a collapse or rock fall. However, appropriate health and safety precautions, consistent with that required by MSHA, would be implemented to reduce potential risks to workers under this alternative.

As described for Alternative 2b, development of a rock source near Tenmile creek would present possible physical risks to workers due to the potential for rock fall at this location. However, appropriate health and safety precautions and engineering controls would be implemented to mitigate these potential risks.

Environmental Impacts

In addition to the potential short-term impacts and mitigation measures related to tailings pile regrading and the installation of hydrostatic bulkheads in the 1500-level, as described under Alternative 2b, the partial relocation of Railroad Creek and placement of Copper Creek in a culvert may result in short-term impacts to water quality and the aquatic community during construction due to the release of fine-grained sediment after the modified channels are put into service. These impacts would be minimized to the extent possible by observing fish windows, removing fish from affected reaches prior to construction, and exercising appropriate construction best management practices. There is also a potential for short-term impacts to water temperature due to limited bank cover during maturation of riparian vegetation.

Under Alternative 4a, there is a potential for slurry losses to Railroad Creek during construction of the East Area partial collection and treatment system. Slurry releases would be minimized, as possible, through the performance of pre-construction investigations to identify zones with high-porosity that may require mitigation measures to prevent potential slurry losses to the creek. If zones of high-porosity are encountered, low-permeability filler material (such as straw) may be used to plug high-porosity zones during trench construction, panel construction methods may be implemented, or cement additives used in areas that would be susceptible to leakage. Containment berms may also be constructed on the downgradient side of barrier wall trenches and slurry mixing areas to reduce the potential for releases to the creek.

Time Required to Reach Remedial Goals

Implementation of Alternative 4a is expected to occur over a one- to two-year period of time. Following implementation, the soil RAO would be met. The groundwater RAO is currently being met in monitoring wells located downgradient of the Site, but is not expected to be achieved at all locations beneath the Site. Groundwater quality throughout the site is expected to improve over time, through on-going natural attenuation.

The surface-water RAO is not expected to be achieved under this alternative in the short-term. However, the results of the long-term post-remediation loading analysis indicate surface water and groundwater RAOs would be achieved in Railroad Creek within approximately 250 years.

7.8.2.4 Implementability

The implementability of Alternative 4a, including technical feasibility, administrative feasibility, and availability of services and materials is evaluated in this section.

Technical Feasibility

Actions described under Alternative 4a are implementable. However, construction of the partial groundwater collection and treatment systems would be difficult due to the relatively flat grade, structural considerations related to installation at the base of the tailings piles, variable characteristics of the alluvial materials below the tailings piles, and varying depth to bedrock or dense till. Data collected during the RI indicate the potential for large granitic boulders and tree stumps at the base of the tailings piles, which would result in increased difficulties in construction of the collection and treatment systems. Groundwater collection efficiencies attained with the open collection trenches are uncertain due to the variable subsurface characteristics and depths to bedrock or dense till.

The treatment of groundwater and seeps in the East Area would also be difficult due to the inability to provide flow equalization and the high concentrations of iron that would result in significant chemical addition requirements and sludge generation. Significant chemical addition rates would be required to provide sufficient alkalinity to neutralize the acidity generated from the oxidation and precipitation of dissolved iron constituents. The large volumes of treatment chemicals would require frequent shipments by barge and truck to the Site.

Administrative Feasibility

The Site is located adjacent to the Holden Village, which is operated under a special-use permit issued by the Forest Service, a wilderness area boundary, and Forest Service lands. As a result, coordination between many local agencies and the Holden Village will be required under Alternatives 2 through 8.

The increased construction activities in both the East and West Areas reduce the administrative feasibility of this alternative. The partial relocation of Railroad Creek under Alternative 5a would require increased coordination with the Holden Village while working on the north side of Railroad Creek.

Availability of Services and Materials

The services and materials required to implement this alternative would be available within the Railroad Creek valley or could be mobilized to the Site by barge. Specialized equipment and personnel for completion of underground actions would be available in the surrounding areas.

Treatment system chemicals would be transported to the Site by barge and truck on a regular basis under this alternative and on site personnel would be required to operate and maintain collection and treatment systems.

7.8.2.5 Cost

The total estimated costs associated with Alternative 4a are $34,420,000 (2004 dollars at a 7-percent discount rate). The increased costs estimated for Alternative 4a compared to Alternative 2b are primarily associated with partial Railroad Creek relocation and partial East area collection and treatment. Table 7-9 provides a summary of capital and O&M costs for each of the eight candidate alternatives, and cost detail sheets are provided in Appendix I.

Capital costs associated with implementation of Alternative 4a are estimated at approximately $19,580,000. Annual O&M costs associated with monitoring, maintaining the upgradient diversion channels, and operating and maintaining the collection and treatment systems are estimated to be approximately $300,000.

7.8.3 Natural Resource Restoration

Alternative 4a would be expected to provide a similar level of natural resource restoration as described under 2b. Additional reductions in PCOC concentrations in Railroad Creek would be expected under this alternative, and thus additional restoration for these resources would be achieved. Habitat enhancement measures would also be implemented in Railroad Creek adjacent to the site under Alternative 4a. A summary of the extent of natural resource restoration expected under each alternative is provided in Appendix J.

7.8.4 Use of Permanent Solutions to the Maximum Extent Practicable

The remedial actions implemented under Alternative 4a constitute permanent solutions since potential ARARs are expected to be achieved in the long term without further actions being required (WAC 173-340-200). The post-remediation loading analysis indicates that PCOC loading to Site groundwater and surface water would be reduced over time and potential ARARs are expected to be achieved within150 to 250 years, depending on the PCOC.

An evaluation the use of permanent solutions to the maximum extent practicable is provided in Section 8 (comparative analysis of alternatives). The evaluation of the practicability of this alternative includes whether the alternative is capable of being designed, constructed, and implemented in a reliable and effective manner, including consideration of cost. In considering cost under this analysis, an alternative shall not be considered practicable if the incremental costs are disproportionate to the incremental degree of benefits provided by the alternative over other lower cost alternatives.

7.8.5 Reasonable Restoration Time Frame

Following implementation of Alternative 4a, the soil RAOs would be met. Remedial actions would also be effective in eliminating potential physical hazards to Holden Village residents and visitors related to mine features and potential future risks to human health due to the possible development of groundwater as a drinking water supply.

PCOC loading to groundwater would be reduced over time under Alternative 4a through natural attenuation, upgradient water diversions, source controls, and partial East Area collection and treatment. Results of the post-remediation loading analysis indicate that groundwater RAOs would be achieved at CPOCs in surface water in the West Area (if applicable) and East Areas within approximately 250 years.

Results of the post-remediation loading analysis indicate that the surface water RAO would be achieved within approximately 250 years. However, the results of toxicological evaluations provided in Appendix H indicate that the predicted short-term post-remediation PCOC concentrations may result in continued potential risks to aquatic life in Railroad Creek. Based on this evaluation, and because other practicable alternatives evaluated in this section are expected to be protective of aquatic life in the short term and achieve ARARs within a shorter restoration time frame, the remedial actions included under Alternative 4a would not likely meet MTCA requirements for a reasonable restoration time frame relative to Alternative 3b.

7.9 ALTERNATIVE 4B: WATER MANAGEMENT AND EXTENDED EAST AREA TREATMENT

The following subsections provide detailed analysis of the remediation components included under Alternative 4b to address Site soils, surface water and groundwater. Alternative 4b includes the same actions described under Alternative 4a, with the addition of extended collection and treatment of East Area seeps and shallow groundwater. The following subsections provide an analysis of the additional components under Alternative 4b.

7.9.1 Threshold Criteria

Evaluation of the two threshold criteria, including overall protection of human health and the environment and compliance with ARARs, is provided in the following subsections for Alternative 4b.

The extended collection and treatment of seeps and groundwater in the East Area is anticipated to further reduce metals loading from the tailings piles (primarily copper, iron, and zinc) to Railroad Creek. As a result, greater reductions in PCOC concentrations in Railroad Creek are expected under Alternative 4b compared to Alternative 4a. Estimated loading reductions from East and West Area sources under Alternative 4b are provided in Appendix D, Tables D1-6, D2-6, and D4. The estimated short- and long-term Railroad Creek water quality for this alternative is summarized on Tables 7-1 through 7-4.

7.9.1.1 Overall Protection of Human Health and the Environment

Protection of Human Health and Terrestrial Ecological Receptors

As described for Alternative 2a, the remedial actions included under Alternative 4b are expected to be protective of human health and terrestrial ecological receptors at the Site. The RAO to implement the remedial action in a manner that is protective of human health, including the Holden Village community, during and after construction would be met under this alternative. The soil RAO would also be achieved following remedy implementation.

Protection of Aquatic Life

Results of the post-remediation loading analysis indicate that seasonal dissolved cadmium, copper, and zinc concentrations in Railroad Creek would be reduced following remedy implementation, and would continue to gradually decline over time through natural attenuation. The analysis predicts that potential ARARs would be met in Railroad Creek for cadmium and zinc within approximately 150 years of remedy implementation, and for copper within approximately 250 years (Tables 7-1 through 7-4). However, based on the toxicological evaluations provided in Appendix H, the estimated short-term PCOC concentrations may result in continued potential risks to resident species in Railroad Creek.

Under Alternative 4b, total iron concentrations are expected to be below the NRWQC following remedy implementation in the short term and seasonal aluminum concentrations are expected to approach the NRWQC and/or background in the long term. An analysis of documented aluminum and iron toxicity, presented in Appendix H, indicates that short-term post-remediation concentrations would be protective of resident aquatic species in Railroad Creek.

The RAOs for groundwater and surface water quality would not be achieved in the short term under Alternative 4b. A discussion of compliance with potential groundwater and surface water ARARs is provided below in Section 7.9.1.2.

Potential for Short-term Impacts

Potential short-term impacts to the environment during construction and implementation would be similar to those described under Alternative 4a. However, there would be a greater potential for short-term impacts to groundwater and surface water due to the increased volume of tailings disturbed during slope regrading activities (approximately 750,000 to 1,000,000 cubic yards). Increased regrading of side slopes would be required under Alternative 4b to install the extended collection systems at the base of the piles. There is also a greater potential for slurry losses to

Railroad Creek during construction of the extended East Area barrier wall and collection system, due to the required trench depths and proximity to Railroad Creek. As described for Alternative 4a, these losses would be minimized through the use of standard engineering controls.

7.9.1.2 Compliance with ARARs

Compliance with ARARs includes the evaluation of potential chemical-specific, location-specific, and action-specific ARARs identified in Section 3.

Potential Chemical-specific ARARs

The following subsections evaluate compliance with potential chemical-specific ARARs identified for Site media, including surface water, groundwater, and soil.

Surface Water

Results of the post-remediation loading analysis indicate dissolved cadmium concentrations in Railroad Creek would be below the SWQC following implementation of Alternative 4b in the short term. The analysis predicts that dissolved zinc concentrations would be below the SWQC within approximately 150 years and dissolved copper would be below the SWQC within approximately 250 years (Tables 7-1 through 7-4).

Dissolved cadmium and zinc concentrations are expected to be below the NRWQC within approximately 150 years and dissolved copper is expected to be below the NRWQC within approximately 250 years (Tables 7-1 through 7-4). Although the post-remediation analysis could not be performed for total aluminum or iron, iron concentrations are expected to be below the NRWQC following remedy implementation, and aluminum concentrations are expected to approach background and/or the NRWQC in the long term.

For the East Area, a point of compliance would be established through a mixing zone where East Area treated effluent discharges to surface water. The CPOC would be monitored at the limits of the established mixing zone.

Groundwater

Portions of the seeps and groundwater beneath the Site would not likely meet potential chemical-specific ARARs in the short or long term under any of the alternatives. Therefore, as discussed under Alternative 2a, it is not practicable to meet potential groundwater ARARs throughout the Site within a reasonable restoration time frame.

The results of the post-remediation loading analysis indicate that potential ARARs would not be met in the short term at points where groundwater flows into surface water. As described above for surface water, results of the loading analysis indicate potential ARARs would be achieved at points in Railroad Creek (represented by stations RC-4 and RC-2) within approximately 250 years. These stations are considered to be generally representative of water quality in Railroad Creek downstream of West and East Area sources. However, it may take longer for some locations within the creek to achieve potential ARARS.

As described for Alternative 2a, CPOCs for Site groundwater would not likely be available for the West Area under Alternative 4b, unless a determination is made that West Area treatment is not practicable or reasonable under MTCA. However, natural attenuation, in conjunction with upgradient water diversion, source controls, and East Area collection and treatment would be more than required to achieve AKART for this area. Therefore, CPOCs at the points where groundwater flows into surface water would apply for this area.

Soils

As described for Alternative 4a, the potential ARARs identified for soil would be achieved under Alternative 4b.

Potential Location-specific ARARs

Compliance with potential location-specific ARARs under Alternative 4b would be the same as discussed under Alternative 4a in Section 7.8.1.2.

Potential Action-specific ARARs

Compliance with potential action-specific ARARs under Alternative 4b would be the same as discussed under Alternative 4a in Section 7.8.1.2.

7.9.2 Primary Balancing Criteria

Evaluation of the five primary balancing criteria, including long-term effectiveness and permanence; reduction of toxicity, mobility, and volume; short-term effectiveness; implementability; and cost is provided in the following subsections for Alternative 4b.

7.9.2.1 Long-term Effectiveness and Permanence

Long-term effectiveness and permanence includes evaluation of the magnitude of residual risk and adequacy and reliability of controls.

Magnitude of Residual Risks

As described for Alternative 4a, the actions included under Alternative 4b would be protective of human health and terrestrial ecological receptors. Therefore, the magnitude of remaining human health risks and risks to terrestrial ecological receptors would be low under this alternative.

If it is assumed that extended collection of groundwater can be implemented effectively, greater improvements in the short- and long-term post-remediation Railroad Creek water quality are estimated under Alternative 4b compared to Alternative 4a, due to the additional collection and treatment of East Area water. Results of the post-remediation loading analysis indicate PCOC concentrations would be below potential surface water ARARs within approximately 250 years. However, based on the toxicological evaluations provided in Appendix H, the predicted short-term PCOC concentrations may result in continued potential risks to aquatic species in Railroad Creek.

The actions included under Alternative 4b would significantly reduce iron concentrations in Railroad Creek in the short term. However, the extent of aquatic habitat improvement resulting from the incremental reduction in iron concentrations under this alternative is unknown.

Metal precipitates and sludge generated in the treatment ponds would require periodic removal and disposal in a suitable containment location on site. Treatment residuals from alkaline precipitation processes are expected to be stable products with reduced metals mobility. However, the containment areas would require periodic maintenance to reduce long-term surface water infiltration.

As described for Alternative 2b, the magnitude of residual risks due to potential surge releases from the underground mine or tailings releases due to potential slope failure would be low under Alternative 4b.

Adequacy and Reliability of Controls

Actions included under Alternative 4b are expected to be difficult to implement. The extended East Area collection system is estimated to intercept groundwater and seeps in the short-term with an estimated collection efficiency of approximately 80 percent. However, there is significant uncertainty regarding the long-term reliability of a subsurface collection trench and drain in the East Area due to the high potential for the formation of iron and other metal oxides to foul and plug the system.

The low-energy treatment system(s) included under this alternative for the East Area would be designed to treat seasonal seep and groundwater flows. Chemical addition rates would be controlled based on seasonal flows and water quality, and the treatment ponds would be sized to provide significant detention times and solids removal prior to discharge to Railroad Creek. An important factor in providing consistent effluent quality under Alternative 4b would be the ability to adjust chemical addition rates in response to variations in influent flows and water chemistry.

7.9.2.2 Reduction of Toxicity, Mobility, and Volume

The alkaline precipitation process included for the East Area under Alternative 4b would reduce the mass and volume of PCOCs released to groundwater and surface water. The treatment process would produce stable treatment residuals, and thus reduce the mobility and toxicity of PCOCs to environmental receptors. The volume of impacted materials requiring management would increase with the sludge generated from the water treatment processes.

Additionally, the mass, and therefore volume, of PCOCs released to groundwater and surface water would be reduced over time from Site sources through the source control actions and the natural geochemical processes described in Appendix E.

7.9.2.3 Short-term Effectiveness

Short-term effectiveness includes evaluation of protection of local communities, worker protection, short-term environmental impacts, and time required to reach remediation goals.

Protection of Local Communities

Appropriate measures would be implemented under Alternative 4b to protect Holden Village residents and visitors from potential risks due to increased traffic and heavy equipment operation during remedy construction and implementation. A temporary stream crossing would be constructed over Railroad Creek at the northeast corner of tailings pile 3, to allow some of the vehicles and equipment to bypass the Village during construction. Access to the top of the tailings piles would also be gained from the new stream crossing. However, the increased heavy equipment and truck traffic on the road to the east of the Village would result in short-term impacts to the local community, including the routine Village bus and supply vehicle traffic, disruption to pedestrian use in the area, and increased noise levels. The level of construction efforts (e.g., large-scale tailings regrading, extended barrier wall construction, etc.), and therefore potential safety risks to the public, would be greater under Alternative 4b than under Alternative 4a.

Operation and maintenance of the East Area treatment system would require periodic deliveries of diesel fuel and treatment chemicals to the Site by barge and truck, and would result in increased traffic and equipment operations on the south side of Railroad Creek during sludge disposal and maintenance activities.

Potential physical hazards to the local community related to the possible development of a rock source located near Tenmile Creek would be mitigated using proven engineering controls.

Worker Protection

Potential risks to workers and mitigation measures implemented under Alternative 4b would be as described for Alternative 4a in Section 7.8.2.3. However, as described above, the level of construction activities, and therefore, potential safety risks to workers, would be greater for Alternative 4b than for Alternative 4a.

Environmental Impacts

The potential for short-term impacts to Railroad Creek resulting from tailings pile regrading would be greater under Alternative 4b than under Alternatives 1 through 4a, as discussed in Section 7.2.3. This is due to the large-scale regrading required for installation of the extended collection and treatment system at the base of the tailings piles. The potential impacts related to elevated metals concentrations in storm-water runoff would be mitigated, as possible, through the implementation of storm-water controls and collection and treatment during construction.

As described for Alternative 4a, the partial relocation of Railroad Creek and placement of Copper Creek in a culvert may result in short-term impacts to water quality and the aquatic community during construction due to the release of fine-grained sediment after the modified channels are put into service. These impacts would be minimized to the extent possible by exercising appropriate construction best management practices. There is also a potential for short-term impacts to water temperature due to limited bank cover during maturation of riparian vegetation.

The potential for slurry losses to Railroad Creek would be greater under Alternative 4b during construction of the extended East Area collection and treatment system. As described under Alternative 4a, slurry releases would be minimized, as possible, through the performance of pre-construction investigations to identify zones with high-porosity that may require mitigation measures to prevent potential slurry losses to the creek. If zones of high-porosity are encountered, low-permeability filler material (such as straw) may be used to plug high-porosity zones during trench construction, panel construction methods may be implemented, or cement additives used in areas that would be susceptible to leakage. Containment berms may also be constructed on the downgradient side of barrier wall trenches and slurry mixing areas to reduce the potential for releases to the creek.

Time Required to Reach Remedial Goals

Implementation of this alternative is expected to occur over a two- to three-year period of time. Following implementation, the soil RAO would be met. The groundwater RAO is currently being met in monitoring wells located downgradient of the Site, but is not expected to be achieved at all locations beneath the Site. Groundwater quality throughout the site is expected to improve over time, through on-going natural attenuation.

The surface-water RAO is not expected to be achieved under this alternative in the short-term. However, the results of the long-term post-remediation loading analysis indicate surface water and groundwater RAOs would be achieved in Railroad Creek within approximately 250 years.

7.9.2.4 Implementability

The implementability of Alternative 4b, including technical feasibility, administrative feasibility, and availability of services and materials is evaluated in this section.

Technical Feasibility

The actions included under Alternative 4b would be difficult to implement. Construction of the extended groundwater collection and treatment systems would be difficult due to the relatively flat grade, structural considerations related to installation at the base of the tailings piles, variable characteristics of the alluvial materials below the tailings piles, varying depth to bedrock or dense till, and the deep trench construction required at the base of the tailings piles where there is limited room for construction. Data collected during the RI indicate the potential for large granitic boulders and tree stumps at the base of the tailings piles, which would also result in increased difficulties in construction of the collection and treatment systems. Groundwater collection efficiencies achieved with the collection trench and barrier wall installations are uncertain due to the variable subsurface characteristics and depths to bedrock or dense till.

The deep collection trench would be prone to fouling and plugging with metal precipitates. The treatment of groundwater and seeps in the East Area would also be difficult due to the high concentrations of iron resulting in significant chemical addition requirements and sludge generation rates, and due to the limited area for construction of treatment systems to the east of tailings piles 1 and 3. High chemical addition rates would be required to provide sufficient alkalinity to neutralize the acidity generated from the oxidation and precipitation of dissolved iron constituents. The large volumes of treatment chemicals would require frequent shipments by barge and truck to the Site.

Administrative Feasibility

As described for Alternative 4a, coordination between many local agencies and the Holden Village would be required under Alternatives 2 through 8. Alternative 4b would have lower administrative implementability due to the increased construction requirements and duration of construction activities.

Availability of Services and Materials

As described for Alternative 4a, the services and materials required for implementation of this alternative would be available within the Railroad Creek valley or could be mobilized to the Site by barge.

Large volumes of treatment chemicals would need to be transported to the Site by barge and truck on a regular basis under this alternative, and on site personnel would be required to operate and maintain collection and treatment systems.

7.9.2.5 Cost

The total estimated cost associated with Alternative 4b is approximately $67,470,000 (2004 dollars at a 7-percent discount rate). The increased costs estimated for Alternatives 4b compared to Alternative 4a are primarily associated with the increased earthwork and barrier wall/collection system construction under this alternative. Table 7-9 provides a summary of capital and O&M costs for each of the eight candidate alternatives, and cost detail sheets are provided in Appendix I.

Capital costs associated with implementation of Alternative 4b are estimated at approximately $40,400,000. Annual O&M costs associated with monitoring, maintaining the upgradient diversion channels, and operating and maintaining the collection and treatment systems are estimated to be approximately $400,000.

7.9.3 Natural Resource Restoration

Alternative 4b would achieve a similar level of natural resource restoration as described for Alternative 4a. Additional improvements in Railroad Creek water quality is expected under this alternative through the extended collection and treatment of East Area waters. Habitat enhancement measures would also be implemented in Railroad Creek adjacent to the site under Alternative 4b. A summary of the extent of natural resource restoration expected under each candidate alternative is provided in Appendix J.

7.9.4 Use of Permanent Solutions to the Maximum Extent Practicable

As described for Alternative 4a, the remedial actions included under Alternative 4b constitute permanent solutions under MTCA since potential ARARs are expected to be achieved in the long term without further actions being required (WAC 173-340-200). The post-remediation loading analysis indicates that PCOC loading to Site groundwater and surface water would be reduced over time and potential ARARs are expected to be achieved within 150 to 250 years, depending on the PCOC.

An evaluation the use of permanent solutions to the maximum extent practicable is provided in Section 8 (comparative analysis of alternatives). The evaluation of the practicability of this alternative includes whether the alternative is capable of being designed, constructed, and implemented in a reliable and effective manner, including consideration of cost. In considering cost under this analysis, an alternative shall not be considered practicable if the incremental costs are disproportionate to the incremental degree of benefits provided by the alternative over other lower cost alternatives.

7.9.5 Reasonable Restoration Time Frame

Following implementation of Alternative 4b, the soil RAOs would be met. Remedial actions would also be effective in eliminating potential physical hazards to Holden Village residents and visitors related to mine features and potential future risks to human health due to the possible development of groundwater as a drinking water supply.

PCOC loading to groundwater would be reduced over time under Alternative 4b through natural attenuation, upgradient water diversions, source controls, and extended East Area collection and treatment. Results of the post-remediation loading analysis indicate that groundwater RAOs would be achieved at CPOCs in surface water in the West Area (if applicable) and East Areas within approximately 250 years.

Results of the post-remediation loading analysis indicate that the surface water RAO would be achieved within approximately 250 years. However, the results of toxicological evaluations provided in Appendix H indicate that the predicted short-term post-remediation PCOC concentrations may result in continued potential risks to aquatic life in Railroad Creek. Based on this evaluation, and because other practicable alternatives evaluated in this section are expected to be protective of aquatic life in the short term and achieve ARARs within a shorter restoration time frame, the remedial actions included under Alternative 4b would not likely meet MTCA requirements for a reasonable restoration time frame relative to Alternative 3b.

7.10 ALTERNATIVE 4C: WATER MANAGEMENT, EXTENDED RAILROAD CREEK RELOCATION, AND EAST AREA TREATMENT

The following subsections provide detailed analysis of the remediation components included under Alternative 4c to address Site soils, surface water and groundwater. Alternative 4c includes the same actions as described under Alternative 4b, substituting extended Railroad Creek relocation and construction of an open collection system in the former Railroad Creek channel for the extended barrier wall/collection system described under Alternative 4b. The following subsections provide an analysis of the unique components under Alternative 4c.

Under Alternative 4c, the extended relocation of railroad creek and use of the existing channel for collection and treatment of East Area Seeps and groundwater is anticipated to achieve similar reductions in metals loading from the tailings piles to Railroad Creek as described under Alternative 4b. Relocation of the creek to the north would likely result in enhanced aquatic habitat adjacent to the Site, and reductions in metals loading from the East and West Areas under Alternative 4c would also likely result in gradual improvements to downstream aquatic habitat. Estimated loading reductions from East and West Area sources under Alternative 4c are summarized in Appendix D, Tables D1-7, D2-7, and D4. The estimated short- and long-term Railroad Creek water quality for this alternative is summarized on Tables 7-1 through 7-4.

7.10.1 Threshold Criteria

Evaluation of the two threshold criteria, including overall protection of human health and the environment and compliance with ARARs, is provided in the following subsections for Alternative 4c.

7.10.1.1 Overall Protection of Human Health and the Environment

Protection of Human Health and Terrestrial Ecological Receptors

As described for Alternative 4b, the remedial actions included under Alternative 4c are expected to be protective of human health and terrestrial ecological receptors at the Site. The RAO to implement the remedial action in a manner that is protective of human health, including the Holden Village community, during and after construction would be met under this alternative. The soil RAO would also be achieved following remedy implementation.

Protection of Aquatic Life

Results of the post-remediation loading analysis indicate that seasonal dissolved cadmium, copper, and zinc concentrations in Railroad Creek would be reduced following remedy implementation, and would continue to gradually decline over time through natural attenuation. The analysis predicts that potential ARARs for cadmium and zinc would be met within approximately 150 years of remedy implementation and potential copper ARARs would be met within approximately 250 years (Tables 7-1 through 7-4). However, based on the toxicological evaluations provided in Appendix H, the estimated short-term PCOC concentrations may result in continued potential risks to resident species in Railroad Creek.

Under Alternative 4c, total iron concentrations are expected to comply with the NRWQC following remedy implementation in the short term. Seasonal concentrations of total aluminum are expected to approach the NRWQC and/or background in the long term. An analysis of documented aluminum and iron toxicity, presented in Appendix H, indicates that short-term post-remediation concentrations would be protective of aquatic life in Railroad Creek.

The RAOs for groundwater and surface water quality would not be achieved in the short term under Alternative 4c. A discussion of compliance with potential groundwater and surface water ARARs is provided below in Section 7.10.1.2.

Potential for Short-term Impacts

Potential short-term impacts to the environment during construction and implementation would be similar to those described under Alternative 4a. However, the potential for short-term impacts to water quality due to potential releases during regrading and barrier wall/collection system construction are expected to be reduced through the relocation of Railroad Creek away from the base of the tailings piles, thereby increasing the distance between construction activities and surface water. Less tailings regrading would also be required under Alternative 4c.

Alternative 4c would have a higher potential for short-term temperature impacts and impacts to surface water and aquatic life due to the release of fine-grained sediment after the new extended Railroad Creek channel is put into service. These potential impacts would be minimized to the extent possible by exercising appropriate construction best management practices.

7.10.1.2 Compliance with ARARs

Compliance with ARARs includes the evaluation of potential chemical-specific, location-specific, and action-specific ARARs identified in Section 3.

Potential Chemical-specific ARARs

The following subsections evaluate compliance with potential chemical-specific ARARs identified for site media, including surface water, groundwater, and soil.

Surface Water

Results of the post-remediation loading analysis for Alternative 4c indicate dissolved cadmium concentrations in Railroad Creek would be below the SWQC within approximately 50 years. The analysis predicts that dissolved zinc concentrations would be below the SWQC within approximately 150 years and dissolved copper would be below the SWQC within approximately 250 years (Tables 7-1 through 7-4).

Dissolved cadmium and zinc concentrations are expected to be below the NRWQC within approximately 150 years and dissolved copper is expected to be below the NRWQC within approximately 250 years (Tables 7-1 through 7-4). Although the post-remediation loading analysis could not be performed for total aluminum or iron, iron concentrations are expected to be below the NRWQC following remedy implementation in the short term. Aluminum concentrations are expected to approach the NRWQC and/or background in the long-term.

For the East Area, a point of compliance would be established through a mixing zone where East Area treated effluent discharges to surface water. The CPOC would be monitored at the limits of the established mixing zone.

Groundwater

Portions of the seeps and groundwater beneath the Site would not likely meet potential chemical-specific ARARs in the short or long term under any of the alternatives. Therefore, as discussed under Alternative 2a, it is not practicable to meet potential groundwater ARARs throughout the Site within a reasonable restoration time frame.

The results of the post-remediation loading analysis indicate that potential ARARs would not be met in the short term at points where groundwater flows into surface water. As described above for surface water, results of the loading analysis indicate potential ARARs would be achieved at points in Railroad Creek (represented by stations RC-4 and RC-2) within approximately 250 years. These stations are considered to be generally representative of water quality in Railroad Creek downstream of West and East Area sources. However, it may take longer for some locations within the creek to achieve potential ARARS.

As described for Alternative 2a, CPOCs for Site groundwater would not likely be available for the West Area under Alternative 4c, unless a determination is made that West Area treatment is not practicable or reasonable under MTCA. However, natural attenuation, in conjunction with upgradient water diversion, source controls, and extended East Area collection and treatment would be more than required to achieve AKART for this area. Therefore, CPOCs at the points where groundwater flows into surface water would apply for this area.

Soils

As described for Alternatives 4a and 4b, the potential ARARs identified for soil would be achieved under Alternative 4c.

Potential Location-specific ARARs

Compliance with potential location-specific ARARs under Alternative 4c would be the same as discussed for Alternatives 4a and 4b in Section 7.8.1.2.

Potential Action-specific ARARs

Compliance with potential action-specific ARARs under Alternative 4c would be the same as discussed for Alternatives 4a and 4b in Section 7.8.1.2.

7.10.2 Primary Balancing Criteria

Evaluation of the five primary balancing criteria, including long-term effectiveness and permanence; reduction of toxicity, mobility, and volume; short-term effectiveness; implementability; and cost is provided in the following subsections for Alternative 4c.

7.10.2.1 Long-term Effectiveness and Permanence

Long-term effectiveness and permanence includes evaluation of the magnitude of residual risk and adequacy and reliability of controls.

Magnitude of Residual Risks

As described for Alternatives 4a and 4b, the actions included under Alternative 4c would be protective of human health and terrestrial ecological receptors. Therefore, the magnitude of remaining human health risks and risks to terrestrial ecological receptors would be low under this alternative.

If it is assumed that extended relocation of Railroad Creek and the collection and treatment of East Area groundwater and seeps can be implemented effectively, similar improvements in the short- and long-term post-remediation Railroad Creek water quality are estimated under Alternative 4c as described for 4b. Results of the post-remediation loading analysis indicate PCOC concentrations would be below potential surface water ARARs within approximately 250 years. However, based on the toxicological evaluations provided in Appendix H, the predicted short-term PCOC concentrations may result in continued potential risks to aquatic species in Railroad Creek.

Metal precipitates and sludge generated in the treatment ponds would require periodic removal and disposal in a suitable containment location on site. Treatment residuals from alkaline precipitation processes are expected to be stable products with reduced metals mobility. However, the containment areas would require periodic maintenance to reduce long-term surface water infiltration.

As described for Alternative 2b, the magnitude of residual risks due to potential surge releases from the underground mine or tailings releases due to potential slope failure would be low under Alternative 4c.

Adequacy and Reliability of Controls

East and West Area actions are expected to be moderately implementable and reliable in reducing metals loading from Site sources and providing long-term protection of human health and the environment. The extended relocation of Railroad Creek to the north and use of the existing creek channel for groundwater collection and treatment is estimated to collect East Area seeps and groundwater with a collection efficiency of approximately 80 to 90 percent. However, there is a potential for an influx of Railroad Creek water to enter the East Area collection and treatment system, especially in the reach adjacent to tailings pile 2, where the valley narrows and space is limited to the north for Railroad Creek relocation. This has been accounted for in the loading analysis and would need to be considered in the design.

Taking into consideration the potential influx of Railroad Creek water, an open collection system constructed in the former Railroad Creek channel is still expected to be more reliable than the collection systems included under Alternatives 4a or 4b.

The low-energy treatment system(s) included under this alternative for the East Area would be designed to treat seasonal seep and groundwater flows. Chemical addition rates would be controlled based on seasonal flows and water quality, and the treatment ponds would be sized to provide significant detention times and solids removal prior to discharge to Railroad Creek. An important factor in providing consistent effluent quality under Alternative 4c would be the ability to adjust chemical addition rates in response to variations in influent flows and water chemistry.

7.10.2.2 Reduction of Toxicity, Mobility, and Volume

The alkaline precipitation process included for the East Area under Alternative 4c would reduce the mass and volume of PCOCs released to groundwater and surface water. The treatment process would produce stable treatment residuals, and thus reduce the mobility and toxicity of PCOCs to environmental receptors. The volume of impacted materials requiring management would increase with the sludge generated from the water treatment processes.

Additionally, the mass, and therefore volume, of PCOCs released to groundwater and surface water would be reduced over time from Site sources through the source control actions and the natural geochemical processes described in Appendix E.

7.10.2.3 Short-term Effectiveness

Short-term effectiveness includes evaluation of protection of local communities, worker protection, short-term environmental impacts, and time required to reach remediation goals.

Protection of Local Communities

Appropriate measures would be implemented under Alternative 4c to protect Holden Village residents and visitors from potential risks due to increased traffic and heavy equipment operation during remedy construction and implementation. A temporary stream crossing would be constructed over Railroad Creek at the northeast corner of tailings pile 3, to allow some of the vehicles and equipment to bypass the Village during construction. Access to the top of the tailings piles would also be gained from the new stream crossing. However, the increased heavy equipment and truck traffic on the road to the east of the Village would result in short-term impacts to the local community, including the routine Village bus and supply vehicle traffic, disruption to pedestrian use in the area, and increased noise levels.

While there would be significantly less tailings regrading under Alternative 4c than Alternative 4b, Alternative 4c would require relocation of Railroad Creek to the north, and therefore heavy construction work would be required adjacent to the Holden Village. This would result in increased noise and risks to the local community, and the removal of trees that currently provide a visual screen between the Village and the tailings piles.

Operation and maintenance of the East Area treatment system would require periodic deliveries of diesel fuel and treatment chemicals to the Site by barge and truck, and would result in increased traffic and equipment operations on the south side of Railroad Creek during sludge disposal and maintenance activities.

Potential physical hazards to the local community related to the possible development of a rock source near Tenmile Creek would be mitigated using proven engineering controls.

Worker Protection

Potential risks to workers and mitigation measures implemented under Alternative 4c would be similar to those described for Alternative 4a in Section 7.8.2.3. However, the level of construction activities (e.g., extended Railroad Creek relocation), and therefore, potential safety risks to workers, would be greater for Alternative 4c.

Environmental Impacts

Potential short-term impacts to the environment during construction and implementation would be similar to Alternative 4a (Section 7.8.2.3). However, the potential for short-term impacts to water quality due to potential releases during regrading and barrier wall/collection system construction is expected to be reduced by relocating Railroad Creek away from the base of the tailings piles, thereby increasing the distance between the construction activities and surface water. Less tailings regrading would also be required under Alternative 4c.

Areas between the existing Railroad Creek channel and the Holden Village would be disturbed during construction of the new Railroad Creek alignment. However, disturbed areas would be reclaimed and the new channel would be designed to provide enhanced aquatic habitat.

Under Alternative 4c, there would be an increased potential for short-term impacts to water quality and aquatic life during the extended relocation of Railroad Creek, due to the release of fine-grained sediment after the modified channel is put into service. As described under Alternatives 4a and 4b, these impacts would be minimized to the extent possible by implementing appropriate construction best management practices. There is also a potential for short-term impacts to water temperature under this alternative due to limited bank cover during maturation of riparian vegetation.

Time Required to Reach Remedial Goals

Implementation of this alternative is expected to occur over a two- to three-year period of time. Following implementation, the soil RAO would be met. The groundwater RAO is currently being met in monitoring wells located downgradient of the Site, but is not expected to be achieved at all locations beneath the Site. Groundwater quality throughout the site is expected to improve over time, through on-going natural attenuation.

The surface-water RAO is not expected to be achieved under this alternative in the short-term. However, the results of the long-term post-remediation loading analysis indicate surface water and groundwater RAOs would be achieved in Railroad Creek within approximately 250 years.

7.10.2.4 Implementability

Implementability includes the evaluation of technical feasibility, administrative feasibility, and availability of services and materials.

Technical Feasibility

The actions described under this alternative are moderately implementable. The relocation of Railroad Creek to the north would have moderately implementability due to the increased design requirements for configuration the new channel alignment and limited space on the north side of the creek adjacent to tailings pile 2 for relocation. Construction of the groundwater collection and treatment systems within the existing creek bed would also be moderately implementable due to the relatively flat grade, variable characteristics of the alluvial materials below the tailings piles, and estimated depth to bedrock or dense till. Construction of the collection and treatment systems within the existing creek channel is expected to be more implementable than installation of the barrier wall and deep collection trench at the base of the tailings piles as described for Alternatives 4a and 4b.

As described for Alternative 4b, the treatment of groundwater and seeps in the East Area would be difficult due to the high concentrations of iron resulting in significant chemical addition requirements and sludge generation rates. High chemical addition rates would be required to provide sufficient alkalinity to neutralize the acidity generated from the oxidation and precipitation of dissolved iron constituents. The large volumes of treatment chemicals would require periodic shipments by barge and truck to the Site.

Administrative Feasibility

As described for Alternatives 4a and 4b, coordination between many local agencies and the Holden Village would be required under Alternatives 2 through 8. Alternative 4c would have lower administrative implementability due to the increased coordination required with local agencies and the Holden Village for extended relocation of Railroad Creek.

Availability of Services and Materials

As described for Alternatives 4a and 4b, the services and materials required for implementation of this alternative would be available within the Railroad Creek valley or could be mobilized to the Site by barge.

Large volumes of treatment chemicals would be transported to the Site by barge and truck on a regular basis under this alternative and on site personnel would be required to operate and maintain collection and treatment systems.

7.10.2.5 Cost

The total estimated cost associated with Alternative 4c is approximately $32,450,000 (2004 dollars at a 7-percent discount rate). The costs estimated for Alternative 4c are lower than the costs associated with Alternative 4b primarily due to the reduced earthwork and barrier wall construction under this alternative. Table 7-9 provides a summary of capital and O&M costs for each of the eight candidate alternatives, and cost detail sheets are provided in Appendix I.

Capital costs associated with implementation of Alternative 4c are estimated at approximately $17,550,000. Annual O&M costs associated with monitoring, maintaining the upgradient diversion channels, and operating and maintaining the collection and treatment systems are estimated to be approximately $380,000.

7.10.3 Natural Resource Restoration

Alternative 4c would achieve a similar level of natural resource restoration as described for Alternatives 4a and 4b. The extended relocation of Railroad Creek to the north would also be expected to provide increased restoration of aquatic habitat adjacent to, and immediately downstream of the Site.

Similar reductions in PCOC loading to Railroad Creek would be expected under this alternative compared to Alternative 4b. Gradual improvements in surface-water and groundwater quality are also expected in the West Area due to source controls, upgradient diversions, and mine actions. A summary of the extent of natural resource restoration expected under each candidate remedial alternative is provided in Appendix J.

7.10.4 Use of Permanent Solutions to the Maximum Extent Practicable

As described for Alternatives 4a and 4b, the remedial actions included under Alternative 4c constitute permanent solutions under MTCA since potential ARARs are expected to be achieved in the long term without further actions being required (WAC 173-340-200). The post-remediation loading analysis indicates that PCOC loading to Site groundwater and surface water would be reduced over time and potential ARARs are expected to be achieved within 150 to 250 years, depending on the PCOC.

An evaluation the use of permanent solutions to the maximum extent practicable is provided in Section 8 (comparative analysis of alternatives). The evaluation of the practicability of this alternative includes whether the alternative is capable of being designed, constructed, and implemented in a reliable and effective manner, including consideration of cost. In considering cost under this analysis, an alternative shall not be considered practicable if the incremental costs are disproportionate to the incremental degree of benefits provided by the alternative over other lower cost alternatives.

7.10.5 Reasonable Restoration Time Frame

Following implementation of Alternative 4c, the soil RAOs would be met. Remedial actions would also be effective in eliminating potential physical hazards to Holden Village residents and visitors related to mine features and potential future risks to human health due to the possible development of groundwater as a drinking water supply.

PCOC loading to groundwater would be reduced over time under Alternative 4c through natural attenuation, upgradient water diversions, source controls, and extended East Area collection and treatment. Results of the post-remediation loading analysis indicate that groundwater RAOs would be achieved at CPOCs in surface water in the West Area (if applicable) and East Areas within approximately 250 years.

Results of the post-remediation loading analysis indicate that the surface water RAO would be achieved within approximately 250 years. However, the results of toxicological evaluations provided in Appendix H indicate that the predicted short-term post-remediation PCOC concentrations may result in continued potential risks to aquatic life in Railroad Creek. Based on this evaluation, and because other practicable alternatives evaluated in this section are expected to be protective of aquatic life in the short term and achieve ARARs within a shorter restoration time frame, the remedial actions included under Alternative 4c would not likely meet MTCA requirements for a reasonable restoration time frame relative to Alternative 3b.

7.11 ALTERNATIVE 5A - WATER MANAGEMENT, PARTIAL EAST AREA COLLECTION, AND EAST/WEST AREA TREATMENT (LOW-ENERGY TREATMENT)

The following subsections provide detailed analysis of the remediation components included under Alternative 5a to address Site soils, surface water and groundwater. This alternative combines the actions included under Alternatives 3b and 4a. As Alternative 5a includes the same remediation components described for Alternatives 3b and 4a, the following subsections provide an analysis of the combined effects of these actions under this alternative.

Under Alternative 5a, the underground mine actions, upgradient water diversions, source controls, and West Area treatment are expected to significantly reduce PCOC loading to the subsurface and improve groundwater quality throughout the Site. The collection and treatment of seeps and groundwater in the both the East and West Areas is also anticipated to further reduce metals loading to Railroad Creek. Estimated loading reductions from East and West Area sources under Alternative 5a are provided in Appendix D, Tables D1-8, D2-8, and D4. The estimated short- and long-term post-remediation Railroad Creek water quality under this alternative is summarized in Tables 7-1 through 7-4.

7.11.1 Threshold Criteria

Evaluation of the two threshold criteria, including overall protection of human health and the environment and compliance with ARARs, is provided in the following subsections for Alternative 5a.

7.11.1.1 Overall Protection of Human Health and the Environment

Protection of Human Health and Terrestrial Ecological Receptors

As described under Alternatives 3b and 4a, the actions included under Alternative 5a are expected to be protective of human health and terrestrial ecological receptors at the Site. The RAO to implement the remedial action in a manner that is protective of human health, including the Holden Village community, during and after construction would be met under this alternative. The soil RAO would also be achieved following remedy implementation.

Protection of Aquatic Life

Results of the post-remediation loading analysis indicate that seasonal dissolved cadmium, copper, and zinc concentrations in Railroad Creek would be reduced following remedy implementation, and would continue to gradually decline over time through natural attenuation. The analysis predicts that the potential ARARS for cadmium, copper, and zinc would be met within approximately 50 years of remedy implementation (Tables 7-1 through 7-4). However, based on the toxicological evaluations provided in Appendix H, post-remediation PCOC concentrations under Alternative 5a would be protective of resident species in Railroad Creek, including salmonids and their prey, following remedy implementation in the short term.

Under Alternative 5a, seasonal concentrations of total aluminum and total iron may remain above the potential NRWQC in the short term. However, an analysis of documented aluminum and iron toxicity, presented in Appendix H, indicates that the short-term post-remediation concentrations would be protective of aquatic life in Railroad Creek. Over the long term, total aluminum and iron concentrations are expected to gradually decline, approaching the NRWQC and/or background.

The RAOs for groundwater and surface water quality would not be achieved in the short term under Alternative 5a. However, results of the post-remediation loading analysis indicate that these RAOs would be met in the long term, as described below in Section 7.11.1.2.

Potential for Short-term Impacts

Potential short-term impacts to the environment during remedy construction and implementation would be similar to those described under Alternatives 3b and 4a. No additional short-term risks would be anticipated for the local community during or after implementation of this alternative. As described for Alternative 3b, areas within the vicinity of the upper collection system and treatment system in the West Area may be impacted during construction. Disturbed areas would be reclaimed, as possible, following construction. Elevated PCOC concentrations in the portal drainage may also result in the short term due to flooding of the underground mine workings. However, potential impacts to site surface water would be mitigated through collection and treatment of the portal drainage.

Under Alternative 5a, possible short-term increases in metals loading from the tailings piles may result during regrading actions due to the exposure of previously unoxidized tailings to air and storm water (Section 7.2.3). Measures would be taken during implementation to control storm-water runoff, reduce the volume of tailings disturbed during construction, and to place and compact materials cut back from the side slopes to minimize additional oxidation and surface water infiltration. There is also a potential for slurry losses to Railroad Creek during construction of the East Area partial collection and treatment system. These losses would be minimized through the use of standard engineering controls.

The partial relocation of Railroad Creek and placement of Copper Creek in a culvert may result in short-term impacts to water quality and the aquatic community during construction, due to the release of fine-grained sediment after the modified channels are put into service. These impacts would be minimized as possible by exercising appropriate construction best management practices.

7.11.1.2 Compliance with ARARs

Compliance with ARARs includes the evaluation of chemical-specific, location-specific, and action-specific ARARs identified in Section 3.

Potential Chemical-specific ARARs

The following subsections evaluate compliance with potential chemical-specific ARARs identified for Site media, including surface water, groundwater, and soil.

Surface Water

Results of the post-remediation loading analysis indicate dissolved cadmium concentrations in Railroad Creek would be below the SWQC in the short term, and dissolved copper and zinc concentrations would be below the SWQC within approximately 50 years (Tables 7-1 through 7-4). However, based on the toxicological evaluations provided in Appendix H, post-remediation PCOC concentrations under Alternative 5a would be protective of resident aquatic species in Railroad Creek following remedy implementation in the short term.

Dissolved zinc concentrations in Railroad Creek are predicted to be below the NRWQC in the short term. Dissolved cadmium and copper concentrations are expected to be below the NRWQC within approximately 50 years. Although the post-remediation analysis could not be performed for total aluminum or iron, concentrations are expected to approach the NRWQC and/or background in the long term, and are expected to be protective of resident aquatic species in Railroad Creek.

For the East and West Areas, points of compliance would be established through mixing zones where treated effluent from the East and West Areas discharge to surface water. The CPOCs would be monitored at the limits of the established mixing zones.

Groundwater

Portions of the seeps and groundwater beneath the Site would not likely meet potential chemical-specific ARARs in the short or long term under any of the alternatives. Therefore, as discussed under Alternative 2a, it is not practicable to meet potential groundwater ARARs throughout the Site within a reasonable restoration time frame.

The results of the post-remediation loading analysis indicate that potential ARARs would not be met in the short term at points where groundwater flows into surface water. As described above, results of the loading analysis indicate potential ARARs would be achieved in Railroad Creek (represented by stations RC-4 and RC-2) within approximately 50 years. These stations are considered to be generally representative of water quality in Railroad Creek downstream of West and East Area sources. However, it may take longer for some locations within the creek to achieve potential ARARs.

Natural attenuation, in conjunction with upgradient water diversions, source controls, and West Area collection and treatment, as described under Alternative 3a constitute AKART for this Site. The additional actions included under Alternative 5a (partial collection and treatment in the East Area) would be more than required to meet the definition of AKART under MTCA. As a result, CPOCs for groundwater in surface water, where groundwater flows into surface water, would apply for the East and West Areas under this alternative.

Soils

The potential ARARs identified for soil would be achieved under Alternative 5a.

Potential Location-specific ARARs

This alternative would meet all potentially applicable location-specific ARARs. The specific requirements of these ARARs would be identified through consultation with federal and state agencies during the RD/RA. The Alternative 5a actions are not expected to influence archaeological and/or historic sites of significance. Construction-related activities, including excavation or earthmoving, would consider the presence of historic or culturally important sites, structures or objects, historical and archeological data, and Native American burial sites, and if present, minimize impacts to such resources.

Construction activities would be conducted to minimize impacts to fish and wildlife and enhance aquatic and upland habitat thereby meeting the potential ARARs associated with fish and wildlife protection. Coordination with Washington State Department of Fish and Wildlife (WDFW) and USFWS would be conducted during the remedial design to identify potentially applicable substantive requirements and incorporate mitigative measures into the design as necessary.

The installation of a Copper Creek culvert and relocation of Railroad Creek would potentially impact shoreline area of the state and thus, consistency with the substantive requirements for shoreline management would evaluated during the remedial design and mitigative measures incorporated into the design. Potential impacts to fish and wildlife, and consistency with the Forest Management Act would be addressed through consultation with USFWS and Forest Service.

Substantive compliance with NPDES discharge requirements for effluent from the East and West Area treatment systems to Railroad Creek would also be evaluated under this alternative, including establishing a mixing zone with monitoring at the limits of the mixing zone. This will be the point of compliance for demonstrating compliance with potential surface-water ARARs.

Potential Action-Specific ARARs

Alternative 5a activities are expected to be in compliance with potential action-specific ARARs through the implementation of institutional controls and monitoring as described in Section 6. Substantive compliance with CWA construction stormwater requirements, CWA section 401 water quality certification, and CWA section 404 would be addressed under this alternative. Substantive compliance with potential action-specific ARARs will be evaluated during the design through consultation with WDFW, USACOE, EPA, DNR, and Ecology. If remedial activities under Alternative 5a are determined to have temporary impacts to water quality, substantive compliance with temporary water quality modification requirements would be achieved. Best management practices will be used to comply with potential substantive stormwater construction requirements and fugitive dust requirements.

Excavated soils and materials removed from the maintenance yard, mill building and lagoon are not expected to be either characteristic hazardous or dangerous waste. However, RCRA and Washington State Dangerous waste regulations may potentially be ARAR if these materials are determined to be hazardous or dangerous waste. These materials would be managed within the area of contamination, stabilized to immobilize the constituents, consolidated within a corrective management unit located on one of the tailings piles, and contained with an appropriate engineered cover in compliance with RCRA and Dangerous Waste regulations.

The tailings piles and waste rock piles would meet relevant and appropriate requirements under the Washington State Requirements for Solid Waste Handling. These areas would be designed to meet the relevant and appropriate requirements for closure systems to prevent exposure of waste, minimize infiltration, prevent erosion from wind and water, be capable of sustaining native vegetation, address anticipated settlement, provide for adequate drainage, provide sufficient stability and mechanical strength, address potential freeze-thaw and desiccation, provide for the management of run on and run off, prevent erosion, and minimizes the need for post-closure maintenance (WAC 173-350-400(3)(e)(i)(A) through (H)). Post-closure care requirements as deemed relevant and appropriate would also be met, including maintaining the vegetative cover, preventing run on and run off, and performing appropriate monitoring (173-350-400(7)(a)).

Limited purpose landfill cover requirements are not potentially applicable or relevant and appropriate to this remedial alternative, but would be potentially relevant and appropriate to those alternatives that include an engineered cover on the waste rock piles and/or tailings piles (Alternative 7 and 8).

7.11.2 Primary Balancing Criteria

Evaluation of the five primary balancing criteria, including long-term effectiveness and permanence; reduction of toxicity, mobility, and volume; short-term effectiveness; implementability; and cost is provided in the following subsections for Alternative 5a.

7.11.2.1 Long-term Effectiveness and Permanence

Long-term effectiveness and permanence includes evaluation of the magnitude of residual risk and adequacy and reliability of controls.

Magnitude of Residual Risks

As described under Alternatives 3b and 4a, the actions included under Alternative 5a would be protective of human health and terrestrial ecological receptors. Therefore, the magnitude of remaining human health risks and risks to ecological receptors would be low under this alternative.

The short- and long-term post-remediation water quality in Railroad Creek is estimated to be slightly improved over Alternative 3b through the collection and treatment in both the East and West Areas. Based on the results of the short-term loading analysis and toxicological analyses provided in Appendix H, post-remediation PCOC concentrations following implementation of

Alternative 5a are not expected to adversely impact the aquatic community in Railroad Creek, including salmonids and their prey.

As described for Alternative 2b, the magnitude of residual risks due to potential surge releases from the underground mine or tailings releases due to potential slope failures would be low under Alternative 5a.

Adequacy and Reliability of Controls

The West Area actions included under this alternative are expected to be implementable and reliable in reducing metals loading from the West Area and providing long-term protection of human health and the environment. The partial collection and treatment of groundwater and seeps in the East Area is expected to be moderately implementable and reliable in reducing metals loading from the tailings piles. The partial East Area collection system is estimated to intercept less than approximately 25 to 30 percent of East Area groundwater and seeps with an estimated collection efficiency of approximately 80 percent. The reliability of the partial collection system for interception of groundwater originating from the tailings piles while segregating clean water from Railroad Creek is uncertain.

Although gradual reductions in PCOC concentrations in the portal drainage and Site seeps and ground water are expected over time through natural attenuation, long-term operations and maintenance of chemical addition systems, collection trenches, treatment ponds, and containment areas would be required under this alternative.

The low-energy treatment systems would have a high degree of implementability and would be designed to reliably treat seasonal portal drainage, seep, and groundwater flows. Chemical addition rates would be controlled based on seasonal flows and water quality, and the settling ponds and media filters would be sized to provide significant detention times and solids removal prior to discharge to Railroad Creek. An important factor in providing consistent effluent quality under Alternative 5a would be the ability to adjust chemical addition rates in response to variable influent flows and water chemistry.

7.11.2.2 Reduction of Toxicity, Mobility, and Volume

The alkaline precipitation process included for the East and West Areas under Alternative 5a would reduce the mass and volume of PCOCs released to groundwater and surface water. The treatment process would produce stable treatment residuals, and thus reduce the mobility and toxicity of PCOCs to environmental receptors. The volume of impacted materials requiring management would increase with the sludge generated from the water treatment processes.

Additionally, the mass, and therefore volume, of PCOCs released to groundwater and surface water would be reduced over time from Site sources through the source control actions and the natural geochemical processes described in Appendix E.

7.11.2.3 Short-term Effectiveness

Short-term effectiveness includes evaluation of protection of local communities, worker protection, short-term environmental impacts, and time required to reach remediation goals.

Protection of Local Communities

Alternative 5a would be protective of Holden Village residents and visitors as described for Alternatives 3b and 4a. However, the increased level of construction and long-term operation and maintenance, and therefore, potential safety risks to the public, would be greater for Alternative 5a.

A stream crossing over Railroad Creek would be constructed at the northeast corner of tailings pile 3, to allow vehicles and equipment to bypass the Village during construction activities. Access to the top of the tailings piles would also be gained from the new stream crossing under this alternative.

Operation and maintenance of the East and West Area treatment system would require periodic deliveries of diesel fuel and treatment chemicals to the Site by barge and truck, and would result in increased traffic and equipment operations on the south side of Railroad Creek during sludge disposal and maintenance activities.

Potential physical hazards to the local community related to the possible development of a rock source near Tenmile creek would be mitigated using proven engineering controls. However, increased risks to the public would potentially result from increased truck traffic on portions of the Site and the Holden Village road during construction.

Worker Protection

The potential risks to workers, and mitigative measures under Alternative 5a would be similar to those described for combined Alternatives 3b and 4a. However, as described above, the increased level of construction and long-term operation and maintenance, and therefore, potential safety risks to workers, would be greater for Alternative 5a.

Potential risks to workers related to the possible generation of fugitive dust or exposure to treatment chemicals and metal constituents during construction and implementation could be adequately mitigated with use of personal protection equipment and engineering controls. Workers at construction and industrial sites are required to comply with the requirements and standards under OSHA.

The installation of hydrostatic bulkheads and other in-mine controls would involve construction work underground in abandoned mine workings on the 300, 1100, and 1500 levels. These actions would present potential physical risks to workers in the event of a collapse or rock fall. However, appropriate health and safety precautions, consistent with that required by MSHA, would be implemented to reduce potential risks to workers under this alternative.

The development of a rock source near Tenmile creek would present possible physical risks to workers due to the potential for rock fall at this location. However, appropriate health and safety precautions and engineering controls would be implemented to mitigate these potential risks.

Environmental Impacts

Potential short-term impacts to the environment during remedy construction and implementation would be similar to those described under combined Alternatives 3b and 4a. No additional short-term risks would be anticipated for the local community during or after implementation of this alternative. As described for Alternative 3b, areas within the vicinity of the upper collection system and treatment system in the West Area may be impacted during construction. Disturbed areas would be reclaimed, as possible, following construction. Elevated PCOC concentrations in the portal drainage may result in the short term due to flooding of the underground mine workings. However, potential impacts to Site surface water would be mitigated through collection and treatment of the portal drainage.

Under Alternative 5a, possible short-term increases in metals loading from the tailings piles may result during regrading actions due to the exposure of previously unoxidized tailings to air and storm water (Section 7.2.3). Measures would be taken during implementation to control storm-water runoff, reduce the volume of tailings disturbed during construction, and to place and compact materials cut back from the side slopes to minimize additional oxidation and surface water infiltration.

The partial relocation of Railroad Creek and placement of Copper Creek in a culvert may result in short-term impacts to water quality and the aquatic community during construction due to the release of fine-grained sediment after the modified channels are put into service. These impacts would be minimized to the extent possible by exercising appropriate construction best management practices. There is also a potential for short-term impacts to water temperature adjacent to the site due to limited bank cover during maturation of riparian vegetation.

There would be a potential for slurry losses to Railroad Creek during construction of the East Area partial collection and treatment system. Slurry releases would be minimized, as possible, through the performance of pre-construction investigations to identify zones with high-porosity that may require mitigation measures to prevent potential slurry losses to the creek. If zones of high-porosity are encountered, low-permeability filler material (such as straw) may be used to plug high-porosity zones during trench construction, panel construction methods may be implemented, or cement additives used in areas that would be susceptible to leakage. Containment berms may also be constructed on the downgradient side of barrier wall trenches and slurry mixing areas to reduce the potential for releases to the creek.

Time Required to Reach Remedial Goals

Implementation of this alternative is expected to occur over a two- to three-year period of time. Following implementation, the soil RAO would be met.

Results of the post-remediation loading analysis indicate that PCOC concentrations would achieve surface water RAOs within approximately 50 years. However, based on the toxicological evaluations provided in Appendix H, short- and long-term post-remediation concentrations are expected to be protective of aquatic life in Railroad Creek.

As described above for surface water, the groundwater RAOs would be expected to be achieved at CPOCs within surface water in approximately 50 years.

7.11.2.4 Implementability

The implementability of Alternative 5a, including technical feasibility, administrative feasibility, and availability of services and materials is evaluated in this section.

Technical Feasibility

As described under Alternative 4a, the East and West Area actions described under this alternative are moderately implementable. Construction of the partial East Area groundwater collection and treatment systems would be difficult due to the relatively flat grade, structural considerations related to installation at the base of the tailings piles, variable characteristics of the alluvial materials below the tailings piles, and varying depth to bedrock or dense till. Data collected during the RI indicate the potential for large granitic boulders and tree stumps at the base of the tailings piles, which would result in increased difficulties in construction of the collection and treatment systems. East Area groundwater collection efficiencies attained with the open collection trenches are uncertain due to the variable subsurface characteristics and estimated depths to bedrock or dense till.

The treatment of groundwater and seeps in the East Area would also be difficult due to the high concentrations of iron resulting in significant chemical addition requirements and sludge generation. High chemical dosing rates would be required to provide sufficient alkalinity to neutralize the acidity generated from the oxidation and precipitation of dissolved iron constituents. The large volumes of treatment chemicals would require periodic shipments by barge and truck to the Site.

Administrative Feasibility

The Site is located adjacent to the Holden Village, which is operated under a special-use permit issued by the Forest Service, a wilderness area boundary, and Forest Service lands. As a result, coordination between many local agencies and the Holden Village will be required under Alternatives 2 through 8.

The increased construction activities in both the East and West Areas reduce the administrative feasibility of this alternative compared to Alternatives 3b and 4a. The partial relocation of Railroad Creek under Alternative 5a would require increased coordination with the Holden Village while working on the north side of Railroad Creek, and additional coordination with the Holden Village would be required under Alternative 5a to facilitate long-term water treatment in the East and West Areas.

Availability of Services and Materials

The services and materials required to implement this alternative would be available within the Railroad Creek valley or could be mobilized to the Site by barge. Specialized equipment and personnel for completion of underground actions would be available in the surrounding areas.

Treatment system chemicals would be transported to the Site by barge and truck on a regular basis under this alternative and on site personnel would be required to operate and maintain collection and treatment systems.

7.11.2.5 Cost

The total estimated cost associated with Alternative 5a is approximately $41,260,000 (2004 dollars at a 7-percent discount rate). The costs estimated for this alternative include costs associated with the collection and treatment of East and West Area waters. Table 7-9 provides a summary of capital and O&M costs for each of the eight candidate alternatives, and cost detail sheets are provided in Appendix I.

Capital costs associated with implementation of Alternative 5a are estimated at approximately $23,870,000. Annual O&M costs associated with monitoring, maintaining the upgradient diversion channels, and operating and maintaining the collection and treatment systems are estimated to be approximately $320,000.

7.11.3 Natural Resource Restoration

Under Alternative 5a, natural resource restoration would be achieved following remedy implementation for soils and vegetation in the West Area and terrestrial wildlife across the Site. Improvements in surface water quality, groundwater quality, and aquatic resources are also expected in the East and West Areas due to source controls, upgradient diversions and downgradient collection and treatment. As described in Appendix H, the predicted short-term concentrations of site PCOCs are expected to be protective of aquatic life in Railroad Creek. A summary of the extent of natural resource restoration expected under each alternative is provided in Appendix J.

7.11.4 Use of Permanent Solutions to the Maximum Extent Practicable

The remedial actions included under Alternative 5a constitute permanent solutions under MTCA since potential ARARs are expected to be achieved in the long term without further actions being required (WAC 173-340-200). The post-remediation loading analysis indicates that PCOC loading to Site groundwater and surface water would be reduced over time and potential ARARs are expected to be achieved within approximately 50 years, depending on the PCOC.

An evaluation the use of permanent solutions to the maximum extent practicable is provided in Section 8 (comparative analysis of alternatives). The evaluation of the practicability of this alternative includes whether the alternative is capable of being designed, constructed, and implemented in a reliable and effective manner, including consideration of cost. In considering cost under this analysis, an alternative shall not be considered practicable if the incremental costs are disproportionate to the incremental degree of benefits provided by the alternative over other lower cost alternatives.

7.11.5 Reasonable Restoration Time Frame

Following implementation of Alternative 5a, the soil RAOs would be met. Remedial actions would also be effective in eliminating potential physical hazards to Holden Village residents and visitors related to mine features and potential future risks to human health due to the possible development of groundwater as a drinking water supply.

PCOC loading to groundwater would be reduced over time under Alternative 5a through natural attenuation, upgradient water diversions, source controls, and East/West Area collection and treatment. Results of the post-remediation loading analysis indicate that the groundwater RAO would be achieved at CPOCs in surface water in the West Area and East Areas within approximately 50 years.

Results of the post-remediation loading analysis indicate that the surface water RAO would also be achieved within approximately 50 years. Results of the toxicological evaluations indicate that surface water quality would be protective of aquatic life in Railroad Creek in the short term under Alternative 5a.

An evaluation of reasonable restoration time frame is provided in Section 8. The evaluation of the practicability of this alternative, which would likely provide a shorter restoration time frame compared to Alternative 3b, includes whether the alternative is capable of being designed, constructed, and implemented in a reliable and effective manner, including consideration of cost. In considering cost under this analysis, an alternative shall not be considered practicable if the incremental costs are disproportionate to the incremental degree of benefits provided by the alternative over other lower cost alternatives.

7.12 ALTERNATIVE 5B: WATER MANAGEMENT, EXTENDED EAST AREA COLLECTION AND EAST/WEST AREA TREATMENT (LOW-ENERGY TREATMENT)

The following subsections provide detailed analysis of the remediation components included under Alternative 5b to address Site soils, surface water and groundwater. Alternative 5b includes the actions described under Alternative 5a with extended East Area collection and treatment. The following subsections provide an analysis of the additional components under Alternative 5b.

Under Alternative 5b, the underground mine actions, upgradient water diversions, source controls, and West Area treatment are expected to significantly reduce PCOC loading to the subsurface and improve groundwater quality throughout the Site. The extended collection and treatment of seeps and groundwater in the East Area is also anticipated to further reduce metals loading from the tailings piles (primarily copper, iron, and zinc) to Railroad Creek. As a result, greater reductions in PCOC concentrations in Railroad Creek are expected under Alternative 5b compared to Alternative 5a. Estimated loading reductions from East and West Area sources under Alternative 5b are provided in Appendix D, Tables D1-9, D2-9, and D4. The estimated short- and long-term post-remediation Railroad Creek water quality for this alternative is summarized in Tables 7-1 through 7-4.

7.12.1 Threshold Criteria

Evaluation of the two threshold criteria, including overall protection of human health and the environment and compliance with ARARs, is provided in the following subsections for Alternative 5b.

7.12.1.1 Overall Protection of Human Health and the Environment

Protection of Human Health and Terrestrial Ecological Receptors

As described for Alternative 5a, the remedial actions included under Alternative 5b are expected to be protective of human health and terrestrial ecological receptors at the Site. The RAO to implement the remedial action in a manner that is protective of human health, including the Holden Village community, during and after construction would be met under this alternative. The soil RAO would also be achieved following remedy implementation.

Protection of Aquatic Life

Results of the post-remediation loading analysis indicate that seasonal dissolved cadmium, copper, and zinc concentrations in Railroad Creek would be reduced following remedy implementation, and would continue to gradually decline over time through natural attenuation. The analysis predicts that the potential surface water ARARs for zinc would be met in the short term, and the potential ARARs for cadmium and copper would be met within approximately 50 years of remedy implementation (Tables 7-1 through 7-4). However, based on the toxicological evaluations provided in Appendix H, post-remediation PCOC concentrations under Alternative 5b would be protective of resident species in Railroad Creek, including salmonids and their prey, following remedy implementation in the short term.

Under Alternative 5b, total iron concentrations are expected to comply with the NRWQC following remedy implementation in the short term. Seasonal concentrations of total aluminum may remain above background in the short term. However, an analysis of documented aluminum toxicity, presented in Appendix H, indicates that the post-remediation aluminum concentrations would be protective of resident aquatic species in Railroad Creek. Over the long term, total aluminum concentrations are expected to continue to decline through natural attenuation and approach the NRWQC and/or background concentrations.

The RAOs for groundwater and surface water quality would not be achieved in the short term under Alternative 5b. However, as described above, results of the post-remediation loading analysis indicate that these RAOs would be met in the long term as described below in Section 7.12.1.2.

Potential for Short-term Impacts

Potential short-term impacts to the environment during construction and implementation would be similar to those described under Alternative 5a. However, there would be a higher potential for short-term impacts to groundwater and surface water due to the increased volume of tailings disturbed during slope regrading activities (approximately 750,000 to 1,000,000 cubic yards). Increased regrading of side slopes would be required to install the extended collection systems at the base of the piles. There is also a greater potential for slurry losses to Railroad Creek during construction of the extended East Area collection and treatment system, due to the required trench depths and proximity to Railroad Creek. As described for Alternative 5a, these losses would be minimized through the use of standard engineering controls.

7.12.1.2 Compliance with ARARs

Compliance with ARARs includes the evaluation of chemical-specific, location-specific, and action-specific ARARs identified in Section 3.

Potential Chemical-specific ARARs

The following subsections evaluate compliance with potential chemical-specific ARARs identified for Site media, including surface water, groundwater and soil.

Surface Water

Results of the post-remediation loading analysis indicate dissolved cadmium and zinc concentrations in Railroad Creek would be below the SWQC following remedy implementation in the short-term. The analysis indicates that dissolved copper concentrations would be below the SWQC within approximately 50 years of remedy implementation (Tables 7-1 through 7-4). However, based on the toxicological evaluations provided in Appendix H, post-remediation PCOC concentrations under Alternative 5b would be protective of resident aquatic species in Railroad Creek following remedy implementation in the short term.

Dissolved zinc concentrations are predicted to meet the NRWQC following remedy implementation in the short term. Dissolved cadmium and copper concentrations are expected to be below the NRWQC within approximately 50 years (Tables 7-1 through 7-4). Although the post-remediation analysis could not be performed for total aluminum or iron, iron concentrations are expected to be below the NRWQC following remedy implementation, and aluminum concentrations are expected to approach the NRWQC and/or background in the long-term. Based on the toxicological evaluations provided in Appendix H, short-term post-remediation iron and aluminum concentrations under Alternative 5b would be protective of resident aquatic species in Railroad Creek.

For the East and West Areas, points of compliance would be established through mixing zones, where treated effluent from the East and West Areas discharge to surface water. The CPOCs would be monitored at the limits of the established mixing zones.

Groundwater

Portions of the seeps and groundwater beneath the Site would not likely meet potential chemical-specific ARARs in the short or long term under any of the alternatives. Therefore, as discussed under Alternative 2a, it is not practicable to meet potential groundwater ARARs throughout the Site within a reasonable restoration time frame.

The results of the post-remediation loading analysis indicate that potential ARARs would not be met in the short term at points where groundwater flows into surface water. As described above, results of the loading analysis indicate potential ARARs would be achieved in Railroad Creek (represented by stations RC-4 and RC-2) within approximately 50 years. These stations are considered to be generally representative of water quality in Railroad Creek downstream of West and East Area sources. However, it may take longer for some locations within the creek to achieve potential ARARs.

Natural attenuation, in conjunction with upgradient water diversions, source controls, and West Area collection and treatment, as described under Alternative 3a constitute AKART for this Site. The additional actions included under Alternative 5b (extended collection and treatment in the East Area) would be more than required to meet the definition of AKART under MTCA. As a result, CPOCs for groundwater in surface water, where groundwater flows into surface water, would apply for the East and West Areas under this alternative.

Soils

As described for Alternative 5a, the potential ARARs identified for soil would be achieved under Alternative 5b.

Potential Location-specific ARARs

Compliance with potential location-specific ARARs for Alternative 5b would be the same as described for Alternative 5a in Sections 7.11.1.2.

Potential Action-Specific ARARs

Compliance with potential action-specific ARARs for Alternative 5b would be the same as described for Alternative 5a in Sections 7.11.1.2.

7.12.2 Primary Balancing Criteria

Evaluation of the five primary balancing criteria, including long-term effectiveness and permanence; reduction of toxicity, mobility, and volume; short-term effectiveness; implementability; and cost is provided in the following subsections for Alternative 5b.

7.12.2.1 Long-term Effectiveness and Permanence

Long-term effectiveness and permanence includes evaluation of the magnitude of residual risk and adequacy and reliability of controls.

Magnitude of Residual Risks

As described under Alternative 5a, the actions included under Alternative 5b would be protective of human health and terrestrial ecological receptors. Therefore, the magnitude of remaining human health risks and risks to ecological receptors would be low under this alternative.

If it is assumed that extended collection of East Area groundwater can be effectively implemented, greater improvements in the short- and long-term post-remediation Railroad Creek water quality are estimated under Alternative 5b compared to Alternative 5a, due to the additional collection and treatment of East Area water. Based on the results of the short-term loading analysis and toxicological analyses provided in Appendix H, post-remediation PCOC concentrations following implementation of Alternative 5b are not expected to adversely impact the aquatic community in Railroad Creek, including salmonids and their prey.

Metal precipitates and sludge generated in the treatment ponds would require periodic removal and disposal in a suitable containment location on site. Treatment residuals from alkaline precipitation processes are expected to be stable products with reduced metals mobility. However, the containment areas would require periodic maintenance to reduce long-term surface water infiltration.

As described for Alternative 2b, the magnitude of residual risks due to potential surge releases from the underground mine or tailings releases due to potential slope failure would be low under Alternative 5b.

Adequacy and Reliability of Controls

West Area actions included under Alternative 5b are expected to be adequate and reliable in reducing metals loading and providing long-term protection of human health and the environment. The East Area actions under Alternative 5b are expected to be difficult to implement and moderately reliable. The extended East Area collection system is estimated to intercept groundwater and seeps in the short-term with an estimated short-term collection efficiency of approximately 80 to 90 percent. However, there is significant uncertainty in the long-term reliability of a subsurface collection trench and drain in the East Area due to the high potential for the formation of iron and other metal oxides to foul and plug the system.

Additionally, the reliability of the extended East Area collection and treatment system would be highly dependent on the adequate operation and maintenance of chemical addition systems, collection trenches, treatment ponds, and containment areas. Although gradual reductions in PCOC concentrations in the portal drainage and Site groundwater are expected over time through natural attenuation, long-term operation and maintenance of chemical addition systems, collection trenches, treatment ponds, and containment areas would be required under this alternative.

The low-energy treatment systems would have a high degree of implementability and would be designed to reliably treat seasonal portal drainage, seep, and groundwater flows. Chemical addition rates would be controlled based on seasonal flows and water quality, and the settling ponds and media filters would be sized to provide significant detention times and solids removal prior to discharge to Railroad Creek. An important factor in providing consistent effluent quality under Alternative 5b would be the ability to adjust chemical addition rates in response to variable influent flows and water chemistry.

7.12.2.2 Reduction of Toxicity, Mobility, and Volume

The alkaline precipitation process included for the East and West Areas under Alternative 5b would reduce the mass and volume of PCOCs released to groundwater and surface water. The treatment process would produce stable treatment residuals, and thus reduce the mobility and toxicity of PCOCs to environmental receptors. The volume of impacted materials requiring management would increase with the sludge generated from the water treatment processes.

Additionally, the mass, and therefore volume, of PCOCs released to groundwater and surface water would be reduced over time from Site sources through the source control actions and the natural geochemical processes described in Appendix E.

7.12.2.3 Short-term Effectiveness

Short-term effectiveness includes evaluation of protection of local communities, worker protection, short-term environmental impacts, and time required to reach remediation goals.

Protection of Local Communities

Alternative 5b would be protective of Holden Village residents and visitors as described for Alternative 5a. However, the level of construction activities (e.g., large-scale tailings regrading, extended barrier wall construction, etc.), and therefore, potential safety risks to the public, would be greater for Alternative 5b than for Alternative 5a.

Operation and maintenance of the East Area treatment system would require periodic deliveries of diesel fuel and treatment chemicals to the Site by barge and truck, and would result in increased traffic and equipment operations on the south side of Railroad Creek during sludge disposal and maintenance activities.

Worker Protection

Potential risks to workers and mitigation measures implemented under Alternative 5b would be as described for Alternative 5a in Section 7.11.2.3. However, as described above, the level of construction activities, and therefore, potential safety risks to workers, would be greater for Alternative 5b than for Alternative 5a.

Environmental Impacts

The potential for short-term impacts to Railroad Creek resulting from tailings pile regrading would be greater under Alternative 5b, as discussed in Section 7.2.3. This is due to the large-scale regrading required for installation of the extended collection and treatment system at the base of the tailings piles. The potential impacts related to elevated metals concentrations in storm-water runoff would be mitigated, as possible, through the implementation of storm-water controls and collection and treatment during construction.

As described for Alternative 5a, the partial relocation of Railroad Creek and placement of Copper Creek in a culvert may result in short-term impacts to water quality and the aquatic community during construction due to the release of fine-grained sediment after the modified channels are put into service. These impacts would be minimized to the extent possible by exercising appropriate construction best management practices. There is also a potential for short-term impacts to water temperature adjacent to the Site due to limited bank cover during maturation of riparian vegetation.

The potential for slurry losses to Railroad Creek would be greater under Alternative 5b during construction of the extended East Area collection and treatment system. As described under Alternative 5a, slurry releases would be minimized, as possible, through the performance of pre-construction investigations to identify zones with high-porosity that may require mitigation measures to prevent potential slurry losses to the creek. If zones of high-porosity are encountered, low-permeability filler material (such as straw) may be used to plug high-porosity zones during trench construction, panel construction methods may be implemented, or cement additives used in areas that would be susceptible to leakage. Containment berms may also be constructed on the downgradient side of barrier wall trenches and slurry mixing areas to reduce the potential for releases to the creek.

Time Required to Reach Remedial Goals

Implementation of this alternative is expected to occur over a two- to three-year period of time. Following implementation, the soil RAO would be met.

Results of the post-remediation loading analysis indicate that PCOC concentrations would achieve surface water RAOs within approximately 50 years. However, based on the toxicological evaluations provided in Appendix H, short- and long-term post-remediation concentrations are expected to be protective of aquatic life in Railroad Creek.

As described above for surface water, the groundwater RAOs would be expected to be achieved at CPOCs within surface water in approximately 50 years.

7.12.2.4 Implementability

The implementability of Alternative 5b including technical feasibility, administrative feasibility, and availability of services and materials is evaluated in this section.

Technical Feasibility

The actions included under Alternative 5b would be difficult to implement. Construction of the extended groundwater collection and treatment systems would be difficult due to the relatively flat grade, structural considerations related to installation at the base of the tailings piles, variable characteristics of the alluvial materials below the tailings piles, varying depth to bedrock or dense till, and the deep trench construction required at the base of the tailings piles where there is limited room for construction. Data collected during the RI indicate the potential for large granitic boulders and tree stumps at the base of the tailings piles, which would also result in increased difficulties in construction of the collection and treatment systems. Groundwater collection efficiencies attained with the collection trench and barrier wall installations are uncertain due to the variable subsurface characteristics and depths to bedrock or dense till.

The treatment of groundwater and seeps in the East Area would also be difficult due to the high concentrations of iron resulting in significant chemical addition requirements and sludge generation rates, and due to the limited area for construction of treatment systems to the east of tailings piles 1 and 3. High chemical addition rates would be required to provide sufficient alkalinity to neutralize the acidity generated from the oxidation and precipitation of dissolved iron constituents. The large volumes of treatment chemicals would require periodic shipments by barge and truck to the Site.

Administrative Feasibility

As described for Alternative 5a, coordination between many local agencies and the Holden Village would be under Alternatives 2 through 8. Alternative 5b would have lower administrative implementability due to the increased construction requirements, duration of construction activities, and long-term treatment system O&M requirements.

Availability of Services and Materials

As described for Alternative 5a, the services and materials required for implementation of this alternative would be available within the Railroad Creek valley or could be mobilized to the Site by barge.

Large volumes of treatment chemicals would be transported to the Site by barge and truck on a regular basis under this alternative and on site personnel would be required to operate and maintain collection and treatment systems.

7.12.2.5 Cost

The total estimated cost associated with Alternative 5b is approximately $74,320,000 (2004 dollars at a 7-percent discount rate). The increased costs estimated for this alternative compared to Alternative 5a are primarily associated with the increased earthwork and barrier wall/collection system construction requirements. Table 7-9 provides a summary of capital and O&M costs for each of the eight candidate alternatives, and cost detail sheets are provided in Appendix I.

Capital costs associated with implementation of Alternative 5b are estimated at approximately $44,700,000. Annual O&M costs associated with monitoring, maintaining the upgradient diversion channels, and operating and maintaining the collection and treatment systems are estimated to be approximately $420,000.

7.12.3 Natural Resource Restoration

Under Alternative 5b, natural resource restoration would be achieved following remedy implementation for soils and vegetation in the West Area and terrestrial wildlife across the Site.

Improvements in surface water quality, groundwater quality, and aquatic resources are also expected in the East and West Areas following remedy implementation due to source controls, upgradient diversions and downgradient collection and treatment. Additional reductions in PCOC concentrations in Railroad Creek are expected over time due to natural attenuation. As described in Appendix H, post-remediation concentrations of site PCOCs are expected to be protective of resident aquatic species in Railroad Creek. A summary of the extent of natural resource restoration expected under each alternative is provided in Appendix J.

7.12.4 Use of Permanent Solutions to the Maximum Extent Practicable

The remedial actions included under Alternative 5b constitute permanent solutions under MTCA since potential ARARs are expected to be achieved in the long term without further actions being required (WAC 173-340-200). The post-remediation loading analysis indicates that PCOC loading to Site groundwater and surface water would be reduced over time and potential ARARs are expected to be achieved within approximately 50 years, depending on the PCOC.

An evaluation the use of permanent solutions to the maximum extent practicable is provided in Section 8 (comparative analysis of alternatives). The evaluation of the practicability of this alternative includes whether the alternative is capable of being designed, constructed, and implemented in a reliable and effective manner, including consideration of cost. In considering cost under this analysis, an alternative shall not be considered practicable if the incremental costs are disproportionate to the incremental degree of benefits provided by the alternative over other lower cost alternatives.

7.12.5 Reasonable Restoration Time Frame

Following implementation of Alternative 5b, the soil RAOs would be met. Remedial actions would also be effective in eliminating potential physical hazards to Holden Village residents and visitors related to mine features and potential future risks to human health due to the possible development of groundwater as a drinking water supply.

PCOC loading to groundwater would be reduced over time under Alternative 5b through natural attenuation, upgradient water diversions, source controls, and East/West Area collection and treatment. Results of the post-remediation loading analysis indicate that the groundwater RAO would be achieved at CPOCs in surface water in the West Area and East Areas within approximately 50 years.

Results of the post-remediation loading analysis indicate that the surface water RAO would also be achieved within approximately 50 years. Results of the toxicological evaluations indicate that surface water quality would be protective of aquatic life in Railroad Creek in the short term under Alternative 5b.

An evaluation of reasonable restoration time frame is provided in Section 8. The evaluation of the practicability of this alternative, which would likely provide a shorter restoration time frame compared to Alternative 3b, includes whether the alternative is capable of being designed, constructed, and implemented in a reliable and effective manner, including consideration of cost. In considering cost under this analysis, an alternative shall not be considered practicable if the incremental costs are disproportionate to the incremental degree of benefits provided by the alternative over other lower cost alternatives.

7.13 ALTERNATIVE 5C: WATER MANAGEMENT, EXTENDED RAILROAD CREEK RELOCATION, AND EAST/WEST AREA TREATMENT

The following subsections provide detailed analysis of the remediation components included under Alternative 5c to address Site soils, surface water and groundwater. Alternative 5c includes the same actions as described under Alternative 5b, substituting extended Railroad Creek relocation and construction of an open collection system in the former Railroad Creek channel for the extended barrier wall/collection system described under Alternative 5b. The following subsections provide an analysis of the unique components under Alternative 5c.

Under Alternative 5c, the underground mine actions, upgradient water diversions, source controls, and West Area treatment are expected to significantly reduce PCOC loading to the subsurface and improve groundwater quality throughout the Site. The extended relocation of railroad creek and use of the existing channel for collection and treatment of East Area Seeps and groundwater is also anticipated to achieve similar reductions in metals loading from the tailings piles to Railroad Creek as described under Alternative 5b. Relocation of the creek to the north would likely result in enhanced aquatic habitat adjacent to the Site, and reductions in metals loading from the East and West Areas under Alternative 5c would also likely result in gradual improvements to downstream aquatic habitat. Estimated loading reductions from East and West Area sources under Alternative 5c are summarized in Appendix D, Tables D1-10, D2-10, and D4. The estimated short- and long-term post-remediation Railroad Creek water quality for this alternative is summarized in Tables 7-1 through 7-4.

7.13.1 Threshold Criteria

Evaluation of the two threshold criteria, including overall protection of human health and the environment and compliance with ARARs, is provided in the following subsections for Alternative 5c.

7.13.1.1 Overall Protection of Human Health and the Environment

Protection of Human Health and Terrestrial Ecological Receptors

As described for Alternative 5b, the remedial actions included under Alternative 5c are expected to be protective of human health and terrestrial ecological receptors at the Site. The RAO to implement the remedial action in a manner that is protective of human health, including the Holden Village community, during and after construction would be met under this alternative. The soil RAO would also be achieved following remedy implementation.

Protection of Aquatic Life

Results of the post-remediation loading analysis indicate that seasonal dissolved cadmium, copper, and zinc concentrations in Railroad Creek would be reduced following remedy implementation, and would continue to gradually decline over time through natural attenuation. The analysis predicts that the potential surface water ARARs for cadmium would be met in the short term, and the potential ARARs for cadmium and copper would be met within approximately 50 years of remedy implementation (Tables 7-1 through 7-4). However, based on the toxicological evaluations provided in Appendix H, post-remediation PCOC concentrations under Alternative 5c would be protective of resident species in Railroad Creek, including salmonids and their prey, following remedy implementation in the short term.

Under Alternative 5c, total iron concentrations are expected to comply with the NRWQC following remedy implementation in the short term. Seasonal concentrations of total aluminum may remain above background in the short term. However, an analysis of documented aluminum toxicity, presented in Appendix H, concludes that the post-remediation aluminum concentrations would be protective of resident aquatic species in Railroad Creek. Over the long term, total aluminum concentrations are expected to continue to decline through natural attenuation, and approach the NRWQC and/or background concentrations.

The RAOs for groundwater and surface water quality would not be achieved in the short term under Alternative 5c. However, results of the post-remediation loading analysis indicate that these RAOs would be met in the long term as described below in Section 7.13.1.2.

Potential for Short-term Impacts

Potential short-term impacts to the environment during construction and implementation would be similar to those described under Alternative 5a. However, the potential for short-term impacts to water quality due to potential releases during regrading and barrier wall/collection system construction are expected to be reduced through the relocation of Railroad Creek away from the base of the tailings piles, thereby increasing the distance between construction activities and surface water. Less tailings regrading would also be required under Alternative 5c. There would be a higher potential for short-term temperature impacts, and impacts to surface water and aquatic life due to the release of fine-grained sediment after the new extended Railroad Creek channel is put into service. These potential impacts would be minimized to the extent possible by exercising appropriate construction best management practices.

7.13.1.2 Compliance with ARARs

Compliance with ARARs includes the evaluation of chemical-specific, location-specific, and action-specific ARARs identified in Section 3.

Potential Chemical-specific ARARs

The following subsections evaluate compliance with potential chemical-specific ARARs identified for Site media, including surface water, groundwater and soil.

Surface Water

Results of the post-remediation loading analysis indicate dissolved cadmium and zinc concentrations in Railroad Creek would be below the SWQC following remedy implementation in the short-term. The analysis indicates that dissolved copper concentrations would be below the SWQC within approximately 50 years of remedy implementation (Tables 7-1 through 7-4). However, based on the toxicological evaluations provided in Appendix H, post-remediation PCOC concentrations under Alternative 5c would be protective of resident aquatic species in Railroad Creek following remedy implementation in the short term.

Dissolved zinc concentrations are predicted to meet the NRWQC following remedy implementation in the short term. Dissolved cadmium and copper concentrations are expected to be below the NRWQC within approximately 50 years (Tables 7-1 through 7-4). Although the post-remediation loading analysis could not be performed for total aluminum or iron, total iron concentrations are expected to be below the NRWQC following remedy implementation, and total aluminum concentrations are expected to approach the NRWQC and/or background concentrations in the long term. The toxicological evaluations provided in Appendix H conclude that the short-term post remediation concentrations of aluminum and iron would be protective of aquatic life in Railroad Creek.

For the East and West Areas, points of compliance would be established through mixing zones where treated effluent from the East and West Areas discharge to surface water. The CPOCs would be monitored at the limits of the established mixing zones.

Groundwater

Portions of the seeps and groundwater beneath the Site would not likely meet potential chemical-specific ARARs in the short or long term under any of the alternatives. Therefore, as discussed under Alternative 2a, it is not practicable to meet potential groundwater ARARs throughout the Site within a reasonable restoration time frame.

The results of the post-remediation loading analysis indicate that potential ARARs would not be met in the short term at points where groundwater flows into surface water. As described above, results of the loading analysis indicate potential ARARs would be achieved in Railroad Creek (represented by stations RC-4 and RC-2) within approximately 50 years. These stations are considered to be generally representative of water quality in Railroad Creek downstream of West and East Area sources. However, it may take longer for some locations within the creek to achieve potential ARARs.

Natural attenuation, in conjunction with upgradient water diversions, source controls, and West Area collection and treatment, as described under Alternative 3a constitute AKART for this Site. The additional actions included under Alternative 5c (extended collection and treatment in the East Area) would be more than required to meet the definition of AKART under MTCA. As a result, CPOCs for groundwater in surface water, where groundwater flows into surface water, would apply for the East and West Areas under this alternative.

Soils

As described for Alternatives 5a and 5b, the potential ARARs identified for soil would be achieved under Alternative 5c.

Potential Location-specific ARARs

Compliance with potential location-specific ARARs for Alternative 5c would be the same as described for Alternatives 5a and 5b in Sections 7.11.1.2.

Potential Action-Specific ARARs

Compliance with potential action-specific ARARs for Alternative 5c would be the same as described for Alternatives 5a and 5b in Sections 7.11.1.2.

7.13.2 Primary Balancing Criteria

Evaluation of the five primary balancing criteria, including long-term effectiveness and permanence; reduction of toxicity, mobility, and volume; short-term effectiveness; implementability; and cost is provided in the following subsections for Alternative 5c.

7.13.2.1 Long-term Effectiveness and Permanence

Long-term effectiveness and permanence includes evaluation of the magnitude of residual risk and adequacy and reliability of controls.

Magnitude of Residual Risks

As described under Alternatives 5a and 5b, the actions included under Alternative 5c would be protective of human health and terrestrial ecological receptors. Therefore, the magnitude of remaining human health risks and risks to ecological receptors would be low under this alternative.

If it is assumed that extended relocation of Railroad Creek and the collection of East Area groundwater and seeps can be effectively implemented, similar improvements in the short- and long-term post-remediation Railroad Creek water quality are estimated under Alternative 5c as described for Alternative 5b. Based on the results of the short-term loading analysis and toxicological analyses provided in Appendix H, post-remediation PCOC concentrations following implementation of Alternative 5c are not expected to adversely impact the aquatic community in Railroad Creek, including salmonids and their prey.

Metal precipitates and sludge generated in the treatment ponds would require periodic removal and disposal in a suitable containment location on site. Treatment residuals from alkaline precipitation processes are expected to be stable products with reduced metals mobility. However, the containment areas would require periodic maintenance to reduce long-term surface water infiltration.

As described for Alternatives 5a and 5b, the magnitude of residual risks due to potential surge releases from the underground mine or tailings releases due to potential slope failure would be low under Alternative 5c.

Adequacy and Reliability of Controls

The actions included under Alternative 5c for the West Area are expected to be implementable and reliable in reducing metals loading from Site sources and providing long-term protection of human health and the environment. The extended relocation of Railroad Creek to the north and use of the existing creek channel for groundwater collection and treatment is expected to be moderately implementable. The open collection system is estimated to collect East Area seeps and groundwater intercepted by Railroad Creek under current conditions with a collection efficiency of approximately 80 to 90 percent. However, there is a potential for an influx of Railroad Creek water to enter the East Area collection and treatment system, especially in the reach adjacent to tailings pile 2, where the valley narrows and space is limited to the north for Railroad Creek relocation. This has been accounted for in the loading analysis and would need to be considered in the design.

Taking into consideration the potential influx of Railroad Creek water, an open collection system constructed in the former Railroad Creek channel is still expected to be more reliable than the collection systems included under Alternatives 5a or 5b.

Although gradual reductions in PCOC concentrations in the portal drainage and Site groundwater are expected over time through natural attenuation, long-term operations and maintenance of chemical addition systems, collection trenches, treatment ponds, and containment areas would be required under this alternative. The low-energy treatment systems would have a high degree of implementability and would be designed to reliably treat seasonal portal drainage, seep, and groundwater flows. Chemical addition rates would be controlled based on seasonal flows and water quality, and the settling ponds and media filters would be sized to provide significant detention times and solids removal prior to discharge to Railroad Creek. An important factor in providing consistent effluent quality under Alternative 5c would be the ability to adjust chemical addition rates in response to variable influent flows and water chemistry.

7.13.2.2 Reduction of Toxicity, Mobility, and Volume

The alkaline precipitation process included for the East and West Areas under Alternative 5c would reduce the mass and volume of PCOCs released to groundwater and surface water. The treatment process would produce stable treatment residuals, and thus reduce the mobility and toxicity of PCOCs to environmental receptors. The volume of impacted materials requiring management would increase with the sludge generated from the water treatment processes.

Additionally, the mass, and therefore volume, of PCOCs released to groundwater and surface water would be reduced over time from Site sources through the source control actions and the natural geochemical processes described in Appendix E.

7.13.2.3 Short-term Effectiveness

Short-term effectiveness includes evaluation of protection of local communities, worker protection, short-term environmental impacts, and time required to reach remediation goals.

Protection of Local Communities

Alternative 5c would be protective of Holden Village residents and visitors. A stream crossing over Railroad Creek would be constructed at the northeast corner of tailings pile 3, to allow vehicles and equipment to bypass the Village during construction and maintenance activities. Access to the top of the tailings piles would be gained from the new stream crossing under this alternative. While there would be significantly less tailings regrading under Alternative 5c than Alternative 5b, Alternative 5c would require relocation of Railroad Creek to the north, and therefore heavy construction work would be required adjacent to the Holden Village. This would result in increased noise and risks to the local community.

Operation and maintenance of the East Area treatment system would require periodic deliveries of diesel fuel and treatment chemicals to the Site by barge and truck, and would result in increased traffic and equipment operations on the south side of Railroad Creek during sludge disposal and maintenance activities.

Potential physical hazards to the local community related to the possible development of a rock source near Tenmile Creek would be mitigated using proven engineering controls.

Worker Protection

Potential risks to workers and mitigation measures implemented under Alternative 5c would be the same as described for Alternative 5a in Section 7.11.2.3. However, the level of construction activities (e.g., extended Railroad Creek relocation), and therefore, potential safety risks to workers, would be greater for Alternative 5c.

Environmental Impacts

Potential short-term impacts to the environment during construction and implementation would be similar to Alternative 5a (Section 7.11.2.3). However, the potential for short-term impacts to water quality due to potential releases during regrading and barrier wall/collection system construction is expected to be reduced through the relocation of Railroad Creek away from the base of the tailings piles, thereby increasing the distance between the construction activities and surface water. Less tailings regrading would also be required under Alternative 5c.

Areas between the existing Railroad Creek channel and the Holden Village would be disturbed during construction of the new Railroad Creek alignment. However, disturbed areas would be reclaimed and the new channel would be designed to provide enhanced aquatic habitat.

Under Alternative 5c, there would be a greater potential for short-term impacts to water quality and aquatic life during the extended relocation of Railroad Creek due to the release of fine-grained sediment after the modified channel is put into service. As described under Alternatives 5a and 5b, these impacts would be minimized to the extent possible by implementing construction best management practices. There is also a greater potential for short-term impacts to water temperature adjacent to the Site under this alternative due to limited bank cover during maturation of riparian vegetation.

Time Required to Reach Remedial Goals

Implementation of Alternative 5c is expected to occur over a two- to three-year period of time. Following implementation, the soil RAO would be met.

Results of the post-remediation loading analysis indicate that PCOC concentrations would achieve surface water RAOs within approximately 50 years. However, based on the toxicological evaluations provided in Appendix H, short- and long-term post-remediation concentrations are expected to be protective of aquatic life in Railroad Creek.

As described above for surface water, the groundwater RAOs would be expected to be achieved at CPOCs within surface water in approximately 50 years.

7.13.2.4 Implementability

Implementability includes the evaluation of technical feasibility, administrative feasibility, and availability of services and materials.

Technical Feasibility

The West Area actions included under Alternative 5c are expected to be implementable. The relocation of Railroad Creek to the north would have moderately implementability due to the increased design requirements for configuration the new channel alignment and limited space on the north side of the creek adjacent to tailings pile 2 for relocation. Construction of the groundwater collection and treatment systems within the existing creek bed would also be moderately implementable due to the relatively flat grade, variable characteristics of the alluvial materials below the tailings piles, and estimated depth to bedrock or dense till. Construction of the collection and treatment systems within the existing creek channel is expected to be more implementable than installation of the deep barrier wall/collection system at the base of the tailings piles as described for Alternatives 5a and 5b.

As described for Alternative 5b, the treatment of groundwater and seeps in the East Area would be difficult due to the high concentrations of iron resulting in significant chemical addition requirements and sludge generation rates. High chemical addition rates would be required to provide sufficient alkalinity to neutralize the acidity generated from the oxidation and precipitation of dissolved iron constituents. The large volumes of treatment chemicals would require regular shipments by barge and truck to the Site.

Administrative Feasibility

As described for Alternatives 5a and 5b, coordination between many local agencies and the Holden Village would be required under Alternatives 2 through 8. Alternative 5c would have lower administrative implementability due to the increased coordination required with local agencies and the Holden Village for extended relocation of Railroad Creek.

Availability of Services and Materials

As described for Alternatives 5a and 5b, the services and materials required for implementation of this alternative would be available within the Railroad Creek valley or could be mobilized to the Site by barge.

Large volumes of treatment chemicals would be transported to the Site by barge and truck on a regular basis under this alternative and on site personnel would be required to operate and maintain collection and treatment systems.

7.13.2.5 Cost

The total estimated cost associated with Alternative 5c is approximately $40,380,000 (2004 dollars at a 7-percent discount rate). The costs estimated for Alternative 5c are lower than the costs associated with Alternative 5b primarily due to the reduced earthwork and barrier wall/collection system construction under this alternative. Table 7-9 provides a summary of capital and O&M costs for each of the eight candidate alternatives, and cost detail sheets are provided in Appendix I.

Capital costs associated with implementation of Alternative 5c are estimated at approximately $22,580,000. Annual O&M costs associated with monitoring, maintaining the upgradient diversion channels, and operating and maintaining the collection and treatment systems are estimated to be approximately $400,000.

7.13.3 Natural Resource Restoration

Alternative 5c would achieve a similar level of natural resource restoration as described for Alternatives 5a and 5b. The extended relocation of Railroad Creek to the north would also be expected to provide increased restoration of aquatic habitat adjacent to, and immediately downstream of the Site.

Similar reductions in PCOC loading to Railroad Creek would be expected under this alternative compared to Alternative 5b. Gradual improvements in surface-water and groundwater quality are also expected over time through natural attenuation. A summary of the extent of natural resource restoration expected under each candidate alternative is provided in Appendix J.

7.13.4 Use of Permanent Solutions to the Maximum Extent Practicable

The remedial actions included under Alternative 5c constitute permanent solutions under MTCA since potential ARARs are expected to be achieved in the long term without further actions being required (WAC 173-340-200). The post-remediation loading analysis indicates that PCOC loading to Site groundwater and surface water would be reduced over time and potential ARARs are expected to be achieved within approximately 50 years, depending on the PCOC.

An evaluation the use of permanent solutions to the maximum extent practicable is provided in Section 8 (comparative analysis of alternatives). The evaluation of the practicability of this alternative includes whether the alternative is capable of being designed, constructed, and implemented in a reliable and effective manner, including consideration of cost. In considering cost under this analysis, an alternative shall not be considered practicable if the incremental costs are disproportionate to the incremental degree of benefits provided by the alternative over other lower cost alternatives.

7.13.5 Reasonable Restoration Time Frame

Following implementation of Alternative 5c, the soil RAOs would be met. Remedial actions would also be effective in eliminating potential physical hazards to Holden Village residents and visitors related to mine features and potential future risks to human health due to the possible development of groundwater as a drinking water supply.

PCOC loading to groundwater would be reduced over time under Alternative 5c through natural attenuation, upgradient water diversions, source controls, and East/West Area collection and treatment. Results of the post-remediation loading analysis indicate that the groundwater RAO would be achieved at CPOCs in surface water in the West Area and East Areas within approximately 50 years.

Results of the post-remediation loading analysis indicate that the surface water RAO would also be achieved within approximately 50 years. Results of the toxicological evaluations indicate that surface water quality would be protective of aquatic life in Railroad Creek in the short term under Alternative 5c.

An evaluation of reasonable restoration time frame is provided in Section 8. The evaluation of the practicability of this alternative, which would likely provide a shorter restoration time frame compared to Alternative 3b, includes whether the alternative is capable of being designed, constructed, and implemented in a reliable and effective manner, including consideration of cost. In considering cost under this analysis, an alternative shall not be considered practicable if the incremental costs are disproportionate to the incremental degree of benefits provided by the alternative over other lower cost alternatives.

7.14 ALTERNATIVE 5D: WATER MANAGEMENT, SECONDARY WEST AREA COLLECTION, EXTENDED RAILROAD CREEK RELOCATION, AND EAST/WEST AREA TREATMENT (LOW-ENERGY TREATMENT)

The following subsections provide detailed analysis of the remediation components included under Alternative 5d to address Site soils, surface water and groundwater. Alternative 5d includes the same actions as described under Alternative 5c, with the addition of a secondary barrier wall/groundwater collection system in the lower West Area. To avoid repetition, the following subsections provide an analysis of the additional remediation components included under Alternative 5d.

Under Alternative 5d, the secondary barrier wall/groundwater collection system installed in the lower West Area is expected to provide slightly greater short-term reductions in metals loading from the West Area to Railroad Creek. As a result, slightly greater reductions in PCOC concentrations in Railroad Creek are expected under Alternative 5d compared to 5c. Estimated loading reductions from East and West Area sources under Alternative 5d are summarized in

Appendix D, Tables D1-10a, D2-10a, and D4. The estimated short- and long-term post-remediation Railroad Creek water quality is summarized for this alternative in Tables 7-1 through 7-4.

7.14.1 Threshold Criteria

Evaluation of the two threshold criteria, including overall protection of human health and the environment and compliance with ARARs, is provided in the following subsections for Alternative 5d.

7.14.1.1 Overall Protection of Human Health and the Environment

Protection of Human Health and Terrestrial Ecological Receptors

As described for Alternative 5c, the remedial actions included under Alternative 5d are expected to be protective of human health and terrestrial ecological receptors at the Site. The RAO to implement the remedial action in a manner that is protective of human health, including the Holden Village community, during and after construction would be met under this alternative. The soil RAO would also be achieved following remedy implementation.

Protection of Aquatic Life

Results of the post-remediation loading analysis indicate that seasonal dissolved cadmium, copper, and zinc concentrations in Railroad Creek would be reduced following remedy implementation, and would continue to gradually decline over time through natural attenuation. The analysis predicts that the potential surface water ARARs for zinc would be met in the short term, and the potential ARARS for cadmium and copper would be met within approximately 50 years of remedy implementation (Tables 7-1 through 7-4). However, based on the toxicological evaluations provided in Appendix H, post-remediation PCOC concentrations under Alternative 5d would be protective of resident species in Railroad Creek, including salmonids and their prey, following remedy implementation in the short term.

Under Alternative 5d, total iron concentrations are expected to comply with the NRWQC following remedy implementation in the short term. Seasonal concentrations of total aluminum may remain above background in the short term. However, an analysis of documented aluminum toxicity, presented in Appendix H, indicates that the post-remediation aluminum concentrations would be protective of resident aquatic species in Railroad Creek. Over the long term, total aluminum concentrations are expected to continue to decline through natural attenuation and approach the NRWQC and/or background concentrations.

The RAOs for groundwater and surface water quality would not be achieved in the short term under Alternative 5d. However, as described above, results of the post-remediation loading analysis indicate that these RAOs would be met in the long term as described below in Section 7.14.1.2.

Potential for Short-term Impacts

Potential short-term impacts to the environment during construction and implementation would be similar to those described under Alternative 5c. However, there would be a higher potential for disturbance of vegetation in the West Area and slurry losses to Railroad Creek during construction of the lower West Area barrier wall. Areas disturbed during construction would be reclaimed and slurry losses would be minimized, as possible, using standard engineering controls.

7.14.1.2 Compliance with ARARs

Compliance with ARARs includes the evaluation of chemical-specific, location-specific, and action-specific ARARs identified in Section 3.

Potential Chemical-specific ARARs

The following subsections evaluate compliance with potential chemical-specific ARARs identified for Site media, including surface water, groundwater and soil.

Surface Water

Results of the post-remediation loading analysis indicate dissolved cadmium and zinc concentrations in Railroad Creek would be below the SWQC following remedy implementation in the short-term. The analysis indicates that dissolved copper concentrations would be below the SWQC within approximately 50 years of remedy implementation (Tables 7-1 through 7-4). However, based on the toxicological evaluations provided in Appendix H, post-remediation PCOC concentrations under Alternative 5d would be protective of resident aquatic species in Railroad Creek following remedy implementation in the short term.

Dissolved zinc concentrations are predicted to meet the NRWQC following remedy implementation in the short term. Dissolved cadmium and copper concentrations are expected to be below the NRWQC within approximately 50 years (Tables 7-1 through 7-4). Although the post-remediation analysis could not be performed for total aluminum or iron, total iron concentrations are expected to be below the NRWQC following remedy implementation. Total aluminum concentrations are expected to approach the NRWQC and/or background in the long term, and the toxicological evaluations provided in Appendix H indicate short-term aluminum concentrations would be protective of aquatic life in Railroad Creek.

For the East and West Areas, points of compliance would be established through mixing zones where treated effluent from the East and West Areas discharge to surface water. The CPOCs would be monitored at the limits of the established mixing zones.

Groundwater

Portions of the seeps and groundwater beneath the Site would not likely meet potential chemical-specific ARARs in the short or long term under any of the alternatives. Therefore, as discussed under Alternative 2a, it is not practicable to meet potential groundwater ARARs throughout the Site within a reasonable restoration time frame.

Under Alternative 5d, which includes the installation of a secondary barrier wall and groundwater collection system adjacent to Railroad Creek in the lower West Area, potential groundwater ARARs may be achieved within Railroad Creek upstream of RC-4 (with the exception of seep SP-26) following remedy implementation. The results of the post-remediation loading analysis indicate that potential ARARs would not be met in the short term at points where groundwater flows into surface water downstream of RC-4. As described above, results of the loading analysis indicate potential ARARs would be achieved in Railroad Creek (represented by stations RC-4 and RC-2) within approximately 50 years. These stations are considered to be generally representative of water quality in Railroad Creek downstream of West and East Area sources. However, it may take longer for some locations within the creek to achieve potential ARARs.

Natural attenuation, in conjunction with upgradient water diversions, source controls, and West Area collection and treatment, as described under Alternative 3a constitute AKART for this Site. The additional actions included under Alternative 5d (secondary collection in the lower West Area, and extended collection and treatment in the East Area) would be more than required to meet the definition of AKART under MTCA. As a result, CPOCs for groundwater in surface water, where groundwater flows into surface water, would apply for the East and West Areas under this alternative.

Soils

As described for Alternatives 5a, 5b, and 5c the potential ARARs identified for soil would be achieved under Alternative 5d.

Potential Location-specific ARARs

Compliance with potential location-specific ARARs for Alternative 5d would be the same as described for Alternatives 5a, 5b, and 5c in Sections 7.11.1.2.

Potential Action-Specific ARARs

Compliance with potential action-specific ARARs for Alternative 5d would be the same as described for Alternatives 5a, 5b, and 5c in Sections 7.11.1.2.

7.14.2 Primary Balancing Criteria

Evaluation of the five primary balancing criteria, including long-term effectiveness and permanence; reduction of toxicity, mobility, and volume; short-term effectiveness; implementability; and cost is provided in the following subsections for Alternative 5d.

7.14.2.1 Long-term Effectiveness and Permanence

Long-term effectiveness and permanence includes evaluation of the magnitude of residual risk and adequacy and reliability of controls.

Magnitude of Residual Risks

As described under Alternative 5c, the actions included under Alternative 5d would be protective of human health and terrestrial ecological receptors. Therefore, the magnitude of remaining human health risks and risks to ecological receptors would be low under this alternative.

If it is assumed that the lower barrier wall/collection system in the West Area can be effectively constructed and implemented, slight improvements in the short- and long-term post-remediation Railroad Creek water quality are estimated under Alternative 5d compared to Alternative 5c. Based on the results of the short-term loading analysis and toxicological analyses provided in Appendix H, post-remediation PCOC concentrations following implementation of Alternative 5d are not expected to adversely impact the aquatic community in Railroad Creek, including salmonids and their prey.

Metal precipitates and sludge generated in the treatment ponds would require periodic removal and disposal in a suitable containment location on site. Treatment residuals from alkaline precipitation processes are expected to be stable products with reduced metals mobility. However, the containment areas would require periodic maintenance to reduce long-term surface water infiltration.

As described for Alternatives 5a, 5b, and 5c the magnitude of residual risks due to potential surge releases from the underground mine or tailings releases due to potential slope failure would be low under Alternative 5d.

Adequacy and Reliability of Controls

The actions included under Alternative 5d are expected to be moderately implementable and reliable in reducing metals loading from Site sources and providing long-term protection of human health and the environment. The lower West Area barrier wall/collection system is estimated to intercept groundwater and seeps in the short-term with an estimated collection efficiency of approximately 90 percent. However, there is significant uncertainty related to the ability to effectively construct the barrier wall/collection trench due to the required depths of trench construction, variable subsurface conditions and depths to low-permeability till/bedrock, and proximity to railroad Creek.

As described under Alternative 5c, the extended relocation of Railroad Creek to the north and use of the existing creek channel for groundwater collection and treatment is expected to be moderately implementable. The open collection system is estimated to collect East Area seeps and groundwater intercepted by Railroad Creek under current conditions with a collection efficiency of approximately 80 to 90 percent. However, there is significant uncertainty related to the potential influx of Railroad Creek water to the East Area collection and treatment system, especially in the reach adjacent to tailings pile 2, where the valley narrows and space is limited to the north for Railroad Creek relocation.

Although gradual reductions in PCOC concentrations in the portal drainage and Site groundwater are expected over time through natural attenuation, long-term operations and maintenance of chemical addition systems, collection trenches, treatment ponds, and containment areas would be required under this alternative. The low-energy treatment systems would have a high degree of implementability and would be designed to reliably treat seasonal portal drainage, seep, and groundwater flows. Chemical addition rates would be controlled based on seasonal flows and water quality, and the settling ponds and media filters would be sized to provide significant detention times and solids removal prior to discharge to Railroad Creek. An important factor in providing consistent effluent quality under Alternative 5d would be the ability to adjust chemical addition rates in response to variable influent flows and water chemistry.

7.14.2.2 Reduction of Toxicity, Mobility, and Volume

The alkaline precipitation process included for the East and West Areas under Alternative 5d would reduce the mass and volume of PCOCs released to groundwater and surface water. The treatment process would produce stable treatment residuals, and thus reduce the mobility and toxicity of PCOCs to environmental receptors. The volume of impacted materials requiring management would increase with the sludge generated from the water treatment processes.

Additionally, the mass, and therefore volume, of PCOCs released to groundwater and surface water would be reduced over time from Site sources through the source control actions and the natural geochemical processes described in Appendix E.

7.14.2.3 Short-term Effectiveness

Short-term effectiveness includes evaluation of protection of local communities, worker protection, short-term environmental impacts, and time required to reach remediation goals.

Protection of Local Communities

Alternative 5d would be protective of Holden Village residents and visitors. A stream crossing over Railroad Creek would be constructed at the northeast corner of tailings pile 3, to allow vehicles and equipment to bypass the Village during construction activities. Access to the top of the tailings piles would also be maintained from the new stream crossing under this alternative. However, Alternative 5d would require additional construction activities in the lower West Area in the vicinity of the Holden Village sauna, West Area pedestrian bridge and current location of the vehicle bridge. The additional construction activities under alternative 5d in conjunction with the extended Railroad Creek relocation would result in increased noise and risks to the local community.

As described under Alternative 5c, operation and maintenance of the East and West Area treatment systems would require regular deliveries of diesel fuel and treatment chemicals to the Site by barge and truck, and would result in increased traffic and equipment operations on the south side of Railroad Creek during sludge disposal and maintenance activities.

Potential physical hazards to the local community related to the possible development of a rock source near Tenmile Creek would be mitigated using proven engineering controls.

Worker Protection

Potential risks to workers and mitigation measures implemented under Alternative 5d would be the same as described for Alternative 5a in Section 7.11.2.3. However, the level of construction activities (e.g., lower West Area barrier wall/collection system and extended Railroad Creek relocation), and therefore, potential safety risks to workers, would be greater for Alternative 5d.

Environmental Impacts

Potential short-term impacts to the environment during construction and implementation would be similar to Alternative 5c. However, additional areas within the lower West Area would be disturbed during construction of the lower West Area barrier wall/collection system. Disturbed areas would be reclaimed following completion of construction.

There is also a greater potential for slurry losses to Railroad Creek during construction of the lower West Area barrier wall and collection system. Slurry releases would be minimized, as possible, through the performance of pre-construction investigations to identify zones with high-porosity that may require mitigation measures to prevent potential slurry losses to the creek. If zones of high-porosity are encountered, low-permeability filler material (such as straw) may be used to plug high-porosity zones during trench construction, panel construction methods may be implemented, or cement additives used in areas that would be susceptible to leakage. Containment berms may also be constructed on the downgradient side of barrier wall trenches and slurry mixing areas to reduce the potential for releases to the creek.

Time Required to Reach Remedial Goals

Implementation of Alternative 5d is expected to occur over a two- to three-year period of time. Following implementation, the soil RAO would be met.

Results of the post-remediation loading analysis indicate that PCOC concentrations would achieve surface water RAOs within approximately 50 years. However, based on the toxicological evaluations provided in Appendix H, short- and long-term post-remediation concentrations are expected to be protective of aquatic life in Railroad Creek.

Through installation of the lower West Area barrier wall under Alternative 5d, groundwater may achieve potential ARARs at the points where groundwater enters surface water in this area. However, the results of the loading analysis indicate compliance with groundwater ARARs in surface water downstream of RC-4 would be expected within approximately 50 years.

7.14.2.4 Implementability

Implementability includes the evaluation of technical feasibility, administrative feasibility, and availability of services and materials.

Technical Feasibility

The actions included under Alternative 5d are expected to be moderately implementable. The construction of the lower West Area barrier wall/collection system is expected to be difficult due to the estimated depths required for trench construction, variable subsurface conditions, and proximity of Railroad Creek to the collection system (e.g., there are portions of the system that would be constructed nearly perpendicular to the current creek flow path).

The relocation of Railroad Creek to the north would have moderate implementability due to the increased design requirements for configuration the new channel alignment and limited space on the north side of the creek adjacent to tailings pile 2 for relocation. Construction of the groundwater collection and treatment systems within the existing creek bed would also be moderately implementable due to the relatively flat grade, variable characteristics of the alluvial materials below the tailings piles, and estimated depth to bedrock or dense till.

As described for Alternative 5c, the treatment of groundwater and seeps in the East Area would be difficult due to the high concentrations of iron resulting in significant chemical addition requirements and sludge generation rates. High chemical addition rates would be required to provide sufficient alkalinity to neutralize the acidity generated from the oxidation and precipitation of dissolved iron constituents. The large volumes of treatment chemicals would require regular shipments by barge and truck to the Site.

Administrative Feasibility

As described for Alternative 5c, coordination between many local agencies and the Holden Village would be required under Alternatives 2 through 8. Alternative 5d would have lower administrative implementability due to the increased coordination required with local agencies and the Holden Village for the lower West Area collection and treatment system.

Availability of Services and Materials

As described for Alternatives 5c, the services and materials required for implementation of this alternative would be available within the Railroad Creek valley or could be mobilized to the Site by barge.

Large volumes of treatment chemicals would be transported to the Site by barge and truck on a regular basis under this alternative and on site personnel would be required to operate and maintain collection and treatment systems.

7.14.2.5 Cost

The total estimated cost associated with Alternative 5d is approximately $45,770,000 (2004 dollars at a 7-percent discount rate). The increased costs estimated for Alternative 5d compared to Alternative 5c are primarily associated with the lower West Area barrier wall/groundwater collection system construction. Table 7-9 provides a summary of capital and O&M costs for each of the eight candidate alternatives, and cost detail sheets are provided in Appendix I.

Capital costs associated with implementation of Alternative 5c are estimated at approximately $25,830,000. Annual O&M costs associated with monitoring, maintaining the upgradient diversion channels, and operating and maintaining the collection and treatment systems are estimated to be approximately $430,000.

7.14.3 Natural Resource Restoration

Alternative 5d would achieve a similar level of natural resource restoration as described for Alternative 5c. Similar reductions in PCOC loadings to Railroad Creek would be expected under this alternative compared to Alternative 5c. A summary of the extent of natural resource restoration expected under each candidate remedial alternative is provided in Appendix J.

7.14.4 Use of Permanent Solutions to the Maximum Extent Practicable

The remedial actions included under Alternative 5d constitute permanent solutions under MTCA since potential ARARs are expected to be achieved in the long term without further actions being required (WAC 173-340-200). The post-remediation loading analysis indicates that PCOC loading to Site groundwater and surface water would be reduced over time and potential ARARs are expected to be achieved within approximately 50 years, depending on the PCOC.

An evaluation the use of permanent solutions to the maximum extent practicable is provided in Section 8 (comparative analysis of alternatives). The evaluation of the practicability of this alternative includes whether the alternative is capable of being designed, constructed, and implemented in a reliable and effective manner, including consideration of cost. In considering cost under this analysis, an alternative shall not be considered practicable if the incremental costs are disproportionate to the incremental degree of benefits provided by the alternative over other lower cost alternatives.

7.14.5 Reasonable Restoration Time Frame

Following implementation of Alternative 5d, the soil RAOs would be met. Remedial actions would also be effective in eliminating potential physical hazards to Holden Village residents and visitors related to mine features and potential future risks to human health due to the possible development of groundwater as a drinking water supply.

PCOC loading to groundwater would be reduced over time under Alternative 5d through natural attenuation, upgradient water diversions, source controls, and East/West Area collection and treatment. Results of the post-remediation loading analysis indicate that the groundwater RAO would be achieved at CPOCs in surface water in the West Area and East Areas within approximately 50 years.

Results of the post-remediation loading analysis indicate that the surface water RAO would also be achieved within approximately 50 years. Results of the toxicological evaluations indicate that surface water quality would be protective of aquatic life in Railroad Creek in the short term under Alternative 5d.

An evaluation of reasonable restoration time frame is provided in Section 8. The evaluation of the practicability of this alternative, which would likely provide a shorter restoration time frame compared to Alternative 3b, includes whether the alternative is capable of being designed, constructed, and implemented in a reliable and effective manner, including consideration of cost. In considering cost under this analysis, an alternative shall not be considered practicable if the incremental costs are disproportionate to the incremental degree of benefits provided by the alternative over other lower cost alternatives.

7.15 ALTERNATIVE 6A: WATER MANAGEMENT, EXTENDED SECONDARY WEST AREA COLLECTION, EXTENDED RAILROAD CREEK RELOCATION, AND EAST/WEST AREA TREATMENT (MECHANICAL TREATMENT)

The following subsections provide detailed analysis of the remediation components included under Alternative 6a to address Site soils, surface water and groundwater. Alternative 6a includes the same actions as described under Alternative 5d, with the addition of an extended secondary barrier wall/groundwater collection system in the lower West Area and a mechanical water treatment system in the West Area. The installation of airflow restrictions in the underground mine without the use of hydrostatic bulkheads to control the 1500-level portal drainage flow is assumed under this alternative. To avoid repetition, the following subsections provide an analysis of the additional remediation components included under Alternative 6a.

Based on results of the loading analysis and available hydrogeologic data in the West Area, the implementation of the extended secondary barrier wall/groundwater collection system in the lower West Area and West Area mechanical treatment are expected to provide slight reductions in short-term PCOC loading to Railroad Creek from the West Area but are not expected to provide additional long-term reductions in PCOC loadings. This is primarily due to the expected collection of unimpacted groundwater upstream of the portal drainage, which is assumed to be discharged to Railroad Creek at the estimated treatment system effluent concentration. As a result, similar post-remediation PCOC concentrations are expected in Railroad Creek under Alternative 6a compared to 5d in the short term, and slightly higher PCOC concentrations are expected in the long term than under Alternatives 5a through 5d.

Estimated loading reductions from East and West Area sources under Alternative 6a are summarized in Appendix D, Tables D1-11, D2-11, and D4. The estimated short- and long-term post-remediation Railroad Creek water quality for this alternative is summarized in Tables 7-1 through 7-4.

7.15.1 Threshold Criteria

Evaluation of the two threshold criteria, including overall protection of human health and the environment and compliance with ARARs, is provided in the following subsections for Alternative 6a.

7.15.1.1 Overall Protection of Human Health and the Environment

Protection of Human Health and Terrestrial Ecological Receptors

As described for Alternative 5d, the remedial actions included under Alternative 6a are expected to be protective of human health and terrestrial ecological receptors at the Site. The RAO to implement the remedial action in a manner that is protective of human health, including the Holden Village community, during and after construction would be met under this alternative. The soil RAO would also be achieved following remedy implementation.

Protection of Aquatic Life

Results of the post-remediation loading analysis indicate that seasonal dissolved cadmium, copper, and zinc concentrations in Railroad Creek would be reduced following remedy implementation, and would continue to gradually decline over time through natural attenuation. The analysis predicts that the potential ARARs for zinc would be met following remedy implementation, and the potential ARARs for cadmium and copper would be met within approximately 250 and 50 years, respectively (Tables 7-1 through 7-4). However, based on the toxicological evaluations provided in Appendix H, post-remediation PCOC concentrations under Alternative 6a would be protective of resident aquatic species in Railroad Creek, including salmonids and their prey, following remedy implementation in the short term.

Under Alternative 6a, total iron concentrations are expected to comply with the NRWQC following remedy implementation in the short term. Seasonal concentrations of total aluminum may remain above background in the short term. However, an analysis of documented aluminum toxicity, presented in Appendix H, concludes that the post-remediation aluminum concentrations would be protective of resident aquatic species in Railroad Creek. Over the long term, total aluminum concentrations are expected to continue to decline through natural attenuation and would approach the NRWQC and/or background concentrations.

The RAOs for groundwater and surface water quality would not be achieved in the short term under Alternative 6a. However, results of the post-remediation loading analysis indicate that these RAOs would be met in the long term as described below under Section 7.15.1.2.

Potential for Short-term Impacts

Potential short-term impacts to the environment during construction and implementation would be similar to those described under Alternative 5d. However, there would be greater disturbance of vegetation in the West Area during construction of the extended lower West Area barrier wall. As described in Section 6, approximately 1,700 feet of the extended barrier wall would be constructed on the steep slopes located upstream (west) of the confluence of P-5 and Railroad Creek. As a result, significant excavation would be required along this portion of the alignment to construct a level work area for barrier wall/collection trench construction. There would also be an increased potential for slurry losses to Railroad Creek during construction of the extended lower West Area barrier wall. Areas disturbed during construction would be reclaimed and slurry losses would be minimized through the use of standard engineering controls.

7.15.1.2 Compliance with ARARs

Compliance with ARARs includes the evaluation of chemical-specific, location-specific, and action-specific ARARs identified in Section 3.

Potential Chemical-specific ARARs

The following subsections evaluate compliance with potential chemical-specific ARARs identified for Site media, including surface water, groundwater and soil.

Surface Water

Results of the post-remediation loading analysis indicate dissolved cadmium and zinc concentrations in Railroad Creek would be below the SWQC following remedy implementation in the short-term. The analysis indicates that dissolved copper concentrations would be below the SWQC within approximately 50 years of remedy implementation (Tables 7-1 through 7-4). However, based on the toxicological evaluations provided in Appendix H, post-remediation PCOC concentrations under Alternative 6a would be protective of resident species in Railroad Creek, including salmonids and their prey, following remedy implementation in the short term.

Dissolved zinc concentrations are predicted to meet the NRWQC following remedy implementation in the short term. Dissolved copper concentrations are expected to be below the NRWQC within approximately 50 years and dissolved cadmium concentrations are expected to be below the NRWQC within approximately 250 years (Tables 7-1 through 7-4). Although the post-remediation analysis could not be performed for total aluminum or iron, iron concentrations are expected to be below the NRWQC following remedy implementation. Total aluminum concentrations are expected to approach the NRWQC and/or background concentrations in the long term. The results of the toxicological evaluations provided in Appendix H indicate short-term aluminum concentrations would be protective of aquatic life in Railroad Creek.

For the East and West Areas, points of compliance would be established through mixing zones where treated effluent from the East and West Areas discharge to surface water. The CPOCs would be monitored at the limits of the established mixing zones.

Groundwater

Portions of the seeps and groundwater beneath the Site would not likely meet potential chemical-specific ARARs in the short or long term under any of the alternatives. Therefore, as discussed under Alternative 2a, it is not practicable to meet potential groundwater ARARs throughout the Site within a reasonable restoration time frame.

Under Alternative 6a, which includes the installation of an extended secondary barrier wall and groundwater collection system adjacent to Railroad Creek in the lower West Area, potential groundwater ARARs may be achieved within Railroad Creek upstream of RC-4 following remedy implementation. The results of the post-remediation loading analysis indicate that potential ARARs would not be met in the short term at points where groundwater flows into surface water downstream of RC-4. As described above, results of the loading analysis indicate potential ARARs would be achieved in Railroad Creek (represented by stations RC-4 and RC-2) within approximately 250 years. These stations are considered to be generally representative of water quality in Railroad Creek downstream of West and East Area sources. However, it may take longer for some locations within the creek to achieve potential ARARs.

Natural attenuation, in conjunction with upgradient water diversions, source controls, and West Area collection and treatment, as described under Alternative 3a constitute AKART for this Site. The additional actions included under Alternative 6a (secondary collection in the lower West Area, and extended collection and treatment in the East Area) would be more than required to meet the definition of AKART under MTCA. As a result, CPOCs for groundwater in surface water, where groundwater flows into surface water, would apply for the East and West Areas under this alternative.

Soils

The potential ARARs identified for soil would be achieved under Alternative 6a.

Potential Location-specific ARARs

Compliance with potential location-specific ARARs for Alternative 6a would be the same as described for Alternatives 5a, 5b, 5c, and 5d in Sections 7.11.1.2.

Potential Action-Specific ARARs

Compliance with potential action-specific ARARs for Alternative 6a would be the same as described for Alternatives 5a, 5b, 5c, and 5d in Sections 7.11.1.2.

7.15.2 Primary Balancing Criteria

Evaluation of the five primary balancing criteria, including long-term effectiveness and permanence; reduction of toxicity, mobility, and volume; short-term effectiveness; implementability; and cost; is provided in the following subsections for Alternative 6a.

7.15.2.1 Long-term Effectiveness and Permanence

Long-term effectiveness and permanence includes evaluation of the magnitude of residual risk and adequacy and reliability of controls.

Magnitude of Residual Risks

As described under Alternative 5d, the actions included under Alternative 6a would be protective of human health and terrestrial ecological receptors. Therefore, the magnitude of remaining human health risks and risks to ecological receptors would be low under this alternative.

If it is assumed that the extended lower barrier wall/collection system in the West Area can be effectively constructed and implemented, similar improvements in the short- and long-term post-remediation Railroad Creek water quality are estimated under Alternative 6a as described for Alternative 5d. Based on the results of the short-term loading analysis and toxicological analyses provided in Appendix H, post-remediation PCOC concentrations following implementation of Alternative 6a are not expected to adversely impact the aquatic community or their prey.

Metal precipitates and sludge generated in the treatment systems would require periodic removal and disposal in a suitable containment location on site. Treatment residuals from alkaline precipitation processes are expected to be stable products with reduced metals mobility. However, the containment areas would require periodic maintenance to reduce long-term surface water infiltration and maintain liner integrity.

As described for Alternative 2b the magnitude of residual risks due to potential surge releases from the underground mine or tailings releases due to potential slope failure would be low under Alternative 6a.

Adequacy and Reliability of Controls

The actions included under Alternative 6a are expected to be difficult to implement and moderately reliable in reducing metals loading from Site sources and providing long-term protection of human health and the environment. The extended lower West Area barrier wall/collection system is estimated to intercept groundwater and seeps in the short-term with an estimated collection efficiency of approximately 80 to 90 percent. However, there is significant uncertainty related to the ability to effectively construct the barrier wall/collection trench due to the steep slopes existing for approximately 1,700 feet of the alignment, heterogeneous subsurface conditions, estimated depths to low-permeability till/bedrock, and proximity to railroad Creek. There is also a potential to collect significant volumes of unimpacted groundwater in the extended West Area collection system, which would increase treatment system sizing and present difficulties in providing adequate flow equalization during the spring flush.

The effectiveness of this alternative would be dependent on the ability to adequately operate and maintain the mechanical treatment equipment (e.g., mixers, chemical feeders, etc.). Effective treatment would depend on reliable diesel-generated power and full-time operators to maintain the system. As a result, these actions are expected to have a low long-term reliability, especially during the winter months when access to the Site from Lake Chelan is not possible. Additionally, a mechanical treatment system that utilizes tanks, pumps, and other mechanical equipment would have a more limited operating range, and would not be as flexible as a system utilizing large settling ponds in treating variable influent flows. Alternatively, oversized mechanical components would likely result in inefficiencies and operational difficulties when treating lower flows following the spring flush. As a result, a mechanical treatment system is not expected to be as robust as a low-energy system in handling variations in influent flow or water quality.

As described under Alternative 5d, the extended relocation of Railroad Creek to the north and use of the existing creek channel for groundwater collection and treatment is also expected to be moderately implementable. The open collection system is estimated to collect East Area seeps and groundwater currently intercepted by Railroad Creek with a collection efficiency of approximately 80 to 90 percent. However, there is significant uncertainty related to the potential influx of Railroad Creek water to the East Area collection and treatment system, especially in the reach adjacent to tailings pile 2, where the valley narrows and space is limited to the north for Railroad Creek relocation.

7.15.2.2 Reduction of Toxicity, Mobility, and Volume

The alkaline precipitation process included for the East and West Areas under Alternative 6a would reduce the mass and volume of PCOCs released to groundwater and surface water. The treatment process would produce stable treatment residuals, and thus reduce the mobility and toxicity of PCOCs to environmental receptors. The volume of impacted materials requiring management would increase with the sludge generated from the water treatment processes.

Additionally, the mass, and therefore volume, of PCOCs released to groundwater and surface water would be reduced over time from Site sources through the source control actions and the natural geochemical processes described in Appendix E.

7.15.2.3 Short-term Effectiveness

Short-term effectiveness includes evaluation of protection of local communities, worker protection, short-term environmental impacts, and time required to reach remediation goals.

Protection of Local Communities

The implementation of a mechanical treatment system in the West Area would require significant quantities of fuel and operation and maintenance activities over the long-term. The energy requirements of a mechanical treatment system would exceed the hydroelectric generation capacity available at the Site. Preliminary calculations indicate approximately 140 to 190 kW of power would be needed for the West Area system during peak flow periods in the spring. This power consumption rate translates to a potential diesel fuel consumption rate between 95,000 and 125,000 gallons per year. To ensure uninterrupted operations during the winter months when access to the Village is limited, a storage tank of approximately 50,000 gallons would likely be needed for fuel storage. The transport and storage of large quantities of fuel would increase potential risks to the environment and Holden Village residents and visitors in the event of a large fire or spill. Assuming a 2,000 gallon capacity truck would be used to deliver fuel to the Site, approximately 50 to 65 shipments of fuel per year would be required under this alternative.

A stream crossing over Railroad Creek would be constructed at the northeast corner of tailings pile 3, to allow vehicles and equipment to bypass the Village during construction activities. Access to the top of the tailings piles would be gained from the new stream crossing under this alternative. However, additional construction activities associated with the extended barrier wall and mechanical treatment system would be conducted in the lower West Area in the vicinity of the Holden Village maintenance building, sauna, West Area pedestrian bridge and current location of the vehicle bridge. These activities in conjunction with extended Railroad Creek relocation would result in increased noise and risks to the local community.

As described under Alternative 5d, operation and maintenance of the East and West Area treatment systems would also require frequent deliveries treatment chemicals to the Site by barge and truck, and would result in increased traffic and equipment operations on the south side of Railroad Creek during sludge disposal and maintenance activities.

Potential physical hazards to the local community related to the possible development of a rock source near Tenmile Creek would be mitigated using proven engineering controls.

Worker Protection

Potential risks to workers and mitigation measures implemented under Alternative 6a would be the same as described for Alternative 5d. However, the level of construction activities (e.g., extended lower West Area barrier wall/collection system and mechanical water treatment system), and therefore, potential safety risks to workers, would be greater for Alternative 6a. The frequent shipments of fuel and treatment chemicals under Alternative 6a would also significantly increase the potential for accidents along the Holden Village access road.

Environmental Impacts

Potential short-term impacts to the environment during construction and implementation would be similar to Alternative 5d. However, additional areas within the lower West Area would be disturbed under Alternative 6a during construction of the extended lower West Area barrier wall/collection system. Disturbed areas would be reclaimed in accordance with state and federal requirements.

There is also a greater potential for slurry losses to Railroad Creek during construction of the extended lower West Area barrier wall and collection system. Slurry releases would be minimized, as possible, through the performance of pre-construction investigations to identify zones with high-porosity that may require mitigation measures to prevent potential slurry losses to the creek. If zones of high-porosity are encountered, low-permeability filler material (such as straw) may be used to plug high-porosity zones during trench construction, panel construction methods may be implemented, or cement additives used in areas that would be susceptible to leakage. Containment berms may also be constructed on the downgradient side of barrier wall trenches and slurry mixing areas to reduce the potential for releases to the creek.

As described above, the transport and storage of large quantities of fuel would increase potential risks to the environment and Holden Village residents and visitors in the event of a large fire or spill. Fuel would need to be transported on a regular basis by barge from Chelan and then by truck from Lucerne to the Holden Village.

Time Required to Reach Remedial Goals

Implementation of Alternative 6a is expected to occur over a two- to three-year period of time. Following implementation, the soil RAO would be met.

Results of the post-remediation loading analysis indicate that PCOC concentrations would achieve surface water RAOs within approximately 250 years. However, based on the toxicological evaluations provided in Appendix H, short- and long-term post-remediation concentrations are expected to be protective of aquatic life in Railroad Creek.

Through installation of the extended lower West Area barrier wall under Alternative 6a, groundwater may achieve potential ARARs at the points where groundwater enters surface water in this area. However, the results of the loading analysis indicate compliance with groundwater ARARs in surface water downstream of RC-4 would be expected within approximately 250 years.

7.15.2.4 Implementability

Implementability includes the evaluation of technical feasibility, administrative feasibility, and availability of services and materials.

Technical Feasibility

Implementation of the actions included under Alternative 6a is expected to be difficult. The construction of the extended lower West Area barrier wall/collection system is expected to be difficult due to the special access requirements for the steep side slopes upstream of P-5, estimated depths required for trench construction, heterogeneous subsurface conditions, and proximity to Railroad Creek (e.g., there are portions of the lower West Area system that would be constructed nearly parallel to the current creek flow).

The construction and operation of a mechanical water treatment system in the West Area is expected to be moderately implementable due to the significant fuel and operation and maintenance requirements. This system would require full time operators, reliable power supply, and daily maintenance to ensure effective and reliable treatment.

The relocation of Railroad Creek to the north would also have moderate implementability due to the increased design requirements for configuration the new channel alignment and limited space on the north side of the creek adjacent to tailings pile 2 for relocation. Construction of the groundwater collection and treatment systems within the existing creek bed would be moderately implementable due to the relatively flat grade, variable characteristics of the alluvial materials below the tailings piles, and estimated depth to bedrock or dense till.

As described for Alternative 5d, the treatment of groundwater and seeps in the East Area would be difficult due to the high concentrations of iron resulting in significant chemical addition requirements and sludge generation rates. High chemical addition rates would be required to provide sufficient alkalinity to neutralize the acidity generated from the oxidation and precipitation of dissolved iron constituents. The large volumes of treatment chemicals would require regular shipments by barge and truck to the Site.

Administrative Feasibility

As described for Alternative 5d, coordination between many local agencies and the Holden Village would be required under Alternatives 2 through 8. Alternative 6a would have lower administrative implementability due to the increased coordination required with local agencies and the Holden Village for relocation of Railroad Creek, and the construction and long-term operation of the mechanical West Area treatment system.

Availability of Services and Materials

As described for Alternatives 5d, the services and materials required for implementation of this alternative would be available within the Railroad Creek valley or could be mobilized to the Site by barge.

Large volumes of fuel and treatment chemicals would be transported to the Site by barge and truck on a regular basis under Alternative 6a and full-time personnel would be required to operate and maintain the collection and treatment systems.

7.15.2.5 Cost

The total estimated cost associated with Alternative 6a is $77,400,000 (2004 dollars at a 7-percent discount rate). The increased costs estimated for Alternative 6a compared to Alternative 5d are primarily associated with the extended portion of the lower West Area barrier wall/groundwater collection system and mechanical treatment. Table 7-9 provides a summary of capital and O&M costs for each of the eight candidate alternatives, and cost detail sheets are provided in Appendix I.

Capital costs associated with implementation of Alternative 5d are estimated at approximately $40,190,000. Annual O&M costs associated with monitoring, maintaining the upgradient diversion channels, and operating and maintaining the collection and treatment systems are estimated to be approximately $970,000.

7.15.3 Natural Resource Restoration

Alternative 6a would achieve a similar level of natural resource restoration as described for Alternative 5d. Similar reductions PCOC loadings to Railroad Creek would be expected under this alternative compared to Alternative 5d. A summary of the extent of natural resource restoration expected under each candidate remedial alternative is provided in Appendix J.

7.15.4 Use of Permanent Solutions to the Maximum Extent Practicable

The remedial actions included under Alternative 6a constitute permanent solutions under MTCA since potential ARARs are expected to be achieved in the long term without further actions being required (WAC 173-340-200). The post-remediation loading analysis indicates that PCOC loading to Site groundwater and surface water would be reduced over time and potential ARARs are expected to be achieved within approximately 50 to 250 years, depending on the PCOC.

An evaluation the use of permanent solutions to the maximum extent practicable is provided in Section 8 (comparative analysis of alternatives). The evaluation of the practicability of this alternative includes whether the alternative is capable of being designed, constructed, and implemented in a reliable and effective manner, including consideration of cost. In considering cost under this analysis, an alternative shall not be considered practicable if the incremental costs are disproportionate to the incremental degree of benefits provided by the alternative over other lower cost alternatives.

7.15.5 Reasonable Restoration Time Frame

Following implementation of Alternative 6a, the soil RAOs would be met. Remedial actions would also be effective in eliminating potential physical hazards to Holden Village residents and visitors related to mine features and potential future risks to human health due to the possible development of groundwater as a drinking water supply.

PCOC loading to groundwater would be reduced over time under Alternative 6a through natural attenuation, upgradient water diversions, source controls, and East/West Area collection and treatment. Results of the post-remediation loading analysis indicate that the groundwater RAO would be achieved at CPOCs in surface water in the West Area and East Areas within approximately 50 to 250 years, depending on the PCOC.

Results of the post-remediation loading analysis indicate that the surface water RAO would also be achieved within approximately 50 to 250 years. Results of the toxicological evaluations indicate that surface water quality would be protective of aquatic life in Railroad Creek in the short term under Alternative 6a.

An evaluation of reasonable restoration time frames is provided in Section 8. The evaluation of the practicability of this alternative, which would likely provide a similar restoration time frame as Alternative 3b, includes whether the alternative is capable of being designed, constructed, and implemented in a reliable and effective manner, including consideration of cost. In considering cost under this analysis, an alternative shall not be considered practicable if the incremental costs are disproportionate to the incremental degree of benefits provided by the alternative over other lower cost alternatives.

7.16 ALTERNATIVE 6B: WATER MANAGEMENT, EXTENDED SECONDARY WEST AREA COLLECTION, EXTENDED RAILROAD CREEK RELOCATION, AND EAST/WEST AREA TREATMENT (MECHANICAL TREATMENT – HYDROSTATIC BULKHEAD)

The following subsections provide detailed analysis of the remediation components included under Alternative 6b to address Site soils, surface water and groundwater. Alternative 6b includes the same actions as described under Alternative 6a, with the addition of installing hydrostatic bulkheads in the 1500-level, installing a low-head bulkhead in the 1100 level, and other in-mine controls. The following subsections provide an analysis of the additional components included under Alternative 6b.

Under Alternative 6b, the installation of hydrostatic bulkheads and other in-mine controls is expected to achieve slightly greater reductions in PCOC loadings to Railroad Creek. As a result, slightly lower post-remediation PCOC concentrations are expected in Railroad Creek under Alternative 6b compared to 6a. But as with Alternative 6a, long-term PCOC concentrations under Alternative 6b are predicted to be slightly higher than for Alternatives 5a through 5d due to the expected collection of unimpacted groundwater in the extended lower West Area collection system. Estimated loading reductions from East and West Area sources under Alternative 6b are summarized in Appendix D, Tables D1-12, D2-12, and D4. The estimated short- and long-term post-remediation Railroad Creek water quality for this alternative is summarized in Tables 7-1 through 7-4.

7.16.1 Threshold Criteria

Evaluation of the two threshold criteria, including overall protection of human health and the environment and compliance with ARARs, is provided in the following subsections for Alternative 6b.

7.16.1.1 Overall Protection of Human Health and the Environment

Protection of Human Health and Terrestrial Ecological Receptors

As described for Alternative 6a, the remedial actions included under Alternative 6b are expected to be protective of human health and terrestrial ecological receptors at the Site. The RAO to implement the remedial action in a manner that is protective of human health, including the Holden Village community, during and after construction would be met under this alternative. The soil RAO would also be achieved following remedy implementation.

Protection of Aquatic Life

Results of the post-remediation loading analysis indicate that seasonal dissolved cadmium, copper, and zinc concentrations in Railroad Creek would be reduced following remedy implementation, and would continue to gradually decline over time through natural attenuation. The analysis predicts that potential ARARs for zinc would be met following remedy implementation, and potential ARARs for cadmium and copper would be achieved within approximately 150 and 50 years respectively (Tables 7-1 through 7-4). However, based on the toxicological evaluations provided in Appendix H, post-remediation PCOC concentrations under Alternative 6b would be protective of resident species in Railroad Creek, including salmonids and their prey, following remedy implementation in the short term.

Under Alternative 6b, total iron concentrations are expected to comply with the NRWQC following remedy implementation in the short term. Seasonal concentrations of total aluminum may remain above background in the short term. However, an analysis of documented aluminum toxicity, presented in Appendix H, indicates that the post-remediation aluminum concentrations would be protective of resident aquatic species in Railroad Creek. Over the long term, total aluminum concentrations are expected to continue to decline through natural attenuation and approach the NRWQC and/or background concentrations.

The RAOs for groundwater and surface water quality would not be achieved in the short term under Alternative 6b. However, as described above, results of the post-remediation loading analysis indicate that these RAOs would be met in the long term as described below in Section 7.16.1.2.

Potential for Short-term Impacts

Potential short-term impacts to the environment during construction and implementation would be similar to those described under Alternative 6a. However, the size of mechanical treatment system components required would likely be reduced, with less duplication, through the use of the underground mine for flow equalization and storage. This would reduce the construction and associated disturbance related to the West Area treatment system. As described for Alternative 6a, approximately 1,700 feet of the extended barrier wall would be constructed on the steep slopes located upstream of the confluence of P-5 and Railroad Creek. As a result, significant excavation would be required along this portion of the alignment to construct a level work area for barrier wall/collection trench construction. There would also be an increased potential for slurry losses to Railroad Creek during construction of the extended lower West Area barrier wall. Areas disturbed during construction would be reclaimed and slurry losses would be minimized through the use of standard engineering controls.

7.16.1.2 Compliance with ARARs

Compliance with ARARs includes the evaluation of chemical-specific, location-specific, and action-specific ARARs identified in Section 3.

Potential Chemical-specific ARARs

The following subsections evaluate compliance with potential chemical-specific ARARs identified for Site media, including surface water, groundwater and soil.

Surface Water

Results of the post-remediation loading analysis indicate dissolved cadmium, copper, and zinc concentrations in Railroad Creek would be below the SWQC following remedy implementation in the short term (Tables 7-1 through 7-4). However, based on the toxicological evaluations provided in Appendix H, post-remediation PCOC concentrations under Alternative 6b would be protective of resident aquatic species in Railroad Creek following remedy implementation in the short term.

Dissolved zinc concentrations in Railroad Creek are predicted to meet the NRWQC following remedy implementation in the short term. Dissolved copper concentrations are expected to be below the NRWQC within approximately 50 years and dissolved cadmium concentrations are expected to be below the NRWQC within approximately 250 years (Tables 7-1 through 7-4). Although the post-remediation analysis could not be performed for total aluminum or iron, total iron concentrations are expected to be below the NRWQC in the short term following remedy implementation, and aluminum concentrations are expected to approach the NRWQC and/or background concentrations in the long term. Results of the toxicological evaluations provided in Appendix H conclude that short-term aluminum concentrations would be protective of aquatic life in Railroad Creek.

For the East and West Areas, points of compliance would be established through mixing zones where treated effluent from the East and West Areas discharge to surface water. The CPOCs would be monitored at the limits of the established mixing zones.

Groundwater

Portions of the seeps and groundwater beneath the Site would not likely meet potential chemical-specific ARARs in the short or long term under any of the alternatives. Therefore, as discussed under Alternative 2a, it is not practicable to meet potential groundwater ARARs throughout the Site within a reasonable restoration time frame.

Under Alternative 6b, which includes the installation of an extended secondary barrier wall and groundwater collection system adjacent to Railroad Creek in the lower West Area, potential groundwater ARARs may be achieved within Railroad Creek upstream of RC-4 following remedy implementation. The results of the post-remediation loading analysis indicate that potential ARARs would not be met in the short term at points where groundwater flows into surface water downstream of RC-4. As described above, results of the loading analysis indicate potential ARARs would be achieved in Railroad Creek (represented by stations RC-4 and RC-2) within approximately 250 years. These stations are considered to be generally representative of water quality in Railroad Creek downstream of West and East Area sources. However, it may take longer for some locations within the creek to achieve potential ARARs.

Natural attenuation, in conjunction with upgradient water diversions, source controls, and West Area collection and treatment, as described under Alternative 3a constitute AKART for this Site. The additional actions included under Alternative 6b (secondary collection in the lower West Area, and extended collection and treatment in the East Area) would be more than required to meet the definition of AKART under MTCA. As a result, CPOCs for groundwater in surface water, where groundwater flows into surface water, would apply for the East and West Areas under this alternative.

Soils

The potential ARARs identified for soil would be achieved under Alternative 6b.

Potential Location-specific ARARs

Compliance with potential location-specific ARARs for Alternative 6b would be the same as described for Alternatives 5a, 5b, 5c, and 5d in Sections 7.11.1.2.

Potential Action-Specific ARARs

Compliance with potential action-specific ARARs for Alternative 6b would be the same as described for Alternatives 5a, 5b, 5c, and 5d in Sections 7.11.1.2.

7.16.2 Primary Balancing Criteria

Evaluation of the five primary balancing criteria, including long-term effectiveness and permanence; reduction of toxicity, mobility, and volume; short-term effectiveness; implementability; and cost; is provided in the following subsections for Alternative 6b.

7.16.2.1 Long-term Effectiveness and Permanence

Long-term effectiveness and permanence includes evaluation of the magnitude of residual risk and adequacy and reliability of controls.

Magnitude of Residual Risks

As described under Alternative 6a, the actions included under Alternative 6b would be protective of human health and terrestrial ecological receptors. Therefore, the magnitude of remaining human health risks and risks to ecological receptors would be low under this alternative.

If it is assumed that the extended lower barrier wall/collection system in the West Area can be effectively constructed and implemented, similar improvements in the short- and long-term post-remediation Railroad Creek water quality are estimated under Alternative 6b as described for Alternative 6a. Based on the results of the short-term loading analysis and toxicological analyses provided in Appendix H, post-remediation PCOC concentrations following implementation of Alternative 6b are not expected to adversely impact the aquatic community or their prey.

Metal precipitates and sludge generated in the treatment systems would require periodic removal and disposal in a suitable containment location on site. Treatment residuals from alkaline precipitation processes are expected to be stable products with reduced metals mobility. However, the containment areas would require periodic maintenance to reduce long-term surface water infiltration and maintain liner integrity.

As described for Alternative 2b the magnitude of residual risks due to potential surge releases from the underground mine or tailings releases due to potential slope failure would be low under Alternative 6b.

Adequacy and Reliability of Controls

The actions included under Alternative 6b are expected to be difficult to implement and moderately reliable in reducing metals loading from Site sources and providing long-term protection of human health and the environment. The extended lower West Area barrier wall/collection system is estimated to intercept groundwater and seeps in the short-term with an estimated collection efficiency of approximately 80 to 90 percent. However, there is significant uncertainty related to the ability to effectively construct the barrier wall/collection trench due to the steep slopes existing for approximately 1,700 feet of the alignment, heterogeneous subsurface conditions, estimated depths to low-permeability till/bedrock, and proximity to railroad Creek. There is also a potential to collect significant volumes of unimpacted groundwater in the extended West Area collection system, which would increase treatment system sizing and present difficulties in providing adequate flow equalization during the spring flush.

The effectiveness of this alternative would be dependent on the ability to adequately operate and maintain the mechanical treatment equipment (e.g., mixers, chemical feeders, etc.). Effective treatment would depend on reliable diesel-generated power and full-time operators to maintain the system. As a result, these actions are expected to have a low long-term reliability, especially during the winter months when access to the Site from Lake Chelan is not possible. Additionally, a mechanical treatment system that utilizes tanks, pumps, and other mechanical equipment would have a more limited operating range, and would not be as flexible as a system utilizing large settling ponds in treating variable influent flows. Alternatively, oversized mechanical components would likely result in inefficiencies and operational difficulties when treating lower flows following the spring flush. As a result, a mechanical treatment system is not expected to be as robust as a low-energy system in handling variations in influent flow or water quality.

As described under Alternative 6a, the extended relocation of Railroad Creek to the north and use of the existing creek channel for groundwater collection and treatment is also expected to be moderately implementable. The open collection system is estimated to collect East Area seeps and groundwater currently intercepted by Railroad Creek with a collection efficiency of approximately 80 to 90 percent. However, there is significant uncertainty related to the potential influx of Railroad Creek water to the East Area collection and treatment system, especially in the reach adjacent to tailings pile 2, where the valley narrows and space is limited to the north for Railroad Creek relocation.

7.16.2.2 Reduction of Toxicity, Mobility, and Volume

The alkaline precipitation process included for the East and West Areas under Alternative 6b would reduce the mass and volume of PCOCs released to groundwater and surface water. The treatment process would produce stable treatment residuals, and thus reduce the mobility and toxicity of PCOCs to environmental receptors. The volume of impacted materials requiring management would increase with the sludge generated from the water treatment processes.

Additionally, the mass, and therefore volume, of PCOCs released to groundwater and surface water would be reduced over time from Site sources through the source control actions and the natural geochemical processes described in Appendix E.

7.16.2.3 Short-term Effectiveness

Short-term effectiveness includes evaluation of protection of local communities, worker protection, short-term environmental impacts, and time required to reach remediation goals.

Protection of Local Communities

The protection of local communities for Alternative 6b would be as described for Alternative 6a. The use of the underground mine for flow equalization and storage would likely reduce the size of treatment system equipment by reducing peak influent volumes. Although the sizing of the mechanical treatment system under Alternative 6b would be generally smaller than under Alternative 6a, the energy requirements would exceed the hydroelectric generation capacity available at the Site. Preliminary calculations indicate approximately 90 to 120 kW of power would need to be generated to operate a 1100 gpm mechanical system (assuming a 95 percent motor efficiency and a power factor of 0.8). This power consumption rate translates into a diesel fuel consumption rate between 60,000 and 80,000 per year. To ensure uninterrupted operations during the winter months when access to the Village is limited, a large tank would be needed for fuel storage on site. The transport and storage of large quantities of fuel would increase potential risks to the environment and Holden Village residents and visitors in the event of a large fire or spill. Assuming a 2,000 gallon capacity truck would be used to deliver fuel to the Site, approximately 30 to 40 shipments of fuel per year would be required under this alternative.

Worker Protection

Potential risks to workers and mitigation measures implemented under Alternative 6b would be the same as described for Alternative 6a in Section 7.15.3.3.

Environmental Impacts

Potential short-term impacts to the environment during construction and implementation would be similar to Alternative 6a.

Time Required to Reach Remedial Goals

Implementation of Alternative 6b is expected to occur over a two- to three-year period of time. Following implementation, the soil RAO would be met.

Results of the post-remediation loading analysis indicate that PCOC concentrations would achieve surface water RAOs within approximately 250 years. However, based on the toxicological evaluations provided in Appendix H, short- and long-term post-remediation concentrations are expected to be protective of aquatic life in Railroad Creek.

Through installation of the extended lower West Area barrier wall under Alternative 6b, groundwater may achieve potential ARARs at the points where groundwater enters surface water in this area. However, the results of the loading analysis indicate compliance with groundwater ARARs in surface water downstream of RC-4 would be expected within approximately 250 years.

7.16.2.4 Implementability

Implementability includes the evaluation of technical feasibility, administrative feasibility, and availability of services and materials.

Technical Feasibility

As described for Alternative 6a, implementation of the actions included under Alternative 6b is expected to be moderate to difficult. The use of the underground mine to provide flow equalization for the portal drainage is expected to result in reduced peak influent flows and reduced treatment equipment sizing, thereby increasing the technical feasibility of this alternative.

Administrative Feasibility

The administrative implementability for Alternative 6b would be as described for Alternative 6a in Section 7.15.3.4.

Availability of Services and Materials

As described for Alternative 6a, the services and materials required for implementation of this alternative would be available within the Railroad Creek valley or could be mobilized to the Site by barge. Specialized personnel and equipment needed for work in the underground mine would be available in the surrounding areas.

Large volumes of fuel and treatment chemicals would be transported to the Site by barge and truck on a regular basis under Alternative 6b, and full-time personnel would be required to operate and maintain the collection and treatment systems.

7.16.2.5 Cost

The total estimated costs associated with Alternative 6b are $74,500,000 (2004 dollars at a 7-percent discount rate). The reduced costs estimated for this alternative compared to Alternative 6a are primarily due to the reduced equipment sizing for the West Area treatment system resulting from influent flow equalization. Table 7-9 provides a summary of capital and O&M costs for each of the eight candidate alternatives, and cost detail sheets are provided in Appendix I.

Capital costs associated with implementation of Alternative 6b are estimated at approximately $38,260,000. Annual O&M costs associated with monitoring, and operation and maintenance of the collection and treatment systems are estimated to be approximately $970,000.

7.16.3 Natural Resource Restoration

Alternative 6b would achieve a similar level of natural resource restoration as described for Alternative 6a. Similar reductions in PCOC loadings to Railroad Creek would be expected under this alternative compared to Alternative 6a. A summary of the extent of natural resource restoration expected under this alternative is provided in Appendix J.

7.16.4 Use of Permanent Solutions to the Maximum Extent Practicable

The remedial actions included under Alternative 6b constitute permanent solutions under MTCA since potential ARARs are expected to be achieved in the long term without further actions being required (WAC 173-340-200). The post-remediation loading analysis indicates that PCOC loading to Site groundwater and surface water would be reduced over time and potential ARARs are expected to be achieved within approximately 50 to 250 years, depending on the PCOC.

An evaluation the use of permanent solutions to the maximum extent practicable is provided in Section 8 (comparative analysis of alternatives). The evaluation of the practicability of this alternative includes whether the alternative is capable of being designed, constructed, and implemented in a reliable and effective manner, including consideration of cost. In considering cost under this analysis, an alternative shall not be considered practicable if the incremental costs are disproportionate to the incremental degree of benefits provided by the alternative over other lower cost alternatives.

7.16.5 Reasonable Restoration Time Frame

Following implementation of Alternative 6b, the soil RAOs would be met. Remedial actions would also be effective in eliminating potential physical hazards to Holden Village residents and visitors related to mine features and potential future risks to human health due to the possible development of groundwater as a drinking water supply.

PCOC loading to groundwater would be reduced over time under Alternative 6b through natural attenuation, upgradient water diversions, source controls, and East/West Area collection and treatment. Results of the post-remediation loading analysis indicate that the groundwater RAO would be achieved at CPOCs in surface water in the West Area and East Areas within approximately 50 to 250 years, depending on the PCOC.

Results of the post-remediation loading analysis indicate that the surface water RAO would also be achieved within approximately 50 to 250 years. Results of the toxicological evaluations indicate that surface water quality would be protective of aquatic life in Railroad Creek in the short term under Alternative 6b.

An evaluation of reasonable restoration time frames is provided in Section 8. The evaluation of the practicability of this alternative, which would likely provide a similar restoration time frame as Alternative 3b, includes whether the alternative is capable of being designed, constructed, and implemented in a reliable and effective manner, including consideration of cost. In considering cost under this analysis, an alternative shall not be considered practicable if the incremental costs are disproportionate to the incremental degree of benefits provided by the alternative over other lower cost alternatives.

7.17 ALTERNATIVE 7 – CAPPING, CONSOLIDATION, WATER MANAGEMENT AND WEST AREA TREATMENT (LOW-ENERGY TREATMENT)

The following subsections provide the detailed analysis of the remediation components included under Alternative 7 to address Site soils, surface water, and groundwater. Alternative 7 combines the actions included under Alternative 3b with the addition of tailings pile consolidation and capping of the consolidated tailings pile and east and west waste rock piles. The following subsections provide an analysis of the additional components under Alternative 7.

Under Alternative 7, tailings pile 1 and a portion of tailings pile 3 would be consolidated onto tailings pile 2 and capped, thereby reducing the anticipated loading of PCOCs from these two areas. Based on the results of the post-remediation loading analysis, tailings consolidation and capping is expected to provide additional short-term reductions in PCOC loading compared to Alternative 3b. However, because Alternative 7 does not include collection and treatment of East Area groundwater or seeps, PCOC concentrations are predicted to be higher in Railroad Creek in the short-term than under Alternatives 5b through 6b. This is due to the anticipated time required for water within the consolidated pile to drain down. Post-remediation Railroad Creek water quality is expected to be slightly improved in the long-term under Alternative 7 than for previous alternatives.

Estimated loading reductions from East and West Area sources under Alternative 7 are summarized in Appendix D, Tables D1-13, D2-13, and D4. The estimated short- and long-term post-remediation Railroad Creek water quality is summarized in Tables 7-1 through 7-4.

7.17.1 Threshold Criteria

Evaluation of the two threshold criteria, including overall protection of human health and the environment and compliance with ARARs, is provided in the following subsections for Alternative 7.

7.17.1.1 Overall Protection of Human Health and the Environment

Protection of Human Health and Terrestrial Ecological Receptors

Alternative 7 is expected to attain the same level of protection to human health and terrestrial ecological receptors as described for previous alternatives. The RAO to implement the remedial action in a manner that is protective of human health, including the Holden Village community, during and after construction would be met under this alternative. The soil RAO would also be achieved following remedy implementation.

Protection of Aquatic Life

Results of the post-remediation loading analysis indicate that seasonal dissolved cadmium, copper, and zinc concentrations in Railroad Creek would be reduced following remedy implementation, and would continue to gradually decline over time through natural attenuation. The analysis predicts that the potential ARARs for dissolved zinc would be met in the short term, and potential ARARs for dissolved cadmium and copper would be met within approximately 50 years of remedy implementation (Tables 7-1 through 7-4). However, based on the toxicological evaluations provided in Appendix H, post-remediation PCOC concentrations under Alternative 7 would be protective of resident species in Railroad Creek, including salmonids and their prey, following remedy implementation in the short term.

Under Alternative 7, seasonal concentrations of total aluminum and iron may remain above background in the short term. However, an analysis of documented aluminum and iron toxicity, presented in Appendix H, conclude that post-remediation aluminum and iron concentrations would be protective of resident aquatic species in Railroad Creek. Over the long term, total aluminum and iron concentrations are expected to continue to decline through natural attenuation and approach the NRWQC and/or background concentrations.

The RAOs for groundwater and surface water quality would not be achieved in the short term under Alternative 7. However, as described above, results of the post-remediation loading analysis indicate that these RAOs would be met in the long term as described below in Section 7.17.1.2

Potential for Short-term Impacts

Potential short-term impacts to the environment during construction and implementation of remediation components in the West Area would be similar to those described under Alternative 3b. However, there would be a higher potential for short-term impacts to groundwater and surface water during tailings pile consolidation due to the exposure of a greater volume of previously unoxidized tailings to air and storm water (Section 7.2.4). Volume estimates using data presented in the revised DRI indicate approximately 3,900,000 cubic yards of tailings would potentially be relocated during consolidation. Although erosion control and water diversion measures would be implemented under this alternative, effective management of surface runoff and associated increases in metals concentrations would be difficult.

Tailings pile consolidation would also require a significant amount of heavy equipment and fuel, which would need to be mobilized to the Site and operated for an extended period of time. The total fuel consumption estimated for these two activities is approximately 700,000 gallons. This fuel would need to be transported by barge from Chelan to a fuel containment facility located within the valley. Assuming a 2,000-gallon fuel truck would be used to haul fuel from Lucerne to the Site, a fuel consumption of approximately 700,000 gallons would translate to approximately 350 fuel deliveries over three seasons (i.e., more than one delivery every two days). This increased level of effort would significantly increase the potential for accidental releases to the environment and injuries to site workers, Holden Village residents, and visitors.

The increased construction requirements under this alternative would be expected to increase the potential for accidental injury to workers and the local community. For example, the application of accident rates recorded by the Washington State Department of Labor and Industry for heavy construction activities in 2001 to the estimated crew size required to implement Alternative 7 (approximately 100 people per season) indicates approximately 8 to 9 injuries and the potential for a fatality (estimated fatality rate of approximately 0.5 deaths) could be expected over the 3-year implementation period.

7.17.1.2 Compliance with ARARs

Compliance with ARARs includes the evaluation of chemical-specific, location-specific, and action-specific ARARs identified in Section 3.

Potential Chemical-specific ARARs

The following subsections evaluate compliance with potential chemical-specific ARARs identified for Site media, including surface water, groundwater and soil.

Surface Water

Results of the post-remediation loading analysis indicate dissolved cadmium and zinc concentrations in Railroad Creek would be below the SWQC following remedy implementation in the short-term. The analysis indicates that dissolved copper concentrations would be below the SWQC within approximately 50 years of remedy implementation (Tables 7-1 through 7-4). However, based on the toxicological evaluations provided in Appendix H, post-remediation PCOC concentrations under Alternative 7 would be protective of resident species in Railroad Creek following remedy implementation in the short term.

Dissolved zinc concentrations in Railroad Creek are predicted to meet the NRWQC following remedy implementation in the short term. Dissolved copper and cadmium concentrations are expected to be below the NRWQC within approximately 50 years (Tables 7-1 through 7-4). Although the post-remediation analysis could not be performed for total aluminum or iron, aluminum and iron concentrations are expected to approach the NRWQC and/or background in the long term. Results of the toxicological evaluations provided in Appendix H conclude that short-term concentrations of aluminum and iron would be protective of aquatic life in Railroad Creek.

For the East and West Areas, points of compliance would be established through mixing zones where treated effluent from the East and West Areas discharge to surface water. The CPOCs would be monitored at the limits of the established mixing zones.

Groundwater

Portions of the seeps and groundwater beneath the Site would not likely meet potential chemical-specific ARARs in the short or long term under any of the alternatives. Therefore, as discussed under Alternative 2a, it is not practicable to meet potential groundwater ARARs throughout the Site within a reasonable restoration time frame.

The results of the post-remediation loading analysis indicate that potential ARARs would not be met in the short term at points where groundwater flows into surface water. As described above, results of the loading analysis indicate potential ARARs would be achieved in Railroad Creek (represented by stations RC-4 and RC-2) within approximately 50 years. These stations are considered to be generally representative of water quality in Railroad Creek downstream of West and East Area sources. However, it may take longer for some locations within the creek to achieve potential ARARs.

Natural attenuation, in conjunction with upgradient water diversions, source controls, and West Area collection and treatment, as described under Alternative 3a constitute AKART for this Site. The additional actions included under Alternative 7 (tailings pile consolidation and capping in the East Area) would be more than required to meet the definition of AKART under MTCA. As a result, CPOCs for groundwater in surface water, where groundwater flows into surface water, would apply for the East and West Areas under this alternative.

Soils

The potential ARARs identified for soil would be achieved under Alternative 7.

Potential Location-specific ARARs

This alternative would address all potentially applicable location-specific ARARs through consultation with federal and state agencies during the RD/RA. The Alternative 7 actions are not expected to influence archaeological and/or historic sites of significance. Construction-related activities, such as excavation or earthmoving, would consider the presence of historic or culturally important sites, structures or objects, historical and archeological data, and Native American burial sites, and if present, minimize impacts to such resources.

Construction activities would be conducted to minimize impacts to fish and wildlife thereby meeting the potential ARARs associated with fish and wildlife protection. Coordination with WDFW and USFWS would be conducted during the remedial design to identify potentially applicable substantive requirements and incorporate mitigative measures into the RD as necessary.

The construction activities under this alternative would potentially impact shoreline area of the state and thus, consistency with the substantive requirements for shoreline management would be evaluated during the remedial design and mitigative measures incorporated into the design. Impacts to fish and wildlife, and consistency with the Forest Management Act would be addressed through consultation with USFWS and the Forest Service.

Potential Action-Specific ARARs

Alternative 7 activities are expected to be in compliance with potential action-specific ARARs through the implementation of institutional controls and monitoring as described in Section 6. Substantive compliance with CWA construction stormwater requirements, CWA section 401 water quality certification, and CWA section 404 would be addressed under this alternative. Substantive compliance with potential action-specific ARARs will be evaluated during the design through consultation with WDFW, USACOE, EPA, DNR, and Ecology. If remedial activities under Alternative 2a are determined to have temporary impacts to water quality, substantive compliance with temporary water quality modification requirements would be achieved. Best management practices would be used to comply with potential substantive stormwater construction requirements and fugitive dust requirements.

Excavated soils and tailings materials removed from the maintenance yard, mill building and lagoon are not expected to be either characteristic hazardous or dangerous waste. However, RCRA and Washington State Dangerous Waste regulations would be potentially applicable if these materials are determined to be hazardous or dangerous waste. If such a determination were made, these materials would be managed within the area of contamination, stabilized to immobilize the constituents, consolidated within a corrective management unit located on one of the tailings piles, and contained with an appropriate engineered cover.

The tailings piles and waste rock piles would meet relevant and appropriate requirements under the Washington State Requirements for Solid Waste Handling. These areas would be designed to meet the relevant and appropriate requirements for closure systems to prevent exposure of waste, minimize infiltration, prevent erosion from wind and water, be capable of sustaining native vegetation, address anticipated settlement, provide for adequate drainage, provide sufficient stability and mechanical strength, address potential freeze-thaw and desiccation, provide for the management of run on and run off, prevent erosion, and minimize the need for post-closure maintenance (WAC 173-350-400(3)(e)(i)(A) through (H)). Post-closure care requirements as deemed relevant and appropriate would also be met, including maintaining the vegetative cover; preventing run on and run off, and performing appropriate monitoring (173-350-400(7)(a)).

Limited purpose landfill cover requirements would be potentially relevant and appropriate to this candidate remedial alternative.

7.17.2 Primary Balancing Criteria

Evaluation of the five primary balancing criteria, including long-term effectiveness and permanence; reduction of toxicity, mobility, and volume; short-term effectiveness; implementability; and cost is provided in the following subsections for Alternative 7.

7.17.2.1 Long-term Effectiveness and Permanence

Long-term effectiveness and permanence includes evaluation of the magnitude of residual risk and adequacy and reliability of controls.

Magnitude of Residual Risks

The actions included under Alternative 7 would be protective of human health and terrestrial ecological receptors. Therefore, the magnitude of remaining human health risks and risks to ecological receptors would be low under this alternative.

Improvements in the short- and long-term post-remediation Railroad creek water quality are estimated for Alternative 7. Based on the results of the toxicological analyses provided in Appendix H, short-term post-remediation PCOC concentrations would be protective of resident aquatic species in Railroad Creek under Alternative 7.

Metal precipitates and sludge generated in West Area treatment ponds would require periodic removal and disposal in a suitable containment location on site. Treatment residuals from alkaline precipitation processes are expected to be stable products with reduced metals mobility. However, the containment areas would require periodic maintenance to reduce long-term surface water infiltration and maintain liner integrity.

As described for Alternative 2b, the magnitude of residual risks due to potential surge releases from the underground mine would be low under Alternative 7. Tailings consolidation and the creation of an approximate 50-foot buffer on the south side of Railroad Creek is expected to provide an additional factor of safety to reduce the potential for a release of tailings to Railroad Creek.

Adequacy and Reliability of Controls

As described under Alternative 3b, West Area Actions proposed under this alternative are expected to be implementable, reliable, and adequate in reducing metals loading to groundwater and surface water and providing long-term protection of human health and the environment. H

Potential short-term impacts to groundwater and surface water may result from the disturbance of large volumes of previously unoxidized tailings during consolidation activities in the East Area. Potential increases in short-term PCOC loadings from the piles may occur under this alternative, and the increased loading could potentially continue into the long term (over 30 years). Increased metals loading would not be addressed in the long-term through treatment under this alternative.

The long-term effectiveness and reliability of Alternative 7 would be dependent on the continued maintenance of the low-permeability cover. Annual maintenance would be required to ensure cover integrity through the long-term and prevent the growth of deep-rooted plants. If the cover integrity were to be compromised in the future, increased release of PCOCs would be expected from the consolidated pile.

Long-term operations and maintenance of West Area diversion ditches, collection trenches, and treatment system would also be required under this alternative. The low-energy treatment system would have a high degree of implementability and would be designed to reliably treat seasonal portal drainage, seep, and groundwater flows. Chemical addition rates would be controlled based on seasonal flows and water quality, and the settling ponds and media filters would be sized to provide significant detention times and solids removal prior to discharge to Railroad Creek. An important factor in providing consistent effluent quality under Alternative 7 would be the ability to adjust chemical addition rates in response to the rapid changes in flows and water chemistry.

7.17.2.2 Reduction of Toxicity, Mobility, and Volume

The alkaline precipitation process included for the West Area under Alternative 7 would reduce the mass and volume of PCOCs released to groundwater and surface water. The treatment process would produce stable treatment residuals, and thus reduce the mobility and toxicity of PCOCs to environmental receptors. The volume of impacted materials requiring management would increase with the sludge generated from the water treatment processes.

Additionally, the mass, and therefore volume, of PCOCs released to groundwater and surface water would be reduced over time from Site sources through the source control actions and the natural geochemical processes described in Appendix E.

7.17.2.3 Short Term Effectiveness

Short-term effectiveness includes evaluation of protection of local communities, worker protection, short-term environmental impacts, and time required to reach remediation goals.

Protection of Local Communities

Actions would be taken to protect Holden Village residents and visitors during implementation of Alternative 7. A stream crossing over Railroad Creek would be constructed at the northeast corner of tailings pile 3, to allow vehicles and equipment to bypass the Village during construction activities. Access to the top of the tailings piles would be gained from the new stream crossing under this alternative. However, tailings pile consolidation would result in significant vehicle and equipment traffic on the south side of Railroad Creek. The increased construction requirements under this alternative would be expected to increase the potential for accidental injury to workers and the local community.

The significant volumes of materials required for construction of the low-permeability cover would result in increased truck traffic from an identified borrow source area or from Lucerne, if the material is imported from off site. Based on a cover depth of approximately 1.5 feet, approximately 121,000 cubic yards of soil would be required for construction. Assuming haul trucks with a capacity of 15 cubic yards, approximately 8,100 round trips would be required to haul this volume of material to the tailings pile locations. If one round-trip were completed per hour, with 12-hour shifts during a 122-day construction season, it would take a fleet of 10 trucks more than 2 months to transport the cover material to the Site. The truck traffic required to haul the cover material would present significant safety risks to the public and workers at the Site.

Similarly, assuming large capacity scrapers (40 cubic yards) would be used to move a majority of the tailings materials, approximately 97,500 round-trips would be required to consolidate the approximately 3,900,000 cubic yards of tailings. With a 122-day construction season, 12-hour shifts, and an average of 3 trips per hour per scraper, it would take a fleet of 10 scrapers more than more than 2 construction seasons to complete the consolidation.

Assuming fuel consumption by each haul truck of 5 gallons per hour, a total of approximately 40,000 gallons of diesel would be consumed to haul the cover material over the construction season. Scrapers would require approximately 20 gallons per hour to operate, resulting in a total fuel consumption of approximately 700,000 gallons over the three construction seasons. Thus, the fuel requirements for the trucks and scrapers would result in a significant number of dedicated barge trips of diesel fuel from Chelan to Lucerne. Assuming a 2,000-gallon fuel truck would be used to haul fuel from Lucerne to the Site, a fuel consumption of approximately 700,000 gallons would translate to approximately 350 fuel deliveries (i.e., more than one delivery every two days). This increased level of effort would significantly increase the potential for accidental releases to the environment and injuries to site workers, Holden Village residents, and visitors. Additionally, a preliminary assessment of potential air emissions indicates that more than 360 combined tons of particulate mater (PM_{10}) carbon dioxide, hydrocarbons, and nitrogen oxides would like be released during implementation of Alternative 7.

Operation and maintenance of the West Area treatment system would also require periodic deliveries of diesel fuel and treatment chemicals to the Site by barge and truck. Maintenance activities would result in increased traffic and equipment operations in the lagoon area.

Potential physical hazards to the local community related to the possible development of a rock source near Tenmile Creek would be mitigated using proven engineering controls.

Worker Protection

Potential risks to workers related to the possible generation of fugitive dust or exposure to treatment chemicals and metal constituents during construction and implementation could be adequately mitigated with use of personal protection equipment and engineering controls. Workers at construction and industrial sites are required to comply with the requirements and standards under OSHA.

The limited mine actions and installation of hydrostatic bulkheads would involve construction work underground in abandoned mine workings on the 300, 1100, and 1500 levels. These actions would present potential physical risks to workers in the event of a collapse or rock fall. However, appropriate health and safety precautions, consistent with that required by MSHA, would be implemented to reduce potential risks to workers under this alternative.

The development of a rock source near Tenmile Creek would present possible physical risks to workers due to the potential for rock fall at this location. However, appropriate health and safety precautions and engineering controls would be implemented to mitigate these potential risks.

As described above, increased construction activities required under this alternative for construction of a low-permeability cover and consolidation would result in increased safety risks to the public and workers. For example, the application of accident rates recorded by the Washington State Department of Labor and Industry for heavy construction activities in 2001 to the estimated crew size required to implement Alternatives 7 (approximately 100 people per season) indicates approximately 8 to 9 injuries and the potential for a fatality (estimated fatality rate of approximately 0.5 deaths) could be expected over the 3-year implementation period.

Environmental Impacts

Potential short-term impacts to the environment during construction and implementation of West Area actions would be as described for Alternative 3b in Section 7.6.3.3.

There would be a high potential for short-term impacts to groundwater and surface water during tailings pile consolidation due to the exposure of a greater volume of previously unoxidized tailings to air and storm water (Section 7.2.4). Volume estimates using data presented in the revised DRI indicate approximately 3,900,000 cubic yards of tailings would potentially be relocated during consolidation. Although erosion control and water diversion measures would be implemented under this alternative, effective management of surface runoff and associated increases in metals concentrations would be difficult.

Tailings pile consolidation would also require a significant amount of fuel and equipment, which would need to be mobilized to the Site and operated for an extended period of time. Implementation of this alternative is estimated to take 3 years, thereby increasing the potential for an accidental release of fuel or other materials during construction or transport. Additionally, as discussed above, a preliminary assessment of potential air emissions indicates that more than 360 combined tons of particulate mater (PM_{10}) carbon dioxide, hydrocarbons, and nitrogen oxides would like be released during implementation of Alternative 7.

Time Required to Reach Remedial Goals

Implementation of this alternative is expected to occur over a two- to three- year period of time. Following implementation, the soil RAO is expected to be met.

The groundwater and surface-water RAOs are not expected to be achieved under this alternative in the short-term. However, results of the toxicological evaluations provided in Appendix H indicate surface water quality would be protective of resident aquatic species following implementation of Alternative 7 in the short term. Results of the post-remediation loading analysis indicate compliance with potential ARARs within approximately 50 years. Similarly, the results of the loading analysis indicate compliance with groundwater ARARs in surface water would be expected within approximately 50 years.

7.17.2.4 Implementability

Implementability includes evaluation of technical feasibility, administrative feasibility, and availability of services and materials.

Technical Feasibility

The West Area actions included under Alternative 7 (upgradient diversion, hydrostatic bulkheads, upper West Area collection, and low-energy treatment) are implementable. These actions have been successfully implemented at other sites, and are based on conventional construction technologies.

Consolidation of the tailings piles in the East Area would also utilize conventional construction equipment. However, additional design efforts would be required for the consolidated pile, and the large volume of materials that would be relocated for cap construction and consolidation would further reduce the implementability of this alternative. As described above, based on a cover depth of approximately 1.5 feet, approximately 121,000 cubic yards of cover soil would be required for construction. To transport this material to the Site from a local borrow source or Lucerne, it would take a fleet of 10 trucks more than 2 months to complete the task. Similarly, assuming large capacity scrapers (40 cubic yards) would be used to move a majority of the tailings materials, it would take a fleet of 10 large capacity scrapers more than two construction seasons to consolidate the approximately 3,900,000 cubic yards of tailings. The increased construction effort, and associated fuel requirements (approximately 700,000 gallons) would lower the implementability of this alternative.

Administrative Feasibility

The Site exists adjacent to the Holden Village, which is operated under a special-use permit issued by the Forest Service, a wilderness area boundary, and Forest Service lands. As a result, coordination between many local agencies and the Holden Village will be required under Alternatives 2 through 8. Alternative 7 would have lower administrative implementability due to the significantly increased construction requirements, duration of construction activities, increased equipment noise, and borrow source development.

Availability of Services and Materials

Materials required to implement this alternative would be available within the Railroad Creek Valley or could be mobilized to the Site by barge. However, if a suitable borrow source cannot be located within the Railroad Creek valley, the transport of cover materials would significantly lower the implementability of this alternative.

Specialized equipment and personnel for completion of underground actions is expected to be available in surrounding areas. Treatment chemicals would be transported to the Site by barge and truck on a regular basis under this alternative and on site personnel would be required to operate and maintain collection and treatment systems.

7.17.2.5 Cost

The total estimated cost associated with Alternative 7 is approximately $100,410,000 (2004 dollars at 7-percent discount rate). The increased costs estimated for Alternative 7 compared to other remedial alternatives are primarily associated with the increased earthwork and mobilization required for consolidation and capping. Table 7-9 provides a summary of capital and O&M costs for each of the eight candidate alternatives, and cost detail sheets are provided in Appendix I.

Capital costs associated with implementation of Alternative 7 are estimated to be approximately $63,160,000. Annual O&M costs associated with monitoring, and maintaining the 1500-level main portal and diversion channels, are estimated to be approximately $310,000.

7.17.3 Natural Resource Restoration

Under Alternative 7, natural resource restoration would be achieved for soils and vegetation in the West Area and terrestrial wildlife across the Site. Through tailings pile consolidation, Alternative 7 would also provide replacement terrestrial habitat over time for other potentially injured areas of the Site at the current location of tailings pile 1. However, prevention of the establishment of deep-rooted plants on the cover would be required to ensure effective long-term performance, and would reduce the potential future habitat for terrestrial wildlife in the East Area.

Slightly greater long-term reductions in metals loading from the tailings piles are anticipated under this alternative relative to Alternatives 1 through 6 due to tailings pile consolidation. Reductions in aluminum, cadmium, copper, iron and zinc loading from East and West Area sources would be expected to result in improved aquatic habitat in Railroad Creek over the long-term. As described in Appendix H, post remediation concentrations of site PCOCs are expected to be protective of resident aquatic species in Railroad Creek following remedy implementation in the short term. A summary of the extent of natural resource restoration expected under this alternative is provided in Appendix J.

7.17.4 Use of Permanent Solutions to the Maximum Extent Practicable

The remedial actions included under Alternative 7 constitute permanent solutions under MTCA since potential ARARs are expected to be achieved in the long term without further actions being required (WAC 173-340-200). The post-remediation loading analysis indicates that PCOC loading to Site groundwater and surface water would be reduced over time and potential ARARs are expected to be achieved within approximately 50 years, depending on the PCOC.

An evaluation the use of permanent solutions to the maximum extent practicable is provided in Section 8 (comparative analysis of alternatives). The evaluation of the practicability of this alternative includes whether the alternative is capable of being designed, constructed, and implemented in a reliable and effective manner, including consideration of cost. In considering cost under this analysis, an alternative shall not be considered practicable if the incremental costs are disproportionate to the incremental degree of benefits provided by the alternative over other lower cost alternatives.

7.17.5 Reasonable Restoration Time Frame

Following implementation of Alternative 7, the soil RAOs would be met. Remedial actions would also be effective in eliminating potential physical hazards to Holden Village residents and visitors related to mine features and potential future risks to human health due to the possible development of groundwater as a drinking water supply.

PCOC loading to groundwater would be reduced over time under Alternative 7 through natural attenuation, upgradient water diversions, source controls, tailing pile consolidation, and West Area collection and treatment. Results of the post-remediation loading analysis indicate that the groundwater RAO would be achieved at CPOCs in surface water in the West Area and East Areas within approximately 50 years, depending on the PCOC.

Results of the post-remediation loading analysis indicate that the surface water RAO would also be achieved within approximately 50 years. Results of the toxicological evaluations indicate that surface water quality would be protective of aquatic life in Railroad Creek in the short term under Alternative 7.

An evaluation of reasonable restoration time frames is provided in Section 8. The evaluation of the practicability of this alternative, which would likely provide a shorter restoration time frame compared to Alternative 3b, includes whether the alternative is capable of being designed, constructed, and implemented in a reliable and effective manner, including consideration of cost. In considering cost under this analysis, an alternative shall not be considered practicable if the incremental costs are disproportionate to the incremental degree of benefits provided by the alternative over other lower cost alternatives.

7.18 ALTERNATIVE 8: SOURCE CONTROL AND EAST/WEST AREA TREATMENT (LOW-ENERGY TREATMENT)

Alternative 8 includes the same remediation components described for Alternative 7, with the addition of extended collection and treatment of East Area groundwater and seeps at the toe of the consolidated tailings pile. The East and West waste rock piles would also be relocated to the consolidated tailings pile and capped under this alternative. The following subsections provide an analysis of the additional components included under Alternative 8.

Under Alternative 8, the extended collection and treatment of East Area groundwater and seeps is anticipated to further reduce potential short-term metals loading to Railroad Creek. Relocation of the waste rock piles would is also expected to reduce PCOC releases to groundwater in the West Area. The incremental reduction in short-term metals loading from the East and West Areas under Alternative 8 would likely result in gradual improvements to aquatic habitat in Railroad Creek adjacent to the site. Estimated loading reductions from East and West Area sources under Alternative 8 are provided in Appendix D, Tables D1-14, D2-14, and D4. The estimated short- and long-term post-remediation Railroad Creek water quality is summarized in Tables 7-1 through 7-4.

7.18.1 Threshold Criteria

Evaluation of the two threshold criteria, including overall protection of human health and the environment and compliance with ARARs, is provided in the following subsections for Alternative 8.

7.18.1.1 Overall Protection of Human Health and the Environment

Protection of Human Health and Terrestrial Ecological Receptors

Alternative 8 is expected to attain the same level of protection to human health and terrestrial ecological receptors as described for previous alternatives. The RAO to implement the remedial action in a manner that is protective of human health, including the Holden Village community, during and after construction would be met under this alternative. The soil RAO would also be achieved following remedy implementation.

Protection of Aquatic Life

Results of the post-remediation loading analysis indicate that seasonal dissolved cadmium, copper, and zinc concentrations in Railroad Creek would be reduced following remedy implementation, and would continue to gradually decline over time through natural attenuation. The analysis predicts that the potential ARARs for zinc would be met following remedy implementation, and the potential ARARs for cadmium and copper would be met within approximately 50 years (Tables 7-1 through 7-4). However, based on the toxicological evaluations provided in Appendix H, post-remediation PCOC concentrations under Alternative 8 would be protective of resident aquatic species, including salmonids and their prey, in Railroad Creek following remedy implementation in the short term.

Under Alternative 8, total iron concentrations are expected to be below the NRWQC following remedy implementation in the short term. Seasonal concentrations of total aluminum may remain above background in the short term. However, an analysis of documented aluminum toxicity, presented in Appendix H, indicates that the post-remediation aluminum concentrations would be protective of resident aquatic species in Railroad Creek. Over the long term, total aluminum concentrations are expected to continue to decline through natural attenuation and approach the NRWQC and/or background concentrations.

The RAOs for groundwater and surface water quality would not be achieved in the short term under Alternative 8. However, as described above, results of the post-remediation loading analysis indicate that these RAOs would be met in the long term as discussed below in Section 7.18.1.2.

Potential Short-term Impacts

Potential short-term impacts to the environment during construction and implementation of Alternative 8 would be similar to those described under Alternative 7.

As described under Alternative 7, there would be a high potential for short-term impacts to groundwater and surface water during tailings pile consolidation due to the exposure of a significant volume of previously unoxidized tailings to air and storm water (Section 7.2.4). Volume estimates using data presented in the revised DRI indicate approximately 3,900,000 cubic yards of tailings would potentially be relocated during consolidation. Although erosion control and water diversion measures would be implemented under this alternative, effective management of surface runoff and associated increases in metals concentrations would be difficult.

Tailings and waste rock consolidation would also require a significant amount of heavy equipment and fuel, which would need to be mobilized to the Site and operated for an extended period of time. The total fuel consumption estimated for these two activities is approximately 700,000 gallons. This fuel would need to be transported by barge from Chelan to a fuel containment facility located within the valley. Assuming a 2,000-gallon fuel truck would be used to haul fuel from Lucerne to the Site, a fuel consumption of approximately 700,000 gallons would translate to approximately 350 fuel deliveries over three seasons (i.e., more than one delivery every two days). This increased level of effort would significantly increase the potential for accidental releases to the environment and injuries to site workers, Holden Village residents, and visitors.

The increased construction requirements under this alternative would be expected to increase the potential for accidental injury to workers and the local community. For example, the application of accident rates recorded by the Washington State Department of Labor and Industry for heavy construction activities in 2001 to the estimated crew size required to implement Alternative 7 (approximately 100 people per season) indicates approximately 8 to 9 injuries and the potential for a fatality (estimated fatality rate of approximately 0.5 deaths) could be expected over the 3-year implementation period.

7.18.1.2 Compliance with ARARs

Compliance with ARARs includes the evaluation of chemical-specific, location-specific, and action-specific ARARs identified in Section 3.

Potential Chemical-specific ARARs

The following subsections evaluate compliance with potential chemical-specific ARARs identified for Site media, including surface water, groundwater and soil.

Surface Water

Results of the post-remediation loading analysis indicate dissolved cadmium and zinc concentrations in Railroad Creek would be below the SWQC following remedy implementation in the short-term. The analysis indicates that dissolved copper concentrations would be below the SWQC within approximately 50 years of remedy implementation (Tables 7-1 through 7-4). However, based on the toxicological evaluations provided in Appendix H, post-remediation PCOC concentrations under Alternative 8 would be protective of resident aquatic species in Railroad Creek following remedy implementation in the short term.

Dissolved zinc concentrations in Railroad Creek are predicted to meet the NRWQC following remedy implementation in the short term. Dissolved cadmium and copper concentrations are expected to be below the NRWQC within approximately 50 years (Tables 7-1 through 7-4). Although the post-remediation analysis could not be performed for total aluminum or iron, iron concentrations are expected to be below the NRWQC following remedy implementation. Aluminum concentrations are expected to approach the NRWQC and/or background concentrations in the long term. Results of the toxicological evaluations in Appendix H conclude that short-term post-remediation aluminum concentrations would be protective of aquatic life in Railroad Creek.

For the East and West Areas, points of compliance would be established through mixing zones where treated effluent from the East and West Areas discharge to surface water. The CPOCs would be monitored at the limits of the established mixing zones.

Groundwater

Portions of the seeps and groundwater beneath the Site would not likely meet potential chemical-specific ARARs in the short or long term under any of the alternatives. Therefore, as discussed under Alternative 2a, it is not practicable to meet potential groundwater ARARs throughout the Site within a reasonable restoration time frame.

The results of the post-remediation loading analysis indicate that potential ARARs would not be met in the short term at points where groundwater flows into surface water. As described above, results of the loading analysis indicate potential ARARs would be achieved in Railroad Creek (represented by stations RC-4 and RC-2) within approximately 50 years. These stations are considered to be generally representative of water quality in Railroad Creek downstream of West and East Area sources. However, it may take longer for some locations within the creek to achieve potential ARARs.

Natural attenuation, in conjunction with upgradient water diversions, source controls, and West Area collection and treatment, as described under Alternative 3a constitute AKART for this Site. The additional actions included under Alternative 8 (tailings and waste rock consolidation and capping in the East Area) would be more than required to meet the definition of AKART under MTCA. As a result, CPOCs for groundwater in surface water, where groundwater flows into surface water, would apply for the East and West Areas under this alternative.

Soils

The potential ARARs identified for soil would be achieved under Alternative 8.

Potential Location-specific ARARs

Compliance with potential location-specific ARARs under Alternative 8 would be as described for Alternative 7 in Section 7.17.1.2.

Potential Action-Specific ARARs

Compliance with potential action-specific ARARs under Alternative 8 would be as described for Alternative 7 in Section 7.17.1.2.

7.18.2 Primary Balancing Criteria

Evaluation of the five primary balancing criteria, including long-term effectiveness and permanence; reduction of toxicity, mobility, and volume; short-term effectiveness; implementability; and cost is provided in the following subsections for Alternative 8.

7.18.2.1 Long-term Effectiveness and Permanence

Long-term effectiveness and permanence includes evaluation of the magnitude of residual risk and adequacy and reliability of controls.

Magnitude of Residual Risks

The actions included under Alternative 8 would be protective of human health and terrestrial ecological receptors. Therefore, the magnitude of remaining human health risks and risks to ecological receptors would be low under this alternative.

Improvements in the short- and long-term post-remediation Railroad creek water quality are estimated for Alternative 8. Based on the results of the toxicological analyses provided in Appendix H, post-remediation PCOC concentrations would be protective of aquatic life in Railroad Creek.

Metal precipitates and sludge generated in East and West Area treatment ponds would require periodic removal and disposal in a suitable containment location on site. Treatment residuals from alkaline precipitation processes are expected to be stable products with reduced metals mobility. However, the containment areas would require periodic maintenance to reduce long-term surface water infiltration and maintain liner integrity.

As described for Alternative 7, the magnitude of residual risks due to potential surge releases from the underground mine would be low under Alternative 8. Tailings consolidation and the creation of an approximate 50-foot buffer on the south side of Railroad Creek is expected to provide an additional factor of safety to reduce the potential for a release of tailings to Railroad Creek.

Adequacy and Reliability of Controls

As described under Alternative 7, West Area Actions proposed under this alternative are expected to be implementable, reliable, and adequate in reducing metals loading to groundwater and surface water and providing long-term protection of human health and the environment. However, in the East Area, potential short-term impacts to groundwater and surface water may result from the disturbance of large volumes of previously unoxidized tailings during consolidation. Potential increases in short-term PCOC loadings from the piles may occur under this alternative.

The extended East Area collection system is estimated to intercept groundwater and seeps in the short-term with an estimated collection efficiency of approximately 80 percent. However, there is significant uncertainty in the long-term reliability of a subsurface collection trench and drain in the East Area due to the high potential for the formation of iron and other metal oxides to foul and plug the system. Reductions in iron loadings to the collection and treatment system are expected in the long-term.

The long-term effectiveness and reliability of Alternative 8 would be dependent on the continued maintenance of the low-permeability cover. Annual maintenance would be required to ensure cover integrity through the long-term and prevent the growth of deep-rooted plants. If the cover integrity were to be compromised, increased release of PCOCs would be expected from the consolidated pile.

Significant long-term operations and maintenance of West Area diversion ditches, and East and West area collection trenches and treatment systems would also be required under this alternative. The low-energy treatment system would have a high degree of implementability and would be designed to reliably treat seasonal portal drainage, seep, and groundwater flows. Chemical addition rates would be controlled based on seasonal flows and water quality, and the settling ponds and media filters would be sized to provide significant detention times and solids removal prior to discharge to Railroad Creek. An important factor in providing consistent effluent quality under Alternative 8 would be the ability to adjust chemical addition rates in response to the rapid changes in flows and water chemistry.

7.18.2.2 Reduction of Toxicity, Mobility, and Volume

The alkaline precipitation process included for the West Area under Alternative 8 would reduce the mass and volume of PCOCs released to groundwater and surface water. The treatment process would produce stable treatment residuals, and thus reduce the mobility and toxicity of PCOCs to environmental receptors. The volume of impacted materials requiring management would increase with the sludge generated from the water treatment processes.

Additionally, the mass, and therefore volume, of PCOCs released to groundwater and surface water would be reduced over time from Site sources through the source control actions and the natural geochemical processes described in Appendix E.

7.18.2.3 Short Term Effectiveness

Short-term effectiveness includes evaluation of protection of local communities, worker protection, short-term environmental impacts, and time required to reach remediation goals.

Protection of Local Communities

Potential impacts to the local community would be similar to those described under Alternative 7. Actions would be taken to protect Holden Village residents and visitors during implementation of Alternative 8. A stream crossing over Railroad Creek would be constructed at the northeast corner of tailings pile 3, to allow vehicles and equipment to bypass the Village during construction activities. Access to the top of the tailings piles would be gained from the new stream crossing under this alternative. However, tailings pile consolidation would result in significant vehicle and equipment traffic on the south side of Railroad Creek. The increased construction requirements under this alternative would be expected to increase the potential for accidental injury to workers and the local community.

The significant volumes of materials required for construction of the low-permeability cover would result in increased truck traffic from an identified borrow source area or from Lucerne, if the material is imported from off site. Based on a cover depth of approximately 1.5 feet, approximately 121,000 cubic yards of soil would be required for construction. Assuming haul trucks with a capacity of 15 cubic yards, approximately 8,100 round trips would be required to haul this volume of material to the tailings pile locations. If one round-trip were completed per hour, with 12-hour shifts during a 122-day construction season, it would take a fleet of 10 trucks more than 2 months to transport the cover material to the Site. The truck traffic required to haul the cover material would present significant safety risks to the public and workers at the Site.

Similarly, assuming large capacity scrapers (40 cubic yards) would be used to move a majority of the tailings materials, approximately 97,500 round-trips would be required to consolidate the approximately 3,900,000 cubic yards of tailings. With a 122-day construction season, 12-hour shifts, and an average of 3 trips per hour per scraper, it would take a fleet of 10 scrapers more than more than 2 construction seasons to complete the consolidation.

Assuming fuel consumption by each haul truck of 5 gallons per hour, a total of approximately 40,000 gallons of diesel would be consumed to haul the cover material over the construction season. Scrapers would require approximately 20 gallons per hour to operate, resulting in a total fuel consumption of approximately 700,000 gallons over the three construction seasons. Thus, the fuel requirements for the trucks and scrapers would result in a significant number of dedicated barge trips of diesel fuel from Chelan to Lucerne. Assuming a 2,000-gallon fuel truck would be used to haul fuel from Lucerne to the Site, a fuel consumption of approximately 700,000 gallons would translate to approximately 350 fuel deliveries (i.e., more than one delivery every two days). This increased level of effort would significantly increase the potential for accidental releases to the environment and injuries to site workers, Holden Village residents, and visitors. Additionally, a preliminary assessment of potential air emissions indicates that more than 360 combined tons of particulate mater (PM_{10}) carbon dioxide, hydrocarbons, and nitrogen oxides would like be released during implementation of Alternative 8.

Operation and maintenance of the West Area treatment system would also require periodic deliveries of diesel fuel and treatment chemicals to the Site by barge and truck. Maintenance activities would result in increased traffic and equipment operations in the lagoon area.

Potential physical hazards to the local community related to the possible development of a rock source near Tenmile Creek would be mitigated using proven engineering controls.

Worker Protection

Potential risks to workers related to the possible generation of fugitive dust or exposure to treatment chemicals and metal constituents during construction and implementation could be adequately mitigated with use of personal protection equipment and engineering controls. Workers at construction and industrial sites are required to comply with the requirements and standards under OSHA.

The limited mine actions and installation of hydrostatic bulkheads would involve construction work underground in abandoned mine workings on the 300, 1100, and 1500 levels. These actions would present potential physical risks to workers in the event of a collapse or rock fall. However, appropriate health and safety precautions, consistent with that required by MSHA, would be implemented to reduce potential risks to workers under this alternative.

The development of a rock source near Tenmile Creek would present possible physical risks to workers due to the potential for rock fall at this location. However, appropriate health and safety precautions and engineering controls would be implemented to mitigate these potential risks.

As described above, increased construction activities required under this alternative for construction of a low-permeability cover and consolidation would result in increased safety risks to the public and workers. For example, the application of accident rates recorded by the Washington State Department of Labor and Industry for heavy construction activities in 2001 to the estimated crew size required to implement Alternative 8 (approximately 100 people per season) indicates approximately 8 to 9 injuries and the potential for a fatality (estimated fatality rate of approximately 0.5 deaths) could be expected over the 3-year implementation period.

Environmental Impacts

Potential short-term impacts to the environment during construction and implementation of West Area actions would be as described for Alternative 3b in Section 7.6.3.3.

There would be a high potential for short-term impacts to groundwater and surface water during tailings pile consolidation in the East Area due to the exposure of a large volume of previously unoxidized tailings to air and storm water (Section 7.2.4). Volume estimates using data presented in the revised DRI indicate approximately 3,900,000 cubic yards of tailings would potentially be relocated during consolidation. Although erosion control and water diversion measures would be implemented under this alternative, effective management of surface runoff and associated increases in metals concentrations would be difficult.

Tailings pile consolidation would also require a significant amount of fuel and equipment, which would need to be mobilized to the Site and operated for an extended period of time. Implementation of this alternative is estimated to take approximately 3 years, thereby increasing the potential for an accidental release of fuel or other materials during construction or transport. Additionally, as discussed above, a preliminary assessment of potential air emissions indicates that more than 360 combined tons of particulate mater (PM_{10}) carbon dioxide, hydrocarbons, and nitrogen oxides would like be released during implementation of Alternative 8.

Time Required to Reach Remedial Goals

Implementation of this alternative is expected to occur over a three-year period of time. Following implementation, the soil RAO is expected to be met.

The groundwater and surface-water RAOs are not expected to be achieved under this alternative in the short-term. However, results of the toxicological evaluations provided in Appendix H indicate surface water quality would be protective of resident aquatic species following implementation of Alternative 8 in the short term. Results of the post-remediation loading analysis indicate compliance with potential ARARs within approximately 50 years. Similarly, the results of the loading analysis indicate compliance with groundwater ARARs in surface water would be expected within approximately 50 years.

7.18.2.4 Implementability

Implementability includes the evaluation of technical feasibility, administrative feasibility, and availability of services and materials.

Technical Feasibility

As described for Alternative 7, the West Area actions included under Alternative 8 (upgradient diversion, hydrostatic bulkheads, upper West Area collection, and low-energy treatment) are expected to be implementable. These actions have been successfully implemented at other sites, and are based on conventional construction technology.

Consolidation of the waste rock and tailings piles would also utilize conventional construction equipment. However, as described for Alternative 7, the additional design effort, significant earth work required for consolidation, and the large volumes of cover soil needed for cap construction would significantly lower the implementablity of this alternative.

Construction of the extended East Area barrier wall and groundwater collection and treatment system would be moderately feasible due to the relatively flat grade, structural considerations related to installation at the base of the consolidated tailings pile, and varying depth to bedrock or dense till. Data collected during the RI indicate the potential for large granitic boulders and tree stumps at the base of the tailings piles, which would result in increased difficulties in construction of the collection and treatment systems. However, construction of the extended barrier wall/collection system under this alternative would be more implementable than the system included under Alternatives 4b and 5b, without consolidation.

The collection of groundwater and seeps in the East Area would also be moderately implementable due to the high potential for the formation of iron and other metal oxides to foul and plug the system. The high concentration of iron in collected East Area groundwater would also result in significant chemical addition requirements and sludge generation in the treatment system.

Administrative Feasibility

The Site exists adjacent to the Holden Village, which is operated under a special-use permit issued by the Forest Service, a wilderness area boundary, and Forest Service lands. As a result, coordination between many local agencies and the Holden Village will be required under Alternatives 2 through 8. Alternative 8 would have lower administrative implementability due to significantly increased construction requirements, duration of construction activities, and borrow source development.

Availability of Services and Materials

Materials required to implement this alternative would be available within the Railroad Creek Valley or could be mobilized to the Site by barge. However, if a suitable borrow source cannot be located within the Railroad Creek valley, the required transport of cover materials would significantly lower the implementability of this alternative.

Specialized equipment and personnel for completion of underground actions is expected to be available in surrounding areas. Treatment chemicals would be transported to the Site by barge and truck on a regular basis under this alternative and on site personnel would be required to operate and maintain collection and treatment systems.

7.18.2.5 Cost

The total estimated costs associated with Alternative 8 are $112,960,000 (2004 dollars at 7-percent discount rate). The increased costs estimated for Alternative 8 compared to Alternative 7 are primarily associated with consolidation of the east and west waste rock piles onto the consolidated tailings pile and the installation and operation of the East Area barrier wall/collection system. Table 7-9 provides a summary of capital and O&M costs for each of the eight candidate alternatives, and cost detail sheets are provided in Appendix I.

Capital costs associated with implementation of Alternative 8 are estimated at approximately $70,460,000. Annual O&M costs associated with monitoring, and maintaining the 1500-level main portal and diversion channels, are estimated to be approximately $390,000.

7.18.3 Natural Resource Restoration

Under Alternative 8, natural resource restoration would be achieved for soils and vegetation in the West Area and terrestrial wildlife across the Site. However, prevention of the establishment of deep-rooted plants on the cover would be required to ensure effective long-term performance, and would reduce the potential future habitat for terrestrial wildlife in this area. Through tailings pile and waste rock consolidation, Alternative 8 would also provide potential replacement terrestrial habitat at the current location of the east and west waste rock piles and tailings pile 1.

Improved long-term reductions in metals loading from the tailings piles are anticipated under this alternative due to tailings pile consolidation. Reductions in PCOC loadings from East and West Area sources would be expected to result in improved aquatic habitat in Railroad Creek over time. As described in Appendix H, the post-remediation concentrations of site PCOCs are expected to be protective of aquatic life in Railroad Creek following remedy implementation in the short term. A summary of the extent of natural resource restoration expected under this alternative is provided in Appendix J.

7.18.4 Use of Permanent Solutions to the Maximum Extent Practicable

The remedial actions included under Alternative 8 constitute permanent solutions under MTCA since potential ARARs are expected to be achieved in the long term without further actions being required (WAC 173-340-200). The post-remediation loading analysis indicates that PCOC loading to Site groundwater and surface water would be reduced over time and potential ARARs are expected to be achieved within approximately 50 years, depending on the PCOC.

An evaluation the use of permanent solutions to the maximum extent practicable is provided in Section 8 (comparative analysis of alternatives). The evaluation of the practicability of this alternative includes whether the alternative is capable of being designed, constructed, and implemented in a reliable and effective manner, including consideration of cost. In considering cost under this analysis, an alternative shall not be considered practicable if the incremental costs are disproportionate to the incremental degree of benefits provided by the alternative over other lower cost alternatives.

7.18.5 Reasonable Restoration Time Frame

Following implementation of Alternative 8, the soil RAOs would be met. Remedial actions would also be effective in eliminating potential physical hazards to Holden Village residents and visitors related to mine features and potential future risks to human health due to the possible development of groundwater as a drinking water supply.

PCOC loading to groundwater would be reduced over time under Alternative 8 through natural attenuation, upgradient water diversions, source controls, tailing pile consolidation, and East/West Area collection and treatment. Results of the post-remediation loading analysis indicate that the groundwater RAO would be achieved at CPOCs in surface water in the West Area and East Areas within approximately 50 years, depending on the PCOC.

Results of the post-remediation loading analysis indicate that the surface water RAO would also be achieved within approximately 50 years. Results of the toxicological evaluations indicate that surface water quality would be protective of aquatic life in Railroad Creek in the short term under Alternative 8.

An evaluation of reasonable restoration time frames is provided in Section 8. The evaluation of the practicability of this alternative, which would likely provide a shorter restoration time frame compared to Alternative 3b, includes whether the alternative is capable of being designed, constructed, and implemented in a reliable and effective manner, including consideration of cost. In considering cost under this analysis, an alternative shall not be considered practicable if the incremental costs are disproportionate to the incremental degree of benefits provided by the alternative over other lower cost alternatives.

Table 7-1
Estimated Short-Term Post-Remediation Water Quality Summary- Railroad Creek

Dissolved metal	Water Quality and Pre-Remediation Concentrations (May 1997)					Alternative 2		Alternative 3		Alternative 4			Alternative 5				Alternative 6		Alternative 7	Alternative 8
	Acute SWQC (ug/L) (1)	Chronic SWQC (ug/L) (1)	Acute 2002 NRWQC (ug/L) (2)	Chronic 2002 NRWQC (ug/L) (2)	Pre-remediation Concentration at Station RC-2 (ug/L)	2a	2b	3a	3b	4a	4b	4c	5a	5b	5c	5d	6a	6b	7	8
Railroad Creek Station RC-4																				
Cd	0.40	0.23	0.28	0.06	0.44	0.39	0.18	0.08	0.05	0.18	0.18	0.18	0.05	0.05	0.05	0.05	0.07	0.05	0.05	0.04
Cu	2.5	2	2	1.6	26.4	23.7	22.3	2.3	2.2	22.3	22.3	22.3	2.2	2.2	2.2	1.8	1.8	1.7	2.2	2.0
Fe	NA	NA	1000	1000	20	20	20	21	20	20	20	20	20	20	20	20	21	20	20	20
Zn	20	19	21	21	73	66	38	15	14	38	38	38	14	14	14	14	15	14	14	13
Railroad Creek Downstream of RC-2																				
Cd	0.47	0.25	0.32	0.07	0.53	0.47	0.27	0.17	0.14	0.28	0.24	0.26	0.16	0.11	0.13	0.13	0.15	0.14	0.12	0.09
Cu	2.8	2.2	2.3	1.8	23.6	21.5	20.4	3.6	3.4	20.3	19.4	19.5	3.3	2.5	2.6	2.3	2.3	2.2	3.2	2.3
Fe	NA	NA	1000	1000	300	301	301	301	301	180	71	72	180	71	72	72	72	72	127	54
Zn	23	21	23.5	23.7	84	76	50	27	26	47	42	44	23	19	20	20	21	21	20	17
	Water Quality and Pre-Remediation Concentrations (September 1997)					**Alternative 2**		**Alternative 3**		**Alternative 4**			**Alternative 5**				**Alternative 6**		**Alternative 7**	**Alternative 8**
Dissolved metal	**Acute SWQC (ug/L) (1)**	**Chronic SWQC (ug/L) (1)**	**Acute 2002 NRWQC (ug/L) (2)**	**Chronic 2002 NRWQC (ug/L) (2)**	**Pre-remediation Concentration at Station RC-2 (ug/L)**	**2a**	**2b**	**3a**	**3b**	**4a**	**4b**	**4c**	**5a**	**5b**	**5c**	**5d**	**6a**	**6b**	**7**	**8**
Railroad Creek Station RC-4																				
Cd	0.37	0.21	0.26	0.06	0.06	0.05	0.16	0.06	0.06	0.16	0.16	0.16	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.04
Cu	2.3	1.9	1.8	1.5	1.8	1.5	15.4	0.9	0.9	15.4	15.4	15.4	0.9	0.9	0.9	0.6	0.6	0.6	0.9	0.7
Fe	NA	NA	1000	1000	40	40	42	41	41	42	42	42	41	41	41	41	41	41	41	40
Zn	19	17	19.4	19.6	11.0	8.9	30.5	5.0	5.1	30.5	30.5	30.5	5.1	5.1	5.1	3.9	3.9	3.9	5.1	3.6
Railroad Creek Downstream of RC-2																				
Cd	0.47	0.25	0.32	0.07	0.10	0.09	0.19	0.10	0.11	0.21	0.18	0.24	0.12	0.09	0.15	0.14	0.16	0.16	0.09	0.05
Cu	2.8	2.2	2.3	1.8	1.2	1.2	6.7	1.0	1.0	6.7	6.4	6.8	1.0	0.6	1.0	0.9	1.0	1.0	0.6	0.4
Fe	NA	NA	1000	1000	1080	1231	1232	1232	1232	445	246	249	444	246	248	248	249	249	404	156
Zn	23	21	23.5	23.7	23	22	41	18	18	38	32	36	15	9	13	12	13	13	11	6

NOTE: This table presents only the estimated expected post-remediation metals concentrations in Railroad Creek. Probabilistically calculated 90% confidence intervals are presented on Table 7-5.

Boxed Cell Result is above the Acute or Chronic SWQC

Shaded Cell Result is above the Acute or Chronic 2002 NRWQC

Pre-Remediation water quality criteria and Railroad Creek concentrations for May 1997 and September 1997 are from the May 19, 1997 and September 15, 1997 sampling events at stations RC-2 and RC-4.

(1) State of Washington hardness adjusted surface water quality criteria calculated based on 13 ppm (RC-4, spring), 12 ppm (RC-4, fall) and 15 ppm (RC-2, spring and fall) hardness values (WAC 173-201A).

(2) 2002 National Recommended Water Quality Criteria hardness adjusted values based on 13 ppm (RC-4, spring), 12 ppm (RC-4, fall) and 15 ppm (RC-2, spring and fall) hardness. Note, the NRWQC for total iron is not hardness dependent.

Table 7-2
Estimated Long-term (Approximately 50 yrs) Post-remediation Water Quality Summary - Railroad Creek Downstream of RC-2

	Water Quality and Pre-remediation Concentrations (May 1997)					Alternative 2		Alternative 3		Alternative 4			Alternative 5				Alternative 6		Alternative 7	Alternative 8
Dissolved metal	Acute SWQC (ug/L) (1)	Chronic SWQC (ug/L) (1)	Acute 2002 NRWQC (ug/L) (2)	Chronic 2002 NRWQC (ug/L) (2)	Pre-remediation Concentration at Station RC-2 (ug/L)	2a	2b	3a	3b	4a	4b	4c	5a	5b	5c	5d	6a	6b	7	8
Cd	0.47	0.25	0.32	0.07	0.53	0.25	0.12	0.09	0.06	0.12	0.11	0.11	0.06	0.06	0.06	0.06	0.12	0.09	0.05	0.04
Cu	2.8	2.2	2.3	1.8	23.6	12.3	8.3	1.6	1.5	8.3	8.3	8.3	1.5	1.5	1.5	1.7	1.8	1.7	1.3	1.3
Fe	NA	NA	1000	1000	300	202	202	202	202	122	51	51	122	51	51	52	52	52	13	13
Zn	23	21	23.5	23.7	84	54	34	25	23	32	28	30	21	18	19	19	21	20	13	12

	Water Quality and Pre-remediation Concentrations (September 1997)					Alternative 2		Alternative 3		Alternative 4			Alternative 5				Alternative 6		Alternative 7	Alternative 8
Dissolved metal	Acute SWQC (ug/L) (1)	Chronic SWQC (ug/L) (1)	Acute 2002 NRWQC (ug/L) (2)	Chronic 2002 NRWQC (ug/L) (2)	Pre-remediation Concentration at Station RC-2 (ug/L)	2a	2b	3a	3b	4a	4b	4c	5a	5b	5c	5d	6a	6b	7	8
Cd	0.47	0.25	0.32	0.07	0.10	0.05	0.05	0.06	0.06	0.05	0.05	0.05	0.06	0.06	0.06	0.07	0.14	0.12	0.06	0.03
Cu	2.8	2.2	2.3	1.8	1.2	0.5	0.5	0.4	0.4	0.6	0.6	0.6	0.4	0.5	0.5	0.9	1.1	1.0	0.4	0.3
Fe	NA	NA	1000	1000	1080	740	740	740	825	304	173	176	304	173	176	176	176	176	36	35
Zn	23	21	23.5	23.7	23	17	18	15	15	16	11	15	13	8	12	12	14	13	4	3

Boxed Cell Result is above the Acute or Chronic SWQC
Shaded Cell Result is above the Acute or Chronic 2002 NRWQC
Pre-Remediation water quality criteria and Railroad Creek concentrations for May 1997 and September 1997 are from the May 19, 1997 and September 15, 1997 sampling events at stations RC-2.
(1) State of Washington hardness adjusted surface water quality criteria calculated based on 15 ppm (RC-2, spring and fall) hardness values (WAC 173-201A).
(2) 2002 National Recommended Water Quality Criteria hardness adjusted values based on 15 ppm (RC-2, spring and fall) hardness. Note, the NRWQC for total iron is not hardness dependent.

Table 7-3
Estimated Long-term (Approximately 150 yrs) Post-remediation Water Quality Summary - Railroad Creek Downstream of RC-2

	Water Quality and Pre-remediation Concentrations (May 1997)					Alternative 2		Alternative 3		Alternative 4			Alternative 5				Alternative 6		Alternative 7	Alternative 8
Dissolved metal	Acute SWQC (ug/L) (1)	Chronic SWQC (ug/L) (1)	Acute 2002 NRWQC (ug/L) (2)	Chronic 2002 NRWQC (ug/L) (2)	Pre-remediation Concentration at Station RC-2 (ug/L)	2a	2b	3a	3b	4a	4b	4c	5a	5b	5c	5d	6a	6b	7	8
Cd	0.47	0.25	0.32	0.07	0.53	0.10	0.06	0.09	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.10	0.07	0.05	0.04
Cu	2.8	2.2	2.3	1.8	23.6	4.3	3.1	1.3	1.2	3.1	3.1	3.1	1.2	1.2	1.2	1.4	1.5	1.4	0.9	0.9
Fe	NA	NA	1000	1000	300	176	176	176	176	107	45	46	107	45	46	46	47	47	14	13
Zn	23	21	23.5	23.7	84	30	24	23	22	22	19	21	20	17	19	19	21	19	13	12

	Water Quality and Pre-remediation Concentrations (September 1997)					Alternative 2		Alternative 3		Alternative 4			Alternative 5				Alternative 6		Alternative 7	Alternative 8
Dissolved metal	Acute SWQC (ug/L) (1)	Chronic SWQC (ug/L) (1)	Acute 2002 NRWQC (ug/L) (2)	Chronic 2002 NRWQC (ug/L) (2)	Pre-remediation Concentration at Station RC-2 (ug/L)	2a	2b	3a	3b	4a	4b	4c	5a	5b	5c	5d	6a	6b	7	8
Cd	0.47	0.25	0.32	0.07	0.10	0.04	0.04	0.06	0.06	0.04	0.04	0.04	0.06	0.06	0.06	0.06	0.09	0.08	0.06	0.03
Cu	2.8	2.2	2.3	1.8	1.2	0.4	0.4	0.4	0.4	0.4	0.5	0.5	0.4	0.5	0.5	0.9	1.1	1.0	0.3	0.3
Fe	NA	NA	1000	1000	1080	646	646	646	720	268	155	157	268	155	157	157	158	158	38	35
Zn	23	21	23.5	23.7	23	13	13	13	14	11	7	11	12	7	11	11	13	13	4	3

Boxed Cell Result is above the Acute or Chronic SWQC
Shaded Cell Result is above the Acute or Chronic 2002 NRWQC
Pre-Remediation water quality criteria and Railroad Creek concentrations for May 1997 and September 1997 are from the May 19, 1997 and September 15, 1997 sampling events at stations RC-2.
(1) State of Washington hardness adjusted surface water quality criteria calculated based on 15 ppm (RC-2, spring and fall) hardness values (WAC 173-201A).
(2) 2002 National Recommended Water Quality Criteria hardness adjusted values based on 15 ppm (RC-2, spring and fall) hardness. Note, the NRWQC for total iron is not hardness dependent.

Table 7-4
Estimated Long-term (Approximately 250 yrs) Post-remediation Water Quality Summary - Railroad Creek Downstream of RC-2

	Water Quality and Pre-remediation Concentrations (May 1997)					Alternative 2		Alternative 3		Alternative 4			Alternative 5				Alternative 6		Alternative 7	Alternative 8
Dissolved metal	Acute SWQC (ug/L) (1)	Chronic SWQC (ug/L) (1)	Acute 2002 NRWQC (ug/L) (2)	Chronic 2002 NRWQC (ug/L) (2)	Pre-remediation Concentration at Station RC-2 (ug/L)	2a	2b	3a	3b	4a	4b	4c	5a	5b	5c	5d	6a	6b	7	8
Cd	0.47	0.25	0.32	0.07	0.53	0.05	0.04	0.06	0.05	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.06	0.04	0.03	0.03
Cu	2.8	2.2	2.3	1.8	23.6	1.8	1.5	1.1	1.0	1.5	1.5	1.5	1.0	1.0	1.1	1.1	1.4	1.3	0.8	0.8
Fe	NA	NA	1000	1000	300	130	130	130	130	81	36	37	81	36	37	37	38	37	13	13
Zn	23	21	23.5	23.7	84	20	19	20	19	18	16	18	18	16	18	18	20	18	13	12

	Water Quality and Pre-remediation Concentrations (September 1997)					Alternative 2		Alternative 3		Alternative 4			Alternative 5				Alternative 6		Alternative 7	Alternative 8
Dissolved metal	Acute SWQC (ug/L) (1)	Chronic SWQC (ug/L) (1)	Acute 2002 NRWQC (ug/L) (2)	Chronic 2002 NRWQC (ug/L) (2)	Pre-remediation Concentration at Station RC-2 (ug/L)	2a	2b	3a	3b	4a	4b	4c	5a	5b	5c	5d	6a	6b	7	8
Cd	0.47	0.25	0.32	0.07	0.10	0.03	0.03	0.04	0.04	0.03	0.03	0.03	0.04	0.04	0.04	0.04	0.05	0.04	0.03	0.03
Cu	2.8	2.2	2.3	1.8	1.2	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.5	0.5	0.6	1.1	1.0	0.3	0.3
Fe	NA	NA	1000	1000	1080	475	475	475	528	202	121	123	202	121	123	123	124	124	36	34
Zn	23	21	23.5	23.7	23	9	9	10	11	9	6	8	10	7	9	9	10	9	4	3

Boxed Cell Result is above the Acute or Chronic SWQC
Shaded Cell Result is above the Acute or Chronic 2002 NRWQC
Pre-Remediation water quality criteria and Railroad Creek concentrations for May 1997 and September 1997 are from the May 19, 1997 and September 15, 1997 sampling events at stations RC-2.
(1) State of Washington hardness adjusted surface water quality criteria calculated based on 15 ppm (RC-2, spring and fall) hardness values (WAC 173-201A).
(2) 2002 National Recommended Water Quality Criteria hardness adjusted values based on 15 ppm (RC-2, spring and fall) hardness. Note, the NRWQC for total iron is not hardness dependent.

Table 7-5
Short-term Post-remediation Loading and Uncertainty Calculations
Railroad Creek - Spring

Alternative		RC-4								Downstream of RC-2							
		Cd		Cu		Fe		Zn		Cd		Cu		Fe		Zn	
	Pre-Remediation Chronic SWQC (ug/L) (1)	0.23		2		NA		19		0.25		2.2		NA		21	
	Pre-Remediation Chronic NRWQC (ug/L) (2)	0.06		1.6		1000		21		0.07		1.8		1000		23	
	Pre-Remediation Concentration (ug/L)	0.44		26.4		20		73		0.53		23.7		303		84	
	Coefficient of Variation	0.05		0.05		0.05		0.05		0.174		0.173		0.172		0.173	
Alternative	90% Confidence Interval	0.40	0.48	24.3	28.6	18	22	67	79	0.39	0.69	17.6	31.0	225	395	62	110
2a	Estimated Post-Remediation Concentration (ug/L)	0.39		23.7		20		66		0.47		21.5		301		76	
	Coefficient of Variation	0.236		0.200		0.301		0.239		0.200		0.212		0.909		0.213	
	90% Confidence Interval	0.26	0.55	16.79	32.16	11.73	30.91	43.22	93.94	0.33	0.63	14.89	29.69	62.08	797.71	52.52	104.95
2b	Estimated Post-Remediation Concentration (ug/L)	0.18		22.3		20		38		0.27		20.4		301		50	
	Coefficient of Variation	0.354		0.285		0.297		0.272		0.249		0.299		0.908		0.229	
	90% Confidence Interval	0.10	0.30	13.54	33.98	12.18	31.68	23.40	56.38	0.18	0.39	12.05	31.60	62.22	798.33	33.41	70.24
3a	Estimated Post-Remediation Concentration (ug/L)	0.08		2.3		21		15		0.17		3.6		301		27	
	Coefficient of Variation	0.156		0.214		0.280		0.195		0.171		0.209		0.908		0.224	
	90% Confidence Interval	0.06	0.10	1.60	3.20	13.04	32.24	10.81	20.43	0.13	0.22	2.47	4.88	62.36	798.96	18.56	38.38
3b	Estimated Post-Remediation Concentration (ug/L)	0.05		2.2		20		14		0.14		3.4		301		26	
	Coefficient of Variation	0.140		0.224		0.293		0.207		0.184		0.213		0.909		0.232	
	90% Confidence Interval	0.04	0.07	1.48	3.06	12.09	31.09	9.67	18.98	0.10	0.19	2.38	4.77	62.12	797.85	17.47	37.06
4a	Estimated Post-Remediation Concentration (ug/L)	0.18		22.3		20		38		0.28		20.3		180		47	
	Coefficient of Variation	0.354		0.285		0.366		0.272		0.240		0.301		0.835		0.225	
	90% Confidence Interval	0.10	0.30	13.54	33.98	10.75	34.48	23.40	56.38	0.19	0.41	11.97	31.49	41.72	456.64	31.50	65.38
4b	Estimated Post-Remediation Concentration (ug/L)	0.18		22.3		20		38		0.24		19.4		71		42	
	Coefficient of Variation	0.354		0.285		0.366		0.272		0.270		0.312		1.037		0.238	
	90% Confidence Interval	0.10	0.30	13.54	33.98	10.75	34.48	23.40	56.38	0.15	0.35	11.20	30.53	12.09	200.88	27.87	60.30
4c	Estimated Post-Remediation Concentration (ug/L)	0.18		22.3		20		38		0.26		19.5		72		44	
	Coefficient of Variation	0.354		0.285		0.366		0.272		0.248		0.310		0.938		0.230	
	90% Confidence Interval	0.10	0.30	13.54	33.98	10.75	34.48	23.40	56.38	0.17	0.38	11.35	30.70	14.20	193.85	29.39	62.02

Table 7-5
Short-term Post-remediation Loading and Uncertainty Calculations
Railroad Creek - Spring

		RC-4								Downstream of RC-2							
		Cd		Cu		Fe		Zn		Cd		Cu		Fe		Zn	
	Pre-Remediation Chronic SWQC (ug/L) [(1)]	0.23		2		NA		19		0.25		2.2		NA		21	
	Pre-Remediation Chronic NRWQC (ug/L) [(2)]	0.06		1.6		1000		21		0.07		1.8		1000		23	
	Pre-Remediation Concentration (ug/L)	0.44		26.4		20		73		0.53		23.7		303		84	
	Coefficient of Variation	0.05		0.05		0.05		0.05		0.174		0.173		0.172		0.173	
Alternative	90% Confidence Interval	0.40	0.48	24.3	28.6	18	22	67	79	0.39	0.69	17.6	31.0	225	395	62	110
5a	Estimated Post-Remediation Concentration (ug/L)	0.05		2.2		20		14		0.16		3.3		180		23	
	Coefficient of Variation	0.140		0.224		0.293		0.207		0.178		0.216		0.835		0.186	
	90% Confidence Interval	0.04	0.07	1.48	3.06	12.09	31.09	9.67	18.98	0.11	0.21	2.31	4.65	41.64	456.04	16.65	30.52
5b	Estimated Post-Remediation Concentration (ug/L)	0.05		2.2		20		14		0.11		2.5		71		19	
	Coefficient of Variation	0.140		0.224		0.293		0.207		0.156		0.218		1.037		0.181	
	90% Confidence Interval	0.04	0.07	1.48	3.06	12.09	31.09	9.67	18.98	0.08	0.14	1.68	3.41	12.04	200.18	13.58	24.55
5c	Estimated Post-Remediation Concentration (ug/L)	0.05		2.2		20		14		0.13		2.6		72		20	
	Coefficient of Variation	0.140		0.224		0.293		0.207		0.293		0.223		0.938		0.205	
	90% Confidence Interval	0.04	0.07	1.48	3.06	12.09	31.09	9.67	18.98	0.08	0.20	1.78	3.67	14.15	193.14	14.19	27.67
5d	Estimated Post-Remediation Concentration (ug/L)	0.05		1.8		20		14		0.13		2.3		72		20	
	Coefficient of Variation	0.171		0.545		0.293		0.214		0.299		0.440		0.938		0.208	
	90% Confidence Interval	0.04	0.07	0.70	3.76	12.13	31.14	9.51	19.05	0.08	0.20	1.05	4.21	14.16	193.17	14.06	27.66
6a	Estimated Post-Remediation Concentration (ug/L)	0.07		1.8		21		15		0.15		2.3		72		21	
	Coefficient of Variation	0.167		0.565		0.283		0.204		0.260		0.442		0.931		0.199	
	90% Confidence Interval	0.05	0.09	0.65	3.69	12.82	31.96	10.34	20.08	0.10	0.23	1.05	4.20	14.45	194.31	15.24	29.11
6b	Estimated Post-Remediation Concentration (ug/L)	0.05		1.7		20		14		0.14		2.2		72		21	
	Coefficient of Variation	0.171		0.595		0.293		0.214		0.287		0.456		0.934		0.205	
	90% Confidence Interval	0.04	0.07	0.59	3.59	12.13	31.14	9.51	19.05	0.08	0.21	0.99	4.12	14.28	193.51	14.45	28.14
7	Estimated Post-Remediation Concentration (ug/L)	0.05		2.2		20		14		0.12		3.2		127		20	
	Coefficient of Variation	0.140		0.224		0.293		0.207		0.141		0.214		0.708		0.165	
	90% Confidence Interval	0.04	0.07	1.48	3.06	12.09	31.09	9.67	18.98	0.10	0.16	2.19	4.39	36.20	294.87	14.91	25.59
8	Estimated Post-Remediation Concentration (ug/L)	0.04		2.0		20		13		0.09		2.3		54		17	
	Coefficient of Variation	0.153		0.237		0.300		0.215		0.191		0.387		0.821		0.190	
	90% Confidence Interval	0.03	0.05	1.35	2.92	11.63	30.55	9.08	18.28	0.06	0.12	1.14	3.89	12.77	135.26	12.11	22.50

[(1)] State of Washington hardness adjusted surface water quality criteria calculated based on 13 ppm (RC-4, spring), 12 ppm (RC-4, fall) and 15 ppm (RC-2, spring and fall) hardness values (WAC 173-201A).
[(2)] 2002 National Recommended Water Quality Criteria hardness adjusted values based on 13 ppm (RC-4, spring), 12 ppm (RC-4, fall) and 15 ppm (RC-2, spring and fall) hardness. Note, the NRWQC for total iron is not hardness dependent.
Pre-remediation water quality criteria are from the May 19, 1997 sampling event at stations RC-2 & RC-4. Pre-remediation concentrations at station RC-4 are measured concentrations at station RC-4.
Pre-remediation concentrations downstream of RC-2 are calculated based on the cumulative metals loading dowstream of RC-2.

Table 7-5
Short-term Post-remediation Loading and Uncertainty Calculations
Railroad Creek - Fall

Alternative		RC-4								Downstream of RC-2							
		Cd		**Cu**		**Fe**		**Zn**		**Cd**		**Cu**		**Fe**		**Zn**	
	Pre-remediation Chronic SWQC (ug/L) (1)	0.21		1.9		NA		17		0.25		2.2		NA		21	
	Pre-remediation Chronic NRWQC (ug/L) (2)	0.06		1.5		1000		19		0.07		1.8		1000		23	
	Pre-remediation Concentration (ug/L)	0.06		1.8		40		11		0.11		1.4		1231		24	
	Coefficient of Variation	0.05		0.05		0.05		0.05		0.127		0.153		0.176		0.113	
Alternative	90% Confidence Interval	0.06	0.07	1.7	2.0	37	43	10	12	0.09	0.13	1.1	1.8	909	1617	20	28
2a	Estimated Post-remediation Concentration (ug/L)	0.05		1.5		40		9		0.09		1.2		1231		22	
	Coefficient of Variation	0.293		0.382		0.195		0.311		0.358		2.017		1.622		0.328	
	90% Confidence Interval	0.03	0.08	0.74	2.49	28.49	53.71	5.18	14.05	0.05	0.16	0.07	4.41	99.75	4181.50	12.18	34.85
2b	Estimated Post-remediation Concentration (ug/L)	0.16		15.4		42		31		0.19		6.7		1232		41	
	Coefficient of Variation	0.424		0.397		0.223		0.330		0.352		1.790		1.621		0.272	
	90% Confidence Interval	0.08	0.29	7.64	26.89	28.55	58.91	17.11	49.20	0.10	0.32	0.46	23.58	100.01	4186.26	25.59	61.62
3a	Estimated Post-remediation Concentration (ug/L)	0.06		0.9		41		5		0.10		1.0		1232		18	
	Coefficient of Variation	0.162		0.307		0.211		0.423		0.312		2.198		1.621		0.381	
	90% Confidence Interval	0.05	0.08	0.53	1.43	28.54	56.70	2.35	8.93	0.06	0.16	0.05	3.71	99.90	4184.27	9.24	31.02
3b	Estimated Post-remediation Concentration (ug/L)	0.06		0.9		41		5		0.11		1.0		1232		18	
	Coefficient of Variation	0.161		0.305		0.211		0.416		0.307		2.193		1.621		0.379	
	90% Confidence Interval	0.05	0.08	0.54	1.44	28.61	56.79	2.43	9.02	0.06	0.17	0.05	3.72	99.91	4184.44	9.32	31.11
4a	Estimated Post-remediation Concentration (ug/L)	0.16		15.4		42		31		0.21		6.7		445		38	
	Coefficient of Variation	0.424		0.397		0.223		0.330		0.353		1.795		1.854		0.273	
	90% Confidence Interval	0.08	0.29	7.64	26.89	28.55	58.91	17.11	49.20	0.11	0.34	0.45	23.59	28.33	1571.53	23.58	56.90
4b	Estimated Post-remediation Concentration (ug/L)	0.16		15.4		42		31		0.18		6.4		246		32	
	Coefficient of Variation	0.424		0.213		0.223		0.330		0.352		1.535		2.063		0.287	
	90% Confidence Interval	0.08	0.29	10.67	21.33	28.55	58.91	17.11	49.20	0.09	0.29	0.57	21.26	12.92	894.50	19.29	48.75
4c	Estimated Post-remediation Concentration (ug/L)	0.16		15.4		42		31		0.24		6.8		249		36	
	Coefficient of Variation	0.424		0.397		0.223		0.330		0.445		1.703		1.900		0.303	
	90% Confidence Interval	0.08	0.29	7.64	26.89	28.55	58.91	17.11	49.20	0.11	0.43	0.50	23.42	15.16	885.36	21.20	56.16

Table 7-5
Short-term Post-remediation Loading and Uncertainty Calculations
Railroad Creek - Fall

		RC-4								**Downstream of RC-2**							
		Cd		**Cu**		**Fe**		**Zn**		**Cd**		**Cu**		**Fe**		**Zn**	
	Pre-remediation Chronic SWQC (ug/L) (1)	0.21		1.9		NA		17		0.25		2.2		NA		21	
	Pre-remediation Chronic NRWQC (ug/L) (2)	0.06		1.5		1000		19		0.07		1.8		1000		23	
	Pre-remediation Concentration (ug/L)	0.06		1.8		40		11		0.11		1.4		1231		24	
	Coefficient of Variation	0.05		0.05		0.05		0.05		0.127		0.153		0.176		0.113	
Alternative	90% Confidence Interval	0.06	0.07	1.7	2.0	37	43	10	12	0.09	0.13	1.1	1.8	909	1617	20	28
5a	Estimated Post-remediation Concentration (ug/L)	0.06		0.9		41		5		0.12		1.0		444		15	
	Coefficient of Variation	0.161		0.305		0.211		0.416		0.347		2.249		1.856		0.365	
	90% Confidence Interval	0.05	0.08	0.54	1.44	28.61	56.79	2.43	9.02	0.06	0.19	0.04	3.64	28.25	1569.61	7.83	25.08
5b	Estimated Post-remediation Concentration (ug/L)	0.06		0.9		41		5		0.09		0.6		246		9	
	Coefficient of Variation	0.161		0.305		0.211		0.416		0.188		1.455		2.066		0.319	
	90% Confidence Interval	0.05	0.08	0.54	1.44	28.61	56.79	2.43	9.02	0.06	0.12	0.06	2.05	12.85	892.51	5.06	14.10
5c	Estimated Post-remediation Concentration (ug/L)	0.06		0.9		41		5		0.15		1.0		248		13	
	Coefficient of Variation	0.161		0.305		0.211		0.416		0.581		1.019		1.903		0.498	
	90% Confidence Interval	0.05	0.08	0.54	1.44	28.61	56.79	2.43	9.02	0.05	0.31	0.18	2.92	15.08	883.43	5.37	25.27
5d	Estimated Post-remediation Concentration (ug/L)	0.06		0.6		41		4		0.14		0.9		248		12	
	Coefficient of Variation	0.136		0.190		0.211		0.454		0.594		0.970		1.902		0.528	
	90% Confidence Interval	0.04	0.07	0.45	0.84	28.61	56.79	1.74	7.23	0.05	0.31	0.18	2.57	15.10	883.69	4.74	24.23
6a	Estimated Post-remediation Concentration (ug/L)	0.06		0.6		41		4		0.16		1.0		249		13	
	Coefficient of Variation	0.136		0.190		0.210		0.451		0.544		0.883		1.899		0.491	
	90% Confidence Interval	0.04	0.07	0.45	0.84	28.58	56.60	1.76	7.25	0.06	0.32	0.22	2.70	15.18	884.88	5.47	25.21
6b	Estimated Post-remediation Concentration (ug/L)	0.06		0.6		41		4		0.16		1.0		249		13	
	Coefficient of Variation	0.136		0.190		0.210		0.454		0.545		0.883		1.899		0.492	
	90% Confidence Interval	0.04	0.07	0.45	0.83	28.56	56.58	1.74	7.23	0.06	0.32	0.22	2.70	15.18	884.84	5.45	25.19
7	Estimated Post-remediation Concentration (ug/L)	0.06		0.9		41		5		0.09		0.6		404		11	
	Coefficient of Variation	0.161		0.305		0.211		0.416		0.159		1.230		1.025		0.208	
	90% Confidence Interval	0.05	0.08	0.54	1.44	28.61	56.79	2.43	9.02	0.07	0.11	0.08	1.91	70.08	1138.23	7.78	15.32
8	Estimated Post-remediation Concentration (ug/L)	0.04		0.7		40		4		0.05		0.4		156		6	
	Coefficient of Variation	0.211		0.376		0.215		0.574		0.221		1.423		1.639		0.361	
	90% Confidence Interval	0.02	0.05	0.38	1.25	27.69	55.68	1.29	7.45	0.04	0.07	0.05	1.45	12.44	532.69	3.24	10.24

(1) State of Washington hardness adjusted surface water quality criteria calculated based on 13 ppm (RC-4, spring), 12 ppm (RC-4, fall) and 15 ppm (RC-2, spring and fall) hardness values (WAC 173-201A).
(2) 2002 National Recommended Water Quality Criteria hardness adjusted values based on 13 ppm (RC-4, spring), 12 ppm (RC-4, fall) and 15 ppm (RC-2, spring and fall) hardness. Note, the NRWQC for total iron is not hardness dependent.
Pre-remediation water quality criteria are from the September 15, 1997 sampling event at stations RC-2 & RC-4. Pre-remediation concentrations at station RC-4 are measured concentrations at station RC-4.
Pre-remediation concentrations downstream of RC-2 are calculated based on the cumulative metals loading dowstream of RC-2.

Table 7-6
Summary of Total Aluminum Loading in Railroad Creek

Station	Spring					Fall				
	RRC Discharge (L/sec)	pH	Total Aluminum (mg/L)	Total Al Loading (kg/Day)	Total Al Loading (% of RC-2)	RRC Discharge (L/sec)	pH	Total Aluminum (mg/L)	Total Al Loading (kg/Day)	Total Al Loading (% of RC-2)
RC-6	14159	5.9	0.090	110	37%	3710	6.1	0.060	19	64%
RC-1	14161	5.45	0.090	110	37%	3737	5.8	0.070	23	75%
RC-4	14161	7.1	0.100	122	41%	3484	6.7	0.050	15	50%
RC-2	15010	6.7	0.230	298	100%	3851	5.7	0.090	30	100%

Values above are for the baseline 1997 dataset. Railroad Creek concentrations correspond to the May 19, 1997 (RC-6, RC-1, and RC-2), May 21, 1997 (RC-4), and September 15, 1997 (RC-6, RC-1, RC-4, and RC-2) sampling events.

Table 7-7
Regraded Tailings Pile Surface-water Runoff Calculation Summary

Alternative 2/3 - Regrading TP-1 & TP-2

Tailings Pile	Length Along Creek (feet)	Tailings Pile X-Section	FS Figure Number	Exposed Pile Horizontal Length (feet)	Horizontal Length to Creek/Ditch/Pipe (feet)	Exposed Pile Slope Length (feet)	Aerial Pile Area (ft^2)	Aerial Pile Area (acres)	Tc* (hr)	Peak Runoff from Regraded Tailings (cfs)	Peak Runoff from Regraded Tailings (L/s)
TP-1	1,400	-	7-13	60	85	70	84,000	1.9	0.02	0.5	15.5
TP-2	1,900	-	7-14	195	265	220	370,500	8.5	0.04	2.4	68.4
TP-3	none	-	-	-	-	-	-	-	--	--	--
						Total	454,500	10.4	--	3.0	83.9

Alternative 4a/5a - Regrading TP-1, TP-2 & TP-3 w/ Partial Collection

Tailings Pile	Length Along Creek (feet)	Tailings Pile X-Section	FS Figure Number	Exposed Pile Horizontal Length (feet)	Horizontal Length to Creek/Ditch/Pipe (feet)	Exposed Pile Slope Length (feet)	Aerial Pile Area (ft^2)	Aerial Pile Area (acres)	Tc* (hr)	Peak Runoff from Regraded Tailings (cfs)	Peak Runoff from Regraded Tailings (L/s)
TP-1 (w/o collection)	100	-	7-13	60	85	70	6,000	0.1	0.02	0.0	1.1
TP-1 (w/ collection)	750	1-1A	6-17	85	85	100	63,750	1.5	0.02	0.4	11.8
TP-2 (w/o collection)	1,400	-	7-14	195	265	220	273,000	6.3	0.04	1.8	50.4
TP-3 (w/ collection)	700	3-3A	6-18	115	115	130	80,500	1.8	0.03	0.5	14.9
						Total	423,250	8.1	--	2.8	78.1

Alternative 4b/5b - Regrading TP-1, TP-2 & TP-3 w/ Extended Collection

Tailings Pile	Length Along Creek (feet)	Tailings Pile X-Section	FS Figure Number	Exposed Pile Horizontal Length (feet)	Horizontal Length to Creek/Ditch/Pipe (feet)	Exposed Pile Slope Length (feet)	Aerial Pile Area (ft^2)	Aerial Pile Area (acres)	Tc* (hr)	Peak Runoff from Regraded Tailings (cfs)	Peak Runoff from Regraded Tailings (L/s)
TP-1	1,250	1-1B	6-25	80	85	90	100,000	2.3	0.02	0.7	18.5
TP-2	1,400	2-2B	6-26	195	235	220	273,000	6.3	0.04	1.8	50.4
TP-3	1,300	3-3B	6-27	100	105	110	130,000	3.0	0.02	0.8	24.0
						Total	503,000	11.5	--	3.3	92.9

Alternative 4c/5c/5d/6a/6b - Regrading TP-2 w/ RRC Relocation

Tailings Pile	Length Along Creek (feet)	Tailings Pile X-Section	FS Figure Number	Exposed Pile Horizontal Length (feet)	Horizontal Length to Creek or Ditch (feet)	Exposed Pile Slope Length (feet)	Aerial Pile Area (ft^2)	Aerial Pile Area (acres)	Tc* (hr)	Peak Runoff from Regraded Tailings (cfs)	Peak Runoff from Regraded Tailings (L/s)
TP-1	none	-	-	-	-	-	-	-	--	--	--
TP-2 (w/ collection)	1,000	-	7-14	195	265	220	195,000	4.5	0.04	1.3	36.0
TP-3	none	-	-	-	-	-	-	-	--	--	--
						Total	195,000	4.5	--	1.3	36.0

Alternative 7/8 - Consolidated Pile
Assume 10% of TP-1 & TP-3 Exposed, Consolidated Pile Exposed

Tailings Pile	Length Along Creek (feet)	Tailings Pile X-Section	FS Figure Number	Exposed Pile Horizontal Length (feet)	Horizontal Length to Creek/Ditch/Pipe (feet)	Exposed Pile Slope Length (feet)	Aerial Pile Area (ft^2)	Aerial Pile Area (acres)	Tc* (hr)	Peak Runoff from Regraded Tailings (cfs)	Peak Runoff from Regraded Tailings (L/s)
TP-1	140	1-1B	6-25	80	85	90	11,200	0.3	0.02	0.1	2.1
TP-3	130	3-3B	6-27	100	105	110	13,000	0.3	0.02	0.1	2.4
CTP	2,750	CTP-1	6-37	290	370	350	797,500	18.3	0.06	5.2	147.2
						Total	821,700	18.9	--	5.4	151.7

Notes for analysis & assumptions:
Runoff from regraded tailings surfaces estimated by Soil Conservation Service (SCS) method TR-55 (USDA 1986), assuming a 1", 24-hr storm event.
A Curve Number of 86 was used (newly graded area/soil type A).
Sheet flow and a Manning's roughness coefficient of 0.06 were assumed for flow over the regraded tailings.
Time of concentration (Tc) was calculated from the farthest regraded point to the creek. It was assumed that the travel time in creek, ditch or pipe is negligible.
Unit peak discharge (Qu) was estimated using Exhibit 4-III. Tc is out of range on this chart (<0.1). Thus, a Tc of 0.1 was assumed.
A regraded slope of 2:1 (0.5 ft/ft) was used for all calculations.

Table 7-8
Estimated Metals Loading in Storm-water Runoff from Regraded Tailings

Alternative	RRC Flow at Downstream of RC-2 (L/sec)	Runoff Discharge from Regraded Tailings Surfaces (L/sec)	Cadmium			Copper			Iron			Zinc		
			Estimated Short-term Post-remediation Metals Loading in RRC Downstream of RC-2 w/out Tailings Runoff (kg/D)	Potential Worst-case Regraded Tailings Runoff Water Quality (mg/L)	Potential Worst-case Loading from Regraded Tailings (kg/D)	Estimated Short-term Post-remediation Metals Loading in RRC Downstream of RC-2 w/out Tailings Runoff (kg/D)	Potential Worst-case Regraded Tailings Runoff Water Quality (mg/L)	Potential Worst-case Loading from Regraded Tailings (kg/D)	Estimated Short-term Post-remediation Metals Loading in RRC Downstream of RC-2 w/out Tailings Runoff (kg/D)	Potential Worst-case Regraded Tailings Runoff Water Quality (mg/L)	Potential Worst-case Loading from Regraded Tailings (kg/D)	Estimated Short-term Post-remediation Metals Loading in RRC Downstream of RC-2 w/out Tailings Runoff (kg/D)	Potential Worst-case Regraded Tailings Runoff Water Quality (mg/L)	Potential Worst-case Loading from Regraded Tailings (kg/D)
2a	3868	84	0.03	3.0	22	0.4	21	149	411	2561	18564	7	12862	93239
2b	3868	84	0.06	3.0	22	2.3	21	149	412	2561	18564	14	12862	93239
3a	3868	84	0.03	3.0	22	0.3	21	149	412	2561	18564	6	12862	93239
3b	3868	84	0.04	3.0	22	0.3	21	149	412	2561	18564	6	12862	93239
4a	3852	78	0.07	3.0	20	2.2	21	139	148	2561	17287	13	12862	86828
4b	3852	93	0.06	3.0	24	2.1	21	165	82	2561	20545	11	12862	103189
4c	3852	36	0.08	3.0	9	2.3	21	64	83	2561	7965	12	12862	40004
5a	3852	78	0.04	3.0	20	0.3	21	139	148	2561	17287	5	12862	86828
5b	3852	93	0.03	3.0	24	0.2	21	165	82	2561	20545	3	12862	103189
5c	3852	36	0.05	3.0	9	0.3	21	64	83	2561	7965	4	12862	40004
5d	3852	36	0.05	3.0	9	0.3	21	64	83	2561	7965	4	12862	40004
6a	3852	36	0.05	3.0	9	0.3	21	64	83	2561	7965	4	12862	40004
6b	3852	36	0.05	3.0	9	0.3	21	64	83	2561	7965	4	12862	40004
7	3868	152	0.03	2.8	37	0.2	9	116	135	1304	17089	4	3112	40784
8	3852	152	0.02	2.8	37	0.1	9	116	52	1304	17089	2	3112	40784

Table 7-9
Candidate Site-Wide Alternative Cost Summary
(US Dollars)

Alternative Number and Description	Capital Cost (Direct)	Engineering, Construction Mgmt.	Project Mgmt.	Total Capital Cost	Annual O&M Cost	Total O&M Cost - Present Worth (30 yrs @ 7%)	Subtotal Cost	Contingency (50%)	Total Estimated Project Costs
1 - No Action/Institutional Controls	450,000	112,500	18,000	581,000	100,000	1,240,000	1,821,000	910,000	**2,731,000**
2A- Water Management (Open Portal)	7,766,000	1,941,500	310,640	10,018,000	150,000	1,486,500	11,505,000	5,752,000	**17,257,000**
2B- Water Management (Hydrostatic Bulkheads)	8,541,000	2,135,250	341,640	11,018,000	150,000	1,486,500	12,504,000	6,252,000	**18,757,000**
3A- Water Management & Low-Energy West Area Treatment (Open Portal)	11,827,000	2,956,750	473,080	15,257,000	256,000	2,801,000	18,058,000	9,029,000	**27,087,000**
3B - Water Management & Low-Energy West Area Treatment (Hydrostatic Bulkheads)	12,382,700	3,095,675	495,308	15,974,000	256,000	2,801,000	18,775,000	9,387,000	**28,162,000**
4A - Water Management & Partial East Area Collection/Treatment	15,916,500	3,183,300	477,495	19,577,000	302,000	3,372,000	22,949,000	11,475,000	**34,424,000**
4B - Water Management & Extended East Area Collection/Treatment	34,233,500	5,135,025	1,027,005	40,396,000	399,500	4,581,000	44,977,000	22,488,000	**67,465,000**
4C - Water Management, Extended Railroad Creek Relocation & Extended East Area Collection/Treatment	14,271,500	2,854,300	428,145	17,554,000	377,500	4,076,000	21,630,000	10,815,000	**32,445,000**
5A - Water Management, Partial East Area Collection & East/West Area Treatment (Low-Energy WTP)	19,563,700	3,717,103	586,911	23,868,000	323,500	3,638,000	27,506,000	13,753,000	**41,259,000**
5B - Water Management, Extended East Area Collection & East/West Area Treatment (Low-Energy WTP)	37,880,700	5,682,105	1,136,421	44,699,000	421,000	4,847,000	49,546,000	24,773,000	**74,319,000**
5C - Water Management, Extended Railroad Creek Relocation & East/West Area Treat (Low-Energy WTP)	18,507,600	3,516,444	555,228	22,579,000	399,000	4,342,000	26,921,000	13,461,000	**40,382,000**
5D - Water Management, Secondary West Area Collection, Extended Railroad Creek Relocation, & East/West Area Treat (Low-Energy WTP)	21,166,900	4,021,711	635,007	25,824,000	427,000	4,689,000	30,513,000	15,256,000	**45,769,000**
6A - Water Management, Extended Secondary West Area Collection, Extended Railroad Creek Relocation & East/West Area Treat (Mechanical WTP)	34,058,400	5,108,760	1,021,752	40,189,000	969,000	11,410,000	51,599,000	25,800,000	**77,399,000**
6B - Water Managment, Extended Secondary West Area Collection, Extended Railroad Creek Relocation & East/West Area Treat (Mechanical WTP - Bulkhead)	32,419,700	4,862,955	972,591	38,255,300	969,000	11,410,000	49,665,300	24,832,650	**74,498,000**
7 - Capping, Consolidation, Water Management & West Area Treatment (Low-Energy WTP)	54,917,600	7,139,288	1,098,352	63,155,000	305,000	3,782,000	66,937,000	33,469,000	**100,406,000**
8 - Source Control & East/West Area Treatment (Low-energy WTP)	61,268,000	7,964,840	1,225,360	70,458,000	391,000	4,848,400	75,307,000	37,653,000	**112,960,000**

* Cost estimates represent order-of-magnitude costs consistent with US Environmental Protection Agency guidelines for evaluating candidate remedial alternatives.

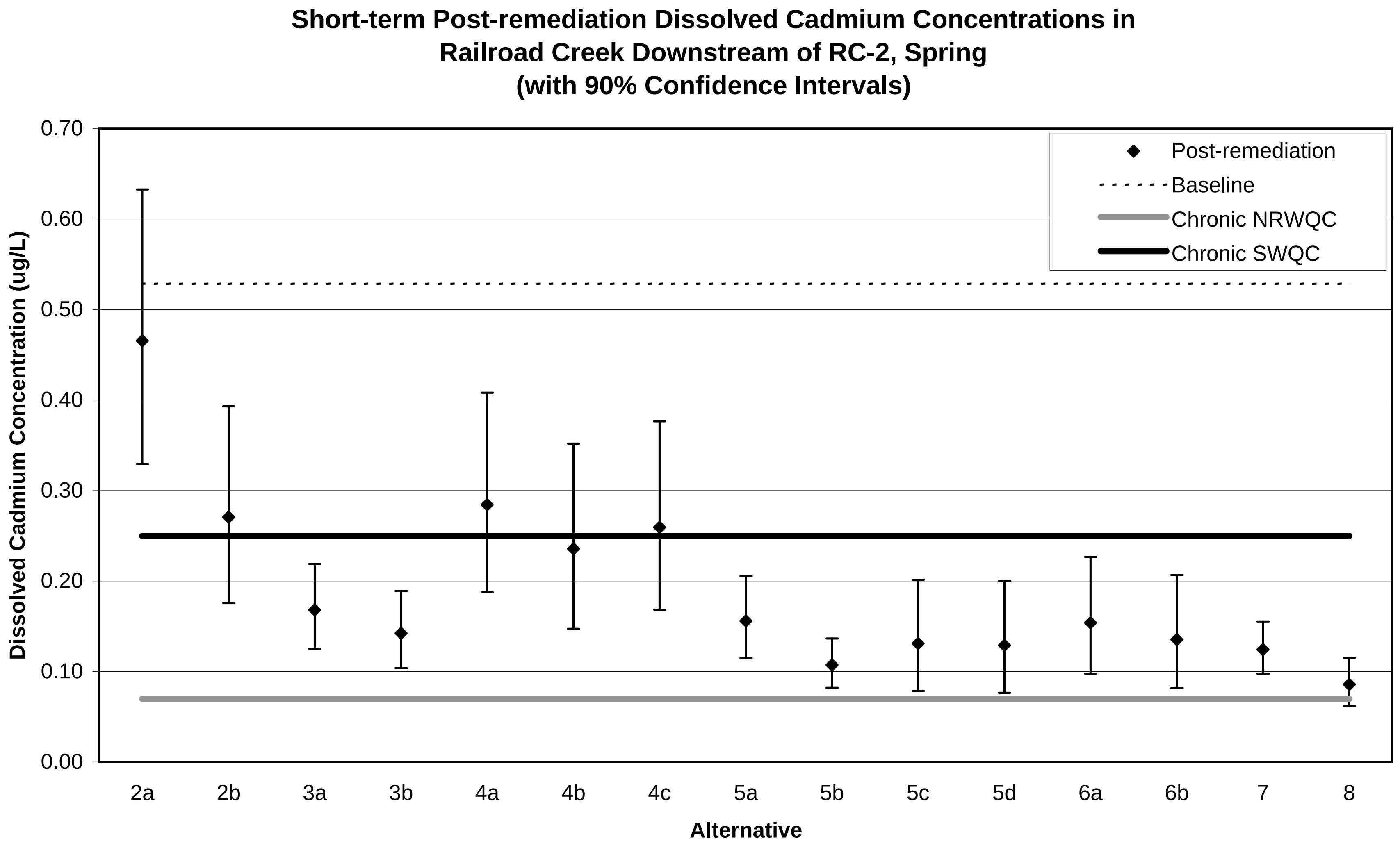

Figure 7-1
Short-term Post-remediation Dissolved Cadmium Concentrations in Railroad Creek Downstream of RC-2, Spring
Draft Final FS Report
February 2004

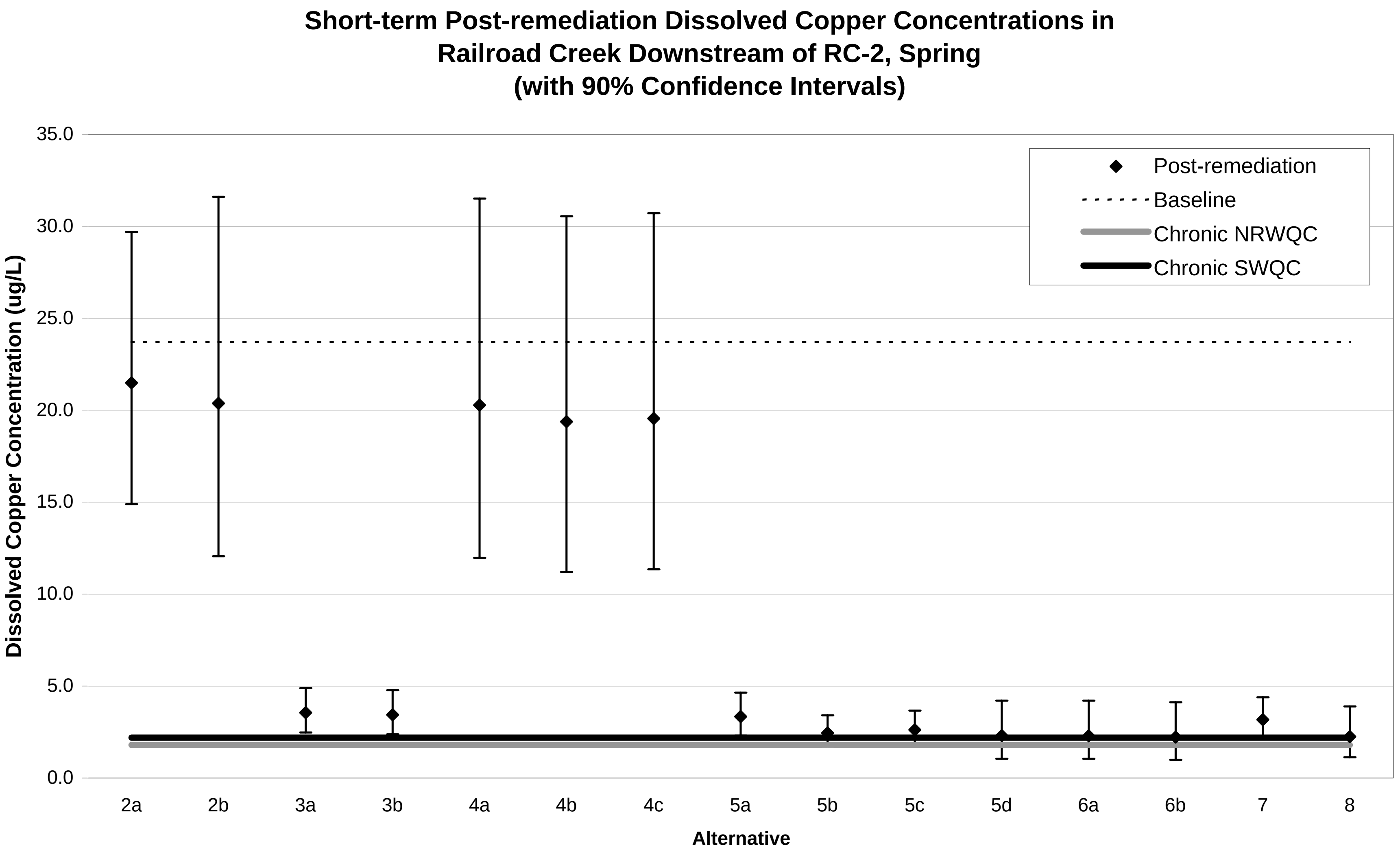

Figure 7-2

Short-term Post-remediation Dissolved Copper Concentrations in Railroad Creek Downstream of RC-2, Spring

Draft Final FS Report

February 2004

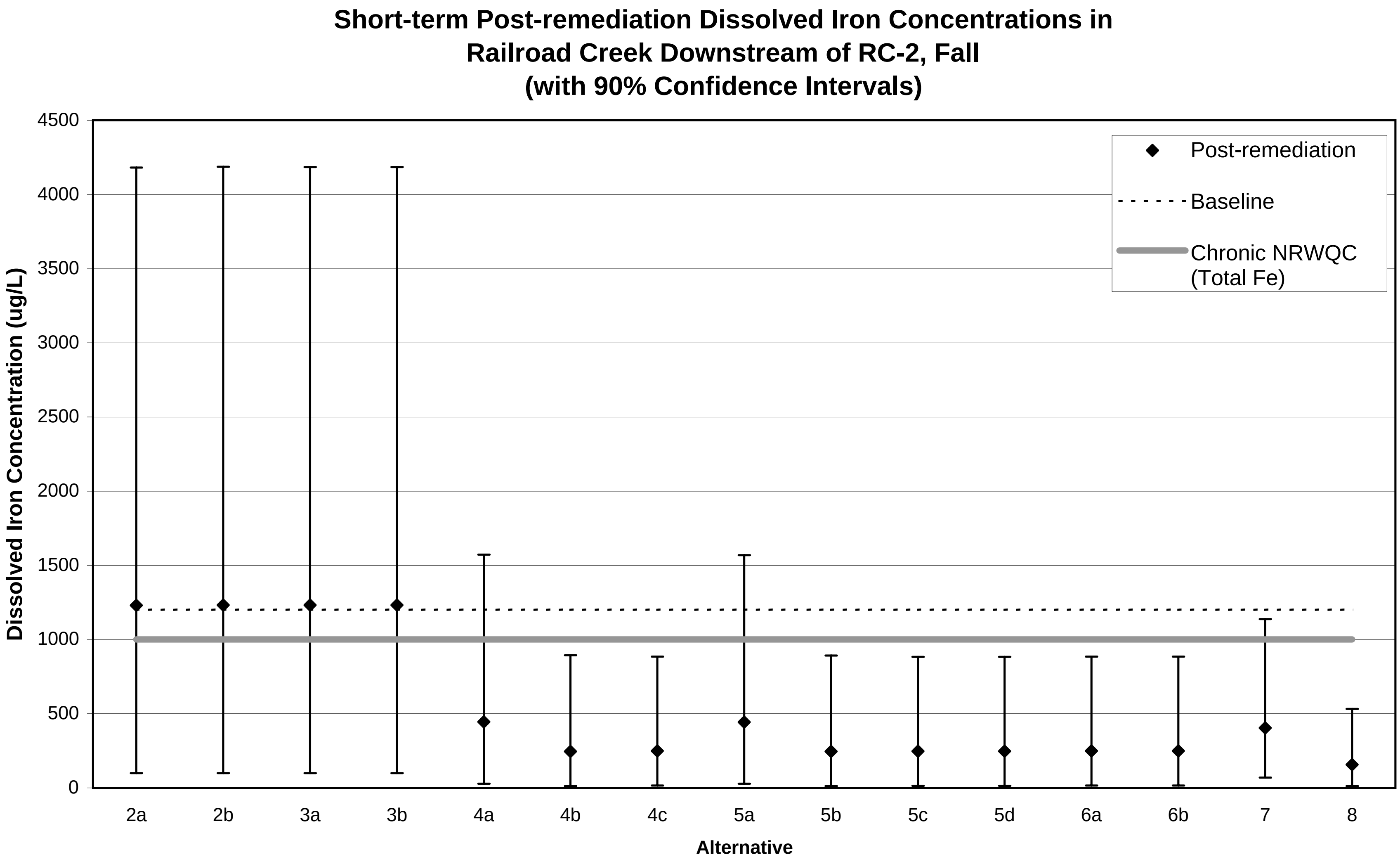

Figure 7-3
Short-term Post-remediation Dissolved Iron Concentrations in Railroad Creek Downstream of RC-2, Fall
Draft Final FS Report
February 2004

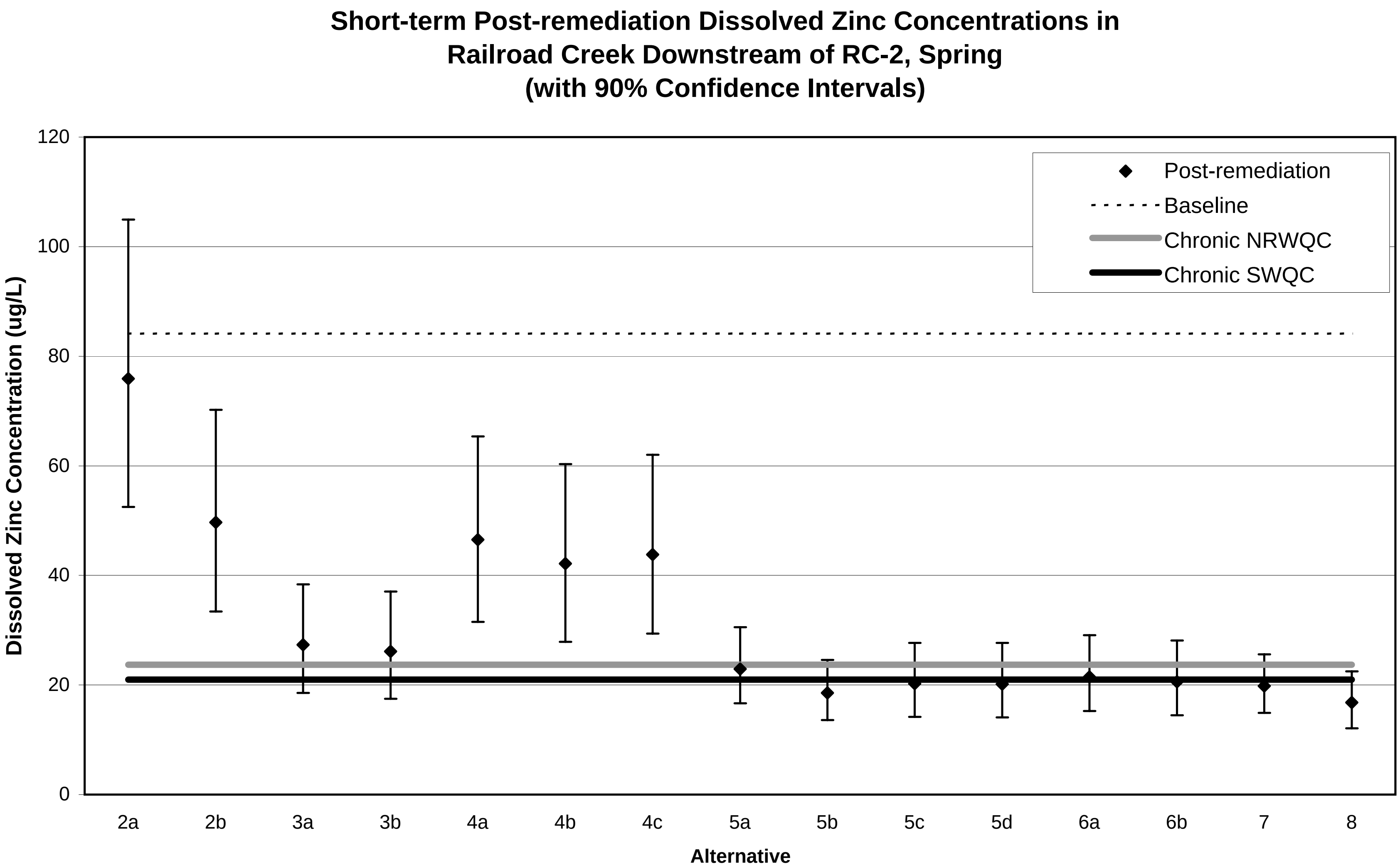

Figure 7-4

Short-term Post-remediation Dissolved Zinc Concentrations in Railroad Creek Downstream of RC-2, Spring

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February 2004

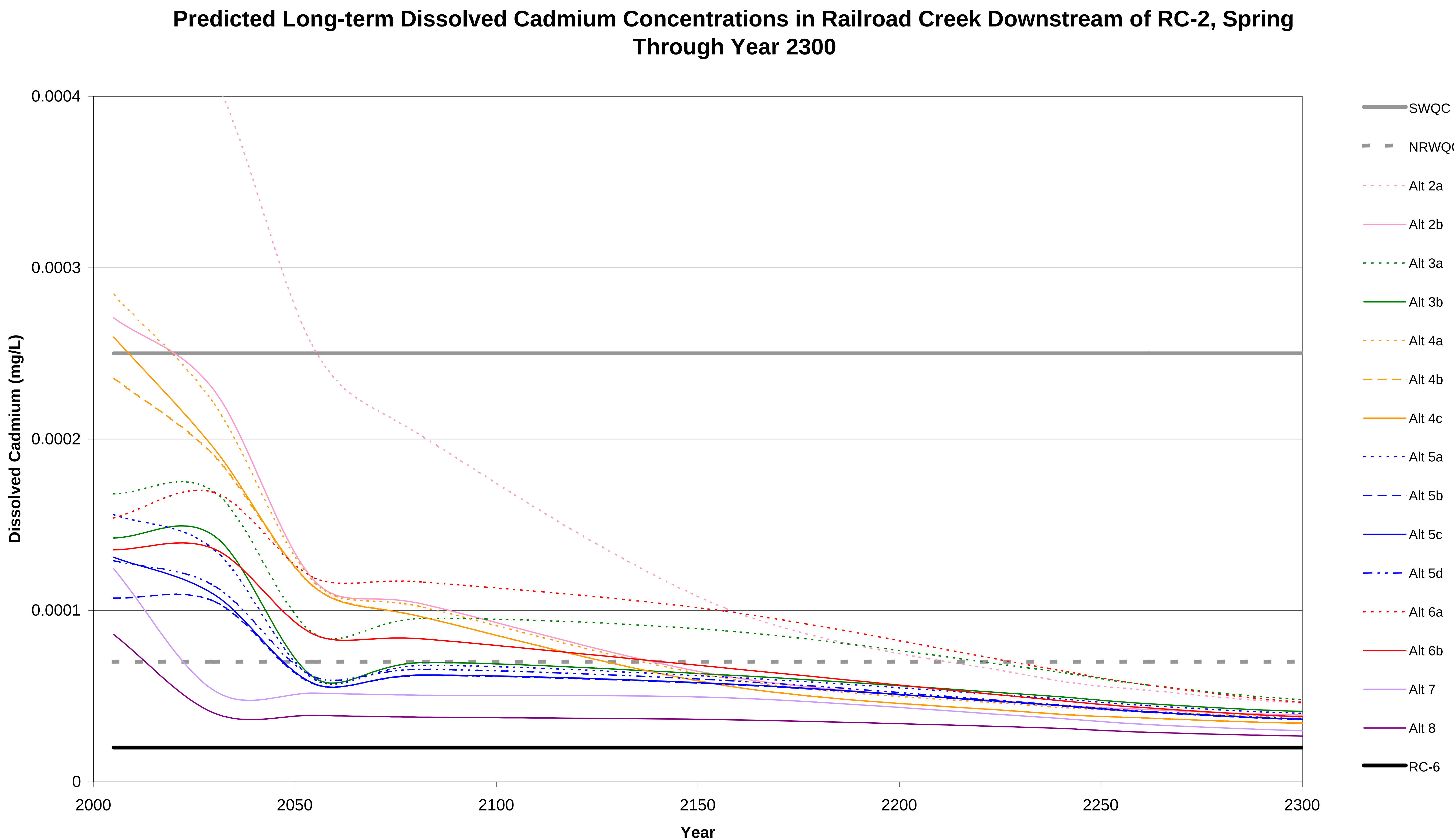

Figure 7-5
Long-term Dissolved Cadmium Concentrations in Railroad Creek (Spring) Through Year 2300
Draft Final FS Report February 2004

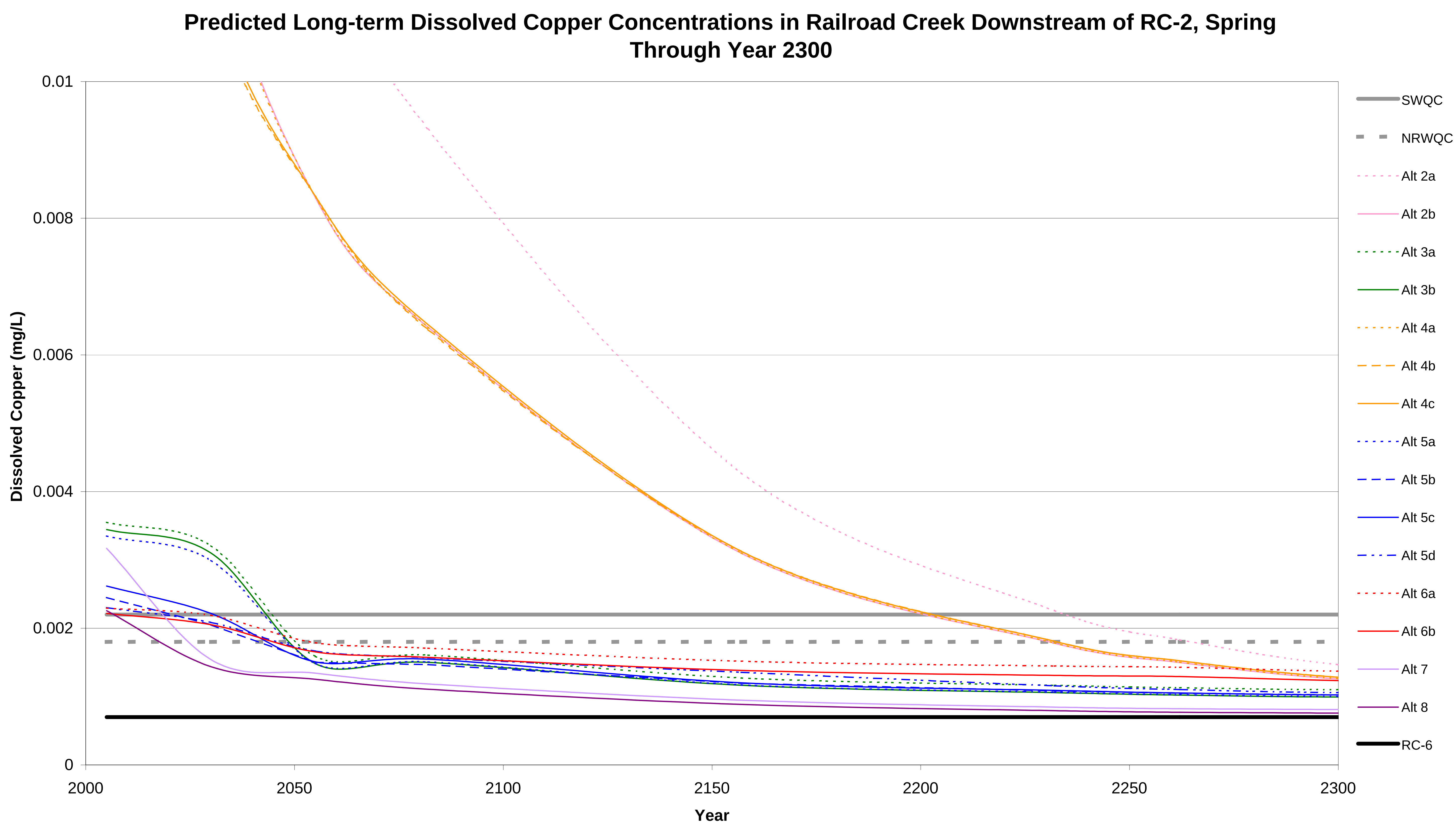

Figure 7-6

Long-term Dissolved Copper Concentrations in Railroad Creek (Spring) Through Year 2300

Draft Final FS Report February 2004

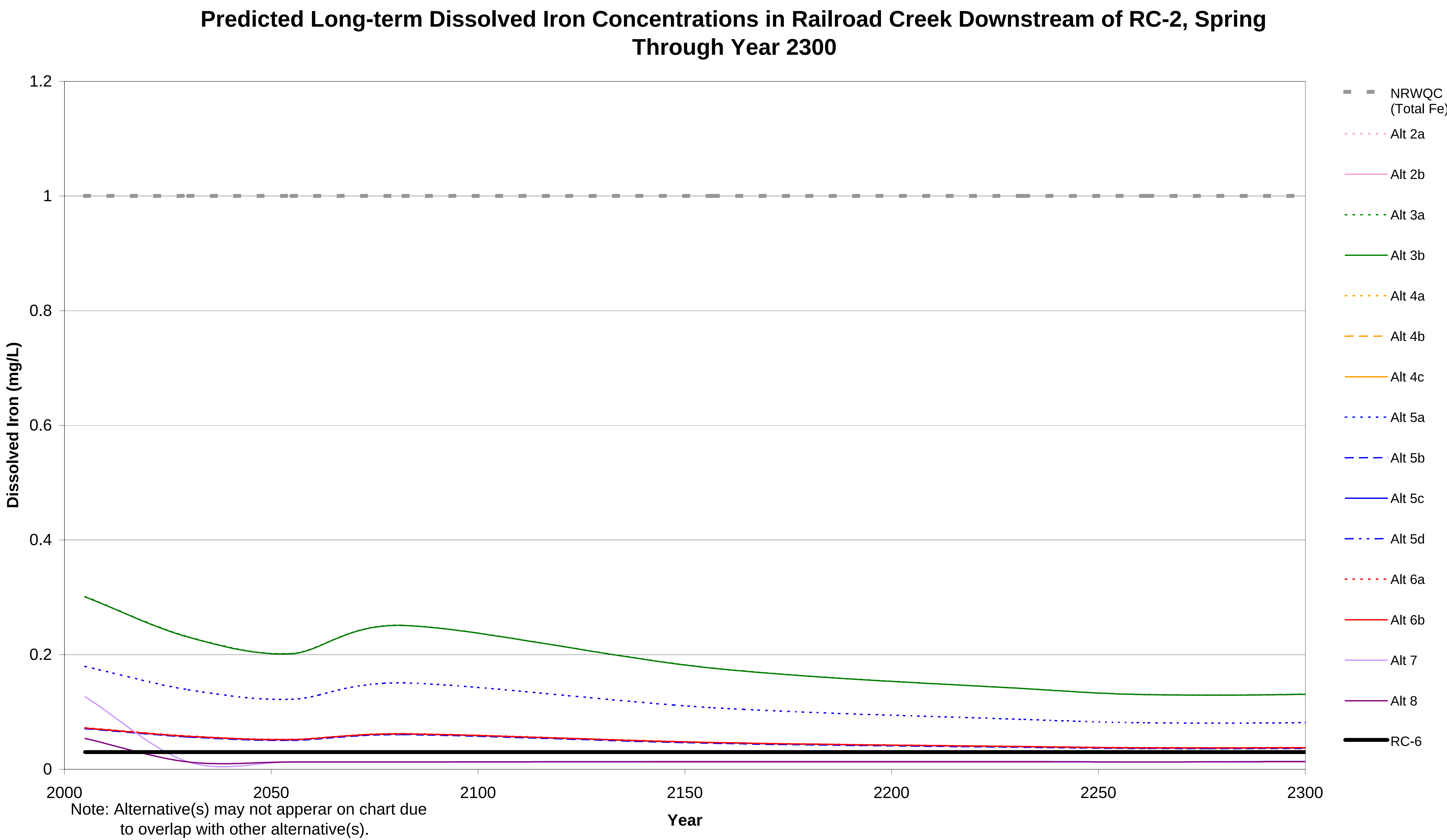

Figure 7-7

Long-term Dissolved Iron Concentrations in Railroad Creek (Spring) Through Year 2300

Draft Final FS Report February 2004

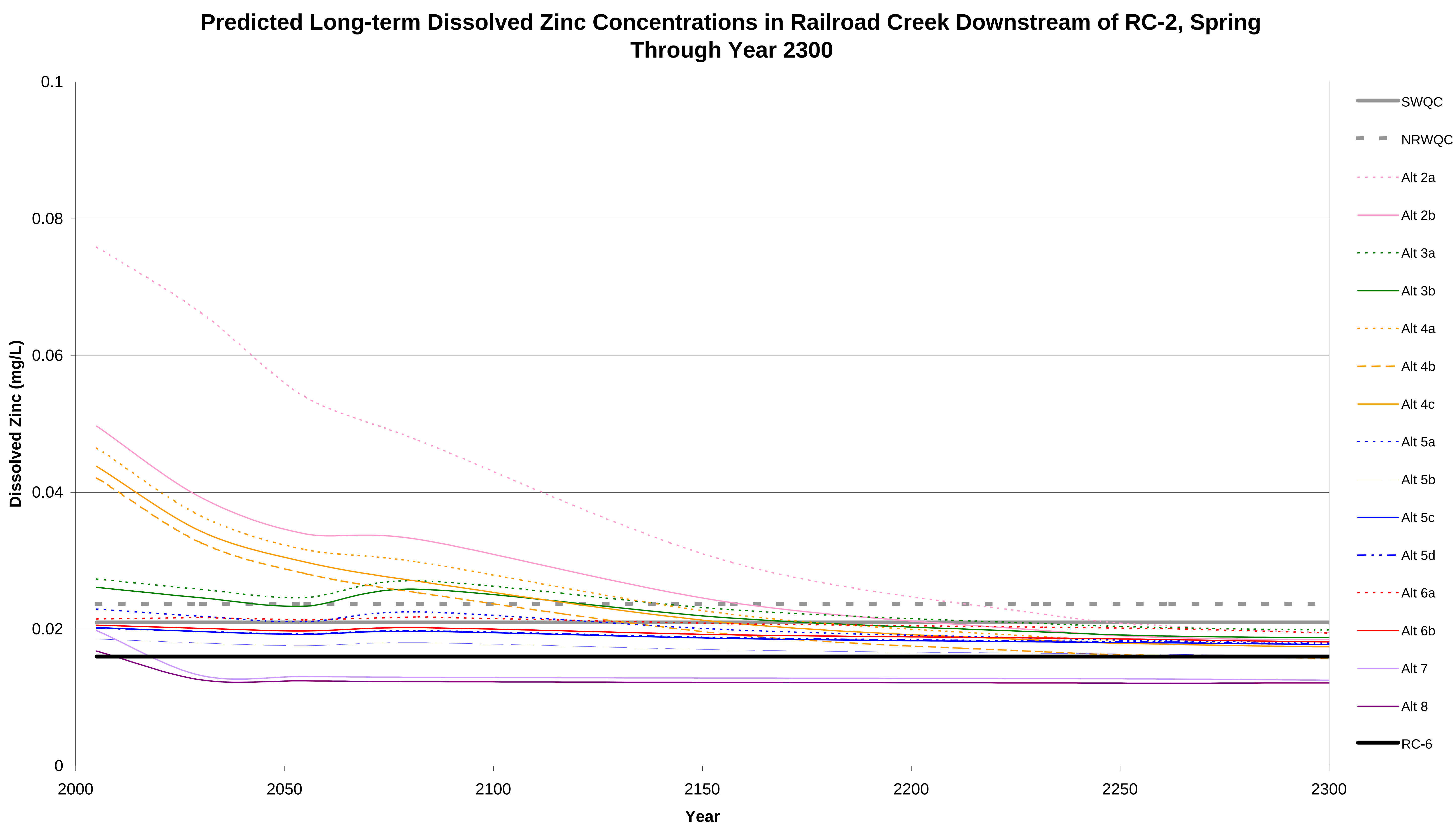

Figure 7-8
Long-term Dissolved Zinc Concentrations in Railroad Creek (Spring) Through Year 2300
Draft Final FS Report February 2004

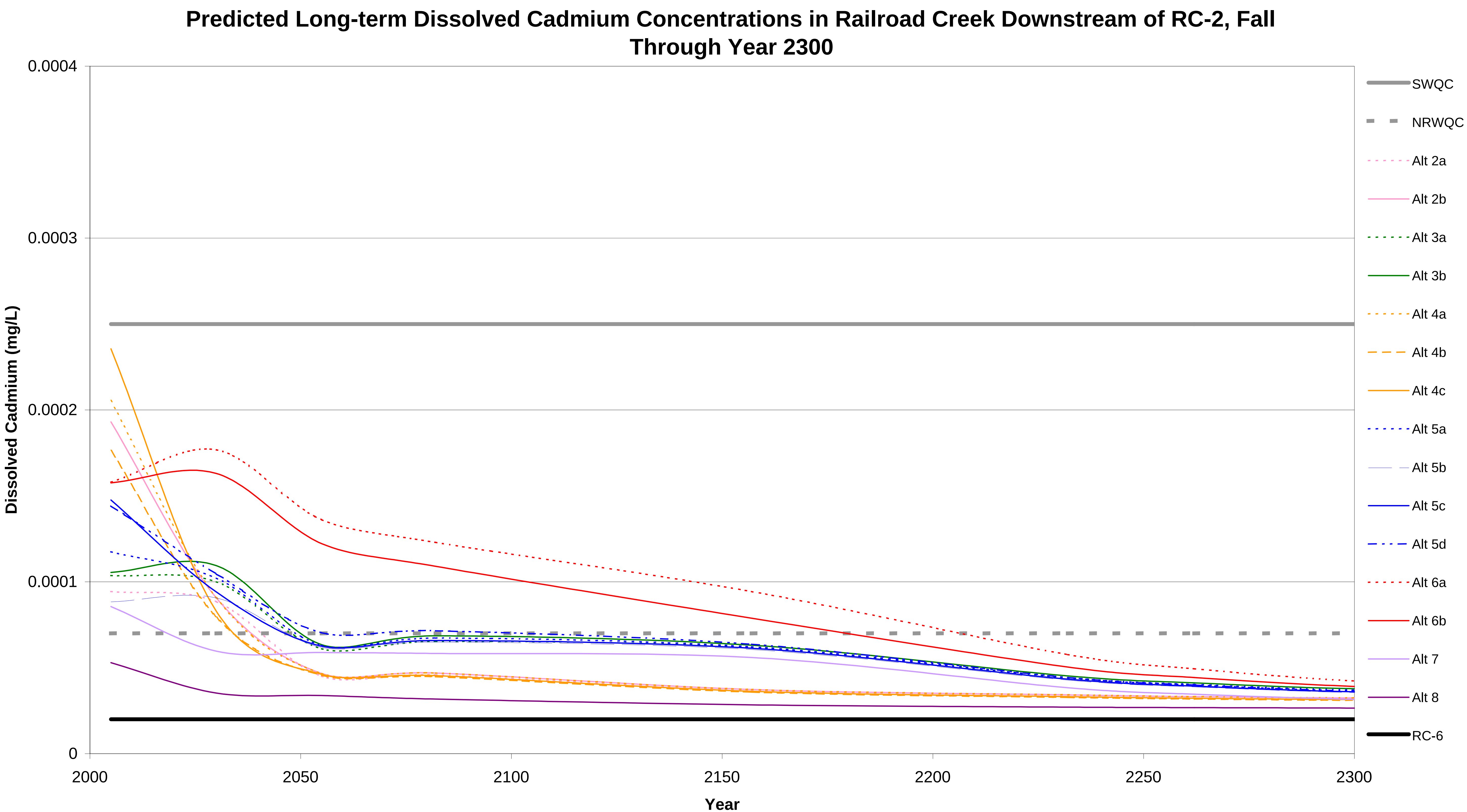

Figure 7-9
Long-term Dissolved Cadmium Concentrations in Railroad Creek (Fall) Through Year 2300
Draft Final FS Report February 2004

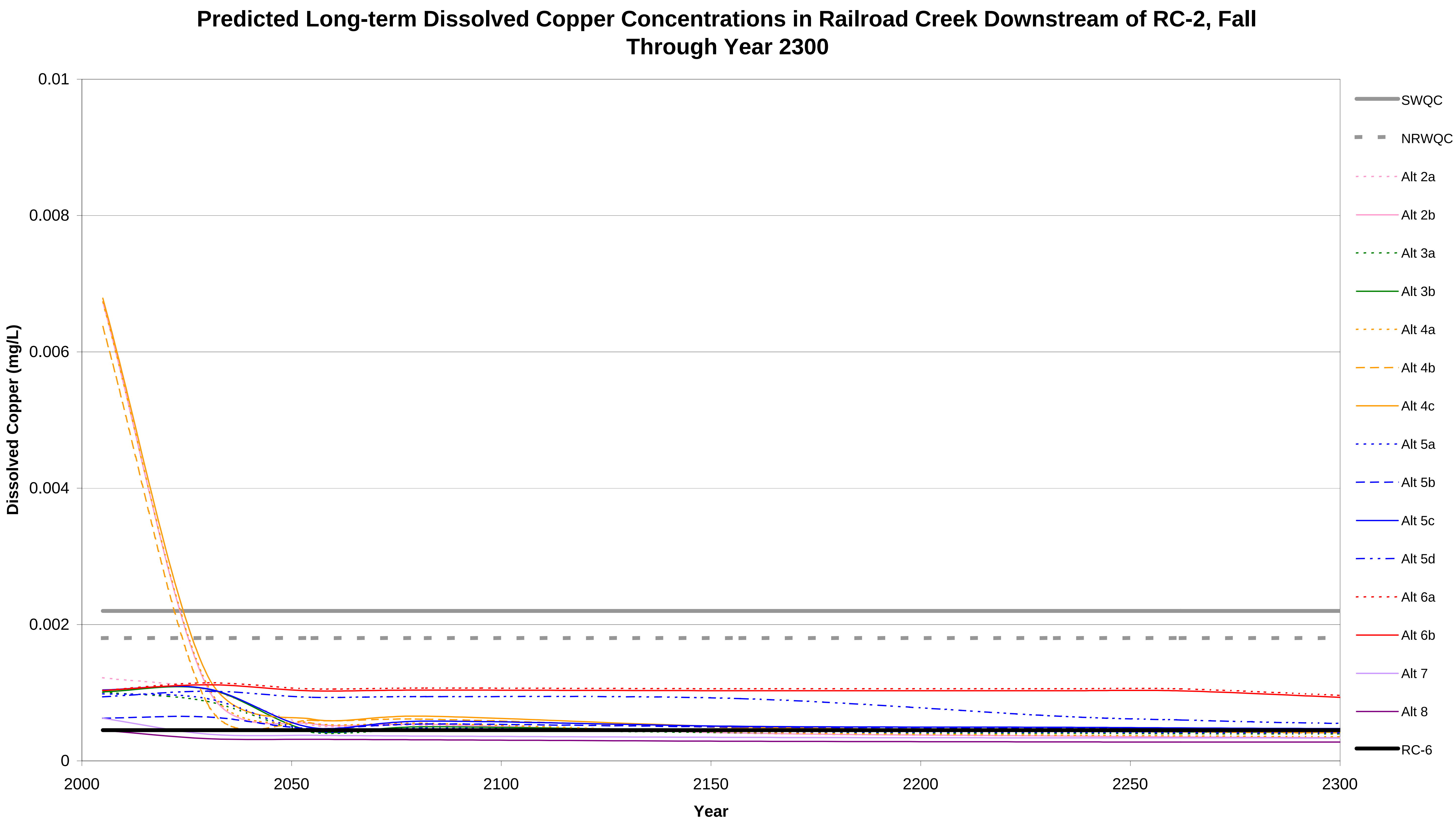

Figure 7-10

<u>Long-term Dissolved Copper Concentrations in Railroad Creek (Fall) Through Year 2300</u>

Draft Final FS Report February 2004

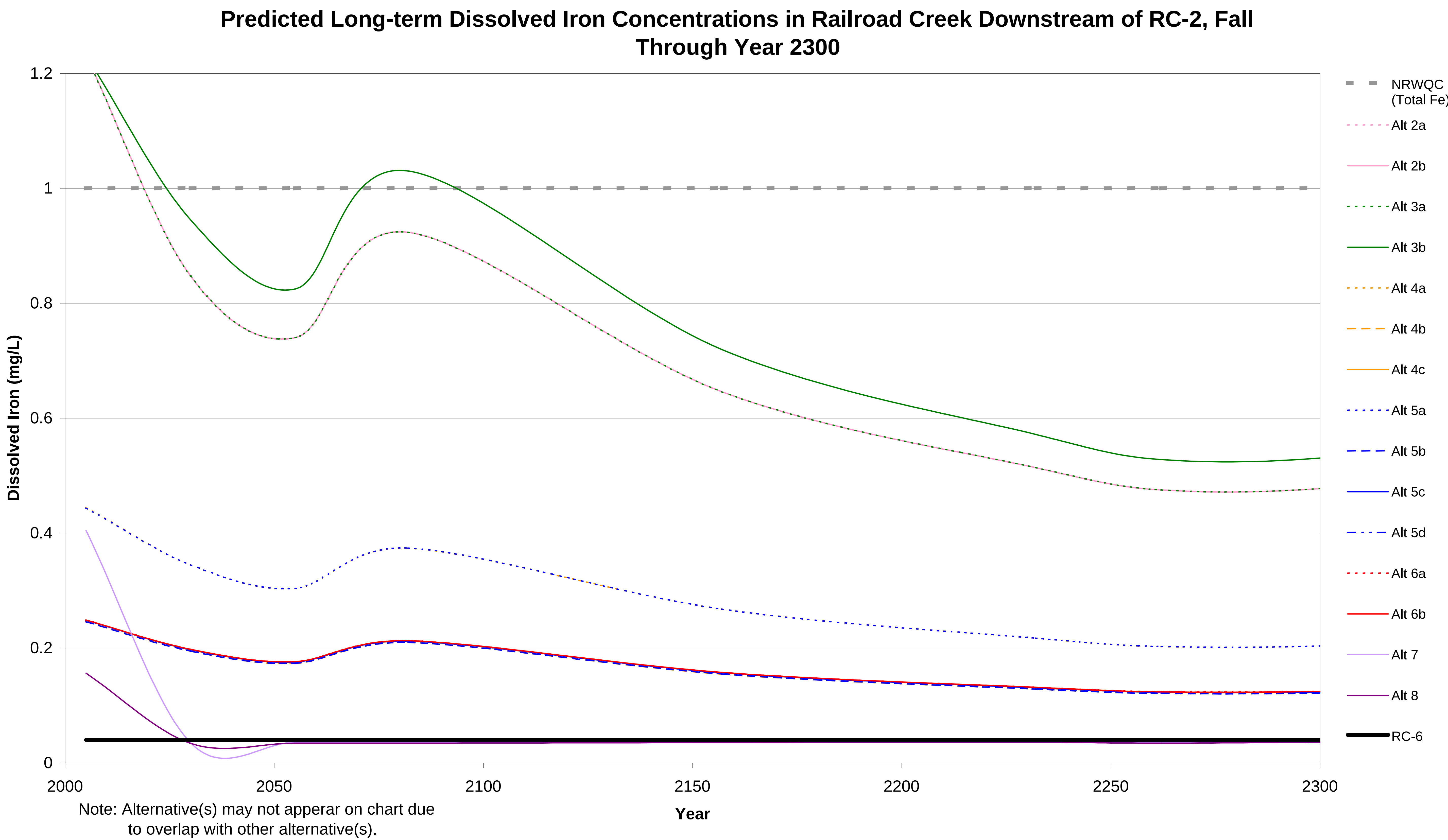

Figure 7-11
Long-term Dussilved Iron Concentrations in Railroad Creek (Fall) Through Year 2300
Draft Final FS Report February 2004

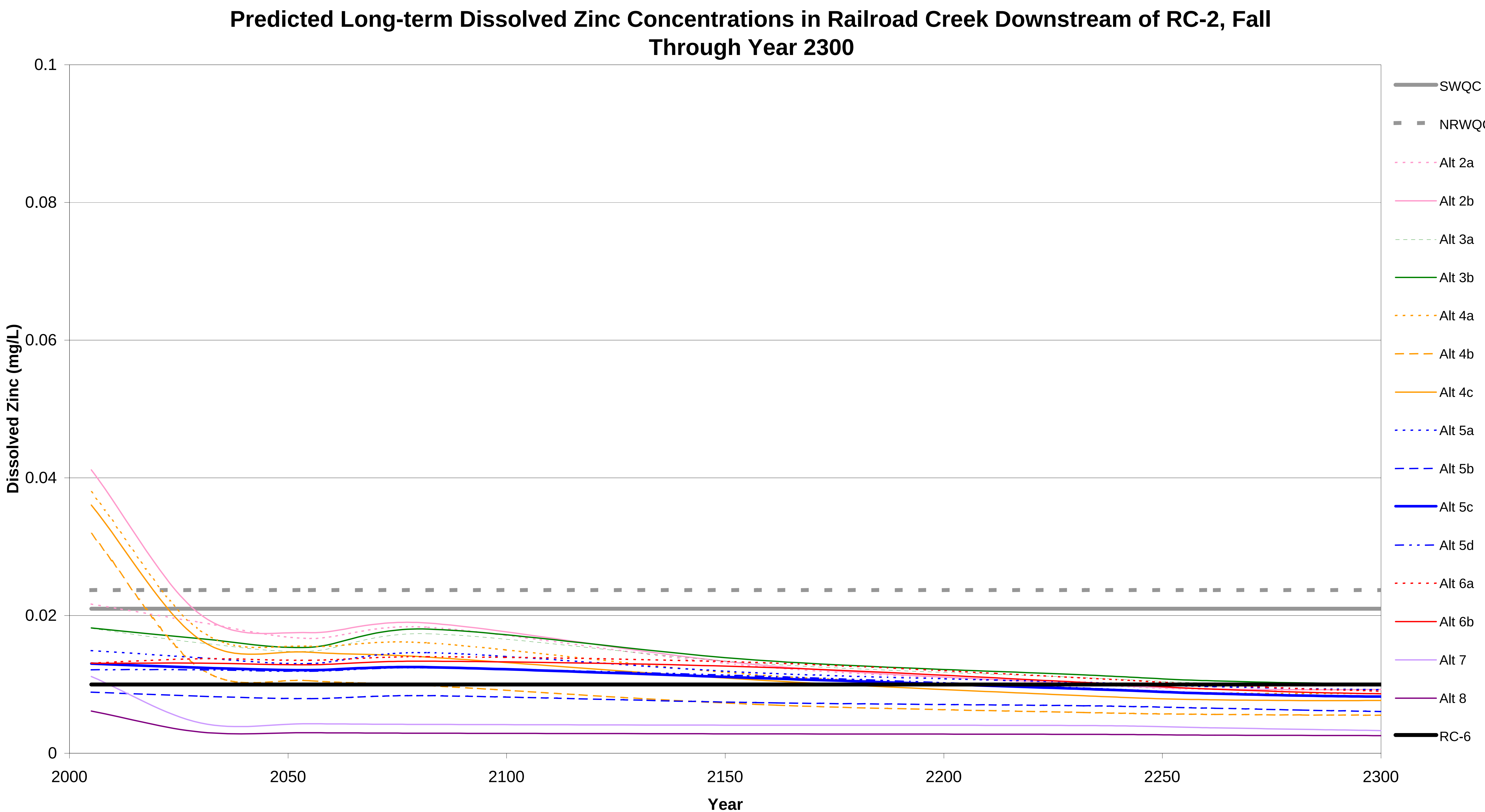

Figure 7-12
Long-term Dissolved Zinc Concentrations in Railroad Creek (Fall) Through Year 2300
Draft Final FS Report February 2004

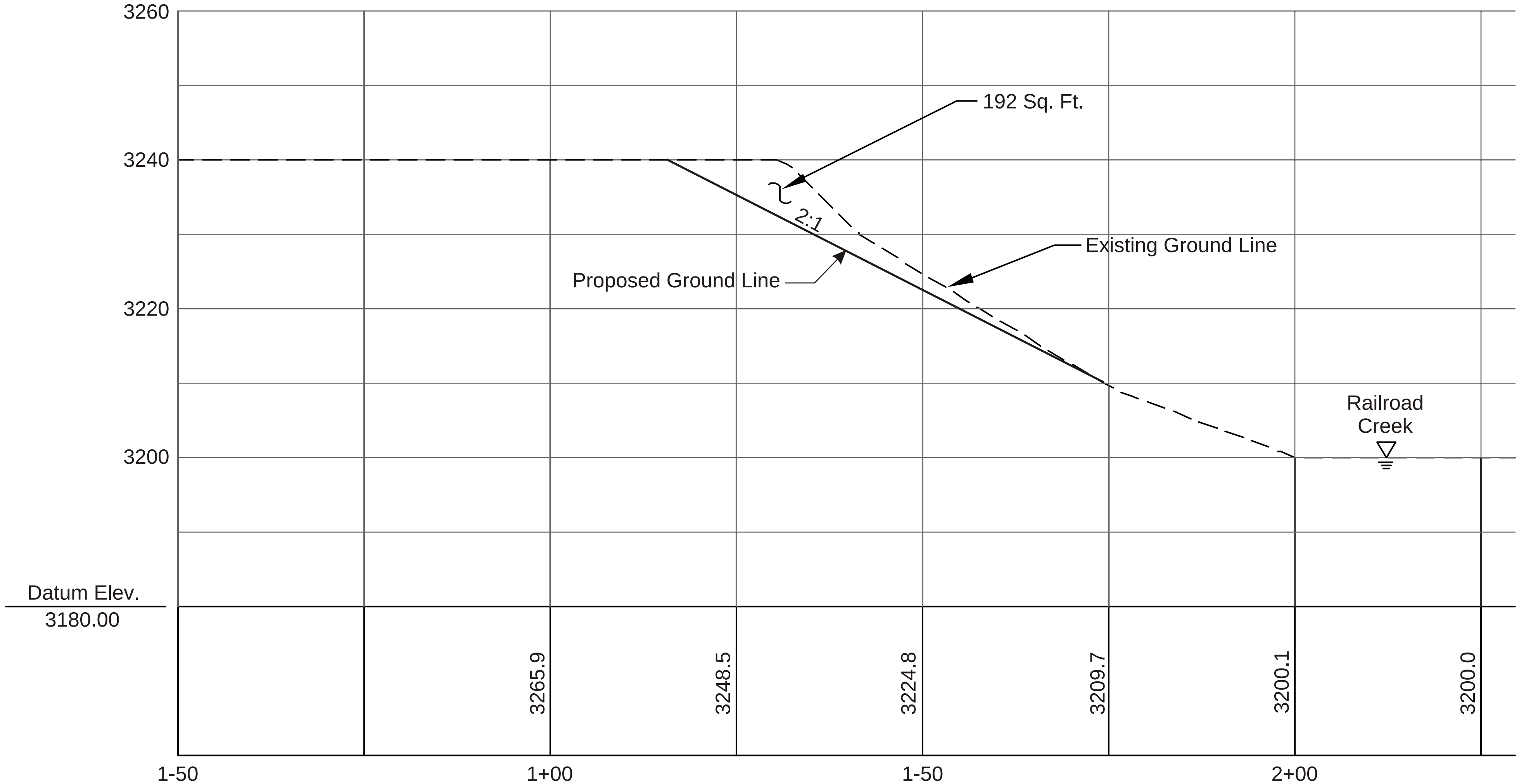

Figure 7-13
Typical Cross Section of Tailings Pile 1 with 2:1 Slopes

Job No. 33750803

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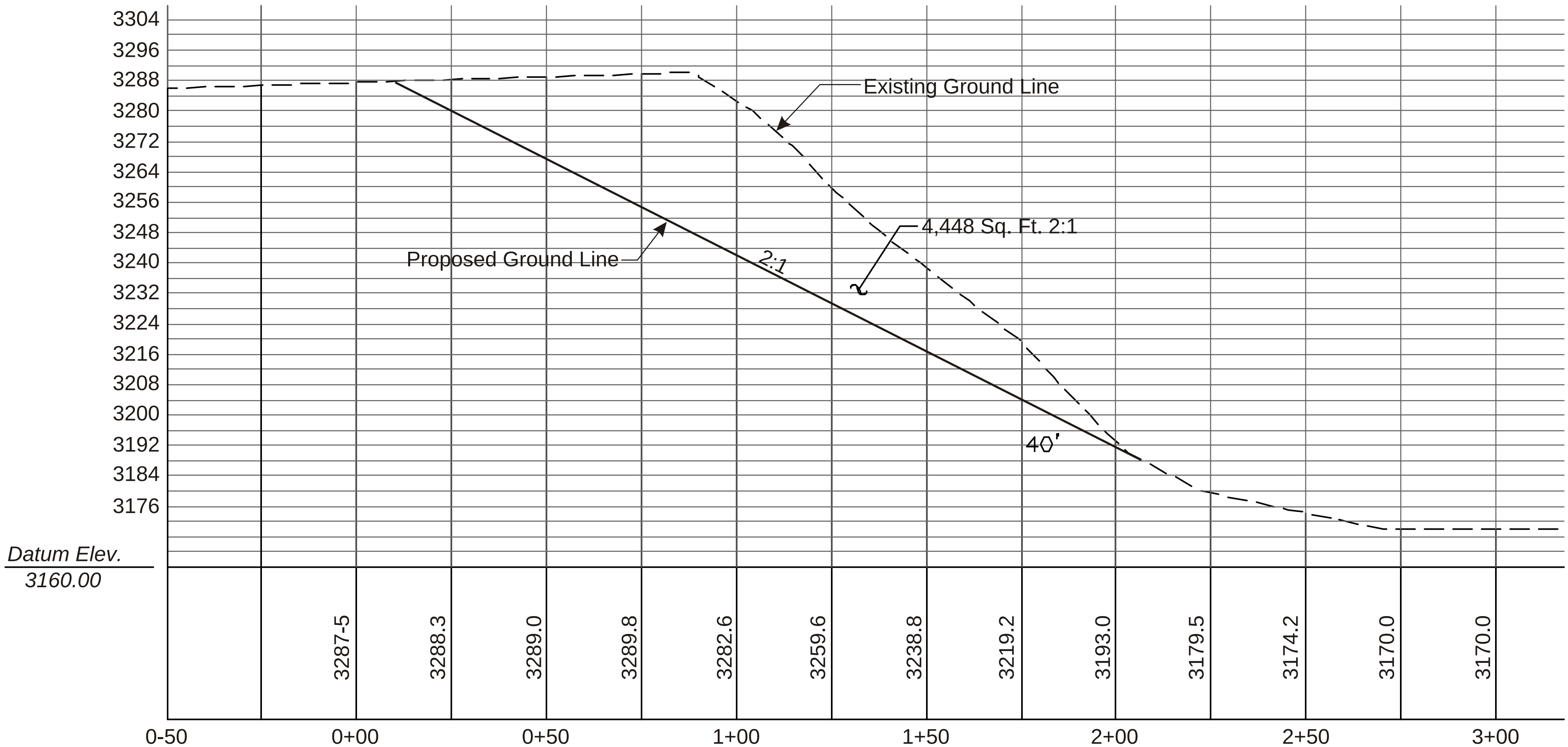

Figure 7-14
Typical Cross Section of Tailings Pile 2 with 2:1 Slopes

Job No. 33750803

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8.0 COMPARATIVE ANALYSIS OF ALTERNATIVES

This section provides a summary of the comparative analysis of candidate remedial alternatives. As described in Section 7.1, the detailed analysis provided in Section 7 includes an evaluation of the 16 candidate alternatives with respect to the two threshold and five primary balancing criteria required under CERCLA, natural resource restoration, and the requirements for evaluating cleanup actions under the Washington State MTCA. The evaluation of the requirements under MTCA was incorporated within the analyses completed for equivalent CERCLA criteria, with the exception of the requirements to use permanent solutions to the maximum extent practicable and to provide for a reasonable restoration time frame. These two MTCA criteria were evaluated separately for each alternative.

Results of the comparative analysis with respect to the following evaluation criteria are summarized in Table 8-1 and provided in this section:

Two threshold criteria:

- Overall protection of human health and the environment; and
- Compliance with applicable relevant and appropriate requirements.

Five primary balancing criteria:

- Long-term effectiveness and permanence;
- Reduction of toxicity, mobility, and volume through treatment;
- Short-term effectiveness;
- Implementability; and
- Cost.

Additional criteria under MTCA:

- Use of permanent solutions to the maximum extent practicable; and
- Reasonable restoration timeframe.

In addition, under the AOC, the following was evaluated:

- Natural resource restoration.

8.1 THRESHOLD CRITERIA

The following subsections provide the results of the comparative analysis for the two threshold criteria:

- Overall protection of human health and the environment; and
- Compliance with ARARS.

8.1.1 Overall Protection of Human Health and the Environment

The comparative analysis of overall protection of human health and the environment, including the protection of human health and terrestrial ecological receptors, the protection of aquatic life, and the potential for short-term impacts to workers, the local community, and environment during remedy implementation is summarized on Table 8-1 and in the following subsections.

8.1.1.1 Protection of Human Health and Terrestrial Ecological Receptors

Results of the human health risk assessment presented in the DRI indicate no existing unacceptable risks to Holden Village residents or visitors based on current reasonable maximum exposures to PCOCs within site surface water, groundwater, sediment, and air. Alternatives 1 through 8 would eliminate potential future risks to human health resulting from possible land use scenarios, such as the use of groundwater as a drinking water source, through the implementation of institutional controls. Physical access restrictions included under Alternatives 1 through 8 would also reduce potential physical hazards to residents and visitors associated with site features related to historical mining activities.

Alternative 2a through 8 would further protect human health and terrestrial ecological receptors though the removal, containment, and/or covering of site soils with PCOCs above potential ARARs. Under these alternatives, the soil RAO to achieve soil quality that is protective of human health and the environment would be achieved following remedy implementation.

8.1.1.2 Protection of Aquatic Life

Alternatives 2a through 8 would reduce PCOC loadings to surface water and groundwater in the short term through the implementation of a combination of source controls, upgradient water diversion, and collection and treatment of the portal drainage, seeps, and groundwater downgradient of site sources. Based on the site-specific geochemical evaluations provided in Appendix E, additional reductions in PCOC loadings from site sources, including the underground mine, waste rock, and tailings piles, are expected under all of the alternatives in the long term through natural attenuation.

The 1500-level main portal drainage and other discreet West Area sources contribute a majority of cadmium, copper, and zinc loading to Railroad Creek. Alternatives 3a, 3b, and 5a through 8, which include the collection and treatment of the portal drainage and upper West Area seeps and groundwater, would significantly reduce the release of these PCOCs to site groundwater and surface water. Based on the results of the post-remediation loading analysis (Appendix D) and toxicological evaluations provided in Appendix H, these alternatives are all expected to result in PCOC concentrations in Railroad Creek that are protective of resident aquatic species, including salmonids and their prey, following remedy implementation. While Alternatives 2a, 2b, 4a, 4b, and 4c, would also reduce copper, cadmium, and zinc loading to groundwater and surface water, predicted short-term seasonal PCOC concentrations in Railroad Creek may result in continued potential risks to aquatic life.

Groundwater and seeps from the East Area contribute a majority of the seasonal aluminum and iron loading to Railroad Creek. Although concentrations of total aluminum and iron measured in

Railroad Creek adjacent to the Site seasonally exceed the NRWQC[1], the toxicological evaluations provided in Appendix H indicate that existing concentrations are not expected to impact the aquatic community. However, based on the findings of the DRI, the precipitation of iron oxyhydroxides on creek substrate, and the formation of ferricrete in isolated locations on the stream bottom may adversely impact aquatic habitat adjacent to the Site. Alternatives 4a through 8, which include the collection and treatment of East Area seeps and groundwater, and/or consolidation and capping of the tailings piles, would provide the greatest reductions in iron loadings to site groundwater and surface water in the short term. However, Alternatives 2a through 8 are all expected to meet the NRWQC in the long term through natural attenuation.

The RAOs for groundwater and surface water are to meet potential ARARs within a reasonable restoration time frame. Compliance with ARARs is discussed in Section 8.1.2.

8.1.1.3 Potential for Short-term Impacts

Appropriate measures would be implemented under Alternatives 1 through 8 to protect workers, Holden Village residents, and visitors from potential risks due to increased traffic and heavy equipment operation during remedy implementation. A temporary stream crossing would likely be constructed over Railroad Creek at the northeast corner of tailings pile 3 to allow some of the vehicles and equipment to bypass the Village during construction activities. Access to the top of the tailings piles would also be gained from the new stream crossing under Alternatives 2a through 8. As a result, the RAO to implement the remedial action in a manner that is protective of human health, including the Holden Village community, would be met under Alternatives 2a through 8. However, under all of the alternatives, the increased heavy equipment and truck traffic on the road to the east of the Holden Village would result in short-term impacts to the local community, including the routine Holden Village bus and supply vehicle traffic, disruption to pedestrian use in the area, and increased noise levels.

Alternatives 1 through 3b would result in the lowest level of potential impacts to workers and the local community. Alternatives 4a through 5d would present increased safety concerns relative to Alternatives 1 through 3b due to the additional construction activities required for tailings regrading and the collection and treatment of East Area waters. Alternatives 4a through 5d also include partial or extended relocation of Railroad Creek, which would result in increased equipment operation on the north side of the current Railroad Creek channel, presenting increased safety risks and potential noise impacts to the Holden Village. The relocation of Railroad Creek to the north would also result in visual impacts due to tree removal. Potential safety concerns would be further increased under Alternatives 6a and 6b due to the implementation of mechanical treatment in the West Area. The additional construction, operation and maintenance, fuel delivery, and fuel storage requirements under Alternatives 6a and 6b would result in increased traffic and risk of fire or accidents at the Site, as well as

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[1] Intalco has provided legal justification and technical documentation showing that the NRWQC (1999 and 2002 publications) are not relevant and appropriate to the Holden Mine site. Intalco's justification has been provided in written correspondence with the Agencies between January and September 2003. This correspondence is part of the administrative record and is incorporated into this FS. Intalco's rationale is also summarized and presented in Section 3 and Appendix B.

increased barge traffic on Lake Chelan. Potential safety concerns and impacts to the local community would be the highest under Alternatives 7 and 8 due to the significantly increased construction effort, transportation of cover materials, extended duration of construction required for tailings pile capping and/or consolidation, and greater potential for the generation of fugitive dust and vehicle emissions.

Alternatives 2a, 3a, and 3b provide the lowest potential for short-term environmental impacts during remedy implementation, followed by Alternative 2b (hydrostatic bulkheads without treatment) and Alternatives 4a, 4c, 5a, 5c, and 5d. Alternatives 4b, 5b, 6a, 6b, 7, and 8 present a higher potential for short-term water quality degradation due to extended barrier wall construction along the south bank of Railroad Creek, large volumes of unoxidized tailings exposed during regrading and consolidation activities, and greater potential for material erosion and impacted runoff during construction.

8.1.2 Compliance with Potential ARARs

Compliance with potential chemical-specific, location-specific, and action-specific ARARs is evaluated in the following subsections.

8.1.2.1 Potential Chemical-specific ARARs

An evaluation of compliance with potential chemical-specific ARARs for site media, including surface water, groundwater, and soil is provided below.

Surface Water

Under all of the alternatives, potential chemical-specific ARARs for surface water are currently being met, and would continue to be met, in Copper Creek, Lake Chelan, and Railroad Creek upstream of the Site. Alternatives 2a through 8 would all result in short- and long-term improvements to surface water quality in Railroad Creek adjacent to and downstream of the Site. Under Alternative 1 (No Action) seasonal PCOC concentrations in Railroad Creek are expected to decline over time through natural attenuation. However, seasonal exceedances of potential ARARs are expected to continue under Alternative 1 in the long term.

For Alternatives 2a and 2b, which do not include East or West Area water treatment, the point of compliance for surface water would be at all points within the surface water body. For Alternatives 3a through 8, which include water treatment in the East and/or West Areas, a point of compliance would be established through a mixing zone where treated effluent(s) discharge to surface water. The conditional point of compliance would be monitored at the limits of the established mixing zone.

Results of the post-remediation loading analysis indicate Alternatives 5a, 5b, 5c, 5d, 6a, 6b, 7, and 8 would achieve the potential SWQC within approximately 50 years. Alternatives 3a and 3b are predicted to achieve the SWQC for dissolved cadmium and copper within 50 years, but seasonal concentrations of zinc are predicted to slightly exceed the SWQC. The analysis predicts the SWQC for zinc would be achieved under Alternatives 3a and 3b within approximately 250 years. Alternatives 2a, 2b, 4a, 4b, and 4c, which do not include West Area treatment, are predicted to achieve the SWQC for cadmium within approximately 50 years, and the SWQC for copper and/or zinc within approximately 250 years.

Alternatives 3b, 5a, 5b, 5c, 5d, 7, and 8 are predicted to achieve the NRWQC within approximately 50 years. Alternatives 6a and 6b are predicted to achieve the NRWQC for copper and zinc within approximately 50 years and the NRWQC for cadmium within approximately 250 and 150 years, respectively. Alternatives 2a, 2b, 3a, 4a, 4b, and 4c are predicted to achieve the NRWQC within approximately 250 years. Although the post-remediation loading analysis could not be performed for total aluminum or iron, the site-specific geochemical analyses provided in Appendix E indicate that aluminum concentrations would approach background (background concentrations seasonally exceed the chronic NRWQC) and iron concentrations would be below the potential NRWQC within approximately 50 years under all of the alternatives.

Although the results of the loading analysis indicate seasonal PCOC concentrations in Railroad Creek may exceed potential chemical-specific ARARs in the short term under all of the alternatives, the toxicological evaluations provided in Appendix H conclude that water quality under Alternatives 3a, 3b, and 5a through 8 would be protective of resident aquatic species in the short term following remedy implementation.

Groundwater

Under all of the alternatives, portions of the seeps and groundwater beneath the Site would not meet potential chemical-specific ARARs in the long term. Based on the analyses presented in Sections 5 through 7, there is no practical approach to achieve potential groundwater ARARs throughout the Site. Therefore, a conditional point of compliance would be required to establish cleanup standards for site groundwater. Under MTCA, the establishment of a conditional point of compliance would require that groundwater discharges be treated using AKART before being released into surface water. The extent to which each of the alternatives would meet the AKART requirement is based on the extent to which groundwater collection and treatment at the Site is practicable.

Conditional points of compliance for groundwater in surface water would be appropriate for both the East and West Areas for Alternatives 3a, 3b, and 5a, through 8. Based on the evaluations provided in Sections 5 through 7, upgradient water diversions and source controls in the East and West Areas, combined with upper West Area collection and low-energy treatment, constitute AKART for this site. Based on the results of the post-remediation loading analysis and the toxicological evaluations provided in Appendix H, these West Area actions (included under Alternatives 3a, 3b, 5a, 5b, 5c, 7, and 8) would result in the achievement of potential ARARs in the long term, and would provide equivalent protection to aquatic life in Railroad Creek as the additional West Area actions included Alternatives 5d, 6a, and 6b.

Based on the results of the post-remediation loading analysis, metals loading to East Area groundwater would be reduced over time through upgradient water diversion, tailings pile regrading, and natural attenuation, and groundwater discharges would not result in exceedances of potential ARARs in the long term or cause an impact to aquatic life. West Area sources contribute a majority of metals loading to Railroad Creek that result in potential risks to aquatic life. The variable subsurface conditions, depth to low-permeability glacial till or bedrock, limited access between the tailings piles and Railroad Creek, and relatively flat grade significantly reduce the technical implementability and increase the costs associated with East Area collection and treatment. As a result, the collection and treatment of East Area groundwater and seeps is not practicable or reasonable, and upgradient water diversion and source control actions in the East Area are considered to be AKART.

Because active collection and treatment is not included for the West Area under Alternatives 2a, 2b, 4a, 4b, and 4c, conditional points of compliance for West Area groundwater would not likely be available unless a determination is made that collection and treatment is not practical or reasonable under MTCA. Therefore, although site groundwater quality would improve over time through natural attenuation, West Area groundwater would not likely meet potential chemical-specific ARARs in the short or long term under these alternatives. A conditional point of compliance in surface water, where groundwater flows into surface water would be available in the East Area under these alternatives.

Based on the post-remediation loading analysis and the information provided above, Alternatives 5a, 5b, 5c, 5d, 7, and 8 are expected to achieve potential chemical-specific ARARs for groundwater at points within Railroad Creek (represented by stations RC-4 and RC-2) within approximately 50 years. These stations are considered to be generally representative of water quality in Railroad Creek downstream of West and East Area sources. However, it may take longer for some locations within the creek to achieve potential ARARs. Alternative 5d, which includes the installation of a secondary barrier wall and groundwater collection system in the lower West Area is also likely to achieve potential groundwater ARARs in the short term upstream of RC-4, with the exception of seep SP-26. Alternatives 6a and 6b, which include the installation of an extended secondary barrier wall and groundwater collection system in the lower West Area, would likely achieve potential groundwater ARARs in the short term upstream of RC-4. However, under Alternatives 6a and 6b, seasonal concentrations of cadmium are predicted to slightly exceed potential groundwater ARARs downstream of RC-4 for approximately 250 years and 150 years, respectively. Alternative 3b is expected to meet potential groundwater ARARs at points in Railroad Creek within approximately 50 years, with the exception of minor seasonal exceedances for zinc. Potential groundwater ARARs are expected to be met within approximately 250 years under both Alternatives 3a and 3b.

Because Alternatives 2a, 2b, 4a, 4b, and 4c do not include West Area collection and treatment, these alternatives would not likely meet potential chemical-specific ARARs for West Area groundwater in the short or long term. Alternatives 2a, 2b, 4a, 4b, and 4c would likely meet potential groundwater ARARs in the East Area within approximately 250 years through natural attenuation.

Soils

Potential chemical-specific ARARs for soils would not be achieved under Alternative 1. Under Alternatives 2a through 8, soils with concentrations above the potential MTCA Method B soil cleanup standards would be excavated and contained on site or covered in-place. These alternatives would meet the potential chemical-specific ARARs for soil.

8.1.3 Potential Location-Specific ARARs

No location specific ARARs would apply under Alternative 1. Alternatives 2a through 8 would meet all potentially applicable location-specific ARARs. The specific requirements of these ARARs would be identified through consultation with the federal and state agencies during the RD/RA. The remedial actions included under Alternatives 2a through 8 are not expected to influence archaeological and/or historic sites of significance. Construction-related activities, including excavation or earthmoving would consider the presence of historic or culturally important sites, structures or objects, historical and archeological data, and Native American burial sites, and if present, minimize impacts to such resources.

Construction activities would be conducted to minimize potential impacts to fish and wildlife, and coordination with WDFW and USFWS would be conducted during the remedial design to identify potentially applicable substantive requirements and incorporate mitigative measures into the design as necessary. Potential impacts to fish and wildlife, and consistency with the Forest Management Act would be addressed through consultation with USFWS and the Forest Service.

8.1.4 Potential Action-Specific ARARs

The institutional controls, physical access restrictions, and long-term monitoring included under Alternative 1 would meet potential action-specific ARARs.

The activities included under Alternatives 2a through 8 are also expected to be in compliance with potential action-specific ARARs through the implementation of institutional controls and monitoring as described in Section 6. Substantive compliance with CWA construction stormwater requirements, CWA section 401 water quality certification, and CWA section 404 would also be addressed under these alternatives. Substantive compliance with potential action-specific ARARs will be evaluated during the design through consultation with WDFW, USACOE, EPA, DNR, and Ecology. If remedial activities under Alternatives 2a through 8 are determined to have temporary impacts to water quality, substantive compliance with temporary water quality requirements would be achieved. Best management practices would be used to comply with potential substantive storm-water construction requirements and fugitive dust requirements.

Excavated soils and tailings materials removed from the maintenance yard, mill building and lagoon are not expected to be either characteristic hazardous or dangerous waste. However, RCRA and Washington State Dangerous Waste regulations would be potentially applicable if these materials are determined to be hazardous or dangerous waste. If such a determination were made, these materials would be managed within the area of contamination, stabilized to immobilize the constituents, consolidated within a corrective management unit located on one of the tailings piles, and contained with an appropriate engineered cover.

Under Alternatives 2a through 8a, the final tailings pile and waste rock pile configurations would meet relevant and appropriate requirements under the Washington State Requirements for Solid Waste Handling. Limited purpose landfill cover requirements would also be potentially relevant and appropriate for Alternatives 7 and 8.

Substantive compliance with NPDES discharge requirements for effluent(s) from the East and/or West Area treatment system(s) to Railroad Creek would also be evaluated under Alternatives 3a through 8, including establishment of a mixing zone with monitoring at the limits of the mixing zone. This will be the point of compliance for demonstrating compliance with potential surface-water ARARs.

8.2 PRIMARY BALANCING CRITERIA

The following subsections provide the results of the comparative analysis for the five balancing criteria:

- Long-term effectiveness and permanence;
- Reduction of toxicity, mobility, and volume;
- Short-term effectiveness;
- Implementability; and
- Cost.

8.2.1 Long-term Effectiveness and Permanence

The comparative evaluation of long-term effectiveness and permanence, including magnitude of residual risk and the adequacy of reliability of environmental controls is provided in the following subsections.

8.2.1.1 Magnitude of Residual Risk

The results of the Human Health Risk Assessment presented in the revised DRI indicate there are no human health risks at the Site under current exposure and land use scenarios. PCOC concentrations in groundwater would likely remain above State and Federal MCLs beneath the Site under all the candidate alternatives. However, there is no current or planned use of site groundwater for drinking water purposes, and Alternatives 1 through 8 would provide adequate protection of human health under potential future scenarios through the implementation of institutional controls. The installation of physical access restrictions would also reduce potential physical hazards to residents and visitors associated with historical mining activities. Therefore, the magnitude of remaining human health risks would be low under Alternatives 1 through 8.

Alternatives 2a through 8 include the removal and/or covering of site soils in areas where the site-specific ecological risk assessment identified a low potential for risk to terrestrial ecological receptors and/or PCOC concentrations above potential Agency-required ARARs for the protection of terrestrial ecological receptors. Therefore the magnitude of residual risks to terrestrial ecological receptors would be low under Alternatives 2a through 8. Areas identified as presenting a potential risk to terrestrial ecological receptors would not be addressed under Alternative 1. Therefore, based on the results of the site-specific risk assessment, a potential risk to terrestrial vegetation, biota, and wildlife would remain under Alternative 1.

Significant long-term improvements in Railroad Creek water quality are expected under Alternatives 3a, 3b, and 5b through 8, through the implementation of source controls, upgradient water diversions, West Area collection and treatment, and natural attenuation. Based on the results of the post-remediation loading analysis and toxicological analyses provided in Appendix H, post-remediation concentrations in Railroad Creek would be protective of resident aquatic species, including salmonids and their prey, following the implementation of these alternatives. Alternatives 3b and 5a through 8 are predicted to provide similar PCOC concentrations in Railroad Creek over the long term, with Alternatives 7 and 8 predicted to meet potential ARARs for all PCOCs within the shortest time frame (50 years). Because Alternative 3a does not include equalization of the portal drainage prior to treatment, the magnitude of seasonal exceedances for cadmium and copper are expected to be slightly higher in the long term than for Alternatives 3b, and 5a through 6b. Although Alternatives 4a, 4b, and 4c include the collection and treatment of East Area groundwater and seeps, these alternatives are expected to provide lower reductions in PCOC concentrations than Alternatives 3a, 3b, and 5a through 8, which include West Area collection and treatment. Alternatives 2a and 2b would provide the lowest reductions in PCOC concentrations in Railroad Creek.

The tailings pile slope stability actions included under Alternatives 2a through 8 would be expected to significantly reduce the potential for release of tailings to Railroad Creek in the event of a slope failure. The installation of hydrostatic bulkheads and other in-mine flow controls (or equalization basins outside of the mine) under Alternatives 2b, and 3b through 8 would also reduce the potential risk of sudden surge flows from the 1500-level main portal.

8.2.1.2 Adequacy and Reliability of Environmental Controls

The actions included under Alternative 3b, including institutional controls, physical access restrictions, source controls, upgradient water diversions, tailings pile regrading, West Area flow equalization, and the collection and low-energy treatment of the portal drainage and upper West Area seeps and groundwater are expected to significantly reduce PCOC releases to groundwater and surface water in the short and long term. These actions, including energy-efficient alkaline precipitation ("low-energy" treatment) consisting of controlled chemical addition, aeration, and settling ponds, would be expected to have a high degree of reliability in the long term. The low-energy treatment process would utilize equivalent unit processes as included for the mechanical treatment system under Alternatives 6a and 6b. Alternative 3a, which includes low-energy treatment in the West Area without flow equalization would also provide significant reductions in PCOC loadings to site groundwater and surface water, but is expected to be less reliable due to the rapid fluctuations observed in portal drainage and groundwater flows during the spring flush.

The collection and treatment of East Area groundwater and seeps under Alternatives 4a through 5d, and 8 is predicted to provide short-term reductions in PCOC loadings from the tailings piles (primarily aluminum, iron, and zinc), however these actions are expected to provide a lower degree of reliability in the long term. Collection and treatment systems installed at the base of the tailings piles under these alternatives would be difficult to effectively construct due to the depth to low-permeability glacial till or bedrock, variable subsurface conditions, relatively flat grade, and proximity to Railroad Creek. The long-term operation of collection and treatment systems in the East Area would also have a lower degree of reliability due to the difficulty in providing adequate flow equalization, high concentrations of iron in the East Area groundwater and seeps that would likely cause fouling of collection systems, significant chemical addition requirements, and sludge generation rates. The extended groundwater collection system under

Alternatives 4b and 5b would be particularly prone to fouling and plugging with metal precipitates compared to the open collection systems included under Alternatives 4a, 4c, 5a, 5c, 5d, 6a, and 6b. The long-term effectiveness of consolidation and capping of the tailings piles and/or waste rock piles under Alternatives 7 and 8 would be highly dependent on the ability to maintain the large cover system. Long-term maintenance would be required under these alternatives to ensure cover integrity and prevent the establishment of deep-rooted plants.

The West Area actions included under Alternatives 6a and 6b, including mechanical treatment and the extended secondary collection of lower West Area seeps and groundwater would be expected to significantly reduce PCOC loading to site surface water. However, the effectiveness of this system would rely on the ability to provide adequate power and operation and maintenance of treatment system equipment, including pumps, mixers, clarifiers, filters, and scrapers in the long term. As a result, these actions are expected to have lower long-term reliability, especially during the winter months when access to the Site from Lake Chelan is not possible. Additionally, a mechanical treatment system that utilizes tanks, pumps, and other mechanical equipment would have a more limited operating range, and would not be as flexible as a system utilizing large settling ponds in treating variable influent flows. Alternatively, oversized mechanical components would likely result in inefficiencies and operational difficulties when treating lower flows following the spring flush. As a result, a mechanical treatment system is not expected to be as robust as a low-energy system in handling variations in influent flow or water quality.

The actions included under Alternatives 2a and 2b, including institutional controls, physical access restrictions, source controls, and upgradient water diversions are expected to be adequate and reliable in protecting human health and terrestrial ecological receptors and reducing PCOC loadings to site groundwater and surface water. However, the collection and low-energy treatment of the portal drainage and West Area seeps and groundwater under Alternatives 3a, 3b, 5a, 5b, 5c, 5d, 7, and 8 is expected to provide greater short-term improvements in groundwater and surface-water quality with a high degree of reliability.

The institutional controls and physical access restrictions included under Alternative 1 would be adequate and reliable in mitigating potential risks to human health related to historical mining features. However, these actions are not expected to adequately protect terrestrial ecological receptors, or mitigate PCOC releases to site groundwater or surface water in the short term.

8.2.2 Reduction of Toxicity, Mobility, and Volume

The alkaline precipitation processes included for the East and West Areas under Alternatives 3a through 8 would reduce the mass and volume of PCOCs released to groundwater and surface water. The treatment processes would produce stable treatment residuals, and thus reduce the mobility and toxicity of PCOCs to environmental receptors. The volume of impacted materials requiring management would increase with the sludge generated from the water treatment processes.

The mass, and therefore volume, of PCOCs released to groundwater and surface water would also be reduced from site sources over time through the natural geochemical processes described in Appendix E.

Stabilization processes included under Alternatives 2a through 8 for limited quantities of solid media determined to be characteristic hazardous wastes would produce a stable product and reduce constituent mobility to environmental receptors.

8.2.3 Short-term Effectiveness

The comparative evaluation of short-term effectiveness, including protection of local communities, worker protection, environmental impacts, and time required to reach remediation goals is provided in the following subsections.

8.2.3.1 Protection of Local Communities

The human health risk assessment found no existing unacceptable risk to Holden Village residents or visitors based on current reasonable maximum exposures to soil, surface water, groundwater, sediments, and air at the Site. Alternative 1, which does not include significant construction or operation and maintenance activities, would present the lowest short-term risks to the local community.

Appropriate measures would be implemented under Alternatives 2a through 8 to protect Holden Village residents and visitors from potential risks due to increased traffic and heavy equipment operation during remedy construction and implementation. A temporary stream crossing would be constructed over Railroad Creek at the northeast corner of tailings pile 3, to allow some of the vehicles and equipment to bypass the Village during construction. Access to the top of the tailings piles would also be gained from the new stream crossing under Alternatives 2a through 8. However, the increased heavy equipment and truck traffic on the road to the east of the Village would result in short-term impacts to the local community, including the routine Village bus and supply vehicle traffic, disruption to pedestrian use in the area, and increased noise levels.

Alternatives 1 through 3b would present fewer short-term safety concerns and noise impacts to Holden Village residents and visitors than Alternatives 4a through 8, due to the overall reduced traffic and equipment operations and reduced construction activities anticipated on the north side of Railroad Creek. Alternatives 4a through 5d would present increased risks and noise impacts to the Holden Village community due to the additional traffic and heavy equipment operation required for tailings regrading and the partial or extended relocation of Railroad Creek to the north. Railroad Creek relocation would require increased construction on the north side of Railroad Creek near several of the Holden Village facilities, and removal of trees that currently provide a visual screen of the tailings piles.

Additional long-term risks to the Holden Village community would result from the implementation of mechanical treatment in the West Area under Alternatives 6a and 6b. The significant long-term equipment operation and maintenance, power generation, fuel delivery, and fuel storage requirements under these alternatives would result in increased traffic and potential for accidents or fire at the Site, and increased barge traffic on Lake Chelan. Based on the analyses provided in Section 7, approximately 95,000 to 125,000 gallons of fuel would be required per year to operate the mechanical plant. Due to winter access limitations, approximately 50,000 gallons of diesel fuel would need to be stored at the Site during the winter months.

Alternatives 7 and 8, which include the consolidation and capping of the tailings piles, would present the greatest short-term risks to the Holden Village community, due to the significantly increased traffic and heavy equipment operation required for tailing consolidation and capping, and the increased potential for fugitive dust and other air emissions (e.g., carbon dioxide, hydrocarbons, and nitrogen oxides). For example, approximately 3.9 million cubic yards of tailings materials would be moved under Alternatives 7 and 8, and 120,000 cubic yards of cover soil would be required for cap installation on the consolidated pile. Based on calculations described in Section 7, it would take a fleet of 10 haul trucks (15 cubic yard capacity) more than two months, operating 12 hours per day, to transport the cover material from a local borrow source area or from Lucerne. Similarly, it would take a fleet of 10 large capacity scrapers (greater than 40 cubic yard capacity) approximately 97,000 round trips, and approximately three construction seasons to consolidate the tailings. The total fuel consumption estimated for these two activities is approximately 700,000 gallons. This fuel would need to be transported by barge from Chelan to a fuel containment facility located within the valley. Assuming a 2,000-gallon fuel truck would be used to haul fuel from Lucerne to the Site, a fuel consumption of approximately 700,000 gallons would translate to approximately 350 fuel deliveries (i.e., more than one delivery every two days). This increased level of effort would significantly increase the potential for accidental releases to the environment and injuries to site workers, Holden Village residents, and visitors. Additionally, a preliminary assessment of potential air emissions indicates that more than 360 combined tons of particulate mater (PM_{10}) carbon dioxide, hydrocarbons, and nitrogen oxides would like be released during implementation of Alternatives 7 and 8.

Alternatives 2a though 8 would also present potential physical hazards related to the development of the talus slope west of Tenmile Creek, which would be used as a source of rip rap. However, engineering controls such as the construction of gabion walls would be expected to adequately reduce this risk.

8.2.3.2 Worker Protection

Alternative 1, which does not include significant construction or operation and maintenance activities, would present the lowest potential short-term risks to workers, followed by Alternatives 2a and 3a. There would be an increased potential risk under Alternatives 2b and 3b due to the installation of hydrostatic bulkheads and in-mine water controls underground within the 1500 level of the mine. Adherence to MSHA standard safety protocols would be maintained to reduce this potential risk.

In general, the risk of worker injury increases with the overall level of construction, operation, and maintenance activities required by an alternative. Above-ground construction activities are estimated to present similar levels of risk to workers. Therefore, increased risk is proportional to the increased level of effort required for alternative implementation, as described in Section 8.2.3.1 above. For example, the application of accident rates recorded by the Washington State Department of Labor and Industry for heavy construction activities in 2001 to the estimated crew size required to implement Alternatives 7 and 8 (approximately 100 people per season) indicates approximately 8 to 9 injuries and the potential for a fatality (estimated fatality rate of approximately 0.5 deaths) could be expected over the 3-year implementation period.

8.2.3.3 Environmental Impacts

Alternatives 2a, 3a, and 3b provide the lowest potential for short-term environmental impacts during remedy implementation, followed by Alternative 2b (hydrostatic bulkheads without treatment) and Alternatives 4a, 4c, 5a, 5c, and 5d. Alternatives 4b, 5b, 6a, 6b, 7, and 8 present a higher potential for short-term water quality degradation due to extended barrier wall construction along the south bank of Railroad Creek, large volumes of unoxidized tailings exposed during regrading and consolidation activities, and greater potential for material erosion and impacted runoff during construction.

The increased fuel requirements for construction and/or long-term operations under Alternatives 4b, 5b, 6a, 6b, 7, and 8 would significantly increase the potential for accidental fuel releases to the environment during transport up Lake Chelan and the Railroad Creek valley.

8.2.3.4 Time Required to Reach Remediation Goals

Implementation of Alternatives 2a through 8 would be expected to occur over a one- to three-year period at which time soil RAOs would be met. Alternatives 7 and 8 would take the longest to implement due to the large material handling and low-permeability capping requirements. Alternatives 2a, 2b, 3a, 3b, 4a, and 5a would take the least amount of time to implement.

Surface Water

Under all of the alternatives, surface-water RAOs are currently being met, and would continue to be met, in Copper Creek, Lake Chelan and Railroad Creek upstream of the Site. Alternatives 5a, 5b, 5c, 5d, 7, and 8 are predicted to fully achieve the surface-water RAOs within approximately 50 years. Alternative 3b is also predicted to achieve surface-water RAOs within approximately 50 years, with the exception of seasonal concentrations of zinc that are predicted to slightly exceed the chronic SWQC. Through a combination of source controls, water treatment, and natural attenuation, Alternative 3b is expected to achieve the SWQC for zinc within approximately 250 years. Similarly, Alternatives 6a and 6b are predicted to meet surface-water RAOs within approximately 50 years, with the exception of cadmium concentrations, which are predicted to slightly exceed the Agency-required NRWQC. Through natural attenuation, the NRWQC for cadmium is predicted to be met under Alternatives 6a and 6b within approximately 250 and 150 years, respectively.

Alternative 3a, which includes West Area treatment without flow equalization, is predicted to significantly reduce PCOC concentrations in Railroad Creek, but is not predicted to achieve surface-water RAOs for approximately 250 years. Alternatives 2a, 2b, 4a, 4b, and 4c, which do not include West Area treatment, are also predicted to achieve surface-water RAOs within approximately 250 years. Under Alternative 1 (No Action) seasonal PCOC concentrations in Railroad Creek are expected to decline over time through natural attenuation. However, potential surface water RAOs are not expected to be met under this alternatives in the long term.

Groundwater

Alternatives 5a, 5b, 5c, 5d, 7, and 8 are expected to achieve groundwater RAOs within approximately 50 years. Alternative 5d, which includes the installation of a secondary barrier wall and groundwater collection system in the lower West Area is also likely to achieve groundwater RAOs in the short-term upstream of RC-4, with the exception of seep SP-26. Similarly, Alternatives 6a and 6b, which include the installation of an extended secondary barrier wall and groundwater collection system in the lower West Area, would also likely achieve groundwater RAOs in the short-term upstream of RC-4. However, under Alternatives 6a and 6b, groundwater RAOs would not be fully achieved for approximately 250 150 years, respectively. Alternatives 3a and 3b are expected to achieve groundwater RAOs within approximately 50 years, with the exception of minor seasonal exceedances for zinc. Potential groundwater RAOs are expected to be fully met under Alternatives 3a and 3b within approximately 250 years.

As discussed in Section 8.1.2.1, because active collection and treatment is not included for the West Area under Alternatives 2a, 2b, 4a, 4b, and 4c, conditional points of compliance for West Area groundwater would not likely be available unless a determination is made that collection and treatment is not practical or reasonable under MTCA. Therefore, although site groundwater quality would improve over time through natural attenuation, West Area groundwater would not likely meet RAOs in the short or long term under these alternatives. Alternatives 2a, 2b, 4a, 4b, and 4c are expected to meet potential groundwater ARARs in the East Area within approximately 250 years through natural attenuation. Alternative 1 is also not expected to meet Groundwater RAOs in the short or long term.

8.2.4 Implementability

The comparative evaluation of implementability, including technical and administrative feasibility and the availability of services and materials is provided in the following subsections.

8.2.4.1 Technical and Administrative Feasibility

Alternatives 1, 2a and 2b would have the highest degree of technical implementability, followed by Alternatives 3a and 3b. While Alternatives 3a and 3b involve long-term treatment of the portal drainage and downgradient West Area water, the collection and low-energy treatment systems proposed under this alternative have been successfully implemented at other sites, and are based on conventional construction techniques and treatment technologies. Alternative 3b would be more implementable than Alternative 3a due to the control and equalization of the portal drainage and upper West Area seeps and groundwater.

Alternatives including treatment of downgradient East Area water (Alternatives 4a through 6b and 8) would be generally less implementable than Alternatives 2a through 3b due to the increased complexity of installing systems to collect and treat East Area ground water and the long-term chemical addition and sludge disposal requirements. Of these alternatives, the East Area collection and treatment systems proposed under Alternatives 4c, 5c, 5d, 6a, and 6b would be generally more implementable due to reduced slope regrading requirements and the use of open collection trenches with limited barrier wall construction. Alternatives 4c, 5c, 6d, 6a, and 6b would require extended relocation of Railroad Creek to the north. While Railroad Creek relocation would require additional design and construction requirements, this would allow the collection and treatment systems to be constructed within the existing creek channel, thereby increasing the feasibility of extended collection system installation. Construction and operation of the East Area collection systems proposed under Alternatives 4a, 4b, 5a, 5b, and 8 would be less implementable due to uncertainties regarding effective deep barrier wall and collection system installation within the variable alluvial material, and maintenance requirements to prevent collection system plugging due to the oxidation and precipitation of aluminum and iron constituents. The extended groundwater collection system under Alternatives 4b and 5b would be particularly prone to fouling and plugging with metal precipitates compared to the open collection systems included under Alternatives 4a, 4c, 5a, 5c, 5d, 6a, and 6b.

The mechanical treatment system and extended secondary barrier wall/collection system included under Alternatives 6a and 6b would have generally lower technical implementability than the West Area actions included under Alternatives 3a through 5d, 7, and 8. The extended lower barrier wall/collection system would be difficult to effectively implement due to construction on steep side slopes, variable topography, and variable subsurface conditions. The long-term operation of a mechanical treatment system in the West Area would also be difficult due to the significant operation and maintenance requirements, and reliance on diesel-powered electricity generation and fuel storage.

Although the actions included under Alternatives 7 and 8 would use conventional equipment and construction techniques, these alternatives would have lower technical implementability relative to the other alternatives due to the magnitude and duration of construction activities required for remedy implementation. A large fleet of heavy equipment operating over at least three construction seasons would be required to complete tailings pile consolidation and capping.

Because Alternative 1 does not include any active remedial measures, this alternative would have the lowest administrative implementability. In general, for Alternatives 2a through 8, the administrative implementability of an alternative is reduced with increasing complexity and construction duration. For example, Alternatives 4c and 5c through 6b would require significantly increased coordination with local Agencies and the Holden Village for relocation of Railroad Creek. Alternatives 7 and 8 would have a reduced administrative implementability relative to the other alternatives due to the increased traffic, borrow source development, and construction duration for consolidation and capping of the tailings piles.

8.2.4.2 Availability of Services and Materials

Specialized equipment and personnel required for the underground mine actions proposed under Alternatives 2a through 8 are expected to be readily available in the area. Alternatives 3a through 8 would require on site personnel for long-term collection and treatment system O&M. Treatment system chemicals and fuel required for implementation of Alternatives 3a through 8 would need to be continuously imported to the Site by barge and truck.

Suitable rip rap and rock required for implementation of Alternative 2a through 8 would be available within approximately 2 miles of the Site near Tenmile Creek. Gravel would likely be obtained from the Dan’s Camp quarry located near Lucerne, as needed.

Due to the site setting within a narrow glacial valley, limited sources of soil suitable for development exist within the Railroad Creek watershed. As a result, soil requirements to provide adequate protection of a low-permeability cover system would reduce the implementability of Alternatives 7 and 8. To provide sufficient cover protection, a large local source of material would need to be developed, or material would need to be imported to the Site by barge and truck.

8.2.5 Cost

Total capital and O&M costs are summarized on Table 8-1. Total costs are provided in 2004 dollars at a 7-percent discount rate). Alternative 1 (No Action/ Institutional Controls) has the lowest estimated total project cost at $2,730,000, followed by Alternatives 2a and 2b. The estimated total costs for Alternatives 2a and 2b are approximately $17,260,000 and $18,760,000, respectively.

The total project costs associated with Alternatives 3a and 3b, which include collection and low-energy treatment of the portal drainage and upper West Area seeps and groundwater, are estimated to be approximately $27,090,000 and $28,160,000, respectively.

The estimate costs of Alternatives 4a, 4b, and 4c, which include the collection and low-energy treatment of East Area groundwater and seeps without West Area collection and treatment range from approximately $32,450,000 (Alternative 4c - extended railroad Creek Relocation and extended East Area collection and treatment) to approximately $67,470,000 (Alternative 4b - extended East Area collection and treatment without Railroad Creek relocation).

The estimate costs of Alternatives 5a through 5d, which include collection and low-energy treatment in the East and West Areas range between approximately $40,380,000 (Alternative 5c - extended Railroad Creek relocation and East/West Area treatment) and approximately $74,320,000 (Alternative 5b - extended East Area collection and East/West Area treatment without Railroad Creek relocation).

The estimated costs of Alternatives 6a and 6b are higher than for Alternative 5, due to the extended secondary collection and treatment of lower West Area groundwater, and the implementation of mechanical treatment in the West Area. The total estimated costs associated with Alternatives 6a and 6b are approximately $77,400,000 and $74,500,000, respectively.

Alternatives 7 and 8 have the highest estimated costs due to consolidation and capping of the tailings piles and/or waste rock piles. The total estimated costs associated with Alternatives 7 and 8 are approximately $100,410,000 and $112,960,000, respectively.

8.3 ADDITIONAL REQUIREMENT UNDER MTCA AND THE AOC

The following subsections provide the results of the comparative analysis for following additional criteria under MTCA and the AOC:

- Use of permanent solutions to the maximum extent practicable;
- Reasonable restoration timeframe; and
- Natural resource restoration.

8.3.1 Use of Permanent Solutions to the Maximum Extent Practicable

The MTCA (WAC 173-340-360(4)(b)) provides that the final remedy use permanent solutions to the maximum extent practicable. A disproportionate cost analysis is used to make this assessment, and includes the evaluation of predicted costs and benefits. The costs and benefits evaluated include overall protection of human health and the environment, permanence, cost, effectiveness over the long term, management of short-term risks, technical and administrative implementability, and consideration of public concerns.

Based on the comparative analysis of alternatives provided in Sections 8.1 and 8.2, Alternative 3b would provide a permanent solution to the maximum extent practicable. Alternative 3b is expected to provide a high-level of overall protection of human health, terrestrial ecological receptors, and aquatic life following remedy implementation in the short and long term. The results of the post-remediation loading analysis indicate that Alternatives 3b would achieve ARARs over time through institutional controls, physical access restrictions, source control actions, upgradient water diversions, the collection and low-energy treatment of the portal drainage and upper West Area seeps/groundwater, and natural attenuation. Therefore, the actions included under Alternative 3b constitute permanent solutions under MTCA. As described previously, Alternative 3b would also adequately manage short-term risks to human health and the environment, including the local community, during remedy implementation, and is technically and administratively implementable.

Alternative 3b is expected to provide a greater degree of overall protection of human health and the environment, permanence, long-term effectiveness, management of short-term risks, technical and administrative implementability, and consideration of public concerns relative to Alternatives 1, 2a, 2b, 3a, 4a, 4b, and 4c. While Alternatives 2a, 2b, 4a, 4b, and 4c would also reduce the release of PCOCs to site groundwater and surface water, predicted short-term seasonal PCOC concentrations in Railroad Creek may result in continued potential risks to aquatic life. Because Alternative 1 does not include any active remedial measures, this alternative would not be expected to meet MTCA requirements for use of permanent solutions to the maximum extent practicable. Alternative 3a, which includes low-energy West Area treatment without flow equalization, would not be expected to be as reliable or effective in reducing PCOC concentrations in Railroad Creek in the short term.

The incremental costs associated with Alternatives 5a through 8 relative to Alternative 3b are summarized on Table 8-1 and range from approximately $12, 220,000 to $84,800,000. Results of the post-remediation loading analysis indicate that Alternatives 5a, 5b, 5c, 5d, 7, and 8 would potentially achieve surface water and groundwater ARARs within a shorter restoration time frame. However, as described previously, short-term PCOC concentrations in Railroad Creek are expected to be protective of resident aquatic species under Alternative 3a, 3b, and 5a through 8, and the predicted differences in long-term dissolved concentrations (within 50 years) under Alternatives 5a through 8 compared to Alternative 3b are minor (i.e., within approximately 0.02 μg/L for cadmium, 0.2 μg/l for copper, 0.79 mg/l for iron, and 11 μg/l for zinc). Therefore, the additional costs associated with Alternatives 5a, 5b, 5c, 5d, 7, and 8 would be disproportionate to the potential incremental benefits to aquatic life in Railroad Creek, and the additional construction requirements under these alternatives would result in lower implementability and increased requirements to manage short-term risks and potential disruption to the local community. Additionally, long-term maintenance would be required to maintain the cover system included under Alternatives 7 and 8. Results of the geochemical analyses provided in Appendix E indicate that the geochemical processes that result in acid mine drainage would be re-initiated if the integrity of the cover system were to be significantly compromised in the future.

Alternatives 6a and 6b are predicted to achieve ARARs within a similar restoration time frame as Alternative 3b, but at a disproportionately higher cost (between approximately $46,340,000 and $49,240,000), and the additional construction and long-term operation and maintenance requirements for mechanical West Area treatment would result in lower implementability and increased requirements to manage short-term risks and potential disruption to the local community.

8.3.2 Reasonable Restoration Timeframe

The MTCA specifies that cleanup actions provide for a reasonable restoration time frame and consideration of the following factors:

Potential Risks Posed by the Site to Human Health and the Environment. Alternatives 1 through 8 would be protective of human health through the implementation of institutional controls and physical access restrictions. Alternatives 2a through 8 would further protect human health and terrestrial ecological receptors though the removal, containment, and/or covering of site soils with PCOCs above potential risk-based ARARs.

Alternatives 3a, 3b, and 5a through 8 are all expected to result in PCOC concentrations in Railroad Creek that are protective of resident aquatic species, including salmonids and their prey, following remedy implementation as shown in the results of the post-remediation loading analysis (Appendix D) and toxicological evaluations provided in Appendix H. Seasonal PCOC concentrations predicted under Alternatives 1, 2a, 2b, 4a, 4b, and 4c may result in continued potential risks to aquatic life in the short term.

Practicability of Achieving a Shorter Restoration Time Frame. As described previously, Alternatives 3a, 3b, and 5a through 8 are expected to result in PCOC concentrations in Railroad Creek that are protective of resident aquatic species, including salmonids and their prey, following remedy implementation. These alternatives are all predicted to achieve potential ARARs in the long term.

Results of the post-remediation loading analysis indicate that Alternatives 5a, 5b, 5c, 5d, 7, and 8 would potentially achieve surface water and groundwater ARARs within a shorter restoration time frame than other alternatives, including Alternative 3b. However, the predicted concentrations in the long-term (within 50 years) under Alternative 3b are relatively similar to the predicted long-term concentrations under Alternatives 5a through 8 (i.e., within approximately 0.02 μg/L for cadmium, 0.2 μg/l for copper, 0.79 mg/l for iron, and 11 μg/l for zinc).

There is uncertainty and reduced practicability related to achieving the shorter restoration timeframe under Alternatives 5a, 5b, 5c, 5d, 7, and 8. In addition, the overall costs of implementing these alternatives are high without achieving any potential incremental benefit to human health and the environment. Alternatives 5, 7, and 8 have lower implementability, and additional short-term risks and potential disruption to the local community.

For these reasons, the additional costs associated with Alternatives 5a, 5b, 5c, 5d, 7, and 8 would be disproportionate to the potential incremental benefits to aquatic life in Railroad Creek.

Current and Potential Future Uses of the Site, Surrounding Areas, and Associated Resources that Are, or May be Affected by Releases from the Site. The Site is situated in a remote area on the eastern slopes of the Cascade Mountains within the Lake Chelan watershed. The Site is surrounded on three sides by designated wilderness and on one side by National Forest System-managed land. The Holden Village, which operates under a special-use permit issued by the Forest Service, is located north of the Site across Railroad Creek. As described under previous evaluation criteria, Alternatives 2 through 8 would result in different levels of impacts to the Holden Village, and provide varying extents of natural resource restoration in the short term. However, each of these alternatives would achieve RAOs and would not preclude current or similar future site uses.

Availability of Alternative Water Supplies. There are no current or planned uses of surface water or groundwater as a drinking water supply downgradient of site influences. The Holden Village currently obtains potable water from Copper Creek upstream of the Site. No exceedances of human health-based criteria have been measured in site surface water, including Railroad Creek downgradient of the Site, or in groundwater near Lucerne. There are no differences between the alternatives with respect to this criterion.

Likely Effectiveness and Reliability of Institutional Controls. Institutional controls would be implemented under Alternatives 1 through 8 to address potential future risks to human health associated with groundwater and potential physical risks associated with the underground mine and mill building. The institutional controls would include land use restrictions; security devices to limit access; and informational devices to notify users about potential risks. Land use restrictions are expected to be implementable, reliable, and adequate in providing long-term protection of human health under all of the alternatives. The installation of access restrictions around select site features is also expected to be reliable in protecting Holden Village residents and visitors from potential physical hazards. There are no differences between the alternatives with respect to this criterion.

Ability to Control and Monitor Migration of Hazardous Substances from the Site. Based on the results of the post-remediation loading analysis, the source controls, upgradient water diversions, upper West Area collection and treatment, and natural attenuation included under Alternatives 3a, 3b, and 5a through 8 would effectively control the migration of hazardous substances from the West Area of the Site. As described under previous evaluation criteria, metals loading to East Area groundwater would be reduced over time through natural attenuation, and groundwater discharges would not result in exceedances of potential ARARs in the long term or cause an impact to aquatic life under Alternatives 3 through 8.

Surface-water monitoring in Railroad Creek and groundwater monitoring in surface water and existing groundwater monitoring wells would be performed under Alternatives 1 through 8 to monitor site conditions over time.

Toxicity of the Hazardous Substances at the Site. Site PCOCs include metals constituents in surface water and groundwater, and metals and total petroleum hydrocarbons (limited areas) in soils. Results of the human health risk assessment presented in the DRI indicate no existing unacceptable risks to Holden Village residents or visitors based on current reasonable maximum exposures to PCOCs within site surface water, groundwater, sediment, and air. The Ecological Risk Assessment presented in the DRI indicated PCOC concentrations in soils in limited areas present a low potential for risk to terrestrial receptors in limited areas of the Site. The ERA also indicated a potential for risk to aquatic life in Railroad Creek due to seasonal PCOC concentrations.

Alternatives 1 through 8 would be protective of human health through the implementation of institutional controls and physical access restrictions. Alternative 2a through 8 would further protect human health and terrestrial ecological receptors though the removal, containment, and/or covering of site soils with PCOCs above potential risk-based ARARs. Alternatives 3a, 3b, and 5a through 8 are all expected to result in PCOC concentrations in Railroad Creek that are protective of resident aquatic species, including salmonids and their prey, following remedy implementation.

Natural Processes that Reduce Concentrations of Hazardous Substances have been documented to Occur at the Site or Under Similar Site Conditions. The attenuation of metals loading from mining residuals is a well understood and documented process. The site-specific geochemical analyses provided in Appendix E document that natural attenuation is occurring in residuals located in the underground mine, waste rock piles, and tailings piles, and that long-term reductions in metals loading from these source areas are expected. These natural geochemical processes contribute to the predicted long-term achievement of potential ARARs for Alternatives 2a through 8.

8.3.3 Natural Resource Restoration

A summary of the natural resource restoration provided by each of the remedial alternatives is included in Appendix J. A general overview of the natural resource restoration provided under Alternatives 2 through 8 is provided below.

Through the implementation of source control measures in the West Area, Alternatives 2a through 8 would reduce potential risks to terrestrial ecological receptors and restore terrestrial habitat. Although the tailings piles are not injured resources, the tailings pile revegetation efforts included under Alternatives 2a through 6b are expected to provide replacement terrestrial habitat over time for other potentially injured areas of the Site. Through tailings pile consolidation, Alternatives 7 and 8 would also restore potential habitat to the current location of tailings pile 1.

The remedial actions and natural attenuation included under Alternatives 2a through 8 would reduce potential risks to aquatic organisms, including trout and benthic macroinvertebrates, over time by reducing the release of PCOCs to Railroad Creek. Based on the results of the post-remediation loading analysis and toxicological evaluations provided in Appendix H, Alternatives 3a, 3b, and 5a through 8, which include the collection and treatment of the portal drainage and upper West Area seeps and groundwater, are all expected to result in PCOC concentrations in Railroad Creek that are protective of resident aquatic species following remedy implementation in the short term.

Table 8-1
Comparative Analysis Summary

Evaluation Criteria	Alt 1 No Action/ Institutional Controls	Alt 2a Water Management (Open Portal)	Alt 2b Water Management (Hydrostatic Bulkheads)	Alt 3a Water Management and Low-Energy West Area Treatment (Open Portal)	Alt 3b Water Management and Low-Energy West Area Treatment (Hydrostatic Bulkheads)	Alt 4a Water Management and East Area Partial Collection and Treatment
Overall Protection of Human Health and the Environment						
Human Health and Terrestrial Ecological Receptors	The human health risk assessment found no existing unacceptable risk to human health at the Site. Institutional controls and physical access restrictions would eliminate potential future risks to human health. Soils with concentrations above potential Agency-required ecological risk-based ARARs would not be addressed.	Institutional controls and physical access restrictions would eliminate potential future risks to human health. Alternative 2a would provide additional protection of human health and terrestrial ecological receptors though the removal, containment, and/or covering of Site soils with PCOCs above potential ARARs. The soil RAO would be achieved following remedy implementation.	As described for Alternative 2a, Alternatives 2b would be protective of human health and terrestrial ecological receptors at the Site. The soil RAO would be achieved following remedy implementation.	As described for Alternative 2a, Alternative 3a would be protective of human health and terrestrial ecological receptors at the Site. The soil RAO would be achieved following remedy implementation.	As described for Alternative 2a, Alternative 3b would be protective of human health and terrestrial ecological receptors at the Site. The soil RAO would be achieved following remedy implementation.	As described for Alternative 2a, Alternative 4a would be protective of human health and terrestrial ecological receptors at the Site. The soil RAO would be achieved following remedy implementation.
Aquatic Life	Potential risks to aquatic life in Railroad Creek would not be addressed under this alternative. Alternative 1 would not meet surface water or groundwater RAOs.	PCOC loading to surface water and groundwater would be reduced following remedy implementation through source controls and upgradient water diversion. Surface-water and groundwater RAOs would be achieved in the long-term. However, predicted short-term seasonal PCOC concentrations in Railroad Creek may result in continued potential risks to aquatic life.	The magnitude of seasonal PCOC loading to Railroad Creek would be reduced over Alternative 2a through portal drainage flow control. Surface-water and groundwater RAOs would be achieved in the long-term. However, predicted short-term seasonal PCOC concentrations in Railroad Creek may result in continued potential risks to aquatic life.	PCOC loading to groundwater and surface water would be significantly reduced over Alternatives 2a and 2b through collection and treatment of the portal drainage and upper West Area seeps/groundwater. As described for Alternatives 3b and 5a through 8, PCOC concentrations in Railroad Creek are predicted to be protective of resident aquatic species in the short term Under Alternative 3a, surface-water and groundwater RAOs would be achieved in the long-term.	PCOC loading to groundwater and surface water would be further reduced over Alternative 3a through equalization of the portal drainage flows. As described for Alternatives 3a and 5a through 8, PCOC concentrations in Railroad Creek are predicted to be protective of resident aquatic species in the short term. Under Alternative 3b, surface-water and groundwater RAOs would be achieved in the long term.	Similar to Alternative 2b, with greater reductions in PCOC loadings from the East Area due to partial collection and treatment of East Area seeps and groundwater. Less effective than Alternatives 3a, 3b, and 4b through 8 in reducing PCOC concentrations in Railroad Creek. Surface-water and groundwater RAOs would be achieved in the long term. However, predicted short-term seasonal PCOC concentrations in Railroad Creek may result in continued potential risks to aquatic life.
Potential Short-term Impacts	Potential short-term risks to the environment are expected to remain unchanged under this Alternative. No additional short-term risks would be created to the local community or environment under Alternative 1. The RAO to implement the remedial action in a manner that is protective of human health, including the Holden Village community would be met.	No additional short-term risks would be anticipated for the local community during or after implementation of Alternative 2a. Possible short-term increases in PCOC loadings from the tailings piles may result during regrading actions; however, mitigation measures would be implemented. The RAO to implement the remedial action in a manner that is protective of human health, including the Holden Village community would be met.	Similar to Alternative 2a; however, elevated PCOC concentrations in the portal drainage may result in the short term due to the installation of hydrostatic bulkheads in the 1500 level of the underground mine and flooding of the underground mine workings. The RAO to implement the remedial action in a manner that is protective of human health, including the Holden Village community would be met.	Similar to Alternative 2a; however, the construction and operation of a low-energy water treatment system in the West Area would potentially result in greater disturbance to soils and vegetation in this area. The RAO to implement the remedial action in a manner that is protective of human health, including the Holden Village community would be met.	Similar to Alternative 3a. The RAO to implement the remedial action in a manner that is protective of human health, including the Holden Village community would be met.	The partial relocation of Railroad Creek to the north would present greater risks to the local community than actions under Alternatives 2a through 3b. The installation of hydrostatic bulkheads without West Area treatment, partial Railroad Creek relocation, placement of Copper Creek in a culvert, and partial barrier wall construction in the East Area would also result in a greater risk of short-term surface-water and groundwater impacts due to the potential for increased PCOCs in the portal drainage and release of fine-grained sediment or slurry to Railroad Creek. The RAO to implement the remedial action in a manner that is protective of human health, including the Holden Village community would be met.
Compliance with ARARs						
Potential Chemical-specific ARARs - Surface Water	Although PCOC releases from Site sources are predicted to decline over time through natural attenuation, long-term seasonal exceedences of potential surface-water ARARs are expected under Alternative 1.	Seasonal PCOC concentrations are predicted to be below the SWQC and NRWQC within approximately 250 years.	Seasonal PCOC concentrations are predicted to be below the SWQC and NRWQC within approximately 250 years.	Seasonal PCOC concentrations are predicted to be below the SWQC and NRWQC within approximately 250 years. However, under Alternative 3a, PCOC concentrations are expected to be protective of resident aquatic species following remedy implementation in the short term.	Seasonal PCOC concentrations are predicted to be below the SWQC within approximately 250 years and the NRWQC within approximately 50 years. However, under Alternative 3b, PCOC concentrations are expected to be protective of resident aquatic species following remedy implementation in the short term.	Seasonal PCOC concentrations are predicted to be below the SWQC and NRWQC within approximately 250 years. PCOC reductions would not be as significant as predicted for Alternatives 3a and 3b or 5a through 8.
Potential Chemical-specific ARARs - Groundwater	Although PCOC releases from Site sources are predicted to decline over time through natural attenuation, long-term exceedences of potential ground-water ARARs are expected under Alternative 1.	Because Alternative 2a does not include West Area collection and treatment, this alternative would not likely meet potential chemical-specific ARARs for West Area groundwater in the short or long term. Potential groundwater ARARs are expected to be achieved at points in Railroad Creek downstream of RC-4 within approximately 250 years.	Because Alternative 2b does not include West Area collection and treatment, this alternative would not likely meet potential chemical-specific ARARs for West Area groundwater in the short or long term. Potential groundwater ARARs are expected to be achieved at points in Railroad Creek downstream of RC-4 within approximately 250 years.	Potential groundwater ARARs are expected to be achieved at points in Railroad Creek within approximately 250 years.	Potential groundwater ARARs are expected to be achieved at points in Railroad Creek within approximately 250 years.	Because Alternative 4a does not include West Area collection and treatment, this alternative would not likely meet potential chemical-specific ARARs for West Area groundwater in the short or long term. Potential groundwater ARARs are expected to be achieved at points in Railroad Creek downstream of RC-4 within approximately 250 years.
Potential Chemical-specific ARARs - Soils	Soils would not addressed under Alternative 1.	Potential soil ARARs would be met under Alternative 2a.	Potential soil ARARs would be met under Alternative 2b.	Potential soil ARARs would be met under Alternative 3a.	Potential soil ARARs would be met under Alternative 3b.	Potential soil ARARs would be met under Alternative 4a.
Potential Location-specific ARARs	No location-specific ARARs would apply under Alternative 1.	Alternative 2a would meet all potential location-specific ARARs.	Alternative 2b would meet all potential location-specific ARARs.	Alternative 3a would meet all potential location-specific ARARs.	Alternative 3b would meet all potential location-specific ARARs.	Alternative 4a would meet all potential location-specific ARARs.
Potential Action-specific ARARs	The institutional controls, physical access restrictions, and long-term monitoring would meet potential action-specific ARARs.	Activities under Alternative 2a are expected to comply with potential action-specific ARARs.	Activities under Alternative 2b are expected to comply with potential action-specific ARARs.	Activities under Alternative 3a are expected to comply with potential action-specific ARARs.	Activities under Alternative 3b are expected to comply with potential action-specific ARARs.	Activities under Alternative 4a are expected to comply with potential action-specific ARARs.

Table 8-1
Comparative Analysis Summary

Evaluation Criteria	**Alt 4b** Water Management and Extended East Area Collection and Treatment	**Alt 4c** Water Management, Extended Railroad Creek Relocation, East Area Collection and Treatment	**Alt 5a** Water Management, Partial East Area Collection, and East/West Area Treatment (Low-Energy WTP)	**Alt 5b** Water Management, Extended East Area Collection, and East/West Area Treatment (Low-Energy WTP)	**Alt 5c** Water Management, Extended Railroad Creek Relocation, and East/West Area Treatment (Low-Energy WTP)	**Alt 5d** Water Management, Secondary West Area Collection, Extended Railroad Creek Relocation, and East/West Area Treatment (Low-Energy WTP)
Overall Protection of Human Health and the Environment						
Human Health and Terrestrial Ecological Receptors	As described for Alternative 2a, Alternative 4b would be protective of human health and terrestrial ecological receptors at the Site. The soil RAO would be achieved following remedy implementation.	As described for Alternative 2a, Alternative 4c would be protective of human health and terrestrial ecological receptors at the Site. The soil RAO would be achieved following remedy implementation.	As described for Alternative 2a, Alternative 5a would be protective of human health and terrestrial ecological receptors at the Site. The soil RAO would be achieved following remedy implementation.	As described for Alternative 2a, Alternative 5b would be protective of human health and terrestrial ecological receptors at the Site. The soil RAO would be achieved following remedy implementation.	As described for Alternative 2a, Alternative 5c would be protective of human health and terrestrial ecological receptors at the Site. The soil RAO would be achieved following remedy implementation.	As described for Alternative 2a, Alternative 5d would be protective of human health and terrestrial ecological receptors at the Site. The soil RAO would be achieved following remedy implementation.
Aquatic Life	Similar to Alternative 4a, with greater reductions in PCOC loadings from the East Area due to extended collection and treatment of East Area seeps and groundwater. Less effective than Alternatives 3a, 3b, and 5a through 8 in reducing PCOC concentrations in Railroad Creek. Surface-water and groundwater RAOs would be achieved in the long term. However, predicted short-term seasonal PCOC concentrations in Railroad Creek may result in continued potential risks to aquatic life.	Similar to Alternative 4b, with slightly lower reductions in PCOC loading to Railroad Creek. Less effective than Alternatives 3a, 3b and 5a through 8 in reducing PCOC concentrations in Railroad Creek. Surface-water and groundwater RAOs would be achieved in the long term. However, predicted short-term seasonal PCOC concentrations in Railroad Creek may result in continued potential risks to aquatic life.	PCOC loading to groundwater and surface water would be further reduced over Alternatives 2a through 4c through collection and treatment of the portal drainage and upper West Area seeps and groundwater, and partial East Area collection and treatment. As described for Alternatives 3a, 3b, and 5b through 8, PCOC concentrations in Railroad Creek are predicted to be protective of resident aquatic species in the short term. Under Alternative 5a, surface-water and groundwater RAOs would be achieved in the long term.	PCOC loading to groundwater and surface water would be further reduced over Alternatives 2a through 5a through collection and treatment of the portal drainage and upper West Area seeps and groundwater, and extended East Area collection and treatment. As described for Alternatives 3a, 3b, 5a, and 5c through 8, PCOC concentrations in Railroad Creek are predicted to be protective of resident aquatic species in the short term. Under Alternative 5b, surface-water and groundwater RAOs would be achieved in the long term.	Reductions in PCOC loading to groundwater and surface water would be similar to Alternative 5b. As described for Alternatives 3a, 3b, 5a, 5b, and 5d through 8, PCOC concentrations in Railroad Creek are predicted to be protective of resident aquatic species in the short term. Under Alternative 5c, surface-water and groundwater RAOs would be achieved in the long term.	PCOC loading to Railroad Creek would be slightly reduced in the short term over Alternatives 5b and 5c through secondary collection and treatment of lower West Area seeps and groundwater. As described for Alternatives 3a, 3b, 5a, 5b, 5c, and 6a through 8, PCOC concentrations in Railroad Creek are predicted to be protective of resident aquatic species in the short term. Under Alternative 5d, surface-water and groundwater RAOs would be achieved in the long term.
Potential Short-term Impacts	Similar to Alternative 4a; however, there would be a higher potential for short-term water quality impacts due to the increased tailings regrading and slurry wall construction requirements adjacent to Railroad Creek. The RAO to implement the remedial action in a manner that is protective of human health, including the Holden Village community, would be met.	Similar to Alternative 4a; however, there would be a lower potential for short-term impacts during regrading and East Area water collection/treatment system construction due to the extended relocation of Railroad Creek. Alternative 4c would have a higher potential for short-term impacts to surface water while the new Railroad Creek channel is put into service. Additional construction near the Holden Village during Railroad Creek relocation would present greater risks to the local community than the actions included under Alternatives 2a through 4b. However, the RAO to implement the remedial action in a manner that is protective of human health, including the Holden Village community, would be met.	Similar to the combined risks as described under Alternatives 3b and 4a. The RAO to implement the remedial action in a manner that is protective of human health, including the Holden Village community, would be met.	Similar to the combined risks as described under Alternatives 3b and 4b. The RAO to implement the remedial action in a manner that is protective of human health, including the Holden Village community, would be met.	Similar to the combined risks as described under Alternatives 3b and 4c. The RAO to implement the remedial action in a manner that is protective of human health, including the Holden Village community, would be met.	Similar to Alternative 5c; however, there would be a higher potential for short-term impacts to West Area vegetation and surface water during construction of the lower West Area barrier wall/collection system. The RAO to implement the remedial action in a manner that is protective of human health, including the Holden Village community, would be met.
Compliance with ARARs						
Potential Chemical-specific ARARs - Surface Water	Seasonal PCOC concentrations are predicted to be below the SWQC and NRWQC within approximately 250 years. PCOC reductions would be greater than those predicted for Alternative 4a, but not as significant as under Alternatives 3a and 3b or 5a through 8.	Seasonal PCOC concentrations are predicted to be below the SWQC and NRWQC within approximately 250 years. PCOC reductions would be greater than those predicted for Alternative 4a, but not as significant as under Alternatives 3a and 3b or 5a through 8.	Seasonal PCOC concentrations are predicted to be below the SWQC and NRWQC within approximately 50 years. As described for Alternatives 3a, 3b, and 5b through 8, PCOC concentrations are expected to be protective of resident aquatic species following remedy implementation in the short term.	Seasonal PCOC concentrations are predicted to be below the SWQC and NRWQC within approximately 50 years. As described for Alternatives 3a, 3b, 5a, and 5c through 8, PCOC concentrations are expected to be protective of resident aquatic species following remedy implementation in the short term.	Seasonal PCOC concentrations are predicted to be below the SWQC and NRWQC within approximately 50 years. As described for Alternatives 3a, 3b, 5a, 5b, and 5d through 8, PCOC concentrations are expected to be protective of resident aquatic species following remedy implementation in the short term.	Seasonal PCOC concentrations are predicted to be below the SWQC and NRWQC within approximately 50 years. As described for Alternatives 3a, 3b, 5a, 5b, 5c, and 6a through 8, PCOC concentrations are expected to be protective of resident aquatic species following remedy implementation in the short term.
Potential Chemical-specific ARARs - Groundwater	Because Alternative 4b does not include West Area collection and treatment, this alternative would not likely meet potential chemical-specific ARARs for West Area groundwater in the short or long term. Potential groundwater ARARs are expected to be achieved at points in Railroad Creek downstream of RC-4 within approximately 250 years.	Because Alternative 4c does not include West Area collection and treatment, this alternative would not likely meet potential chemical-specific ARARs for West Area groundwater in the short or long term. Potential groundwater ARARs are expected to be achieved at points in Railroad Creek downstream of RC-4 within approximately 250 years.	Potential groundwater ARARs are expected to be achieved at points in Railroad Creek within approximately 50 years.	Potential groundwater ARARs are expected to be achieved at points in Railroad Creek within approximately 50 years.	Potential groundwater ARARs are expected to be achieved at points in Railroad Creek within approximately 50 years.	Potential groundwater ARARs may be achieved within Railroad Creek upstream of RC-4 (with exception of seep SP 26) following remedy implementation, and downstream of RC-4 within approximately 50 years.
Potential Chemical-specific ARARs - Soils	Potential soil ARARs would be met under Alternative 4b.	Potential soil ARARs would be met under Alternative 4c.	Potential soil ARARs would be met under Alternative 5a.	Potential soil ARARs would be met under Alternative 5b.	Potential soil ARARs would be met under Alternative 5c.	Potential soil ARARs would be met under Alternative 5d.
Potential Location-specific ARARs	Alternative 4b would meet all potential location-specific ARARs.	Alternative 4c would meet all potential location-specific ARARs.	Alternative 5a would meet all potential location-specific ARARs.	Alternative 5b would meet all potential location-specific ARARs.	Alternative 5c would meet all potential location-specific ARARs.	Alternative 5d would meet all potential location-specific ARARs.
Potential Action-specific ARARs	Activities under Alternative 4b are expected to comply with potential action-specific ARARs.	Activities under Alternative 4c are expected to comply with potential action-specific ARARs.	Activities under Alternative 5a are expected to comply with potential action-specific ARARs.	Activities under Alternative 5b are expected to comply with potential action-specific ARARs.	Activities under Alternative 5c are expected to comply with potential action-specific ARARs.	Activities under Alternative 5d are expected to comply with potential action-specific ARARs.

Table 8-1
Comparative Analysis Summary

Evaluation Criteria	**Alt 6a** Water Management, Extended Secondary West Area Collection, Extended Railroad Creek Relocation, and East/West Area Treatment (Mechanical WTP)	**Alt 6b** Water Management, Extended Secondary West Area Collection, Extended Railroad Creek Relocation, and East/West Area Treatment (Mechanical WTP with Bulkhead)	**Alt 7** Capping, Consolidation, Water Management, and West Area Treatment	**Alt 8** Source Control and East/West Area Treatment
Overall Protection of Human Health and the Environment				
Human Health and Terrestrial Ecological Receptors	As described for Alternative 2a, Alternative 6a would be protective of human health and terrestrial ecological receptors at the Site. The soil RAO would be achieved following remedy implementation.	As described for Alternative 2a, Alternative 6b would be protective of human health and terrestrial ecological receptors at the Site. The soil RAO would be achieved following remedy implementation.	As described for Alternative 2a, Alternative 7 would be protective of human health and terrestrial ecological receptors at the Site. The soil RAO would be achieved following remedy implementation.	As described for Alternative 2a, Alternative 8 would be protective of human health and terrestrial ecological receptors at the Site. The soil RAO would be achieved following remedy implementation.
Aquatic Life	Reductions in PCOC loadings to groundwater and surface water would be similar to Alternatives 5d and 6b. As described for Alternatives 3a, 3b, 5a, 5b, 5c, 5d, and 6b through 8, PCOC concentrations in Railroad Creek are predicted to be protective of resident aquatic species in the short term. Under Alternative 6a, surface-water and groundwater RAOs would be achieved in the long term.	Reductions in PCOC loadings to groundwater and surface water would be similar to Alternatives 5d and 6a. As described for Alternatives 3a, 3b, 5a through 6a, 7, and 8, PCOC concentrations in Railroad Creek are predicted to be protective of resident aquatic species in the short term. Under Alternative 6b, surface-water and groundwater RAOs would be achieved in the long term.	Reductions in short-term PCOC loading to groundwater and surface water would be similar to Alternative 5a. Increased long-term loading reductions are expected under Alternative 7 compared to Alternatives 1 through 6b due to tailings pile consolidation and capping. However, as described for Alternatives 3a, 3b, 5a through 6b, and 8, PCOC concentrations in Railroad Creek are predicted to be protective of resident aquatic species in the short term. Under Alternative 7, surface-water and groundwater RAOs would be achieved in the long term.	PCOC loading to groundwater and surface water would be reduced over Alternatives 1 through 7 through consolidation and capping of the east and west waste rock piles and tailings, and the collection and treatment of the portal drainage, seeps, and groundwater in the East and West Areas. As described for Alternatives 3a, 3b, and 5a through 7, PCOC concentrations in Railroad Creek are predicted to be protective of resident aquatic species in the short term. Under Alternative 8, surface-water and groundwater RAOs would be achieved in the long term.
Potential Short-term Impacts	Similar to Alternative 5d; however, Alternative 6a would have a higher risk to workers and the environment due to the increased long-term fuel and O&M requirements associated with a mechanical treatment system. Short-term impacts to West Area vegetation and surface water during construction of the extended lower West Area barrier wall/collection system would also be greater under this alternative. The RAO to implement the remedial action in a manner that is protective of human health, including the Holden Village community, would be met.	Similar to Alternative 6a. The RAO to implement the remedial action in a manner that is protective of human health, including the Holden Village community would be met.	The potential for short-term impacts due to West Area actions would be similar to Alternative 3b. However, the significant earth work and materials transport required for tailings pile consolidation and capping would greatly increase the potential for PCOC releases to Railroad Creek during construction, and the potential for accidents and impacts to workers, the local community, and environment relative to Alternatives 1 through 6b. However, the RAO to implement the remedial action in a manner that is protective of human health, including the Holden Village community, would be met.	Similar to Alternative 7; however, the potential for PCOC releases to Railroad Creek during tailings consolidation and capping would be reduced through East Area collection and treatment. The RAO to implement the remedial action in a manner that is protective of human health, including the Holden Village community, would be met.
Compliance with ARARs				
Potential Chemical-specific ARARs - Surface Water	Seasonal PCOC concentrations are predicted to be below the SWQC within approximately 50 years, and the NRWQC within approximately 250 years. As described for Alternatives 3a, 3b, 5a, 5b, 5c, 5d, and 6b through 8, PCOC concentrations are expected to be protective of resident aquatic species following remedy implementation in the short term.	Seasonal PCOC concentrations are predicted to be below the SWQC within approximately 50 years, and the NRWQC within approximately 250 years. As described for Alternatives 3a, 3b, 5a through 6a, 7, and 8, PCOC concentrations are expected to be protective of resident aquatic species following remedy implementation in the short term.	Seasonal PCOC concentrations are predicted to be below the SWQC and NRWQC within approximately 50 years. As described for Alternatives 3a, 3b, 5a through 6b, and 8, PCOC concentrations are expected to be protective of resident aquatic species following remedy implementation in the short term.	Seasonal PCOC concentrations are predicted to be below the SWQC and NRWQC within approximately 50 years. As described for Alternatives 3a, 3b, and 5a through 7, PCOC concentrations are expected to be protective of resident aquatic species following remedy implementation in the short term.
Potential Chemical-specific ARARs - Groundwater	Potential groundwater ARARs may be achieved within Railroad Creek upstream of RC-4 following remedy implementation, and downstream of RC-4 within approximately 250 years.	Potential groundwater ARARs may be achieved within Railroad Creek upstream of RC-4 following remedy implementation, and downstream of RC-4 within approximately 250 years.	Potential groundwater ARARs may be achieved in Railroad Creek within approximately 50 years.	Potential groundwater ARARs may be achieved in Railroad Creek within approximately 50 years.
Potential Chemical-specific ARARs - Soils	Potential soil ARARs would be met under Alternative 6a.	Potential soil ARARs would be met under Alternative 6b.	Potential soil ARARs would be met under Alternative 7.	Potential soil ARARs would be met under Alternative 8.
Potential Location-specific ARARs	Alternative 6a would meet all potential location-specific ARARs.	Alternative 6b would meet all potential location-specific ARARs.	Alternative 7 would meet all potential location-specific ARARs.	Alternative 8 would meet all potential location-specific ARARs.
Potential Action-specific ARARs	Activities under Alternative 6a are expected to comply with potential action-specific ARARs.	Activities under Alternative 6b are expected to comply with potential action-specific ARARs.	Activities under Alternative 7 are expected to comply with potential action-specific ARARs.	Activities under Alternative 8 are expected to comply with potential action-specific ARARs.

Table 8-1
Comparative Analysis Summary

Evaluation Criteria	Alt 1 No Action/ Institutional Controls	Alt 2a Water Management (Open Portal)	Alt 2b Water Management (Hydrostatic Bulkheads)	Alt 3a Water Management and Low-Energy West Area Treatment (Open Portal)	Alt 3b Water Management and Low-Energy West Area Treatment (Hydrostatic Bulkheads)	Alt 4a Water Management and East Area Partial Collection and Treatment
Primary Balancing Criteria						
Long-term Effectiveness & Permanence	Potential future risks to human health would be eliminated through institutional controls. Soils with PCOC concentrations above the Agency-required ARARs for protection of terrestrial ecological receptors would remain in isolated locations. Seasonal PCOC concentrations in Railroad Creek may also result in continued potential risks to aquatic life in the long-term.	Potential future risks to human health would be eliminated through institutional controls. The magnitude of residual risks to terrestrial ecological receptors would be low following soil removal and/or containment actions. PCOC concentrations in Railroad Creek are predicted to meet potential ARARs in the long term. However, predicted short term PCOC concentrations in Railroad Creek may result in continued potential risks to aquatic life. Alternative 2a actions would be reliable.	Similar to Alternative 2a, but would further reduce the magnitude of seasonal PCOC exceedences in Railroad Creek in the long term through portal drainage flow control. PCOC concentrations in Railroad Creek are predicted to meet potential ARARs in the long term. However, predicted short term PCOC concentrations in Railroad Creek may result in continued potential risks to aquatic life. Alternative 2b actions would be reliable.	Similar to Alternative 2a; however, concentrations of PCOCs would be protective of resident aquatic species in the short term. Alternative 3a would be implementable, have a high degree of reliability, and similar long-term effectiveness as expected under Alternatives 3b and 5a through 8.	Similar to Alternative 3a, but West Area treatment is expected to be more reliable and long-term PCOC concentrations in Railroad Creek are expected to be slightly lower under Alternative 3b through equalization of the portal drainage, and other in-mine controls. Alternative 3b would have similar long-term effectiveness as expected under Alternatives 3a and 5a through 8.	Similar to Alternative 2b, but greater long-term improvements in surface water quality are expected under Alternative 4a through the partial collection and treatment of East Area seeps and groundwater. Alternative 4a is predicted to have reduced long-term effectiveness and permanence compared to Alternatives 3a, 3b, and 5a through 8, as predicted short-term PCOC concentrations in Railroad Creek may result in continued potential risks to aquatic life.
Reduction of Toxicity, Mobility, and Volume	The mass, and therefore volume, of PCOCs released from the Site would be reduced over time through natural geochemical attenuation processes.	The mass, and therefore volume, of PCOCs released from the Site would be reduced over time compared to Alternative 1 through source control actions and natural geochemical attenuation processes.	Similar to Alternative 2a.	Alkaline precipitation processes included for the West Area would significantly reduce the mass and volume of PCOCs released to surface water and groundwater compared to Alternatives 1 through 2b. The volume of PCOCs released from the Site would also be reduced over time through source controls and natural geochemical attenuation processes.	As described for Alternative 3a, alkaline precipitation processes included for the West Area would significantly reduce the mass and volume of PCOCs released to surface water and groundwater. Additionally, the volume of PCOCs released from the Site would be reduced over time through source controls and natural geochemical attenuation processes.	Alkaline precipitation processes included for the East Area would reduce mass and volume of PCOCs released compared to Alternatives 1, 2a, and 2b. The volume of PCOCs released from the Site would also be reduced over time through source controls and natural geochemical attenuation processes.
Short-term Effectiveness	Short-term risks to the environment would remain unchanged under Alternative 1. No additional short-term risks would be created for the local community under this alternative. Alternative 1 would have lower short-term effectiveness than Alternatives 2a through 8.	Alternative 2a would be implemented in a manner that is protective of workers, the local community, and the environment. The possible development of a rock source near Tenmile creek would present potential risks to workers and the community. Underground mine actions would also present increased risks to workers. Possible short-term increases in PCOC loading to surface water may result during tailings pile regrading. The time required to reach remediation goals is predicted to be less than under Alternative 1, but greater than Alternatives 2b through 8.	Similar to Alternative 2a. However, the additional activities associated with installation of hydrostatic bulkheads in the underground mine would present increased risks to workers under Alternative 2b, and short-term increases in portal drainage PCOC concentrations may result following bulkhead placement. The time required to reach remediation goals is predicted to be less than Alternatives 1 and 2a, but greater than Alternatives 2b through 8.	Potential short-term impacts to workers and the local community would be similar to Alternative 2b. However, significant short-term improvements in Railroad Creek water quality are expected under Alternative 3a through West Area treatment. The time required to reach remediation goals is expected to be less than Alternatives 1, 2a, 2b, and 4a through 4b. Alternative 3a has similar short-term effectiveness as Alternatives 3b, and 5b through 8 since Railroad Creek water quality is predicted to be protective of resident aquatic species following remedy implementation.	Similar to Alternative 3a, but greater short-term improvements in Railroad Creek water quality are expected through the equalization of portal drainage flows. The time required to reach remediation goals is expected to be less under Alternative 3b than Alternatives 1, 2a, 2b, 3a, and 4a through 4b. This alternative has similar short-term effectiveness as Alternatives 3b, and 5b through 8 since Railroad Creek water quality is predicted to be protective of resident aquatic species following remedy implementation.	The partial relocation of Railroad Creek to the north would present greater risks to the local community than Alternatives 2a through 3b due to increased construction activity near the Holden Village. The partial Railroad Creek relocation, placement of Copper Creek in a culvert, and partial barrier wall construction in the East Area would also result in a greater risk of short-term water quality impacts due to the potential release of fine-grained sediment or slurry. The time required to reach remediation goals is expected to be less than for Alternatives 1, 2a, and 2b. However, greater short-term improvements in Railroad Creek water quality are predicted under Alternatives 3a, 3b, and 4b through 8.
Implementability	Actions included under this alternative would be technically implementable, but would have low administrative implementability.	Implementable. Underground mine actions would require specialized equipment and crews. Alternative 2a would require coordination with the Forest Service, Holden Village, and other local agencies during implementation.	Similar to Alt 2a, but additional design and construction activities would be required for the installation of hydrostatic bulkheads.	Alternative 3a would be technically implementable. Required materials, equipment, and personnel are expected to be available in the surrounding area. Additional coordination would be required with the Holden Village to facilitate long-term water treatment in the West Area.	Similar to Alt 3a, but additional design and construction activities would be required for the installation of hydrostatic bulkheads.	Actions included under Alternative 4a are technically implementable. However, construction of the partial groundwater collection and treatment systems in the East Area and partial Railroad Creek relocation would be difficult due to subsurface characteristics. Additional coordination with the Holden Village would be required due to the increased construction activities on the north side of Railroad Creek.
Estimated Total Cost (Million USD)	$2.7	$17.3	$18.8	$27.1	$28.2	$34.4

Table 8-1
Comparative Analysis Summary

Evaluation Criteria	**Alt 4b** Water Management and Extended East Area Collection and Treatment	**Alt 4c** Water Management, Extended Railroad Creek Relocation, East Area Collection and Treatment	**Alt 5a** Water Management, Partial East Area Collection, and East/West Area Treatment (Low-Energy WTP)	**Alt 5b** Water Management, Extended East Area Collection, and East/West Area Treatment (Low-Energy WTP)	**Alt 5c** Water Management, Extended Railroad Creek Relocation, and East/West Area Treatment (Low-Energy WTP)	**Alt 5d** Water Management, Secondary West Area Collection, Extended Railroad Creek Relocation, and East/West Area Treatment (Low-Energy WTP)
Primary Balancing Criteria						
Long-term Effectiveness & Permanence	Similar to Alternative 4a, but greater long-term improvements in surface water quality are expected under Alternative 4b through extended East Area collection and treatment. However, Alternative 4b is predicted to have reduced long-term effectiveness and permanence compared to Alternatives 3a, 3b, and 5a through 8 due difficulties associated with long-term O&M of the extended East Area collection system, and because expected PCOC concentrations in Railroad Creek may result in continued potential risks to aquatic life.	Similar to Alternative 4b, but greater long-term improvements in Railroad Creek water quality are expected adjacent to the site through extended Railroad Creek relocation. Alternative 4c is predicted to have reduced long-term effectiveness and permanence compared to Alternatives 3a, 3b, and 5a through 8, as predicted short term PCOC concentrations in Railroad Creek may result in continued potential risks to aquatic life.	Similar to Alternative 3b, but slight improvements in long-term Railroad Creek water quality are expected through partial East Area collection and treatment. Alternative 5a would have similar long-term effectiveness as expected under Alternatives 3a, 3b, and 5b through 8.	Similar to Alternative 5a, but slight improvements in long-term Railroad Creek water quality are expected through extended East Area collection and treatment. Alternative 5b would have similar long-term effectiveness as predicted for Alternatives 3a, 3b, 5a, and 5c through 8. However, difficulties associated with long-term O&M of the extended East Area collection systems would result in lower long-term reliability.	Similar improvements in long-term Railroad Creek water quality are expected under Alternative 5c as described for Alternative 5b. Alternative 5c would have similar long-term effectiveness as predicted for Alternatives 3a, 3b, 5a, 5b, and 5d through 8.	Similar improvements in long-term Railroad Creek water quality are expected under Alternative 5d as described for Alternatives 5b and 5c. Alternative 5d would have similar long-term effectiveness as predicted for Alternatives 3a, 3b, 5a, 5b, 5c, and 6a through 8.
Reduction of Toxicity, Mobility, and Volume	Alkaline precipitation processes included for the East Area would reduce the mass and volume of PCOCs released compared to Alternatives 1, 2a, 2b, and 4a. The volume of PCOCs released from the Site would also be reduced over time through source controls and natural geochemical attenuation processes.	Alkaline precipitation processes included for the East Area would reduce mass and volume of PCOCs released, as described for Alternative 4b. The volume of PCOCs released from the Site would also be reduced over time through source controls and natural geochemical attenuation processes.	Alkaline precipitation processes included for the East and West Areas would reduce mass and volume of PCOCs released compared to Alternatives 1 through 4c. The volume of PCOCs released from the Site would also be reduced over time through source controls and natural geochemical attenuation processes.	Alkaline precipitation processes included for the East and West Areas would reduce mass and volume of PCOCs released compared to Alternatives 1 through 5a. The volume of PCOCs released from the Site would also be reduced over time through source controls and natural geochemical attenuation processes.	Similar to Alternatives 5b, 5d, 6a, 6b and 8, alkaline precipitation processes included for the East and West Areas would reduce the mass and volume of PCOCs released. The volume of PCOCs released from the Site would also be reduced over time through source controls and natural geochemical attenuation processes.	Similar to Alternatives 5b, 5c, 6a, 6b and 8, alkaline precipitation processes included for the East and West Areas would reduce the mass and volume of PCOCs released. The volume of PCOCs released from the Site would also be reduced over time through source controls and natural geochemical attenuation processes.
Short-term Effectiveness	Similar to Alternative 4a; however, there would be a higher potential for short-term water quality impacts due to increased tailings regrading and slurry wall construction requirements adjacent to Railroad Creek. The time required to reach remediation goals is expected to be less under Alternative 4b than Alternatives 1, 2a, 2b, 4a, and 4c. However, greater short-term improvements in Railroad Creek water quality are predicted under Alternatives 3a, 3b, and 5a through 8.	Similar to Alternative 4a; however, a lower potential for short-term water quality impacts during regrading and East Area construction activities is expected due to extended Railroad Creek relocation. Alternative 4c would have a higher potential for short-term impacts to surface water while the new extended creek channel is put into service. Additional construction near the Holden Village during Railroad Creek relocation would also present greater risks to the local community than the actions included under Alternatives 2a through 4b. The time required to reach remediation goals is expected to be less than for Alternatives 1, 2a, 2b, and 4a. However, greater short-term improvements in Railroad Creek water quality are predicted under Alternatives 3a, 3b, 4b, and 5a through 8.	Potential short-term impacts to workers, the local community, and environment would be similar to combined Alternatives 3b and 4a. The time required to reach remediation goals is predicted to be less than under Alternatives 1 through 4c. However, the short-term effectiveness would be similar to Alternatives 3a, 3b, and 5b through 8 since Railroad Creek water quality is predicted to be protective of resident aquatic species following remedy implementation.	Potential short-term impacts to workers, the local community, and environment would be similar to combined Alternatives 3b and 4b. The time required to reach remediation goals is predicted to be less than under Alternatives 1 through 5a. However, the short-term effectiveness would be similar to Alternatives 3a, 3b, 5a, and 5c through 8 since Railroad Creek water quality is predicted to be protective of resident aquatic species following remedy implementation.	Potential short-term impacts to workers, the local community, and environment would be similar to combined Alternatives 3b and 4c. The time required to reach remediation goals is predicted to be similar to Alternatives 5b and 5d. However, the short-term effectiveness would be similar to Alternatives 3a, 3b, 5a, 5b, and 5d through 8 since Railroad Creek water quality is predicted to be protective of resident aquatic species following remedy implementation.	Similar to Alternative 5c; however, Alternative 5d would have a higher potential for short-term impacts to West Area vegetation and surface water during construction of the lower West Area barrier wall/collection system. The time required to reach remediation goals is predicted to be similar to Alternatives 5b and 5c. However, the short-term effectiveness would be similar to Alternatives 3a, 3b, 5a, 5b, 5c, and 6a through 8 since Railroad Creek water quality is predicted to be protective of resident aquatic species following remedy implementation.
Implementability	Actions included under Alternative 4b, including construction and operation of the extended barrier wall/collection system and East Area water treatment system would be difficult to implement and would be less implementable than the actions under Alternatives 4a or 4c due to subsurface conditions in the East Area and high iron concentrations in East Area waters, which would likely foul collection system components.	Actions included under Alternative 4c would be moderately implementable due to increased design and restoration requirements associated with extended Railroad Creek relocation and construction of the extended East Area collection/treatment system. However, these actions would be more implementable than those included under Alternative 4b.	Technical and administrative implementability would be similar to combined Alternatives 3b and 4a.	Technical and administrative implementability would be similar to combined Alternatives 3b and 4b.	Technical and administrative implementability would be similar to combined Alternatives 3b and 5c.	Alternative 5d would have lower technical implementability than 5c due to the additional design and construction requirements associated with the secondary lower West Area barrier wall/collection system.
Estimated Total Cost (Million USD)	$67.5	$32.4	$41.3	$74.3	$40.4	$45.8

Table 8-1
Comparative Analysis Summary

Evaluation Criteria	**Alt 6a** Water Management, Extended Secondary West Area Collection, Extended Railroad Creek Relocation, and East/West Area Treatment (Mechanical WTP)	**Alt 6b** Water Management, Extended Secondary West Area Collection, Extended Railroad Creek Relocation, and East/West Area Treatment (Mechanical WTP with Bulkhead)	**Alt 7** Capping, Consolidation, Water Management, and West Area Treatment	**Alt 8** Source Control and East/West Area Treatment
Primary Balancing Criteria				
Long-term Effectiveness & Permanence	Similar improvements in long-term Railroad Creek water quality are expected under Alternative 6a as described for Alternatives 5b, 5c, 5d, and 6b. Alternative 6a would have similar long-term effectiveness as predicted for Alternatives 3a, 3b, 5a, 5b, 5c, and 6a through 8. However, the significant long-term O&M requirements and dependence on diesel generated power for continued mechanical treatment would result in lower long-term reliability.	Similar improvements in long-term Railroad Creek water quality are expected under Alternative 6b as described for Alternatives 5b through 6a. Alternative 6b would have similar long-term effectiveness as predicted for Alternatives 3a, 3b, 5a, 5b, 5c, and 6a through 8. However, the significant long-term O&M requirements and dependence on a reliable power source for continued mechanical treatment would result in lower long-term reliability.	Slight improvements in long-term Railroad Creek water quality are expected under Alternative 7 compared to Alternatives 5b through 6b due to tailings pile consolidation and capping. Alternative 7 would have similar long-term effectiveness as predicted for Alternatives 3a, 3b, 5a through 6b, and 8. However, continued maintenance of the tailings pile cap would be required to ensure the long-term effectiveness and permanence of this alternative.	Improved long-term Railroad Creek water quality is expected under Alternative 8 compared to Alternatives 1 through 7 due to tailings and waste rock consolidation and capping. Alternative 8 would have similar long-term effectiveness as predicted for Alternatives 3a, 3b, and 5a through 7. However, continued maintenance of the consolidated cap would be required to ensure the long-term effectiveness and permanence of this alternative.
Reduction of Toxicity, Mobility, and Volume	Similar to Alternatives 5b, 5c, 5d, 6b and 8, alkaline precipitation processes included for the East and West Areas would reduce the mass and volume of PCOCs released. The volume of PCOCs released from the Site would also be reduced over time through source controls and natural geochemical attenuation processes.	Similar to Alternatives 5b, 5c, 5d, 6a and 8, alkaline precipitation processes included for the East and West Areas would reduce the mass and volume of PCOCs released. The volume of PCOCs released from the Site would also be reduced over time through source controls and natural geochemical attenuation processes.	Alkaline precipitation processes included for the West Area would reduce the mass and volume of PCOCs released, as described for Alternatives 3a and 3b. Additionally, the volume of PCOCs released from the Site would be reduced over time through source controls and natural geochemical attenuation processes.	Similar to Alternatives 5b through 6b, alkaline precipitation processes included for the East and West Areas would reduce the mass and volume of PCOCs released. The volume of PCOCs released from the Site would also be reduced over time through source controls and natural geochemical attenuation processes.
Short-term Effectiveness	Similar to Alternative 5d; however, Alternative 6a would have a higher risk to workers and the environment due to increased fuel shipments and long-term O&M requirements associated with a mechanical treatment system. The potential for short-term impacts to West Area vegetation and surface water during construction of the extended lower West Area barrier wall/collection system would also be higher. The time required to reach remediation goals is predicted to be similar to Alternatives 5b, 5c, and 5d, although cadmium concentrations are predicted to remain above the NRWQC in the long-term. The short-term effectiveness would be similar to Alternatives 3a, 3b, 5a, 5b, 5c, 5d, and 6b through 8 since Railroad Creek water quality is predicted to be protective of resident aquatic species following remedy implementation.	Similar to Alternative 6a.	The potential for short-term impacts due to West Area actions would be similar to Alternative 3b. However, the significant earth work and materials transport required for tailings pile consolidation and capping would greatly increase the potential for accidents and impacts to workers, the local community, and environment relative to Alternatives 1 through 6b. The time to reach remediation goals is predicted to be similar to Alternatives 5b, 5c, and 5d. However, the short-term effectiveness would be similar to Alternatives 3a, 3b, 5a through 6b, and 8 since Railroad Creek water quality is predicted to be protective of resident aquatic species following remedy implementation.	Potential short-term impacts to workers, the local community, and environment would be similar to Alternative 7. The time required to reach remediation goals is predicted to be less than Alternatives 1 through 7. However, the short-term effectiveness would be similar to Alternatives 3a, 3b, and 5a through 7since Railroad Creek water quality is predicted to be protective of resident aquatic species following remedy implementation.
Implementability	The additional actions included under Alternative 6a, including construction and operation of the extended lower West Area barrier wall/collection system and mechanical treatment would have low technical implementability due to construction on steep side slopes, variable subsurface conditions, and significant long-term O&M and diesel generated power requirements.	Similar to Alt 6a, but additional design and construction activities would be required for the installation of hydrostatic bulkheads.	Although Alternative 7 utilizes conventional equipment and construction techniques, this alternative would be more difficult to implement than Alternatives 1 through 6 due the significant earth work and materials transport requirements for tailings pile consolidation and capping.	Similar to Alternative 7, but additional design and construction activities would be required for installation of the East Area groundwater collection and treatment system.
Estimated Total Cost (Million USD)	$77.4	$74.5	$100.4	$113.0

Table 8-1
Comparative Analysis Summary

Evaluation Criteria	**Alt 1** **No Action/ Institutional Controls**	**Alt 2a** **Water Management** **(Open Portal)**	**Alt 2b** **Water Management** **(Hydrostatic Bulkheads)**	**Alt 3a** **Water Management and** **Low-Energy West Area Treatment** **(Open Portal)**	**Alt 3b** **Water Management and** **Low-Energy West Area Treatment** **(Hydrostatic Bulkheads)**	**Alt 4a** **Water Management and** **East Area Partial Collection and Treatment**
Additional Washington State MTCA Criteria						
Use of Permanent Solutions to the Maximum Extent Practicable	Because Alternative 1 does not include any active remedial measures, this alternative would not be expected to meet the MTCA requirements for use of permanent solutions to the maximum extent practicable.	The remedial actions included under Alternative 2a constitute permanent solutions. However, additional measures included under Alternative 3b, including the collection and treatment of the portal drainage and West Area seeps/groundwater are practical, effective, and are expected to provide a greater degree of protectiveness by significantly reducing PCOC concentrations in Railroad Creek.	The remedial actions included under Alternative 2b constitute permanent solutions. However, additional measures included under Alternative 3b, including the collection and treatment of the portal drainage and West Area seeps/groundwater are practical, effective, and are expected to provide a greater degree of protectiveness by significantly reducing PCOC concentrations in Railroad Creek.	The remedial actions included under Alternative 3a constitute permanent solutions and could be designed, constructed, and implemented in a reliable and effective manner to significantly reduce seasonal PCOC concentrations in groundwater and surface water and protect aquatic life in Railroad Creek. However, the additional flow equalization included under Alternative 3b is expected to be practical and result in greater treatment effectiveness and reliability.	The remedial actions included under Alternative 3b constitute permanent solutions and could be designed, constructed, and implemented in a reliable and effective manner to significantly reduce seasonal PCOC concentrations in groundwater and surface water and protect aquatic life in Railroad Creek. The additional costs associated with Alternatives 4 through 8 compared to Alternative 3b are disproportionate to the potential incremental benefits to aquatic life in Railroad Creek. Therefore, this alternative constitutes the use of permanent solutions to the maximum extent practical under MTCA.	The remedial actions included under Alternative 4a constitute permanent solutions. However, measures included under Alternative 3b, including the collection and treatment of the portal drainage and West Area seeps/groundwater are practical, effective, and are expected to provide a greater degree of protectiveness by significantly reducing PCOC concentrations in Railroad Creek.
Reasonable Restoration Time Frame	No remedial actions are included under Alternative 1 to mitigate potential short-term risks to terrestrial or aquatic ecological receptors. Therefore, Alternative 1 would not likely meet MTCA requirements for a reasonable restoration time-frame.	Soil RAOs would be met following remedy implementation. PCOC loading to groundwater would be reduced over time, and the groundwater and surface-water RAOs are predicted to be met in the long term. However, predicted short-term seasonal PCOC concentrations may result in continued potential risks to aquatic life in Railroad Creek. Therefore, the actions under Alternative 2a would not likely meet MTCA requirements for a reasonable restoration time frame.	As described for Alternative 2a, the actions included under Alternative 2b would not likely meet MTCA requirements for a reasonable restoration time frame.	Alternative 3a would address potential risks to human health, and terrestrial and aquatic ecological receptors in the short term following remedy implementation. However, the additional flow equalization provided under Alternative 3b is expected to be practical and achieve greater reductions in PCOC concentrations in Railroad Creek. Therefore, Alternative 3a would not likely meet MTCA requirements for a reasonable restoration time frame.	Alternative 3b would address potential risks to human health and terrestrial and aquatic ecological receptors in the short term following remedy implementation. Alternatives 5a, 5b, 5c, 5d, 7, and 8 would potentially achieve ARARs within a shorter restoration time frame. However the additional costs associated with these alternatives are disproportionate to the potential incremental benefits. Therefore, Alternative 3b would provide a reasonable restoration time frame.	As described for Alternatives 2a and 2b, the actions included under Alternative 4a would not likely meet MTCA requirements for a reasonable restoration time frame.
Additional Criterion as Required by AOC						
Natural Resource Restoration	Natural resource restoration would not be achieved at the Site in the short-term. The release of hazardous substances from Site sources is expected to decline over time through natural geochemical attenuation processes, thereby resulting in improved groundwater and surface water quality in the long-term.	Restoration would be achieved for soils and vegetation in the West Area and terrestrial wildlife across the Site. Although not an injured resource, tailings pile revegetation efforts are expected to provide replacement terrestrial habitat in the long term. Improvements in groundwater and surface water quality are predicted over time and PCOC concentrations in Railroad Creek are expected to achieve potential ARARs in the long term.	Similar to Alt 2a.	Similar natural resource restoration for soils, vegetation, and terrestrial wildlife as Alternatives 2a and 2b. Additional improvements in groundwater quality, Railroad Creek water quality, and aquatic resources are expected in the short term through West Area treatment under Alternative 3a. PCOC concentrations in Railroad Creek are predicted to be protective of resident aquatic species in the short term.	Similar to Alternative 3a; however, slight improvements in Railroad Creek water quality are expected in the short and long term under this alternative through equalization of the portal drainage and West Area seep/groundwater flows. PCOC concentrations in Railroad Creek are predicted to be protective of resident aquatic species in the short term.	Similar to Alternative 2b; however, slight improvements in Railroad Creek water quality and aquatic habitat are expected in the short and long term over Alternative 2b through the partial collection and treatment of East Area seeps and groundwater, and habitat enhancement measures implemented adjacent to the Site.

Table 8-1
Comparative Analysis Summary

Evaluation Criteria	**Alt 4b** Water Management and Extended East Area Collection and Treatment	**Alt 4c** Water Management, Extended Railroad Creek Relocation, East Area Collection and Treatment	**Alt 5a** Water Management, Partial East Area Collection, and East/West Area Treatment (Low-Energy WTP)	**Alt 5b** Water Management, Extended East Area Collection, and East/West Area Treatment (Low-Energy WTP)	**Alt 5c** Water Management, Extended Railroad Creek Relocation, and East/West Area Treatment (Low-Energy WTP)	**Alt 5d** Water Management, Secondary West Area Collection, Extended Railroad Creek Relocation, and East/West Area Treatment (Low-Energy WTP)
Additional Washington State MTCA Criteria						
Use of Permanent Solutions to the Maximum Extent Practicable	The remedial actions included under Alternative 4b constitute permanent solutions. However, measures included under Alternative 3b, including the collection and treatment of the portal drainage and West Area seeps/groundwater are practical, effective, and are expected to provide a greater degree of protectiveness by significantly reducing PCOC concentrations in Railroad Creek.	The remedial actions included under Alternative 4c constitute permanent solutions. However, measures included under Alternative 3b, including the collection and treatment of the portal drainage and West Area seeps/groundwater are practical, effective, and are expected to provide a greater degree of protectiveness by significantly reducing PCOC concentrations in Railroad Creek.	The remedial actions included under Alternative 5a constitute permanent solutions and are predicted to significantly reduce seasonal PCOC concentrations in groundwater and surface water and protect aquatic life in Railroad Creek. However, the East Area actions included under this alternative would have moderate implementability and the additional costs associated with Alternative 5a compared to Alternative 3b (approximately $13.1 million) are disproportionate to the potential incremental environmental benefits.	The remedial actions included under Alternative 5b constitute permanent solutions and are predicted to significantly reduce seasonal PCOC concentrations in groundwater and surface water and protect aquatic life in Railroad Creek. However, the East Area actions included under this alternative would have low implementability and the additional costs associated with Alternative 5b compared to Alternative 3b (approximately $46.2 million) are disproportionate to the potential incremental environmental benefits.	The remedial actions included under Alternative 5c constitute permanent solutions and are predicted to significantly reduce seasonal PCOC concentrations in groundwater and surface water and protect aquatic life in Railroad Creek. However, the East Area actions included under this alternative would have moderate implementability and the additional costs associated with Alternative 5c compared to Alternative 3b (approximately $12.2 million) are disproportionate to the potential incremental environmental benefits.	The remedial actions included under Alternative 5d constitute permanent solutions and are predicted to significantly reduce seasonal PCOC concentrations in groundwater and surface water and protect aquatic life in Railroad Creek. However, the secondary collection of lower West Area groundwater and the East Area actions included under this alternative would have moderate implementability, and the additional costs associated with Alternative 5d compared to Alternative 3b (approximately $17.6 million) are disproportionate to the potential incremental environmental benefits.
Reasonable Restoration Time Frame	As described for Alternatives 2a, 2b, and 4a, the actions included under Alternative 4b would not likely meet MTCA requirements for a reasonable restoration time frame.	As described for Alternatives 2a, 2b, 4a, and 4b, the actions included under Alternative 4c would not likely meet MTCA requirements for a reasonable restoration time frame.	Alternative 5a would address potential risks to human health and terrestrial and aquatic ecological receptors in the short term following remedy implementation. However, the additional costs associated with Alternative 5a are disproportionate to the potential incremental benefits compared to Alternative 3b.	Alternative 5b would address potential risks to human health and terrestrial and aquatic ecological receptors in the short term following remedy implementation. However, the additional costs associated with Alternative 5b are disproportionate to the potential incremental benefits compared to Alternative 3b.	Alternative 5c would address potential risks to human health and terrestrial and aquatic ecological receptors in the short term following remedy implementation. However, the additional costs associated with Alternative 5c are disproportionate to the potential incremental benefits compared to Alternative 3b.	Alternative 5d would address potential risks to human health and terrestrial and aquatic ecological receptors in the short term following remedy implementation. However, the additional costs associated with Alternative 5a are disproportionate to the potential incremental benefits compared to Alternative 3b.
Additional Criterion as Required by AOC						
Natural Resource Restoration	Similar to Alternative 2b; however, improvements in Railroad Creek water quality and aquatic habitat are expected in the short and long term due to the extended collection and treatment of East Area seeps and groundwater, and habitat enhancement measures implemented adjacent to the Site.	Similar to Alt 4b, but additional restoration of aquatic habitat is expected adjacent to the Site through the extended relocation of Railroad Creek, and habitat enhancement measures implemented adjacent to the Site.	Similar to Alternative 3b; however, slight improvements in Railroad Creek water quality and aquatic habitat are expected in the short and long term through the partial collection and treatment of East Area seeps and groundwater, and habitat enhancement measures adjacent to the Site. PCOC concentrations in Railroad Creek are predicted to be protective of aquatic species in the short term.	Similar to Alt 5a, but may provide additional short-term improvements in aquatic habitat through extended collection and treatment of East Area seeps. PCOC concentrations in Railroad Creek are predicted to be protective of aquatic species in the short term.	Similar to Alt 5b, but additional restoration of aquatic habitat is expected adjacent to the Site through extended relocation of Railroad Creek. PCOC concentrations in Railroad Creek are predicted to be protective of aquatic species in the short term.	Similar to Alt 5c, 6a, and 6b. PCOC concentrations in Railroad Creek are predicted to be protective of aquatic species in the short term.

Table 8-1
Comparative Analysis Summary

Evaluation Criteria	**Alt 6a** **Water Management, Extended Secondary West Area Collection, Extended Railroad Creek Relocation, and East/West Area Treatment (Mechanical WTP)**	**Alt 6b** **Water Management, Extended Secondary West Area Collection, Extended Railroad Creek Relocation, and East/West Area Treatment (Mechanical WTP with Bulkhead)**	**Alt 7** **Capping, Consolidation, Water Management, and West Area Treatment**	**Alt 8** **Source Control and East/West Area Treatment**
Additional Washington State MTCA Criteria				
Use of Permanent Solutions to the Maximum Extent Practicable	The remedial actions included under Alternative 6a constitute permanent solutions and are predicted to significantly reduce seasonal PCOC concentrations in groundwater and surface water and protect aquatic life in Railroad Creek. However, mechanical treatment, extended secondary collection of lower West Area groundwater, and the East Area actions included under this alternative would have low technical implementability, and the additional costs associated with Alternative 6a compared to Alternative 3b (approximately $49.2 million) are disproportionate to the potential incremental environmental benefits.	The remedial actions included under Alternative 6b constitute permanent solutions and are predicted to significantly reduce seasonal PCOC concentrations in groundwater and surface water and protect aquatic life in Railroad Creek. However, mechanical treatment, extended secondary collection of lower West Area groundwater, and the East Area actions included under this alternative would have low technical implementability, and the additional costs associated with Alternative 6b compared to Alternative 3b (approximately $46.3 million) are disproportionate to the potential incremental environmental benefits.	The remedial actions included under Alternative 7 constitute permanent solutions and are predicted to significantly reduce seasonal PCOC concentrations in groundwater and surface water and protect aquatic life in Railroad Creek. However, tailings pile consolidation and capping would have low implementability, and the additional costs associated with Alternative 7 compared to Alternative 3b (approximately $72.2 million) are disproportionate to the potential incremental environmental benefits.	The remedial actions included under Alternative 8 constitute permanent solutions and are predicted to significantly reduce seasonal PCOC concentrations in groundwater and surface water and protect aquatic life in Railroad Creek. However, tailings pile consolidation and capping would have low implementability, and the additional costs associated with Alternative 8 compared to Alternative 3b (approximately $84.9 million) are disproportionate to the potential incremental environmental benefits.
Reasonable Restoration Time Frame	Alternative 6a would address potential risks to human health and terrestrial and aquatic ecological receptors in the short term following remedy implementation. However, the actions included under Alternative 6a are not practicable, and the additional costs are disproportionate to the potential incremental benefits compared to Alternative 3b.	Alternative 6b would address potential risks to human health and terrestrial and aquatic ecological receptors in the short term following remedy implementation. However, the actions included under Alternative 6b are not practicable, and the additional costs are disproportionate to the potential incremental benefits compared to Alternative 3b.	Alternative 7 would address potential risks to human health and terrestrial and aquatic ecological receptors in the short term following remedy implementation. However, the actions included under Alternative 7 are not practicable, and the additional costs are disproportionate to the potential incremental benefits compared to Alternative 3b.	Alternative 8 would address potential risks to human health and terrestrial and aquatic ecological receptors in the short term following remedy implementation. However, the actions included under Alternative 8 are not practicable, and the additional costs are disproportionate to the potential incremental benefits compared to Alternative 3b.
Additional Criterion as Required by AOC				
Natural Resource Restoration	Similar to Alternatives 5c, 5d, and 6b. PCOC concentrations in Railroad Creek are predicted to be protective of aquatic species in the short term.	Similar to Alternatives 5c, 5d, and 6a. PCOC concentrations in Railroad Creek are predicted to be protective of aquatic species in the short term.	Restoration in the West Area would be similar to Alternative 3b. Through tailings pile consolidation, Alternative 7 would also provide potential replacement habitat at the current location of tailings pile 1. However, prevention of the establishment of deep-rooted plants on the low-permeability cover would reduce the potential for significant upland habitat in this area. PCOC concentrations in Railroad Creek are predicted to be protective of aquatic species in the short term.	Similar to Alternative 7. PCOC concentrations in Railroad Creek are predicted to be protective of aquatic species in the short term.

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DRAFT FINAL FEASIBILITY STUDY

HOLDEN MINE SITE

Appendices A through K

Prepared for

INTALCO

By

URS CORPORATION

February 19, 2004

APPENDIX A
SITE-WIDE BASELINE LOADING ANALYSIS
(Tables Also Included on a CD in Appendix D)

TABLES

FIGURES

ATTACHMENT A-1

Tables A-1 and A-2 Notes
Loading Calculations - Railroad Creek, West Area
Holden Mine RI/FS

General Notes:

Underlined concentrations represent metals which were not detected in the sample. A value of one-half (1/2) the reporting limit was used for the loading calculations.
NF = No Flow
NA = Not Analyzed

Notes: (Tables referenced below from the DRI Report, July 28, 1998)

a Flow data from Table 6.6-1 (May) and 6.6-2 (September); concentration data from Table 5.3-22 (RC-6 and RC-1; May 19 - 20, 1997) and 5.3-28 (RC-4 and RC-2). An average of the concentrations reported for RC-6 North Bank and RC-6X North Bank was used for RC-6 September 1997 values.
b Flow data from Table 4.3-6 (July 1997, average flow assumed to be 4 gpm); concentration data from Table 5.4-2 (July 1997)
c Unaccounted groundwater load calculated by subtracting the cumulative surface water load to RRC at the confluence of SP-26 from the measured load at RC-1.
d Flow data from Table 6.6-1; concentration data from Table 5.4-2
e Flow and concentration data from Table 5.3-30
f Flow loss taken from DRI section 4.4.4.5; load to subsurface calculated by multiplying the reported flow loss by the average of metals concentrations measured at P-1 and P-5.
h Flow data from Table 6.6-4; concentration data from Table 5.4-2
I Flow data from Table 4.3-6 (assumed to be 1.5 gpm); concentration data from Table 5.4-2
j The un-accounted groundwater load was calculated by subtracting the cumulative surface water load to RRC from the measured loading at RC-4. The unaccounted flow was taken from the "Reach 1 Balance" on Tables 6.6-1 (May) and 6.6-2 (September). Metals concentrations were back-calculated based on the calculated unaccounted load and the unaccounted flow (Reach 1 Balance). If the unaccounted load was negative (-) then the concentration was not calculated and reported as 0.
k Flow data from Table 4.3-6 (assumed to be 42.5 gpm); concentration data from Table 5.4-2
l Load loss from SP-8 to SP-19 calculated by subtracting the loading measured at SP-19 from the loading measured at SP-8.
m Groundwater contribution from the Mine Influenced Area presented in the flow net analysis (FS Figure A-8 and Table A1-1). Flow tube S1 is shown on Loading Analysis Figure A-8. Groundwater contribution from flow tube S1 in September 1997 is presented on FS Table A-4.
n Flow data from Table 6.6-1; concentration data from Table 5.3-32
o Loading measured at SP-19 is subtracted from the loading measured at CCD-1 to differentiate the load attributed to the Copper Creek Diversion (CCD-1 minus SP-19) from the East Waste Rock Pile loading (SP-19).
p Calculated by adding the measured surface water loading downcreek of RC-4 to measured load at RC-4. If constituent not analyzed for at RC-4, the total cumulative loading value was reported (e.g. arsenic)
q Flow data from Table 6.6-2; concentration data from Table 5.4-2
r No flow in September 1997 per Table 4.3-6
s Recorded as "Very Low Flow" in September 1997 per Table 4.3-6. Flow assumed to be 0.001 L/s for loading calculations.
t Potential source area due to elevated metals concentrations in soils. No surface water discharge observed, only infiltration from the lagoon bottom.
u Loading associated with west area sources calculated by subtracting the measured loading at RC-6 from the total west area loading (see note "p" above).

Table A-1
Loading Calculations - Railroad Creek, West Area - May 1997
Figures A-1 and A-2
Holden Mine RI/FS

Source Area	Seep/Tributary Discharge to RRC	Discharges To	Flows (L/s)	Magnesium: Conc. (mg/L)	Magnesium – Loading to Subsurface, Seeps, or Tributaries From Source Area: Load to Subsurf/ Seep/ Tributary (kg/d)	Total Load to Subsurf (kg/d)	% Load of RC-2	Magnesium – Surface Water Loading to RRC from Source Area: Load to RRC (kg/d)	Total Load to RRC (kg/d)	% Load at RC-2 (%)	Magnesium – Cumulative Surface Water Loading to RRC: Load (kg/d)	% Load of RC-2	Aluminum: Conc. (mg/L)	Aluminum – Loading to Subsurface, Seeps, or Tributaries From Source Area: Load to Subsurf/ Seep/ Tributary (kg/d)	Total Load to Subsurf (kg/d)	% Load of RC-2	Aluminum – Surface Water Loading to RRC from Source Area: Load to RRC (kg/d)	Total Load to RRC (kg/d)	% Load at RC-2 (%)	Aluminum – Cumulative Surface Water Loading to RRC: Load (kg/d)	% Load of RC-2
Measured Value at RC-6 (a)			*14159.0*	*0.4*					*440.40*	*53.9%*	*440.40*	*53.9%*	*0.02*					*18.35*	*15.7%*	*18.35*	*15.7%*
SP-26																					
	SP-26 (b)	RRC	0.3	0.5				0.01		0.0%			0.03				0.00		0.0%		
	Source Area Total								0.01	0.0%	440.41	53.9%						0.00	0.0%	18.35	15.7%
Unaccounted (Groundwater) Load to RC-1 (c)									0.06	0.0%								18.35	15.7%		
Measured Value at RC-1 (a)			*14161.1*	*0.4*					*440.47*	*53.9%*	*440.47*	*53.9%*	*0.03*					*36.71*	*31.4%*	*36.71*	*31.4%*
SP-23/Honeymoon Heights																					
	SP-23 (d)	RRC	14.2	5.1				6.29		0.8%			7.89				9.68		8.3%		
	SP-23B (d)	RRC	1.9	3.9				0.64		0.1%			5.25				0.86		0.7%		
	SP-12 (d)	RRC	1.9	1.5				0.24		0.0%			1.38				0.23		0.2%		
	Source Area Total								7.17	0.9%	447.64	54.8%						10.76	9.2%	47.47	40.7%
Underground Mine																					
	P-1 (e)	P-5	74.5	10.7									13.2								
	P-5 (e)	RRC	96.8	9.3				77.73		9.5%			5.84				48.86		41.9%		
	Loss P-1 to P-5 (f)	GW	9.9	*10.0*	*8.5*		1.0%						9.52	*8.1*		7.0%					
	Source Area Total					8.5	1.0%		77.73	9.5%	525.37	64.3%			8.14	7.0%		48.86	41.9%	96.33	82.5%
West Waste Rock Pile																					
	SP-6 (h)	SP15E->Lagoon	0.4	15.0	0.6		0.1%						14.60	0.6		0.5%					
	SP-15W (h)	Lagoon	2.1	2.6	0.5		0.1%						0.03	0.0		0.0%					
	Source Area Total					1.0	0.1%				525.37	64.3%			0.56	0.5%				96.33	82.5%
Mill Building															8.70	7.46%					
	SP-22 (h)	GW	0.9	6.9	0.6		0.1%						0.19	0.0		0.0%					
	SP-7 (h)	SP15E->Lagoon	4.3	4.8	1.8		0.2%						0.19	0.1		0.1%					
	Source Area Total					2.3	0.3%				525.37	64.3%			0.09	0.1%				96.33	82.5%
Lagoon															8.79	7.53%					
	SP-16(s)	GW	(s)								525.37	64.3%								96.33	82.5%
West Area Seeps (Upstream of RC-4)																					
	SP-9 (d)	RRC	0.5	2.1				0.09		0.0%			0.03				0.00		0.0%		
	SP-11 (d)	RRC	0.5	3.2				0.13		0.0%			0.15				0.01		0.0%		
	SP-25 (i)	RRC	0.1	5.1				0.04		0.0%			0.89				0.01		0.0%		
	SP-24 (d)	RRC	0.9	6.2				0.51		0.1%			2.41				0.20		0.2%		
	Source Area Total								0.77	0.1%	526.14	64.4%						0.21	0.2%	96.54	82.7%
Unaccounted (Groundwater) Load to RC-4 (j)									48.92	6.0%								-59.84	-51.3%		
Measured Value at RC-4 (a)			*14161.1*	*0.5*					*575.05*	*70.4%*	*575.05*	*70.4%*	*0.03*					*36.71*	*31.4%*	*36.71*	*31.4%*
West Area Seeps (Downstream of RC-4)																					
	SP-10W (d)	RRC	0.3	3.9				0.11		0.0%			4.74				0.13		0.1%		
	SP-10E (d)	RRC	0.3	1.4				0.04		0.0%			9.85				0.27		0.2%		
	Source Area Total		0.6						0.14	0.0%	575.20	70.4%						0.40	0.3%	37.10	31.8%
East Waste Rock Pile																					
	SP-8 (h)	SP-19	0.6	5.4	0.3		0.0%						9.62	0.5		0.4%					
	SP-19 (k)	CCD->RRC	2.7	3.3				0.76		0.1%			4.64				1.07		0.9%		
	Loss SP-8 to SP-19 (l)	GW	NA	NA	-0.5		-0.1%						NA	-0.6		-0.5%					
	Source Area Total					-0.5	-0.1%		0.76	0.1%	575.96	70.5%			-0.60	-0.5%		1.07	0.9%	38.18	32.7%
Groundwater Flow from Native Material															8.19	7.01%					
	Flow Tube S1 (m)	RRC	1.3	4.4				0.48		0.1%			2.7				0.30		0.3%		
	Source Area Total								0.48	0.1%	576.44	70.6%						0.30	0.3%	38.47	33.0%
Copper Creek Diversion																					
	CC-D1 (n)	RRC	198.2	0.7									0.02								
	CC-D1 (minus SP-19) (o)	*RRC*	*NA*	*NA*				*10.54*		*1.3%*			NA				*-0.73*		*-0.6%*		
	Source Area Total								10.54	1.3%	586.98	71.8%						0.00	0.0%	38.47	33.0%
Total West Area Surface Water Loading to RRC (p)			**14359.9**						**586.98**	**71.8%**	**586.98**	**71.8%**						**38.47**	**33.0%**	**38.47**	**33.0%**
Total West Area Loading to Subsurface						11.9	1.5%								8.79	7.5%					
Loading to Railroad Creek Associated w/West Area Sources (u)									**146.58**	**17.9%**								**20.12**	**17.2%**		
Measured Value at RC-2 (a)			**15009.5**	**0.6**					**817.00**	**100.0%**	**817.00**	**100.0%**	**0.09**					**116.71**	**100.0%**	**116.71**	**100.0%**

Table A-1
Loading Calculations - Railroad Creek, West Area - May 1997
Figures A-1 and A-2
Holden Mine RI/FS

				Cadmium									Copper								
	Seep / Tributary Information				Loading to Subsurface, Seeps, or Tributaries From Source Area			Surface Water Loading to RRC from Source Area			Cumulative Surface Water Loading to RRC			Loading to Subsurface, Seeps, or Tributaries From Source Area			Surface Water Loading to RRC from Source Area			Cumulative Surface Water Loading to RRC	
Source Area	Seep/Tributary Discharge to RRC	Discharges To	Flows (L/s)	Conc. (mg/L)	Load to Subsurf/ Seep/ Tributary (kg/d)	Total Load to Subsurf (kg/d)	% Load of RC-2	Load to RRC (kg/d)	Total Load to RRC (kg/d)	% Load at RC-2 (%)	Load (kg/d)	% Load of RC-2	Conc. (mg/L)	Load to Subsurf/ Seep/ Tributary (kg/d)	Total Load to Subsurf (kg/d)	% Load of RC-2	Load to RRC (kg/d)	Total Load to RRC (kg/d)	% Load at RC-2 (%)	Load (kg/d)	% Load of RC-2
Measured Value at RC-6 (a)			*14159.0*	*0.00*					*0.02*	*3.6%*	*0.024*	*3.6%*	*0.0*					*0.86*	*2.8%*	*0.86*	*2.8%*
SP-26																					
	SP-26 (b)	RRC	0.3	0.00				0.00		0.0%			0.0				0.00		0.0%		
	Source Area Total								0.00	0.0%	0.024	3.6%						0.00	0.0%	0.86	2.8%
Unaccounted (Groundwater) Load to RC-1 (c)									0.00	0.0%								0.49	1.6%		
Measured Value at RC-1 (a)			*14161.1*	*0.00*					*0.02*	*3.6%*	*0.024*	*3.6%*	*0.0*					*1.35*	*4.4%*	*1.35*	*4.4%*
SP-23/Honeymoon Heights																					
	SP-23 (d)	RRC	14.2	0.04				0.05		6.9%			6.9				8.40		27.5%		
	SP-23B (d)	RRC	1.9	0.03				0.00		0.7%			4.9				0.80		2.6%		
	SP-12 (d)	RRC	1.9	0.01				0.00		0.3%			2.0				0.33		1.1%		
	Source Area Total								0.05	7.9%	0.079	11.5%						9.53	31.1%	10.88	35.5%
Underground Mine																					
	P-1 (e)	P-5	74.5	0.08									5.8								
	P-5 (e)	RRC	96.8	0.05				0.44		63.9%			2.3				19.58		64.0%		
	Loss P-1 to P-5 (f)	GW	9.9	0.07	*0.06*		8.3%						4.1	*3.5*		11.3%					
	Source Area Total					0.06	8.3%		0.44	63.9%	0.518	75.4%			3.5	11.3%		19.58	64.0%	30.46	99.5%
West Waste Rock Pile																					
	SP-6 (h)	SP15E->Lagoon	0.4	0.17	0.01		1.0%						12.7	0.5		1.6%					
	SP-15W (h)	Lagoon	2.1	0.01	0.00		0.2%						0.2	0.0		0.1%					
	Source Area Total					0.01	1.2%				0.518	75.4%			0.5	1.7%				30.46	99.5%
Mill Building																					
	SP-22 (h)	GW	0.9	0.05	0.00		0.6%						2.1	0.2		0.6%					
	SP-7 (h)	SP15E->Lagoon	4.3	0.03	0.01		1.8%						2.8	1.0		3.4%					
	Source Area Total					0.02	2.4%				0.518	75.4%			1.2	4.0%				30.46	99.5%
Lagoon																					
	SP-16(s)	GW	(s)								0.518	75.4%								30.46	99.5%
West Area Seeps (Upstream of RC-4)																					
	SP-9 (d)	RRC	0.5	0.00				0.00		0.0%			0.0				0.00		0.0%		
	SP-11 (d)	RRC	0.5	0.01				0.00		0.1%			0.5				0.02		0.1%		
	SP-25 (i)	RRC	0.1	0.03				0.00		0.0%			1.9				0.02		0.1%		
	SP-24 (d)	RRC	0.9	0.05				0.00		0.6%			3.7				0.30		1.0%		
	Source Area Total								0.00	0.7%	0.523	76.1%						0.33	1.1%	30.79	100.6%
Unaccounted (Groundwater) Load to RC-4 (j)									0.02	2.2%							1.51		4.9%		
Measured Value at RC-4 (a)			*14161.1*	*0.00*				*0.54*	*0.54*	*78.3%*	*0.538*	*78.3%*	*0.0*				*32.30*	*32.30*	*105.5%*	*32.30*	*105.5%*
West Area Seeps (Downstream of RC-4)																					
	SP-10W (d)	RRC	0.3	0.03				0.00		0.1%			2.2				0.06		0.2%		
	SP-10E (d)	RRC	0.3	0.01				0.00		0.0%			0.8				0.02		0.1%		
	Source Area Total		0.6						0.00	0.1%	0.539	78.5%						0.08	0.3%	32.38	105.8%
East Waste Rock Pile																					
	SP-8 (h)	SP-19	0.6	0.09	0.00		0.6%						7.9	0.4		1.3%					
	SP-19 (k)	CCD->RRC	2.7	0.05				0.01		1.7%			4.2				0.97		3.2%		
	Loss SP-8 to SP-19 (l)	GW	NA	NA	-0.01		-1.1%						NA	-0.6		-1.9%					
	Source Area Total					-0.01	-1.1%		0.01	1.7%	0.551	80.1%			-0.6	-1.9%		0.97	3.2%	33.35	109.0%
Groundwater Flow from Native Material																					
	Flow Tube S1 (m)	RRC	1.3	0.03				0.00		0.5%			2.6				0.29		0.9%		
	Source Area Total								0.00	0.5%	0.555	80.7%						0.29	0.9%	33.64	109.9%
Copper Creek Diversion																					
	CC-D1 (n)	RRC	198.2	0.00									0.0								
	CC-D1 (minus SP-19) (o)	*RRC*	NA	NA				*0.02*		*2.7%*			NA				*-0.18*		*-0.6%*		
	Source Area Total								0.02	2.7%	0.573	83.4%						0.00	0.0%	33.64	109.9%
Total West Area Surface Water Loading to RRC (p)			**14359.9**						**0.57**	**83.4%**	**0.573**	**83.4%**						**33.64**	**109.9%**	**33.64**	**109.9%**
Total West Area Loading to Subsurface						0.08	11.9%								5.2	17.0%					
Loading to Railroad Creek Associated w/West Area Sources (u)									**0.55**	**79.8%**								**32.78**	**107.1%**		
Measured Value at RC-2 (a)			**15009.5**	**0.00**					**0.69**	**100.0%**	**0.687**	**100.0%**	**0.0**					**30.61**	**100.0%**	**30.61**	**100.0%**

Table A-1
Loading Calculations - Railroad Creek, West Area - May 1997
Figures A-1 and A-2
Holden Mine RI/FS

				Iron									Sulfate								
	Seep / Tributary Information				Loading to Subsurface, Seeps, or Tributaries From Source Area			Surface Water Loading to RRC from Source Area			Cumulative Surface Water Loading to RRC			Loading to Subsurface, Seeps, or Tributaries From Source Area			Surface Water Loading to RRC from Source Area			Cumulative Surface Water Loading to RRC	
Source Area	Seep/Tributary Discharge to RRC	Discharges To	Flows (L/s)	Conc. (mg/L)	Load to Subsurf/ Seep/ Tributary (kg/d)	Total Load to Subsurf (kg/d)	% Load of RC-2	Load to RRC (kg/d)	Total Load to RRC (kg/d)	% Load at RC-2 (%)	Load (kg/d)	% Load of RC-2	Conc. (mg/L)	Load to Subsurf/ Seep/ Tributary (kg/d)	Total Load to Subsurf (kg/d)	% Load of RC-2	Load to RRC (kg/d)	Total Load to RRC (kg/d)	% Load at RC-2 (%)	Load (kg/d)	% Load of RC-2
Measured Value at RC-6 (a)			*14159.0*	*0.03*					*36.70*	*9.4%*	*36.70*	*9.4%*	*5*					*5994*	*55.7%*	*5994*	*55.7%*
SP-26																					
	SP-26 (b)	RRC	0.3	0.01				0.00		0.0%			6				0		0.0%		
	Source Area Total								0.00	0.0%	36.70	9.4%						0	0.0%	5994	55.7%
Unaccounted (Groundwater) Load to RC-1 (c)									0.01	0.0%								3427	31.8%		
Measured Value at RC-1 (a)			*14161.1*	*0.03*					*36.71*	*9.4%*	*36.71*	*9.4%*	*8*					*9421*	*87.5%*	*9421*	*87.5%*
SP-23/Honeymoon Heights																					
	SP-23 (d)	RRC	14.2	0.01				0.01		0.0%			130				159		1.5%		
	SP-23B (d)	RRC	1.9	0.01				0.00		0.0%			100				16		0.2%		
	SP-12 (d)	RRC	1.9	0.01				0.00		0.0%			45				7		0.1%		
	Source Area Total								0.02	0.0%	36.72	9.4%						183	1.7%	9604	89.2%
Underground Mine																					
	P-1 (e)	P-5	74.5	0.24									270								
	P-5 (e)	RRC	96.8	0.19				1.59		0.4%			190				1590		14.8%		
	Loss P-1 to P-5 (f)	GW	9.9	*0.22*	*0.18*		0.0%						*230*	*197*		1.8%					
	Source Area Total					0.18	0.0%		1.59	0.4%	38.31	9.8%			197	1.8%		1590	14.8%	11194	104.0%
West Waste Rock Pile																					
	SP-6 (h)	SP15E->Lagoon	0.4	0.03	0.00		0.0%						600	23		0.2%					
	SP-15W (h)	Lagoon	2.1	0.01	0.00		0.0%						78	14		0.1%					
	Source Area Total					0.00	0.0%				38.31	9.8%			37	0.3%				11194	104.0%
Mill Building																					
	SP-22 (h)	GW	0.9	0.01	0.00		0.0%						200	16		0.2%					
	SP-7 (h)	SP15E->Lagoon	4.3	0.12	0.04		0.0%						79	29		0.3%					
	Source Area Total					0.05	0.0%				38.31	9.8%			45	0.4%				11194	104.0%
Lagoon																					
	SP-16(s)	GW	(s)								38.31	9.8%								11194	104.0%
West Area Seeps (Upstream of RC-4)																					
	SP-9 (d)	RRC	0.5	0.01				0.00		0.0%			44				2		0.0%		
	SP-11 (d)	RRC	0.5	0.01				0.00		0.0%			82				3		0.0%		
	SP-25 (i)	RRC	0.1	0.01				0.00		0.0%			170				1		0.0%		
	SP-24 (d)	RRC	0.9	0.22				0.02		0.0%			180				15		0.1%		
	Source Area Total								0.02	0.0%	38.33	9.9%						21	0.2%	11215	104.2%
Unaccounted (Groundwater) Load to RC-4 (j)									-13.86	-3.6%								-2651	-24.6%		
Measured Value at RC-4 (a)			*14161.1*	*0.02*				*24.47*	*24.47*	*6.3%*	*24.47*	*6.3%*	*7*				*8565*	*8565*	*79.6%*	*8565*	*79.6%*
West Area Seeps (Downstream of RC-4)																					
	SP-10W (d)	RRC	0.3	0.03				0.00		0.0%			170				5		0.0%		
	SP-10E (d)	RRC	0.3	14.10				0.38		0.1%			120				3		0.0%		
	Source Area Total		0.6						0.39	0.1%	24.86	6.4%						8	0.1%	8573	79.6%
East Waste Rock Pile																					
	SP-8 (h)	SP-19	0.6	0.03	0.0015		0.0%						240	12		0.1%					
	SP-19 (k)	CCD->RRC	2.7	0.07				0.02		0.0%			130				30		0.3%		
	Loss SP-8 to SP-19 (l)	GW	NA	NA	-0.01		0.0%						NA	-18		-0.2%					
	Source Area Total					-0.01	0.0%		0.02	0.0%	24.87	6.4%			-18	-0.2%		30	0.3%	8603	79.9%
Groundwater Flow from Native Material																					
	Flow Tube S1 (m)	RRC	1.3	0.135				0.01		0.0%			150				16.4		0.2%		
	Source Area Total								0.01	0.0%	24.89	6.4%						16	0.2%	8619	80.1%
Copper Creek Diversion																					
	CC-D1 (n)	RRC	198.2	0.23									0								
	CC-D1 (minus SP-19) (o)	*RRC*	*NA*	*NA*				*3.92*		*1.0%*			*NA*				*-30*		*-0.3%*		
	Source Area Total								3.92	1.0%	28.81	7.4%						0	0.0%	8619	80.1%
Total West Area Surface Water Loading to RRC (p)			**14359.9**						**28.81**	**7.4%**	**28.81**	**7.4%**						**8619**	**80.1%**	**8619**	**80.1%**
Total West Area Loading to Subsurface						0.23	0.1%								279	2.6%					
Loading to Railroad Creek Associated w/West Area Sources (u)									**-7.89**	**-2.0%**								**2625**	**24.4%**		
Measured Value at RC-2 (a)			**15009.5**	**0.30**					**389.05**	**100.0%**	**389.05**	**100.0%**	**8**					**10764**	**100.0%**	**10764**	**100.0%**

Table A-1
Loading Calculations - Railroad Creek, West Area - May 1997
Figures A-1 and A-2
Holden Mine RI/FS

				Zinc								
	Seep / Tributary Information				Loading to Subsurface, Seeps, or Tributaries From Source Area			Surface Water Loading to RRC from Source Area			Cumulative Surface Water Loading to RRC	
Source Area	Seep/Tributary Discharge to RRC	Discharges To	Flows (L/s)	Conc. (mg/L)	Load to Subsurf/ Seep/ Tributary (kg/d)	Total Load to Subsurf (kg/d)	% Load of RC-2	Load to RRC (kg/d)	Total Load to RRC (kg/d)	% Load at RC-2 (%)	Load (kg/d)	% Load of RC-2
Measured Value at RC-6 (a)			***14159.0***	***0.0***					***19.57***	***18.0%***	***19.57***	***18.0%***
SP-26												
	SP-26 (b)	RRC	0.3	0.0				0.00		0.0%		
	Source Area Total								0.00	0.0%	19.57	18.0%
Unaccounted (Groundwater) Load to RC-1 (c)									-3.67	-3.4%		
Measured Value at RC-1 (a)			*14161.1*	*0.0*					*15.91*	*14.6%*	*15.91*	*14.6%*
SP-23/Honeymoon Heights												
	SP-23 (d)	RRC	14.2	5.0				6.13		5.6%		
	SP-23B (d)	RRC	1.9	3.6				0.59		0.5%		
	SP-12 (d)	RRC	1.9	2.2				0.36		0.3%		
	Source Area Total								7.09	6.5%	22.99	21.1%
Underground Mine												
	P-1 (e)	P-5	74.5	14.9								
	P-5 (e)	RRC	96.8	8.8				73.80		67.7%		
	Loss P-1 to P-5 (f)	GW	9.9	11.9	*10.1*		9.3%					
	Source Area Total					10.1	9.3%		73.80	67.7%	96.79	88.9%
West Waste Rock Pile												
	SP-6 (h)	SP15E->Lagoon	0.4	22.1	0.8		0.8%					
	SP-15W (h)	Lagoon	2.1	2.3	0.4		0.4%					
	Source Area Total					1.3	1.1%				96.79	88.9%
Mill Building												
	SP-22 (h)	GW	0.9	7.4	0.6		0.5%					
	SP-7 (h)	SP15E->Lagoon	4.3	4.3	1.6		1.5%					
	Source Area Total					2.2	2.0%				96.79	88.9%
Lagoon												
	SP-16(s)	GW	(s)								96.79	88.9%
West Area Seeps (Upstream of RC-4)												
	SP-9 (d)	RRC	0.5	0.3				0.01		0.0%		
	SP-11 (d)	RRC	0.5	2.3				0.10		0.1%		
	SP-25 (i)	RRC	0.1	5.6				0.05		0.0%		
	SP-24 (d)	RRC	0.9	7.6				0.62		0.6%		
	Source Area Total								0.77	0.7%	97.56	89.6%
Unaccounted (Groundwater) Load to RC-4 (j)									-8.24	-7.6%		
Measured Value at RC-4 (a)			*14161.1*	*0.1*				*89.32*	*89.32*	*82.0%*	*89.32*	*82.0%*
West Area Seeps (Downstream of RC-4)												
	SP-10W (d)	RRC	0.3	3.2				0.09		0.1%		
	SP-10E (d)	RRC	0.3	0.7				0.02		0.0%		
	Source Area Total		0.6						0.11	0.1%	89.42	82.1%
East Waste Rock Pile												
	SP-8 (h)	SP-19	0.6	11.2	0.5		0.5%					
	SP-19 (k)	CCD->RRC	2.7	6.2				1.43		1.3%		
	Loss SP-8 to SP-19 (l)	GW	NA	NA	-0.9		-0.8%					
	Source Area Total					-0.9	-0.8%		1.43	1.3%	90.85	83.4%
Groundwater Flow from Native Material												
	Flow Tube S1 (m)	RRC	1.3	4.1				0.44		0.4%		
	Source Area Total								0.44	0.4%	91.30	83.8%
Copper Creek Diversion												
	CC-D1 (n)	RRC	198.2	0.2								
	CC-D1 (minus SP-19) (o)	*RRC*	*NA*	NA				*1.52*		*1.4%*		
	Source Area Total								1.52	1.4%	92.81	85.2%
Total West Area Surface Water Loading to RRC (p)			**14359.9**						**92.81**	**85.20%**	**92.81**	**85.2%**
Total West Area Loading to Subsurface						13.6	12.5%					
Loading to Railroad Creek Associated w/West Area Sources (u)									**73.24**	**67.2%**		
Measured Value at RC-2 (a)			**15009.5**	**0.1**					**108.93**	**100.0%**	**108.93**	**100.0%**

Table A-2
Loading Calculations - Railroad Creek, West Area - September 1997
Figures A-3 and A-4
Holden Mine RI/FS

				Magnesium									Aluminum								
	Seep / Tributary Information				Loading to Subsurface, Seeps, or Tributaries From Source Area			Surface Water Loading to RRC from Source Area			Cumulative Surface Water Loading to RRC			Loading to Subsurface, Seeps, or Tributaries From Source Area			Surface Water Loading to RRC from Source Area			Cumulative Surface Water Loading to RRC	
Source Area	Seep/Tributary Discharge to RRC	Discharges To	Flows (L/s)	Conc. (mg/L)	Load to Subsurf/ Seep/ Tributary (kg/d)	Total Load to Subsurf (kg/d)	% Load of RC-2	Load to RRC (kg/d)	Total Load to RRC (kg/d)	% Load at RC-2 (%)	Load (kg/d)	% Load of RC-2	Conc. (mg/L)	Load to Subsurf/ Seep/ Tributary (kg/d)	Total Load to Subsurf (kg/d)	% Load of RC-2	Load to RRC (kg/d)	Total Load to RRC (kg/d)	% Load at RC-2 (%)	Load (kg/d)	% Load of RC-2
Measured Value at RC-6 (a)			*3710.0*	*0.4*					*112.19*	*59.2%*	*112.19*	*59.2%*	*0.03*					*9.62*	*72.3%*	*9.62*	*72.3%*
SP-26																					
	SP-26 (q)	RRC	0.3	0.5				0.01		0.0%			0.01				0.00		0.0%		
	Source Area Total								0.01	0.0%	112.20	59.2%						0.00	0.0%	9.62	72.3%
Unaccounted (Groundwater) Load to RC-1 (c)									0.81	0.4%								-6.39	-48.0%		
Measured Value at RC-1 (a)			*3737.1*	*0.4*					*113.01*	*59.6%*	*113.01*	*59.6%*	*0.01*					*3.23*	*24.3%*	*3.23*	*24.3%*
SP-23/Honeymoon Heights																					
	SP-23 (r)	RRC	NF	0				0.00		0			0				0		0		
	SP-23B (r)	RRC	NF	0				0.00		0			0				0		0		
	SP-12 (r)	RRC	NF	0				0.00		0			0				0		0		
	Source Area Total								0.00	0.0%	113.01	59.6%						0.00	0.0%	3.23	24.3%
Underground Mine																					
	P-1 (e)	P-5	6.0	9.8									0.02								
	P-5 (e)	RRC	4.3	9.9				3.62		1.9%			0.02				0.01		0.1%		
	Loss P-1 to P-5 (f)	GW	1.7	*9.8*	*1.446*		0.8%						*0.02*	*0.00*		0.0%					
	Source Area Total					1.446	0.8%		3.62	1.9%	116.63	61.5%			0.00	0.0%		0.01	0.1%	3.24	24.3%
West Waste Rock Pile																					
	SP-6 (r)	P15E->Lagoo	NF	0	0.000		0						0	0.00		0.0%					
	SP-15W (r)	Lagoon	NF	0	0.000		0						0	0.00		0.0%					
	Source Area Total					0.000	0.0%				116.63	61.5%			0.00	0.0%				3.24	24.3%
Mill Building																					
	SP-22 (r)	GW	NF	0	0.000		0						0	0.00		0.0%					
	SP-7 (s)	P15E->Lagoo	0.0	11.5	0.001		0.0%						1.79	0.00		0.0%					
	Source Area Total					0.001	0.0%				116.63	61.5%			0.00	0.0%				3.24	24.3%
Lagoon															0.00						
	SP-16(t)	GW	(s)								116.63	61.5%			0.00001					3.24	24.3%
West Area Seeps (Upstream of RC-4)																					
	SP-9 (r)	RRC	NF	0				0.00		0			0				0		0		
	SP-11 (r)	RRC	NF	0				0.00		0			0				0		0		
	SP-25 (r)	RRC	NF	0				0.00		0			0				0		0		
	SP-24 (r)	RRC	NF	0				0.00		0			0				0		0		
	Source Area Total								0.00	0.0%	116.63	61.5%						0.00	0.0%	3.24	24.3%
Unaccounted (Groundwater) Load to RC-4 (j)									-5.26	-2.8%								-0.23	-1.7%		
Measured Value at RC-4 (a)			*3483.8*	*0.4*					*111.37*	*58.7%*	*111.37*	*58.7%*	*0.01*					*3.01*	*22.6%*	*3.01*	*22.6%*
West Area Seeps (Downstream of RC-4)																					
	SP-10W (r)	RRC	NF	0				0.00		0			0				0		0		
	SP-10E (r)	RRC	NF	0				0.00		0			0				0		0		
	Source Area Total								0.00	0.0%	111.37	58.7%						0.00	0.0%	3.01	22.6%
East Waste Rock Pile																					
	SP-8 (r)	SP-19	NF	0	0.000								0	0.00							
	SP-19 (r)	CCD->RRC	NF	0				0.00					0				0				
	Loss SP-8 to SP-19 (l)	GW			0.000		0.0%							0.00		0.0%					
	Source Area Total					0.000	0.0%		0.00	0.0%	111.37	58.7%			0.00	0.0%		0.00	0.0%	3.01	22.6%
Copper Creek Diversion																					
	CC-D1 (n)	RRC	198.2	0.5									0.01								
	CC-D1 (minus SP-19) (o)	*RRC*	NA	NA				*7.88*		*4.2%*			NA				*0.17*		*1.3%*		
	Source Area Total								7.88	4.2%	119.25	62.9%						0.17	1.3%	3.18	23.9%
Total West Area Surface Water Loading to RRC (p)			**3682.0**						**119.25**	**62.9%**	**119.25**	**62.9%**						**3.18**	**23.9%**	**3.18**	**23.9%**
Total West Area Loading to Subsurface						1.447	0.8%								0.00	0.0%					
Loading to Railroad Creek Associated w/West Area Sources (u)									**7.06**	**3.7%**								**-6.44**	**-48.4%**		
Measured Value at RC-2 (a)			*3850.9*	*0.6*					**189.65**	**100.0%**	**189.65**	**100.0%**	*0.04*					**13.31**	**100.0%**	**13.3**	**100.0%**

Table A-2
Loading Calculations - Railroad Creek, West Area - September 1997
Figures A-3 and A-4
Holden Mine RI/FS

Source Area	Seep/Tributary Discharge to RRC	Discharges To	Flows (L/s)	Cadmium Conc. (mg/L)	Cadmium: Loading to Subsurface, Seeps, or Tributaries From Source Area: Load to Subsurf/ Seep/ Tributary (kg/d)	Total Load to Subsurf (kg/d)	% Load of RC-2	Cadmium: Surface Water Loading to RRC from Source Area: Load to RRC (kg/d)	Total Load to RRC (kg/d)	% Load at RC-2 (%)	Cadmium: Cumulative Surface Water Loading to RRC: Load (kg/d)	% Load of RC-2	Copper Conc. (mg/L)	Copper: Loading to Subsurface, Seeps, or Tributaries From Source Area: Load to Subsurf/ Seep/ Tributary (kg/d)	Total Load to Subsurf (kg/d)	% Load of RC-2	Copper: Surface Water Loading to RRC from Source Area: Load to RRC (kg/d)	Total Load to RRC (kg/d)	% Load at RC-2 (%)	Copper: Cumulative Surface Water Loading to RRC: Load (kg/d)	% Load of RC-2
Measured Value at RC-6 (a)			*3710.0*	*0.0000*					*0.006*	*19.3%*	*0.01*	*19.3%*	*0.00*					*0.14*	*36.1%*	*0.14*	*36.1%*
SP-26																					
	SP-26 (q)	RRC	0.3	0.0003				0.000		0.0%			0.02				0.00		0.1%		
	Source Area Total								0.000	0.0%	0.01	19.3%						0.00	0.1%	0.14	36.3%
Unaccounted (Groundwater) Load to RC-1 (c)									0.000	0.1%								-0.02	-3.9%		
Measured Value at RC-1 (a)			*3737.1*	*0.0000*					*0.006*	*19.4%*	*0.01*	*19.4%*	*0.00*					*0.13*	*32.3%*	*0.13*	*32.3%*
SP-23/Honeymoon Heights																					
	SP-23 (r)	RRC	NF	0				0		0			0				0		0		
	SP-23B (r)	RRC	NF	0				0		0			0				0		0		
	SP-12 (r)	RRC	NF	0				0		0			0				0		0		
	Source Area Total								0.000	0.0%	0.01	19.4%						0.00	0.0%	0.13	32.3%
Underground Mine																					
	P-1 (e)	P-5	6.0	0.0080									0.08								
	P-5 (e)	RRC	4.3	0.0080				0.003		8.8%			0.03				0.01		2.6%		
	Loss P-1 to P-5 (f)	GW	1.7	*0.0080*	*0.001*		3.5%						*0.05*	*0.01*		1.9%					
	Source Area Total					0.001	3.5%		0.003	8.8%	0.01	28.2%			0.01	1.9%		0.01	2.6%	0.14	34.9%
West Waste Rock Pile																					
	SP-6 (r)	P15E->Lagoo	NF	0	0		0						0	0		0					
	SP-15W (r)	Lagoon	NF	0	0		0						0	0		0					
	Source Area Total					0.000	0.0%				0.01	28.2%			0	0.0%				0.14	34.9%
Mill Building																					
	SP-22 (r)	GW	NF	0	0		0						0	0		0					
	SP-7 (s)	P15E->Lagoo	0.0	0.0480	0.000		0.0%						7.56	0.00		0.2%					
	Source Area Total					0.000	0.0%				0.01	28.2%			0.00	0.2%				0.14	34.9%
Lagoon																					
	SP-16(t)	GW	(s)								0.01	28.2%								0.14	34.9%
West Area Seeps (Upstream of RC-4)																					
	SP-9 (r)	RRC	NF	0				0		0			0				0		0		
	SP-11 (r)	RRC	NF	0				0		0			0				0		0		
	SP-25 (r)	RRC	NF	0				0		0			0				0		0		
	SP-24 (r)	RRC	NF	0				0		0			0				0		0		
	Source Area Total								0.000	0.0%	0.01	28.2%						0.00	0.0%	0.14	34.9%
Unaccounted (Groundwater) Load to RC-4 (j)									0.009	26.0%								0.40	100.8%		
Measured Value at RC-4 (a)			*3483.8*	*0.0001*					*0.018*	*54.3%*	*0.02*	*54.3%*	*0.00*					*0.54*	*135.7%*	*0.54*	*135.7%*
West Area Seeps (Downstream of RC-4)																					
	SP-10W (r)	RRC	NF	0				0		0			0				0		0		
	SP-10E (r)	RRC	NF	0				0		0			0				0		0		
	Source Area Total								0.000	0.0%	0.02	54.3%						0.00	0.0%	0.54	135.7%
East Waste Rock Pile																					
	SP-8 (r)	SP-19	NF	0	0								0	0							
	SP-19 (r)	CCD->RRC	NF	0				0					0				0				
	Loss SP-8 to SP-19 (l)	GW			0.000		0.0%							0		0.0%					
	Source Area Total					0.000	0.0%		0.000	0.0%	0.02	54.3%			0	0.0%		0.00	0.0%	0.54	135.7%
Copper Creek Diversion																					
	CC-D1 (n)	RRC	198.2	0.0001									0.00								
	CC-D1 (minus SP-19) (o)	*RRC*	NA	NA				*0.002*		*5.1%*			NA				*0.02*		*4.3%*		
	Source Area Total								0.002	5.1%	0.02	59.4%						0.02	4.3%	0.56	140.0%
Total West Area Surface Water Loading to RRC (p)			**3682.0**						**0.020**	**59.4%**	**0.02**	**59.4%**						**0.56**	**140.0%**	**0.56**	**140.0%**
Total West Area Loading to Subsurface						0.001	3.5%								0.01	2.1%					
Loading to Railroad Creek Associated w/West Area Sources (u)									**0.013**	**40.2%**								**0.41**	**103.9%**		
Measured Value at RC-2 (a)			*3850.9*	*0.0001*					**0.033**	**100.0%**	**0.03**	**100.0%**	*0.00*					**0.40**	**100.0%**	**0.40**	**100.0%**

Table A-2
Loading Calculations - Railroad Creek, West Area - September 1997
Figures A-3 and A-4
Holden Mine RI/FS

				Iron									Sulfate								
	Seep / Tributary Information				Loading to Subsurface, Seeps, or Tributaries From Source Area			Surface Water Loading to RRC from Source Area			Cumulative Surface Water Loading to RRC			Loading to Subsurface, Seeps, or Tributaries From Source Area			Surface Water Loading to RRC from Source Area			Cumulative Surface Water Loading to RRC	
Source Area	Seep/Tributary Discharge to RRC	Discharges To	Flows (L/s)	Conc. (mg/L)	Load to Subsurf/ Seep/ Tributary (kg/d)	Total Load to Subsurf (kg/d)	% Load of RC-2	Load to RRC (kg/d)	Total Load to RRC (kg/d)	% Load at RC-2 (%)	Load (kg/d)	% Load of RC-2	Conc. (mg/L)	Load to Subsurf/ Seep/ Tributary (kg/d)	Total Load to Subsurf (kg/d)	% Load of RC-2	Load to RRC (kg/d)	Total Load to RRC (kg/d)	% Load at RC-2 (%)	Load (kg/d)	% Load of RC-2
Measured Value at RC-6 (a)			*3710.0*	*0.04*					*12.82*	*3.6%*	*12.82*	*3.6%*	*5*					*1539*	*67.0%*	*1539*	*67.0%*
SP-26																					
	SP-26 (q)	RRC	0.3	0.01				0.00		0.0%			1				0		0.0%		
	Source Area Total								0.00	0.0%	12.82	3.6%						0	0.0%	1539	67.0%
Unaccounted (Groundwater) Load to RC-1 (c)									0.09	0.0%								-376	-16.4%		
Measured Value at RC-1 (a)			*3737.1*	*0.04*					*12.92*	*3.6%*	*12.92*	*3.6%*	*4*					*1162*	*50.6%*	*1162*	*50.6%*
SP-23/Honeymoon Heights																					
	SP-23 (r)	RRC	NF	0				0		0			0				0		0		
	SP-23B (r)	RRC	NF	0				0		0			0				0		0		
	SP-12 (r)	RRC	NF	0				0		0			0				0		0		
	Source Area Total								0.00	0.0%	12.92	3.6%						0	0.0%	1162	50.6%
Underground Mine																					
	P-1 (e)	P-5	6.0	0.11									310								
	P-5 (e)	RRC	4.3	0.01				0.00		0.0%			340				125		5.4%		
	Loss P-1 to P-5 (f)	GW	1.7	*0.06*	*0.01*		0.0%						*325*	*48*		2.1%					
	Source Area Total					0.01	0.0%		0.00	0.0%	12.92	3.6%			48	2.1%		125	5.4%	1287	56.1%
West Waste Rock Pile																					
	SP-6 (r)	SP15E->Lagoo	NF	0	0		0.0%						0	0		0					
	SP-15W (r)	Lagoon	NF	0	0		0.0%						0	0		0					
	Source Area Total					0.00	0.0%				12.92	3.6%			0	0.0%				1287	56.1%
Mill Building																					
	SP-22 (r)	GW	NF	0	0		0.0%						0	0		0					
	SP-7 (s)	SP15E->Lagoo	0.0	0.71	0.00		0.0%						260	0		0.0%					
	Source Area Total					0.00	0.0%				12.92	3.6%			0	0.0%				1287	56.1%
Lagoon																					
	SP-16(t)	GW	(s)								12.92	3.6%								1287	56.1%
West Area Seeps (Upstream of RC-4)																					
	SP-9 (r)	RRC	NF	0				0		0			0				0		0		
	SP-11 (r)	RRC	NF	0				0		0			0				0		0		
	SP-25 (r)	RRC	NF	0				0		0			0				0		0		
	SP-24 (r)	RRC	NF	0				0		0			0				0		0		
	Source Area Total								0.00	0.0%	12.92	3.6%						0	0.0%	1287	56.1%
Unaccounted (Groundwater) Load to RC-4 (j)									-0.88	-0.2%								-83	-3.6%		
Measured Value at RC-4 (a)			*3483.8*	*0.04*					*12.04*	*3.4%*	*12.04*	*3.4%*	*4*					*1204*	*52.4%*	*1204*	*52.4%*
West Area Seeps (Downstream of RC-4)																					
	SP-10W (r)	RRC	NF	0				0		0			0				0		0		
	SP-10E (r)	RRC	NF	0				0		0			0				0		0		
	Source Area Total								0.00	0.0%	12.04	3.4%						0	0.0%	1204	52.4%
East Waste Rock Pile																					
	SP-8 (r)	SP-19	NF	0	0								0	0							
	SP-19 (r)	CCD->RRC	NF	0				0					0				0				
	Loss SP-8 to SP-19 (l)	GW			0.00		0.0%							0		0.0%					
	Source Area Total					0.00	0.0%		0.00	0.0%	12.04	3.4%			0	0.0%		0	0.0%	1204	52.4%
Copper Creek Diversion																					
	CC-D1 (n)	RRC	198.2	0.01									3								
	CC-D1 (minus SP-19) (o)	*RRC*	NA	NA				*0.17*		*0.0%*			NA				*49*		*2.1%*		
	Source Area Total								0.17	0.0%	12.21	3.4%						49	2.1%	1253	54.6%
Total West Area Surface Water Loading to RRC (p)			**3682.0**						**12.21**	**3.4%**	**12.21**	**3.4%**						**1253**	**54.6%**	**1253**	**54.6%**
Total West Area Loading to Subsurface						0.01	0.0%								48	2.1%					
Loading to Railroad Creek Associated w/West Area Sources (u)									**-0.61**	**-0.2%**								**-286**	**-12.4%**		
Measured Value at RC-2 (a)			*3850.9*	*1.08*					**359.34**	**100.0%**	**359.34**	**100.0%**	*7*					**2296**	**100.0%**	**2296**	**100.0%**

Table A-2
Loading Calculations - Railroad Creek, West Area - September 1997
Figures A-3 and A-4
Holden Mine RI/FS

				Zinc								
	Seep / Tributary Information				Loading to Subsurface, Seeps, or Tributaries From Source Area			Surface Water Loading to RRC from Source Area			Cumulative Surface Water Loading to RRC	
Source Area	Seep/Tributary Discharge to RRC	Discharges To	Flows (L/s)	Conc. (mg/L)	Load to Subsurf/ Seep/ Tributary (kg/d)	Total Load to Subsurf (kg/d)	% Load of RC-2	Load to RRC (kg/d)	Total Load to RRC (kg/d)	% Load at RC-2 (%)	Load (kg/d)	% Load of RC-2
Measured Value at RC-6 (a)			*3710.0*	*0.01*					*3.21*	*41.9%*	*3.21*	*41.9%*
SP-26												
	SP-26 (q)	RRC	0.3	0.02				0.00		0.01%		
	Source Area Total								0.00	0.0%	3.21	41.9%
Unaccounted (Groundwater) Load to RC-1 (c)									-2.56	-33.5%		
Measured Value at RC-1 (a)			*3737.1*	*0.00*					*0.65*	*8.4%*	*0.65*	*8.4%*
SP-23/Honeymoon Heights												
	SP-23 (r)	RRC	NF	0				0		0		
	SP-23B (r)	RRC	NF	0				0		0		
	SP-12 (r)	RRC	NF	0				0		0		
	Source Area Total								0.00	0.0%	0.65	8.4%
Underground Mine												
	P-1 (e)	P-5	6.0	3.28								
	P-5 (e)	RRC	4.3	2.98				1.09		14.3%		
	Loss P-1 to P-5 (f)	GW	1.7	*3.13*	*0.46*		6.0%					
	Source Area Total					0.46	6.0%		1.09	14.3%	1.74	22.7%
West Waste Rock Pile												
	SP-6 (r)	SP15E->Lagoon	NF	0	0		0					
	SP-15W (r)	Lagoon	NF	0	0		0					
	Source Area Total					0	0.0%				1.74	22.7%
Mill Building												
	SP-22 (r)	GW	NF	0	0		0					
	SP-7 (s)	SP15E->Lagoon	0.0	6.43	0.00		0.0%					
	Source Area Total					0.00	0.0%				1.74	22.7%
Lagoon												
	SP-16(t)	GW	(s)								1.74	22.7%
West Area Seeps (Upstream of RC-4)												
	SP-9 (r)	RRC	NF	0				0		0		
	SP-11 (r)	RRC	NF	0				0		0		
	SP-25 (r)	RRC	NF	0				0		0		
	SP-24 (r)	RRC	NF	0				0		0		
	Source Area Total								0.00	0.0%	1.74	22.7%
Unaccounted (Groundwater) Load to RC-4 (j)									1.57	20.5%		
Measured Value at RC-4 (a)			*3483.8*	*0.01*					*3.31*	*43.3%*	*3.31*	*43.3%*
West Area Seeps (Downstream of RC-4)												
	SP-10W (r)	RRC	NF	0				0		0		
	SP-10E (r)	RRC	NF	0				0		0		
	Source Area Total								0.00	0.0%	3.31	43.3%
East Waste Rock Pile												
	SP-8 (r)	SP-19	NF	0	0							
	SP-19 (r)	CCD->RRC	NF	0				0				
	Loss SP-8 to SP-19 (l)	GW			0		0.0%					
	Source Area Total					0	0.0%		0.00	0.0%	3.31	43.3%
Copper Creek Diversion												
	CC-D1 (n)	RRC	198.2	0.00								
	CC-D1 (minus SP-19) (o)	*RRC*	NA	NA				*0.03*		*0.4%*		
	Source Area Total								0.03	0.4%	3.35	43.7%
Total West Area Surface Water Loading to RRC (p)			**3682.0**						**3.35**	**43.7%**	**3.35**	**43.7%**
Total West Area Loading to Subsurface						0.46	6.0%					
Loading to Railroad Creek Associated w/West Area Sources (u)									**0.14**	**1.8%**		
Measured Value at RC-2 (a)			*3850.9*	*0.02*					**7.65**	**100.0%**	**7.65**	**100.0%**

General Notes:

Groundwater contribution presented in the flow net analysis (FS Figures A-5 through A-8 and Attachment 1 to FS Appendix A Tables A1-1 and A1-2).

If more than one monitoring well or seep was associated with a groundwater flow tube, the average of concentrations was used for loading calculations.

Underlined concentrations represent metals not measured above detection limits in the sample. A value of one-half (1/2) the detection limit was used for the loading calculations

NF = No Flow

NA = Not Analyzed

Notes:

(a) Total loading from background and west area sources from FS Table A-1: Draft Loading Calculations - Railroad Creek, West Area – May 1997.

(b) Flow data from DRI Table 6.6-1; concentration data from DRI Table 5.4-2.

(c) There are no groundwater wells completed in the tailings unit at TP-1. Therefore, groundwater flow in TP-1 was estimated using the estimated flow per unit length in tailings materials at TP-2 and 3. The total flow in TP-2 and TP-3 (0.084 cfs) was adjusted by the length of Railroad Creek adjacent to TP-2 and TP-3 (3,190 ft) to give a flow of groundwater from tailings per length of stream ($2.63X10^{-5}$ cfs/ft). The stream length adjacent to TP-1 (1,400 ft.) was multiplied by the flow of groundwater from tailings per length of stream ($2.63X10^{-5}$ cfs/ft) to give the estimated groundwater contribution from the tailings in TP-1 (0.037 cfs). Water chemistry data is from DRI Table 5.4-2.

(d) Groundwater flow in flow tubes and associated monitoring well IDs (for water chemistry) taken from FS Table A1-1. Water chemistry data from DRI Table 5.4-1.

(e) Flow data from DRI Table 6.6-1; concentration data from DRI Table 5.3-34.

(f) Groundwater flow in flow tubes and associated seep IDs (for water chemistry) taken from FS Table A1-1. Water chemistry data from DRI Table 5.4-2.

(g) Flow data from DRI Table 6.6-1; concentration data from DRI Table 5.3-28 – May 19 – 20, 1997. (RC-7 not used in the calculations)

(h) Groundwater flow in flow tubes and associated monitoring well IDs (for water chemistry) taken from FS Table A1-2. Water chemistry data from DRI Table 5.4-1.

(i) Groundwater flow in flow tubes and associated seep IDs (for water chemistry) taken from FS Table A1-2. Water chemistry data from DRI Table 5.4-2.

(j) Groundwater flow in flow tubes and associated monitoring well and seep IDs (for water chemistry) taken from FS Table A1-2. Water chemistry data from DRI Tables 5.4-1 and 5.4-2.

(k) The unaccounted load to Railroad Creek station RC-2 was calculated by subtracting the sum of loading sources between RC-4 and RC-2 from the measured load at RC-2. The unaccounted flow presented in this table was calculated in Section 4 of the DRI and originally presented in the DRI loading calculation Table 6.6-1 (Reach 2 Balance). The concentrations for the accounted loading at RC-2 were back-calculated from the unaccounted loading and unaccounted flow.

(l) Flow data from DRI Table 6.6-4; concentration data from DRI Table 5.4-2.

(m) This is the flow measured at RC-2 + Seep SP-21 in May 97. Concentrations are from RC-5 in May 97. There is no flow data for RC-5 in May 97. Water chemistry data is from DRI Table 5.3-29.

(n) Loading associated with East Area sources was calculated by subtracting the total background + West Area loading from the total East Area loading (RC-2 + SP-21).

Table A-3
Loading Calculations - Railroad Creek, East Area - May 1997
Figures A-5, A-7, A-8, and A-11
Holden Mine RI/FS

				Magnesium						Aluminum						Cadmium						Copper					
								Cumulative						Cumulative						Cumulative						Cumulative	
Source Area	Contribution to Railroad Creek	Associated Monitoring Well/Seep	Flows [a] L/s	Conc.[b] mg/L	Load to RRC kg/d	Total Load to RRC kg/d	% Load of RC-2	Load kg/d	% Load of RC-2	Conc. mg/L	Load to RRC kg/d	Total Load to RRC kg/d	% Load of RC-2	Load kg/d	% Load of RC-2	Conc. mg/L	Load kg/d	Total Load to RRC kg/d	% Load of RC-2	Load kg/d	% Load of RC-2	Conc. mg/L	Load kg/d	Total Load to RRC kg/d	% Load of RC-2	Load kg/d	% Load of RC-2
Total From Background & West Area Sources(a)			**14359.9**			***587.0***	***71.8%***	***586.98***	***71.8%***			***38.5***	***33.0%***	***38.5***	***33.0%***			***0.57***	***83.4%***	***0.57***	***83.4%***			***33.64***	***109.9%***	***33.64***	***109.9%***
Tailings Pile 1																											
Groundwater Seeps and Flow from Tailings																											
	SP-1 (b)		0.9	53.5	4.4		0.5%			27.1	2.2		1.9%			0.02	0.002		0.3%			0.70	0.06		0.2%		
	Tailings Pile 1 (c)	SP-1,SP-2	1.0	75.2	6.8		0.8%			60.85	5.5		4.7%			0.02	0.002		0.3%			0.81	0.07		0.2%		
	SP-2 (b)		0.9	96.8	7.9		1.0%			94.6	7.7		6.6%			0.02	0.002		0.3%			0.91	0.07		0.2%		
Groundwater Flow from Native Material																											
	Flow Tube S2 (d)	TP1-6A	1.7	29.4	4.3		0.5%			46.3	6.8		5.9%			0.10	0.015		2.2%			1.10	0.16		0.5%		
	Flow Tube S3 (d)	TP1-2A	1.8	33.2	5.0		0.6%			7.11	1.1		0.9%			0.00	0.000		0.0%			0.00	0.00		0.0%		
	Flow Tube S4 (d)	TP1-2A, TP1-3A	3.5	44.7	13.4		1.6%			4.6	1.4		1.2%			0.00	0.000		0.0%			0.00	0.00		0.0%		
	Flow Tube S5 (d)	TP1-5A	2.2	78.4	14.8		1.8%			103	19.4		16.7%			0.01	0.002		0.3%			0.20	0.04		0.1%		
	Flow Tube S6 (d)	TP1-5A	3.5	78.4	24.0		2.9%			103	31.5		27.0%			0.01	0.003		0.4%			0.20	0.06		0.2%		
			15.6			80.7	9.9%	667.64	81.7%			75.7	64.9%	114.2	97.8%			0.03	3.8%	0.60	87.2%			0.46	1.5%	34.10	111.4%
Copper Creek																											
	Copper Creek (e)		424.8	0.5	19.8		2.4%			0.01	0.4		0.3%			0.00	0.001		0.1%	0.00		0.00	0.04		0.1%	0.04	
			424.8			19.8	2.4%	687.46	84.1%			0.4	0.3%	114.5	98.1%			0.00	0.1%	0.60	87.3%			0.04	0.1%	34.14	111.5%
Tailings Pile 2 (Upstream of RC-7)																											
Groundwater Seeps and Flow from Tailings																											
	SP-3 (b)		4.7	47.9	19.6		2.4%			33.4	13.7		11.7%			0.04	0.016		2.4%			1.28	0.52		1.7%		
	Flow Tube TP-1 (d)	SP-3	0.1	47.9	0.4		0.1%			33.4	0.3		0.2%			0.04	0.000		0.1%			1.28	0.01		0.0%		
	Flow Tube TP-2 (d)	SP-3	0.2	47.9	0.7		0.1%			33.4	0.5		0.4%			0.04	0.001		0.1%			1.28	0.02		0.1%		
	Flow Tube TP-3 (d)	SP-3	0.2	47.9	0.7		0.1%			33.4	0.5		0.4%			0.04	0.001		0.1%			1.28	0.02		0.1%		
	Flow Tube TP-4 (d)	SP-3	0.2	47.9	0.7		0.1%			33.4	0.5		0.4%			0.04	0.001		0.1%			1.28	0.02		0.1%		
	Flow Tube TP-5 (d)	SP-3	0.1	47.9	0.6		0.1%			33.4	0.4		0.3%			0.00	0.000		0.0%			1.28	0.01		0.0%		
	Flow Tube TP-6 (f)	SP-3	0.2	47.9	0.7		0.1%			33.4	0.5		0.4%			0.04	0.001		0.1%			1.28	0.02		0.1%		
	Flow Tube TP-7 (f)	SP-3	0.3	47.9	1.0		0.1%			33.4	0.7		0.6%			0.04	0.001		0.1%			1.28	0.03		0.1%		
Groundwater Flow from Native Material																											
	Flow Tube S7 (d)	TP2-11	4.7	4.9	2.0		0.2%			0.33	0.1		0.1%			0.00	0.001		0.1%			0.01	0.00		0.0%		
	Flow Tube S8 (d)	TP2-11	4.0	4.9	1.7		0.2%			0.33	0.1		0.1%			0.00	0.001		0.1%			0.01	0.00		0.0%		
	Flow Tube S9 (d)	TP2-11	1.3	4.9	0.5		0.1%			0.33	0.0		0.0%			0.00	0.000		0.0%			0.01	0.00		0.0%		
	Flow Tube S10 (d)	PZ-3A	2.7	24.1	5.7		0.7%			0.01	0.0		0.0%			0.00	0.000		0.1%			0.00	0.00		0.0%		
			18.7			34.4	4.2%	721.85	88.4%			17.4	14.9%	131.9	113.0%			0.02	3.2%	0.62	90.5%			0.66	2.2%	34.80	113.7%
Measured Load at RC-7 (for comparison only) (g)			*14867.8*	*0.6*	*757.9*	*757.9*	*92.8%*			*0.06*	*77.1*	*77.1*	*66.0%*			*0.00*	*0.745*	*0.75*	*108.4%*			*0.02*	*29.55*	*29.55*	*96.5%*		
Tailings Pile 2 & 3 (Downstream of RC-7)																											
Groundwater Seeps and Flow from Tailings																											
	SP-4 (b)		14.2	36.3	44.5		5.5%			19	23.3		20.0%			0.01	0.009		1.3%			0.67	0.82		2.7%		
	Flow Tube TP-8 (i)	SP-3, SP-4	0.2	42.1	0.6		0.1%			26.2	0.4		0.3%			0.02	0.000		0.1%			0.98	0.01		0.0%		
	Flow Tube TP-9 (i)	SP-3, SP-4	0.1	42.1	0.3		0.0%			26.2	0.2		0.1%			0.02	0.000		0.0%			0.98	0.01		0.0%		
	Flow Tube TP-10 (i)	SP-4	0.1	36.3	0.3		0.0%			19	0.1		0.1%			0.01	0.000		0.0%			0.67	0.00		0.0%		
	Flow Tube TP-11 (i)	SP-4	0.2	36.3	0.5		0.1%			19	0.3		0.2%			0.01	0.000		0.0%			0.67	0.01		0.0%		
	Flow Tube TP-12 (i)	SP-4	0.1	36.3	0.3		0.0%			19	0.2		0.2%			0.01	0.000		0.0%			0.67	0.01		0.0%		
	Flow Tube TP-13 (j)	SP-4, PZ-6A	0.1	50.7	0.6		0.1%			9.51	0.1		0.1%			0.00	0.000		0.0%			0.34	0.00		0.0%		
	Flow Tube TP-14 (h)	PZ-6A	0.2	65.1	0.9		0.1%			0.01	0.0		0.0%			0.00	0.000		0.0%			0.00	0.00		0.0%		
	Flow Tube TP-15 (h)	PZ-6A	0.2	65.1	1.2		0.1%			0.01	0.0		0.0%			0.00	0.000		0.0%			0.00	0.00		0.0%		
	Flow Tube TP-16 (h)	PZ-6A	0.1	65.1	0.5		0.1%			0.01	0.0		0.0%			0.00	0.000		0.0%			0.00	0.00		0.0%		
Groundwater Flow from Native Material																											
	Flow Tube S11 (h)	PZ-3A	2.5	24.1	5.2		0.6%			0.01	0.0		0.0%			0.00	0.000		0.1%			0.00	0.00		0.0%		
	Flow Tube S12 (h)	TP2-4A	1.4	27.4	3.2		0.4%			0.01	0.0		0.0%			0.00	0.000		0.0%			0.00	0.00		0.0%		
	Flow Tube S13 (h)	TP2-4A	1.2	27.4	2.8		0.3%			0.01	0.0		0.0%			0.00	0.000		0.0%			0.00	0.00		0.0%		
	Flow Tube S14 (h)	TP3-8A	1.8	17.4	2.8		0.3%			0.12	0.0		0.0%			0.00	0.000		0.0%			0.00	0.00		0.0%		
	Flow Tube S15 (h)	TP3-8A	0.5	17.4	0.7		0.1%			0.12	0.0		0.0%			0.00	0.000		0.0%			0.00	0.00		0.0%		
	Flow Tube S16 (h)	TP3-8A	1.2	17.4	1.8		0.2%			0.12	0.0		0.0%			0.00	0.000		0.0%			0.00	0.00		0.0%		
	Flow Tube S17 (h)	TP3-10	1.9	3.6	0.6		0.1%			0.29	0.0		0.0%			0.00	0.000		0.0%			0.01	0.00		0.0%		
	Flow Tube S18 (h)	TP3-10	1.9	3.6	0.6		0.1%			0.29	0.0		0.0%			0.00	0.000		0.0%			0.01	0.00		0.0%		
	Flow Tube S19 (h)	TP3-10	3.1	3.6	1.0		0.1%			0.29	0.1		0.1%			0.00	0.000		0.0%			0.01	0.00		0.0%		
			30.9			68.4	8.4%	790.30	96.7%			24.8	21.2%	156.7	134.2%			0.01	1.6%	0.63	92.1%			0.88	2.9%	35.68	116.6%
Unaccounted (Groundwater) Load to RC-2 (k)						26.7	3.3%					-39.9	-34.2%					0.05	7.9%					-5.07	-16.6%		
Measured Values at RC-2 (g)			*15009.5*	*0.6*		*817.0*	*100.0%*	*817.00*	*100.0%*	*0.09*		*116.7*	*100.0%*	*116.7*	*100.0%*	*0.00*		*0.69*	*100.0%*	*0.69*	*100.0%*	*0.02*		*30.61*	*100.0%*	*30.61*	*100.0%*
Loading Downstream of RC-2																											
	SP-21 (l)		55.5	3.8	18.3		2.2%			1.50	7.2		6.2%			0.00	0.000		0.0%			0.05	0.25		0.8%		
			55.5			18.3	2.2%	835.32	102.2%			7.2	6.2%	123.9	106.2%			0.00	0.0%	0.69	100.0%			0.25	0.8%	30.85	100.8%
Total Values (Measured RC-2 + SP-21)			**15065.0**			**835.3**		**835**	**102.2%**			**123.9**		**123.9**	**106.2%**			**0.69**		**0.69**	**100.0%**			**30.85**		**30.85**	**100.8%**
Total Loading Attributed to the East Area (n)						**248.3**	**30.4%**					**85.4**	**73.2%**					**0.11**	**16.7%**					**-2.78**	**-9.1%**		
Measured Values at RC-5 (m)			*15065.0*	*0.7*		*872.1*	*106.7%*	*872.08*	*106.7%*	*0.07*		*91.1*	*78.1%*	*91.1*	*78.1%*	*0.00*		*0.65*	*94.7%*	*0.65*	*94.7%*	*0.02*		*27.98*	*91.4%*	*27.98*	*91.4%*

Table A-3
Loading Calculations - Railroad Creek, East Area - May 1997
Figures A-5, A-7, A-8, and A-11
Holden Mine RI/FS

				Iron						Sulfate						Zinc					
								Cumulative						Cumulative						Cumulative	
Source Area	Contribution to Railroad Creek	Associated Monitoring Well/Seep	Flows [(a)] L/s	Conc. mg/L	Load kg/d	RRC kg/d	% Load of RC-2	Load kg/d	% Load of RC-2	Conc. mg/L	Load kg/d	RRC kg/d	% Load of RC-2	Load kg/d	% Load of RC-2	Conc. mg/L	Load kg/d	Total Load to RRC kg/d	% Load of RC-2	Load kg/d	% Load of RC-2
Total From Background & West Area Sources(a)			**14359.9**			***28.8***	***7.4%***	***28.8***	***7.4%***			***8619***	***80.1%***	***8619***	***80.1%***			***92.81***	***85.2%***	***92.81***	***85.2%***
Tailings Pile 1																					
Groundwater Seeps and Flow from Tailings																					
	SP-1 (b)		0.9	542	44.3		11.4%			1700	139		1.3%			3.49	0.29		0.3%		
	Tailings Pile 1 (c)	SP-1,SP-2	1.0	515	46.4		11.9%			1900	171		1.6%			4.55	0.41		0.4%		
	SP-2 (b)		0.9	487	39.8		10.2%			2100	172		1.6%			5.60	0.46		0.4%		
Groundwater Flow from Native Material																					
	Flow Tube S2 (d)	TP1-6A	1.7	145	21.4		5.5%			850	126		1.2%			11.4	1.69		1.5%		
	Flow Tube S3 (d)	TP1-2A	1.8	321	48.6		12.5%			1000	151		1.4%			2.27	0.34		0.3%		
	Flow Tube S4 (d)	TP1-2A, TP1-3A	3.5	333	100.1		25.7%			1250	376		3.5%			3.66	1.10		1.0%		
	Flow Tube S5 (d)	TP1-5A	2.2	246	46.4		11.9%			1700	321		3.0%			9.81	1.85		1.7%		
	Flow Tube S6 (d)	TP1-5A	3.5	246	75.2		19.3%			1700	520		4.8%			9.81	3.00		2.8%		
			15.6			422.4	108.6%	451.2	116.0%			1976	18.4%	10595	98.4%			9.14	8.4%	101.95	93.6%
Copper Creek																					
	Copper Creek (e)		424.8	0	1.5		0.4%	1.5		5	176		1.6%	176		0.013	0.48		0.4%	0.48	
			424.8			1.5	0.4%	452.6	116.3%			176	1.6%	10772	100.1%			0.48	0.4%	102.43	94.0%
Tailings Pile 2 (Upstream of RC-7)																					
Groundwater Seeps and Flow from Tailings																					
	SP-3 (b)		4.7	154	63.0		16.2%			880	360		3.3%			4.03	1.65		1.5%		
	Flow Tube TP-1 (d)	SP-3	0.1	154	1.3		0.3%			880	8		0.1%			4.03	0.0349		0.0%		
	Flow Tube TP-2 (d)	SP-3	0.2	154	2.3		0.6%			880	13		0.1%			4.03	0.0596		0.1%		
	Flow Tube TP-3 (d)	SP-3	0.2	154	2.4		0.6%			880	14		0.1%			4.03	0.0629		0.1%		
	Flow Tube TP-4 (d)	SP-3	0.2	154	2.3		0.6%			880	13		0.1%			4.03	0.0599		0.1%		
	Flow Tube TP-5 (d)	SP-3	0.1	154	1.8		0.5%			880	10		0.1%			4.03	0.0469		0.0%		
	Flow Tube TP-6 (f)	SP-3	0.2	154	2.3		0.6%			880	13		0.1%			4.03	0.06		0.1%		
	Flow Tube TP-7 (f)	SP-3	0.3	154	3.4		0.9%			880	19		0.2%			4.03	0.09		0.1%		
Groundwater Flow from Native Material																					
	Flow Tube S7 (d)	TP2-11	4.7	0	0.0		0.0%			150	61		0.6%			0.169	0.07		0.1%		
	Flow Tube S8 (d)	TP2-11	4.0	0	0.0		0.0%			150	52		0.5%			0.169	0.06		0.1%		
	Flow Tube S9 (d)	TP2-11	1.3	0	0.0		0.0%			150	17		0.2%			0.169	0.02		0.0%		
	Flow Tube S10 (d)	PZ-3A	2.7	6	1.3		0.3%			670	158		1.5%			0.0025	0.0006		0.0%		
			18.7			80.1	20.6%	532.7	136.9%			738	6.9%	11510	106.9%			2.21	2.0%	104.63	96.1%
Measured Load at RC-7 (for comparison only) (g)			*14867.8*	*0*	*616.6*	*616.6*	158.5%			*5*	*5909*	*5909*	54.9%			*0.085*	*109.19*	*109.19*	100.2%		
Tailings Pile 2 & 3 (Downstream of RC-7)																					
Groundwater Seeps and Flow from Tailings																					
	SP-4 (b)		14.2	75	91.9		23.6%			660	810		7.5%			0.904	1.11		1.0%		
	Flow Tube TP-8 (i)	SP-3, SP-4	0.2	114	1.7		0.4%			770	11		0.1%			2.467	0.04		0.0%		
	Flow Tube TP-9 (i)	SP-3, SP-4	0.1	114	0.7		0.2%			770	5		0.0%			2.467	0.01		0.0%		
	Flow Tube TP-10 (i)	SP-4	0.1	75	0.5		0.1%			660	5		0.0%			0.904	0.007		0.0%		
	Flow Tube TP-11 (i)	SP-4	0.2	75	1.1		0.3%			660	9		0.1%			0.904	0.01		0.0%		
	Flow Tube TP-12 (i)	SP-4	0.1	75	0.7		0.2%			660	6		0.1%			0.904	0.008		0.0%		
	Flow Tube TP-13 (j)	SP-4, PZ-6A	0.1	67	0.8		0.2%			1080	13		0.1%			0.46	0.005		0.0%		
	Flow Tube TP-14 (h)	PZ-6A	0.2	58	0.8		0.2%			1500	20		0.2%			0.015	0.0002		0.0%		
	Flow Tube TP-15 (h)	PZ-6A	0.2	58	1.1		0.3%			1500	28		0.3%			0.015	0.0003		0.0%		
	Flow Tube TP-16 (h)	PZ-6A	0.1	58	0.5		0.1%			1500	12		0.1%			0.015	0.0001		0.0%		
Groundwater Flow from Native Material																					
	Flow Tube S11 (h)	PZ-3A	2.5	6	1.2		0.3%			670	145		1.3%			0.003	0.0005		0.0%		
	Flow Tube S12 (h)	TP2-4A	1.4	7	0.8		0.2%			720	85		0.8%			0.006	0.001		0.0%		
	Flow Tube S13 (h)	TP2-4A	1.2	7	0.7		0.2%			720	75		0.7%			0.006	0.00		0.0%		
	Flow Tube S14 (h)	TP3-8A	1.8	55	8.8		2.3%			340	54		0.5%			0.058	0.01		0.0%		
	Flow Tube S15 (h)	TP3-8A	0.5	55	2.4		0.6%			340	15		0.1%			0.058	0.002		0.0%		
	Flow Tube S16 (h)	TP3-8A	1.2	55	5.7		1.5%			340	35		0.3%			0.058	0.01		0.0%		
	Flow Tube S17 (h)	TP3-10	1.9	0	0.0		0.0%			100	17		0.2%			0.068	0.01		0.0%		
	Flow Tube S18 (h)	TP3-10	1.9	0	0.0		0.0%			100	16		0.2%			0.068	0.01		0.0%		
	Flow Tube S19 (h)	TP3-10	3.1	0	0.0		0.0%			100	27		0.3%			0.068	0.02		0.0%		
			30.9			119.4	30.7%	652.1	167.6%			1386	12.9%	12896	119.8%			1.3	1.2%	105.9	97.2%
Unaccounted (Groundwater) Load to RC-2 (k)						-263.0	-67.6%					-2132	-19.8%					3.0	0.4%		
Measured Values at RC-2 (g)			*15009.5*	*0*		*389.0*	*100.0%*	*389.0*	*100.0%*	*8*		*10764*	*100.0%*	*10764*	*100.0%*	*0.084*		*108.9*	*100.0%*	*108.9*	*100.0%*
Loading Downstream of RC-2																					
	SP-21 (l)		55.5	1	4.8		1.2%			84	403		3.7%			0.109	0.52		0.5%		
			55.5			4.8	1.2%	393.8	101.2%			403	3.7%	11166	103.7%			0.52	0.5%	109.46	100.5%
Total Values (Measured RC-2 + SP-21)			**15065.0**			**393.8**		**393.8**	**101.2%**			**11166**		**11166**	**103.7%**			**109.5**		**109**	**100.5%**
Total Loading Attributed to the East Area (n)						**365.0**	**93.8%**					**2547**	**23.7%**					**16.6**	**15.3%**		
Measured Values at RC-5 (m)			*15065.0*	*0*		*455.6*	*117.1%*	*455.6*	*117.1%*	*8*		*10543*	*98.0%*	*10543*	*98.0%*	*0.084*		*109.3*	*100.4%*	*109*	*100.4%*

General Notes:

Groundwater contribution presented in the flow net analysis (FS Figures A-8 through A-10 and Attachment 1 to FS Appendix A Tables A1-3 through A1-5).

If more than one monitoring well or seep was associated with a groundwater flow tube, the average of concentrations was used for loading calculations.

Underlined concentrations represent metals not measured above detection limits. A value of one-half (1/2) the detection limit was used for the loading calculations.

NF = No Flow

NA = Not Analyzed

Notes:

(a) Total loading from background and west area sources from FS Table A-2 - Draft Loading Calculations – Railroad Creek, West Area – September 1997.

(b) No flow in September 1997 per DRI Table 4.3-6.

(c) There are no groundwater wells completed in the tailings unit at TP-1. Therefore, groundwater flow in TP-1 was estimated using the estimated flow per unit length in tailings materials at TP-2 and 3. The total flow in TP-2 and TP-3 (0.072 cfs) was adjusted by the length of Railroad Creek adjacent to TP-2 and TP-3 (3,190 ft) to give a flow of groundwater from tailings per length of stream ($2.27X10^{-5}$ cfs/ft). The stream length adjacent to TP-1 (1,400 ft) was multiplied by the flow of groundwater from tailings per length of stream ($2.27X10^{-5}$ cfs/ft) to give the estimated groundwater contribution from the tailings in TP-1 (0.032 cfs).

(d) Groundwater flow in flow tubes and associated monitoring well IDs (for water chemistry) taken from FS Table A1-3. Water chemistry data from DRI Table 5.4-1.

(e) Flow data from DRI Table 6.6-2; concentration data from DRI Table 5.4-2.

(f) Flow data from DRI Table 6.6-2; concentration data from DRI Table 5.3-34.

(g) Groundwater flow in flow tubes and associated seep IDs (for water chemistry) taken from DRI Appendix I Table 3. Water chemistry data from DRI Table 5.4-2.

(h) Flow data from DRI Table 6.6-2; concentration data from DRI Table 5.3-28 May 19 – 20, 1997.

(i) Groundwater flow in flow tubes and associated monitoring well IDs (for water chemistry) taken from FS Table A1-4. Water chemistry data from DRI Table 5.4-1.

(j) A transition from gaining condition to losing condition in Railroad Creek occurs within flow tube S8. Tube S8 IN represents flow into Railroad Creek (gain); tube S8 OUT represents flow into the tailings from Railroad Creek (loss). (See figure A-10) Flow values and associated Railroad Creek monitoring location ID (for water chemistry) taken from FS Table A1-4. Water chemistry data from DRI Table 5.3-28 and 5.4-1.

(k) Flow tubes SL1, SL2 and SL3 all represent groundwater flow from Railroad Creek into Tailings Pile 3 (losing condition). (See figure 10) Flow values and associated Railroad Creek monitoring location ID (for water chemistry) taken from FS Table A1-4. Water chemistry data from DRI Table 5.3-28.

(l) Groundwater flow in flow tubes and associated seep IDs (for water chemistry) taken from FS Table A1-4. Water chemistry data from DRI Table 5.4-2.

(m) Groundwater flow in flow tubes and associated monitoring well and seep IDs (for water chemistry) taken from FS Table A1-4. Water chemistry data from DRI Table 5.4-1 and 5.4-2.

(n) The unaccounted load to Railroad Creek station RC-2 was calculated by subtracting the sum of loading sources between RC-4 and RC-2 from the measured load at RC-2. The unaccounted flow presented in this table was calculated in Section 4 of the DRI and originally presented in the DRI loading calculation Table 6.6-2 (Reach 2 Balance). The concentrations for the unaccounted loading at RC-2 were back-calculated from the unaccounted loading and unaccounted flow.

(o) Water lost from Railroad Creek into Tailing Pile 3 upstream of RC-2 is assumed to pass through the lagoon downstream of RC-2 and then to re-enter Railroad Creek. Groundwater flow tubes (S8

OUT, SL1, SL2 and SL3) are represented as gains to Railroad Creek downstream of RC-2. (See Figure 10). Two additional groundwater flow tubes (SL4 and SL5) are also represented as gains to Railroad Creek downstream of RC-2. Groundwater flows in flow tubes S8 OUT, SL1, SL2, SL3, SL4 and SL5 taken from FS Table A1-5.

(p) Flow data from DRI Table 4.3-6, assumed to be 1.5 gpm; concentration data from DRI Table 5.4-2.

(q) Flow data from FS Table A1-5; concentration data from DRI Table 5.4-1.

(r) Loading associated with East Area sources was calculated by subtracting the total background + West Area loading from the total East Area loading (RC-2 + SP-21).

(s) Flow data and concentration data from DRI Table 5.3-29.

Table A-4
Loading Calculations - Railroad Creek, East Area - September 1997
Figures A-6, A-9, A-10, and A-11
Holden Mine RI/FS

				Magnesium						Aluminum						Cadmium						Copper					
								Cumulative						Cumulative						Cumulative						Cumulative	
Source Area	Contribution to Railroad Creek	Associated Monitoring Well/Seep	Flows L/s	Conc. mg/L	Load to RRC kg/d	Total Load to RRC kg/d	% Load of RC-2	Load (kg/d)	% Load of RC-2	Conc. mg/L	Load to RRC kg/d	Total Load to RRC kg/d	% Load of RC-2	Load (kg/d)	% Load of RC-2	Conc. mg/L	Load kg/d	Total Load to RRC kg/d	% Load of RC-2	Load (kg/d)	% Load of RC-2	Conc. mg/L	Load kg/d	Total Load to RRC kg/d	% Load of RC-2	Load (kg/d)	% Load of RC-2
Total From Background & West Area Sources(a)			*3682.0*			*119.25*	*62.9%*	*119.25*	*62.9%*			*3.18*	*23.9%*	*3.18*	*23.9%*			*0.0198*	*59.4%*	*0.02*	*59.4%*			*0.559*	*140.0%*	*0.56*	*140.0%*
Tailings Pile 1																											
Groundwater Seeps and Flow from Tailings																											
	SP-1 (b)		NF																								
	Tailings Pile 1 (c)	SP-2	0.9	94.2	7.32		3.9%			67.90	5.27		39.6%			0.0039	0.0003		0.9%			0.101	0.008		2.0%		
	SP-2 (e)		0.1	94.2	0.81		0.4%			67.90	0.59		4.4%			0.0039	0.0000		0.1%			0.101	0.001		0.2%		
Groundwater Flow from Native Material																											
	Flow Tube S1 (d)	HBKG-1, TP1-6A	2.2	9.9	1.88		1.0%			7.80	1.49		11.2%			0.0335	0.0064		19.2%			1.591	0.304		76.1%		
	Flow Tube S2 (d)	TP1-2, TP1-3	1.2	135.5	13.94		7.4%			5.52	0.57		4.3%			0.0009	0.0001		0.3%			0.005	0.001		0.1%		
	Flow Tube S3 (d)	TP1-5	3.6	46.0	14.19		7.5%			25.5	7.87		59.1%			0.0018	0.0006		1.7%			0.048	0.015		3.7%		
			8.0			38.14	20.1%	157.39	83.0%			15.78	118.6%	18.96	142.5%			0.0074	22.2%	0.03	81.6%			0.328	82.1%	0.89	222.1%
Copper Creek																											
	Copper Creek (f)		141.6	0.5	5.63		3.0%			0.01	0.12		0.9%			0.0000	0.0002		0.7%	0.00		0.000	0.004		0.9%	0.00	
			141.6			5.63	3.0%	163.02	86.0%			0.12	0.9%	19.09	143.4%			0.0002	0.7%	0.03	82.3%			0.004	0.9%	0.89	223.0%
Tailings Pile 2 (Upstream of RC-7)																											
Groundwater Seeps and Flow from Tailings																											
	SP-3 (e)		0.4	62.3	2.15		1.1%			3.92	0.14		1.0%			0.0020	0.0001		0.2%			0.090	0.003		0.8%		
	Flow Tube TP-1 (d)	SP-3	0.4	62.3	2.42		1.3%			3.92	0.15		1.1%			0.0020	0.0001		0.2%			0.090	0.003		0.9%		
	Flow Tube TP-2 (d)	SP-3	0.1	62.3	0.59		0.3%			3.92	0.04		0.3%			0.0020	0.0000		0.1%			0.090	0.001		0.2%		
	Flow Tube TP-3 (d)	SP-3	0.2	62.3	0.86		0.5%			3.92	0.05		0.4%			0.0020	0.0000		0.1%			0.090	0.001		0.3%		
	Flow Tube TP-4 (d)	SP-3	0.2	62.3	0.88		0.5%			3.92	0.06		0.4%			0.0020	0.0000		0.1%			0.090	0.001		0.3%		
	Flow Tube TP-5 (g)	SP-3	0.1	62.3	0.50		0.3%			3.92	0.03		0.2%			0.0020	0.0000		0.0%			0.090	0.001		0.2%		
	Flow Tube TP-6 (g)	SP-3	0.2	62.3	1.00		0.5%			3.92	0.06		0.5%			0.0020	0.0000		0.1%			0.090	0.001		0.4%		
Groundwater Flow from Native Material																											
	Flow Tube S4 (d)	TP2-11A	4.5	12.8	5.01		2.6%			0.44	0.17		1.3%			0.0029	0.0011		3.4%			0.010	0.004		1.0%		
	Flow Tube S5 (d)	TP2-11A	0.6	12.8	0.64		0.3%			0.44	0.02		0.2%			0.0029	0.0001		0.4%			0.010	0.001		0.1%		
	Flow Tube S6 (d)	TP2-11A, PZ-3A	2.8	17.5	4.20		2.2%			0.23	0.05		0.4%			0.0015	0.0004		1.1%			0.006	0.001		0.3%		
			9.4			18.26	9.6%	181.27	95.6%			0.78	5.8%	19.86	149.3%			0.0019	5.7%	0.03	88.1%			0.018	4.5%	0.91	227.5%
Measured Value at RC-7 (for comparison only)(h)			*4134.0*	*0.5*		*189.30*	*99.8%*			*0.04*	*14.29*		*107.4%*			*0.0001*		*0.0321*	*96.6%*			*0.001*		*0.464*	*116.3%*		
Tailings Pile 2 & 3 Downstream of RC-7																											
Groundwater Seeps and Flow from Tailings																											
	SP-4 (b)		NF																								
	Flow Tube TP-7 (l)	SP-3	0.1	62.3	0.29		0.2%			3.92	0.02		0.1%			0.0020	0.0000		0.0%			0.090	0.000		0.1%		
	Flow Tube TP-8 (l)	SP-3	0.1	62.3	0.79		0.4%			3.92	0.05		0.4%			0.0020	0.0000		0.1%			0.090	0.001		0.3%		
	Flow Tube TP-9 (l)	SP-3	0.2	62.3	0.82		0.4%			3.92	0.05		0.4%			0.0020	0.0000		0.1%			0.090	0.001		0.3%		
	Flow Tube TP-10 (l)	SP-3	0.2	62.3	1.05		0.6%			3.92	0.07		0.5%			0.0020	0.0000		0.1%			0.090	0.002		0.4%		
	Flow Tube TP-11 (m)	SP-3, PZ-6A	0.0	72.8	0.13		0.1%			1.97	0.00		0.0%			0.0011	0.0000		0.0%			0.046	0.000		0.0%		
	Flow Tube TP-12 (i)	PZ-6A	0.0	83.3	0.20		0.1%			0.02	0.00		0.0%			0.0001	0.0000		0.0%			0.002	0.000		0.0%		
	Flow Tube TP-13 (i)	PZ-6A	0.1	83.3	0.45		0.2%			0.02	0.00		0.0%			0.0001	0.0000		0.0%			0.002	0.000		0.0%		
	Flow Tube TP-14 (i)	PZ-6A	0.1	83.3	0.75		0.4%			0.02	0.00		0.0%			0.0001	0.0000		0.0%			0.002	0.000		0.0%		
	Flow Tube TP-15 (i)	PZ-6A	0.1	83.3	0.90		0.5%			0.02	0.00		0.0%			0.0001	0.0000		0.0%			0.002	0.000		0.0%		
Groundwater Flow from Native Material																											
	Flow Tube S7 (i)	TP2-4A	2.5	29.6	6.50		3.4%			0.01	0.00		0.0%			0.0001	0.0000		0.1%			0.001	0.000		0.1%		
	Flow Tube S8 IN (j)	TP2-4A	0.3	29.6	0.89		0.5%			0.01	0.00		0.0%			0.0001	0.0000		0.0%			0.001	0.000		0.0%		
	Flow Tube S8 OUT (j)	RC-7	-1.2	0.5	-0.06		0.0%			0.04	0.00		0.0%			0.0001	0.0000		0.0%			0.001	0.000		0.0%		
	Flow Tube SL1 (k)	RC-7	-7.0	0.5	-0.32		-0.2%			0.04	-0.02		-0.2%			0.0001	-0.0001		-0.2%			0.001	-0.001		-0.2%		
	Flow Tube SL2 (k)	RC-7	-5.8	0.5	-0.27		-0.1%			0.04	-0.02		-0.2%			0.0001	0.0000		-0.1%			0.001	-0.001		-0.2%		
	Flow Tube SL3 (k)	RC-7	-1.9	0.5	-0.09		0.0%			0.04	-0.01		0.0%			0.0001	0.0000		0.0%			0.001	0.000		-0.1%		
			-12.2			12.02	6.3%	193.29	101.9%			0.14	1.0%	20.00	150.3%			0.0000	0.0%	0.03	88.1%			0.003	0.7%	0.91	228.2%
Unaccounted (Groundwater) Load to RC-2 (n)						-3.64	-1.9%					-6.69	-50.3%					0.0040	11.9%					-0.512	-128.2%		
Measured Value at RC-2 (h)			*3850.9*	*0.6*		*189.65*	*100.0%*	*189.65*	*100.0%*	*0.04*		*13.31*	*100.0%*	*13.31*	*100.0%*	*0.0001*		*0.0333*	*100.0%*	*0.03*	*100.0%*	*0.001*		*0.399*	*100.0%*	*0.40*	*100.0%*
Loading Downstream of RC-2 (o)																											
Groundwater Seep and Flow from Native Material																											
	SP-21 (p)		0.1	7.6	0.06		0.0%			1.80	0.01		0.1%			0.0011	0.0000		0.0%			0.034	0.000		0.1%		
	Flow Tube S8 OUT (q)	DS-1, TP3-9	1.2	23.2	2.50		1.3%			4.97	0.54		4.0%			0.0025	0.0003		0.8%			0.045	0.005		1.2%		
	Flow Tube SL1 (q)	DS-1, TP3-9	7.0	23.2	14.02		7.4%			4.97	3.01		22.6%			0.0025	0.0015		4.5%			0.045	0.027		6.8%		
	Flow Tube SL2 (q)	DS-1	5.8	5.0	2.49		1.3%			0.25	0.13		0.9%			0.0014	0.0007		2.1%			0.039	0.020		4.9%		
	Flow Tube SL3 (q)	DS-1	1.9	5.0	0.82		0.4%			0.25	0.04		0.3%			0.0014	0.0002		0.7%			0.039	0.006		1.6%		
	Flow Tube SL4 (q)	TP3-9	0.3	41.4	1.10		0.6%			9.69	0.26		1.9%			0.0035	0.0001		0.3%			0.051	0.001		0.3%		
	Flow Tube SL5 (q)	TP3-9	0.4	41.4	1.39		0.7%			9.69	0.33		2.4%			0.0035	0.0001		0.4%			0.051	0.002		0.4%		
			16.8			22.39	11.8%	212.04	111.8%			4.31	32.4%	17.62	132.4%			0.0029	8.7%	0.04	108.7%			0.061	15.4%	0.46	115.4%
Total Values (Measured RC-2 + Downstream of RC-2)			**3867.7**			**212.04**	**111.8%**	**212.04**	**111.8%**			**17.62**	**132.4%**	**17.6**	**132.4%**			**0.0362**	**108.7%**	**0.04**	**108.7%**			**0.461**	**115.4%**	**0.46**	**115.4%**
Total Loading Attributed to the East Area (r)						**92.79**	**48.9%**					**14.43**	**108.5%**					**0.0164**	**49.3%**					**-0.098**	**-24.6%**		
Measured Value at RC-5 (s)			*3658.9*	*0.7*		*214.97*	*113.4%*	*214.97*	*113.4%*	*0.05*		*15.81*	*118.8%*	*15.81*	*118.8%*	*0.0001*		*0.0379*	*114.0%*	*0.04*	*114.0%*	*0.002*		*0.506*	*126.7%*	*0.51*	*126.7%*

Table A-4
Loading Calculations - Railroad Creek, East Area - September 1997
Figures A-6, A-9, A-10, and A-11
Holden Mine RI/FS

				Iron						Sulfate						Zinc					
								Cumulative						Cumulative						Cumulative	
Source Area	**Contribution to Railroad Creek**	**Associated Monitoring Well/Seep**	**Flows L/s**	**Conc. mg/L**	**Load kg/d**	**Total Load to RRC kg/d**	**% Load of RC-2**	**Load (kg/d)**	**% Load of RC-2**	**Conc. mg/L**	**Load kg/d**	**Total Load to RRC kg/d**	**% Load of RC-2**	**Load (kg/d)**	**% Load of RC-2**	**Conc. mg/L**	**Load kg/d**	**Total Load to RRC kg/d**	**% Load of RC-2**	**Load (kg/d)**	**% Load of RC-2**
Total From Background & West Area Sources(a)			*3682.0*			*12.2*	*3.4%*	*12.2*	*3.4%*			*1253*	*54.6%*	*1253*	*54.6%*			*3.35*	*43.7%*	*3.3*	*43.7%*
Tailings Pile 1																					
Groundwater Seeps and Flow from Tailings																					
	SP-1 (b)		NF																		
	Tailings Pile 1 (c)	SP-2	0.9	685.0	53.20		14.8%			2200	170.87		7.4%			5.70	0.44		5.8%		
	SP-2 (e)		0.1	685.0	5.92		1.6%			2200	19.01		0.8%			5.70	0.05		0.6%		
Groundwater Flow from Native Material																					
	Flow Tube S1 (d)	HBKG-1, TP1-6A	2.2	40.2	7.68		2.1%			240	45.82		2.0%			4.26	0.81		10.6%		
	Flow Tube S2 (d)	TP1-2, TP1-3	1.2	1605.0	165.12		46.0%			3750	385.80		16.8%			4.59	0.47		6.2%		
	Flow Tube S3 (d)	TP1-5	3.6	413.0	127.39		35.5%			1000	308.45		13.4%			2.73	0.84		11.0%		
			8.0			359.31	100.0%	371.52	103.4%			929.94	40.5%	2182.75	95.1%			2.62	34.2%	5.96	77.9%
Copper Creek																					
	Copper Creek (f)		141.6	0.0	0.12		0.0%	0.12		1	15.29		0.7%	15.29		0.00	0.02		0.3%	0.02	
			141.6			0.12	0.0%	371.64	103.4%			15.29	0.7%	2198.04	95.7%			0.02	0.3%	5.99	78.3%
Tailings Pile 2 (Upstream of RC-7)																					
Groundwater Seeps and Flow from Tailings																					
	SP-3 (e)		0.4	251.0	8.67		2.4%			1300	44.9		2.0%			0.61	0.02		0.3%		
	Flow Tube TP-1 (d)	SP-3	0.4	251.0	9.74		2.7%			1300	50.5		2.2%			0.61	0.02		0.3%		
	Flow Tube TP-2 (d)	SP-3	0.1	251.0	2.39		0.7%			1300	12.4		0.5%			0.61	0.01		0.1%		
	Flow Tube TP-3 (d)	SP-3	0.2	251.0	3.48		1.0%			1300	18.0		0.8%			0.61	0.01		0.1%		
	Flow Tube TP-4 (d)	SP-3	0.2	251.0	3.56		1.0%			1300	18.4		0.8%			0.61	0.01		0.1%		
	Flow Tube TP-5 (g)	SP-3	0.1	251.0	2.01		0.6%			1300	10.4		0.5%			0.61	0.00		0.1%		
	Flow Tube TP-6 (g)	SP-3	0.2	251.0	4.02		1.1%			1300	20.8		0.9%			0.61	0.01		0.1%		
Groundwater Flow from Native Material																					
	Flow Tube S4 (d)	TP2-11A	4.5	0.1	0.04		0.0%			390	152.7		6.7%			0.31	0.12		1.6%		
	Flow Tube S5 (d)	TP2-11A	0.6	0.1	0.005		0.0%			390	19.6		0.9%			0.31	0.02		0.2%		
	Flow Tube S6 (d)	TP2-11A, PZ-3A	2.8	2.9	0.70		0.2%			450	107.9		4.7%			0.16	0.04		0.5%		
			9.4			34.63	9.6%	406.27	113.1%			455.6	19.8%	2653.65	115.6%			0.26	3.4%	6.25	81.6%
Measured Value at RC-7 (for comparison only)(h)			*4134.0*	*1.2*		*410.75*	*114.3%*			*6*		*2285.94*	*99.6%*			*0.02*		*6.79*	*88.7%*		
Tailings Pile 2 & 3 Downstream of RC-7																					
Groundwater Seeps and Flow from Tailings																					
	SP-4 (b)		NF																		
	Flow Tube TP-7 (l)	SP-3	0.1	251.0	1.17		0.3%			1300	6.08		0.3%			0.61	0.00		0.0%		
	Flow Tube TP-8 (l)	SP-3	0.1	251.0	3.17		0.9%			1300	16.44		0.7%			0.61	0.01		0.1%		
	Flow Tube TP-9 (l)	SP-3	0.2	251.0	3.28		0.9%			1300	17.01		0.7%			0.61	0.01		0.1%		
	Flow Tube TP-10 (l)	SP-3	0.2	251.0	4.23		1.2%			1300	21.91		1.0%			0.61	0.01		0.1%		
	Flow Tube TP-11 (m)	SP-3, PZ-6A	0.0	163.4	0.29		0.1%			1500	2.63		0.1%			0.32	0.00		0.0%		
	Flow Tube TP-12 (i)	PZ-6A	0.0	75.7	0.18		0.1%			1700	4.09		0.2%			0.03	0.00		0.0%		
	Flow Tube TP-13 (i)	PZ-6A	0.1	75.7	0.41		0.1%			1700	9.19		0.4%			0.03	0.00		0.0%		
	Flow Tube TP-14 (i)	PZ-6A	0.1	75.7	0.68		0.2%			1700	15.25		0.7%			0.03	0.00		0.0%		
	Flow Tube TP-15 (i)	PZ-6A	0.1	75.7	0.81		0.2%			1700	18.28		0.8%			0.03	0.00		0.0%		
Groundwater Flow from Native Material																					
	Flow Tube S7 (i)	TP2-4A	2.5	5.6	1.24		0.3%			570	125.13		5.5%			0.01	0.00		0.0%		
	Flow Tube S8 IN (j)	TP2-4A	0.3	5.6	0.17		0.0%			570	17.05		0.7%			0.01	0.00		0.0%		
	Flow Tube S8 OUT (j)	RC-7	-1.2	1.2	-0.12		0.0%			6	-0.69		0.0%			0.02	0.00		0.0%		
	Flow Tube SL1 (k)	RC-7	-7.0	1.2	-0.70		-0.2%			6	-3.87		-0.2%			0.02	-0.01		-0.2%		
	Flow Tube SL2 (k)	RC-7	-5.8	1.2	-0.58		-0.2%			6	-3.21		-0.1%			0.02	-0.01		-0.1%		
	Flow Tube SL3 (k)	RC-7	-1.9	1.2	-0.19		-0.1%			6	-1.06		0.0%			0.02	0.00		0.0%		
			-12.2			14.05	3.9%	420.32	117.0%			244.24	10.6%	2897.88	126.2%			0.01	0.1%	6.25	81.7%
Unaccounted (Groundwater) Load to RC-2 (n)						-60.98	-17.0%					-602.13	-26.2%					1.40	18.3%		
Measured Value at RC-2 (h)			*3850.9*	*1.1*		*359.34*	*100.0%*	*359.34*	*100.0%*	*7*		*2295.75*	*100.0%*	*2295.75*	*100.0%*	*0.02*		*7.65*	*100.0%*	*7.65*	*100.0%*
Loading Downstream of RC-2 (o)																					
Groundwater Seep and Flow from Native Material																					
	SP-21 (p)		0.1	1.5	0.01		0.0%			140	1.14		0.0%			0.13	0.00		0.0%		
	Flow Tube S8 OUT (q)	DS-1, TP3-9	1.2	62.5	6.75		1.9%			1	0.066		0.0%			0.24	0.03		0.3%		
	Flow Tube SL1 (q)	DS-1, TP3-9	7.0	62.5	37.81		10.5%			1	0.369		0.0%			0.24	0.15		1.9%		
	Flow Tube SL2 (q)	DS-1	5.8	0.0	0.01		0.0%			0	0.060		0.0%			0.08	0.04		0.5%		
	Flow Tube SL3 (q)	DS-1	1.9	0.0	0.00		0.0%			0	0.020		0.0%			0.08	0.01		0.2%		
	Flow Tube SL4 (q)	TP3-9	0.3	125.0	3.32		0.9%			1	0.029		0.0%			0.40	0.01		0.1%		
	Flow Tube SL5 (q)	TP3-9	0.4	125.0	4.21		1.2%			1	0.04		0.0%			0.40	0.01		0.2%		
			16.8			52.10	14.5%	411.43	114.5%			1.73	0.1%	2297.48	100.1%			0.25	3.3%	7.90	103.3%
Total Values (Measured RC-2 + Downstream of RC-2)			**3867.7**			**411.43**	**114.5%**	**411.43**	**114.5%**			**2297**	**100.1%**	**2297**	**100.1%**			**7.90**	**103.3%**	**7.90**	**103.3%**
Total Loading Attributed to the East Area (r)						**399.22**	**111.1%**					**1045**	**45.5%**					**4.56**	**59.5%**		
Measured Value at RC-5 (s)			*3658.9*	*1.3*		*395.17*	*110.0%*	*395.17*	*110.0%*	*11*		*3477.46*	*151.5%*	*3477.46*	*151.5%*	*0.03*		*9.48*	*123.9%*	*9.48*	*123.9%*

Notes to Tables A-5 & A-6
Uncertainty Analysis
Baseline Loading Calculations – Railroad Creek
Holden Mine RI/FS

(a) Concentration data is as presented and referenced in the Loading Analysis, FS Tables A-1 through A-4. The reported value is assumed to be the best estimate of expected value of the concentration, E[C].

(b) The accuracy of concentration measurements was conservatively estimated to be 5% for surface water (i.e. Railroad Creek, seeps and tributaries) where the flow was not adjusted. Concentration accuracy was assumed to be 10% for Railroad Creek stations where the flow was adjusted (stations RC-6, RC-1, RC-4 and RC-2 during Spring 1997). This estimate accounts for analytical uncertainty and sampling variability. Accuracy of groundwater concentrations was estimated to be 50% and accounts for spatial variation in groundwater quality, sampling variability and analytical uncertainty. Each accuracy is assumed to equal the coefficient of variation for the concentration (CV[C]), a measure of the uncertainty around the estimate of the expected concentration, E[C].

(c) Surface water flow measurements and calculated groundwater flows are as presented and referenced in the Loading Analysis, FS Tables A-1 through A-4. The reported value is assumed to be the best estimate of expected value of the flow, E[Q].

(d) The accuracies of flow measurements for seeps, tributaries and Railroad Creek stations are presented in Sections 4.4.4 (Site Water Balance) and 6.6 (Surface Water Loading Analysis) of the DRI Report. Variability in groundwater flowtubes and Tailings Pile 1 discharges to Railroad Creek was calculated based on the range of hydraulic conductivity (k) values presented in DRI and subsequent investigations . As the range between the lower and upper bounds for hydraulic conductivities in native material (2.95×10^{-5} ft/sec to 6.04×10^{-3} ft/sec) and tailings (6.76×10^{-6} ft/sec to 1.44×10^{-4} ft/sec) spans an order of magnitude, the accuracy of the groundwater flow from each tube was estimated based on a lognormal distribution of measured hydraulic conductivities in the two media. The accuracy of groundwater flow through tailings and native material was estimated to be 1.95 and 1.28, respectively. Each surface water or groundwater flow accuracy is assumed to equal the coefficient of variation for the flow (CV[Q]), a measure of the uncertainty around the estimate of the expected flow, E[Q].

(e) The total loading from each source is as presented in the Loading Analysis, FS Tables A-1 through A-4. The loading (L) is equal to the flow (Q) multiplied by the concentration (C), or

$$L = Q * C$$

For the purpose of this metals loading and uncertainty analysis, it assumed that there is no covariance between the variables of flow (Q) and concentration (C), that is to say that the correlation coefficient between flow and concentration is zero. With this assumption, the loading calculation above may be re-written as

$$E[L] = E[Q] * E[C]$$

in which case the expected value of metals loading (E[L]) is equal to the product of the expected values of flow and concentration. The expected value of loading (E[L]) is assumed to be equivalent with the calculated metal loadings presented in Tables 1-4 of the Loading Analysis.

(g) The cumulative loading in Railroad Creek represents the sum of calculated loads to Railroad after the addition of any given seep, source or groundwater flow tube contribution. For the purpose of this analysis, the calculated cumulative load is assumed to represent the expected value of true loading, $E[L_{Cumulative}]$, and may be represented as the sum of two or more expected loads, $E[L_i]$:

$$E[L_{Cumulative}] = E[L_1] + E[L_2] + E[L_3] + ...$$

(h) The coefficient of variation for the calculated (expected) load, CV[L], is a measure of the variability or uncertainty associated with the calculated load. If Q and C are assumed to be independent variables (correlation coefficient = 0), then CV[L] is a function of CV[Q] and CV[C] and is expressed as:

$$CV[L] = [(CV[Q]^2 + 1)(CV[C]^2 + 1) - 1]^{1/2}$$

(i) The coefficient of variation CV[L] and the expected value E[L] are related by the variance, V[L]. The variance of metals loading is equal to the square of the standard deviation of the expected loading, SD[L]:

$$V[L] = SD[L]^2$$

The standard deviation of the expected loading (SD[L]) is equal to the product of the coefficient of variation for the expected loading (CV[L]) and the expected loading (E[L]):
SD[L] = CV[L] * E[L]

By substituting the CV[L]*E[L] for the standard deviation (SD[L]) the variance for each calculated load may be expressed as:

$$V[L] = (CV[L] * E[L])^2$$

The variance of the calculated loadings may then be used to assess the variance of the calculated cumulative loading to Railroad Creek.

(j) If loading from individual sources are assumed to be independent of each other (correlation coefficient = 0), then the variance of the sum of calculated (expected) loading may be expressed as the sum of the individual variances, or

$$V[L_{Cumulative}] = V[L_1] + V[L_2] + V[L_3] + ...$$

The cumulative variance for the difference of calculated (expected) loads is represented by the same equation. This is important when assessing the uncertainty associated with the calculations of Unaccounted Loading and the Total Loading Attributed to the East and West Areas.

(k) The coefficient of variation for the cumulative loading $CV[L_{Cumulative}]$ is related to the variance and the calculated (expected) values of the cumulative loading ($V[L_{Cumulative}]$ and $E[L_{Cumulative}]$) as described in note (i), above. The coefficient of variance for the cumulative loading ($CV[L_{Cumulative}]$) is calculated with the expression:

$$CV[L_{Cumulative}] = (V[L_{Cumulative}]^{1/2}) / E[L_{Cumulative}]$$

The coefficient of variation for the cumulative loading $CV[L_{Cumulative}]$ represents the variability or uncertainty associated with the calculated metals loading to Railroad Creek, and for the purpose of this analysis may be used interchangeably as the “% accuracy” of the calculated loading, given the input parameters (flow and concentration), their associated uncertainties (% accuracies) and the assumptions described in the notes above.

Table A-5.1
Uncertainty Analysis - Magnesium
Baseline Loading Calculations - Railroad Creek - Spring 1997
Holden Mine RI/FS

West Area - Spring 1997			**Magnesium**									
	Seep / Tributary Information		Loading Parameters and Accuracies				Surface Water Loading to RRC from Source Area		Source Loading Accuracy		Cumulative Loading Accuracy	
Source Area	Seep/Tributary	Discharges To	Conc.E[C] (a) (mg/L)	Accuracy of Conc. CV[C] (b) (%)	Flow E[Q] (c) (L/s)	Accuracy of Flow CV[Q] (d) (%)	Total Load to RRC, E[L] (e) (kg/d)	Cumulative Load, $E[L_{Cumulative}]$ (g) (kg/D)	CV[L] (h)	V[L] (i)	$V[L_{CUMULATIVE}]$ (j)	$CV[L_{CUMULATIVE}]$ (k)
Measured Value at RC-6			0.4	10%	14159.0	10%	440.4	440.40	0.142	3898.466	3898.466	0.142
SP-26												
	SP-26	RRC	0.5	5%	0.3	50%	0.0	440.41	0.503	0.000	3898.466	0.142
	Source Area Total						0.0	440.41	0.503	0.000	3898.466	0.142
	Cumulative Loading						440.4	440.41			3898.466	0.142
Unaccounted (Groundwater) Load to RC-1 (h)							0.1	440.47			7798.094	0.200
Measured Value at RC-1			0.4	10%	14161.1	10%	440.5	440.47	0.142	3899.628	3899.628	0.142
SP-23/Honeymoon Heights:												
	SP-23	RRC	5.1	5%	14.2	25%	6.3	446.76	0.255	2.580	3902.208	0.140
	SP-23B	RRC	3.9	5%	1.9	25%	0.6	447.40	0.255	0.027	3902.235	0.140
	SP-12	RRC	1.5	5%	1.9	50%	0.2	447.64	0.503	0.015	3902.250	0.140
	Source Area Total						7.2	447.64	0.226	2.622	3902.250	0.140
Underground Mine												
	P-5	RRC	9.3	5%	96.8	20%	77.7	525.37	0.206	257.382	4159.632	0.123
	Source Area Total						77.7	525.37	0.206	257.382	4159.632	0.123
West Area Seeps (Upstream of RC-4)												
	SP-9	RRC	2.1	5%	0.5	25%	0.1	525.46	0.255	0.000	4159.632	0.123
	SP-11	RRC	3.2	5%	0.5	50%	0.1	525.59	0.503	0.004	4159.636	0.123
	SP-25	RRC	5.1	5%	0.1	50%	0.0	525.63	0.503	0.000	4159.637	0.123
	SP-24	RRC	6.2	5%	0.9	50%	0.5	526.14	0.503	0.066	4159.703	0.123
	Source Area Total						0.8	526.14	0.347	0.071	4159.703	0.123
	Cumulative Loading						526.1	526.14			4159.703	0.123
Unaccounted (Groundwater) Load to RC-4 (h)							48.9	575.05			10806.523	0.181
Measured Value at RC-4			0.5	10%	14161.1	10%	575.1	575.05	0.142	6646.820	6646.820	0.142
West Area Seeps (Downstream of RC-4)												
	SP-10W	RRC	3.9	5%	0.3	50%	0.1	575.16	0.503	0.003	6646.823	0.142
	SP-10E	RRC	1.4	5%	0.3	50%	0.0	575.20	0.503	0.000	6646.823	0.142
	Source Area Total						0.1	575.20	0.393	0.003	6646.823	0.142
East Waste Rock Pile												
	SP-19	CCD	3.3	5%	2.7	25%	0.8	575.20	0.255	0.038		
	Source Area Total						0.8	575.20	0.255	0.038		
Groundwater Flow from Native Material												
	Flow Tube S1	RRC	4.4	50%	1.3	128%	0.5	575.68	1.516	0.524	6647.347	0.142
	Source Area Total						0.5	575.68	1.516	0.524	6647.347	0.142
Copper Creek Diversion												
	CC-D1	RRC	0.7	5%	198.2	7%	11.3	586.98	0.086	0.947	6648.294	0.139
	CCD1-SP19	*RRC*	3.3	5%	2.7	25%	10.5		0.094	0.985		
	Source Area Total						11.3	586.98	0.086	0.947	6648.294	0.139
Total West Area Surface Water Loading to RRC					**14359.9**		**587.0**	**586.98**			**6648.294**	**0.139**
Loading to Railroad Creek Associated w/West Area Sources							**146.6**	**146.58**			**10546.759**	**0.701**

East Area - Spring 1997			**Magnesium**									
	Seep / Tributary Information		Loading Parameters and Accuracies				Surface Water Loading to RRC from Source Area		Source Loading Accuracy		Cumulative Loading Accuracy	
Source Area	Contribution to Railroad Creek	Associted Monitoring Well/Seep	Conc.E[C] (a) (mg/L)	Accuracy of Conc. CV[C] (b) (%)	Flow E[Q] (c) (L/s)	Accuracy of Flow CV[Q] (d) (%)	Total Load to RRC, E[L] (e) (kg/d)	Cumulative Load, $E[L_{Cumulative}]$ (g) (kg/D)	CV[L] (h)	V[L] (i)	$V[L_{CUMULATIVE}]$ (j)	$CV[L_{CUMULATIVE}]$ (k)
Total From Background & West Area Sources					**14359.9**		**587.0**	**586.98**			**6648.294**	**0.139**
Tailings Pile 1												
Groundwater Seeps and Flow from Tailings												
	SP-1		53.5	5%	0.9	50%	4.4	591.35	0.503	4.845	6653.139	0.138
	Tailings Pile 1	SP-1,SP-2	75.2	50%	1.0	195%	6.8	598.13	2.237	229.868	6883.007	0.139
	SP-2		96.8	5%	0.9	50%	7.9	606.05	0.503	15.862	6898.869	0.137
Groundwater Flow from Native Material												
	Flow Tube S2	TP1-6A	29.4	50%	1.7	128%	4.3	610.40	1.516	43.453	6942.322	0.137
	Flow Tube S3	TP1-2A	33.2	50%	1.8	128%	5.0	615.42	1.516	57.943	7000.265	0.136
	Flow Tube S4	TP1-2A, TP1-3A	44.7	50%	3.5	128%	13.4	628.86	1.516	415.490	7415.755	0.137
	Flow Tube S5	TP1-5A	78.4	50%	2.2	128%	14.8	643.66	1.516	503.254	7919.009	0.138
	Flow Tube S6	TP1-5A	78.4	50%	3.5	128%	24.0	667.64	1.516	1321.345	9240.354	0.144
	Source Area Total						80.7	667.64	0.631	2592.060	9240.354	0.144
Copper Creek												
	Copper Creek		0.5	5%	424.8	7%	19.8	687.46	0.086	2.911	9243.265	0.140
	Source Area Total						19.8	687.46	0.086	2.911	9243.265	0.140
Tailings Pile 2 (Upstream of RC-7)												
Groundwater Seeps and Flow from Tailings												
	SP-3		47.9	5%	4.7	50%	19.6	707.04	0.503	97.099	9340.364	0.137
	Flow Tube TP-1	SP-3	47.9	50%	0.1	195%	0.4	707.46	2.237	0.859	9341.223	0.137
	Flow Tube TP-2	SP-3	47.9	50%	0.2	195%	0.7	708.17	2.237	2.511	9343.734	0.136
	Flow Tube TP-3	SP-3	47.9	50%	0.2	195%	0.7	708.91	2.237	2.793	9346.527	0.136
	Flow Tube TP-4	SP-3	47.9	50%	0.2	195%	0.7	709.63	2.237	2.533	9349.060	0.136
	Flow Tube TP-5	SP-3	47.9	50%	0.1	195%	0.6	710.18	2.237	1.557	9350.618	0.136
	Flow Tube TP-6	SP-3	47.9	50%	0.2	195%	0.7	710.90	2.237	2.544	9353.162	0.136
	Flow Tube TP-7	SP-3	47.9	50%	0.3	195%	1.0	711.94	2.237	5.474	9358.636	0.136
Groundwater Flow from Native Material												
	Flow Tube S7	TP2-11	4.9	50%	4.7	128%	2.0	713.93	1.516	9.064	9367.700	0.136
	Flow Tube S8	TP2-11	4.9	50%	4.0	128%	1.7	715.62	1.516	6.565	9374.265	0.135
	Flow Tube S9	TP2-11	4.9	50%	1.3	128%	0.5	716.17	1.516	0.693	9374.959	0.135
	Flow Tube S10	PZ-3A	24.1	50%	2.7	128%	5.7	721.85	1.516	74.249	9449.208	0.135
	Source Area Total						34.4	721.85	0.417	205.943	9449.208	0.135
	Cumulative Loading						104.63	721.85			9449.208	0.135
Measured Load at RC-7 (for comparison only)			0.6	5%	14867.8	7%	757.9	757.90	0.086	4257.697		
Tailings Pile 2 & 3 (Downstream of RC-7)												
Groundwater Seeps and Flow from Tailings												
	SP-4		36.3	5%	14.2	50%	44.5	766.38	0.503	501.880	9951.088	0.130
	Flow Tube TP-8	SP-3, SP-4	42.1	50%	0.2	195%	0.6	767.01	2.237	1.957	9953.045	0.130
	Flow Tube TP-9	SP-3, SP-4	42.1	50%	0.1	195%	0.3	767.26	2.237	0.313	9953.358	0.130
	Flow Tube TP-10	SP-4	36.3	50%	0.1	195%	0.3	767.52	2.237	0.354	9953.712	0.130
	Flow Tube TP-11	SP-4	36.3	50%	0.2	195%	0.5	768.04	2.237	1.359	9955.072	0.130
	Flow Tube TP-12	SP-4	36.3	50%	0.1	195%	0.3	768.38	2.237	0.577	9955.649	0.130
	Flow Tube TP-13	SP-4, PZ-6A	50.7	50%	0.1	195%	0.6	768.97	2.237	1.745	9957.394	0.130
	Flow Tube TP-14	PZ-6A	65.1	50%	0.2	195%	0.9	769.85	2.237	3.803	9961.196	0.130
	Flow Tube TP-15	PZ-6A	65.1	50%	0.2	195%	1.2	771.04	2.237	7.141	9968.337	0.129
	Flow Tube TP-16	PZ-6A	65.1	50%	0.1	195%	0.5	771.56	2.237	1.361	9969.698	0.129
Groundwater Flow from Native Material												
	Flow Tube S11	PZ-3A	24.1	50%	2.5	128%	5.2	776.78	1.516	62.533	10032.230	0.129
	Flow Tube S12	TP2-4A	27.4	50%	1.4	128%	3.2	780.01	1.516	23.937	10056.167	0.129
	Flow Tube S13	TP2-4A	27.4	50%	1.2	128%	2.8	782.85	1.516	18.623	10074.791	0.128
	Flow Tube S14	TP3-8A	17.4	50%	1.8	128%	2.8	785.62	1.516	17.599	10092.390	0.128
	Flow Tube S15	TP3-8A	17.4	50%	0.5	128%	0.7	786.36	1.516	1.266	10093.656	0.128
	Flow Tube S16	TP3-8A	17.4	50%	1.2	128%	1.8	788.15	1.516	7.348	10101.004	0.128
	Flow Tube S17	TP3-10	3.6	50%	1.9	128%	0.6	788.75	1.516	0.829	10101.833	0.127
	Flow Tube S18	TP3-10	3.6	50%	1.9	128%	0.6	789.33	1.516	0.780	10102.613	0.127
	Flow Tube S19	TP3-10	3.6	50%	3.1	128%	1.0	790.30	1.516	2.146	10104.759	0.127
	Source Area Total						68.4	790.30	0.374	655.551	10104.759	0.127
	Cumulative Loading						790.30	790.30			10104.759	0.127
Unaccounted (Groundwater) Load to RC-2 (h)							26.7	817.00			23521.235	0.188
Measured Values at RC-2			0.6	10%	15009.5	10%	817.0	817.00	0.142	13416.476	13416.476	0.142
Loading Downstream of RC-2												
	SP-21		3.8	5%	55.5	25%	18.3	835.32	0.255	21.862	13438.339	0.139
	Source Area Total						18.3	835.32	0.255	21.862	13438.339	0.139
Total Values (Measured RC-2 + SP-21)					**15065.0**		**835.3**	**835.32**			**13438.339**	**0.139**
Total Loading Attributed to the East Area							**248.3**	**248.34**			**20086.632**	**0.571**
Measured Values at RC-5 (i)			0.7	5%	15065.0	25%	872.1	872.08	0.255	49553.327		

Table A-5.2
Uncertainty Analysis - Aluminum
Baseline Loading Calculations - Railroad Creek - Spring 1997
Holden Mine RI/FS

West Area - Spring 1997 — Aluminum

Source Area	Seep/Tributary	Discharges To	Conc.E[C] (a) (mg/L)	Accuracy of Conc. CV[C] (b) (%)	Flow E[Q] (c) (L/s)	Accuracy of Flow CV[Q] (d) (%)	Total Load to RRC, E[L] (e) (kg/d)	Cumulative Load, $E[L_{Cumulative}]$ (g) (kg/D)	CV[L] (h)	V[L] (i)	$V[L_{CUMULATIVE}]$ (j)	$CV[L_{CUMULATIVE}]$ (k)
	Seep / Tributary Information		Loading Parameters and Accuracies				Surface Water Loading to RRC from Source Area		Source Loading Accuracy		Cumulative Loading Accuracy	
Measured Value at RC-6			0.0	10%	14159.0	10%	18.4	18.35	0.142	6.768	6.768	0.142
SP-26												
	SP-26	RRC	0.0	5%	0.3	50%	0.0	18.35	0.503	0.000	6.768	0.142
	Source Area Total						0.0	18.35	0.503	0.000	6.768	0.142
	Cumulative Loading						18.4	18.35			6.768	0.142
Unaccounted (Groundwater) Load to RC-1 (h)							18.4	36.71			33.849	0.159
Measured Value at RC-1			0.0	10%	14161.1	10%	36.7	36.71	0.142	27.081	27.081	0.142
SP-23/Honeymoon Heights:												
	SP-23	RRC	7.9	5%	14.2	25%	9.7	46.38	0.255	6.103	33.184	0.124
	SP-23B	RRC	5.3	5%	1.9	25%	0.9	47.24	0.255	0.048	33.232	0.122
	SP-12	RRC	1.4	5%	1.9	50%	0.2	47.47	0.503	0.013	33.245	0.121
	Source Area Total						10.8	47.47	0.231	6.164	33.245	0.121
Underground Mine												
	P-5	RRC	5.8	5%	96.8	20%	48.9	96.33	0.206	101.712	134.957	0.121
	Source Area Total						48.9	96.33	0.206	101.712	134.957	0.121
West Area Seeps (Upstream of RC-4)												
	SP-9	RRC	0.0	5%	0.5	25%	0.0	96.33	0.255	0.000	134.957	0.121
	SP-11	RRC	0.2	5%	0.5	50%	0.0	96.34	0.503	0.000	134.957	0.121
	SP-25	RRC	0.9	5%	0.1	50%	0.0	96.35	0.503	0.000	134.957	0.121
	SP-24	RRC	2.4	5%	0.9	50%	0.2	96.54	0.503	0.010	134.967	0.120
	Source Area Total						0.2	96.54	0.469	0.010	134.967	0.120
	Cumulative Loading						96.5	96.54			134.967	0.120
Unaccounted (Groundwater) Load to RC-4 (h)							-59.8	36.71			162.048	0.347
Measured Value at RC-4			0.0	10%	14161.1	10%	36.7	36.71	0.142	27.081	27.081	0.142
West Area Seeps (Downstream of RC-4)												
	SP-10W	RRC	4.7	5%	0.3	50%	0.1	36.83	0.503	0.004	27.085	0.141
	SP-10E	RRC	9.9	5%	0.3	50%	0.3	37.10	0.503	0.018	27.103	0.140
	Source Area Total						0.4	37.10	0.377	0.022	27.103	0.140
East Waste Rock Pile												
	SP-19	CCD	4.6	5%	2.7	25%	1.1	37.10	0.255	0.075		
	Source Area Total						1.1	37.10	0.255	0.075		
Groundwater Flow from Native Material												
	Flow Tube S1	RRC	2.7	50%	1.3	128%	0.3	37.40	1.516	0.200	27.304	0.140
	Source Area Total						0.3	37.40	1.516	0.200	27.304	0.140
Copper Creek Diversion												
	CC-D1	RRC	0.0	5%	198.2	7%	0.3	37.74	0.086	0.001	27.304	0.138
	CCD1-SP19	*RRC*	4.6	5%	2.7	25%	-0.7		-0.377	0.076		
	Source Area Total						0.3	37.74	0.086	0.001	27.304	0.138
Total West Area Surface Water Loading to RRC					**14359.9**		**38.5**	**38.47**			**27.304**	**0.136**
Loading to Railroad Creek Associated w/West Area Sources							**20.1**	**20.12**			**34.073**	**0.290**

East Area - Spring 1997 — Aluminum

Source Area	Contribution to Railroad Creek	Associted Monitoring Well/Seep	Conc.E[C] (a) (mg/L)	Accuracy of Conc. CV[C] (b) (%)	Flow E[Q] (c) (L/s)	Accuracy of Flow CV[Q] (d) (%)	Total Load to RRC, E[L] (e) (kg/d)	Cumulative Load, $E[L_{Cumulative}]$ (g) (kg/D)	CV[L] (h)	V[L] (i)	$V[L_{CUMULATIVE}]$ (j)	$CV[L_{CUMULATIVE}]$ (k)
	Seep / Tributary Information		Loading Parameters and Accuracies				Surface Water Loading to RRC from Source Area		Source Loading Accuracy		Cumulative Loading Accuracy	
Total From Background & West Area Sources					**14359.9**		**38.5**	**38.47**			**27.304**	**0.136**
Tailings Pile 1												
Groundwater Seeps and Flow from Tailings												
	SP-1		27.1	5%	0.9	50%	2.2	40.69	0.503	1.243	28.548	0.131
	Tailings Pile 1	SP-1,SP-2	60.9	50%	1.0	195%	5.5	46.18	2.237	150.710	179.258	0.290
	SP-2		94.6	5%	0.9	50%	7.7	53.91	0.503	15.149	194.407	0.259
Groundwater Flow from Native Material												
	Flow Tube S2	TP1-6A	46.3	50%	1.7	128%	6.8	60.76	1.516	107.767	302.174	0.286
	Flow Tube S3	TP1-2A	7.1	50%	1.8	128%	1.1	61.84	1.516	2.657	304.831	0.282
	Flow Tube S4	TP1-2A, TP1-3A	4.6	50%	3.5	128%	1.4	63.22	1.516	4.400	309.232	0.278
	Flow Tube S5	TP1-5A	103.0	50%	2.2	128%	19.4	82.66	1.516	868.620	1177.852	0.415
	Flow Tube S6	TP1-5A	103.0	50%	3.5	128%	31.5	114.17	1.516	2280.649	3458.501	0.515
	Source Area Total						75.7	114.17	0.774	3431.196	3458.501	0.515
Copper Creek												
	Copper Creek		0.0	5%	424.8	7%	0.4	114.53	0.086	0.001	3458.502	0.513
	Source Area Total						0.4	114.53	0.086	0.001	3458.502	0.513
Tailings Pile 2 (Upstream of RC-7)												
Groundwater Seeps and Flow from Tailings												
	SP-3		33.4	5%	4.7	50%	13.7	128.19	0.503	47.210	3505.712	0.462
	Flow Tube TP-1	SP-3	33.4	50%	0.1	195%	0.3	128.48	2.237	0.418	3506.130	0.461
	Flow Tube TP-2	SP-3	33.4	50%	0.2	195%	0.5	128.97	2.237	1.221	3507.351	0.459
	Flow Tube TP-3	SP-3	33.4	50%	0.2	195%	0.5	129.49	2.237	1.358	3508.709	0.457
	Flow Tube TP-4	SP-3	33.4	50%	0.2	195%	0.5	129.99	2.237	1.232	3509.941	0.456
	Flow Tube TP-5	SP-3	33.4	50%	0.1	195%	0.4	130.38	2.237	0.757	3510.698	0.454
	Flow Tube TP-6	SP-3	33.4	50%	0.2	195%	0.5	130.88	2.237	1.237	3511.935	0.453
	Flow Tube TP-7	SP-3	33.4	50%	0.3	195%	0.7	131.61	2.237	2.662	3514.596	0.450
Groundwater Flow from Native Material												
	Flow Tube S7	TP2-11	0.3	50%	4.7	128%	0.1	131.74	1.516	0.042	3514.638	0.450
	Flow Tube S8	TP2-11	0.3	50%	4.0	128%	0.1	131.86	1.516	0.030	3514.668	0.450
	Flow Tube S9	TP2-11	0.3	50%	1.3	128%	0.0	131.89	1.516	0.003	3514.671	0.449
	Flow Tube S10	PZ-3A	0.0	50%	2.7	128%	0.0	131.89	1.516	0.000	3514.671	0.449
	Source Area Total						17.4	131.89	0.432	56.170	3514.671	0.449
	Cumulative Loading						104.63	131.89			3514.671	0.449
Measured Load at RC-7 (for comparison only)			0.1	5%	14867.8	7%	77.1	77.07	0.086	44.032		
Tailings Pile 2 & 3 (Downstream of RC-7)												
Groundwater Seeps and Flow from Tailings												
	SP-4		19.0	5%	14.2	50%	23.3	155.20	0.503	137.497	3652.169	0.389
	Flow Tube TP-8	SP-3, SP-4	26.2	50%	0.2	195%	0.4	155.59	2.237	0.758	3652.926	0.388
	Flow Tube TP-9	SP-3, SP-4	26.2	50%	0.1	195%	0.2	155.75	2.237	0.121	3653.048	0.388
	Flow Tube TP-10	SP-4	19.0	50%	0.1	195%	0.1	155.89	2.237	0.097	3653.145	0.388
	Flow Tube TP-11	SP-4	19.0	50%	0.2	195%	0.3	156.16	2.237	0.372	3653.517	0.387
	Flow Tube TP-12	SP-4	19.0	50%	0.1	195%	0.2	156.34	2.237	0.158	3653.675	0.387
	Flow Tube TP-13	SP-4, PZ-6A	9.5	50%	0.1	195%	0.1	156.45	2.237	0.061	3653.737	0.386
	Flow Tube TP-14	PZ-6A	0.0	50%	0.2	195%	0.0	156.45	2.237	0.000	3653.737	0.386
	Flow Tube TP-15	PZ-6A	0.0	50%	0.2	195%	0.0	156.45	2.237	0.000	3653.737	0.386
	Flow Tube TP-16	PZ-6A	0.0	50%	0.1	195%	0.0	156.45	2.237	0.000	3653.737	0.386
Groundwater Flow from Native Material												
	Flow Tube S11	PZ-3A	0.0	50%	2.5	128%	0.0	156.45	1.516	0.000	3653.737	0.386
	Flow Tube S12	TP2-4A	0.0	50%	1.4	128%	0.0	156.45	1.516	0.000	3653.737	0.386
	Flow Tube S13	TP2-4A	0.0	50%	1.2	128%	0.0	156.45	1.516	0.000	3653.737	0.386
	Flow Tube S14	TP3-8A	0.1	50%	1.8	128%	0.0	156.47	1.516	0.001	3653.738	0.386
	Flow Tube S15	TP3-8A	0.1	50%	0.5	128%	0.0	156.48	1.516	0.000	3653.738	0.386
	Flow Tube S16	TP3-8A	0.1	50%	1.2	128%	0.0	156.49	1.516	0.000	3653.738	0.386
	Flow Tube S17	TP3-10	0.3	50%	1.9	128%	0.0	156.54	1.516	0.005	3653.743	0.386
	Flow Tube S18	TP3-10	0.3	50%	1.9	128%	0.0	156.58	1.516	0.005	3653.749	0.386
	Flow Tube S19	TP3-10	0.3	50%	3.1	128%	0.1	156.66	1.516	0.014	3653.763	0.386
	Source Area Total						24.8	156.66	0.476	139.091	3653.763	0.386
	Cumulative Loading						156.66	156.66			3653.763	0.386
Unaccounted (Groundwater) Load to RC-2 (h)							-39.9	116.71			3927.568	0.537
Measured Values at RC-2			0.1	10%	15009.5	10%	116.7	116.71	0.142	273.806	273.806	0.142
Loading Downstream of RC-2												
	SP-21		1.5	5%	55.5	25%	7.2	123.91	0.255	3.371	277.177	0.134
	Source Area Total						7.2	123.91	0.255	3.371	277.177	0.134
Total Values (Measured RC-2 + SP-21)					**15065.0**		**123.9**	**123.91**			**277.177**	**0.134**
Total Loading Attributed to the East Area							**85.4**	**85.43**			**304.481**	**0.204**
Measured Values at RC-5 (i)			0.1	5%	15065.0	25%	91.1	91.11	0.255	540.903		

Table A-5.3
Uncertainty Analysis - Cadmium
Baseline Loading Calculations - Railroad Creek - Spring 1997
Holden Mine RI/FS

West Area - Spring 1997			**Cadmium**									
	Seep / Tributary Information		**Loading Parameters and Accuracies**				**Surface Water Loading to RRC from Source Area**		**Source Loading Accuracy**		**Cumulative Loading Accuracy**	
Source Area	**Seep/Tributary**	**Discharges To**	**Conc.E[C] (a) (mg/L)**	**Accuracy of Conc. CV[C] (b) (%)**	**Flow E[Q] (c) (L/s)**	**Accuracy of Flow CV[Q] (d) (%)**	**Total Load to RRC, E[L] (e) (kg/d)**	**Cumulative Load, $E[L_{Cumulative}]$ (g) (kg/D)**	**CV[L] (h)**	**V[L] (i)**	**$V[L_{CUMULATIVE}]$ (j)**	**$CV[L_{CUMULATIVE}]$ (k)**
Measured Value at RC-6			0.000	10%	14159.0	10%	0.024	0.02	0.142	0.000	0.000	0.142
SP-26												
	SP-26	RRC	0.000	5%	0.3	50%	0.000	0.02	0.503	0.000	0.000	0.142
	Source Area Total						0.000	0.02	0.503	0.000	0.000	0.142
	Cumulative Loading						0.024	0.02			0.000	0.142
Unaccounted (Groundwater) Load to RC-1 (h)							0.000	0.02			0.000	0.200
Measured Value at RC-1			0.000	10%	14161.1	10%	0.024	0.02	0.142	0.000	0.000	0.142
SP-23/Honeymoon Heights:												
	SP-23	RRC	0.039	5%	14.2	25%	0.048	0.07	0.255	0.000	0.000	0.175
	SP-23B	RRC	0.028	5%	1.9	25%	0.005	0.08	0.255	0.000	0.000	0.166
	SP-12	RRC	0.014	5%	1.9	50%	0.002	0.08	0.503	0.000	0.000	0.162
	Source Area Total						0.055	0.08	0.225	0.000	0.000	0.162
Underground Mine												
	P-5	RRC	0.053	5%	96.8	20%	0.439	0.52	0.206	0.008	0.008	0.177
	Source Area Total						0.439	0.52	0.206	0.008	0.008	0.177
West Area Seeps (Upstream of RC-4)												
	SP-9	RRC	0.001	5%	0.5	25%	0.000	0.52	0.255	0.000	0.008	0.177
	SP-11	RRC	0.013	5%	0.5	50%	0.001	0.52	0.503	0.000	0.008	0.176
	SP-25	RRC	0.034	5%	0.1	50%	0.000	0.52	0.503	0.000	0.008	0.176
	SP-24	RRC	0.048	5%	0.9	50%	0.004	0.52	0.503	0.000	0.008	0.175
	Source Area Total						0.005	0.52	0.419	0.000	0.008	0.175
	Cumulative Loading						0.523	0.52			0.008	0.175
Unaccounted (Groundwater) Load to RC-4 (h)							0.015	0.54			0.014	0.221
Measured Value at RC-4			0.000	10%	14161.1	10%	0.538	0.54	0.142	0.006	0.006	0.142
West Area Seeps (Downstream of RC-4)												
	SP-10W	RRC	0.026	5%	0.3	50%	0.001	0.54	0.503	0.000	0.006	0.142
	SP-10E	RRC	0.007	5%	0.3	50%	0.000	0.54	0.503	0.000	0.006	0.142
	Source Area Total						0.001	0.54	0.410	0.000	0.006	0.142
East Waste Rock Pile												
	SP-19	CCD	0.050	5%	2.7	25%	0.012	0.54	0.255	0.000		
	Source Area Total						0.012	0.54	0.255	0.000		
Groundwater Flow from Native Material												
	Flow Tube S1	RRC	0.034	50%	1.3	128%	0.004	0.54	1.516	0.000	0.006	0.141
	Source Area Total						0.004	0.54	1.516	0.000	0.006	0.141
Copper Creek Diversion												
	CC-D1	RRC	0.002	5%	198.2	7%	0.030	0.57	0.086	0.000	0.006	0.134
	CCD1-SP19	*RRC*	0.050	5%	2.7	25%	0.019		0.212	0.000		
	Source Area Total						0.030	0.57	0.086	0.000	0.006	0.134
Total West Area Surface Water Loading to RRC					**14359.9**		**0.573**	**0.57**			**0.006**	**0.134**
Loading to Railroad Creek Associated w/West Area Sources							**0.549**	**0.55**			**0.006**	**0.140**

East Area - Spring 1997			**Cadmium**									
	Seep / Tributary Information		**Loading Parameters and Accuracies**				**Surface Water Loading to RRC from Source Area**		**Source Loading Accuracy**		**Cumulative Loading Accuracy**	
Source Area	**Contribution to Railroad Creek**	**Associted Monitoring Well/Seep**	**Conc.E[C] (a) (mg/L)**	**Accuracy of Conc. CV[C] (b) (%)**	**Flow E[Q] (c) (L/s)**	**Accuracy of Flow CV[Q] (d) (%)**	**Total Load to RRC, E[L] (e) (kg/d)**	**Cumulative Load, $E[L_{Cumulative}]$ (g) (kg/D)**	**CV[L] (h)**	**V[L] (i)**	**$V[L_{CUMULATIVE}]$ (j)**	**$CV[L_{CUMULATIVE}]$ (k)**
Total From Background & West Area Sources					**14359.9**		**0.6**	**0.57**			**0.006**	**0.134**
Tailings Pile 1												
Groundwater Seeps and Flow from Tailings												
	SP-1		0.023	5%	0.9	50%	0.0	0.57	0.503	0.000	0.006	0.133
	Tailings Pile 1	SP-1,SP-2	0.023	50%	1.0	195%	0.0	0.58	2.237	0.000	0.006	0.133
	SP-2		0.023	5%	0.9	50%	0.0	0.58	0.503	0.000	0.006	0.133
Groundwater Flow from Native Material												
	Flow Tube S2	TP1-6A	0.100	50%	1.7	128%	0.0	0.59	1.516	0.001	0.006	0.135
	Flow Tube S3	TP1-2A	0.000	50%	1.8	128%	0.0	0.59	1.516	0.000	0.006	0.135
	Flow Tube S4	TP1-2A, TP1-3A	0.001	50%	3.5	128%	0.0	0.59	1.516	0.000	0.006	0.135
	Flow Tube S5	TP1-5A	0.010	50%	2.2	128%	0.0	0.60	1.516	0.000	0.006	0.134
	Flow Tube S6	TP1-5A	0.010	50%	3.5	128%	0.0	0.60	1.516	0.000	0.006	0.134
	Source Area Total						0.0	0.60	0.911	0.001	0.006	0.134
Copper Creek												
	Copper Creek		0.000	5%	424.8	7%	0.0	0.60	0.086	0.000	0.006	0.134
	Source Area Total						0.0	0.60	0.086	0.000	0.006	0.134
Tailings Pile 2 (Upstream of RC-7)												
Groundwater Seeps and Flow from Tailings												
	SP-3		0.040	5%	4.7	50%	0.0	0.62	0.503	0.000	0.006	0.131
	Flow Tube TP-1	SP-3	0.040	50%	0.1	195%	0.0	0.62	2.237	0.000	0.006	0.131
	Flow Tube TP-2	SP-3	0.040	50%	0.2	195%	0.0	0.62	2.237	0.000	0.006	0.131
	Flow Tube TP-3	SP-3	0.040	50%	0.2	195%	0.0	0.62	2.237	0.000	0.006	0.130
	Flow Tube TP-4	SP-3	0.040	50%	0.2	195%	0.0	0.62	2.237	0.000	0.006	0.130
	Flow Tube TP-5	SP-3	0.000	50%	0.1	195%	0.0	0.62	2.237	0.000	0.006	0.130
	Flow Tube TP-6	SP-3	0.040	50%	0.2	195%	0.0	0.62	2.237	0.000	0.006	0.130
	Flow Tube TP-7	SP-3	0.040	50%	0.3	195%	0.0	0.62	2.237	0.000	0.007	0.130
Groundwater Flow from Native Material												
	Flow Tube S7	TP2-11	0.002	50%	4.7	128%	0.0	0.62	1.516	0.000	0.007	0.130
	Flow Tube S8	TP2-11	0.002	50%	4.0	128%	0.0	0.62	1.516	0.000	0.007	0.130
	Flow Tube S9	TP2-11	0.002	50%	1.3	128%	0.0	0.62	1.516	0.000	0.007	0.130
	Flow Tube S10	PZ-3A	0.002	50%	2.7	128%	0.0	0.62	1.516	0.000	0.007	0.130
	Source Area Total						0.0	0.62	0.414	0.000	0.007	0.130
	Cumulative Loading						104.63	0.62			0.007	0.130
Measured Load at RC-7 (for comparison only)			0.001	5%	14867.8	7%	0.7	0.75	0.086	0.004		
Tailings Pile 2 & 3 (Downstream of RC-7)												
Groundwater Seeps and Flow from Tailings												
	SP-4		0.007	5%	14.2	50%	0.0	0.63	0.503	0.000	0.007	0.128
	Flow Tube TP-8	SP-3, SP-4	0.024	50%	0.2	195%	0.0	0.63	2.237	0.000	0.007	0.128
	Flow Tube TP-9	SP-3, SP-4	0.024	50%	0.1	195%	0.0	0.63	2.237	0.000	0.007	0.128
	Flow Tube TP-10	SP-4	0.007	50%	0.1	195%	0.0	0.63	2.237	0.000	0.007	0.128
	Flow Tube TP-11	SP-4	0.007	50%	0.2	195%	0.0	0.63	2.237	0.000	0.007	0.128
	Flow Tube TP-12	SP-4	0.007	50%	0.1	195%	0.0	0.63	2.237	0.000	0.007	0.128
	Flow Tube TP-13	SP-4, PZ-6A	0.005	50%	0.1	195%	0.0	0.63	2.237	0.000	0.007	0.128
	Flow Tube TP-14	PZ-6A	0.002	50%	0.2	195%	0.0	0.63	2.237	0.000	0.007	0.128
	Flow Tube TP-15	PZ-6A	0.002	50%	0.2	195%	0.0	0.63	2.237	0.000	0.007	0.128
	Flow Tube TP-16	PZ-6A	0.002	50%	0.1	195%	0.0	0.63	2.237	0.000	0.007	0.128
Groundwater Flow from Native Material												
	Flow Tube S11	PZ-3A	0.002	50%	2.5	128%	0.0	0.63	1.516	0.000	0.007	0.128
	Flow Tube S12	TP2-4A	0.002	50%	1.4	128%	0.0	0.63	1.516	0.000	0.007	0.128
	Flow Tube S13	TP2-4A	0.002	50%	1.2	128%	0.0	0.63	1.516	0.000	0.007	0.128
	Flow Tube S14	TP3-8A	0.000	50%	1.8	128%	0.0	0.63	1.516	0.000	0.007	0.128
	Flow Tube S15	TP3-8A	0.000	50%	0.5	128%	0.0	0.63	1.516	0.000	0.007	0.128
	Flow Tube S16	TP3-8A	0.000	50%	1.2	128%	0.0	0.63	1.516	0.000	0.007	0.128
	Flow Tube S17	TP3-10	0.001	50%	1.9	128%	0.0	0.63	1.516	0.000	0.007	0.128
	Flow Tube S18	TP3-10	0.001	50%	1.9	128%	0.0	0.63	1.516	0.000	0.007	0.128
	Flow Tube S19	TP3-10	0.001	50%	3.1	128%	0.0	0.63	1.516	0.000	0.007	0.128
	Source Area Total						0.0	0.63	0.419	0.000	0.007	0.128
	Cumulative Loading						0.63	0.63			0.007	0.128
Unaccounted (Groundwater) Load to RC-2 (h)							0.1	0.69			0.016	0.184
Measured Values at RC-2			0.001	10%	15009.5	10%	0.7	0.69	0.142	0.009	0.009	0.142
Loading Downstream of RC-2												
	SP-21		0.000	5%	55.5	25%	0.0	0.69	0.255	0.000	0.009	0.142
	Source Area Total						0.0	0.69	0.255	0.000	0.009	0.142
Total Values (Measured RC-2 + SP-21)					**15065.0**		**0.7**	**0.69**			**0.009**	**0.142**
Total Loading Attributed to the East Area							**0.1**	**0.11**			**0.015**	**1.083**
Measured Values at RC-5 (i)			0.001	5%	15065.0	25%	0.7	0.65	0.255	0.028		

Table A-5.4
Uncertainty Analysis - Copper
Baseline Loading Calculations - Railroad Creek - Spring 1997
Holden Mine RI/FS

West Area - Spring 1997			**Copper**									
	Seep / Tributary Information		Loading Parameters and Accuracies				Surface Water Loading to RRC from Source Area		Source Loading Accuracy		Cumulative Loading Accuracy	
Source Area	Seep/Tributary	Discharges To	Conc.E[C] (a) (mg/L)	Accuracy of Conc. CV[C] (b) (%)	Flow E[Q] (c) (L/s)	Accuracy of Flow CV[Q] (d) (%)	Total Load to RRC, E[L] (e) (kg/d)	Cumulative Load, $E[L_{Cumulative}]$ (g) (kg/D)	CV[L] (h)	V[L] (i)	$V[L_{CUMULATIVE}]$ (j)	$CV[L_{CUMULATIVE}]$ (k)
Measured Value at RC-6			0.0	10%	14159.0	10%	0.9	0.86	0.142	0.015	0.015	0.142
SP-26												
	SP-26	RRC	0.0	5%	0.3	50%	0.0	0.86	0.503	0.000	0.015	0.142
	Source Area Total						0.0	0.86	0.503	0.000	0.015	0.142
	Cumulative Loading						0.9	0.86			0.015	0.142
Unaccounted (Groundwater) Load to RC-1 (h)							0.5	1.35			0.051	0.168
Measured Value at RC-1			0.0	10%	14161.1	10%	1.3	1.35	0.142	0.036	0.036	0.142
SP-23/Honeymoon Heights:												
	SP-23	RRC	6.9	5%	14.2	25%	8.4	9.75	0.255	4.600	4.637	0.221
	SP-23B	RRC	4.9	5%	1.9	25%	0.8	10.55	0.255	0.042	4.679	0.205
	SP-12	RRC	2.0	5%	1.9	50%	0.3	10.88	0.503	0.027	4.706	0.199
	Source Area Total						9.5	10.88	0.227	4.669	4.706	0.199
Underground Mine												
	P-5	RRC	2.3	5%	96.8	20%	19.6	30.46	0.206	16.330	21.035	0.151
	Source Area Total						19.6	30.46	0.206	16.330	21.035	0.151
West Area Seeps (Upstream of RC-4)												
	SP-9	RRC	0.0	5%	0.5	25%	0.0	30.46	0.255	0.000	21.035	0.151
	SP-11	RRC	0.5	5%	0.5	50%	0.0	30.47	0.503	0.000	21.035	0.150
	SP-25	RRC	1.9	5%	0.1	50%	0.0	30.49	0.503	0.000	21.036	0.150
	SP-24	RRC	3.7	5%	0.9	50%	0.3	30.79	0.503	0.023	21.058	0.149
	Source Area Total						0.3	30.79	0.453	0.023	21.058	0.149
	Cumulative Loading						30.8	30.79			21.058	0.149
Unaccounted (Groundwater) Load to RC-4 (h)							1.5	32.30			42.030	0.201
Measured Value at RC-4			0.0	10%	14161.1	10%	32.3	32.30	0.142	20.971	20.971	0.142
West Area Seeps (Downstream of RC-4)												
	SP-10W	RRC	2.2	5%	0.3	50%	0.1	32.36	0.503	0.001	20.972	0.142
	SP-10E	RRC	0.8	5%	0.3	50%	0.0	32.38	0.503	0.000	20.972	0.141
	Source Area Total						0.1	32.38	0.396	0.001	20.972	0.141
East Waste Rock Pile												
	SP-19	CCD	4.2	5%	2.7	25%	1.0	32.38	0.255	0.061		
	Source Area Total						1.0	32.38	0.255	0.061		
Groundwater Flow from Native Material												
	Flow Tube S1	RRC	2.6	50%	1.3	128%	0.3	32.67	1.516	0.189	21.161	0.141
	Source Area Total						0.3	32.67	1.516	0.189	21.161	0.141
Copper Creek Diversion												
	CC-D1	RRC	0.0	5%	198.2	7%	0.8	33.45	0.086	0.005	21.166	0.138
	CCD1-SP19	*RRC*	4.2	5%	2.7	25%	-0.2		-1.393	0.066		
	Source Area Total						0.8	33.45	0.086	0.005	21.166	0.138
Total West Area Surface Water Loading to RRC					**14359.9**		**33.6**	**33.64**			**21.166**	**0.137**
Loading to Railroad Creek Associated w/West Area Sources							**32.8**	**32.78**			**21.180**	**0.140**

East Area - Spring 1997			**Copper**									
	Seep / Tributary Information		Loading Parameters and Accuracies				Surface Water Loading to RRC from Source Area		Source Loading Accuracy		Cumulative Loading Accuracy	
Source Area	Contribution to Railroad Creek	Associted Monitoring Well/Seep	Conc.E[C] (a) (mg/L)	Accuracy of Conc. CV[C] (b) (%)	Flow E[Q] (c) (L/s)	Accuracy of Flow CV[Q] (d) (%)	Total Load to RRC, E[L] (e) (kg/d)	Cumulative Load, $E[L_{Cumulative}]$ (g) (kg/D)	CV[L] (h)	V[L] (i)	$V[L_{CUMULATIVE}]$ (j)	$CV[L_{CUMULATIVE}]$ (k)
Total From Background & West Area Sources					**14359.9**		**33.6**	**33.64**			**21.166**	**0.137**
Tailings Pile 1												
Groundwater Seeps and Flow from Tailings												
	SP-1		0.7	5%	0.9	50%	0.1	33.69	0.503	0.001	21.166	0.137
	Tailings Pile 1	SP-1,SP-2	0.8	50%	1.0	195%	0.1	33.77	2.237	0.026	21.193	0.136
	SP-2		0.9	5%	0.9	50%	0.1	33.84	0.503	0.001	21.194	0.136
Groundwater Flow from Native Material												
	Flow Tube S2	TP1-6A	1.1	50%	1.7	128%	0.2	34.00	1.516	0.061	21.255	0.136
	Flow Tube S3	TP1-2A	0.0	50%	1.8	128%	0.0	34.00	1.516	0.000	21.255	0.136
	Flow Tube S4	TP1-2A, TP1-3A	0.0	50%	3.5	128%	0.0	34.00	1.516	0.000	21.255	0.136
	Flow Tube S5	TP1-5A	0.2	50%	2.2	128%	0.0	34.04	1.516	0.003	21.258	0.135
	Flow Tube S6	TP1-5A	0.2	50%	3.5	128%	0.1	34.10	1.516	0.008	21.266	0.135
	Source Area Total						0.5	34.10	0.684	0.101	21.266	0.135
Copper Creek												
	Copper Creek		0.0	5%	424.8	7%	0.0	34.14	0.086	0.000	21.266	0.135
	Source Area Total						0.0	34.14	0.086	0.000	21.266	0.135
Tailings Pile 2 (Upstream of RC-7)												
Groundwater Seeps and Flow from Tailings												
	SP-3		1.3	5%	4.7	50%	0.5	34.66	0.503	0.069	21.336	0.133
	Flow Tube TP-1	SP-3	1.3	50%	0.1	195%	0.0	34.67	2.237	0.001	21.336	0.133
	Flow Tube TP-2	SP-3	1.3	50%	0.2	195%	0.0	34.69	2.237	0.002	21.338	0.133
	Flow Tube TP-3	SP-3	1.3	50%	0.2	195%	0.0	34.71	2.237	0.002	21.340	0.133
	Flow Tube TP-4	SP-3	1.3	50%	0.2	195%	0.0	34.73	2.237	0.002	21.342	0.133
	Flow Tube TP-5	SP-3	1.3	50%	0.1	195%	0.0	34.75	2.237	0.001	21.343	0.133
	Flow Tube TP-6	SP-3	1.3	50%	0.2	195%	0.0	34.76	2.237	0.002	21.345	0.133
	Flow Tube TP-7	SP-3	1.3	50%	0.3	195%	0.0	34.79	2.237	0.004	21.349	0.133
Groundwater Flow from Native Material												
	Flow Tube S7	TP2-11	0.0	50%	4.7	128%	0.0	34.80	1.516	0.000	21.349	0.133
	Flow Tube S8	TP2-11	0.0	50%	4.0	128%	0.0	34.80	1.516	0.000	21.349	0.133
	Flow Tube S9	TP2-11	0.0	50%	1.3	128%	0.0	34.80	1.516	0.000	21.349	0.133
	Flow Tube S10	PZ-3A	0.0	50%	2.7	128%	0.0	34.80	1.516	0.000	21.349	0.133
	Source Area Total						0.7	34.80	0.433	0.082	21.349	0.133
	Cumulative Loading						104.63	34.80			21.349	0.133
Measured Load at RC-7 (for comparison only)			0.0	5%	14867.8	7%	29.5	29.55	0.086	6.470		
Tailings Pile 2 & 3 (Downstream of RC-7)												
Groundwater Seeps and Flow from Tailings												
	SP-4		0.7	5%	14.2	50%	0.8	35.62	0.503	0.171	21.520	0.130
	Flow Tube TP-8	SP-3, SP-4	1.0	50%	0.2	195%	0.0	35.64	2.237	0.001	21.521	0.130
	Flow Tube TP-9	SP-3, SP-4	1.0	50%	0.1	195%	0.0	35.64	2.237	0.000	21.521	0.130
	Flow Tube TP-10	SP-4	0.7	50%	0.1	195%	0.0	35.65	2.237	0.000	21.521	0.130
	Flow Tube TP-11	SP-4	0.7	50%	0.2	195%	0.0	35.66	2.237	0.000	21.522	0.130
	Flow Tube TP-12	SP-4	0.7	50%	0.1	195%	0.0	35.66	2.237	0.000	21.522	0.130
	Flow Tube TP-13	SP-4, PZ-6A	0.3	50%	0.1	195%	0.0	35.67	2.237	0.000	21.522	0.130
	Flow Tube TP-14	PZ-6A	0.0	50%	0.2	195%	0.0	35.67	2.237	0.000	21.522	0.130
	Flow Tube TP-15	PZ-6A	0.0	50%	0.2	195%	0.0	35.67	2.237	0.000	21.522	0.130
	Flow Tube TP-16	PZ-6A	0.0	50%	0.1	195%	0.0	35.67	2.237	0.000	21.522	0.130
Groundwater Flow from Native Material												
	Flow Tube S11	PZ-3A	0.0	50%	2.5	128%	0.0	35.67	1.516	0.000	21.522	0.130
	Flow Tube S12	TP2-4A	0.0	50%	1.4	128%	0.0	35.67	1.516	0.000	21.522	0.130
	Flow Tube S13	TP2-4A	0.0	50%	1.2	128%	0.0	35.67	1.516	0.000	21.522	0.130
	Flow Tube S14	TP3-8A	0.0	50%	1.8	128%	0.0	35.67	1.516	0.000	21.522	0.130
	Flow Tube S15	TP3-8A	0.0	50%	0.5	128%	0.0	35.67	1.516	0.000	21.522	0.130
	Flow Tube S16	TP3-8A	0.0	50%	1.2	128%	0.0	35.67	1.516	0.000	21.522	0.130
	Flow Tube S17	TP3-10	0.0	50%	1.9	128%	0.0	35.67	1.516	0.000	21.522	0.130
	Flow Tube S18	TP3-10	0.0	50%	1.9	128%	0.0	35.67	1.516	0.000	21.522	0.130
	Flow Tube S19	TP3-10	0.0	50%	3.1	128%	0.0	35.68	1.516	0.000	21.522	0.130
	Source Area Total						0.9	35.68	0.475	0.173	21.522	0.130
	Cumulative Loading						35.68	35.68			21.522	0.130
Unaccounted (Groundwater) Load to RC-2 (h)							-5.1	30.61			40.349	0.208
Measured Values at RC-2			0.0	10%	15009.5	10%	30.6	30.61	0.142	18.827	18.827	0.142
Loading Downstream of RC-2												
	SP-21		0.1	5%	55.5	25%	0.2	30.85	0.255	0.004	18.831	0.141
	Source Area Total						0.2	30.85	0.255	0.004	18.831	0.141
Total Values (Measured RC-2 + SP-21)					**15065.0**		**30.9**	**30.85**			**18.831**	**0.141**
Total Loading Attributed to the East Area							**-2.8**	**-2.78**			**39.997**	**-2.272**
Measured Values at RC-5 (i)			0.0	5%	15065.0	25%	28.0	27.98	0.255	51.027		

Table A-5.5
Uncertainty Analysis - Iron
Baseline Loading Calculations - Railroad Creek - Spring 1997
Holden Mine RI/FS

West Area - Spring 1997 — Iron

Source Area	Seep/Tributary (Seep / Tributary Information)	Discharges To	Conc.E[C] (a) (mg/L) (Loading Parameters and Accuracies)	Accuracy of Conc. CV[C] (b) (%)	Flow E[Q] (c) (L/s)	Accuracy of Flow CV[Q] (d) (%)	Total Load to RRC, E[L] (e) (kg/d) (Surface Water Loading to RRC from Source Area)	Cumulative Load, $E[L_{Cumulative}]$ (g) (kg/D)	CV[L] (h) (Source Loading Accuracy)	V[L] (i)	$V[L_{CUMULATIVE}]$ (j) (Cumulative Loading Accuracy)	$CV[L_{CUMULATIVE}]$ (k)
Measured Value at RC-6			0.03	10%	14159.0	10%	36.7	36.70	0.142	27.073	27.073	0.142
SP-26												
	SP-26	RRC	0.01	5%	0.3	50%	0.0	36.70	0.503	0.000	27.073	0.142
	Source Area Total						0.0	36.70	0.503	0.000	27.073	0.142
	Cumulative Loading						36.7	36.70			27.073	0.142
Unaccounted (Groundwater) Load to RC-1 (h)							0.0	36.71			54.153	0.200
Measured Value at RC-1			0.03	10%	14161.1	10%	36.7	36.71	0.142	27.081	27.081	0.142
SP-23/Honeymoon Heights:												
	SP-23	RRC	0.01	5%	14.2	25%	0.0	36.72	0.255	0.000	27.081	0.142
	SP-23B	RRC	0.01	5%	1.9	25%	0.0	36.72	0.255	0.000	27.081	0.142
	SP-12	RRC	0.01	5%	1.9	50%	0.0	36.72	0.503	0.000	27.081	0.142
	Source Area Total						0.0	36.72	0.210	0.000	27.081	0.142
Underground Mine												
	P-5	RRC	0.19	5%	96.8	20%	1.6	38.31	0.206	0.108	27.188	0.136
	Source Area Total						1.6	38.31	0.206	0.108	27.188	0.136
West Area Seeps (Upstream of RC-4)												
	SP-9	RRC	0.01	5%	0.5	25%	0.0	38.31	0.255	0.000	27.188	0.136
	SP-11	RRC	0.01	5%	0.5	50%	0.0	38.31	0.503	0.000	27.188	0.136
	SP-25	RRC	0.01	5%	0.1	50%	0.0	38.31	0.503	0.000	27.188	0.136
	SP-24	RRC	0.22	5%	0.9	50%	0.0	38.33	0.503	0.000	27.189	0.136
	Source Area Total						0.0	38.33	0.479	0.000	27.189	0.136
	Cumulative Loading						38.3	38.33			27.189	0.136
Unaccounted (Groundwater) Load to RC-4 (h)							-13.9	24.47			39.224	0.256
Measured Value at RC-4			0.02	10%	14161.1	10%	24.5	24.47	0.142	12.036	12.036	0.142
West Area Seeps (Downstream of RC-4)												
	SP-10W	RRC	0.03	5%	0.3	50%	0.0	24.47	0.503	0.000	12.036	0.142
	SP-10E	RRC	14.10	5%	0.3	50%	0.4	24.86	0.503	0.037	12.073	0.140
	Source Area Total						0.4	24.86	0.502	0.037	12.073	0.140
East Waste Rock Pile												
	SP-19	CCD	0.07	5%	2.7	25%	0.0	24.86	0.255	0.000		
	Source Area Total						0.0	24.86	0.255	0.000		
Groundwater Flow from Native Material												
	Flow Tube S1	RRC	0.14	50%	1.3	128%	0.0	24.87	1.516	0.001	12.074	0.140
	Source Area Total						0.0	24.87	1.516	0.001	12.074	0.140
Copper Creek Diversion												
	CC-D1	RRC	0.23	5%	198.2	7%	3.9	28.81	0.086	0.115	12.189	0.121
	CCD1-SP19	*RRC*	0.07	5%	2.7	25%	3.9		0.086	0.115		
	Source Area Total						3.9	28.81	0.086	0.115	12.189	0.121
Total West Area Surface Water Loading to RRC					**14359.9**		**28.8**	**28.81**			**12.189**	**0.121**
Loading to Railroad Creek Associated w/West Area Sources							**-7.9**	**-7.89**			**39.261**	**-0.794**

East Area - Spring 1997 — Iron

Source Area	Contribution to Railroad Creek (Seep / Tributary Information)	Associted Monitoring Well/Seep	Conc.E[C] (a) (mg/L) (Loading Parameters and Accuracies)	Accuracy of Conc. CV[C] (b) (%)	Flow E[Q] (c) (L/s)	Accuracy of Flow CV[Q] (d) (%)	Total Load to RRC, E[L] (e) (kg/d) (Surface Water Loading to RRC from Source Area)	Cumulative Load, $E[L_{Cumulative}]$ (g) (kg/D)	CV[L] (h) (Source Loading Accuracy)	V[L] (i)	$V[L_{CUMULATIVE}]$ (j) (Cumulative Loading Accuracy)	$CV[L_{CUMULATIVE}]$ (k)
Total From Background & West Area Sources					**14359.9**		**28.8**	**28.81**			**12.189**	**0.121**
Tailings Pile 1												
Groundwater Seeps and Flow from Tailings												
	SP-1		542.0	5%	0.9	50%	44.3	73.13	0.503	497.282	509.470	0.309
	Tailings Pile 1	SP-1,SP-2	514.5	50%	1.0	195%	46.4	119.54	2.237	10774.359	11283.830	0.889
	SP-2		487.0	5%	0.9	50%	39.8	159.36	0.503	401.478	11685.307	0.678
Groundwater Flow from Native Material												
	Flow Tube S2	TP1-6A	145.0	50%	1.7	128%	21.4	180.81	1.516	1056.965	12742.272	0.624
	Flow Tube S3	TP1-2A	321.0	50%	1.8	128%	48.6	229.36	1.516	5416.719	18158.992	0.588
	Flow Tube S4	TP1-2A, TP1-3A	332.5	50%	3.5	128%	100.1	329.49	1.516	23040.960	41199.951	0.616
	Flow Tube S5	TP1-5A	246.0	50%	2.2	128%	46.4	375.93	1.516	4954.795	46154.746	0.571
	Flow Tube S6	TP1-5A	246.0	50%	3.5	128%	75.2	451.17	1.516	13009.310	59164.056	0.539
	Source Area Total						422.4	451.17	0.576	59151.867	59164.056	0.539
Copper Creek												
	Copper Creek		0.0	5%	424.8	7%	1.5	452.64	0.086	0.016	59164.072	0.537
	Source Area Total						1.5	452.64	0.086	0.016	59164.072	0.537
Tailings Pile 2 (Upstream of RC-7)												
Groundwater Seeps and Flow from Tailings												
	SP-3		154.0	5%	4.7	50%	63.0	515.61	0.503	1003.657	60167.728	0.476
	Flow Tube TP-1	SP-3	154.0	50%	0.1	195%	1.3	516.94	2.237	8.882	60176.611	0.475
	Flow Tube TP-2	SP-3	154.0	50%	0.2	195%	2.3	519.22	2.237	25.954	60202.565	0.473
	Flow Tube TP-3	SP-3	154.0	50%	0.2	195%	2.4	521.62	2.237	28.871	60231.436	0.470
	Flow Tube TP-4	SP-3	154.0	50%	0.2	195%	2.3	523.91	2.237	26.187	60257.622	0.469
	Flow Tube TP-5	SP-3	154.0	50%	0.1	195%	1.8	525.70	2.237	16.096	60273.718	0.467
	Flow Tube TP-6	SP-3	154.0	50%	0.2	195%	2.3	527.99	2.237	26.297	60300.015	0.465
	Flow Tube TP-7	SP-3	154.0	50%	0.3	195%	3.4	531.35	2.237	56.587	60356.601	0.462
Groundwater Flow from Native Material												
	Flow Tube S7	TP2-11	0.0	50%	4.7	128%	0.0	531.36	1.516	0.000	60356.601	0.462
	Flow Tube S8	TP2-11	0.0	50%	4.0	128%	0.0	531.36	1.516	0.000	60356.601	0.462
	Flow Tube S9	TP2-11	0.0	50%	1.3	128%	0.0	531.36	1.516	0.000	60356.601	0.462
	Flow Tube S10	PZ-3A	5.7	50%	2.7	128%	1.3	532.70	1.516	4.095	60360.697	0.461
	Source Area Total						80.1	532.70	0.432	1196.625	60360.697	0.461
	Cumulative Loading						104.63	532.70			60360.697	0.461
Measured Load at RC-7 (for comparison only)			0.5	5%	14867.8	7%	616.6	616.60	0.086	2818.080		
Tailings Pile 2 & 3 (Downstream of RC-7)												
Groundwater Seeps and Flow from Tailings												
	SP-4		74.9	5%	14.2	50%	91.9	624.58	0.503	2136.731	62497.428	0.400
	Flow Tube TP-8	SP-3, SP-4	114.5	50%	0.2	195%	1.7	626.28	2.237	14.463	62511.891	0.399
	Flow Tube TP-9	SP-3, SP-4	114.5	50%	0.1	195%	0.7	626.96	2.237	2.314	62514.206	0.399
	Flow Tube TP-10	SP-4	74.9	50%	0.1	195%	0.5	627.50	2.237	1.509	62515.715	0.398
	Flow Tube TP-11	SP-4	74.9	50%	0.2	195%	1.1	628.58	2.237	5.787	62521.502	0.398
	Flow Tube TP-12	SP-4	74.9	50%	0.1	195%	0.7	629.28	2.237	2.459	62523.960	0.397
	Flow Tube TP-13	SP-4, PZ-6A	66.6	50%	0.1	195%	0.8	630.06	2.237	3.010	62526.971	0.397
	Flow Tube TP-14	PZ-6A	58.3	50%	0.2	195%	0.8	630.84	2.237	3.050	62530.020	0.396
	Flow Tube TP-15	PZ-6A	58.3	50%	0.2	195%	1.1	631.91	2.237	5.727	62535.747	0.396
	Flow Tube TP-16	PZ-6A	58.3	50%	0.1	195%	0.5	632.37	2.237	1.091	62536.839	0.395
Groundwater Flow from Native Material												
	Flow Tube S11	PZ-3A	5.7	50%	2.5	128%	1.2	633.60	1.516	3.449	62540.288	0.395
	Flow Tube S12	TP2-4A	7.0	50%	1.4	128%	0.8	634.43	1.516	1.580	62541.868	0.394
	Flow Tube S13	TP2-4A	7.0	50%	1.2	128%	0.7	635.16	1.516	1.229	62543.097	0.394
	Flow Tube S14	TP3-8A	55.4	50%	1.8	128%	8.8	643.97	1.516	178.406	62721.504	0.389
	Flow Tube S15	TP3-8A	55.4	50%	0.5	128%	2.4	646.34	1.516	12.837	62734.341	0.388
	Flow Tube S16	TP3-8A	55.4	50%	1.2	128%	5.7	652.03	1.516	74.487	62808.828	0.384
	Flow Tube S17	TP3-10	0.1	50%	1.9	128%	0.0	652.04	1.516	0.000	62808.829	0.384
	Flow Tube S18	TP3-10	0.1	50%	1.9	128%	0.0	652.05	1.516	0.000	62808.829	0.384
	Flow Tube S19	TP3-10	0.1	50%	3.1	128%	0.0	652.07	1.516	0.001	62808.830	0.384
	Source Area Total						119.4	652.07	0.414	2448.133	62808.830	0.384
	Cumulative Loading						652.07	652.07			62808.830	0.384
Unaccounted (Groundwater) Load to RC-2 (h)							-263.0	389.05			65851.114	0.660
Measured Values at RC-2			0.3	10%	15009.5	10%	389.0	389.05	0.142	3042.285	3042.285	0.142
Loading Downstream of RC-2												
	SP-21		1.0	5%	55.5	25%	4.8	393.84	0.255	1.498	3043.783	0.140
	Source Area Total						4.8	393.84	0.255	1.498	3043.783	0.140
Total Values (Measured RC-2 + SP-21)					**15065.0**		**393.8**	**393.84**			**3043.783**	**0.140**
Total Loading Attributed to the East Area							**365.0**	**365.03**			**3055.972**	**0.151**
Measured Values at RC-5 (i)			0.4	5%	15065.0	25%	455.6	455.57	0.255	13522.572		

Table A-5.6
Uncertainty Analysis - Zinc
Baseline Loading Calculations - Railroad Creek - Spring 1997
Holden Mine RI/FS

West Area - Spring 1997			**Zinc**									
	Seep / Tributary Information		**Loading Parameters and Accuracies**				**Surface Water Loading to RRC from Source Area**		**Source Loading Accuracy**		**Cumulative Loading Accuracy**	
Source Area	**Seep/Tributary**	**Discharges To**	**Conc.E[C] (a) (mg/L)**	**Accuracy of Conc. CV[C] (b) (%)**	**Flow E[Q] (c) (L/s)**	**Accuracy of Flow CV[Q] (d) (%)**	**Total Load to RRC, E[L] (e) (kg/d)**	**Cumulative Load, $E[L_{Cumulative}]$ (g) (kg/D)**	**CV[L] (h)**	**V[L] (i)**	**$V[L_{CUMULATIVE}]$ (j)**	**$CV[L_{CUMULATIVE}]$ (k)**
Measured Value at RC-6			0.0	10%	14159.0	10%	19.6	19.57	0.142	7.701	7.701	0.142
SP-26												
	SP-26	RRC	0.0	5%	0.3	50%	0.0	19.57	0.503	0.000	7.701	0.142
	Source Area Total						0.0	19.57	0.503	0.000	7.701	0.142
	Cumulative Loading						19.6	19.57			7.701	0.142
Unaccounted (Groundwater) Load to RC-1 (h)							-3.7	15.91			12.786	0.225
Measured Value at RC-1			0.0	10%	14161.1	10%	15.9	15.91	0.142	5.085	5.085	0.142
SP-23/Honeymoon Heights:												
	SP-23	RRC	5.0	5%	14.2	25%	6.1	22.04	0.255	2.451	7.536	0.125
	SP-23B	RRC	3.6	5%	1.9	25%	0.6	22.63	0.255	0.023	7.559	0.121
	SP-12	RRC	2.2	5%	1.9	50%	0.4	22.99	0.503	0.034	7.593	0.120
	Source Area Total						7.1	22.99	0.223	2.507	7.593	0.120
Underground Mine												
	P-5	RRC	8.8	5%	96.8	20%	73.8	96.79	0.206	231.998	239.590	0.160
	Source Area Total						73.8	96.79	0.206	231.998	239.590	0.160
West Area Seeps (Upstream of RC-4)												
	SP-9	RRC	0.3	5%	0.5	25%	0.0	96.80	0.255	0.000	239.590	0.160
	SP-11	RRC	2.3	5%	0.5	50%	0.1	96.90	0.503	0.002	239.593	0.160
	SP-25	RRC	5.6	5%	0.1	50%	0.0	96.94	0.503	0.001	239.593	0.160
	SP-24	RRC	7.6	5%	0.9	50%	0.6	97.56	0.503	0.097	239.690	0.159
	Source Area Total						0.8	97.56	0.410	0.100	239.690	0.159
	Cumulative Loading						97.6	97.56			239.690	0.159
Unaccounted (Groundwater) Load to RC-4 (h)							-8.2	89.32			400.038	0.224
Measured Value at RC-4			0.1	10%	14161.1	10%	89.3	89.32	0.142	160.348	160.348	0.142
West Area Seeps (Downstream of RC-4)												
	SP-10W	RRC	3.2	5%	0.3	50%	0.1	89.40	0.503	0.002	160.350	0.142
	SP-10E	RRC	0.7	5%	0.3	50%	0.0	89.42	0.503	0.000	160.350	0.142
	Source Area Total						0.1	89.42	0.422	0.002	160.350	0.142
East Waste Rock Pile												
	SP-19	CCD	6.2	5%	2.7	25%	1.4	89.42	0.255	0.133		
	Source Area Total						1.4	89.42	0.255	0.133		
Groundwater Flow from Native Material												
	Flow Tube S1	RRC	4.1	50%	1.3	128%	0.4	89.87	1.516	0.452	160.802	0.141
	Source Area Total						0.4	89.87	1.516	0.452	160.802	0.141
Copper Creek Diversion												
	CC-D1	RRC	0.2	5%	198.2	7%	2.9	92.81	0.086	0.064	160.866	0.137
	CCD1-SP19	*RRC*	6.2	5%	2.7	25%	1.5		0.293	0.197		
	Source Area Total						2.9	92.81	0.086	0.064	160.866	0.137
Total West Area Surface Water Loading to RRC					**14359.9**		**92.8**	**92.81**			**160.866**	**0.137**
Loading to Railroad Creek Associated w/West Area Sources							**73.2**	**73.24**			**168.567**	**0.177**

East Area - Spring 1997			**Zinc**									
	Seep / Tributary Information		**Loading Parameters and Accuracies**				**Surface Water Loading to RRC from Source Area**		**Source Loading Accuracy**		**Cumulative Loading Accuracy**	
Source Area	**Contribution to Railroad Creek**	**Associted Monitoring Well/Seep**	**Conc.E[C] (a) (mg/L)**	**Accuracy of Conc. CV[C] (b) (%)**	**Flow E[Q] (c) (L/s)**	**Accuracy of Flow CV[Q] (d) (%)**	**Total Load to RRC, E[L] (e) (kg/d)**	**Cumulative Load, $E[L_{Cumulative}]$ (g) (kg/D)**	**CV[L] (h)**	**V[L] (i)**	**$V[L_{CUMULATIVE}]$ (j)**	**$CV[L_{CUMULATIVE}]$ (k)**
Total From Background & West Area Sources					**14359.9**		**92.8**	**92.81**			**160.866**	**0.137**
Tailings Pile 1												
Groundwater Seeps and Flow from Tailings												
	SP-1		3.5	5%	0.9	50%	0.3	93.10	0.503	0.021	160.887	0.136
	Tailings Pile 1	SP-1,SP-2	4.5	50%	1.0	195%	0.4	93.51	2.237	0.841	161.728	0.136
	SP-2		5.6	5%	0.9	50%	0.5	93.97	0.503	0.053	161.781	0.135
Groundwater Flow from Native Material												
	Flow Tube S2	TP1-6A	11.4	50%	1.7	128%	1.7	95.65	1.516	6.533	168.314	0.136
	Flow Tube S3	TP1-2A	2.3	50%	1.8	128%	0.3	96.00	1.516	0.271	168.585	0.135
	Flow Tube S4	TP1-2A, TP1-3A	3.7	50%	3.5	128%	1.1	97.10	1.516	2.792	171.377	0.135
	Flow Tube S5	TP1-5A	9.8	50%	2.2	128%	1.9	98.95	1.516	7.879	179.256	0.135
	Flow Tube S6	TP1-5A	9.8	50%	3.5	128%	3.0	101.95	1.516	20.688	199.944	0.139
	Source Area Total						9.1	101.95	0.684	39.078	199.944	0.139
Copper Creek												
	Copper Creek		0.0	5%	424.8	7%	0.5	102.43	0.086	0.002	199.946	0.138
	Source Area Total						0.5	102.43	0.086	0.002	199.946	0.138
Tailings Pile 2 (Upstream of RC-7)												
Groundwater Seeps and Flow from Tailings												
	SP-3		4.0	5%	4.7	50%	1.6	104.07	0.503	0.687	200.633	0.136
	Flow Tube TP-1	SP-3	4.0	50%	0.1	195%	0.0	104.11	2.237	0.006	200.639	0.136
	Flow Tube TP-2	SP-3	4.0	50%	0.2	195%	0.1	104.17	2.237	0.018	200.657	0.136
	Flow Tube TP-3	SP-3	4.0	50%	0.2	195%	0.1	104.23	2.237	0.020	200.677	0.136
	Flow Tube TP-4	SP-3	4.0	50%	0.2	195%	0.1	104.29	2.237	0.018	200.695	0.136
	Flow Tube TP-5	SP-3	4.0	50%	0.1	195%	0.0	104.34	2.237	0.011	200.706	0.136
	Flow Tube TP-6	SP-3	4.0	50%	0.2	195%	0.1	104.40	2.237	0.018	200.724	0.136
	Flow Tube TP-7	SP-3	4.0	50%	0.3	195%	0.1	104.49	2.237	0.039	200.763	0.136
Groundwater Flow from Native Material												
	Flow Tube S7	TP2-11	0.2	50%	4.7	128%	0.1	104.56	1.516	0.011	200.774	0.136
	Flow Tube S8	TP2-11	0.2	50%	4.0	128%	0.1	104.61	1.516	0.008	200.782	0.135
	Flow Tube S9	TP2-11	0.2	50%	1.3	128%	0.0	104.63	1.516	0.001	200.782	0.135
	Flow Tube S10	PZ-3A	0.0	50%	2.7	128%	0.0	104.63	1.516	0.000	200.782	0.135
	Source Area Total						2.2	104.63	0.414	0.836	200.782	0.135
	Cumulative Loading						104.63	104.63			200.782	0.135
Measured Load at RC-7 (for comparison only)			0.1	5%	14867.8	7%	109.2	109.19	0.086	88.371		
Tailings Pile 2 & 3 (Downstream of RC-7)												
Groundwater Seeps and Flow from Tailings												
	SP-4		0.9	5%	14.2	50%	1.1	105.74	0.503	0.311	201.094	0.134
	Flow Tube TP-8	SP-3, SP-4	2.5	50%	0.2	195%	0.0	105.78	2.237	0.007	201.100	0.134
	Flow Tube TP-9	SP-3, SP-4	2.5	50%	0.1	195%	0.0	105.79	2.237	0.001	201.101	0.134
	Flow Tube TP-10	SP-4	0.9	50%	0.1	195%	0.0	105.80	2.237	0.000	201.102	0.134
	Flow Tube TP-11	SP-4	0.9	50%	0.2	195%	0.0	105.81	2.237	0.001	201.102	0.134
	Flow Tube TP-12	SP-4	0.9	50%	0.1	195%	0.0	105.82	2.237	0.000	201.103	0.134
	Flow Tube TP-13	SP-4, PZ-6A	0.5	50%	0.1	195%	0.0	105.83	2.237	0.000	201.103	0.134
	Flow Tube TP-14	PZ-6A	0.0	50%	0.2	195%	0.0	105.83	2.237	0.000	201.103	0.134
	Flow Tube TP-15	PZ-6A	0.0	50%	0.2	195%	0.0	105.83	2.237	0.000	201.103	0.134
	Flow Tube TP-16	PZ-6A	0.0	50%	0.1	195%	0.0	105.83	2.237	0.000	201.103	0.134
Groundwater Flow from Native Material												
	Flow Tube S11	PZ-3A	0.0	50%	2.5	128%	0.0	105.83	1.516	0.000	201.103	0.134
	Flow Tube S12	TP2-4A	0.0	50%	1.4	128%	0.0	105.83	1.516	0.000	201.103	0.134
	Flow Tube S13	TP2-4A	0.0	50%	1.2	128%	0.0	105.83	1.516	0.000	201.103	0.134
	Flow Tube S14	TP3-8A	0.1	50%	1.8	128%	0.0	105.84	1.516	0.000	201.103	0.134
	Flow Tube S15	TP3-8A	0.1	50%	0.5	128%	0.0	105.84	1.516	0.000	201.103	0.134
	Flow Tube S16	TP3-8A	0.1	50%	1.2	128%	0.0	105.85	1.516	0.000	201.103	0.134
	Flow Tube S17	TP3-10	0.1	50%	1.9	128%	0.0	105.86	1.516	0.000	201.104	0.134
	Flow Tube S18	TP3-10	0.1	50%	1.9	128%	0.0	105.87	1.516	0.000	201.104	0.134
	Flow Tube S19	TP3-10	0.1	50%	3.1	128%	0.0	105.89	1.516	0.001	201.105	0.134
	Source Area Total						1.3	105.89	0.453	0.322	201.105	0.134
	Cumulative Loading						105.89	105.89			201.105	0.134
Unaccounted (Groundwater) Load to RC-2 (h)							26.7	108.93			439.620	0.192
Measured Values at RC-2			0.1	10%	15009.5	10%	108.9	108.93	0.142	238.515	238.515	0.142
Loading Downstream of RC-2												
	SP-21		0.1	5%	55.5	25%	0.5	109.46	0.255	0.018	238.533	0.141
	Source Area Total						0.5	109.46	0.255	0.018	238.533	0.141
Total Values (Measured RC-2 + SP-21)					**15065.0**		**109.5**	**109.46**			**238.533**	**0.141**
Total Loading Attributed to the East Area							**16.6**	**16.64**			**399.399**	**1.201**
Measured Values at RC-5 (i)			0.1	5%	15065.0	25%	109.3	109.34	0.255	778.900		

Table A-6.1
Uncertainty Analysis - Magnesium
Baseline Loading Calculations - Railroad Creek - Fall 1997
Holden Mine RI/FS

West Area - Fall 1997			Magnesium									
	Seep / Tributary Information		Loading Parameters and Accuracies				Surface Water Loading to RRC		Source Loading Accuracy		Cumulative Loading Accuracy	
Source Area	Seep/Tributary	Discharges To	Conc.E[C] (a) (mg/L)	Accuracy of Conc. CV[C] (b) (%)	Flow E[Q] (c) (L/s)	Accuracy of Flow CV[Q] (d) (%)	Total Load to RRC, E[L] (e) (kg/d)	Cumulative Load, $E[L_{Cumulative}]$ (g) (kg/D)	CV[L] (h)	V[L] (i)	$V[L_{CUMULATIVE}]$ (j)	$CV[L_{CUMULATIVE}]$ (k)
Measured Value at RC-6			0.4	5%	3710.0	7%	112.2	112.19	0.086	93.296	93.296	0.086
SP-26												
	SP-26	RRC	0.5	5%	0.3	50%	0.0	112.20	0.503	0.000	93.296	0.086
	Source Area Total						112.2	112.20		0.000	93.296	0.086
	Cumulative Loading						112.2	112.20			93.296	0.086
Unaccounted (Groundwater) Load to RC-1 (h)							0.8	112.20			253.255	19.756
Measured Value at RC-1			0.4	5%	3737.1	10%	113.0	113.01	0.112	159.960	159.960	0.112
Underground Mine												
	P-5	RRC	9.9	5%	4.3	20%	3.6	116.63	0.206	0.557	160.517	0.109
	Source Area Total						3.6	116.63		0.557	160.517	0.109
	Cumulative Loading						116.6	116.63			160.517	0.109
Unaccounted (Groundwater) Load to RC-4 (h)							-5.3	111.37			315.868	3.381
Measured Value at RC-4			0.4	5%	3483.8	10%	111.4	111.37	0.112	155.351	155.351	0.112
Copper Creek Diversion												
	CC-D1	RRC	0.5	5%	198.2	7%	7.9	119.25	0.086	0.460	155.811	0.105
	Source Area Total						7.9	119.25		0.460	155.811	0.105
Total West Area Surface Water Loading to RRC					3682.0		119.2	119.25			155.811	0.105
Loading to Railroad Creek Associated w/West Area Sources							7.1	7.06			1.017	0.143

East Area - Fall 1997			Magnesium									
	Seep / Tributary Information		Loading Parameters and Accuracies				Surface Water Loading to RRC		Source Loading Accuracy		Cumulative Loading Accuracy	
Source Area	Contribution to Railroad Creek	Associted Monitoring Well/Seep	Conc.E[C] (a) (mg/L)	Accuracy of Conc. CV[C] (b) (%)	Flow E[Q] (c) (L/s)	Accuracy of Flow CV[Q] (d) (%)	Total Load to RRC, E[L] (e) (kg/d)	Cumulative Load, $E[L_{Cumulative}]$ (g) (kg/D)	CV[L] (h)	V[L] (i)	$V[L_{CUMULATIVE}]$ (j)	$CV[L_{CUMULATIVE}]$ (k)
Total From Background & West Area Sources					3682.0		119.25	119.25		0.000	155.811	0.105
Tailings Pile 1												
Groundwater Seeps and Flow from Tailings												
	Tailings Pile 1	SP-2	94.2	50%	0.9	195%	7.32	126.56	2.237	267.806	423.618	0.163
	SP-2		94.2	5%	0.1	50%	0.81	127.38	0.503	0.168	423.785	0.162
Groundwater Flow from Native Material												
	Flow Tube S1	HBKG-1, TP1-6A	9.9	50%	2.2	128%	1.88	129.26	1.516	8.134	431.919	0.161
	Flow Tube S2	TP1-2, TP1-3	135.5	50%	1.2	128%	13.94	143.20	1.516	446.561	878.480	0.207
	Flow Tube S3	TP1-5	46.0	50%	3.6	128%	14.19	157.39	1.516	462.635	1341.115	0.233
	Source Area Total				8.0		38.14	157.39		1185.304	1341.115	0.233
Copper Creek												
	Copper Creek		0.5	5%	141.6	7%	5.63	163.02	0.086	0.235	1341.350	0.225
	Source Area Total				141.6		5.63	163.02		0.235	1341.350	0.225
Tailings Pile 2 (Upstream of RC-7)												
Groundwater Seeps and Flow from Tailings												
	SP-3		62.3	5%	0.4	50%	2.15	165.17	0.503	1.173	1342.523	0.222
	Flow Tube TP-1	SP-3	62.3	50%	0.4	195%	2.42	167.59	2.237	29.269	1371.792	0.221
	Flow Tube TP-2	SP-3	62.3	50%	0.1	195%	0.59	168.18	2.237	1.755	1373.547	0.220
	Flow Tube TP-3	SP-3	62.3	50%	0.2	195%	0.86	169.04	2.237	3.733	1377.281	0.220
	Flow Tube TP-4	SP-3	62.3	50%	0.2	195%	0.88	169.93	2.237	3.905	1381.186	0.219
	Flow Tube TP-5	SP-3	62.3	50%	0.1	195%	0.50	170.43	2.237	1.250	1382.435	0.218
	Flow Tube TP-6	SP-3	62.3	50%	0.2	195%	1.00	171.42	2.237	4.980	1387.415	0.217
Groundwater Flow from Native Material												
	Flow Tube S4	TP2-11A	12.8	50%	4.5	128%	5.01	176.44	1.516	57.706	1445.122	0.215
	Flow Tube S5	TP2-11A	12.8	50%	0.6	128%	0.64	177.08	1.516	0.946	1446.068	0.215
	Flow Tube S6	TP2-11A, PZ-3A	17.5	50%	2.8	128%	4.20	181.27	1.516	40.466	1485.588	0.213
	Source Area Total				9.4		18.26	181.27		145.184	1485.588	0.213
	Cumulative Loading						181.3	181.27			1485.588	0.213
Measured Value at RC-7 (for comparison only)			0.5	5%	4134.0	7%	189.30		0.086	265.626		
Tailings Pile 2 & 3 Downstream of RC-7												
Groundwater Seeps and Flow from Tailings												
	Flow Tube TP-7	SP-3	62.3	50%	0.1	195%	0.29	181.57	2.237	0.425	1486.013	0.212
	Flow Tube TP-8	SP-3	62.3	50%	0.1	195%	0.79	182.35	2.237	3.106	1489.120	0.212
	Flow Tube TP-9	SP-3	62.3	50%	0.2	195%	0.82	183.17	2.237	3.324	1492.443	0.211
	Flow Tube TP-10	SP-3	62.3	50%	0.2	195%	1.05	184.22	2.237	5.518	1497.961	0.210
	Flow Tube TP-11	SP-3, PZ-6A	72.8	50%	0.0	195%	0.13	184.35	2.237	0.082	1498.043	0.210
	Flow Tube TP-12	PZ-6A	83.3	50%	0.0	195%	0.20	184.55	2.237	0.201	1498.244	0.210
	Flow Tube TP-13	PZ-6A	83.3	50%	0.1	195%	0.45	185.00	2.237	1.015	1499.259	0.209
	Flow Tube TP-14	PZ-6A	83.3	50%	0.1	195%	0.75	185.74	2.237	2.794	1502.053	0.209
	Flow Tube TP-15	PZ-6A	83.3	50%	0.1	195%	0.90	186.64	2.237	4.013	1506.065	0.208
Groundwater Flow from Native Material												
	Flow Tube S7	TP2-4A	29.6	50%	2.5	128%	6.50	193.14	1.516	97.034	1603.099	0.207
	Flow Tube S8 IN	TP2-4A	29.6	50%	0.3	128%	0.89	194.02	1.516	1.801	1604.900	0.206
	Flow Tube S8 OUT	RC-7	0.5	50%	-1.2	128%	-0.06	193.97	1.516	0.008	1604.907	0.207
	Flow Tube SL1	RC-7	0.5	50%	-7.0	128%	-0.32	193.65	1.516	0.236	1605.143	0.207
	Flow Tube SL2	RC-7	0.5	50%	-5.8	128%	-0.27	193.38	1.516	0.163	1605.306	0.207
	Flow Tube SL3	RC-7	0.5	50%	-1.9	128%	-0.09	193.29	1.516	0.018	1605.324	0.207
	Source Area Total				-12.2		12.02	193.29		119.736	1605.324	0.207
	Cumulative Loading						193.3	193.29			1605.324	0.207
Unaccounted (Groundwater) Load to RC-2 (h)							-3.64	189.6			1871.918	-11.878
Measured Value at RC-2			0.6	5%	3850.9	7%	189.65	189.65	0.086	266.595	266.595	0.086
Loading Downstream of RC-2												
Groundwater Seep and Flow from Native Material												
	SP-21		7.6	5%	0.1	25%	0.06	189.71	0.255	0.000	266.595	0.086
	Flow Tube S8 OUT	DS-1, TP3-9	23.2	50%	1.2	128%	2.50	192.21	1.516	14.389	280.984	0.087
	Flow Tube SL1	DS-1, TP3-9	23.2	50%	7.0	128%	14.02	206.23	1.516	451.706	732.690	0.131
	Flow Tube SL2	DS-1	5.0	50%	5.8	128%	2.49	208.72	1.516	14.242	746.932	0.131
	Flow Tube SL3	DS-1	5.0	50%	1.9	128%	0.82	209.54	1.516	1.542	748.474	0.131
	Flow Tube SL4	TP3-9	41.4	50%	0.3	128%	1.10	210.64	1.516	2.780	751.254	0.130
	Flow Tube SL5	TP3-9	41.4	50%	0.4	128%	1.39	212.04	1.516	4.458	755.712	0.130
	Source Area Total				16.8		22.39	212.04		489.118	755.712	0.130
Total Values (Measured RC-2 + Downstream of RC-2)					3867.7		212.04	212.04		0.000	755.712	0.130
Total Loading Attributed to the East Area							92.79	92.8			1938.630	0.475
Measured Value at RC-5			0.7	5%	3658.9	7%	214.97		0.086	342.537		

Table A-6.2
Uncertainty Analysis - Aluminum
Baseline Loading Calculations - Railroad Creek - Fall 1997
Holden Mine RI/FS

West Area - Fall 1997			Aluminum									
	Seep / Tributary Information		Loading Parameters and Accuracies				Surface Water Loading to RRC		Source Loading Accuracy		Cumulative Loading Accuracy	
Source Area	Seep/Tributary	Discharges To	Conc.E[C] (a) (mg/L)	Accuracy of Conc. CV[C] (b) (%)	Flow E[Q] (c) (L/s)	Accuracy of Flow CV[Q] (d) (%)	Total Load to RRC, E[L] (e) (kg/d)	Cumulative Load, $E[L_{Cumulative}]$ (g) (kg/D)	CV[L] (h)	V[L] (i)	$V[L_{CUMULATIVE}]$ (j)	$CV[L_{CUMULATIVE}]$ (k)
Measured Value at RC-6			0.0	5%	3710.0	7%	9.6	9.62	0.086	0.685	0.685	0.086
SP-26												
	SP-26	RRC	0.0	5%	0.3	50%	0.0	9.62	0.503	0.000	0.685	0.086
	Source Area Total						9.6	9.62		0.000	0.685	0.086
	Cumulative Loading						9.6	9.62			0.685	0.086
Unaccounted (Groundwater) Load to RC-1 (h)							-6.4	9.62			0.816	-0.141
Measured Value at RC-1			0.0	5%	3737.1	10%	3.2	3.23	0.112	0.131	0.131	0.112
Underground Mine												
	P-5	RRC	0.0	5%	4.3	20%	0.0	3.24	0.206	0.000	0.131	0.112
	Source Area Total						0.0	3.24		0.000	0.131	0.112
	Cumulative Loading						3.2	3.24			0.131	0.112
Unaccounted (Groundwater) Load to RC-4 (h)							-0.2	3.01			0.244	2.184
Measured Value at RC-4			0.0	5%	3483.8	10%	3.0	3.01	0.112	0.113	0.113	0.112
Copper Creek Diversion												
	CC-D1	RRC	0.0	5%	198.2	7%	0.2	3.18	0.086	0.000	0.114	0.106
	Source Area Total						0.2	3.18		0.000	0.114	0.106
Total West Area Surface Water Loading to RRC					3682.0		3.2	3.18			0.114	0.106
Loading to Railroad Creek Associated w/West Area Sources							-6.4	-6.44			0.000	-0.002

East Area - Fall 1997			Aluminum									
	Seep / Tributary Information		Loading Parameters and Accuracies				Surface Water Loading to RRC		Source Loading Accuracy		Cumulative Loading Accuracy	
Source Area	Contribution to Railroad Creek	Associted Monitoring Well/Seep	Conc.E[C] (a) (mg/L)	Accuracy of Conc. CV[C] (b) (%)	Flow E[Q] (c) (L/s)	Accuracy of Flow CV[Q] (d) (%)	Total Load to RRC, E[L] (e) (kg/d)	Cumulative Load, $E[L_{Cumulative}]$ (g) (kg/D)	CV[L] (h)	V[L] (i)	$V[L_{CUMULATIVE}]$ (j)	$CV[L_{CUMULATIVE}]$ (k)
Total From Background & West Area Sources					3682.0		3.18	3.18		0.000	0.114	0.106
Tailings Pile 1												
Groundwater Seeps and Flow from Tailings												
	Tailings Pile 1	SP-2	67.9	50%	0.9	195%	5.27	8.45	2.237	139.142	139.256	1.396
	SP-2		67.9	5%	0.1	50%	0.59	9.04	0.503	0.087	139.343	1.306
Groundwater Flow from Native Material												
	Flow Tube S1	HBKG-1, TP1-6A	7.8	50%	2.2	128%	1.49	10.53	1.516	5.096	144.438	1.141
	Flow Tube S2	TP1-2, TP1-3	5.5	50%	1.2	128%	0.57	11.10	1.516	0.741	145.179	1.086
	Flow Tube S3	TP1-5	25.5	50%	3.6	128%	7.87	18.96	1.516	142.168	287.348	0.894
	Source Area Total				8.0		15.78	18.96		287.234	287.348	0.894
Copper Creek												
	Copper Creek		0.0	5%	141.6	7%	0.12	19.09	0.086	0.000	287.348	0.888
	Source Area Total				141.6		0.12	19.09		0.000	287.348	0.888
Tailings Pile 2 (Upstream of RC-7)												
Groundwater Seeps and Flow from Tailings												
	SP-3		3.9	5%	0.4	50%	0.14	19.22	0.503	0.005	287.353	0.882
	Flow Tube TP-1	SP-3	3.9	50%	0.4	195%	0.15	19.37	2.237	0.116	287.469	0.875
	Flow Tube TP-2	SP-3	3.9	50%	0.1	195%	0.04	19.41	2.237	0.007	287.475	0.873
	Flow Tube TP-3	SP-3	3.9	50%	0.2	195%	0.05	19.47	2.237	0.015	287.490	0.871
	Flow Tube TP-4	SP-3	3.9	50%	0.2	195%	0.06	19.52	2.237	0.015	287.506	0.869
	Flow Tube TP-5	SP-3	3.9	50%	0.1	195%	0.03	19.55	2.237	0.005	287.511	0.867
	Flow Tube TP-6	SP-3	3.9	50%	0.2	195%	0.06	19.62	2.237	0.020	287.530	0.864
Groundwater Flow from Native Material												
	Flow Tube S4	TP2-11A	0.4	50%	4.5	128%	0.17	19.79	1.516	0.068	287.599	0.857
	Flow Tube S5	TP2-11A	0.4	50%	0.6	128%	0.02	19.81	1.516	0.001	287.600	0.856
	Flow Tube S6	TP2-11A, PZ-3A	0.2	50%	2.8	128%	0.05	19.86	1.516	0.007	287.605	0.854
	Source Area Total				9.4		0.78	19.86		0.258	287.605	0.854
	Cumulative Loading						19.9	19.86			287.605	0.854
Measured Value at RC-7 (for comparison only)			0.0	5%	4134.0	7%	0.00		0.086	0.000		
Tailings Pile 2 & 3 Downstream of RC-7												
Groundwater Seeps and Flow from Tailings												
	Flow Tube TP-7	SP-3	3.9	50%	0.1	195%	0.02	19.88	2.237	0.002	287.607	0.853
	Flow Tube TP-8	SP-3	3.9	50%	0.1	195%	0.05	19.93	2.237	0.012	287.619	0.851
	Flow Tube TP-9	SP-3	3.9	50%	0.2	195%	0.05	19.98	2.237	0.013	287.632	0.849
	Flow Tube TP-10	SP-3	3.9	50%	0.2	195%	0.07	20.05	2.237	0.022	287.654	0.846
	Flow Tube TP-11	SP-3, PZ-6A	2.0	50%	0.0	195%	0.00	20.05	2.237	0.000	287.654	0.846
	Flow Tube TP-12	PZ-6A	0.0	50%	0.0	195%	0.00	20.05	2.237	0.000	287.654	0.846
	Flow Tube TP-13	PZ-6A	0.0	50%	0.1	195%	0.00	20.05	2.237	0.000	287.654	0.846
	Flow Tube TP-14	PZ-6A	0.0	50%	0.1	195%	0.00	20.05	2.237	0.000	287.654	0.846
	Flow Tube TP-15	PZ-6A	0.0	50%	0.1	195%	0.00	20.05	2.237	0.000	287.654	0.846
Groundwater Flow from Native Material												
	Flow Tube S7	TP2-4A	0.0	50%	2.5	128%	0.00	20.06	1.516	0.000	287.654	0.846
	Flow Tube S8 IN	TP2-4A	0.0	50%	0.3	128%	0.00	20.06	1.516	0.000	287.654	0.846
	Flow Tube S8 OUT	RC-7	0.0	50%	-1.2	128%	0.00	20.05	1.516	0.000	287.654	0.846
	Flow Tube SL1	RC-7	0.0	50%	-7.0	128%	-0.02	20.03	1.516	0.001	287.656	0.847
	Flow Tube SL2	RC-7	0.0	50%	-5.8	128%	-0.02	20.01	1.516	0.001	287.657	0.848
	Flow Tube SL3	RC-7	0.0	50%	-1.9	128%	-0.01	20.00	1.516	0.000	287.657	0.848
	Source Area Total				-12.2		0.14	20.00		0.051	287.657	0.848
	Cumulative Loading						20.0	20.00			287.657	0.848
Unaccounted (Groundwater) Load to RC-2 (h)							-6.69	13.3			288.970	-2.540
Measured Value at RC-2			0.0	5%	3850.9	7%	13.31	13.31	0.086	1.313	1.313	0.086
Loading Downstream of RC-2												
Groundwater Seep and Flow from Native Material												
	SP-21		1.8	5%	0.1	25%	0.01	13.32	0.255	0.000	1.313	0.086
	Flow Tube S8 OUT	DS-1, TP3-9	5.0	50%	1.2	128%	0.54	13.86	1.516	0.661	1.974	0.101
	Flow Tube SL1	DS-1, TP3-9	5.0	50%	7.0	128%	3.01	16.87	1.516	20.765	22.740	0.283
	Flow Tube SL2	DS-1	0.3	50%	5.8	128%	0.13	16.99	1.516	0.036	22.776	0.281
	Flow Tube SL3	DS-1	0.3	50%	1.9	128%	0.04	17.03	1.516	0.004	22.780	0.280
	Flow Tube SL4	TP3-9	9.7	50%	0.3	128%	0.26	17.29	1.516	0.152	22.932	0.277
	Flow Tube SL5	TP3-9	9.7	50%	0.4	128%	0.33	17.62	1.516	0.244	23.176	0.273
	Source Area Total				16.8		4.31	17.62		21.864	23.176	0.273
Total Values (Measured RC-2 + Downstream of RC-2)					3867.7		17.62	17.62		0.000	23.176	0.273
Total Loading Attributed to the East Area							14.43	14.4			309.407	1.219
Measured Value at RC-5			0.1	5%	3658.9	7%	15.81		0.086	1.852		

Table A-6.3
Uncertainty Analysis - Cadmium
Baseline Loading Calculations - Railroad Creek - Fall 1997
Holden Mine RI/FS

West Area - Fall 1997			Cadmium									
	Seep / Tributary Information		Loading Parameters and Accuracies				Surface Water Loading to RRC		Source Loading Accuracy		Cumulative Loading Accuracy	
Source Area	Seep/Tributary	Discharges To	Conc.E[C] (a) (mg/L)	Accuracy of Conc. CV[C] (b) (%)	Flow E[Q] (c) (L/s)	Accuracy of Flow CV[Q] (d) (%)	Total Load to RRC, E[L] (e) (kg/d)	Cumulative Load, $E[L_{Cumulative}]$ (g) (kg/D)	CV[L] (h)	V[L] (i)	$V[L_{CUMULATIVE}]$ (j)	$CV[L_{CUMULATIVE}]$ (k)
Measured Value at RC-6			0.000	5%	3710.0	7%	0.006	0.006	0.086	0.000	0.000	0.086
SP-26												
	SP-26	RRC	0.000	5%	0.3	50%	0.000	0.006	0.503	0.000	0.000	0.086
	Source Area Total						0.006	0.006		0.000	0.000	0.086
	Cumulative Loading						0.006	0.006			0.000	0.086
Unaccounted (Groundwater) Load to RC-1 (h)							0.000	0.006			0.000	23.286
Measured Value at RC-1			0.000	5%	3737.1	10%	0.006	0.006	0.112	0.000	0.000	0.112
Underground Mine												
	P-5	RRC	0.008	5%	4.3	20%	0.003	0.009	0.206	0.000	0.000	0.100
	Source Area Total						0.003	0.009		0.000	0.000	0.100
	Cumulative Loading						0.009	0.009			0.000	0.100
Unaccounted (Groundwater) Load to RC-4 (h)							0.009	0.018			0.000	0.257
Measured Value at RC-4			0.000	5%	3483.8	10%	0.018	0.018	0.112	0.000	0.000	0.112
Copper Creek Diversion												
	CC-D1	RRC	0.000	5%	198.2	7%	0.002	0.020	0.086	0.000	0.000	0.102
	Source Area Total						0.002	0.020		0.000	0.000	0.102
Total West Area Surface Water Loading to RRC					3682.0		0.020	0.020			0.000	0.102
Loading to Railroad Creek Associated w/West Area Sources							0.013	0.013			0.000	0.047

East Area - Fall 1997			Cadmium									
	Seep / Tributary Information		Loading Parameters and Accuracies				Surface Water Loading to RRC		Source Loading Accuracy		Cumulative Loading Accuracy	
Source Area	Contribution to Railroad Creek	Associted Monitoring Well/Seep	Conc.E[C] (a) (mg/L)	Accuracy of Conc. CV[C] (b) (%)	Flow E[Q] (c) (L/s)	Accuracy of Flow CV[Q] (d) (%)	Total Load to RRC, E[L] (e) (kg/d)	Cumulative Load, $E[L_{Cumulative}]$ (g) (kg/D)	CV[L] (h)	V[L] (i)	$V[L_{CUMULATIVE}]$ (j)	$CV[L_{CUMULATIVE}]$ (k)
Total From Background & West Area Sources					3682.0		0.020	0.020		0.000	0.000	0.102
Tailings Pile 1												
Groundwater Seeps and Flow from Tailings												
	Tailings Pile 1	SP-2	0.004	50%	0.9	195%	0.000	0.020	2.237	0.000	0.000	0.106
	SP-2		0.004	5%	0.1	50%	0.000	0.020	0.503	0.000	0.000	0.106
Groundwater Flow from Native Material												
	Flow Tube S1	HBKG-1, TP1-6A	0.034	50%	2.2	128%	0.006	0.027	1.516	0.000	0.000	0.375
	Flow Tube S2	TP1-2, TP1-3	0.001	50%	1.2	128%	0.000	0.027	1.516	0.000	0.000	0.373
	Flow Tube S3	TP1-5	0.002	50%	3.6	128%	0.001	0.027	1.516	0.000	0.000	0.367
	Source Area Total				8.0		0.007	0.027		0.000	0.000	0.367
Copper Creek												
	Copper Creek		0.000	5%	141.6	7%	0.000	0.027	0.086	0.000	0.000	0.364
	Source Area Total				141.6		0.000	0.027		0.000	0.000	0.364
Tailings Pile 2 (Upstream of RC-7)												
Groundwater Seeps and Flow from Tailings												
	SP-3		0.002	5%	0.4	50%	0.000	0.027	0.503	0.000	0.000	0.363
	Flow Tube TP-1	SP-3	0.002	50%	0.4	195%	0.000	0.028	2.237	0.000	0.000	0.362
	Flow Tube TP-2	SP-3	0.002	50%	0.1	195%	0.000	0.028	2.237	0.000	0.000	0.362
	Flow Tube TP-3	SP-3	0.002	50%	0.2	195%	0.000	0.028	2.237	0.000	0.000	0.361
	Flow Tube TP-4	SP-3	0.002	50%	0.2	195%	0.000	0.028	2.237	0.000	0.000	0.361
	Flow Tube TP-5	SP-3	0.002	50%	0.1	195%	0.000	0.028	2.237	0.000	0.000	0.361
	Flow Tube TP-6	SP-3	0.002	50%	0.2	195%	0.000	0.028	2.237	0.000	0.000	0.360
Groundwater Flow from Native Material												
	Flow Tube S4	TP2-11A	0.003	50%	4.5	128%	0.001	0.029	1.516	0.000	0.000	0.351
	Flow Tube S5	TP2-11A	0.003	50%	0.6	128%	0.000	0.029	1.516	0.000	0.000	0.350
	Flow Tube S6	TP2-11A, PZ-3A	0.002	50%	2.8	128%	0.000	0.029	1.516	0.000	0.000	0.346
	Source Area Total				9.4		0.002	0.029		0.000	0.000	0.346
	Cumulative Loading						0.029	0.029			0.000	0.346
Measured Value at RC-7 (for comparison only)			0.000	5%	4134.0	7%	0.032		0.086	0.000		
Tailings Pile 2 & 3 Downstream of RC-7												
Groundwater Seeps and Flow from Tailings												
	Flow Tube TP-7	SP-3	0.002	50%	0.1	195%	0.000	0.029	2.237	0.000	0.000	0.346
	Flow Tube TP-8	SP-3	0.002	50%	0.1	195%	0.000	0.029	2.237	0.000	0.000	0.345
	Flow Tube TP-9	SP-3	0.002	50%	0.2	195%	0.000	0.029	2.237	0.000	0.000	0.345
	Flow Tube TP-10	SP-3	0.002	50%	0.2	195%	0.000	0.029	2.237	0.000	0.000	0.345
	Flow Tube TP-11	SP-3, PZ-6A	0.001	50%	0.0	195%	0.000	0.029	2.237	0.000	0.000	0.345
	Flow Tube TP-12	PZ-6A	0.000	50%	0.0	195%	0.000	0.029	2.237	0.000	0.000	0.345
	Flow Tube TP-13	PZ-6A	0.000	50%	0.1	195%	0.000	0.029	2.237	0.000	0.000	0.345
	Flow Tube TP-14	PZ-6A	0.000	50%	0.1	195%	0.000	0.029	2.237	0.000	0.000	0.345
	Flow Tube TP-15	PZ-6A	0.000	50%	0.1	195%	0.000	0.029	2.237	0.000	0.000	0.345
Groundwater Flow from Native Material												
	Flow Tube S7	TP2-4A	0.000	50%	2.5	128%	0.000	0.029	1.516	0.000	0.000	0.344
	Flow Tube S8 IN	TP2-4A	0.000	50%	0.3	128%	0.000	0.029	1.516	0.000	0.000	0.344
	Flow Tube S8 OUT	RC-7	0.000	50%	-1.2	128%	0.000	0.029	1.516	0.000	0.000	0.344
	Flow Tube SL1	RC-7	0.000	50%	-7.0	128%	0.000	0.029	1.516	0.000	0.000	0.345
	Flow Tube SL2	RC-7	0.000	50%	-5.8	128%	0.000	0.029	1.516	0.000	0.000	0.346
	Flow Tube SL3	RC-7	0.000	50%	-1.9	128%	0.000	0.029	1.516	0.000	0.000	0.346
	Source Area Total				-12.2		0.000	0.029		0.000	0.000	0.346
	Cumulative Loading						0.029	0.029			0.000	0.346
Unaccounted (Groundwater) Load to RC-2 (h)							0.004	0.033			0.000	2.652
Measured Value at RC-2			0.000	5%	3850.9	7%	0.033	0.033	0.086	0.000	0.000	0.086
Loading Downstream of RC-2												
Groundwater Seep and Flow from Native Material												
	SP-21		0.001	5%	0.1	25%	0.000	0.033	0.255	0.000	0.000	0.086
	Flow Tube S8 OUT	DS-1, TP3-9	0.002	50%	1.2	128%	0.000	0.034	1.516	0.000	0.000	0.086
	Flow Tube SL1	DS-1, TP3-9	0.002	50%	7.0	128%	0.001	0.035	1.516	0.000	0.000	0.105
	Flow Tube SL2	DS-1	0.001	50%	5.8	128%	0.001	0.036	1.516	0.000	0.000	0.107
	Flow Tube SL3	DS-1	0.001	50%	1.9	128%	0.000	0.036	1.516	0.000	0.000	0.107
	Flow Tube SL4	TP3-9	0.004	50%	0.3	128%	0.000	0.036	1.516	0.000	0.000	0.106
	Flow Tube SL5	TP3-9	0.004	50%	0.4	128%	0.000	0.036	1.516	0.000	0.000	0.106
	Source Area Total				16.8		0.003	0.036		0.000	0.000	0.106
Total Values (Measured RC-2 + Downstream of RC-2)					3867.7		0.036	0.036		0.000	0.000	0.106
Total Loading Attributed to the East Area							0.016	0.016			0.000	0.625
Measured Value at RC-5			0.000	5%	3658.9	7%	0.038		0.086	0.000		

Table A-6.4
Uncertainty Analysis - Copper
Baseline Loading Calculations - Railroad Creek - Fall 1997
Holden Mine RI/FS

West Area - Fall 1997			**Copper**									
	Seep / Tributary Information		Loading Parameters and Accuracies				Surface Water Loading to RRC		Source Loading Accuracy		Cumulative Loading Accuracy	
Source Area	Seep/Tributary	Discharges To	Conc.E[C] (a) (mg/L)	Accuracy of Conc. CV[C] (b) (%)	Flow E[Q] (c) (L/s)	Accuracy of Flow CV[Q] (d) (%)	Total Load to RRC, E[L] (e) (kg/d)	Cumulative Load, $E[L_{Cumulative}]$ (g) (kg/D)	CV[L] (h)	V[L] (i)	$V[L_{CUMULATIVE}]$ (j)	$CV[L_{CUMULATIVE}]$ (k)
Measured Value at RC-6			0.000	5%	3710.0	7%	0.14	0.14	0.086	0.000	0.000	0.086
SP-26												
	SP-26	RRC	0.022	5%	0.3	50%	0.00	0.14	0.503	0.000	0.000	0.086
	Source Area Total						0.14	0.14		0.000	0.000	0.086
	Cumulative Loading						0.14	0.14			0.000	0.086
Unaccounted (Groundwater) Load to RC-1 (h)							-0.02	0.14			0.000	-1.217
Measured Value at RC-1			0.000	5%	3737.1	10%	0.13	0.13	0.112	0.000	0.000	0.112
Underground Mine												
	P-5	RRC	0.028	5%	4.3	20%	0.01	0.14	0.206	0.000	0.000	0.105
	Source Area Total						0.01	0.14		0.000	0.000	0.105
	Cumulative Loading						0.14	0.14			0.000	0.105
Unaccounted (Groundwater) Load to RC-4 (h)							0.40	0.54			0.004	0.155
Measured Value at RC-4			0.002	5%	3483.8	10%	0.54	0.54	0.112	0.004	0.004	0.112
Copper Creek Diversion												
	CC-D1	RRC	0.001	5%	198.2	7%	0.02	0.56	0.086	0.000	0.004	0.109
	Source Area Total						0.02	0.56		0.000	0.004	0.109
Total West Area Surface Water Loading to RRC					3682.0		0.56	0.56			0.004	0.109
Loading to Railroad Creek Associated w/West Area Sources							0.41	0.41			0.000	0.006
East Area - Fall 1997			**Copper**									
	Seep / Tributary Information		Loading Parameters and Accuracies				Surface Water Loading to RRC		Source Loading Accuracy		Cumulative Loading Accuracy	
Source Area	Contribution to Railroad Creek	Associted Monitoring Well/Seep	Conc.E[C] (a) (mg/L)	Accuracy of Conc. CV[C] (b) (%)	Flow E[Q] (c) (L/s)	Accuracy of Flow CV[Q] (d) (%)	Total Load to RRC, E[L] (e) (kg/d)	Cumulative Load, $E[L_{Cumulative}]$ (g) (kg/D)	CV[L] (h)	V[L] (i)	$V[L_{CUMULATIVE}]$ (j)	$CV[L_{CUMULATIVE}]$ (k)
Total From Background & West Area Sources					3682.0		0.56	0.56		0.000	0.004	0.109
Tailings Pile 1												
Groundwater Seeps and Flow from Tailings												
	Tailings Pile 1	SP-2	0.101	50%	0.9	195%	0.01	0.57	2.237	0.000	0.004	0.111
	SP-2		0.101	5%	0.1	50%	0.00	0.57	0.503	0.000	0.004	0.111
Groundwater Flow from Native Material												
	Flow Tube S1	HBKG-1, TP1-6A	1.591	50%	2.2	128%	0.30	0.87	1.516	0.212	0.216	0.533
	Flow Tube S2	TP1-2, TP1-3	0.005	50%	1.2	128%	0.00	0.87	1.516	0.000	0.216	0.533
	Flow Tube S3	TP1-5	0.048	50%	3.6	128%	0.01	0.89	1.516	0.001	0.216	0.525
	Source Area Total				8.0		0.33	0.89		0.213	0.216	0.525
Copper Creek												
	Copper Creek		0.000	5%	141.6	7%	0.00	0.89	0.086	0.000	0.216	0.522
	Source Area Total				141.6		0.00	0.89		0.000	0.216	0.522
Tailings Pile 2 (Upstream of RC-7)												
Groundwater Seeps and Flow from Tailings												
	SP-3		0.090	5%	0.4	50%	0.00	0.89	0.503	0.000	0.216	0.521
	Flow Tube TP-1	SP-3	0.090	50%	0.4	195%	0.00	0.90	2.237	0.000	0.216	0.519
	Flow Tube TP-2	SP-3	0.090	50%	0.1	195%	0.00	0.90	2.237	0.000	0.216	0.518
	Flow Tube TP-3	SP-3	0.090	50%	0.2	195%	0.00	0.90	2.237	0.000	0.216	0.518
	Flow Tube TP-4	SP-3	0.090	50%	0.2	195%	0.00	0.90	2.237	0.000	0.216	0.517
	Flow Tube TP-5	SP-3	0.090	50%	0.1	195%	0.00	0.90	2.237	0.000	0.216	0.516
	Flow Tube TP-6	SP-3	0.090	50%	0.2	195%	0.00	0.90	2.237	0.000	0.216	0.516
Groundwater Flow from Native Material												
	Flow Tube S4	TP2-11A	0.010	50%	4.5	128%	0.00	0.91	1.516	0.000	0.216	0.513
	Flow Tube S5	TP2-11A	0.010	50%	0.6	128%	0.00	0.91	1.516	0.000	0.216	0.513
	Flow Tube S6	TP2-11A, PZ-3A	0.006	50%	2.8	128%	0.00	0.91	1.516	0.000	0.216	0.512
	Source Area Total				9.4		0.02	0.91		0.000	0.216	0.512
	Cumulative Loading						0.9	0.91			0.216	0.512
Measured Value at RC-7 (for comparison only)			0.001	5%	4134.0	7%	0.46		0.086	0.002		
Tailings Pile 2 & 3 Downstream of RC-7												
Groundwater Seeps and Flow from Tailings												
	Flow Tube TP-7	SP-3	0.090	50%	0.1	195%	0.00	0.91	2.237	0.000	0.216	0.512
	Flow Tube TP-8	SP-3	0.090	50%	0.1	195%	0.00	0.91	2.237	0.000	0.217	0.511
	Flow Tube TP-9	SP-3	0.090	50%	0.2	195%	0.00	0.91	2.237	0.000	0.217	0.511
	Flow Tube TP-10	SP-3	0.090	50%	0.2	195%	0.00	0.91	2.237	0.000	0.217	0.510
	Flow Tube TP-11	SP-3, PZ-6A	0.046	50%	0.0	195%	0.00	0.91	2.237	0.000	0.217	0.510
	Flow Tube TP-12	PZ-6A	0.002	50%	0.0	195%	0.00	0.91	2.237	0.000	0.217	0.510
	Flow Tube TP-13	PZ-6A	0.002	50%	0.1	195%	0.00	0.91	2.237	0.000	0.217	0.510
	Flow Tube TP-14	PZ-6A	0.002	50%	0.1	195%	0.00	0.91	2.237	0.000	0.217	0.510
	Flow Tube TP-15	PZ-6A	0.002	50%	0.1	195%	0.00	0.91	2.237	0.000	0.217	0.510
Groundwater Flow from Native Material												
	Flow Tube S7	TP2-4A	0.001	50%	2.5	128%	0.00	0.91	1.516	0.000	0.217	0.510
	Flow Tube S8 IN	TP2-4A	0.001	50%	0.3	128%	0.00	0.91	1.516	0.000	0.217	0.510
	Flow Tube S8 OUT	RC-7	0.001	50%	-1.2	128%	0.00	0.91	1.516	0.000	0.217	0.510
	Flow Tube SL1	RC-7	0.001	50%	-7.0	128%	0.00	0.91	1.516	0.000	0.217	0.510
	Flow Tube SL2	RC-7	0.001	50%	-5.8	128%	0.00	0.91	1.516	0.000	0.217	0.511
	Flow Tube SL3	RC-7	0.001	50%	-1.9	128%	0.00	0.91	1.516	0.000	0.217	0.511
	Source Area Total				-12.2		0.00	0.91		0.000	0.217	0.511
	Cumulative Loading						0.9	0.91			0.217	0.511
Unaccounted (Groundwater) Load to RC-2 (h)							-0.51	0.4			0.218	-0.912
Measured Value at RC-2			0.001	5%	3850.9	7%	0.40	0.40	0.086	0.001	0.001	0.086
Loading Downstream of RC-2												
Groundwater Seep and Flow from Native Material												
	SP-21		0.034	5%	0.1	25%	0.00	0.40	0.255	0.000	0.001	0.086
	Flow Tube S8 OUT	DS-1, TP3-9	0.045	50%	1.2	128%	0.00	0.40	1.516	0.000	0.001	0.087
	Flow Tube SL1	DS-1, TP3-9	0.045	50%	7.0	128%	0.03	0.43	1.516	0.002	0.003	0.126
	Flow Tube SL2	DS-1	0.039	50%	5.8	128%	0.02	0.45	1.516	0.001	0.004	0.137
	Flow Tube SL3	DS-1	0.039	50%	1.9	128%	0.01	0.46	1.516	0.000	0.004	0.137
	Flow Tube SL4	TP3-9	0.051	50%	0.3	128%	0.00	0.46	1.516	0.000	0.004	0.136
	Flow Tube SL5	TP3-9	0.051	50%	0.4	128%	0.00	0.46	1.516	0.000	0.004	0.136
	Source Area Total				16.8		0.06	0.46		0.003	0.004	0.136
Total Values (Measured RC-2 + Downstream of RC-2)					3867.7		0.46	0.46		0.000	0.004	0.136
Total Loading Attributed to the East Area							-0.10	-0.1			0.216	-4.727
Measured Value at RC-5			0.002	5%	3658.9	7%	0.51		0.086	0.002		

Table A-6.5
Uncertainty Analysis - Iron
Baseline Loading Calculations - Railroad Creek - Fall 1997
Holden Mine RI/FS

West Area - Fall 1997			Iron									
	Seep / Tributary Information		Loading Parameters and Accuracies				Surface Water Loading to RRC		Source Loading Accuracy		Cumulative Loading Accuracy	
Source Area	Seep/Tributary	Discharges To	Conc.E[C] (a) (mg/L)	Accuracy of Conc. CV[C] (b) (%)	Flow E[Q] (c) (L/s)	Accuracy of Flow CV[Q] (d) (%)	Total Load to RRC, E[L] (e) (kg/d)	Cumulative Load, $E[L_{Cumulative}]$ (g) (kg/D)	CV[L] (h)	V[L] (i)	$V[L_{CUMULATIVE}]$ (j)	$CV[L_{CUMULATIVE}]$ (k)
Measured Value at RC-6			0.04	5%	3710.0	7%	12.82	12.82	0.086	1.219	1.219	0.086
SP-26												
	SP-26	RRC	0.01	5%	0.3	50%	0.00	12.82	0.503	0.000	1.219	0.086
	Source Area Total						12.82	12.82		0.000	1.219	0.086
	Cumulative Loading						12.82	12.82			1.219	0.086
Unaccounted (Groundwater) Load to RC-1 (h)							0.09	12.82			3.308	19.473
Measured Value at RC-1			0.04	5%	3737.1	10%	12.92	12.92	0.112	2.089	2.089	0.112
Underground Mine												
	P-5	RRC	0.01	5%	4.3	20%	0.00	12.92	0.206	0.000	2.089	0.112
	Source Area Total						0.00	12.92		0.000	2.089	0.112
	Cumulative Loading						12.92	12.92			2.089	0.112
Unaccounted (Groundwater) Load to RC-4 (h)							-0.88	12.04			3.905	2.248
Measured Value at RC-4			0.04	5%	3483.8	10%	12.04	12.04	0.112	1.816	1.816	0.112
Copper Creek Diversion												
	CC-D1	RRC	0.01	5%	198.2	7%	0.17	12.21	0.086	0.000	1.816	0.110
	Source Area Total						0.17	12.21		0.000	1.816	0.110
Total West Area Surface Water Loading to RRC					3682.0		12.21	12.21			1.816	0.110
Loading to Railroad Creek Associated w/West Area Sources							-0.61	-0.61			0.000	-0.024

East Area - Fall 1997			Iron									
	Seep / Tributary Information		Loading Parameters and Accuracies				Surface Water Loading to RRC		Source Loading Accuracy		Cumulative Loading Accuracy	
Source Area	Contribution to Railroad Creek	Associted Monitoring Well/Seep	Conc.E[C] (a) (mg/L)	Accuracy of Conc. CV[C] (b) (%)	Flow E[Q] (c) (L/s)	Accuracy of Flow CV[Q] (d) (%)	Total Load to RRC, E[L] (e) (kg/d)	Cumulative Load, $E[L_{Cumulative}]$ (g) (kg/D)	CV[L] (h)	V[L] (i)	$V[L_{CUMULATIVE}]$ (j)	$CV[L_{CUMULATIVE}]$ (k)
Total From Background & West Area Sources					3682.0		12.21	12.21		0.000	2	0.110
Tailings Pile 1												
Groundwater Seeps and Flow from Tailings												
	Tailings Pile 1	SP-2	685.0	50%	0.9	195%	53.20	65.41	2.237	14161.198	14163	1.819
	SP-2		685.0	5%	0.1	50%	5.92	71.33	0.503	8.866	14172	1.669
Groundwater Flow from Native Material												
	Flow Tube S1	HBKG-1, TP1-6A	40.2	50%	2.2	128%	7.68	79.01	1.516	135.381	14307	1.514
	Flow Tube S2	TP1-2, TP1-3	1605.0	50%	1.2	128%	165.12	244.13	1.516	62654.488	76962	1.136
	Flow Tube S3	TP1-5	413.0	50%	3.6	128%	127.39	371.52	1.516	37292.620	114254	0.910
	Source Area Total				8.0		359.31	371.52		114252.553	114254	0.910
Copper Creek												
	Copper Creek		0.0	5%	141.6	7%	0.12	371.64	0.086	0.000	114254	0.910
	Source Area Total				141.6		0.12	371.64		0.000	114254	0.910
Tailings Pile 2 (Upstream of RC-7)												
Groundwater Seeps and Flow from Tailings												
	SP-3		251.0	5%	0.4	50%	8.67	380.32	0.503	19.047	114273	0.889
	Flow Tube TP-1	SP-3	251.0	50%	0.4	195%	9.74	390.06	2.237	475.088	114749	0.868
	Flow Tube TP-2	SP-3	251.0	50%	0.1	195%	2.39	392.45	2.237	28.493	114777	0.863
	Flow Tube TP-3	SP-3	251.0	50%	0.2	195%	3.48	395.93	2.237	60.598	114838	0.856
	Flow Tube TP-4	SP-3	251.0	50%	0.2	195%	3.56	399.49	2.237	63.384	114901	0.849
	Flow Tube TP-5	SP-3	251.0	50%	0.1	195%	2.01	401.50	2.237	20.285	114921	0.844
	Flow Tube TP-6	SP-3	251.0	50%	0.2	195%	4.02	405.52	2.237	80.839	115002	0.836
Groundwater Flow from Native Material												
	Flow Tube S4	TP2-11A	0.1	50%	4.5	128%	0.04	405.56	1.516	0.004	115002	0.836
	Flow Tube S5	TP2-11A	0.1	50%	0.6	128%	0.01	405.56	1.516	0.000	115002	0.836
	Flow Tube S6	TP2-11A, PZ-3A	2.9	50%	2.8	128%	0.70	406.27	1.516	1.138	115003	0.835
	Source Area Total				9.4		34.63	406.27		748.876	115003	0.835
	Cumulative Loading						406.3	406.27			115003	0.835
Measured Value at RC-7 (for comparison only)			1.2	5%	4134.0	7%	410.75		0.086	1250.588		
Tailings Pile 2 & 3 Downstream of RC-7												
Groundwater Seeps and Flow from Tailings												
	Flow Tube TP-7	SP-3	251.0	50%	0.1	195%	1.17	407.44	2.237	6.902	115010	0.832
	Flow Tube TP-8	SP-3	251.0	50%	0.1	195%	3.17	410.62	2.237	50.420	115061	0.826
	Flow Tube TP-9	SP-3	251.0	50%	0.2	195%	3.28	413.90	2.237	53.949	115115	0.820
	Flow Tube TP-10	SP-3	251.0	50%	0.2	195%	4.23	418.13	2.237	89.573	115204	0.812
	Flow Tube TP-11	SP-3, PZ-6A	163.4	50%	0.0	195%	0.29	418.42	2.237	0.411	115205	0.811
	Flow Tube TP-12	PZ-6A	75.7	50%	0.0	195%	0.18	418.60	2.237	0.166	115205	0.811
	Flow Tube TP-13	PZ-6A	75.7	50%	0.1	195%	0.41	419.01	2.237	0.838	115206	0.810
	Flow Tube TP-14	PZ-6A	75.7	50%	0.1	195%	0.68	419.69	2.237	2.307	115208	0.809
	Flow Tube TP-15	PZ-6A	75.7	50%	0.1	195%	0.81	420.50	2.237	3.314	115211	0.807
Groundwater Flow from Native Material												
	Flow Tube S7	TP2-4A	5.6	50%	2.5	128%	1.24	421.74	1.516	3.510	115215	0.805
	Flow Tube S8 IN	TP2-4A	5.6	50%	0.3	128%	0.17	421.91	1.516	0.065	115215	0.805
	Flow Tube S8 OUT	RC-7	1.2	50%	-1.2	128%	-0.12	421.78	1.516	0.035	115215	0.805
	Flow Tube SL1	RC-7	1.2	50%	-7.0	128%	-0.70	421.09	1.516	1.112	115216	0.806
	Flow Tube SL2	RC-7	1.2	50%	-5.8	128%	-0.58	420.51	1.516	0.766	115217	0.807
	Flow Tube SL3	RC-7	1.2	50%	-1.9	128%	-0.19	420.32	1.516	0.083	115217	0.808
	Source Area Total				-12.2		14.05	420.32		213.452	115217	0.808
	Cumulative Loading						420.3	420.32			115217	0.808
Unaccounted (Groundwater) Load to RC-2 (h)							-60.98	359.3			116174	-5.589
Measured Value at RC-2			1.1	5%	3850.9	7%	359.34	359.34	0.086	957.083	957	0.086
Loading Downstream of RC-2												
Groundwater Seep and Flow from Native Material												
	SP-21		1.5	5%	0.1	25%	0.01	359.35	0.255	0.000	957	0.086
	Flow Tube S8 OUT	DS-1, TP3-9	62.5	50%	1.2	128%	6.75	366.10	1.516	104.621	1062	0.089
	Flow Tube SL1	DS-1, TP3-9	62.5	50%	7.0	128%	37.81	403.90	1.516	3284.421	4346	0.163
	Flow Tube SL2	DS-1	0.0	50%	5.8	128%	0.01	403.91	1.516	0.000	4346	0.163
	Flow Tube SL3	DS-1	0.0	50%	1.9	128%	0.00	403.91	1.516	0.000	4346	0.163
	Flow Tube SL4	TP3-9	125.0	50%	0.3	128%	3.32	407.23	1.516	25.340	4371	0.162
	Flow Tube SL5	TP3-9	125.0	50%	0.4	128%	4.21	411.43	1.516	40.643	4412	0.161
	Source Area Total				16.8		52.10	411.43		3455.026	4412	0.161
Total Values (Measured RC-2 + Downstream of RC-2)					3867.7		411.43	411.43		0.000	4412	0.161
Total Loading Attributed to the East Area							399.22	399.2			118670	0.863
Measured Value at RC-5			1.3	5%	3658.9	7%	395.17		0.086	1157.468		

Table A-6.6
Uncertainty Analysis - Zinc
Baseline Loading Calculations - Railroad Creek - Fall 1997
Holden Mine RI/FS

West Area - Fall 1997			**Zinc**									
	Seep / Tributary Information		Loading Parameters and Accuracies				Surface Water Loading to RRC		Source Loading Accuracy		Cumulative Loading Accuracy	
Source Area	Seep/Tributary	Discharges To	Conc.E[C] (a) (mg/L)	Accuracy of Conc. CV[C] (b) (%)	Flow E[Q] (c) (L/s)	Accuracy of Flow CV[Q] (d) (%)	Total Load to RRC, E[L] (e) (kg/d)	Cumulative Load, $E[L_{Cumulative}]$ (g) (kg/D)	CV[L] (h)	V[L] (i)	$V[L_{CUMULATIVE}]$ (j)	$CV[L_{CUMULATIVE}]$ (k)
Measured Value at RC-6			0.01	5%	3710.0	7%	3.2	3.21	0.086	0.076	0.076	0.086
SP-26												
	SP-26	RRC	0.02	5%	0.3	50%	0.0	3.21	0.503	0.000	0.076	0.086
	Source Area Total						3.2	3.21		0.000	0.076	0.086
	Cumulative Loading						3.2	3.21			0.076	0.086
Unaccounted (Groundwater) Load to RC-1 (h)							-2.6	3.21			0.081	-0.111
Measured Value at RC-1			0.00	5%	3737.1	10%	0.6	0.65	0.112	0.005	0.005	0.112
Underground Mine												
	P-5	RRC	2.98	5%	4.3	20%	1.1	1.74	0.206	0.051	0.056	0.136
	Source Area Total						1.1	1.74		0.051	0.056	0.136
	Cumulative Loading						1.7	1.74			0.056	0.136
Unaccounted (Groundwater) Load to RC-4 (h)							1.6	3.31			0.194	0.280
Measured Value at RC-4			0.01	5%	3483.8	10%	3.3	3.31	0.112	0.137	0.137	0.112
Copper Creek Diversion												
	CC-D1	RRC	0.00	5%	198.2	7%	0.0	3.35	0.086	0.000	0.137	0.111
	Source Area Total						0.0	3.35		0.000	0.137	0.111
Total West Area Surface Water Loading to RRC					3682.0		3.3	3.35			0.137	0.111
Loading to Railroad Creek Associated w/West Area Sources							0.1	0.14			0.051	1.616

East Area - Fall 1997			**Zinc**									
	Seep / Tributary Information		Loading Parameters and Accuracies				Surface Water Loading to RRC		Source Loading Accuracy		Cumulative Loading Accuracy	
Source Area	Contribution to Railroad Creek	Associted Monitoring Well/Seep	Conc.E[C] (a) (mg/L)	Accuracy of Conc. CV[C] (b) (%)	Flow E[Q] (c) (L/s)	Accuracy of Flow CV[Q] (d) (%)	Total Load to RRC, E[L] (e) (kg/d)	Cumulative Load, $E[L_{Cumulative}]$ (g) (kg/D)	CV[L] (h)	V[L] (i)	$V[L_{CUMULATIVE}]$ (j)	$CV[L_{CUMULATIVE}]$ (k)
Total From Background & West Area Sources					3682.0		3.35	3.35		0.000	0.137	0.111
Tailings Pile 1												
Groundwater Seeps and Flow from Tailings												
	Tailings Pile 1	SP-2	5.70	50%	0.9	195%	0.44	3.79	2.237	0.981	1.118	0.279
	SP-2		5.70	5%	0.1	50%	0.05	3.84	0.503	0.001	1.118	0.276
Groundwater Flow from Native Material												
	Flow Tube S1	HBKG-1, TP1-6A	4.26	50%	2.2	128%	0.81	4.65	1.516	1.520	2.638	0.349
	Flow Tube S2	TP1-2, TP1-3	4.59	50%	1.2	128%	0.47	5.12	1.516	0.512	3.151	0.347
	Flow Tube S3	TP1-5	2.73	50%	3.6	128%	0.84	5.96	1.516	1.629	4.780	0.367
	Source Area Total				8.0		2.62	5.96		4.643	4.780	0.367
Copper Creek												
	Copper Creek		0.00	5%	141.6	7%	0.02	5.99	0.086	0.000	4.780	0.365
	Source Area Total				141.6		0.02	5.99		0.000	4.780	0.365
Tailings Pile 2 (Upstream of RC-7)												
Groundwater Seeps and Flow from Tailings												
	SP-3		0.61	5%	0.4	50%	0.02	6.01	0.503	0.000	4.780	0.364
	Flow Tube TP-1	SP-3	0.61	50%	0.4	195%	0.02	6.03	2.237	0.003	4.783	0.362
	Flow Tube TP-2	SP-3	0.61	50%	0.1	195%	0.01	6.04	2.237	0.000	4.783	0.362
	Flow Tube TP-3	SP-3	0.61	50%	0.2	195%	0.01	6.05	2.237	0.000	4.784	0.362
	Flow Tube TP-4	SP-3	0.61	50%	0.2	195%	0.01	6.06	2.237	0.000	4.784	0.361
	Flow Tube TP-5	SP-3	0.61	50%	0.1	195%	0.00	6.06	2.237	0.000	4.784	0.361
	Flow Tube TP-6	SP-3	0.61	50%	0.2	195%	0.01	6.07	2.237	0.000	4.785	0.360
Groundwater Flow from Native Material												
	Flow Tube S4	TP2-11A	0.31	50%	4.5	128%	0.12	6.19	1.516	0.034	4.818	0.354
	Flow Tube S5	TP2-11A	0.31	50%	0.6	128%	0.02	6.21	1.516	0.001	4.819	0.354
	Flow Tube S6	TP2-11A, PZ-3A	0.16	50%	2.8	128%	0.04	6.25	1.516	0.003	4.822	0.352
	Source Area Total				9.4		0.26	6.25		0.042	4.822	0.352
	Cumulative Loading						6.2	6.25			4.822	0.352
Measured Value at RC-7 (for comparison only)			0.02	5%	4134.0	7%	6.79		0.086	0.341		
Tailings Pile 2 & 3 Downstream of RC-7												
Groundwater Seeps and Flow from Tailings												
	Flow Tube TP-7	SP-3	0.61	50%	0.1	195%	0.00	6.25	2.237	0.000	4.822	0.351
	Flow Tube TP-8	SP-3	0.61	50%	0.1	195%	0.01	6.26	2.237	0.000	4.822	0.351
	Flow Tube TP-9	SP-3	0.61	50%	0.2	195%	0.01	6.26	2.237	0.000	4.822	0.351
	Flow Tube TP-10	SP-3	0.61	50%	0.2	195%	0.01	6.27	2.237	0.001	4.823	0.350
	Flow Tube TP-11	SP-3, PZ-6A	0.32	50%	0.0	195%	0.00	6.28	2.237	0.000	4.823	0.350
	Flow Tube TP-12	PZ-6A	0.03	50%	0.0	195%	0.00	6.28	2.237	0.000	4.823	0.350
	Flow Tube TP-13	PZ-6A	0.03	50%	0.1	195%	0.00	6.28	2.237	0.000	4.823	0.350
	Flow Tube TP-14	PZ-6A	0.03	50%	0.1	195%	0.00	6.28	2.237	0.000	4.823	0.350
	Flow Tube TP-15	PZ-6A	0.03	50%	0.1	195%	0.00	6.28	2.237	0.000	4.823	0.350
Groundwater Flow from Native Material												
	Flow Tube S7	TP2-4A	0.01	50%	2.5	128%	0.00	6.28	1.516	0.000	4.823	0.350
	Flow Tube S8 IN	TP2-4A	0.01	50%	0.3	128%	0.00	6.28	1.516	0.000	4.823	0.350
	Flow Tube S8 OUT	RC-7	0.02	50%	-1.2	128%	0.00	6.28	1.516	0.000	4.823	0.350
	Flow Tube SL1	RC-7	0.02	50%	-7.0	128%	-0.01	6.26	1.516	0.000	4.823	0.351
	Flow Tube SL2	RC-7	0.02	50%	-5.8	128%	-0.01	6.25	1.516	0.000	4.823	0.351
	Flow Tube SL3	RC-7	0.02	50%	-1.9	128%	0.00	6.25	1.516	0.000	4.823	0.351
	Source Area Total				-12.2		0.01	6.25		0.002	4.823	0.351
	Cumulative Loading						6.3	6.25			4.823	0.351
Unaccounted (Groundwater) Load to RC-2 (h)							1.40	7.7			5.257	1.637
Measured Value at RC-2			0.02	5%	3850.9	7%	7.65	7.65	0.086	0.434	0.434	0.086
Loading Downstream of RC-2												
Groundwater Seep and Flow from Native Material												
	SP-21		0.13	5%	0.1	25%	0.00	7.65	0.255	0.000	0.434	0.086
	Flow Tube S8 OUT	DS-1, TP3-9	0.24	50%	1.2	128%	0.03	7.68	1.516	0.002	0.436	0.086
	Flow Tube SL1	DS-1, TP3-9	0.24	50%	7.0	128%	0.15	7.83	1.516	0.049	0.484	0.089
	Flow Tube SL2	DS-1	0.08	50%	5.8	128%	0.04	7.86	1.516	0.004	0.488	0.089
	Flow Tube SL3	DS-1	0.08	50%	1.9	128%	0.01	7.88	1.516	0.000	0.488	0.089
	Flow Tube SL4	TP3-9	0.40	50%	0.3	128%	0.01	7.89	1.516	0.000	0.489	0.089
	Flow Tube SL5	TP3-9	0.40	50%	0.4	128%	0.01	7.90	1.516	0.000	0.489	0.088
	Source Area Total				16.8		0.25	7.90		0.055	0.489	0.088
Total Values (Measured RC-2 + Downstream of RC-2)					3867.7		7.90	7.90		0.000	0.489	0.088
Total Loading Attributed to the East Area							4.56	4.6			4.741	0.478
Measured Value at RC-5			0.03	5%	3658.9	7%	9.48		0.086	0.667		

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Parameter	RC-6 pH = 5.9 Load (kg/D)	% RC-2
Magnesium	440.40	53.9%
Aluminum	18.35*	15.7%
Cadmium	0.02 *	3.6%
Copper	0.86	2.8%
Iron	36.70	9.4%
Zinc	19.57	18.0%

1500-Level Ventilator Portal

Parameter	SP-26 pH = 8.26 Load (kg/D)	% RC-2	Cumulative Load (kg/D)	% RC-2
Magnesium	0.01	0.0%	440.41	53.9%
Aluminum	0.00	0.0%	18.35	15.7%
Cadmium	0.00	0.0%	0.02	3.6%
Copper	0.00	0.0%	0.86	2.8%
Iron	0.00 *	0.0%	36.70	9.4%
Zinc	0.00	0.0%	19.57	18.0%

Parameter	RC-1 pH = 5.45 Load (kg/D)	% RC-2
Magnesium	440.47	53.9%
Aluminum	36.71	31.4%
Cadmium	0.02 *	3.6%
Copper	1.35	4.4%
Iron	36.71	9.4%
Zinc	15.91	14.6%

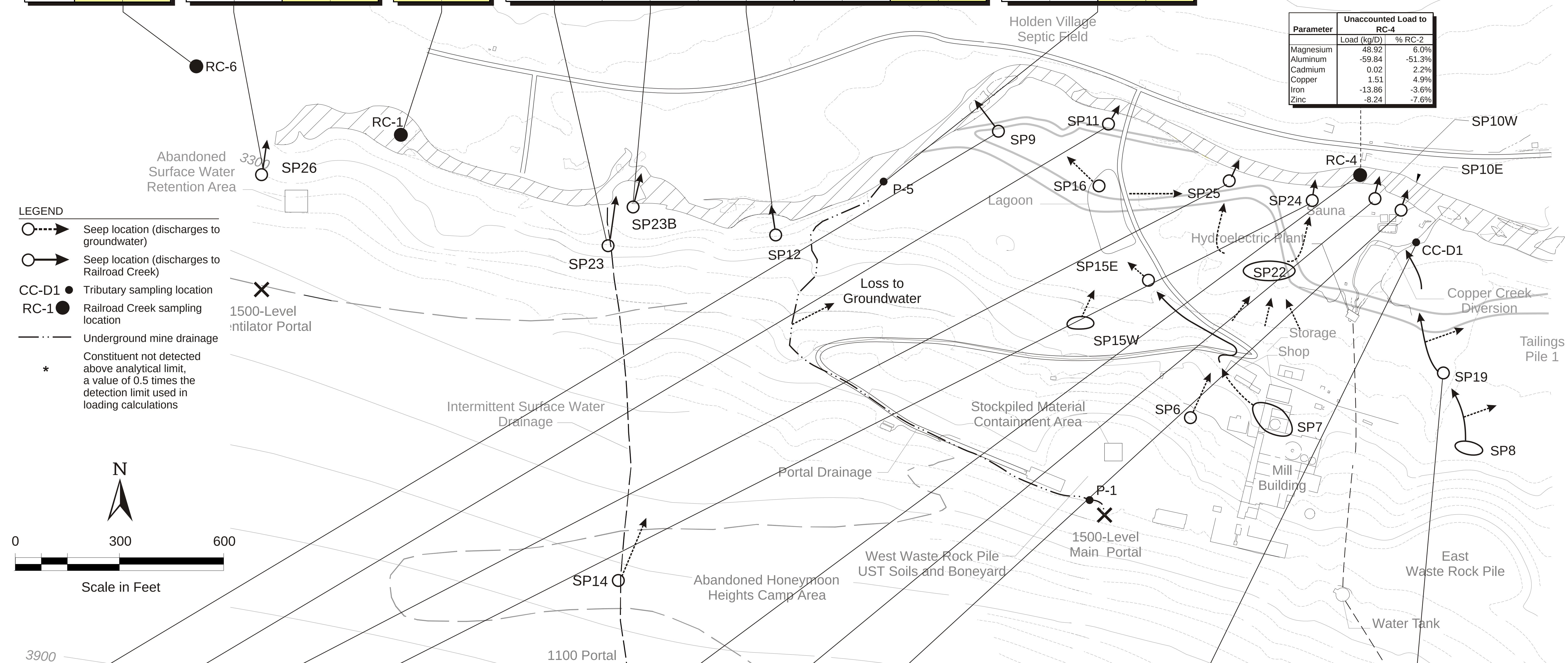
SP-23 / Honeymoon Heights

Parameter	SP-23 pH = 4.2 Load (kg/D)	% RC-2	SP-23B pH = 4.3 Load (kg/D)	% RC-2	SP-12 pH = 5.03 Load (kg/D)	% RC-2	*Source Area Total* Load (kg/D)	% RC-2	Cumulative Load (kg/D)	% RC-2
Magnesium	6.29	0.8%	0.64	0.1%	0.24	0.0%	*7.17*	*0.9%*	447.64	54.8%
Aluminum	9.68	8.3%	0.86	0.7%	0.23	0.2%	*10.76*	*9.2%*	47.47	40.7%
Cadmium	0.05	6.9%	0.01	0.7%	0.00	0.3%	*0.05*	*7.9%*	0.08	11.5%
Copper	8.40	27.5%	0.80	2.6%	0.33	1.1%	*9.53*	*31.1%*	10.88	35.5%
Iron	0.01 *	0.0%	0.00 *	0.0%	0.00 *	0.0%	*0.02*	*0.0%*	36.72	9.4%
Zinc	6.13	5.6%	0.59	0.5%	0.37	0.3%	*7.09*	*6.5%*	22.99	21.1%

Underground Mine

Parameter	P-5 pH = 4.9 Load (kg/D)	% RC-2	Cumulative Load (kg/D)	% RC-2
Magnesium	77.73	9.5%	525.37	64.3%
Aluminum	48.86	41.9%	96.33	82.5%
Cadmium	0.44	63.9%	0.52	75.4%
Copper	19.58	64.0%	30.46	99.5%
Iron	1.59	0.4%	38.31	9.8%
Zinc	73.80	67.7%	96.79	88.9%

Parameter	Unaccounted Load to RC-4 Load (kg/D)	% RC-2
Magnesium	48.92	6.0%
Aluminum	-59.84	-51.3%
Cadmium	0.02	2.2%
Copper	1.51	4.9%
Iron	-13.86	-3.6%
Zinc	-8.24	-7.6%



West Area Seeps (Upstream of RC-4)

Parameter	SP-9 pH = 6.4 Load (kg/D)	% RC-2	SP-11 pH = 5.8 Load (kg/D)	% RC-2	SP-25 pH = 5.5 Load (kg/D)	% RC-2	SP-24 pH = 4.9 Load (kg/D)	% RC-2	*Source Area Total* Load (kg/D)	% RC-2	Cumulative Load (kg/D)	% RC-2
Magnesium	0.09	0.0%	0.13	0.0%	0.04	0.0%	0.51	0.1%	*0.77*	*0.1%*	526.14	64.4%
Aluminum	0.00	0.0%	0.01	0.0%	0.01	0.0%	0.20	0.2%	*0.21*	*0.2%*	96.54	82.7%
Cadmium	0.00	0.0%	0.00	0.1%	0.00	0.0%	0.00	0.6%	*0.01*	*0.7%*	0.52	76.1%
Copper	0.00	0.0%	0.02	0.1%	0.02	0.1%	0.30	1.0%	*0.33*	*1.1%*	30.79	100.6%
Iron	0.00 *	0.0%	0.00 *	0.0%	0.00 *	0.0%	0.02	0.0%	*0.02*	*0.0%*	38.33	9.8%
Zinc	0.01	0.0%	0.10	0.1%	0.05	0.0%	0.62	0.6%	*0.77*	*0.7%*	97.56	89.6%

Parameter	RC-4 pH = 7.1 Load (kg/D)	% RC-2
Magnesium	575.05	70.4%
Aluminum	36.71	31.4%
Cadmium	0.54	78.3%
Copper	32.30	105.5%
Iron	24.47	6.3%
Zinc	89.32	82.0%

West Area Seeps (Downstream of RC-4)

Parameter	SP-10W pH = 4.15 Load (kg/D)	% RC-2	SP-10E pH = 3.3 Load (kg/D)	% RC-2	*Source Area Total* Load (kg/D)	% RC-2	Cumulative Load (kg/D)	% RC-2
Magnesium	0.11	0.0%	0.04	0.0%	*0.14*	*0.0%*	575.20	70.4%
Aluminum	0.13	0.1%	0.27	0.2%	*0.40*	*0.3%*	37.10	31.8%
Cadmium	0.00	0.0%	0.00	0.0%	*0.00*	*0.1%*	0.54	78.5%
Copper	0.06	0.2%	0.02	0.1%	*0.08*	*0.3%*	32.38	105.8%
Iron	0.00	0.0%	0.38	0.1%	*0.39*	*0.1%*	24.86	6.4%
Zinc	0.09	0.1%	0.02	0.0%	*0.11*	*0.1%*	89.42	82.1%

Copper Creek Diversion

Parameter	CCD-1 (Minus SP-19) pH (CCD-1) = 7.1 Load (kg/D)	% RC-2	Cumulative Load (kg/D)	% RC-2
Magnesium	10.54	1.3%	587.02	71.8%
Aluminum	0.00	0.0%	38.47	33.0%
Cadmium	0.02	2.7%	0.57	83.4%
Copper	0.00	0.0%	33.66	109.9%
Iron	3.92	1.0%	28.81	7.4%
Zinc	1.52	1.4%	92.86	85.2%

East Waste Rock Pile

Parameter	SP-19 pH = 4.61 Load (kg/D)	% RC-2	Cumulative Load (kg/D)	% RC-2
Magnesium	0.76	0.1%	575.96	70.5%
Aluminum	1.07	0.9%	38.18	32.7%
Cadmium	0.01	1.7%	0.55	80.1%
Copper	0.97	3.2%	33.35	109.0%
Iron	0.02	0.0%	24.87	6.4%
Zinc	1.43	1.3%	90.85	83.4%

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

Job No. 33750803

Figure A-1

Metals Loading to Railroad Creek from Seeps and Tributaries West Area – Spring 1997

33750803_149.CDR

Measured Values of Loading in Railroad Creek

Parameter	RC-6 pH = 5.9	
	Load (kg/D)	% RC-2
Magnesium	440.40	53.9%
Aluminum	18.35*	15.7%
Cadmium	0.02 *	3.6%
Copper	0.86	2.8%
Iron	36.70	9.4%
Zinc	19.57	18.0%

Parameter	RC-1 pH = 5.45	
	Load (kg/D)	% RC-2
Magnesium	440.47	53.9%
Aluminum	36.71	31.4%
Cadmium	0.02 *	3.6%
Copper	1.35	4.4%
Iron	36.71	9.4%
Zinc	15.91	14.6%

Parameter	RC-4 pH = 7.1	
	Load (kg/D)	% RC-2
Magnesium	575.05	70.1%
Aluminum	36.71	31.4%
Cadmium	0.54	78.3%
Copper	32.30	105.5%
Iron	24.47	6.3%
Zinc	89.32	82.0%

Measured Loading from Surface Water Seeps and Tributaries into Railroad Creek

Parameter	SP-26			
	SP-26 Source Area Total		Cumulative Load to RRC	
	Load (kg/D)	% RC-2	Load (kg/D)	% RC-2
Magnesium	0.01	0.0%	440.41	53.9%
Aluminum	0.00	0.0%	18.35	15.7%
Cadmium	0.00	0.0%	0.02	3.6%
Copper	0.00	0.0%	0.86	2.8%
Iron	0.00 *	0.0%	36.70	9.4%
Zinc	0.00	0.0%	19.57	18.0%

Parameter	SP-23 / Honeymoon Heights			
	SP-23, SP-23B, SP-12 Source Area Total		Cumulative Load to RRC	
	Load (kg/D)	% RC-2	Load (kg/D)	% RC-2
Magnesium	7.17	0.9%	447.64	54.8%
Aluminum	10.76	9.2%	47.47	40.7%
Cadmium	0.05	7.9%	0.08	11.5%
Copper	9.53	31.1%	10.88	35.5%
Iron	0.02 *	0.0%	36.72	9.4%
Zinc	7.09	6.5%	22.99	21.1%

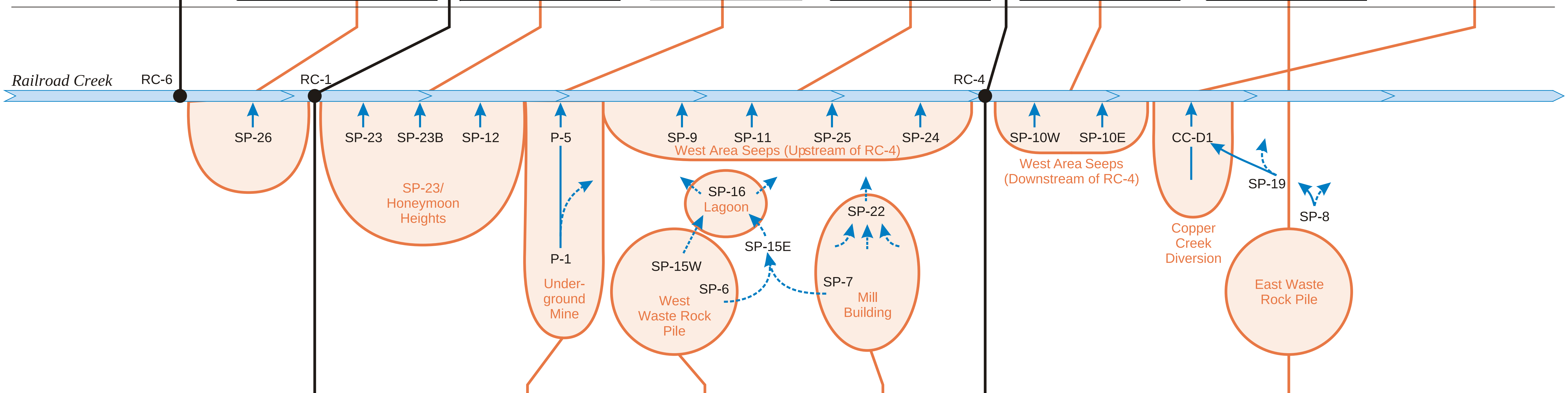
Parameter	Underground Mine			
	P-5 Source Area Total		Cumulative Load to RRC	
	Load (kg/D)	% RC-2	Load (kg/D)	% RC-2
Magnesium	77.73	9.5%	525.37	64.3%
Aluminum	48.86	41.9%	96.33	82.5%
Cadmium	0.44	63.9%	0.52	75.4%
Copper	19.58	64.0%	30.46	99.5%
Iron	1.59	0.4%	38.31	9.8%
Zinc	73.80	67.7%	96.79	88.9%

Parameter	West Area Seeps (Upstream of RC-4)			
	SP-9, SP-11, SP-25, SP-24 Source Area Total		Cumulative Load to RRC	
	Load (kg/D)	% RC-2	Load (kg/D)	% RC-2
Magnesium	0.77	0.1%	526.14	64.4%
Aluminum	0.21	0.2%	96.54	82.7%
Cadmium	0.01	0.7%	0.52	76.1%
Copper	0.33	1.1%	30.79	100.6%
Iron	0.02 *	0.0%	38.33	9.8%
Zinc	0.77	0.7%	97.56	89.6%

Parameter	West Area Seeps (Downstream of RC-4)			
	SP-10W, SP-10E Source Area Total		Cumulative Load to RRC	
	Load (kg/D)	% RC-2	Load (kg/D)	% RC-2
Magnesium	0.14	0.0%	575.20	70.4%
Aluminum	0.40	0.3%	37.10	31.8%
Cadmium	0.00	0.1%	0.54	78.5%
Copper	0.08	0.3%	32.38	105.8%
Iron	0.39	0.1%	24.86	6.4%
Zinc	0.11	0.1%	89.42	82.1%

Parameter	East Waste Rock Pile			
	SP-19 Source Area Total		Cumulative Load to RRC	
	Load (kg/D)	% RC-2	Load (kg/D)	% RC-2
Magnesium	0.76	0.1%	575.96	70.5%
Aluminum	1.07	0.9%	38.18	32.7%
Cadmium	0.01	1.7%	0.55	80.1%
Copper	0.97	3.2%	33.35	109.0%
Iron	0.02	0.0%	24.87	6.4%
Zinc	1.43	1.3%	90.85	83.4%

Parameter	Copper Creek Diversion			
	CCD-1 (minus SP-19) Source Area Total		Cumulative Load to RRC	
	Load (kg/D)	% RC-2	Load (kg/D)	% RC-2
Magnesium	10.54	1.3%	587.02	71.8%
Aluminum	0.00	0.0%	38.47	33.0%
Cadmium	0.02	2.7%	0.57	83.4%
Copper	0.00	0.0%	33.66	109.9%
Iron	3.92	1.0%	28.81	7.4%
Zinc	1.52	1.4%	92.86	85.2%



Loading to Groundwater

Parameter	Underground Mine			
	Loss P-1 to P-5 Source Area Total		Cumulative Load to GW	
	Load (kg/D)	% RC-2	Load (kg/D)	% RC-2
Magnesium	8.55	1.0%	8.55	1.0%
Aluminum	8.14	7.0%	8.14	7.0%
Cadmium	0.06	8.3%	0.06	8.3%
Copper	3.47	11.3%	3.47	11.3%
Iron	0.18	0.0%	0.18	0.0%
Zinc	10.14	9.3%	10.14	9.3%

Parameter	West Waste Rock Pile			
	SP-6, SP-15W Source Area Total		Cumulative Load to GW	
	Load (kg/D)	% RC-2	Load (kg/D)	% RC-2
Magnesium	1.04	0.1%	9.59	1.2%
Aluminum	0.56	0.5%	8.70	7.5%
Cadmium	0.01	1.2%	0.07	9.5%
Copper	0.52	1.7%	3.99	13.0%
Iron	0.00 *	0.0%	0.19	0.1%
Zinc	1.25	1.1%	11.40	10.5%

Parameter	Mill Building			
	SP-7, SP-22 Source Area Total		Cumulative Load to GW	
	Load (kg/D)	% RC-2	Load (kg/D)	% RC-2
Magnesium	2.33	0.3%	11.92	1.5%
Aluminum	0.09	0.1%	8.79	7.5%
Cadmium	0.02	2.5%	0.08	11.9%
Copper	1.21	4.0%	5.20	17.0%
Iron	0.05 *	0.0%	0.23	0.1%
Zinc	2.20	2.0%	13.59	12.5%

Parameter	East Waste Rock Pile			
	Loss SP-8 to SP-19 Source Area Total		Cumulative Load to GW	
	Load (kg/D)	% RC-2	Load (kg/D)	% RC-2
Magnesium	-0.50	NA	11.92	1.5%
Aluminum	-0.60	NA	8.79	7.5%
Cadmium	-0.01	NA	0.08	11.9%
Copper	-0.58	NA	5.20	17.0%
Iron	-0.01	NA	0.23	0.1%
Zinc	-0.88	NA	13.59	12.5%

Unaccounted (Groundwater) Loading to Railroad Creek

Parameter	Unaccounted Load to RC-1	
	Load (kg/D)	% RC-2
Magnesium	0.06	0.0%
Aluminum	18.35	15.7%
Cadmium	0.00	0.0%
Copper	0.49	1.6%
Iron	0.01	0.0%
Zinc	-3.67	-3.4%

Parameter	Unaccounted Load to RC-4	
	Load (kg/D)	% RC-2
Magnesium	48.92	6.0%
Aluminum	-59.84	-51.3%
Cadmium	0.02	2.2%
Copper	1.51	4.9%
Iron	-13.86	-3.6%
Zinc	-8.24	-7.6%

LEGEND

- Source area
- SP-26 Surface seep/tributary
- RC-1 ● Railroad creek sampling station
- Surface water loading into Railroad Creek
- Loading into groundwater
- * Constituent not detected above analytical limit, a value of 0.5 times the detection limit used in loading calculations

N

Not to Scale

Job No. 33750803

Figure A-2

Metals Loading Schematic by Source Area to Railroad Creek and Groundwater West Area – Spring 1997

URS

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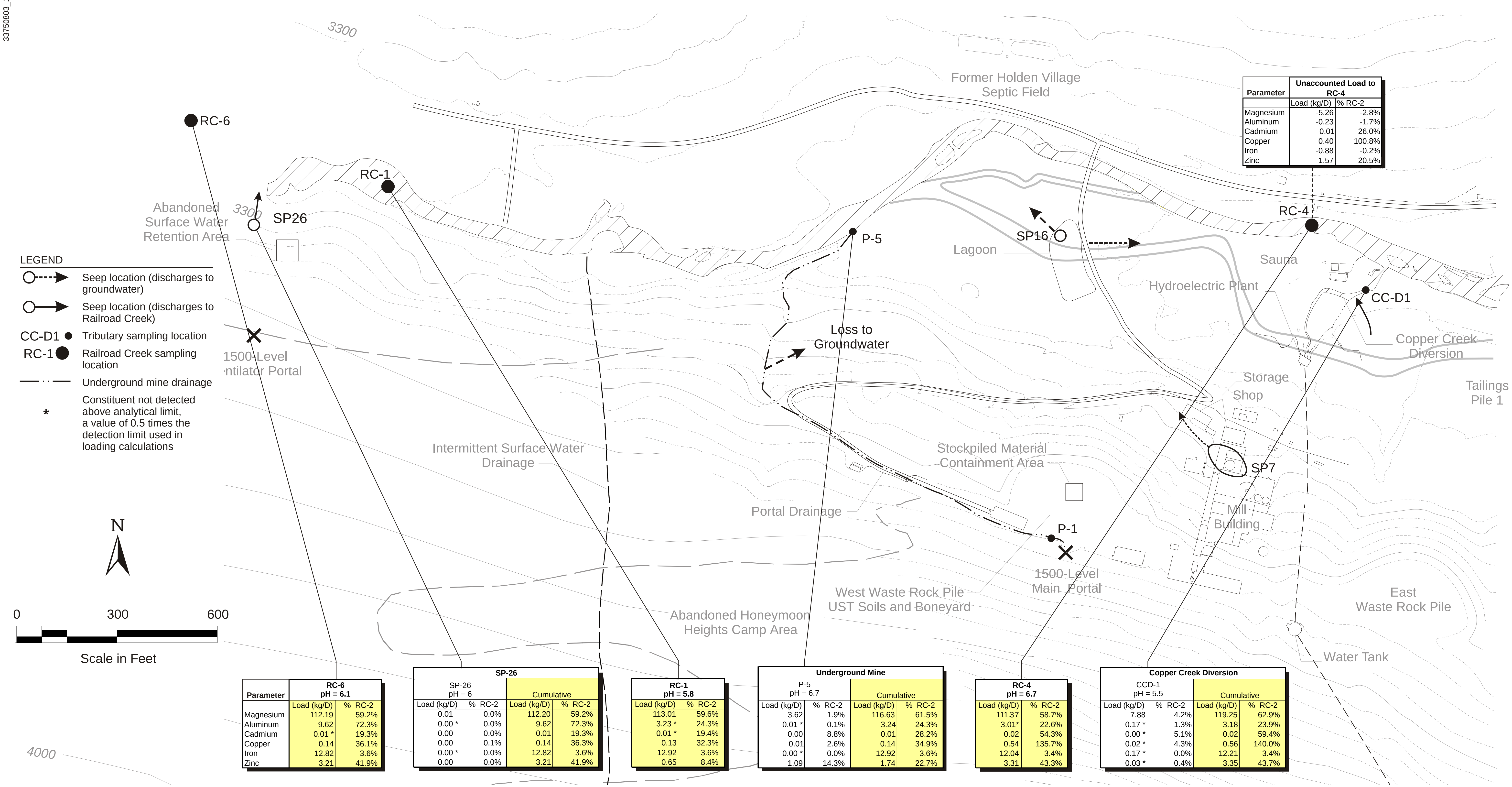

Parameter	Unaccounted Load to RC-4	
	Load (kg/D)	% RC-2
Magnesium	-5.26	-2.8%
Aluminum	-0.23	-1.7%
Cadmium	0.01	26.0%
Copper	0.40	100.8%
Iron	-0.88	-0.2%
Zinc	1.57	20.5%

Parameter	RC-6 pH = 6.1	
	Load (kg/D)	% RC-2
Magnesium	112.19	59.2%
Aluminum	9.62	72.3%
Cadmium	0.01 *	19.3%
Copper	0.14	36.1%
Iron	12.82	3.6%
Zinc	3.21	41.9%

SP-26			
SP-26 pH = 6		Cumulative	
Load (kg/D)	% RC-2	Load (kg/D)	% RC-2
0.01	0.0%	112.20	59.2%
0.00 *	0.0%	9.62	72.3%
0.00	0.0%	0.01	19.3%
0.00	0.1%	0.14	36.3%
0.00 *	0.0%	12.82	3.6%
0.00	0.0%	3.21	41.9%

RC-1 pH = 5.8	
Load (kg/D)	% RC-2
113.01	59.6%
3.23 *	24.3%
0.01 *	19.4%
0.13	32.3%
12.92	3.6%
0.65	8.4%

Underground Mine			
P-5 pH = 6.7		Cumulative	
Load (kg/D)	% RC-2	Load (kg/D)	% RC-2
3.62	1.9%	116.63	61.5%
0.01 *	0.1%	3.24	24.3%
0.00	8.8%	0.01	28.2%
0.01	2.6%	0.14	34.9%
0.00 *	0.0%	12.92	3.6%
1.09	14.3%	1.74	22.7%

RC-4 pH = 6.7	
Load (kg/D)	% RC-2
111.37	58.7%
3.01*	22.6%
0.02	54.3%
0.54	135.7%
12.04	3.4%
3.31	43.3%

Copper Creek Diversion			
CCD-1 pH = 5.5		Cumulative	
Load (kg/D)	% RC-2	Load (kg/D)	% RC-2
7.88	4.2%	119.25	62.9%
0.17 *	1.3%	3.18	23.9%
0.00 *	5.1%	0.02	59.4%
0.02 *	4.3%	0.56	140.0%
0.17 *	0.0%	12.21	3.4%
0.03 *	0.4%	3.35	43.7%

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

Job No. 33750803

Figure A-3

Metals Loading to Railroad Creek from Seeps and Tributaries West Area – Fall 1997

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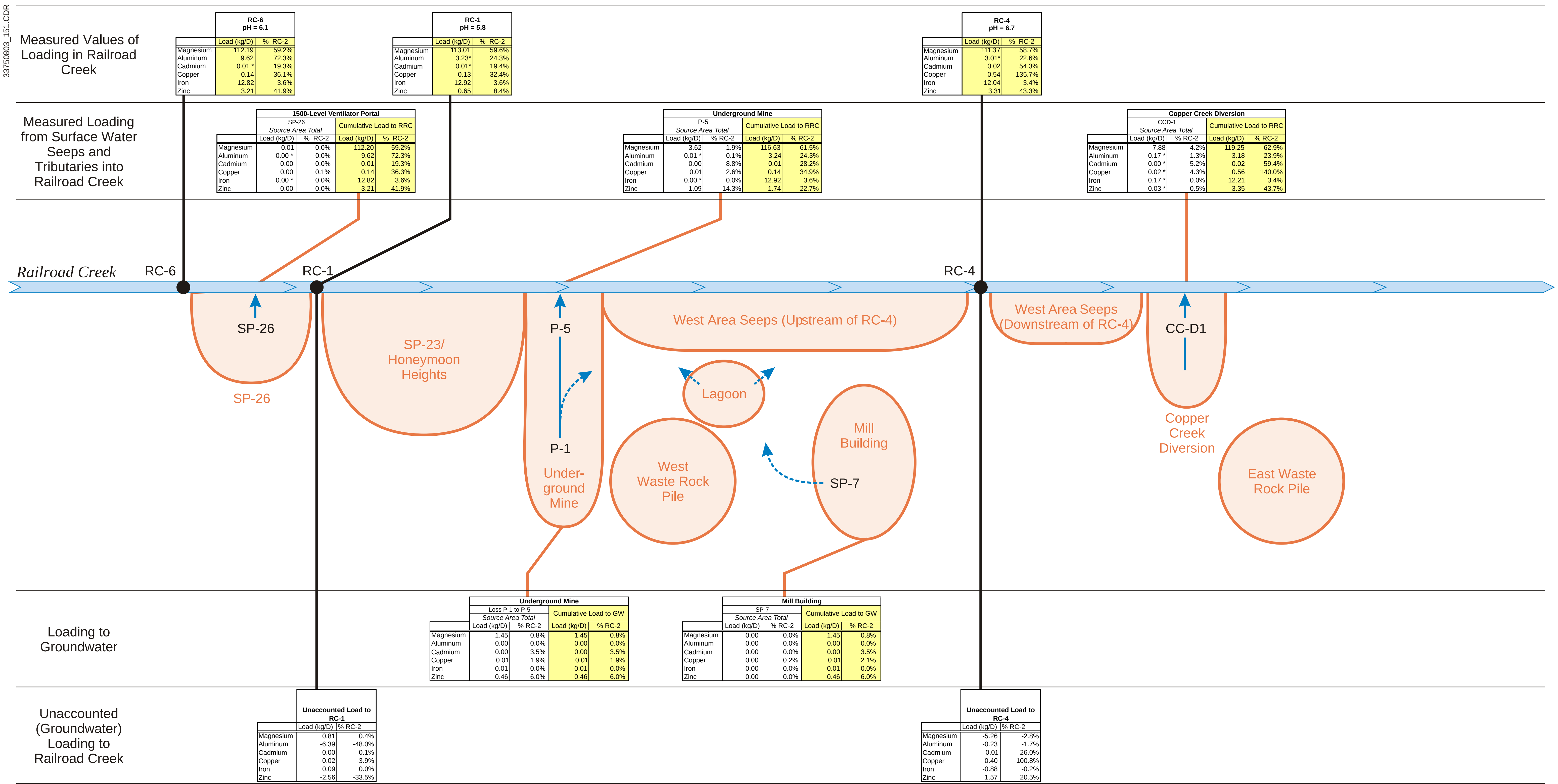
Holden Mine RI/FS
Draft Final FS Report
February 2004



RC-6 pH = 6.1

	Load (kg/D)	% RC-2
Magnesium	112.19	59.2%
Aluminum	9.62	72.3%
Cadmium	0.01 *	19.3%
Copper	0.14	36.1%
Iron	12.82	3.6%
Zinc	3.21	41.9%

RC-1 pH = 5.8

	Load (kg/D)	% RC-2
Magnesium	113.01	59.6%
Aluminum	3.23*	24.3%
Cadmium	0.01*	19.4%
Copper	0.13	32.4%
Iron	12.92	3.6%
Zinc	0.65	8.4%

RC-4 pH = 6.7

	Load (kg/D)	% RC-2
Magnesium	111.37	58.7%
Aluminum	3.01*	22.6%
Cadmium	0.02	54.3%
Copper	0.54	135.7%
Iron	12.04	3.4%
Zinc	3.31	43.3%

1500-Level Ventilator Portal

	SP-26 Source Area Total		Cumulative Load to RRC	
	Load (kg/D)	% RC-2	Load (kg/D)	% RC-2
Magnesium	0.01	0.0%	112.20	59.2%
Aluminum	0.00 *	0.0%	9.62	72.3%
Cadmium	0.00	0.0%	0.01	19.3%
Copper	0.00	0.1%	0.14	36.3%
Iron	0.00 *	0.0%	12.82	3.6%
Zinc	0.00	0.0%	3.21	41.9%

Underground Mine

	P-5 Source Area Total		Cumulative Load to RRC	
	Load (kg/D)	% RC-2	Load (kg/D)	% RC-2
Magnesium	3.62	1.9%	116.63	61.5%
Aluminum	0.01 *	0.1%	3.24	24.3%
Cadmium	0.00	8.8%	0.01	28.2%
Copper	0.01	2.6%	0.14	34.9%
Iron	0.00 *	0.0%	12.92	3.6%
Zinc	1.09	14.3%	1.74	22.7%

Copper Creek Diversion

	CCD-1 Source Area Total		Cumulative Load to RRC	
	Load (kg/D)	% RC-2	Load (kg/D)	% RC-2
Magnesium	7.88	4.2%	119.25	62.9%
Aluminum	0.17 *	1.3%	3.18	23.9%
Cadmium	0.00 *	5.2%	0.02	59.4%
Copper	0.02 *	4.3%	0.56	140.0%
Iron	0.17 *	0.0%	12.21	3.4%
Zinc	0.03 *	0.5%	3.35	43.7%

Underground Mine

	Loss P-1 to P-5 Source Area Total		Cumulative Load to GW	
	Load (kg/D)	% RC-2	Load (kg/D)	% RC-2
Magnesium	1.45	0.8%	1.45	0.8%
Aluminum	0.00	0.0%	0.00	0.0%
Cadmium	0.00	3.5%	0.00	3.5%
Copper	0.01	1.9%	0.01	1.9%
Iron	0.01	0.0%	0.01	0.0%
Zinc	0.46	6.0%	0.46	6.0%

Mill Building

	SP-7 Source Area Total		Cumulative Load to GW	
	Load (kg/D)	% RC-2	Load (kg/D)	% RC-2
Magnesium	0.00	0.0%	1.45	0.8%
Aluminum	0.00	0.0%	0.00	0.0%
Cadmium	0.00	0.0%	0.00	3.5%
Copper	0.00	0.2%	0.01	2.1%
Iron	0.00	0.0%	0.01	0.0%
Zinc	0.00	0.0%	0.46	6.0%

Unaccounted Load to RC-1

	Load (kg/D)	% RC-2
Magnesium	0.81	0.4%
Aluminum	-6.39	-48.0%
Cadmium	0.00	0.1%
Copper	-0.02	-3.9%
Iron	0.09	0.0%
Zinc	-2.56	-33.5%

Unaccounted Load to RC-4

	Load (kg/D)	% RC-2
Magnesium	-5.26	-2.8%
Aluminum	-0.23	-1.7%
Cadmium	0.01	26.0%
Copper	0.40	100.8%
Iron	-0.88	-0.2%
Zinc	1.57	20.5%

LEGEND

- Source area
- SP-26 Surface seep/tributary
- RC-1 ● Railroad creek sampling station
- Surface water loading into Railroad Creek
- Loading into groundwater
- * Constituent not detected above analytical limit, a value of 0.5 times the detection limit used in loading calculations

N

Not to Scale

Job No. 33750803

Figure A-4

Metals Loading Schematic by Source Area to Railroad Creek and Groundwater West Area – Fall 1997

URS

Measured Values of Loading in Railroad Creek

Parameter	Measured Loading at RC-7 (for comparison only) pH = 7.1	
	Load (kg/D)	% RC-2
Magnesium	757.90	92.8%
Aluminum	77.07	66.0%
Cadmium	0.75	108.4%
Copper	29.55	96.5%
Iron	616.60	158.5%
Zinc	109.19	100.2%

Parameter	Measured Loading at RC-2 pH = 6.7	
	Load (kg/D)	% RC-2
Magnesium	817.00	100.0%
Aluminum	116.71	100.0%
Cadmium	0.69	100.0%
Copper	30.61	100.0%
Iron	389.05	100.0%
Zinc	108.93	100.0%

Parameter	Measured Loading at RC-5 pH = 7	
	Load (kg/D)	% RC-2
Magnesium	872.08	106.7%
Aluminum	91.11	78.1%
Cadmium	0.65	94.7%
Copper	27.98	91.4%
Iron	455.57	117.1%
Zinc	109.34	100.4%

Estimated Loading from Groundwater and Tributaries into Railroad Creek

Parameter	Total Loading from West Area	
	Load (kg/D)	% RC-2
Magnesium	586.98	71.8%
Aluminum	38.47	33.0%
Cadmium	0.57	83.4%
Copper	33.64	109.9%
Iron	28.81	7.4%
Zinc	92.81	85.2%

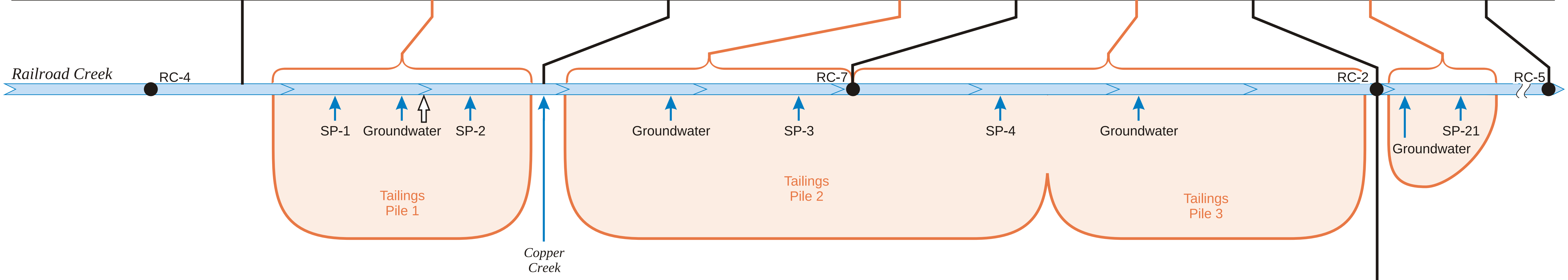
Parameter	Loading from Seeps and Groundwater Tailings Pile 1			
	Source Area Total		Cumulative Load to RRC	
	Load (kg/D)	% RC-2	Load (kg/D)	% RC-2
Magnesium	80.66	9.9%	667.64	81.7%
Aluminum	75.69	64.9%	114.17	97.8%
Cadmium	0.03 *	3.8%	0.60	87.2%
Copper	0.46 *	1.5%	34.10	111.4%
Iron	422.36	108.6%	451.17	116.0%
Zinc	9.14	8.4%	101.95	93.6%

Parameter	Loading from Copper Creek			
	Source Area Total		Cumulative Load to RRC	
	Load (kg/D)	% RC-2	Load (kg/D)	% RC-2
Magnesium	19.82	2.4%	687.46	84.1%
Aluminum	0.37 *	0.3%	114.53	98.1%
Cadmium	0.00 *	0.1%	0.60	87.3%
Copper	0.04 *	0.1%	34.14	111.5%
Iron	1.47	0.4%	452.64	116.3%
Zinc	0.48	0.4%	102.43	94.0 %

Parameter	Loading from Seeps and Groundwater Tailings Pile 2 Upstream of RC-7			
	Source Area Total		Cumulative Load to RRC	
	Load (kg/D)	% RC-2	Load (kg/D)	% RC-2
Magnesium	34.39	4.2%	721.85	88.4%
Aluminum	17.36 *	14.9%	131.89	113.0%
Cadmium	0.02 *	3.2%	0.62	90.5%
Copper	0.66 *	2.2%	34.80	113.7%
Iron	80.06	20.6%	532.70	136.9%
Zinc	2.21 *	2.0%	104.63	96.1%

Parameter	Loading from Seeps and Groundwater Tailings Piles 2 & 3 Downstream of RC-7			
	Source Area Total		Cumulative Load to RRC	
	Load (kg/D)	% RC-2	Load (kg/D)	% RC-2
Magnesium	68.45	8.4%	790.30	96.7%
Aluminum	24.77 *	21.2%	156.66	134.2%
Cadmium	0.01 *	1.6%	0.63	92.1%
Copper	0.88 *	2.9%	35.68	116.6%
Iron	119.37 *	30.7%	652.07	167.6%
Zinc	1.25	1.2%	105.89	97.2%

Parameter	Loading Downstream of RC-2			
	Source Area Total		Cumulative Load to RRC	
	Load (kg/D)	% RC-2	Load (kg/D)	% RC-2
Magnesium	18.32	2.2%	835.32	102.22%
Aluminum	7.19	6.2%	123.91	106.2%
Cadmium	0.00	0.0%	0.69	100.0%
Copper	0.25	0.8%	30.85	100.8%
Iron	4.80	1.2%	393.84	101.2%
Zinc	0.52	0.5%	109.46	100.5%



Unaccounted (Groundwater) Loading to Railroad Creek

Parameter	Unaccounted Load to RC-2	
	Load (kg/D)	% RC-2
Magnesium	26.70	3.3%
Aluminum	-39.95	-34.2%
Cadmium	0.05	7.9%
Copper	-5.07	-16.6%
Iron	-263.02	-67.6%
Zinc	3.04	0.4%

LEGEND

- Source area
- SP-1 Surface seep
- RC-1 ● Railroad creek sampling station
- Seep/groundwater loading from tailings and native material into Railroad Creek
- * Constituent not detected above analytical limit in one or more sample(s), a value of 0.5 times the reporting limit used in loading calculations
- Groundwater loading from “Old Railroad Creek” channel

N

Not to Scale

Figure A-5

Metals Loading Schematic by Source Area to Railroad Creek East Area – Spring 1997

Job No. 33750803

URS

33750803_155.CDR

Measured Values of Loading in Railroad Creek

Parameter	Measured Loading at RC-7 (for comparison only) pH = 7	
	Load (kg/D)	% RC-2
Magnesium	189.30	99.8%
Aluminum	14.29	107.4%
Cadmium	0.03	96.6%
Copper	0.46	116.3%
Iron	410.75	114.3%
Zinc	6.79	88.7%

Parameter	Measured Loading at RC-2 pH = 5.7	
	Load (kg/D)	% RC-2
Magnesium	189.65	100.0%
Aluminum	13.31	100.0%
Cadmium	0.03	100.0%
Copper	0.40	100.0%
Iron	359.34	100.0%
Zinc	7.65	100.0%

Parameter	Measured Loading at RC-5 pH = 7.1	
	Load (kg/D)	% RC-2
Magnesium	214.97	113.4%
Aluminum	15.81	118.8%
Cadmium	0.04	114.0%
Copper	0.51	126.7%
Iron	395.17	110.0%
Zinc	9.48	123.9%

Estimated Loading from Groundwater and Tributaries into Railroad Creek

Parameter	Total Loading from West Area	
	Load (kg/D)	% RC-2
Magnesium	119.25	62.9%
Aluminum	3.18	23.9%
Cadmium	0.02	59.4%
Copper	0.56	140.0%
Iron	12.21	3.4%
Zinc	3.35	43.7%

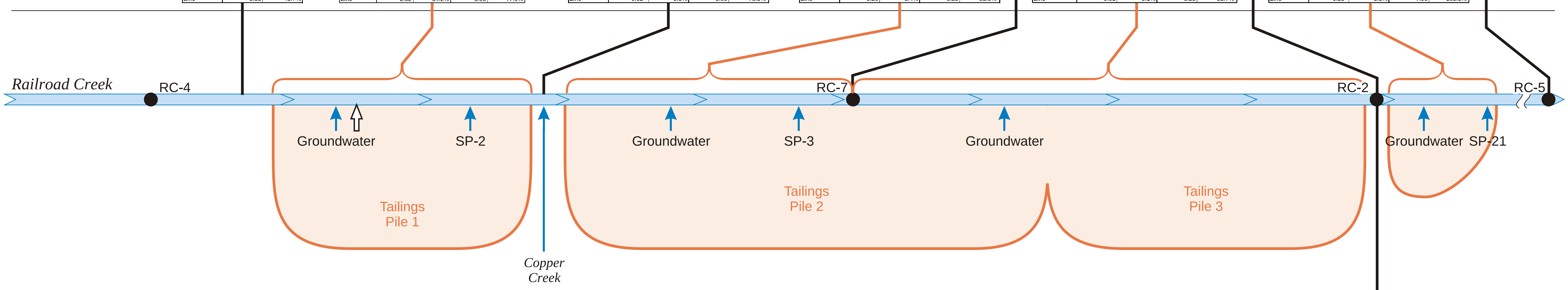
Parameter	Loading from Seeps and Groundwater Tailings Pile 1			
	Source Area Total		Cumulative Load to RRC	
	Load (kg/D)	% RC-2	Load (kg/D)	% RC-2
Magnesium	38.14	20.1%	157.39	83.0%
Aluminum	15.78	118.6%	18.96	142.5%
Cadmium	0.01 *	22.2%	0.03	81.6%
Copper	0.33 *	82.1%	0.89	222.1%
Iron	359.31	100.0%	371.52	103.4%
Zinc	2.62	34.2%	5.96	77.9%

Parameter	Loading from Copper Creek			
	Source Area Total		Cumulative Load to RRC	
	Load (kg/D)	% RC-2	Load (kg/D)	% RC-2
Magnesium	5.63	3.0%	163.02	86.0%
Aluminum	0.12 *	0.9%	19.09	143.4%
Cadmium	0.00 *	0.7%	0.03	82.3%
Copper	0.00	0.9%	0.89	223.0%
Iron	0.12 *	0.0%	371.64	103.4%
Zinc	0.02 *	0.3%	5.99	78.3%

Parameter	Loading from Seeps and Groundwater Tailings Pile 2 Upstream of RC-7			
	Source Area Total		Cumulative Load to RRC	
	Load (kg/D)	% RC-2	Load (kg/D)	% RC-2
Magnesium	18.26	9.6%	181.27	95.6%
Aluminum	0.78	5.8%	19.86	149.3%
Cadmium	0.00 *	5.7%	0.03	88.1%
Copper	0.02 *	4.5%	0.91	227.5%
Iron	34.63	9.6%	406.27	113.1%
Zinc	0.26	3.4%	6.25	81.6%

Parameter	Loading from Seeps and Gorundwater Tailings Piles 2 & 3 Downstream of RC-7			
	Source Area Total		Cumulative Load to RRC	
	Load (kg/D)	% RC-2	Load (kg/D)	% RC-2
Magnesium	12.02	6.3%	193.29	101.9%
Aluminum	0.14 *	1.0%	20.00	150.3%
Cadmium	0.00 *	0.0%	0.03	88.1%
Copper	0.00 *	0.7%	0.91	228.2%
Iron	14.05	3.9%	420.32	117.0%
Zinc	0.01	0.1%	6.25	81.7%

Parameter	Loading Downstream of RC-2			
	Source Area Total		Cumulative Load to RRC	
	Load (kg/D)	% RC-2	Load (kg/D)	% RC-2
Magnesium	22.39	11.8%	212.04	111.8%
Aluminum	4.31	32.4%	17.62	132.4%
Cadmium	0.00	8.7%	0.04	108.7%
Copper	0.06	15.4%	0.46	115.4%
Iron	52.10 *	14.5%	411.43	114.5%
Zinc	0.25	3.3%	7.90	103.3%



Unaccounted (Groundwater) Loading to Railroad Creek

Parameter	Unaccounted Load to RC-2	
	Load (kg/D)	% RC-2
Magnesium	-3.64	-1.9%
Aluminum	-6.69	-50.3%
Cadmium	0.00	11.9%
Copper	-0.51	-128.2%
Iron	-60.98	-17.0%
Zinc	1.40	18.3%

LEGEND

- Source area (orange line)
- SP-1 Surface seep
- RC-1 ● Railroad creek sampling station
- Seep/groundwater loading from tailings and native material into Railroad Creek (blue arrow)
- * Constituent not detected above analytical limit in one or more sample(s), a value of 0.5 times the reporting limit used in loading calculations
- Groundwater loading from "Old Railroad Creek" channel (open arrow)

N

Not to Scale

Job No. 33750803

Figure A-6

Metals Loading Schematic by Source Area to Railroad Creek East Area – Fall 1997

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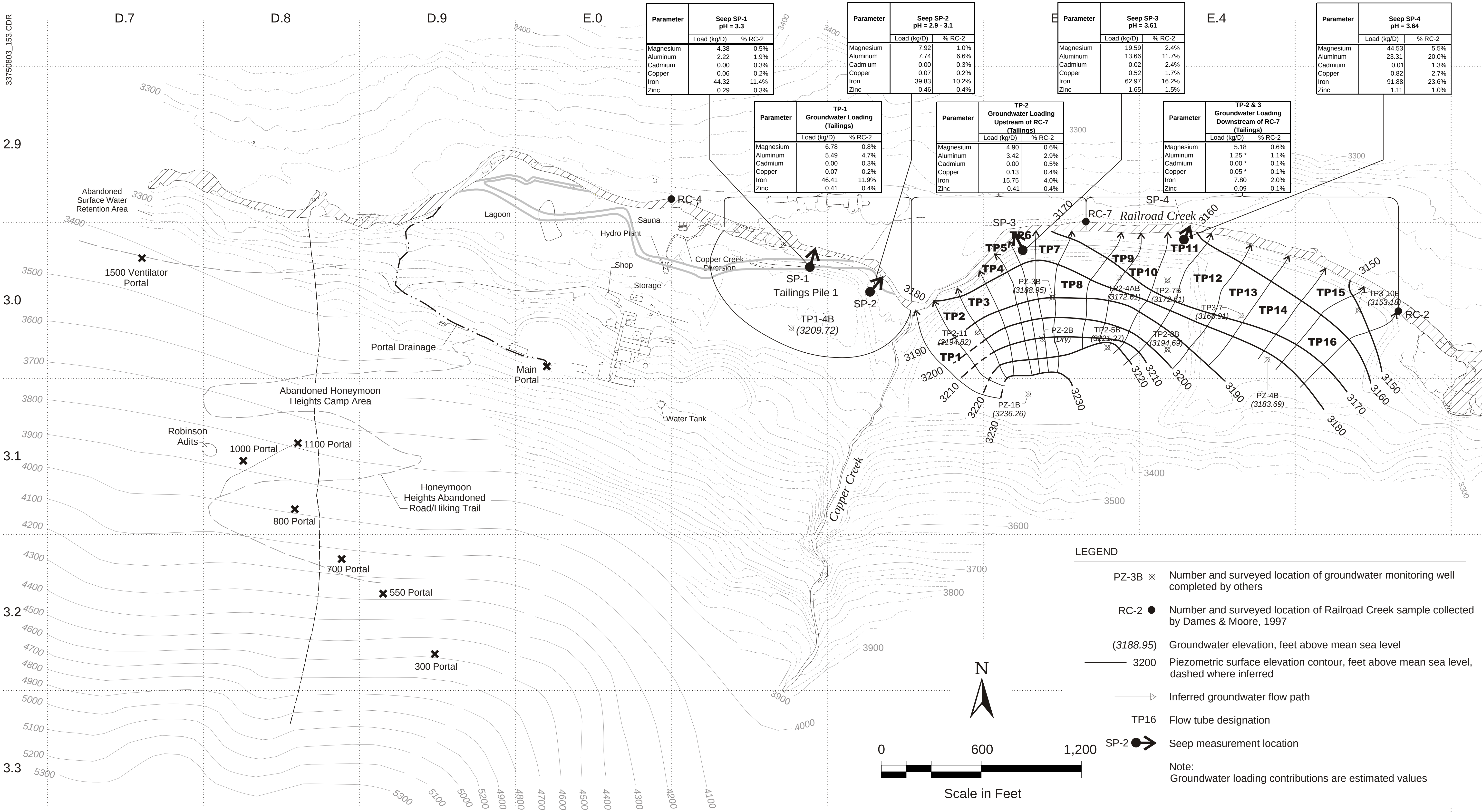
Holden Mine RI/FS
Draft Final FS Report
February 2004



Parameter	Seep SP-1 pH = 3.3	
	Load (kg/D)	% RC-2
Magnesium	4.38	0.5%
Aluminum	2.22	1.9%
Cadmium	0.00	0.3%
Copper	0.06	0.2%
Iron	44.32	11.4%
Zinc	0.29	0.3%

Parameter	Seep SP-2 pH = 2.9 - 3.1	
	Load (kg/D)	% RC-2
Magnesium	7.92	1.0%
Aluminum	7.74	6.6%
Cadmium	0.00	0.3%
Copper	0.07	0.2%
Iron	39.83	10.2%
Zinc	0.46	0.4%

Parameter	Seep SP-3 pH = 3.61	
	Load (kg/D)	% RC-2
Magnesium	19.59	2.4%
Aluminum	13.66	11.7%
Cadmium	0.02	2.4%
Copper	0.52	1.7%
Iron	62.97	16.2%
Zinc	1.65	1.5%

Parameter	Seep SP-4 pH = 3.64	
	Load (kg/D)	% RC-2
Magnesium	44.53	5.5%
Aluminum	23.31	20.0%
Cadmium	0.01	1.3%
Copper	0.82	2.7%
Iron	91.88	23.6%
Zinc	1.11	1.0%

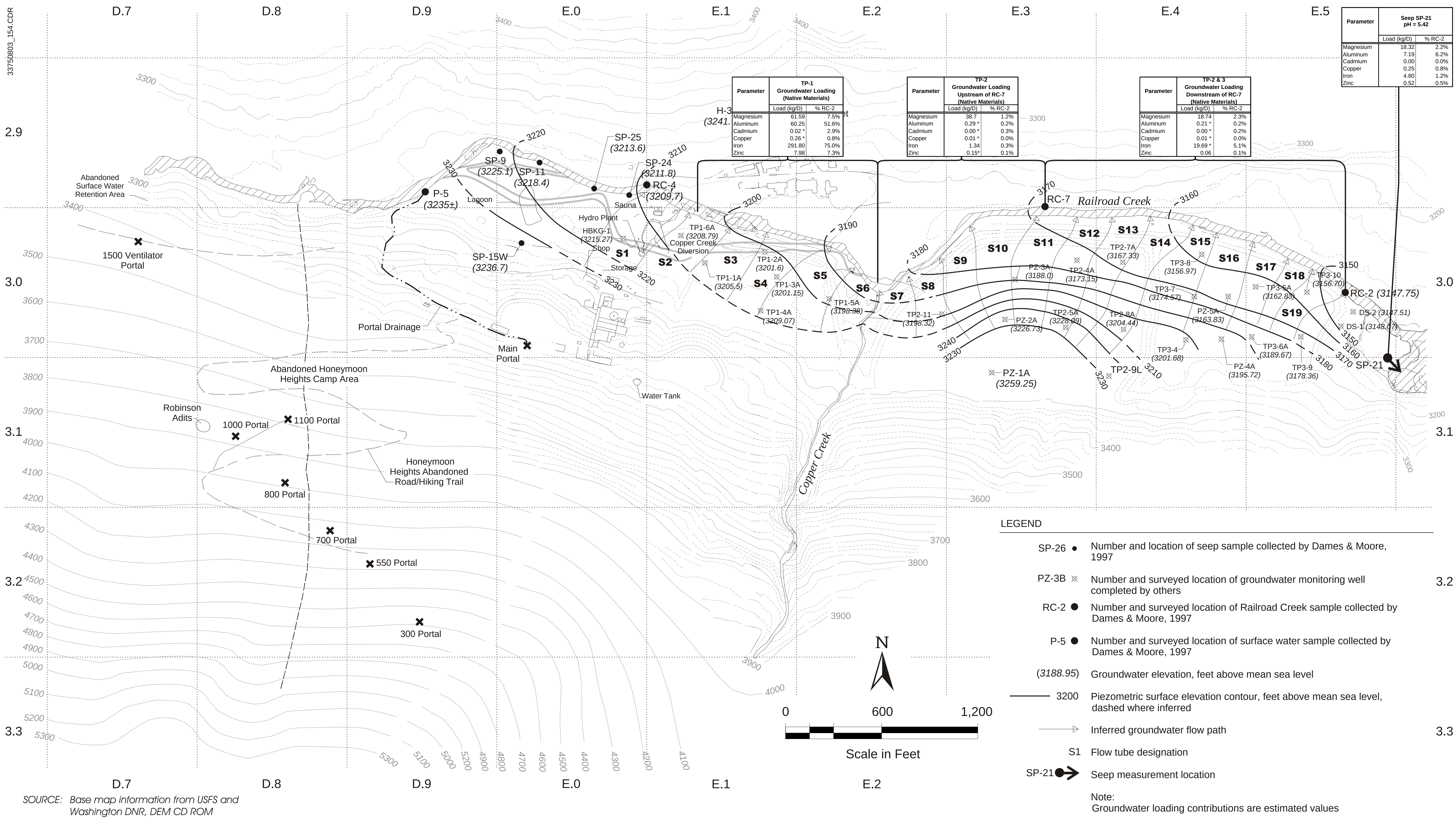
Parameter	TP-1 Groundwater Loading (Tailings)	
	Load (kg/D)	% RC-2
Magnesium	6.78	0.8%
Aluminum	5.49	4.7%
Cadmium	0.00	0.3%
Copper	0.07	0.2%
Iron	46.41	11.9%
Zinc	0.41	0.4%

Parameter	TP-2 Groundwater Loading Upstream of RC-7 (Tailings)	
	Load (kg/D)	% RC-2
Magnesium	4.90	0.6%
Aluminum	3.42	2.9%
Cadmium	0.00	0.5%
Copper	0.13	0.4%
Iron	15.75	4.0%
Zinc	0.41	0.4%

Parameter	TP-2 & 3 Groundwater Loading Downstream of RC-7 (Tailings)	
	Load (kg/D)	% RC-2
Magnesium	5.18	0.6%
Aluminum	1.25 *	1.1%
Cadmium	0.00 *	0.1%
Copper	0.05 *	0.1%
Iron	7.80	2.0%
Zinc	0.09	0.1%

Figure A-7

Seep and Groundwater Loading from Tailings – May 1997



Parameter	TP-1 Groundwater Loading (Native Materials)	
	Load (kg/D)	% RC-2
Magnesium	61.59	7.5%
Aluminum	60.25	51.6%
Cadmium	0.02 *	2.9%
Copper	0.26 *	0.8%
Iron	291.80	75.0%
Zinc	7.98	7.3%

Parameter	TP-2 Groundwater Loading Upstream of RC-7 (Native Materials)	
	Load (kg/D)	% RC-2
Magnesium	38.7	1.2%
Aluminum	0.29 *	0.2%
Cadmium	0.00 *	0.3%
Copper	0.01 *	0.0%
Iron	1.34	0.3%
Zinc	0.15*	0.1%

Parameter	TP-2 & 3 Groundwater Loading Downstream of RC-7 (Native Materials)	
	Load (kg/D)	% RC-2
Magnesium	18.74	2.3%
Aluminum	0.21 *	0.2%
Cadmium	0.00 *	0.2%
Copper	0.01 *	0.0%
Iron	19.69 *	5.1%
Zinc	0.06	0.1%

Parameter	Seep SP-21 pH = 5.42	
	Load (kg/D)	% RC-2
Magnesium	18.32	2.2%
Aluminum	7.19	6.2%
Cadmium	0.00	0.0%
Copper	0.25	0.8%
Iron	4.80	1.2%
Zinc	0.52	0.5%

LEGEND

SP-26 ●	Number and location of seep sample collected by Dames & Moore, 1997
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
P-5 ●	Number and surveyed location of surface water 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
S1	Flow tube designation
SP-21	Seep measurement location

Note:
Groundwater loading contributions are estimated values

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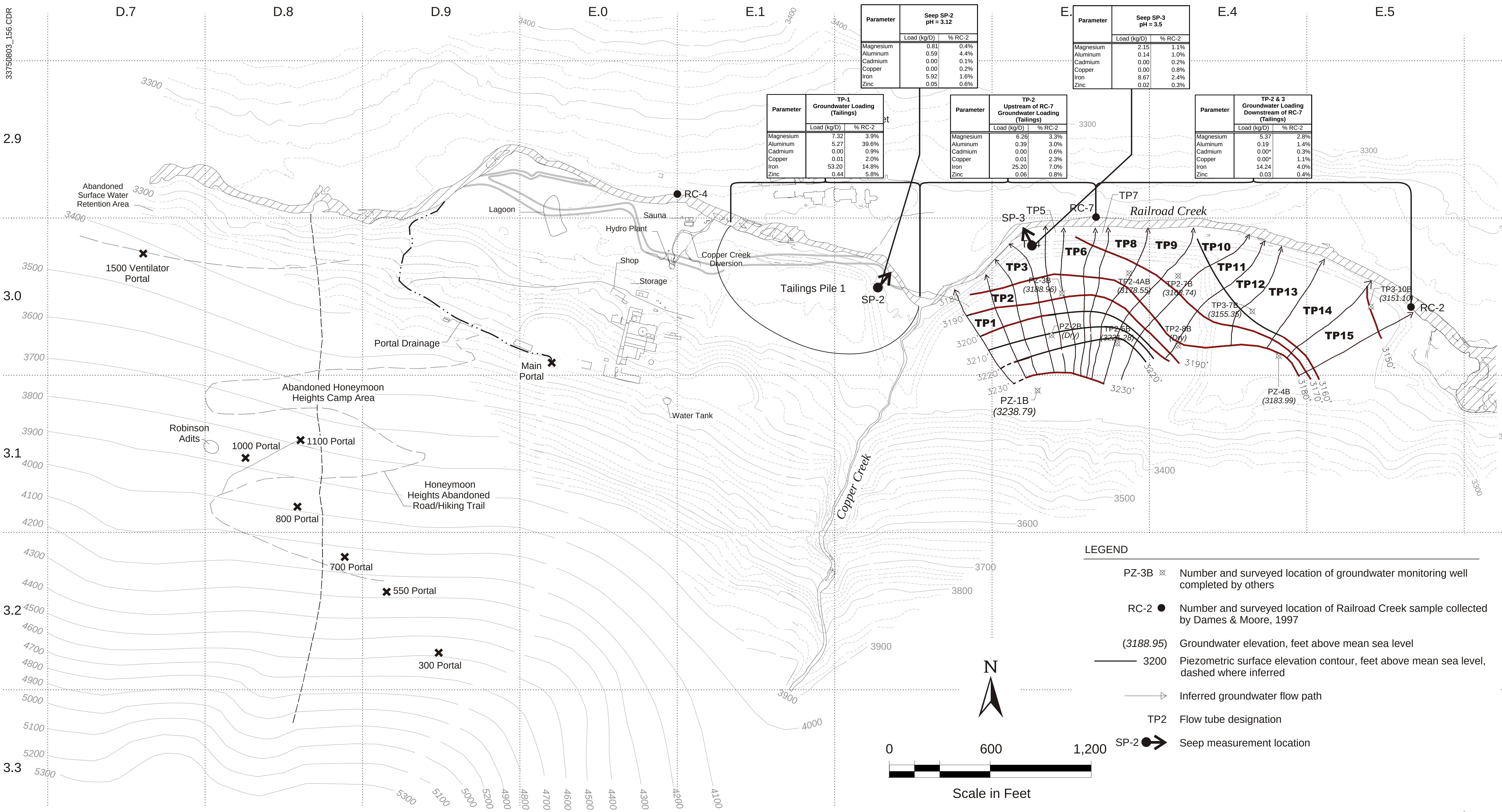
Figure A-8
Groundwater Loading from Native Materials – May 1997

URS



Parameter	Seep SP-2 pH = 3.12	
	Load (kg/D)	% RC-2
Magnesium	0.81	0.4%
Aluminum	0.59	4.4%
Cadmium	0.00	0.1%
Copper	0.00	0.2%
Iron	5.92	1.6%
Zinc	0.05	0.6%

Parameter	Seep SP-3 pH = 3.5	
	Load (kg/D)	% RC-2
Magnesium	2.15	1.1%
Aluminum	0.14	1.0%
Cadmium	0.00	0.2%
Copper	0.00	0.8%
Iron	8.67	2.4%
Zinc	0.02	0.3%

Parameter	TP-1 Groundwater Loading (Tailings)	
	Load (kg/D)	% RC-2
Magnesium	7.32	3.9%
Aluminum	5.27	39.6%
Cadmium	0.00	0.9%
Copper	0.01	2.0%
Iron	53.20	14.8%
Zinc	0.44	5.8%

Parameter	TP-2 Upstream of RC-7 Groundwater Loading (Tailings)	
	Load (kg/D)	% RC-2
Magnesium	6.26	3.3%
Aluminum	0.39	3.0%
Cadmium	0.00	0.6%
Copper	0.01	2.3%
Iron	25.20	7.0%
Zinc	0.06	0.8%

Parameter	TP-2 & 3 Groundwater Loading Downstream of RC-7 (Tailings)	
	Load (kg/D)	% RC-2
Magnesium	5.37	2.8%
Aluminum	0.19	1.4%
Cadmium	0.00*	0.3%
Copper	0.00*	1.1%
Iron	14.24	4.0%
Zinc	0.03	0.4%

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
SP-2	Seep measurement location

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

Job No. 33750803

Figure A-9

Seep and Groundwater Loading from Tailings – September 1997

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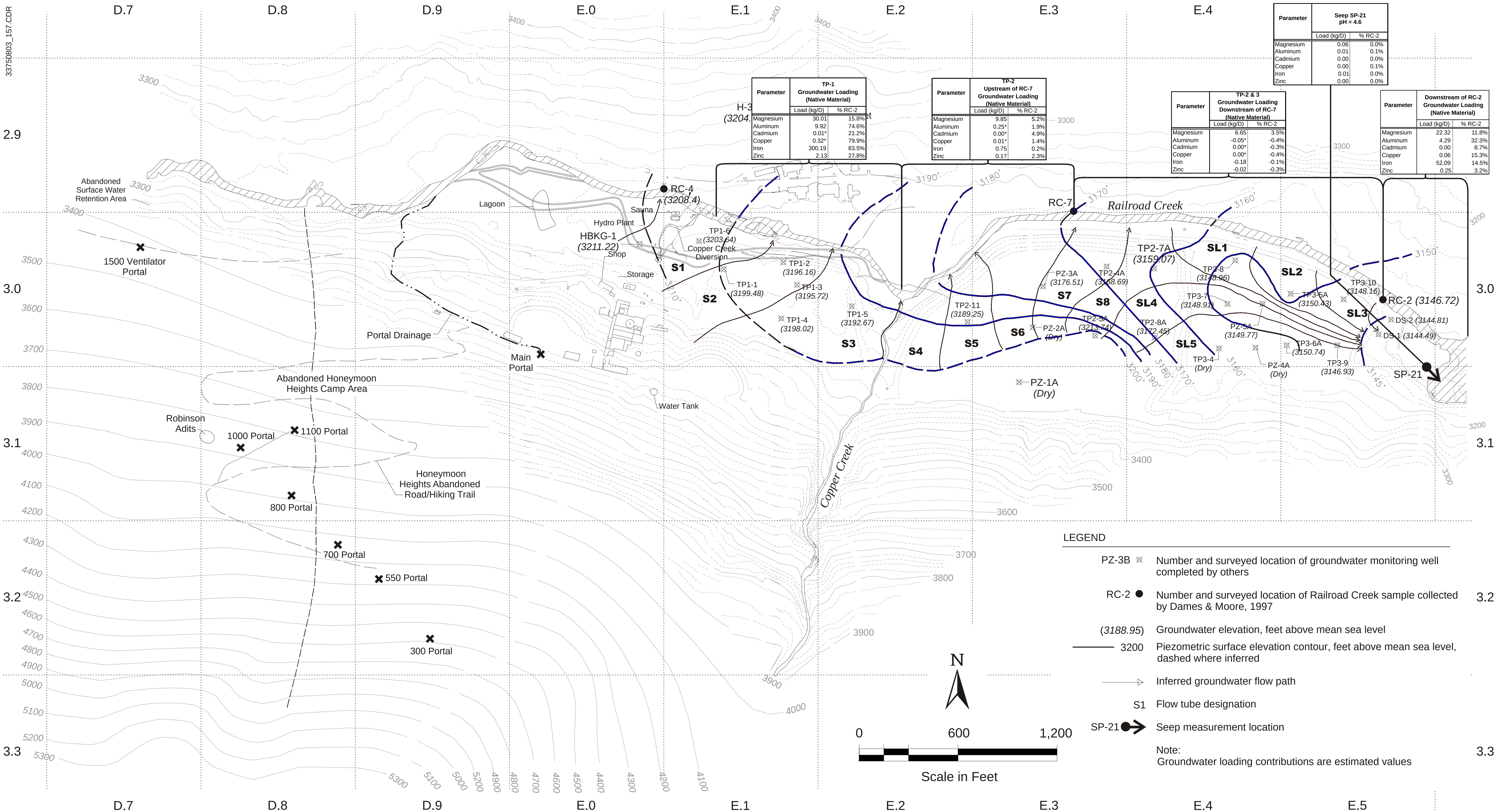
Holden Mine RI/FS
Draft Final FS Report
February 2004



Parameter	TP-1 Groundwater Loading (Native Material)	
	Load (kg/D)	% RC-2
Magnesium	30.01	15.8%
Aluminum	9.92	74.6%
Cadmium	0.01*	21.2%
Copper	0.32*	79.9%
Iron	300.19	83.5%
Zinc	2.13	27.8%

Parameter	TP-2 Upstream of RC-7 Groundwater Loading (Native Material)	
	Load (kg/D)	% RC-2
Magnesium	9.85	5.2%
Aluminum	0.25*	1.9%
Cadmium	0.00*	4.9%
Copper	0.01*	1.4%
Iron	0.75	0.2%
Zinc	0.17	2.3%

Parameter	TP-2 & 3 Groundwater Loading Downstream of RC-7 (Native Material)	
	Load (kg/D)	% RC-2
Magnesium	6.65	3.5%
Aluminum	-0.05*	-0.4%
Cadmium	0.00*	-0.3%
Copper	0.00*	-0.4%
Iron	-0.18	-0.1%
Zinc	-0.02	-0.3%

Parameter	Seep SP-21 pH = 4.6	
	Load (kg/D)	% RC-2
Magnesium	0.06	0.0%
Aluminum	0.01	0.1%
Cadmium	0.00	0.0%
Copper	0.00	0.1%
Iron	0.01	0.0%
Zinc	0.00	0.0%

Parameter	Downstream of RC-2 Groundwater Loading (Native Material)	
	Load (kg/D)	% RC-2
Magnesium	22.32	11.8%
Aluminum	4.29	32.3%
Cadmium	0.00	8.7%
Copper	0.06	15.3%
Iron	52.09	14.5%
Zinc	0.25	3.2%

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

Job No. 33750803

Figure A-10
Groundwater Loading from Native Materials – September 1997

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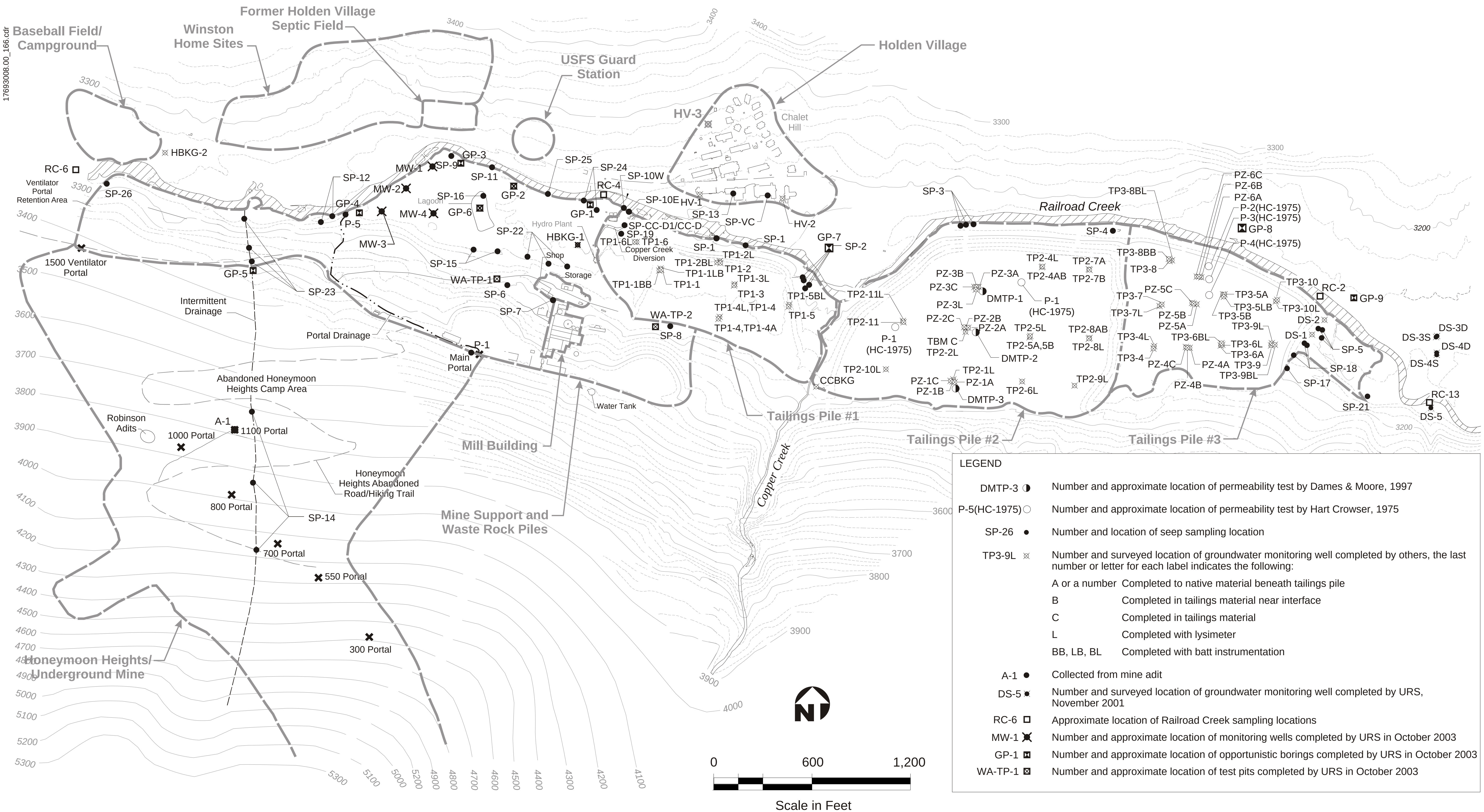

Figure A-11
Hydrogeologic Investigation Locations
Holden Mine Site

TABLE A1-1
GROUNDWATER DISCHARGE AND LOADING CALCULATIONS
(FROM RC-4 TO RC-7, MAY 1997)
HOLDEN MINE RI/FS

Flow Tube	West Edge (ft)	East Edge (ft)	Mean Length (ft)	Top Head (ft)	Bottom Head (ft)	Hydraulic Gradient (ft/ft)*	Stream Length (ft)	Aquifer Thickness (ft)	Tube k low (ft/sec)	Tube k mean (ft/sec)	Tube k high (ft/sec)	Tube Q low (ft^3/sec)	Tube Q mean (ft^3/sec)	Tube Q high (ft^3/sec)	Well(s), seep(s) for constituent concentrations	Zn (ug/L)	Fe (ug/L)	Cd (ug/L)	Cu (ug/L)	Zn load mean (mg/s)	Fe load mean (mg/s)	Cd load mean (mg/s)	Cu load mean (mg/s)
S1	70	260	165	3210	3207.5	0.015	295	10	0.0001	0.0010	0.0032	0.004	0.045	0.143	HBKG-1, SP-10W	4055	135	34.4	2620	5.129	0.171	0.044	3.314
S2	260	410	335	3210	3202.5	0.022	270	10	0.0001	0.0010	0.0032	0.006	0.060	0.193	TP1-6A	11400	145000	100	1100	19.502	248.047	0.171	1.882
S3	410	500	455	3210	3197.5	0.027	225	10	0.0001	0.0010	0.0032	0.006	0.062	0.198	TP1-2A	2270	321000	0.3	1	3.971	561.530	0.001	0.002
S4	90	300	195	3200	3194	0.031	400	10	0.0001	0.0010	0.0032	0.012	0.123	0.394	TP1-2A, TP1-3A	3660	332500	1	1	12.748	1158.123	0.003	0.003
S5	300	260	280	3200	3188	0.043	180	10	0.0001	0.0010	0.0032	0.008	0.077	0.247	TP1-5A	9810	246000	10	196	21.417	537.053	0.022	0.428
S6	100	60	80	3190	3186	0.050	250	10	0.0001	0.0010	0.0032	0.013	0.125	0.400	TP1-5A	9810	246000	10	196	34.703	870.225	0.035	0.693
S7	60	150	105	3190	3183	0.067	250	10	0.0001	0.0010	0.0032	0.017	0.167	0.533	TP2-11A	169	10	1.6	10	0.797	0.047	0.008	0.047
S8	150	230	190	3190	3179	0.058	245	10	0.0001	0.0010	0.0032	0.014	0.142	0.454	TP2-11A	169	10	1.6	10	0.678	0.040	0.006	0.040
S9	110	300	205	3180	3176.5	0.017	270	10	0.0001	0.0010	0.0032	0.005	0.046	0.148	TP2-11A	169	10	1.6	10	0.220	0.013	0.002	0.013
S10	300	310	305	3180	3173	0.023	420	10	0.0001	0.0010	0.0032	0.010	0.096	0.308	PZ-3A	2.5	5660	2	1	0.007	15.440	0.005	0.003
Total alluvial reworked till discharge												0.094	0.943	3.018	Total alluvial reworked till load					99.172	3390.689	0.297	6.425
TP-1	250	250	250	3190	3182	0.032	130	10	6.70E-06	0.000085	0.000144	0.000	0.004	0.006	SP-3	4030	154000	40.3	1280	0.403	15.411	0.004	0.128
TP-2	250	245	247.5	3190	3179	0.044	160	10	6.70E-06	0.000085	0.000144	0.000	0.006	0.010	SP-3	4030	154000	40.3	1280	0.689	26.343	0.007	0.219
TP-3	45	75	60	3180	3177.5	0.042	180	10	6.70E-06	0.000085	0.000144	0.001	0.006	0.011	SP-3	4030	154000	40.3	1280	0.727	27.784	0.007	0.231
TP-4	75	135	105	3180	3175	0.048	150	10	6.70E-06	0.000085	0.000144	0.000	0.006	0.010	SP-3	4030	154000	40.3	1280	0.692	26.461	0.007	0.220
TP-5	135	190	162.5	3180	3173	0.043	130	10	6.70E-06	0.000085	0.000144	0.000	0.005	0.008	SP-3	4030	154000	40.3	1280	0.543	20.745	0.005	0.172
TP-6	190	190	190	3180	3171.5	0.045	160	10	6.70E-06	0.000085	0.000144	0.000	0.006	0.010	SP-3	4030	154000	40.3	1280	0.694	26.516	0.007	0.220
TP-7	190	210	200	3180	3170	0.050	210	10	6.70E-06	0.000085	0.000144	0.001	0.009	0.015	SP-3	4030	154000	40.3	1280	1.018	38.897	0.010	0.323
Tailings Pile 1 **							1400					0.003	0.037	0.062	SP-1, SP-2	4545	514500	22.8	806	4.741	536.728	0.024	0.841
Total tailings discharge												0.006	0.079	0.133	Total tailings load					9.508	718.884	0.071	2.355
Total groundwater discharge RC-4 to RC-7												**0.101**	**1.022**	**3.151**	**Total load RC-4 to RC-7**					**108.680**	**4109.573**	**0.369**	**8.780**

Notes:

For metals reported as not-detected in the sample a value of one-half (1/2) the reporting limit was used for loading calculations.

* Hydraulic gradient measured in feet per foot.

** There are no groundwater wells completed in the tailings unit at TP-1. Therefore, groundwater flow in TP-1 was estimated using the estimated flow per unit length in tailings materials at TP-2 and 3. The total flow in TP-2 and TP-3 (0.084 cfs) was adjusted by the length of Railroad Creek adjacent to TP-2 and TP-3 (3,190 ft) to give a flow of groundwater from tailings per length of stream (2.63X10-5 cfs/ft). The stream length adjacent to TP-1 (1,400 ft.) was multiplied by the flow of groundwater from tailings per length of stream (2.63X10-5 cfs/ft) to give the estimated groundwater contribution from the tailings in TP-1 (0.037 cfs).

TABLE A1-2
GROUNDWATER DISCHARGE AND LOADING CALCULATIONS
(FROM RC-7 TO RC-2, MAY 1997)
HOLDEN MINE RI/FS

Flow Tube	West Edge (ft)	East Edge (ft)	Mean Length (ft)	Top Head (ft)	Bottom Head (ft)	Hydraulic Gradient (ft/ft)*	Stream Length (ft)	Aquifer Thickness (ft)	Tube k low (ft/sec)	Tube k mean (ft/sec)	Tube k high (ft/sec)	Tube Q low (ft^3/sec)	Tube Q mean (ft^3/sec)	Tube Q high (ft^3/sec)	Well(s), seep(s) for constituent concentrations	Zn (ug/L)	Fe (ug/L)	Cd (ug/L)	Cu (ug/L)	Zn load mean (mg/s)	Fe load mean (mg/s)	Cd load mean (mg/s)	Cu load mean (mg/s)
S11	310	340	325	3180	3168.5	0.035	250	10	0.0001	0.0010	0.0032	0.009	0.088	0.283	PZ-3A	2.5	5660	2	1	0.006	14.170	0.005	0.003
S12	170	260	215	3170	3165.5	0.021	230	10	0.0001	0.0010	0.0032	0.005	0.048	0.154	TP2-4A	5.5	7040	2	3	0.007	9.591	0.003	0.004
S13	260	390	325	3170	3164	0.018	230	10	0.0001	0.0010	0.0032	0.004	0.042	0.136	TP2-4A	5.5	7040	2	3	0.007	8.460	0.002	0.004
S14	390	410	400	3170	3160	0.025	260	10	0.0001	0.0010	0.0032	0.007	0.065	0.208	TP3-8	58	55400	0.4	1	0.107	101.908	0.001	0.002
S15	180	210	195	3160	3158	0.010	170	10	0.0001	0.0010	0.0032	0.002	0.017	0.056	TP3-8	58	55400	0.4	1	0.029	27.336	0.000	0.000
S16	210	190	200	3160	3156.5	0.018	240	10	0.0001	0.0010	0.0032	0.004	0.042	0.134	TP3-8	58	55400	0.4	1	0.069	65.848	0.000	0.001
S17	190	180	185	3160	3154.5	0.030	230	10	0.0001	0.0010	0.0032	0.007	0.068	0.219	TP3-10L	68	20	0.6	13	0.132	0.039	0.001	0.025
S18	180	230	205	3160	3152	0.039	170	10	0.0001	0.0010	0.0032	0.007	0.066	0.212	TP3-10L	68	20	0.6	13	0.128	0.038	0.001	0.024
S19	230	250	240	3160	3149	0.046	240	10	0.0001	0.0010	0.0032	0.011	0.110	0.352	TP3-10L	68	20	0.6	13	0.212	0.062	0.002	0.040
Total alluvial reworked till discharge												0.055	0.548	1.754	Total alluvial reworked till load					0.696	227.452	0.016	0.104
TP-8	40	170	105	3170	3167	0.029	250	10	6.70E-06	0.000085	0.000144	0.000	0.006	0.010	SP-3, SP-4	2467	114450	23.8	975	0.424	19.665	0.004	0.168
TP-9	170	250	210	3170	3165	0.024	120	10	6.70E-06	0.000085	0.000144	0.000	0.002	0.004	SP-3, SP-4	2467	114450	23.8	975	0.170	7.866	0.002	0.067
TP-10	250	340	295	3170	3163.5	0.022	160	10	6.70E-06	0.000085	0.000144	0.000	0.003	0.005	SP-4	904	74900	7.3	670	0.077	6.352	0.001	0.057
TP-11	340	390	365	3170	3161	0.025	280	10	6.70E-06	0.000085	0.000144	0.000	0.006	0.010	SP-4	904	74900	7.3	670	0.150	12.439	0.001	0.111
TP-12	60	120	90	3160	3158.5	0.017	270	10	6.70E-06	0.000085	0.000144	0.000	0.004	0.006	SP-4	904	74900	7.3	670	0.098	8.108	0.001	0.073
TP-13	120	180	150	3160	3156.5	0.023	240	10	6.70E-06	0.000085	0.000144	0.000	0.005	0.008	SP-4, PZ-6A	459.5	66600	4.65	335.5	0.062	8.972	0.001	0.045
TP-14	180	230	205	3160	3154.5	0.027	240	10	6.70E-06	0.000085	0.000144	0.000	0.005	0.009	PZ-6A	15	58300	2	1	0.002	9.030	0.000	0.000
TP-15	230	280	255	3160	3151	0.035	250	10	6.70E-06	0.000085	0.000144	0.001	0.008	0.013	PZ-6A	15	58300	2	1	0.003	12.374	0.000	0.000
TP-16	70	200	135	3150	3148	0.015	260	10	6.70E-06	0.000085	0.000144	0.000	0.003	0.006	PZ-6A	15	58300	2	1	0.001	5.402	0.000	0.000
Total tailings discharge												0.003	0.042	0.071	Total tailings load					0.987	90.207	0.010	0.521
Total groundwater discharge RC-7 to RC-2												**0.058**	**0.590**	**1.826**	**Total groundwater load, RC-7 to RC-2**					**1.682**	**317.659**	**0.026**	**0.625**

Notes:
For metals reported as not-detected in the sample a value of one-half (1/2) the reporting limit was used for loading calculations.
* Hydraulic gradient measured in feet per foot.

TABLE A1-3
GROUNDWATER DISCHARGE AND LOADING CALCULATIONS
(FROM RC-4 TO RC-7, SEPTEMBER 1997)
HOLDEN MINE RI/FS

Flow Tube	West Edge (ft)	East Edge (ft)	Mean Length (ft)	Top Head (ft)	Bottom Head (ft)	Hydraulic Gradient (ft/ft)*	Stream Length (ft)	Aquifer Thickness (ft)	Tube k low (ft/sec)	Tube k mean (ft/sec)	Tube k high (ft/sec)	Tube Q low (ft^3/sec)	Tube Q mean (ft^3/sec)	Tube Q high (ft^3/sec)	Well(s), seep(s) for constituent concentrations	Zn (ug/L)	Fe (ug/L)	Cd (ug/L)	Cu (ug/L)	Zn load mean (mg/s)	Fe load mean (mg/s)	Cd load mean (mg/s)	Cu load mean (mg/s)
S1	210	700	455	3210	3205	0.011	710	10	0.0001	0.0010	0.0032	0.008	0.078	0.250	HBKG-1, TP1-6A	4260	40205	33.5	1590	9.406	88.774	0.074	3.511
S2	280	600	440	3200	3195	0.011	370	10	0.0001	0.0010	0.0032	0.004	0.042	0.135	TP1-2A, TP1-3A	4590	1605000	0.85	5	5.462	1909.768	0.001	0.006
S3	600	390	495	3200	3188	0.024	520	10	0.0001	0.0010	0.0032	0.013	0.126	0.403	TP1-5A	2730	413000	1.8	48	9.739	1473.384	0.006	0.171
S4	50	300	175	3190	3183	0.040	400	10	0.0001	0.0010	0.0032	0.016	0.160	0.512	TP2-11A	309	100	2.9	10	1.399	0.453	0.013	0.045
S5	100	310	205	3180	3178	0.010	210	10	0.0001	0.0010	0.0032	0.002	0.020	0.066	TP2-11A	309	100	2.9	10	0.179	0.058	0.002	0.006
S6	320	480	400	3180	3173	0.018	560	10	0.0001	0.0010	0.0032	0.010	0.098	0.314	TP2-11A, PZ-3A	158	2935	1.5	5.5	0.438	8.140	0.004	0.015
Total alluvial reworked till discharge												0.052	0.525	1.679	Total alluvial reworked till load					26.624	3480.576	0.100	3.754
TP-1	140	160	150	3190	3180	0.067	280	10	0.0000067	0.000085	0.0001443	0.001	0.016	0.027	SP-3	611	251000	2	90	0.274	112.706	0.001	0.040
TP-2	50	90	70	3180	3178	0.029	160	10	0.0000067	0.000085	0.0001443	0.000	0.004	0.007	SP-3	611	251000	2	90	0.067	27.601	0.000	0.010
TP-3	90	180	135	3180	3175	0.037	180	10	0.0000067	0.000085	0.0001443	0.000	0.006	0.010	SP-3	611	251000	2	90	0.098	40.252	0.000	0.014
TP-4	180	260	220	3180	3172.5	0.034	200	10	0.0000067	0.000085	0.0001443	0.000	0.006	0.010	SP-3	611	251000	2	90	0.100	41.167	0.000	0.015
TP-5	260	300	280	3180	3171	0.032	120	10	0.0000067	0.000085	0.0001443	0.000	0.003	0.006	SP-3	611	251000	2	90	0.057	23.289	0.000	0.008
TP-6	300	300	300	3180	3169	0.037	210	10	0.0000067	0.000085	0.0001443	0.001	0.007	0.011	SP-3	611	251000	2	90	0.113	46.491	0.000	0.017
Tailings Pile 1**							1400					0.003	0.032	0.054	SP-2	5700	685000	3.9	101	5.120	615.331	0.004	0.091
Total tailings discharge												0.006	0.073	0.124	Total tailings load					5.830	906.837	0.006	0.195
Total groundwater discharge RC-4 to RC-7												**0.058**	**0.597**	**1.802**	**Total Load RC-4 to RC-7**					**32.453**	**4387.412**	**0.106**	**3.950**

Notes:

For metals reported as not-detected in the sample a value of one-half (1/2) the reporting limit was used for loading calculations.

* Hydraulic gradient measured in feet per foot.

** There are no groundwater wells completed in the tailings unit at TP-1. Therefore, groundwater flow in TP-1 was estimated using the estimated flow per unit length in tailings materials at TP-2 and 3. The total flow in TP-2 and TP-3 (0.072 cfs) was adjusted by the length of Railroad Creek adjacent to TP-2 and TP-3 (3,190 ft) to give a flow of groundwater from tailings per length of stream (2.27X10-5 cfs/ft). The stream length adjacent to TP-1 (1,400 ft) was multiplied by the flow of groundwater from tailings per length of stream (2.27X10-5 cfs/ft) to give the estimated groundwater contribution from the tailings in TP-1 (0.032 cfs).

TABLE A1-4
GROUNDWATER DISCHARGE AND LOADING CALCULATIONS
(FROM RC-7 TO RC-2, SEPTEMBER 1997)
HOLDEN MINE RI/FS

Flow Tube	West Edge (ft)	East Edge (ft)	Mean Length (ft)	Top Head (ft)	Bottom Head (ft)	Hydraulic Gradient (ft/ft)*	Stream Length (ft)	Aquifer Thickness (ft)	Tube k low (ft/sec)	Tube k mean (ft/sec)	Tube k high (ft/sec)	Tube Q low (ft3/sec)	Tube Q mean (ft3/sec)	Tube Q high (ft3/sec)	Well(s), seep(s) for constituent concentrations	Zn (ug/l)	Fe (ug/l)	Cd (ug/l)	Cu (ug/l)	Zn load mean (mg/s)	Fe load mean (mg/s)	Cd load mean (mg/s)	Cu load mean (mg/s)
S7	470	600	535	3180	3168	0.022	400	10	0.0001	0.0010	0.0032	0.009	0.090	0.287	TP2-4A	7	5630	0.1	1	0.018	14.295	0.000	0.003
S8 IN	380	520	450	3170	3165	0.011	110	10	0.0001	0.0010	0.0032	0.001	0.012	0.039	TP2-4A	7	5630	0.1	1	0.002	1.947	0.000	0.000
S8 OUT	210	130	170	3165	3160	0.029	150	10	0.0001	0.0010	0.0032	-0.004	-0.044	-0.141	RC-7	19	1150	0.09	1.3	-0.024	-1.436	0.000	-0.002
SL1	370	75	222.5	3160	3150	0.045	550	10	0.0001	0.0010	0.0032	-0.025	-0.247	-0.791	RC-7	19	1150	0.09	1.3	-0.133	-8.045	-0.001	-0.009
SL2	75	120	97.5	3155	3150	0.051	400	10	0.0001	0.0010	0.0032	-0.021	-0.205	-0.656	RC-7	19	1150	0.09	1.3	-0.110	-6.676	-0.001	-0.008
SL3	470	90	280	3149.5	3145	0.016	420	10	0.0001	0.0010	0.0032	-0.007	-0.068	-0.216	RC-7	19	1150	0.09	1.3	-0.036	-2.197	0.000	-0.002
Total alluvial reworked till discharge												-0.046	-0.462	-1.478	Total alluvial reworked till load					-0.283	-2.111	-0.001	-0.018
TP-7	100	140	120	3170	3167	0.025	90	10	6.7E-06	0.000085	0.000144	0.000	0.002	0.003	SP-3	611	251000	2	90	0.033	13.585	0.000	0.005
TP-8	140	230	185	3170	3165.5	0.024	250	10	6.7E-06	0.000085	0.000144	0.000	0.005	0.009	SP-3	611	251000	2	90	0.089	36.716	0.000	0.013
TP-9	230	390	310	3170	3162.5	0.024	260	10	6.7E-06	0.000085	0.000144	0.000	0.005	0.009	SP-3	611	251000	2	90	0.092	37.980	0.000	0.014
TP-10	390	560	475	3170	3159	0.023	350	10	6.7E-06	0.000085	0.000144	0.001	0.007	0.012	SP-3	611	251000	2	90	0.119	48.938	0.000	0.018
TP-11	270	370	320	3160	3157	0.009	90	10	6.7E-06	0.000085	0.000144	0.000	0.001	0.001	SP-3, PZ-6A	318	163350	1.05	46	0.006	3.315	0.000	0.001
TP-12	370	460	415	3160	3156	0.010	120	10	6.7E-06	0.000085	0.000144	0.000	0.001	0.002	PZ-6A	25	75700	0.1	2	0.001	2.106	0.000	0.000
TP-13	460	540	500	3160	3155	0.010	260	10	6.7E-06	0.000085	0.000144	0.000	0.002	0.004	PZ-6A	25	75700	0.1	2	0.002	4.735	0.000	0.000
TP-14	540	610	575	3160	3152	0.014	310	10	6.7E-06	0.000085	0.000144	0.000	0.004	0.006	PZ-6A	25	75700	0.1	2	0.003	7.854	0.000	0.000
TP-15	610	690	650	3160	3148	0.018	280	10	6.7E-06	0.000085	0.000144	0.000	0.004	0.007	PZ-6A	25	75700	0.1	2	0.003	9.413	0.000	0.000
Total tailings discharge												0.002	0.031	0.053	Total tailings load					0.348	164.642	0.001	0.051
Total groundwater discharge RC-7 TO RC-2												**-0.044**	**-0.431**	**-1.425**	**Total discharge RC-7 TO RC-2**					**0.065**	**162.531**	**0.000**	**0.033**

Notes:
For metals reported as not-detected in the sample a value of one-half (1/2) the reporting limit was used for loading calculations.
* Hydraulic gradient measured in feet per foot

TABLE A1-5
GROUNDWATER FLOW CALCULATIONS FOR LOADING ANALYSIS
(DOWNSTREAM OF RC-2, SEPTEMBER 1997)
HOLDEN MINE RI/FS

Flow Tube	North Edge (ft)	South Edge (ft)	Mean Length (ft)	Top Head (ft)	Bottom Head (ft)	Hydraulic Gradient (ft/ft) *	Stream Length (ft)	Aquifer Thickness (ft)	Tube k low (ft/sec)	Tube k mean (ft/sec)	Tube k high (ft/sec)	Tube Q low (ft3/sec)	Tube Q mean (ft3/sec)	Tube Q high (ft3/sec)	Well(s), seep(s) for constituent concentrations	Zn (ug/l)	Fe (ug/l)	Cd (ug/l)	Cu (ug/l)	Zn load mean (mg/s)	Fe load mean (mg/s)	Cd load mean (mg/s)	Cu load mean (mg/s)
S8 OUT	210	130	170	3165	3160	0.029	150	10	0.0001	0.0010	0.0032	0.004	0.044	0.141	DS-1, TP3-9	240.5	62505	2.45	45	0.300	78.039	0.003	0.056
SL1	370	75	222.5	3160	3150	0.045	550	10	0.0001	0.0010	0.0032	0.025	0.247	0.791	DS-1, TP3-9	240.5	62505	2.45	45	1.682	437.254	0.017	0.315
SL2	75	120	97.5	3155	3150	0.051	400	10	0.0001	0.0010	0.0032	0.021	0.205	0.656	DS-1	79	10	1.4	39	0.459	0.058	0.008	0.226
SL3	470	90	280	3149.5	3145	0.016	420	10	0.0001	0.0010	0.0032	0.007	0.068	0.216	DS-1	79	10	1.4	39	0.151	0.019	0.003	0.074
SL4	930	820	875	3150	3145	0.006	190	10	0.0001	0.0010	0.0032	0.001	0.011	0.035	TP3-9	402	125000	3.5	51	0.124	38.407	0.001	0.016
SL5	820	380	600	3150	3145	0.008	165	10	0.0001	0.0010	0.0032	0.001	0.014	0.044	TP3-9	402	125000	3.5	51	0.156	48.641	0.001	0.020
Total alluvial reworked till discharge/load												0.059	0.589	1.883	Total alluvial reworked till load					2.872	602.418	0.033	0.707

Notes:
For metals reported as not-detected in the sample a value of one-half (1/2) the reporting limit was used for loading calculations.
* Hydraulic gradient measured in feet per foot

APPENDIX B
SUPPORTING INFORMATION RELATING TO THE 1999/2002 NRWQC FOR ALUMINUM, CADMIUM, COPPER, AND IRON

Supporting Information relating to the 1999/2002 NRWQC for Aluminum, Cadmium, Copper, and Iron.

ATTACHMENT B-1

Stephen R. Hansen, 2003a. *Critique of Applying the 2002 National Recommended Water Quality Criteria for Copper and Cadmium as TRVs for the Holden Mine Site*. June 2003.

ATTACHMENT B-2

Stephen R. Hansen, 2003b. *Critique of Applying the USEPA Ambient Water Quality Criterion for Iron as a Cleanup Level for the Holden Mine Site*. June 2003

ATTACHMENT B-3

Stephen R. Hansen, 2004b. *Critique of Applying the USEPA Ambient Water Quality Criterion for Aluminum as a Cleanup Level for the Holden Mine Site*. February 2004.

Appendix B

Supporting Information Relating to the 1999/2002 NRWQC for Aluminum, Cadmium, Copper, and Iron.

Intalco has previously commented that the Federal National Recommended Water Quality Criteria (NRWQC) (1999 and 2002 publications) are not relevant and appropriate to the Holden Mine site (Site). Specifically, the NRWQC for cadmium and copper are not relevant and appropriate to the Site and the NRWQC for iron and aluminum while relevant are not appropriate requirements since they are based upon out-dated scientific data. This Appendix summarizes the legal justifications and provides scientific information in Attachments B-1 through B-3 demonstrating that the NRWQC for aluminum, cadmium, copper, and iron are not relevant and appropriate to the Site. This document is summary in nature and should be read together with information previously submitted to the Agencies[1].

1. MTCA Cannot Incorporate by Reference the NRWQC Since the NRWQC is Non-binding Federal Guidance Which has Not Been Subject to Federal APA Requirements.

The Washington State Administrative Procedure Act (WA APA) prescribes the process for ensuring that the public is given proper notice and the opportunity to comment on promulgated rules and regulations in the State. The WA APA provides for a more streamlined notice, comment and analysis where a state regulation adopts a federal regulation by reference. The streamlined procedures, thus, are limited to the incorporation by reference of "codes, standards, rules or regulations adopted by federal agencies." Where a federal requirement is not a "code, standard, rule or regulation" or has not been properly "adopted" by a federal agency, the federal requirement cannot be merely "incorporated by reference" but must be subject to the complete notice and comment provisions under the WA APA.

The NRWQC are not "adopted" by EPA but "developed" by EPA for use by the states in adopting their own standards. Further, the NRWQC are not binding on EPA, the states, or regulated community. The NRWQC are developed by EPA under the authority of Section 304(a) and are issued periodically to the States as guidance for use (by the States) in developing state standards.[2] EPA does not adopt NRWQC; states adopt state water quality criteria.[3] In fact, Ecology, in its most recent promulgated revisions to Chapter 173-201A WAC did not adopt or modify the toxic water quality standards for the potential constituents of concern (PCOCs) at the Site.[4] Therefore, the NRWQC cannot be incorporated by reference into the State of Washington

[1] Intalco January 22, 2003; Intalco June 4, 2003, including Hansen, 2003a/2003b; and Intalco August 27, 2003.

[2] 40 CFR 131.3(c)

[3] The 2002 NRWQC indicates, "States and authorized tribes must <u>adopt</u> water quality criteria."

[4] WAC 173-201A-240(3), July 1, 2003. EPA evaluated the NRWQC and adopted the 1999 NRWQC revision to the ammonia standard only.

Model Toxics Control Act (MTCA) under the WA APA because the NRWQC is merely non-binding federal guidance which has not been established or adopted under federal law. This provision of MTCA is invalid as a matter of law and as such, under the provisions of MTCA, the NRWQC cannot be identified as a potentially applicable or relevant and appropriate requirement (ARAR) at the Site or otherwise enforced under Washington State law.

In addition, MTCA specifies requirements for establishing MTCA cleanup levels. Specifically, WAC 173-340-730(3)(b)(i) requires that the MTCA Method B cleanup levels be at least as stringent as "concentrations established under applicable state and federal laws." (Emphasis supplied). As discussed above, the NRWQC are not "established" under federal law. The NRWQC are non-binding federal guidance which has not undergone appropriate review and comment at the federal level. The review and comment of the NRWQC is conducted when the state establishes state water quality standards as required by the Clean Water Act (CWA). Therefore, according to MTCA, the NRWQC, which are criteria that have not been established under federal law, cannot be considered as a potential ARAR.

2. MTCA Rulemaking did not comply with the WA APA when it incorporated by reference the NRWQC.

Even if the NRWQC can arguably be incorporated by reference, MTCA rulemaking incorporating these materials did not comply with the WA APA. Under the WA APA, the material to be incorporated by reference must be 1) fully identified, 2) copies of the incorporated materials must be made available to the public at the time of the state rulemaking, and 3) the rule must state where the copies are available for public review.[5] Most importantly future amendments to the incorporated materials cannot be incorporated by reference, only the version that is referenced in the regulation.[6]

When MTCA was originally promulgated in 1991 and amended in 2001, the WA APA requirements for incorporating by reference federal materials were not complied with. The MTCA provision states, "Water quality criteria based on the protection of aquatic organisms…and human health published under section 304 of the Clean Water Act…" This provision of MTCA does not fully identify the version of the NRWQC, which was in existence at the time. In addition, copies of incorporated materials at the time of public review and comment were not included in the administrative record and the rule does not state where the

[5] RCW 34.04.365

[6] For example, recently promulgated revisions to the Washington state drinking water regulations included the following text: "The following sections and subsections of Title 40 Code of Federal Regulations (CFR) Part 141 National Primary Drinking Water Regulations revised as of July 1, 2002, and including all amendments and modifications thereto effective as of the date of adoption of this chapter are adopted by reference…Copies of the incorporated sections and subsections of Title 40 CFR are available from the Department of Health, Airdustrial Center Building 3, P.O. Box 47822, Olympia, Washington 98504-7822, or by calling the department's drinking water hotline at 1-800-521-0323." The Department of Health webpage further provides direct links to the Code of Federal Regulations "adopted" by EPA. Thus, the WA APA requirements were fully met in this instance because: 1) information was fully identified, 2) copies of the incorporated materials were made available to the public at the time of the state rulemaking, and 3) the rule stated where the copies are available for public review. In comparison, this WA APA process was not followed in the 2001 MTCA rulemaking.

copies are available for public review. Because the rulemaking related to this MTCA provision did not comply with the WA APA, this provision of MTCA is invalid as a matter of law and as such, under the provisions of MTCA NRWQC cannot be identified as a potential ARAR at the Site or otherwise enforced under Washington State law.

3. Future Provisions of Federal Requirements Cannot be Incorporated by Reference into State Laws or Regulations.

Even if the 2001 Amendments to MTCA arguably complied with the WA APA by meeting the notice and comment requirements specified above, the WA APA limits the incorporation by reference of all subsequent revisions and amendments. Thus, even if the administrative record for the 2001 MTCA amendments arguably met the WA APA requirements, the version in existence at the time of the MTCA amendments would have been the 1999 NRWQC, not the 2002 NRWQC.

Under no circumstances could the 2002 NRWQC be relevant and appropriate since the 2002 NRWQC did not meet the WA APA requirements: 1) the 2002 NRWQC could not have been fully identified since it did not exist; 2) copies of the incorporated materials were not made available to the public at the time of the state rulemaking since the criteria did not exist; and 3) the rule did not state where the copies were available for public review because the criteria did not exist. Therefore, under the WA APA the 2002 NRWQC cannot be identified as a potential ARAR for the Site or otherwise enforced under Washington State law.

4. The Washington State Water Quality Standards in Chapter 173-201A WAC are Potentially Applicable and Therefore, Better Suited to the Circumstances of the Site

Under CERLCA, where a state-specific, promulgated water quality standard exists under Chapter 173-201A WAC, which is a potentially "applicable" requirement, the NRWQC, which is guidance, is not "relevant and appropriate". Thus, a determination that the NRWQC is relevant and appropriate for the Holden Mine site would be inappropriate because Washington has promulgated water quality standards for Railroad Creek under Chapter 173-201A WAC.

As previously presented, the NRWQC are intended to be used only if a State fails to adopt its own standard. Two EPA guidance documents address situations where a NRWQC and a SWQS are in conflict. EPA instructs that in such situations, the SWQS, and not the NRWQC, should be used as the ARAR. In short, if "the State has promulgated water quality standards for the specific pollutants and water body at the site," the state WQS is the proper ARAR, not the FWQC [NRWQC]. [7] Use of the NRWQC for cadmium and copper at the Site would be

[7] US EPA. *ARARs Q's & A's: Compliance with Federal Water Quality Criteria*, Pub. 9234.2-09/FS, p. 2 (June 1990); US EPA. *Abandoned Mine Site Characterization and Cleanup Handbook*, (August 2000) Appx. D., p. 26.

inconsistent with EPA's established guidelines and inconsistent with WAC 173-201A-240(3).[8] In addition, Washington State has recently modified its water quality regulations and standards.[9] The NRWQC were considered[10], however, no modifications to the toxic substance standards for cadmium and copper were promulgated to reflect changes in either EPA's 1999 NRWQC or November 2002 NRWQC.[11]

Moreover, the preamble to the NCP and other EPA documents provide interpretation of "relevant and appropriate" as it applies to situations where state water quality or other promulgated standards exist. EPA guidance states that because states use NRWQC to promulgate state water quality standards, the state water quality standards "essentially represent a site-specific adoption of the national water quality criteria."[12] The preamble to the NCP states:

> Whether a [NRWQC] is relevant and appropriate depends on the availability of standards, such as…state water quality standard, specific for the constituent and use…EPA believes that at many sites, [NRWQC] will not be both relevant and appropriate in light of other potential ARARs…The availability of certain requirements that more fully match the circumstances of the site may result in a decision that another requirement is not relevant and appropriate." (55 FR 8752, March 8, 1990).

Likewise, the Congressional Record discusses the use of the NRWQC which identify criteria "for some 140 chemicals frequently found at Superfund sites". Even though the NRWQC specify potential criteria for a broad range of chemicals, the Congressional Record concludes that "EPA should select the specific exposure level which best fits the circumstances by the Superfund Site."[13] For the Holden Mine Site, the SWQC which represent the Washington State standards for cadmium, copper and zinc are the specific exposure level which best fit the circumstances for a water body in the state and thus are best suited to the circumstances at the Site.

The toxic criteria promulgated in WAC 173-201A-240(3) are legally applicable, not just relevant and appropriate. The state of Washington pursuant to rulemaking has identified potential uses for Railroad Creek which include aquatic life uses; Ecology, utilizing the non-binding federal NRWQC guidance from EPA, has developed and promulgated toxic water quality criteria for individual hazardous constituents for aquatic life uses for waters of the state. Chapter 173-201A

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[8] "USEPA Quality Criteria for Water, 1986, as revised, shall be used in the use and interpretation of the values listed in subsection (3) of this section. "(WAC 173-201A-240(3)). Note that under the Washington State nondelegation doctrine discussed previously in this Appendix, future or "as revised" versions of federal guidance cannot be incorporated by reference; thus, the 1986 Water Quality Criteria shall be used in the state of Washington in the use and interpretation of the toxic substance values listed in WAC 173-201A-240(3).

[9] Chapter 173-201A WAC. July 1, 2003.

[10] See Footnote 3.

[11] WAC 173-201A-240(3), July 1, 2003.

[12] Footnote 4, EPA, 1988.

[13] H. Cong. Rec., daily ed. Oct. 8, 1986, p. 29754.

WAC also provides provisions for modifying these criteria on a site-specific basis (discussed below). Given that a state-specific standard exists, the NRWQC, which are merely guidance values provided by EPA, to the states are less well suited to the circumstances at the site.

5. NRWQC do not meet the criteria for "relevant and appropriate" under MTCA or CERCLA

CERCLA section 120(d)(2)(B)(I) includes provisions for determining whether or not water quality criteria under the CWA are relevant and appropriate under the circumstances, which shall consider, 1) the designated or potential use of the surface or groundwater, 2) the environmental media affected, 3) the purposes for which such criteria were developed, and 4) the latest information available.

The criteria for determining relevance and appropriateness under MTCA are specified in WAC 173-340-710(4). Set forth below is the preliminary assessment provided by Intalco to the Agencies on June 4, 2003 which the Agencies have yet to respond to regarding the relevance and appropriateness of the NRWQC to the Site. Intalco reserves the right to augment this assessment, as necessary, in the future. The NRWQC for cadmium and copper are not relevant and appropriate under either MTCA or CERCLA for the following reasons.

- **Purpose**. The purpose of the NRWQC is to provide guidance to the states based upon general scientific data so that the state may establish state-specific standards for specific, classified water bodies. Washington state has applied the NRWQC on a state-specific basis in Chapter 173-201A WAC. The 2002 NRWQC for cadmium and copper are more stringent than the WAC 173-201A standards due to an increased emphasis on the protection of sensitive species (i.e., daphnids for copper and daphnids and amphipods for cadmium) which do not inhabit fast-flowing waters such as those found in Railroad Creek.[14] A review of current toxicological data (referenced in and used as a basis for the 2002 NRWQC) indicates that the 2002 NRWQC do not provide improved protection of the species of concern in Railroad Creek (i.e., salmonids and their prey items). The data suggest the species of concern in Railroad Creek are significantly less sensitive to the presence of dissolved cadmium and copper than the species for which the more stringent criteria were derived. Additional information on the specific purposes of the 2002 NRWQC for cadmium and copper, the sensitivity of site-specific species, and the inappropriateness of using these standards for the Site is included as Attachment B-1.

- **Media regulated**. Although the NRWQC may regulate the same media, i.e., surface water, the NRWQC merely provide general scientific information as guidance to the states for any potential surface water. The specific media regulated (i.e., Railroad Creek) does not support the sensitive species that were used to derive the more stringent NRWQC. In addition, the NRWQC guidance notes that scientific data for hardness-corrected dissolved metals at

[14] *Ambient Water Quality Criteria for Cadmium and Copper* (EPA-440/5-84-031/-032), 1995 Updates (EPA-820-B-96-001), and *the National Recommended Water Quality Criteria: 2002* (EPA-822-R-02-47).

hardness below 25 mg/l is either limited or non-existent.[15] Surface water monitoring data for Railroad Creek indicate hardness values as low as 7 ppm. Therefore, the NRWQC guidance calls into question the appropriateness of the NRWQC data for hardness-corrected metals in situations like Railroad Creek.

- **Substance**. The substances, i.e., certain metals, are similar for both the NRWQC and the applicable state water quality standards under WAC 173-201A-040. However, data regarding NRWQC substances are intended for general application to a variety of state-specific situations; therefore, NRWQC cannot be specifically applied to the variable, seasonal and other site circumstances at the Site. These considerations, and the process to modify these standards, were made by the State of Washington in promulgating Chapter 173-201A WAC.

- **Actions or activities**. The actions or activities specified for the NRWQC are different from the site conditions. The NRWQC envisions providing general guidance to states so that site- or state-specific standards are developed. Remedial actions, mining and natural background conditions are not considered in the stringent NRWQC criteria. For instance, natural background entering the Site under some circumstances exceeds the NRWQC (i.e., cadmium). Application of the NRWQC would be inappropriate and any treatment during the remedial action would require zero discharge of that constituent to meet the stringent NRWQC but would not provide any added protection to the species that inhabit Railroad Creek.

- **Variance, waiver, or exemption**. The NRWQC, as merely guidance, does not address variances, waivers or exemptions. Variances, waivers and exemptions are expected to be addressed by the state when the NRWQC guidance criteria are considered and promulgated into state water quality standards. WAC 173-201A-400 through -450 specify requirements for applying or modifying the use designations and SWQC on a site-specific basis. These include but are not limited to, establishment of a mixing zone, short-term water quality modification, applying for a variance, development of site-specific water quality criteria, conducting a use attainability analysis, and applying for water quality offsets.

- **Place (MTCA only).** As guidance, the NRWQC does not consider the "place" where the NRWQC would be applied. The place or specific water body and associated background issues are expected to be addressed by the state in promulgating state water quality standards.

- **Type and Size of Site**. The type and size of the site is not addressed in the NRWQC since it is anticipated that the type and size of the site will be considered by the state in establishing state-specific water quality standards for specific water bodies. The type, size, and natural conditions of the site may be considered by the state in applying the SWQS.

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[15] Available toxicity data in this range for copper, zinc and cadmium (EPA 440/5-84-031,EPA 440/5-87- 003, and EPA-822-R-01-001) are somewhat limited, and are quite limited for silver, lead, chromium III and nickel (EPA 440/5-80-071,EPA 440/5-84-027,EPA 440/5-84-029 and EPA 440/5-86-004). Even fewer data are available below 20 mg/L hardness for copper, zinc and cadmium and none are available for silver, lead, chromium III and nickel. EPA evaluated these limited data, available in the current metals ' criteria documents, and determined that they are inconclusive. (EPA, 2002)

- **Use or Potential Use**. The 2002 NRWQC have been revised based on an increased emphasis on protection of daphnid species that are not present in Railroad Creek. The toxicological data suggests that the species of concern in Railroad Creek are significantly less sensitive to the regulated metals of concern as discussed in Attachment B-1.

Because the NRWQC for cadmium and copper do not meet the criteria under CERCLA section 120(d)(2)(B)(i) and WAC 173-340-710(4), these NRWQC are not relevant and appropriate to the Site.

6. The NRWQC for Iron or Aluminum are Not Appropriate and Therefore, Cannot be Potential ARARs Since These Criteria Are Based Upon Out-dated Scientific Information Which is Under Scrutiny by EPA.

The NRWQC for iron and aluminum are not appropriate and cannot be identified as potential ARARs for the Site for the following reasons. In the 2002 NRWQC publication, EPA has called into question the validity of the iron and aluminum NRWQC values, which were adopted almost 30 years ago and have not been evaluated by the scientific community.

It is Intalco's position that the scientific information for iron and aluminum is outdated. Intalco's previous assessment was confirmed when EPA issued the 2002 NRWQC document.
In the 2002 NRWQC, EPA notes that the iron NRWQC is outdated and is under scrutiny by EPA and the scientific community. A review of current scientific data available for iron indicates that the 1976 NRWQC of 1 mg/L is scientifically inappropriate and out-dated. The data suggests that based on current scientific literature, a more appropriate standard for site surface water would be in the range of 3 – 6 mg/l. Additional information regarding the appropriateness of the 1976 NRWQC for iron is provided in Attachment B-2 to this memo. For these reasons, the iron NRWQC is not a potential ARAR at the Site.

For aluminum, in the 2002 NRWQC, EPA notes that "[it] is aware of field data indicating that many high quality waters in the U. S. contain more than 87 µg aluminum/L, when either total recoverable or dissolved is measured." The Agencies' also acknowledge the uncertainties regarding the NRWQC aluminum chronic criteria in their response document.[16] A review of current scientifc data available for aluminum indicates that the 1988 chronic NRWQC value of 87 ug/L is scientifically inappropriate and out-dated. The data suggests a more appropriate standard for Site surface water would be in the range of 320 ug/L. Additional information regarding the appropriateness of the 1988 NRWQC for aluminum is provided in Attachment B-3. For these reasons, the chronic aluminum NRWQC is not a potential ARAR for the Site.

[16] (USFS, July 28, 2003), Attachment 1, page 17.

Critique of Applying the 2002 National Recommended Water Quality Criteria for Copper and Cadmium as TRVs for the Holden Mine Site

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It has been suggested by the regulatory agencies that the 2002 National Recommended Water Quality Criteria (NRWQC) for copper and cadmium (USEPA 2002) be adopted as cleanup levels for surface water at the Holden Mine Site. A review of these 2002 criteria indicates that both the copper and cadmium criteria are less appropriate than their predecessor criteria because they are more conservative but do not provide any increased protection to the species-of-concern in Railroad Creek (i.e., salmonids and their prey items). This information should be considered when evaluating the NWQC as a potential ARAR for the Holden Site.

The appropriateness of implementing the 2002 NWQCs was evaluated by reviewing the databases that were used in their development and comparing these databases with those used in the development of predecessor criteria promulgated in 1984 and 1995. Of principal interest is the question whether the 2002 criteria provide better protection for the species-of-concern that inhabit Railroad Creek (i.e., salmonids and their prey items) than previous criteria. The major issue in this regard is the degree to which the various criteria are influenced by the sensitivity of species that do not inhabit the receiving waters. For both copper and cadmium, daphnids are the prime examples of very sensitive species which do not inhabit fast-flowing waters such as those found in Railroad Creek. In the criteria setting process, if daphnids are assigned extremely low acute and/or chronic values, the resulting criteria are correspondingly reduced to protect the daphnid species. However, since the daphnids do not inhabit Railroad Creek, these lower criteria do not translate into greater protection of species-of-concern.

It should be noted that both acute and chronic daphnid data can affect NWQCs. In the case of cadmium, the chronic criterion is calculated directly using chronic data and, therefore, incorporation of low chronic daphnid data into the criterion-setting database reduces the resulting cadmium chronic criterion. On the other hand, for copper, the chronic criterion is calculated indirectly by applying a correction factor (i.e., and acute to chronic ratio or ACR) to acute data and, therefore, incorporation of low acute daphnid data into criterion-setting database reduces the resulting copper chronic criterion.

Copper – The 2002 NWQC for copper is more stringent than the previously promulgated copper criterion (USEPA 1984a) which has been adopted by Washington State under WAC 173-201A.. At a water hardness of 10 ppm, the 1984 chronic criterion for copper is 1.65 and the 2002 chronic criterion (based on a1995 update as described in USEPA 1996) is 1.304 ug/l. However, the increased conservatism of the 2002 criterion does not improve protection of species of concern in Railroad Creek. As illustrated in Table 1, the 2002 criterion is lower due to an increased emphasis on the protection of daphnids. In the 2002 criterion, the two most sensitive genera are *Daphnia* and *Ceriodaphnia* and their genus mean acute values are considerably lower than those designated in the 1984 criterion. These lower daphnid values (ranging from 9.9 to 14.5 ug/l at a water hardness of 50 ppm) are primarily responsible for the reduced 2002 chronic criterion. However, this lower criterion does not provide any added protection for salmonids which, as can be seen in Table 1, are 5 to 10 times less sensitive than daphnids to copper (i.e., acute values for salmonids ranging between 74 and 110 ug/l at a water hardness of 50 ppm). In addition, the more conservative 2002 criterion does not provide additional protection for invertebrate species that could serve as prey items for salmonids. Based on acute toxicity data, these invertebrate species are less sensitive to copper than the salmonids themselves.

As noted above, for copper, the chronic criterion is calculated indirectly by applying a conversion factor (i.e., an acute to chronic ratio or ACR) to acute data and, therefore, incorporation of low acute daphnid data into the criterion-setting database reduces the resulting copper chronic criterion. If one were to apply the mean ACR of 2.823 (which was used by USEPA to calculate the 2002 chronic criterion for all aquatic life) to the acute data for salmonids, a chronic criterion for the protection of salmonids would be approximately 26 ug/l at a water hardness of 50 ppm. It should be noted that data presented in the USEPA 1995 updates to the copper criterion (USEPA 1996) indicates that the ACR for salmonids is probably higher than the mean value of 2.823 and, therefore, use of the 2.823 value produces a conservative estimate of the salmonid chronic toxicity threshold.

Cadmium - The 2002 NWQC for cadmium is considerably more stringent than the two previously promulgated cadmium criteria (USEPA 1984b and USEPA 1996). At a water hardness of 10 ppm, the 1984 chronic criterion for cadmium is 0.186 ug/l, the 1995 chronic criterion is 0.404, and the 2002 chronic criterion (based on a 2001update as described in USEPA 2001) is 0.049 ug/l. However, the increased conservatism of the 2002 criterion does not improve protection of species-of-concern in Railroad Creek. As illustrated in Table 2, the 2002 criterion is lower due to an increased emphasis on two genera that would not be found in Railroad Creek – i.e., two daphnid species (*Daphnia magna* and *Daphnia pulex*) and one amphipod species (*Hyalella azteca*). These species inhabit lakes and ponds, not fast moving streams. It is clear that these low daphnid and amphipod genus mean chronic values (i.e., 0.275 ug/l and 0.379 ug/l, respectively) are primarily responsible for the reduced 2002 cadmium criterion, since the other genus mean chronic values included in the 2002 database do not differ from those included in the databases used in the calculation of the 1984 and 1995 criteria. This lower 2002 criterion does not provide any added protection for salmonids which, as can be seen in Table 2, are at least 10 times less sensitive than *Hyalella* and at least 6 times less sensitive than *Daphnia* (i.e., chronic values for salmonids ranging between 2.44 and 6.30 ug/l). In addition, the lower 2002 cadmium chronic criterion does not provide additional protection for invertebrate species that could serve as prey items for salmonids. Based on acute toxicity data, these invertebrate species are less sensitive to cadmium than the salmonids themselves.

As noted above, in the case of cadmium, the chronic criterion is calculated directly using chronic data and, therefore, incorporation of low chronic daphnid data into the criterion-setting database reduces the resulting cadmium chronic criterion. If one were to use only the data for salmonids, the resulting criterion would be 2.44 ug/l at a water hardness of 50 mg/l.

It should be noted that another important factor in generating the inappropriately low 2002 cadmium chronic criterion is the underlying assumption concerning the size of the database. In 1984, the USEPA initially calculated the cadmium criteria based on 13 genus mean chronic values. Using N = 13 in the calculation algorithm would have produced a chronic criterion of 0.0405 ug/l (at a water hardness of 50 mg/l). However, USEPA decided that the use of N =13 was inappropriate in the calculation because, as stated in the 1984 Criteria Document (UESPA 1984b), "the thirteen Genus Chronic Values contain values for five of the six freshwater genera that are acutely most sensitive to cadmium, and it seemed more appropriate to calculate the Final Chronic Value using N = 44, rather than N = 13". When this adjustment was made to correct for the underlying bias of the chronic data, the chronic criterion was set at 0.6582 ug/l (at a water hardness of 50 mg/l). This is an increase in the criterion by a factor of 16. This issue still holds for the database used to establish the 2002 criterion (i.e., based on N=16) and should have been addressed in the same manner as was used in 1984. There is no explanation in the 2002 criterion document as to why the "bias adjustment" was not made. Perhaps it was an oversight.

It should also be noted that, of the three cadmium criteria developed since 1984, the one developed in 1995 (USEPA 1996) is the most appropriate for Railroad Creek. The 1995 criterion is less stringent than either the 2002 or the 1984 criteria. At a water hardness of 10 ppm, the 1995 chronic criterion is 0.404 ug/l, whereas the 1984 and 2002 chronic criteria are 0.186 ug/l and 0.049 ug/l, respectively. However, this decreased conservatism of the 1995 criterion does not endanger the species of concern in Railroad Creek. As illustrated in Table 2, the 1995 criterion is higher due to a decreased emphasis on the protection of daphnids. In both the 1995 and 1984 criteria, the most sensitive genus is *Daphnia* and the assigned genus mean chronic value is the same in both documents. However, in 1984, two additional genera of very sensitive cladocerans (*Moina* and *Ceriodaphnia*) were also considered in the development of the criterion. These genera were eliminated from consideration in 1995 (as well as in 2002), resulting in a higher 1995 criterion. The salmonids are still protected by this less stringent 1995 criterion because the salmon genera are (based on the 1995 database) 25 to 57 times less sensitive to cadmium than are the daphnids (i.e., salmonid chronic values ranging from 3.399 to 7.771 ug/l). In addition, the 1995 cadmium chronic criterion provides more than adequate protection for invertebrate species that could serve as prey items for salmonids because these invertebrate species are less sensitive to cadmium than the salmonids themselves.

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Table 1. Basis for Copper Ambient Water Quality Criteria - Comparison of 1984 and 2002 Criteria

1984 Criteria			2002 Criteria		
Rank	**Genus**	**Genus Mean Acute Value (ug/l) @ hardness = 50 ppm**	**Rank**	**Genus**	**Genus Mean Acute Value (ug/l) @ hardness = 50 ppm**
1	Squawfish (Ptychocheilus)	16.74	1	**Cladoceran (Ceriodaphnia)**	**9.92**
2	**Cladoceran (Daphnia)**	**17.08**	2	**Cladoceran (Daphnia)**	**14.48**
3	**Cladoceran (Ceriodaphnia)**	**18.77**	3	Squawfish (Ptychocheilus)	16.74
4	Amphipod (Gammarus)	25.22	4	Amphipod (Gammarus)	22.09
5	Bryozoan (Plumatella)	37.05	5	Bryozoan (Plumatella)	37.05
6	Bryozoan (Lophopodella)	37.05	6	Bryozoan (Lophopodella)	37.05
7	Snail (Physa)	39.33	7	Snail (Physa)	39.33
8	Worm (Limnodrilus)	53.08	8	Bass (Morone)	52
9	Snail (Gyraulis)	56.21	9	Worm (Limnodrilus)	53.08
10	Bullhead (Ictalurus)	69.81	10	Snail (Gyraulis)	56.21
11	Midge (Chironomus)	76.92	11	Bullhead (Ictalurus)	69.81
12	Stoneroller (Campostoma)	78.55	12	**Salmonid (Oncorhynchus)**	**73.99**
13	**Salmonid (Salmo)**	**82.11**	13	Stoneroller (Campostoma)	78.55
14	Chub (Semotilus)	83.97	14	Guppy (Poecilia)	83
15	Dace (Rhinichthys)	86.67	15	Chub (Semotilus)	83.97
16	**Salmonid (Oncorhynchus)**	**88.54**	16	Dace (Rhinichthys)	86.67
17	Worm (Nals)	90	17	Worm (Nals)	90
18	Minnow (Pimephales)	91.29	18	Minnow (Pimephales)	97.9
19	**Salmonid (Salvelinus)**	**110**	19	**Salmonid (Salmo)**	**110**
20	Guppy (Poecilia)	125	20	**Salmonid (Salvelinus)**	**110**
Chronic Criteria @ hardness = 10 ppm		**1.653**	**Chronic Criteria @ hardness = 10 ppm**		**1.304**

Table 2. Basis for Cadmium Ambient Water Quality Criteria - Comparison of 1984, 1995, and 2002 Criteria

1984 Criteria			1995 Criteria			2002 Criteria		
Rank	Genus	Genus Mean Chronic Value (ug/l)*	Rank	Genus	Genus Mean Chronic Value (ug/l)*	Rank	Genus	Genus Mean Chronic Value (ug/l)*
1	**Cladoceran (Daphnia)**	**0.1354**	1	**Cladoceran (Daphnia)**	**0.1354**	1	Amphipod (Hyalella)	0.2747
2	**Cladoceran (Moina)**	**0.1918**	2	**Salmonid (Oncorhynchus)**	**3.399**	2	**Cladoceran (Daphnia)**	**0.3794**
3	**Salmonid (Oncorhynchus)**	**3.399**	3	**Salmonid (Salvelinus)**	**4.383**	3	**Salmonid (Oncorhynchus)**	**2.443**
4	**Cladoceran (Ceriodaphnia)**	**3.932**	4	Snail (Aplexa)	4.841	4	Midge (Chironomous)	**2.804**
5	**Salmonid (Salvelinus)**	**4.383**	5	Flagfish (Jordanella)	5.336	5	**Salmonid (Salvelinus)**	**4.624**
6	Snail (Aplexa)	4.841	6	**Salmonid (Salmo)**	**7.771**	6	Snail (Aplexa)	4.82
7	Flagfish (Jordanella)	5.336	7	Sucker (Catostomus)	7.849	7	Flagfish (Jordanella)	5.318
8	**Salmonid (Salmo)**	**7.771**	8	Pike (Esox)	8.138	8	**Salmonid (Salmo)**	**6.296**
9	Sucker (Catostomus)	7.849	9	Bass (Micropterus)	8.17	9	Sucker (Catostomus)	7.804
10	Pike (Esox)	8.138	10	Minnow (Pimephales)	15.4	10	Pike (Esox)	8.092
11	Bass (Micropterus)	8.17	11	Bluegill (Lepomis)	16.32	11	Bass (Micropterus)	8.12
12	Minnow (Pimephales)	15.22	12	Oligochaete (Aeolosoma)	20.5	12	Minnow (Pimephales)	16.4
13	Bluegill (Lepomis)	16.32				13	Bluegill (Lepomis)	17.38
						14	Oligochaete (Aeolosoma)	20.74
	Criterion @ hardness = 10 ppm	**0.186**		**Criterion @ hardness = 10 ppm**	**0.404**		**Criterion @ hardness = 10 ppm**	**0.0494**
	Criterion @ hardness = 50 ppm	**0.658 (n=44)** [0.0405 if n=13]		**Criterion @ hardness = 50 ppm**	**1.429**		**Criterion @ hardness = 50 ppm**	**0.152**

* - Genus Mean Chronic Values are reported at a water hardness of 50 ppm

Critique of Applying USEPA Ambient Water Quality Criterion for Iron as a Cleanup Level for the Holden Mine Site

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It has been suggested by the regulatory agencies that the National Ambient Water Quality Criterion (NAWQC) for iron be adopted as a cleanup level for the Holden Mine Site. However, a review of this criterion (which was issued in 1976) and of more recent scientific publications on the ecotoxicity of iron clearly indicates that application of the NWQC would be overly conservative for the Holden Mine Site and, therefore, not appropriate as a cleanup level. This information should be considered when evaluating the NWQC as a potential ARAR for the Holden Mine Site.

Of principal concern is the unscientific basis of the NWQC for iron. It was issued as guidance in 1976 at 1.0 mg/l (total iron) and has not been modified since. As stated in the criterion document, it is "based on field observations principally". Reliance on field observations greatly reduces the accuracy of a criterion because it is not possible to discriminate between the effects of co-occurring multiple toxicants (e.g., low pH, iron, and other heavy metals). In fact, a review of the actual documents cited in the 1976 NWQC for iron clearly indicates that, in those cases in which an attempt was made to measure other contaminants, adverse impacts to fish were primarily observed when pH was depressed (Brandt 1948, Doudoroff & Katz 1953)[1]. In its database on Toxicological Benchmarks for Screening Potential Contaminants of Potential Concern for Effects on Aquatic Biota (updated in 1996), the Oakridge National Laboratory acknowledges this concern and states that "the NAWQC for iron is based on a field study at a site receiving acid mine drainage and is not consistent with current methods for deriving criteria". It should be noted that, in the early to mid 1980s, USEPA developed NWQCs for almost all heavy metals of concern, using a procedure which requires a robust set of toxicological data generated under controlled laboratory conditions. No such effort has currently been undertaken for iron.

A review of the scientific literature since 1976 indicates that the toxicity of iron to aquatic organisms has not been a major area of investigation. However, the studies that have been performed clearly demonstrate that the toxicity of iron to both fish and invertebrates in natural stream waters (such as those found in Railroad Creek) is governed by the effects of the iron floc produced rather than by dissolved iron (which is a very small percentage of the total iron due to the very low solubility of iron under aerobic and neutral pH conditions). In addition, after the initial formation of the iron floc, it rapidly becomes less toxic to fish and invertebrates because of changes in the floc's physical structure (i.e, precipitated particles get larger and are less able to bind to gills and cell membranes of aquatic organisms).

[1] Results reported in these papers are for exposures performed at pHs of between 5 and 6. In Railroad Creek, the median pH is 7.1 during spring high flow and 6.8 during fall low flow.

For salmonids in Railroad Creek, the scientific literature suggests that a protective concentration of iron from prolonged exposure (i.e., 30 days to 2 years) is between 3 and 6 ppm. In 35-week and 2-year studies on brook trout exposed to iron floc (Sykora et al. 1972 and Sykora et al. 1975, respectively), it was demonstrated that brook trout do not suffer reduced survival, growth, or egg hatchability at concentrations less than 12 ppm. Rainbow trout appear to have a similar level of sensitivity. In fish farms in Germany, it was reported that rainbow trout exhibited good survival and growth when the total iron content in the water was between 5 and 10 ppm as long as the pH was circumneutral or slightly alkaline and the dissolved oxygen remained higher than 5 mg/l (Steffins et al. 1993). Fertilized eggs of coho salmon and brook trout, exposed for approximately 45 days, exhibited no reduction in hatchability at 12 ppm iron floc, which was the highest concentration tested (Smith & Sykora 1976). In the same study, when exposed for 30, 60 and 90 days, coho salmon juveniles suffered reduced survival and growth in 6 ppm iron floc, but were not adversely affected in a 3 ppm solution (Smith & Sykora 1976). Smith et al. (1973) suggest that fish species that "live in cool, fast-flowing, spring-fed streams, where iron is more common and remains in suspension for longer periods" are more resistant to the toxicological effects of iron floc than are other species of fish.

For invertebrates likely to be found in Railroad Creek, the scientific literature suggests a wide range of sensitivities to iron, with a protective level of approximately 5 ppm for the most sensitive species and a much higher level for the majority of species. Daphnids, which are not residents of fast-flowing streams such as Railroad Creek, are apparently the most sensitive aquatic invertebrates to iron. However, even for daphnids, under conditions found in Railroad Creek, a 3-week exposure resulted in a LOEC (i.e., lowest observed effect concentration) for reproduction of 4.38 ppm and a LC50 for survival of 5.9 ppm (Biesinger and Christensen 1972, Dave 1984). Other stream invertebrate species have been shown to be considerably less sensitive, with the mayfly, *Leptophlebia marginata*, exhibiting no reduction in survival when exposed for 30 days at 40 ppm (Gerhardt 1995). Warnick & Bell (1969) reported 7-day and 9-day LC50s of 16 ppm for a caddisfly, *Hydropsyche betteni*, and a stonefly, *Acroneuria lycorias*, respectively.[2]

Based on available monitoring data in Railroad Creek, concentrations of total are likely to be the highest during low-flow periods and will exceed 1 ppm (with a maximum of approximately 2.6 ppm). The available toxicological data clearly indicates that this exposure scenario will not adversely impact salmonid eggs or juveniles or the prey items upon which they feed.

It should be noted that several studies have been reported in the toxicological literature which indicate that some aquatic species can be inversely impacted by iron at concentrations less than 1.0 mg/l. For example, Dave (1984) reports a 21-day chronic value of 0.158 mg/l for Daphnia magna and Amelung (1982) reports acute mortality to freshly hatched rainbow trout at 0.47 mg/l. However, a review of these studies indicates that the results are based on a different form of iron than would be found in Railroad Creek and, therefore, are not applicable to Railroad Creek. In some of these studies, the test organisms were exposed to the reduced, ferrous form of iron;

[2] In the same study, they reported that a mayfly, *Ephemerella subvaria*, had a 96-hr LC50 of 0.32 ppm. However, as pointed out in the Canadian Water Quality Guidelines for Iron (1987), this value is in question because of the unusual sensitivity exhibited by this species to almost every metal tested in the Warnick & Bell study.

whereas in Railroad Creek iron is in the oxidized, ferric form.[3] In other of these studies, the oxidation and precipitation of iron occurred in the exposure chamber and, consequently, the test organisms were exposed to very fine ferric hydroxide precipitates which aggressively bind to gills and cause suffocation. In a majority of Railroad Creek, on the other hand, the salmonids and their prey items would be exposed to much larger ferric hydroxide precipitates because the iron has been oxidized and precipitated further upstream. As explained above, these larger particles are less likely to bind to the gills of aquatic organisms and, therefore, are less harmful to aquatic life.

In summary, the NWQC for iron is not based on current scientific literature and it does not consider differences in the toxicological effects of the different forms of iron described above. If the current scientific literature was used to formulate a water quality criterion for iron in Railroad Creek, the resulting value would likely fall in the 3 to 6 ppm range.

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[3] As reported in the scientific literature, the ferric form of iron is less toxic than the ferrous form.

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Critique of Applying USEPA Ambient Water Quality Criterion for Aluminum as a Cleanup Level for the Holden Mine Site

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It has been suggested by the regulatory agencies that the National Ambient Water Quality Criterion (NAWQC) for aluminum be adopted as a cleanup level for the Holden Mine Site. However, a review of this criterion (which was issued in 1988) and of more recent scientific publications on the ecotoxicity of aluminum clearly indicates that application of the NAWQC would be overly conservative for the Holden Mine Site and, therefore, not appropriate as a cleanup level. Of principal concern is the unorthodox manner in which the NAWQC for aluminum was derived and, consequently, the inapplicability of the criterion to Railroad Creek. This information should be considered when evaluating the NAWQC as a potential ARAR for the Holden Mine Site.

Unorthodox Method Used in Deriving Aluminum Chronic Criterion

The ambient water quality criterion for aluminum for chronic exposure is set at 87 ug/l as total recoverable aluminum (USEPA 1988). This criterion was not derived following the normal EPA procedures (USEPA 1985), but rather was based solely on the results of two studies, neither of which were deemed of sufficient quality by EPA to be used as input data in the normal chronic criterion calculation procedure.

In the 1988 criteria document, EPA did derive a chronic criterion using standard procedures and came up with a value of 748 ug/l. The standard procedure used by EPA consisted of applying an Acute-to-Chronic Ratio (ACR) of 2.0 to the Final Acute Value of 1,496 ug/l. The Final Acute Value was based on results from 15 species of freshwater aquatic organisms representing 14 genera, with species mean LC50 values ranging from 1,900 ug/l to >79,900 ug/l. The chronic criterion was estimated from acute data because of the paucity of acceptable chronic data. In order to directly calculate a chronic criterion from chronic data, the database must consist of test results from at least 8 species representing 8 different families of freshwater aquatic organisms . In the NAWQC document, EPA identifies only 3 chronic tests which have acceptable data for criteria derivation purposes. This chronic database includes test results for two cladoceran species (i.e., Ceriodaphnia dubia and Daphnia magna) and one fish species (Pimephales promelas). The results of these chronic tests (ranging from 742 to 3,288 ug/l) are consistent with the calculated criterion of 748 ug/l.

This derived chronic criterion was then lowered by EPA to 87 ug/l in order to provide additional protection for brook trout and striped bass. This was deemed necessary by EPA because a 60-day brook trout test (Cleveland et al., undated manuscript) indicated that the NOEC for growth was 88 ug/l and the 7-day striped bass test (Buckler et al., undated manuscript) indicated that the NOEC for survival was 87.2 ug/l. Each of these tests was performed under slightly acidic conditions with a pH of 6.5 to 6.6. Interestingly, results from neither of these studies were included in the database of chronic results deemed acceptable by EPA for the derivation of criteria (Table 2 of the criteria document). Instead, they are included in Table 6 of the NAWQC document which includes "Other Data" which fall short of acceptability. Unfortunately, the citations for both of these studies (i.e., Buckler et al. and Cleveland et al.) are both undated manuscripts which were apparently not published and, therefore, cannot be reviewed to determine why EPA deemed them unacceptable for criteria derivation.

The aforementioned brook trout and striped bass results are inappropriate as the basis for a national criterion because they apply to an unusual chemical condition (i.e., low pH) and they are not supported by other studies. Applicability to only low pH situations is apparent because, as presented in the criteria document, Buckler et al. performed the striped bass tests at two pH values (i.e., 6.5 and 7.2) and the results were quite different for each pH. At the lower pH, the NOEC for survival was 87.2 ug/l, but at the slightly higher pH, the NOEC for survival was twice as high at 174.4 ug/l. Similarly, for brook trout, at pH 7.2 to 7.8, the onset of chronic effects appears to be in the range of 242 to 283 ug/l (Cleveland et al. 1986, Hunn et al 1987), as opposed to the 88 ug/l cited by EPA as the rationale for the lower chronic criterion. Inconsistency with other results is also apparent in data cited in the criteria document itself. Apparently, Buckler et al. performed two other studies with striped bass (both undated manuscripts) and found, in both studies, that there was no mortality to striped bass at 390 ug/l at either pH 6.5 or pH 7.2. Age-specific sensitivities to aluminum does not explain the differences in these results since in all three of the Buckler et al. studies, the age of the striped bass was essentially the same (i.e., 159 – 195 days old).

The over-conservatism of the aluminum chronic criterion is indicated in a review of toxicological benchmarks that were compiled by the Oak Ridge National Laboratory (Sutter and Tsao 1996). In this document, the authors indicate that "the toxicity of aluminum has been shown to vary widely with water hardness and pH" and considering data from tests in circumneutral water, the lowest chronic value for fish is 3,288 ug/l for fathead minnows and for invertebrates is 1,900 ug/l for daphnids.

In a more recent revision of the ambient water quality criteria (USEPA 1999), EPA has also recognized some short-comings with the criterion. EPA states that (apparently due to the unorthodox manner in which it was derived) the aluminum chronic criterion may not be appropriate for all ambient waters for the following three major reasons:

- "The value of 87 ug/l is based on a toxicity test with the striped bass in water with pH=6.5-6.6 and hardness <10mg/l. Data in "Aluminum Water Effect Ratio for the 3M Plant Effluent Discharge, Middleway, West Virginia" (May 1994) indicate that aluminum is substantially less toxic at higher pH and hardness, but effects of pH and hardness are not well quantified at this time."

- "In tests with the brook trout at low pH and hardness, effects increased with increasing concentrations of total aluminum even though the concentrations of dissolved aluminum were constant, indicating that total recoverable is a more appropriate measurement than dissolved, at least when particulate aluminum is primarily aluminum hydroxide particles.

In surface waters, however, that total recoverable procedure might measure aluminum associated with clay particles, which might be less toxic than aluminum associated with aluminum hydroxide."

- "EPA is aware of field data indicating that many high quality waters in the U.S. contain more than 87 ug aluminum/L, when either total recoverable or dissolved is measured."

Inapplicability of Aluminum Criterion to Railroad Creek

As described above, due to the unorthodox manner in which the aluminum chronic criterion was derived, it would be overly conservative if applied to Railroad Creek. In addition, there are two major issues which limit the applicability of this criterion to Railroad Creek. First, the criterion is based on providing protection for two species of fish (i.e., brook trout and striped bass) which do not occur in Railroad Creek. Second, the criterion assumes that all of the aluminum (both dissolved and particulate) occurs in chemical forms that are the most biologically available and toxic. Available data indicate that this is not the case for aluminum in Railroad Creek.

Resident Species are Less Sensitive - As mentioned above, the chronic criterion is based on tests performed with brook trout and striped bass. Neither of these species is resident in Railroad Creek and the available data suggest that other species which are resident are less sensitive to aluminum. Data on the sensitivity of aquatic species to aluminum are presented in the 1988 criteria document (USEPA 1988). Based on these data, rainbow trout are the most sensitive of the resident species tested, with an acute 96-hr LC50 of 10,390 ug/l. According to these data, rainbow trout are approximately 3 times less sensitive than brook trout (96-hr LC50 of 3,600 ug/l). Assuming that the acute and chronic relative sensitivities of these species are similar, one can conclude that, based solely on sensitivity, a concentration of aluminum which is safe for resident species in Railroad Creek, including rainbow trout and other salmonids, can be set at 3 times the ambient criterion or approximately 260 ug/l. It should be noted that this estimated safe concentration of aluminum would still be overly conservative because it is primarily based on the sensitivity of the early life-stages of salmonids. Since resident rainbow trout and cutthroat trout do not spawn in Railroad Creek until mid-summer, the sensitive early-life stages are not present in the creek until September or October. At other times of the year, including the spring flush, early life-stage salmonids would not be present and, consequently, the concentration of aluminum which would be safe to the resident biological community would be substantially higher.

Portion of Aluminum is not Biologically Available - Specification of the aluminum chronic criterion as total recoverable metal is apparently overly protective for Railroad Creek because a significant portion of the aluminum that is attached to particulate matter will be in biologically unavailable and non-toxic forms. The aluminum which is found in Railroad Creek downstream of the portal drainage and tailings piles consists of aluminum that emanates from the portal and tailings piles and background aluminum which comes from sources upstream of the site. The aluminum emanating from the portals and tailings piles is expected to be mostly biologically available, consisting of dissolved aluminum and aluminum hydroxide-type floc. However, available monitoring data indicate that there is a relatively high background concentration of total aluminum (i.e., a mean of 86 ug/l) and that approximately 66% of this background aluminum (i.e., 57 ug/l) is associated with rock particles (i.e., feldspars and micas) and clay particles (i.e., aluminum silicates), which are not biologically available. Therefore, for Railroad Creek, the chronic criterion of 87 ug/l should be increased by 57 ug/l in order to account for this difference in chemical form. The aforementioned adjustment to the criterion due to the sensitivity of resident species should be added to this chemical-form adjustment resulting in a site-specific criterion of approximately 320 ug/l.

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APPENDIX C
SUMMARY OF PRELIMINARY ANALYSES
ON SITE RELOCATION OF TAILINGS PILES, MINE BACKFILLING, AND TAILINGS REPROCESSING OPTIONS

TABLES

FIGURES

MEMORANDUM

TO: Jennifer Deters, URS-Seattle

FROM: Rik Langendoen, URS-Seattle

TOPIC: Summary of Preliminary Analyses
On site Relocation of Tailings Piles, Mine Backfilling &Tailings Reprocessing Options
Holden Mine RI/FS Project, Chelan County, Washington

DATE: June 6, 2002

COMMENTS:

INTRODUCTION

This memorandum has been prepared in support of the ongoing Holden Mine Remedial Investigation and Feasibility Study (RI/FS) being completed by URS on behalf of Intalco. The subject Site is located in the Railroad Creek watershed of Lake Chelan situated in north-central Washington State (Figures F-1, F-2 and F-3). The U.S. Forest Service (Forest Service), U.S. Environmental Protection Agency (USEPA) and the Washington State Department of Ecology (Ecology), hereafter noted as the Agencies, are overseeing the preparation of the RI/FS.

The draft FS Report includes the detailed analysis of eight remedial alternatives developed by the Agencies and Intalco through a series of meetings and communications conducted between January 2001 and March 2002. Three process options that were not included in these alternatives include the on site relocation of tailings, mine backfilling, and tailings reprocessing. These options were evaluated and eliminated during the technology evaluation and screening step as a result of preliminary analyses by URS. The Agencies have requested that Intalco prepare a memorandum summarizing the results of the preliminary analyses that lead to the elimination of these process options from further consideration in the detailed analysis. This memorandum serves to address the Agency request.

ON SITE RELOCATION OF TAILINGS

Overview

The Agencies requested that Intaclo evaluate the relocation of the tailings piles to another location within the Railroad Creek drainage. The objective of on site tailings relocation would be to reduce impacts to surface water and groundwater resulting from tailings pile drainage, and to reduce the potential for a release of tailings due to a potential slope failure or high stream flow. Off site relocation of the tailings was not considered feasible due to the logistics of having to barge all materials to any site outside the Railroad Creek watershed.

Approximately 230,500,000 cubic feet (8,500,000 cubic yards) of tailings are currently contained in three piles located along Railroad Creek. Based on the review of aerial photographs (stereo sets, USDA Forest Service, 1992), five potential sites were identified for relocation of the tailings within the portion of the Railroad Creek watershed outside of the Glacier Peak Wilderness Area. The sites were identified based on topography and size; all of the identified sites have a relatively flat to gently sloping topography and an area estimated to be greater than 15 acres in size.

It has been assumed that the construction of engineered containment cells would be required at the potential sites prior to disposal of the tailings. A liner would be placed below the material, and the new piles would be covered with an engineered cap or revegetated as appropriate.

Based on the volume estimates and shortened construction season due to snow being typically on the ground between later October and May, the relocation of the three tailings piles would likely require several field seasons to complete. To prevent potential impacts to the selected site(s) and to Railroad Creek at the current disposal location, it is assumed that cover material would be placed over exposed tailings at the end of each field season. Although this cover material could be reused from season to season, native sources are limited and, therefore, material would likely need to be hauled in from off site for this purpose.

Accommodations for construction crews would be limited at Holden Village without disrupting current operations. The village typically operates at capacity for a majority of the summer months. Temporary facilities would likely be needed for the personnel, and additional existing water, waste, and sewage systems would likely need to be provided.

The following subsections provide a description of each potential disposal site, including the relative advantages and disadvantages of each and a list of equipment potentially required for tailings relocation. The approximate locations of the five sites are shown on Figure F-2.

Area A

Description

Area A consists of approximately 18 acres located immediately west of Tailings Pile 1, as shown on Figures F-2 and F-4. The site extends west from the foot bridge, includes the lagoon area, and is bordered on the north and west sides by Railroad Creek, and the south side by the north-facing slope on which the waste rock piles and maintenance yard are situated.

Assuming that the pile would be built with 2 foot horizontal to 1 foot vertical (2H:1V) side slopes placed in a pyramid shape, it is estimated that this site could hold a maximum of approximately 1.5 million cubic yards of tailings (approximately 18% of the total quantity currently contained in the three tailings piles) with a resulting pile height of 90 feet; volume calculations are presented in Table F-1).

Advantages

Area A is located on the south side of Railroad Creek, immediately west of Tailings Pile 1. Relocation of the tailings to this site would not require crossing Railroad Creek, and large scrapers could be used to transport a majority of the material instead of using loaders and haul trucks. The use of scrapers would reduce equipment mobilization requirements, and shorten the overall relocation time.

Disposal at Area A would require fewer improvements to the existing infrastructure (e.g. roads, bridges) relative to the other sites identified because scrapers and other equipment could operate on the existing tailings piles and roads.

Disadvantages

Area A is too small to hold all of the existing tailings. The site could be used in conjunction with other sites, or with other technologies; however, relocation of the tailing to this site could not be used as a stand-alone solution.

Area A may be less suitable due to its close proximity to Railroad Creek, and the shallow groundwater table. The site location is very similar to the current location of the three tailings piles with respect to Railroad Creek and the relatively high seasonal water table. Portions of the area are currently under water during the spring and early summer. An elevated water table can cause a reverse pressure gradient to occur on a lined impoundment, reducing the effectiveness of the liner.

The site is situated near Railroad Creek, within its historic flood plain. There is a potential risk for erosion by Railroad Creek during storm events. Therefore, erosion control measures would be required prior to disposing of material at this location.

Assuming large capacity scrapers (40 cubic-yard capacity) could be used to move a majority of the tailings, approximately 37,500 round-trips would be required to move 1.5 million cubic yards of material to the new location. The construction season for this site would be limited from mid July to early November (post spring run-off to the first snow). Assuming a 122-day construction season, 12-hour shifts, and 2 trips per hour per scraper, it would take a fleet of 10 scrapers approximately 2 construction seasons to complete the relocation, and approximately 38,000 gallons of diesel fuel based on an assumed consumption rates of 20 gallons per hour per scraper.

The use of Area A would temporarily impair access to the maintenance yard due to closing of the current road from the vehicle bridge, and an alternate route may be difficult to provide for the Holden Village. The Holden Village's maintenance garage, composting facility, incinerator, and water treatment system is currently located in this area. Substantial land clearing would also be required during preparation of this site.

The placement of tailings at Area A would have similar visual impacts as the existing tailings piles.

Estimated Cost

The estimated capital cost to implement the relocation of the tailings materials to Area A is approximately $32 million in 2002 dollars (Table F-6). These costs do not include long-term operations and maintenance (O&M) of the new containment area, restoration of the current tailings pile location, or the construction and operation of water treatment facilities at the new or current location.

Potential Equipment and Material Types

- 40-cubic yard (or larger) scrapers
- Spreaders
- Sheeps-foot rollers
- Dozers
- Water trucks
- Roller compactors
- Site clearing equipment
- De-watering equipment; pumps and piping, power (diesel generator)
- Bentonite (or equivalent) liner
- Equipment and materials for construction of an engineered or vegetated cap

Area B

Description

Area B consists of approximately 60 acres located to the east of Tailings Pile 3, as shown on Figures F- 2 and F-4. The site is situated on the north side of Railroad Creek, in the existing wetland area between the road and the creek.

Assuming the pile would be built with 2H:1V side slopes placed in a pyramid shape, it is estimated this area could hold all 8.5 million cubic yards of existing tailings with a resulting pile height of approximately 145 feet; volume calculations are presented in Table F-2.

Advantages

Area B is large enough to hold all of the tailings at one location. In addition, the site is located immediately east of Tailings Pile 3, resulting in a relatively short haul distance compared with other sites under consideration.

Disadvantages

Area B is located across Railroad Creek from Tailings Pile 3. As a result, construction of a bridge, or the installation of culverts to act as a bridge, would be required. The potential for adverse impacts to Railroad Creek due to accidental spillage would be increased. Permits from the US Forest Service, the Army Corp of Engineers, the State of Washington Fish and Wildlife Department, and possibly Chelan County may be required prior to construction of a bridge or installation of culverts at this location.

Assuming that large capacity scrapers (40 cubic-yards) could be used to move a majority of the tailings, approximately 212,500 round-trips (using scrapers) would be required to move the entire 8.5 million cubic yards of material to the new location. The construction season for this site would be limited from mid July to early November (post spring run-off to the first snow). Assuming a 122-day construction season, 12-hour shifts, and 2 trips per hour per scraper, it would take a fleet of 10 scrapers more than 7 construction seasons to complete the relocation, and approximately 213,000 gallons of diesel fuel based on an assumed consumption rates of 20 gallons per hour per scraper.

This site includes land that likely would be classified as a wetland. If tailings were placed within a designated wetland, a wetland of equal size, or larger, would likely need to be created elsewhere. However, there is the potential for creation of a new wetland at the current location of tailings piles 1, 2 and 3 following relocation. In addition, endangered and/or threatened species of plants and/or animals may be present in the area; this would need to be evaluated before any earthwork was conducted.

As with Area A, Area B would not be ideal due to its close proximity to Railroad Creek, and the shallow groundwater table. The site location is very similar to the current location of the three tailings piles with respect to Railroad Creek and the water table. Portions of Area B are under water during the spring and early summer, and beaver ponds have been observed in the area. An elevated water table can cause a reverse pressure gradient to occur on a lined impoundment, reducing the liner's effectiveness.

The site is situated near Railroad Creek, within its historic flood plain. There is a potential risk for erosion by Railroad Creek during storm events. Therefore, erosion control measures would be required prior to disposing of material at this location.

Although the topography is relatively flat in this location, substantial land clearing would be required during site preparation. In addition, Area B is bisected by the lower reach of Tenmile Creek. Therefore, the placement of the tailings at this location would require that the creek be either diverted or placed in a culvert that would be buried beneath the tailings.

The placement of tailings at Area B would have similar visual impacts as the existing tailings piles.

Estimated Cost

The estimated capital cost to implement the relocation of the tailings materials to Area B, is approximately $155 million in 2002 dollars (Table F-7). These costs do not include long-term operations and maintenance (O&M) of the new containment area, restoration of the current tailings pile location, or the construction and operation of water treatment facilities at the new or current location.

Potential Equipment and Material Types

- 40-cubic yard (or larger) scrapers
- Spreaders
- Sheeps-foot rollers
- Dozers
- Water trucks
- Roller compactors
- Site clearing equipment
- De-watering equipment; pumps and piping, power (diesel generator)
- Bentonite (or equivalent) liner
- Equipment and materials for construction of an engineered or vegetated cap
- Equipment and materials for construction of a bridge across Railroad Creek
- Backhoe, fertilizer, native plants – for wetland creation
- Temporary cover material for placement at the end of each construction season

Area C

Description

Area C consists of approximately 30 acres located across Railroad Creek to the northwest of tailings pile 1 and west of Holden Village, as shown on Figures F-2 and F-5. This area extends from the Glacier Peak Wilderness boundary on the west, to the Holden Village septic field on the east. The site includes the Holden baseball field, the Forest Service Campground, the Winston Home Site area (with the exception of the Holden Village septic field), and the surrounding lowlands.

Assuming 2H:1V side slopes, it is estimated that this area could potentially hold 3.5 million cubic yards of tailings (approximately 41% of the total quantity currently contained in the three tailings piles) with a resulting pile of height of 80 feet; volume calculations are presented in Table F-3.

This site is at the base of an established avalanche chute. Because the valley becomes increasingly steep at the elevation approximately 80-feet above Railroad Creek, this was determined to be the upper-most point that would be useful for placement of the tailings. To construct the tailings pile any higher would result in an increased risk of the liner being damaged by an avalanche.

Advantages

Area C is located a relatively short distance from the existing tailings piles, and scrapers could likely be used to transport a majority of the material, instead of a loader and haul trucks. The use of large scrapers would reduce equipment mobilization requirements, and shorten the overall relocation time.

Disposal at this location would require minimal road construction since equipment could operate on existing roads with improvements. However, construction of a short segment of new road (approximately 500 feet would be required).

Disadvantages

Area C is too small to hold all of the existing tailings. The site could be used in conjunction with other sites, or with other technologies; however, relocation of the tailing to this site could not be used as a stand-alone solution.

Area C is located across Railroad Creek from the tailings piles. As a result, the construction of a bridge, or culverts that would act as a bridge, would be required. The existing vehicle-bridge may potentially be upgraded to meet these requirements; however, the bridge would likely not accommodate scrapers and significant improvements would be required for increasing the weight capacity. Permits from the US Forest Service, the Army Corp of Engineers, the State of Washington Fish and Wildlife Department, and possibly Chelan County would be required prior to construction of a bridge or placement of culverts at this location. Transportation of material across Railroad Creek would also increase the potential for adverse impacts due to accidental spillage.

Assuming large capacity scrapers (40 cubic-yards) could be used to move a majority of the tailings, approximately 87,500 round-trips would be still required to move the entire 3.5 million cubic yards of material to the new location. The construction season for this site would be limited from mid July to early November (post spring run-off to the first snow). Assuming a 122-day construction season, 12-hour shifts, and 2 trips per hour per scraper, it would take a fleet of 10 scrapers approximately 3 construction seasons to complete the relocation, and about 88,000 gallons of diesel fuel based on an assumed consumption rates of 20 gallons per hour per scraper.

A portion of Area C is currently used by Holden Village as recreational playing fields. Placement of tailings in this area would likely require approval by Holden Village, even though it is recognized that the playing fields are on Forest Service managed land. Additionally, disposal at this location would require the relocation of the existing campground operated by the Forest Service, and the trailhead for the Glacier Peak Wilderness Area. The construction activities and transportation of tailings would occur immediately adjacent to the Glacier Peak Wilderness Area; it would be difficult if not impossible to prevent the windblown transport and deposition of tailings within the wilderness boundary.

We understand that the Winston Home Sites has been nominated to be on the Federal Register of Historic Places and results of this are pending.

Area C is located in close proximity to Railroad Creek and there is a potential risk for erosion during a 100-year storm event. Therefore, erosion control measures may be required prior to disposing of material at this location.

The relocation of materials to Area C would temporarily impair access to the maintenance yard due to the use of the current road from the tailings to the new location, and an alternate route may be difficult to provide for the Holden Village. The Holden Village's maintenance garage, composting facility, incinerator, and water treatment system is currently located in this area. Substantial land clearing would also be required during preparation of this site.

The placement of tailings at Area C would have similar visual impacts as the existing tailings piles.

Estimated Cost

The estimated capital cost to implement the relocation of the tailings materials to Area C is approximately $68 million in 2002 dollars (Table F-8). These costs do not include long-term operations and maintenance (O&M) of the new containment area, restoration of the current tailings pile location, or the construction and operation of water treatment facilities at the new or current location.

Potential Equipment and Material types

- 40-cubic yard (or larger) scrapers
- Spreaders
- Sheeps-foot rollers
- Dozers
- Water trucks
- Roller compactor
- Site clearing equipment
- De-watering equipment; pumps and piping, power (diesel generator)
- Bentonite (or equivalent) liner
- Equipment and materials for construction of an engineered or vegetated cap
- Equipment and materials for construction of a bridge across Railroad Creek
- Backhoe, fertilizer, native plants – for wetland creation
- Temporary cover material for placement at the end of each construction season

Area D

Description

Area D consists of approximately 64 acres located about 8 miles east of the existing tailings piles, in the immediate proximity of a rock quarry that was developed by the Forest Service as a riprap source during the Holden Mine Site rehabilitation effort completed between 1989 and 1991. The quarry is no longer in use but has been identified as potential source of riprap for future site work, even though the rock generally appears to be of relatively low quality. The location of Area D is shown on Figure F-2 and F-6. This area is slightly more sloped than the other prospect areas, and is estimated to average between 6 and 15 percent slope.

Assuming 2H:1V side slopes, it is estimated that this area could potentially hold nearly all 8.5 million cubic yards of existing tailings materials with a resulting pile of height of approximately 92 feet; volume calculations are presented in Table F-4.

Advantages

Area D is large enough to hold all the tailings at one location. Additionally, the site is located well above the water table at a stable location. An abandoned haul road currently exists to the site; however, the road has been officially closed by the Forest Service, and will require improvement to make it again useable.

Disadvantages

Area D is located approximately eight miles east of the current tailings pile locations and would require crossing Railroad Creek somewhere near the existing tailings piles. As a result of the transport distance, it will not be possible to utilize scrapers; therefore, the use of loaders and 15-cubic yard-haul trucks with trailers would be required to relocate material to this location. In order to move 8.5 million cubic yards of material with 15 cubic-yard-capacity haul trucks, approximately 567,000 round-trips would be required. A substantial road maintenance program would need to be implemented to accommodate the increased traffic, and the existing roads would need to be upgraded. The roads would require widening and the construction of turnaround points to allow trucks to pass.

The construction season for this site would be limited from mid July to early November (post spring run-off to the first snow). Assuming a 122-day construction season, 12-hour shifts, and 1 trip per hour per truck, it would take a fleet of 30 trucks approximately 13 construction seasons to complete the relocation, and approximately 189,000 gallons of diesel fuel based on an assumed consumption rates of 10 gallons per hour per truck.

Construction of a bridge across Railroad Creek, or culverts that would act as a bridge, would be required. The potential for adverse impacts to Railroad Creek due to accidental spillage would be increased. Permits from the US Forest Service, the Army Corp of Engineers, and the State of Washington Fish and Wildlife Department, and possibly Chelan County may be required prior to construction of a bridge or culvers at this location.

The Area D site would require additional work in clearing and preparing the liner due to the 6 to 15% slope throughout. Bedrock is near or near the ground surface, making the preparation of the subgrade for placement of a liner more difficult than the other sites.

The relocation of tailings to this area would result in significant disruption to the Holden Village operations due to the continuous use of the access road from Lucerne by haul trucks. Use of the access road would be required for multiple construction seasons.

The placement of tailings at Area D would have similar visual impacts as the existing tailings piles. The pile would not be visible from Holden Village but would be visible from the road between Lucerne and Holden Village, and would also be visible from Lake Chelan.

Estimated Cost

The estimated capital cost to implement the relocation of the tailings materials to Area D is approximately $183 million in 2002 dollars (Table F-9). These costs do not include long-term operations and maintenance (O&M) of the new containment area, restoration of the current tailings pile location, or the construction and operation of water treatment facilities at the new or current location.

Potential Equipment and Material types

- 10-cubic yard (or larger) light trucks
- Loaders
- Spreaders
- Sheeps-foot rollers
- Dozers
- Water trucks
- Roller compactors
- Site clearing equipment
- De-watering equipment; pumps and piping, power (diesel generator)
- Bentonite (or equivalent) liner
- Equipment and materials for construction of an engineered or vegetated cap
- Equipment and materials for construction of a bridge across Railroad Creek
- Temporary cover material for placement at the end of each construction season

Area E

Description

Area E consists of about 20.5 acres located approximately 8 miles east of the tailings piles in the area surrounding an existing gravel pit that is currently used by the Forest Service and is known as the "Dan's Camp" gravel source. The gravel source was used by the Forest Service to supply gravel cover for the tailings piles during the rehabilitation effort completed between 1989 and 1991. Area E is shown on Figures F-2 and F-6.

Assuming 2:1 side slopes, it is estimated that this area can hold approximately 3.15 million cubic yards of tailings (approximately 37% of the total quantity currently contained in the three tailings piles) with a resulting pile height of 125 feet; volume calculations are presented in Table F-5.

Advantages

The Area E site is located well above the water table. Additionally, a haul road exists to the site; therefore, major road construction would likely not be required for use of this location. This road is currently open, but may require additional improvements to be used consistently by haul trucks.

Disadvantages

Area E is too small to hold all of the existing tailings. The site could be used in conjunction with other sites, or with other technologies; however, relocation of the tailings to this site could not be used as a stand-alone solution.

The Area E site is located approximately eight miles east of the current tailings pile locations and would require crossing Railroad Creek at some location near the existing tailings piles. As a result, the use of loaders and 15-cubic yard-haul trucks and trailers would be required to relocate material to this location. In order to move 3.1 million cubic yards of material with 15 cubic-yard-capacity haul trucks, approximately 207,000 round-trips would be required. A substantial road maintenance program would have to be implemented to accommodate the increased traffic, and the existing roads would need to be upgraded. The roads would require widening and the construction of turnaround points to allow trucks to pass.

The construction season for this site would be limited from mid July to early November (post spring run-off to the first snow). Assuming a 122-day construction season, 12-hour shifts, and 1 trip per hour per truck, it would take a fleet of 30 trucks approximately 5 construction seasons to complete relocation to this site, and approximately 69,000 gallons of diesel fuel based on an assumed consumption rates of 10 gallons per hour per truck.

In addition, the site is located adjacent to a steep slope to Railroad Creek. The stability and practicality of building a landfill at this location would require further study.

Construction of a bridge, or installation of culverts that would act as a bridge, across Railroad Creek would be required. The potential for adverse impacts to Railroad Creek due to accidental spillage would be increased. Permits from the US Forest Service, the Army Corp of Engineers, and the State of Washington Fish and Wildlife Department, and possibly Chelan County may be required prior to construction of a bridge or culverts at this location.

The relocation of tailings to this area would result in significant disruption to the Holden Village operations due to the continuous use of the access road from Lucerne by haul trucks. Use of the access road would be required for multiple construction seasons.

The placement of tailings at Area E would have similar visual impacts as the existing tailings piles. The pile would not be visible from Holden Village but would be visible from the road between Lucerne and Holden Village, and would also be visible from Lake Chelan.

Estimated Cost

The estimated capital cost to implement the relocation of the tailings materials to Area E is approximately $72 million in 2002 dollars (Table F-10). These costs do not include long-term operations and maintenance (O&M) of the new containment area, restoration of the current tailings pile location, or the construction and operation of water treatment facilities at the new or current location.

Potential Equipment and Material types

- 10-cubic yard (or larger) light trucks
- Loaders
- Spreaders
- Sheeps-foot rollers
- Dozers
- Water trucks
- Roller compactors
- Site clearing equipment
- De-watering equipment; pumps and piping, power (diesel generator)
- Bentonite (or equivalent) liner
- Equipment and materials for construction of an engineered or vegetated cap
- Equipment and materials for construction of a bridge across Railroad Creek

Discussion

Comparison Between Alternative Relocation Areas

The above evaluation of the five potential on site areas for relocation of the tailings materials indicates that all of the sites are relatively comparable. The most significant differences are related to the areal size, transport distances from the existing tailings piles and visual impacts. Based on these differences, the site that would be able to accommodate all of the existing tailings materials with the least amount of adverse impacts is Area B. The area is one of the closest sites to the existing tailings piles and, based on the analysis, would be able to accommodate all of the existing tailings at one location. However, the placement of the tailings materials at this site would require the functions of the existing wetland to be eliminated, and Ten-Mile Creek would need to be rerouted or placed in a culvert beneath the tailings. It may be possible to off-set the loss of wetlands at the new disposal site by restoring the wetlands beneath the tailings piles.

Comparison Between Relocation and Leaving Tailings at Existing Location

In comparing relocating the tailings materials at Area B versus leaving the tailings piles at the existing location, the following advantages and disadvantages were noted:

<u>Advantages of relocating tailings to Area B</u>

- May provide enhanced control of leachate generated by the tailings
- May be able to potentially restore the groundwater quality beneath the existing tailings piles
- May be able to potentially restore the wetland function of the area beneath the existing tailings piles

<u>Disadvantages of relocating tailings to Area B</u>

- Would result in exposing unoxidized tailings that would cause the generation of additional acid-rock drainage when compared to regrading the existing tailings piles
- Would, therefore, require additional water to be treated when compared to regrading of the tailings piles
- Would disrupt operations of Holden Village more than regrading existing tailings piles
- Would result in higher risk to Holden Village inhabitants and visitors due to increased exposure to dust from tailings during transport
- The physical size limitation of even the best site would prevent utilizing passive treatment options; therefore, active treatment would be required. If more than one site is required for relocation, a treatment systems would need to be constructed for each site.
- The temporary impacts and risks to the environment resulting from the removal, transport and placement of the tailings materials to s different site may offset the benefits of relocating the piles.
- The cost of relocating the tailings to Area B is estimated to be $95,000,000, significantly higher than the costs to reslope the existing tailings to a 2H:1V, or to consolidate the three existing tailings piles into one pile.

Summary

The Agencies they have requested an evaluation of relocation of the tailings piles within the Railroad Creek drainage. The objective of on site tailings relocation would be to reduce impacts to surface water and groundwater resulting from tailings pile drainage, and to reduce the potential for a release of tailings due to a potential slope failure or high stream flow.

There are approximately 230,500,000 cubic feet (8,500,000 cubic yards) of tailings contained in three piles located along Railroad Creek. Based on the review of aerial photographs, five sites (Areas A through E) were identified as potentially suitable for tailings relocation within the Railroad Creek watershed, excluding the Glacier Peak Wilderness Area. The sites were identified based on topography and size, and all of the identified sites have a relatively flat to gently sloping topography and an area estimated to be greater than 15 acres.

Based on the analysis provided above, three of the five areas (Areas A, C, and E) would not be of sufficient size to contain all the tailings material, even with the three areas combined, and were therefore eliminated from further consideration. Of the two remaining identified areas that could accommodate the total volume of tailings, one is located approximately 8 miles east of the site (Area D), and one is located across Railroad Creek, just east of tailings pile 3 (Area B). These sites were not retained for further consideration due to the following:

- Relocation of the tailings to a new undisturbed location within the Railroad Creek watershed would not reduce the overall volume of tailings requiring long-term management in the valley.

- To relocate the tailings to Area B, located across Railroad Creek immediately east of tailings pile 3, it would take a fleet of ten 40-cubic yard scrapers more than seven construction seasons to complete, approximately 213,000 round trips, and 213,000 gallons of diesel fuel.

- To relocate the tailings to Area D, located approximately eight miles east of the Site, it would take a fleet of thirty 15-cubic yard haul trucks more than 13 construction seasons to complete, approximately 567,000 round trips, and 189,000 gallons of diesel fuel.

- The exposure of unoxidized tailings during excavation and relocation would potentially cause the generation of additional acid-rock drainage.

- During relocation, multiple water treatment systems may be required to mitigate acidic run-off from the new and current locations.

- Relocation would cause the disruption of the Holden Village over an extended period of time, and may result in a higher risk to Holden Village inhabitants and visitors due to increased exposure to dust from tailings during transport.

- The cost of relocating the tailings to Area B is estimated to be approximately $155,000,000 and the cost of relocating the tailings to Area D is estimated to be approximately $183,000,000.

Based on the above-mentioned findings, the relocation of the tailings to another on site area was not carried through the detailed analysis.

BACKFILLING OF THE UNDERGROUND MINE

Overview

The removal of ore materials from the mine resulted in the formation of underground voids, called stopes, as well as other tunnels and openings to allow human access, transport of ore and equipment, and ventilation. During operations, a large portion of the openings below the 1500 level of the mine was backfilled with tailings materials. Approximately 1.5 million cubic yards of tailings were reportedly backfilled in the mine over the period of operations. However, stopes present above the 1500 level of the mine were not backfilled. A number of the stopes have been documented to be within 50 feet of the ground surface. Therefore, the agencies have requested an evaluation of mine backfill as a possible means to reduce the potential for subsidence of these upper stopes, which could result in increased surface water infiltration and airflow into the mine.

An initial assessment completed as part of the RI indicated there was a potential for subsidence within the mine. Due to the relatively large size of the underground stopes, measures to mitigate the potential for future subsidence are limited. At other abandoned and active mine sites, tailings have been used with varying degrees of success to backfill underground openings to mitigate potential subsidence. The use of tailings as backfill was evaluated for the Site for the primary objective of reducing the potential for subsidence, and the secondary objective of reducing the volume of tailings outside the mine that currently provide a source of metals loading to surface water and groundwater.

The initial evaluation of backfilling options was conducted to: 1) identify primary issues related to backfilling open voids in the Holden Mine with tailings; 2) describe how such backfilling could be accomplished; 3) list likely advantages and disadvantages of backfilling the mine; and 4) list potential references and case studies for the issues raised.

Backfill Options

Tailings can be used for backfilling underground mines by either pumping the tailings into the open void spaces, or allowing them to flow by gravity. The tailings can be backfilled as dry material, or prepared for backfilling as either one of the following two types of non-Newtonian fluid:

- Hydraulic backfill that consists of a tailings slurry thickened to a viscous liquid
- Paste backfill that consists of thickened tailings and cement and possibly fly ash

Dry backfill was not considered for the Site due to the high degree of uncertainty regarding the ability to effectively place dry tailings within the non-uniform void spaces to prevent future settlement and provide structural support to mitigate the potential for subsidence. The dry backfill methods would be especially problematic for the large stopes (several of which are on the order of 700 feet in height) and numerous horizontal passages that would not allow for physical compaction of the tailings materials during placement. The method is also problematic for those stopes that are not near the ground surface and would underground transport.

As described further below, the hydraulic backfill method has been utilized at other sites but is also problematic. One of the challenges is addressing the decant water that needs to be captured, transported and treated. In addition, even though the method is more effective in achieving compaction than dry backfill methods, the results are less than acceptable if the objective is decreasing the potential for surface subsidence, especially for those large stopes (the largest being on the order of 700 in height) on the Holden site that present the highest potential for subsidence. It is possible to add hydraulic backfill as settlement occurs over time but this may take several or more years to achieve, and the effectiveness in reducing subsidence would still be uncertain.

Case studies have documented that mine stabilization is typically better achieved with paste backfill because the cement provides a more stable mass and easier management of water. The paste is prepared by dewatering the tailings as necessary, by conventional thickening or filtering, and mixing the dewatered tailings in a concrete-type batch plant with water and cement to obtain a consistency of medium slump concrete. The water and cement can be added together in the batch plant after dewatering, or the water can be added first, with the cement added later at the point where the tailings are discharged into the mine.

The paste, either with or without cement, is pumped to the mine where the cement can be added to create the paste. The pumping distances for known conventional paste backfill operations are typically less than approximately 3000 feet. The paste is then typically released by gravity down the mine shaft and flows horizontally to the voids being filled.

In order to have a workable paste, the tailings slurry must have a relatively consistent composition over time with at least some particles being smaller than 20 microns (625 mesh) in size. Relatively small amounts of cement such as 3 to 5% have produced stiff backfill material with strengths ranging from 200 to 500 pounds per square inch (psi).

Paste and Hydraulic Backfill Comparison

Comparisons between paste and hydraulic backfill methods are as follows:

- Paste backfill is stronger than hydraulic backfill because of the cement content
- Water does not need to be decanted from paste backfill, but does need to decanted from hydraulic backfill. Fine-grained material (such as slimes) is typically removed from the tailing matrix prior to hydraulic backfill to maintain a free-draining material.
- The decant water from hydraulic backfill contains fine tailings that causes wear on pumps and must be recaptured and safely disposed of
- All of the tailings can be usually be used for paste backfill, however, often only the coarser tailings are suited for hydraulic backfill
- Paste backfill is more dense and less porous than hydraulic backfill, so more tailings can be disposed underground
- Paste backfilling is faster than hydraulic backfilling because the consolidation and strength are achieved quicker and less barricading is necessary
- Paste backfilling can be a continuous operation because barricading is relatively simple, whereas hydraulic barricading usually must be started and stopped
- Paste systems require a higher capital investment than hydraulic systems but can have lower operating costs and increased productivity if there are adequate tailings

Tests Required for Backfill Feasibility Evaluation

The following geotechnical tests would be required to determine the suitability of using existing tailings for either paste or hydraulic backfill:

- Grain Size Distribution by Sieve and Hydrometer
- Grain Shape
- Mineralogy
- Moisture Content and Density
- Compaction (Optimum Moisture and Maximum Density)
- Atterberg Limits (Liquid and Plastic Limits)
- Porosity
- Permeability
- Abrasiveness
- Bin Flowability
- Slump vs. Water Content
- Thickening
- Filtration
- Cycloning
- Visual Paste Mixing
- Pipe Column Flow
- Compressive Strength

Full-scale pump tests would also be required at the site following the laboratory tests in order to scale paste flow characteristics from the laboratory to operating pipeline conditions. Therefore, the following pilot plant tests would need to be designed and completed on the basis of the geotechnical laboratory test results:

- Thickening at the Plant Site
- Filtration at the Plant Site
- Slump vs. Mixing Power Needs
- Pumping Loop Test

Current Conditions at Holden Mine Site

Based on available Site information, the following conditions exist at the Holden Mine site in terms of potential backfilling of the underground mine:

- Open stope volume estimated by URS: 67,938,000 cu. ft (2,516,222 cu. yd) (Table F-11)
- Estimated volume of tailings in tailings piles 1, 2, and 3: 229,500,000 cu. ft (8,500,000 cu. yd)
- Estimated moisture content of tailings: approximately 30 to 40 percent
- Tailings pile elevation: 3200 to 3300 ft approximately
- Stope levels elevation: 3450 (1500 Level) to 4500 feet (300 Level)
- Estimated horizontal transport distance of tailings to mix plant located near tailings pile 1:: 0 to 4350 ft.
- Vertical pumping from mix plant to 1500 & 300 portals: 250 to 1300 ft
- Horizontal pumping from mix plant to 1500 & 300 portals: 1200 to 3000 ft.

- Pipeline length from mix plant to 1500 & 300 Portals: 1226 ft (at 21%) to 3270 ft (at 44%)
- Pipeline length in 1500 level from portal into mine: as much as 8000 lateral ft.
- The largest stope is approximately 700 feet in height and the top of the stope is reported to be within about 50 feet of the ground surface

Discussion

Potential Advantages of Backfilling Holden Mine

The potential advantages of backfilling the underground workings at Holden Mine would include:

- May possibly remove approximately 30 percent of the tailings from the ground surface adjacent to Railroad Creek
- May potentially provide additional room to reshape the existing tailings piles to provide more stable slopes and revegetation.
- May potentially reduce concerns related to the potential for future subsidence
- The use of paste backfill may reduce the potential for the tailings particles to generate acid mine water

Disadvantages of Backfilling Holden Mine

The disadvantages of backfilling the underground workings at Holden Mine are as follows:

- A majority of the tailings piles would remain outside the mine, adjacent to Railroad Creek. These materials would require reshaping to provide stable slopes and allow for revegetation.
- Uncertain effectiveness in reducing the potential for future subsidence.
- Unknown effect on mine water quantity and quality.
- Significant power requirements would be associated with the use of large capacity pumps to convey paste or hydraulic backfill to the top of the open stopes. Implementation of this option would potentially require the construction of a conventional fuel-based power generation facility at the Site. It may be possible to transport the tailings to Honeymoon Heights by truck to reduce the pump capacity requirements. However, the Honeymoon Heights area has relatively steep topography, has limited area to construct an area to temporarily store the tailings and mix the tailings with water for backfilling, and the area that is potentially available near the pre-existing home sites (near the base of the 1100 level waste rock pile) is susceptible to avalanche danger.
- A large processing facility would be required for screen the tailings materials to achieve proper grain size distributions for either paste or hydraulic backfilling techniques. The operation of a large processing facility would be required for several seasons, and may impact Holden Village operations during this period.
- At 200 tons per hour, 8 hours per day, and 300 days per year, backfilling would take approximately 6.5 years.
- The backfill points at the ground surface along the strike of the stopes (in Honeymoon Heights) would be very difficult to access due to the existing topography.
- There is a high degree of uncertainty in terms of the safety of drilling holes from the surface into the top of the largest stope that has been reported to have about 50 feet of bedrock cover. Drilling holes into the bedrock would have an unknown effect on the strength of the rock that separates the stope from the ground surface and, in a worse case condition, could result in the collapse of rock. These operations would occur above the largest stope that is on the order of 700 feet in height.

- The potential input points for backfilling the underground mine, the highest being in the immediate proximity of the 300-level mine portal, are situated as much as 1,500 vertical feet above the tailings piles, making significant challenges for the pumping requirements.
- Paste would be created from existing tailings piles instead of a mill slurry discharge. This would involve processing the materials to create a slurry suitable for backfill.
- The tailings piles are not homogeneous as in a continuous slurry from an operating mill.
- The lack of homogeneity would impact pumping efficiency as tailings properties change.
- Backfilled tailings in a fluctuating groundwater environment could generate acid mine water
- The pumping distance is at the upper limit of conventional mine backfill operations.
- Workers would need to go deep into a long abandoned mine to ensure backfill penetration, which would present significant safety concerns.
- A large capital expenditure is required for an operation of relatively short duration.
- The risk of pipeline breaks and tailings spills
- The amount of water necessary to complete the backfilling, depending on the method utilized, would be relatively high (Table F-12):

  Standard slurry (65% water):

  32 cfs if placed in one season
  16 cfs if placed in two seasons
  11 cfs if placed in three seasons

  Thickened slurry (36% water)

  9 cfs if placed in one season
  5 cfs if placed in two seasons
  3 cfs if placed in three seasons

  It should be noted that the average flow in Railroad Creek between June and September is about 170 cfs. The base flow during the autumn is about 80 cfs.

Estimated Cost

Without completing a relatively detailed analysis, it is very difficult to estimate the cost of backfilling the Holden Mine utilizing the methods described above. The lower range of costs would be to use dry and hydraulic backfill methods that would likely not achieve the desired results of significantly reducing the potential for subsidence. Paste backfilling would result in a higher probability that the objective of reducing the potential of subsidence would be achieved, at a higher cost. There is a wide range in potential costs associated with the use of paste backfill methods.

We were not successful in finding another site where a similar backfilling operation has been completed under such challenging conditions. However, based on rough estimates, it is likely that the costs to construct the paste backfilling plant, access and prepare the injection points, mix the tailings to create a paste backfill, transport the materials to the injection points, and control the backfill process through the construction of underground bulkheads could easily result in costs in excess of $20 per cubic yard. Assuming that about 2.5 million cubic yards can be backfilled in the mine (based on the above-mentioned calculations of existing open stopes) , this would result in a lower range of costs in 2002 dollars of approximately $50 million. It should be noted that there is a high level of uncertainty in terms of the feasibility of completing the backfilling operations and with the associated cost estimates.

Summary

The removal of ore materials from the mine resulted in the formation of underground voids, called stopes, as well as other tunnels and openings to allow human access, ore and equipment transport, and ventilation. During operations, a large portion of the openings created below the 1500 level of the mine were backfilled with tailings material. Approximately 1.5 million cubic yards of tailings were reportedly backfilled in the mine over the period of operations. However, stopes present above the 1500 level were not backfilled. A number of the stopes have been documented to be within 50 feet of the ground surface. Therefore, the Agencies have requested an evaluation of mine backfill as a possible means to reduce the potential for subsidence of these upper stopes, which could result in increased surface water infiltration and airflow into the mine.

An initial assessment completed as part of the RI indicated there was a potential for subsidence within the mine. Due to the relatively large size of the underground stopes, measures to mitigate the potential for future subsidence are limited. At other abandoned and active mine sites, tailings have been used with varying degrees of success to backfill underground openings with the intent to mitigate potential subsidence. The use of tailings as backfill was evaluated for the Site for the primary objective of reducing the potential for subsidence, and the secondary objective of reducing the volume of tailings outside the mine that currently provide a source of metals loading to surface water and groundwater.

There are three backfilling methods currently employed by the mining industry:

- Dry backfill - involves the placement of dry solids, such as tailings, into open voids using haul trucks or various types of belt conveyance systems
- Hydraulic backfill - a tailings slurry thickened to a viscous liquid is pumped into the open voids
- Paste backfill – a thickened mixture of tailings and cement or fly ash is pumped into the open voids

Dry backfill was not considered for the Site due to the high degree of uncertainty regarding the ability to effectively place dry tailings within the non-uniform void spaces to prevent future settlement and provide structural support to mitigate the potential for subsidence.

Results of the preceding evaluation indicate that although the use of hydraulic or paste backfill has advantages over the placement of dry tailings, significant uncertainties remain with respect to the effectiveness of these options in mitigating the potential for subsidence. This is due to the future settlement of the backfilled material, and technical difficulties in achieving complete fill of the void spaces. The analysis also indicates that the use of hydraulic or paste backfilling techniques may achieve the relocation of only approximately 30 percent of the total volume of tailings present in tailings piles 1, 2, and 3.

In addition to the uncertainties related to achieving the objectives stated above, results of the evaluation also indicate the following technical disadvantages associated with this option:

- Mine backfilling would have an unknown effect on mine water quantity and quality. The backfilled tailings could generate significant quantities of acidic mine water that would discharge from the portal or elsewhere.
- Significant power requirements would be associated with the use of large capacity pumps to convey paste or hydraulic backfill to the top of the open stopes. Implementation of this option may require the construction of a conventional fuel-based power generation facility at the Site.
- A large processing facility would be required to screen the tailings materials to achieve proper grain size distributions for either paste or hydraulic backfilling techniques. The lack of homogeneity of the

tailings materials would adversely impact pumping efficiencies for both techniques as tailings properties change. The implementation of hydraulic backfill would require the materials to be free-draining, which would involve the removal of fine-grained materials. Operation of a processing facility would be required for several seasons, and may disrupt operations of the Holden Village during that time.

- The net gain in elevation between the tailings piles and input points near the 300 level portal may be as much as 1,500 vertical feet, resulting in a complex, staged, pumping process.
- Drilling holes into the bedrock would have an unknown effect on the strength of the rock that separates the stope from the ground surface and, in a worse case condition, could result in the collapse of rock.
- The existing pumping distance and elevation gain from the tailings piles to the potential input points is greater than current known backfilling operations.
- Significant safety concerns exist related to the need for workers to enter and work deep within the underground mine workings to ensure backfill penetration.
- A large capital expenditure (likely greater than approximately $50 million) would be required for implementation of this option.
- Assuming a backfill rate of 200 tons per hour, 8 hours per day, and 300 days per year, backfilling would take 6.5 years.
- There are significant risks of pipeline breaks and tailings spills during the backfilling operation.
- The amount of water necessary for backfilling would be significant. Depending in part on the type of backfill utilized, water requirements are estimated to range between 1 percent and 20 percent of average flow in Railroad Creek, and between about 4 percent and 40 percent of base flow in the creek.

Based on the above-mentioned findings, backfilling of the tailings into the underground mine was not carried through to the detailed analysis.

REPROCESSING OF TAILINGS MATERIALS

Overview

The tailings piles consist of the remains of the ore milling process conducted by Howe Sound Co. for the extraction of economic metal sulfide minerals. The metals that were removed during the operation of the mine included copper, zinc, gold and silver, and the efficiency of ore extraction/recovery varied for each metal. As a result, the existing tailings contain varying concentrations of both economic metal sulfide minerals and iron sulfides. The Agencies requested an evaluation of tailings reprocessing in the technology screening step of the FS as a means to potentially reduce the reactivity of the tailings and subsequent metals loading to surface water and groundwater at the Site.

Tailings reprocessing was evaluated for the potential to: 1) reduce metal sulfide concentrations, thereby reducing the acid-generating characteristics of the tailings; and 2) recover economic metal sulfides, and associated precious metals (gold and silver) to potentially offset the costs of reprocessing and site remediation.

Basis for Assumptions

The basis for the assumptions used to develop a conceptual metallurgical process flow is the information contained in an October 24, 1996 letter from Titan Environmental Corporation (Titan); Titan completed a preliminary assessment of the site for possible reprocessing of the tailings materials. The major assumptions set forth in that letter are as follows:

- Eight million tons of tailings are presently contained in three separate impoundments.
- The tailings contain copper, zinc, gold and silver, the quantities and concentrations of which were based on boring explorations and assays completed by the US Bureau of Mines in 1996.
- Sulfide minerals appear to constitute approximately 10% of the 800,000 tons of the original tailings.
- Approximately 94% of the sulfide minerals would be removed from the original tailings.
- Gold, silver, and copper recoveries would be about 70%; and zinc recoveries would be about 94%. Based on these values:
  - Approximately 100,625 oz of gold would be recovered.
  - Approximately 827,800 oz of silver would be recovered
  - Approximately 19,754 tons of copper concentrate would be recovered at a grade of 25% containing copper.
  - Approximately 69,767 tons of zinc concentrate would be recovered at a grade of 50% containing zinc.
- Inherent in the above assumptions is that 710,479 tons of sulfide concentrate would be produced. Based on typical industry mixtures, the residual sulfide concentrate would most likely be iron pyrites.

Utilizing the above information, URS made the additional following assumptions in order to develop a conceptual process flow for evaluation.

- The tailings would be reclaimed and processed over a period of 5 years.
- The tailings reprocessing would operate 330 days per year, on a 7-day per week, 24 hr/day basis.
- A bulk flotation sulfide concentrate would be made as the first processing step. (the Titan assumption is 94% of the sulfide would be recovered.)
- The bulk concentrate would be subjected to selective flotation to initially separate a copper concentrate, then a zinc concentrate.
- The remaining sulfides would be considered pyrite tailings from the zinc recovery circuit
- The gold and silver precious metals would be split 50% to the copper concentrate and 50% to the zinc concentrate.

There are several potentially significant risks in utilizing the Titan information and assumptions. The most significant risk is that the metals concentration data from a single bore hole in each existing tailings impoundment were averaged for developing the metals concentration estimates; the use of only one bore hole to represent such a large volume of tailings cannot provide a reliable gold analysis. In addition, the one sample was averaged over the full depth for each tailings impoundment which presents a significant risk in assuming that the gold concentration used is sustainable. The second potentially significant assumption is that 94% of the contained zinc would be recovered. The gold and zinc values potentially represent approximately 85% of the potential revenue generated in the following process concept.

Conceptual Reprocessing Description

The conceptual process description is presented in the following subsections and organized as follows:

- Tailings reclaim
- Grinding
- Floatation
- Products produced
- Tailings disposal

The processing of the approximately 8 million tons of tailings over five years and 330 days per year would result in processing dry short tons per day (DSTPD) of tailings. On a 24 hr per day basis, this would amount to 202 dry short tons per hour (DSTPH). For approximation, the actual rates used in the analysis were 4, 800 DSTPD and 200 DSTPH.

Tailings Reclaim

The tailings would be reclaimed only 8 hrs per day or at a rate of 600 DSTPH. Based on engineering judgement and reprocessing options conducted elsewhere, the Marona flow reclaim process, which is a self-contained pumping/high pressure hydraulic spray unit, was identified as potentially appropriate for the tailings at the Holden Mine Site. The Marona flow unit has the capability to sink itself into the tailings and generate slurry (a mixture of solids and water) which can then be pumped to a storage holding tank. Once a working area has been developed, an additional high-pressure water spray would be used to re-slurry the tailings and cause their flow to the pumping unit. The range of the high-pressure sprays for reclaiming tailings is approximately 75 to 150 feet. The tailings would be pumped to agitated steel storage tanks which act as holding tanks for leveling out the one shift/day reclaim with the 24 hour per day processing plant.

Grinding

Although the tailings are a product from former operations and have ground down during the previous milling process, it would still be necessary to grind the reclaimed tailings again to: 1) to decrease the particle size to obtain better mineral separation, and 2) polish the surface of the sulfide minerals. The polished or fresh sulfide mineral surfaces would then be more amenable to extraction in the flotation process than surfaces that have been oxidized and tarnished over time.

Grinding would primarily be carried out in ball mills or similar equipment, the same process used during the original milling at the Holden Mine Site. The typical ball mill is a barrel shaped vessel rotating on its horizontal access. It has several steel cylindrical liners, lifters and end plates. It is partially filled with balls of steel or cast iron. A slurry of ore, in this case the reclaimed tailings, would be fed into the ball mill and discharged axially. The flow would carry out the ground product. The amount of grinding required must be determined by metallurgical testing. Nevertheless, it is anticipated that sufficient grinding would be required to pass Tyler screen equivalent of 1050 mesh to 200 mesh (0.0162 to 0.1075 mm).

The ball mill discharge would also need to be pumped through a cyclone. The purpose of the cyclone is to separate the particle sizes at the desired mesh or mm range. In the cyclone, the proper sized particle leaves the overflow of the cyclone and would discharge into an agitated conditioner tank. The coarse particles would be discharged from the bottom of the cyclone and returned to the ball mill. In general, the ball mill would receive new tailings and recycled tailings from the cyclone, and the ball mill would handle about twice the quantity of tailings. In this case, the ball mill would need to have an approximate capacity of 400 DSTPH; 200 DSTPH of new tailings and 200 DSTPH of recycled tailings from the cyclone classifier.

Flotation

The flotation process concentrates the finely ground minerals. The process involves chemical treatment of the ground tailings in a slurry to create conditions favorable for the attachment of certain particles to air bubbles. The air bubbles would carry the select minerals to the surface of the slurry and form a stabilized broth that is skimmed off. In general there are four types of chemicals in the flotation process:

The chemicals normally used would be collectors (sometimes called promoters), modifying agents, activating agents, and depressing agents. The collectors in the case of sulfides are generally a family of chemicals known as xanthates that, under suitable conditions, are excellent promoters for all sulfide minerals. In the absence of modifying agents the xanthates are essentially non selective in their actions. For example, in the floatation process the intent would be to float all sulfide minerals. Based on the Titan assumptions, the most likely sulfide minerals are pyrite (iron sulfide), chalcopyrite (copper iron sulfide), and/or chalcocite (copper iron sulfide, copper sulfide), and sphalerite (zinc sulfide).

The function of the modifying agents or modifiers would be to control the alkalinity or acidity of the slurry, and to counteract the interfering effect of detrimental slimes, colloids, and soluble salts. In the majority of the flotation operations, there usually is a given pH range in which the optimum floatation results are obtained. For this reason, proper pH control would be of great importance. The reagents commonly used for pH adjustments are lime and sulfuric acid, or sometimes sulfurous acid to acidify the slurry or decrease the pH and alkalinity.

In the case of the rougher flotation, the intent would be to float the maximum amount of the sulfide minerals. The Titan data and assumptions indicated an estimated 4,480 DSTPD or 200 DSTPH of sulfide concentrates would be produced. The remainder of the tailings fed into the circuit would be new tailings at an estimated rate of 4,320 DSTPD or 180 DSTPH.

The tailings would need to be dewatered; therefore, they would be pumped to a settling device referred to as a thickener. The thickener recovers a relatively clear water overflow for recycling. The thickener underflow is a slurry with approximately 50% solids.

The disposition of the tailings at this point would be undefined and is a critical issue. The tailings could be redeposited at either a new location, or at the location of the current tailings impoundments.

The bulk sulfide concentrate would then be conditioned with another chemical. The purpose of the conditioning is to produce "differential floatation" or "selective flotation". The differential or selective flotation is restricted to operations involving similar mineral types. The copper would need to be separated from the zinc and iron, and then the zinc from the iron. The chemical reagent visualized in the copper flotation circuit is called a depressant. Depressing agents assist in the separation of one mineral or another.

The separation of the various minerals would require careful selection of the reagents and careful control of the operations. In general, lime is a depressing agent as well as a pH regulator. Lime is often used to depress pyrite so that copper minerals can be separated. In addition, sodium cyanide is sometimes used to depress lead, zinc, and iron minerals for better flotation of the copper sulfide minerals. In the case of the copper sulfide flotation there are two products, tailings and concentrate. The tailings would primarily consist of zinc sulfide and the iron sulfide minerals. The concentrate would consist of the copper sulfide minerals.

In order to make a product for final sale, copper floatation would be required to be performed in two stages. As part of the cleaning cycle, a regrind ball mill is visualized as a requirement. The purpose of the regrind ball mill is to regenerate smaller particle sizes in order to better separate the copper sulfide minerals from the zinc and iron sulfide minerals as well as any residual waste minerals. The copper flotation tailings would be discharged to another agitated conditioner tank. In this conditioner tank, activating agents would be added. Activating agents would be used to affect the flotation of certain minerals that are normally difficult to process or float with normal floaters alone. For example, copper sulfate is universally used for the activation of sphalerite (zinc sulfide) that will not respond readily to flotation with common collectors in the absence of these chemicals.

The zinc flotation circuit would operate similarly to the copper flotation circuit. The products of zinc flotation would be pyrite tailings and zinc concentrate. Pyrite tailings would be discharged to a thickener to increase the percent solids content and produce a relatively clear water overflow for recycling. Metallurgical testing would be required to determine where the recycled thickener overflow can go. The various chemicals added throughout the circuit (through the initial rougher flotation, copper flotation and zinc flotation) could have an impact on where thickener overflow water would be recycled.

The thickener underflow, approximately 126 DSTDP or 17.8 DSPTH of pyrite solids would be a disposal dilemma. The high sulfur content in pyrite presents a potential environmental problem. Pyrite concentrate can become pyrophoric, e.g. they can cause spontaneous combustion. They can be disposed, after proper treatment, in a RCRA landfill or they may be sold. In North America, the sale of pyrite for the production of sulfuric acid is uncommon. Therefore, the disposition of the pyrite tailings is a major environmental issue that would need to be addressed.

The zinc flotation concentrate would be processed through two clean-up stages. The cleaner concentrates, similar to the copper concentrates, would be reground in their own regrind ball mill. The purpose of the regrind would be to generate smaller particles for separation of the sphalerite from any residual iron and waste minerals.

The complexity of bulk flotation followed by differential or selective flotation should be noted. A variety of chemical reagents supported by extensive metallurgical testing would be required. The assumption of a 25% copper in concentrate and 50% zinc in concentrate may well be an assumption that cannot be substantiated. Each step in the flotation process has inefficiencies. For example, it is not possible to produce a copper concentrate that does not contain some zinc sulfide or some iron sulfide. In a similar manner, it is impossible to produce a zinc sulfide that does not contain some copper sulfide and some iron sulfide. Therefore, the assumption that 94% of the zinc would be recovered in the zinc concentrate is an unlikely assumption.

The other assumption made by URS is that the precious metals, gold and silver, are split 50% to copper concentrate and 50% to zinc concentrate. In general, gold and silver are more readily recovered from copper materials than they are from zinc materials. The Titan assumption of 70% recovery of the precious metals may also be a high-risk assumption. The assumption appears to indicate the expectation of the gold and silver being present in the sulfide minerals. If some of the gold and silver is present in the waste minerals, such as the silica, the likelihood of their recovery decreases significantly. In addition, some of the precious metals would be lost in the rougher concentrate tailings and in the iron pyrite tailings. With the gold and zinc concentrate representing approximately 85% of the potential revenues, the assumptions present a high degree of risk.

Products Produced

There would be four products generated from the proposed retreatment of the Holden Mine tailings: 1) new tailings, 2) iron sulfide tailings, 3) copper sulfide concentrate, and 4) zinc sulfide concentrate tailings. There currently is a saleable market for both copper and zinc concentrates. The final location of the sale of these two concentrates would depend on the anticipated freight costs. The zinc concentrate could potentially be sent to British Columbia, while the copper concentrates most likely would go to the southwestern United States.

The disposal of the rougher tailings has several options as mentioned earlier.

The disposition of the pyrite tailings is more complicated. For the purposes of this analysis, it is assumed these materials would be disposed in a RCRA landfill.

Anticipated Capital Cost, Operating Cost and Revenue

The preliminary capital and operating cost estimate is presented in the following subsections and is organized as follows:

- Basis for assumptions
- Capital cost
- Operating cost

Basis for Assumptions

The capital cost preliminary budgetary estimate for retreatment of the Holden Mine tailings is based upon escalating a similar project of smaller scale. In 1998, URS performed a preliminary feasibility study for a 220 DSTDP gold extraction plant from tailings. The estimated capital cost for that facility was $15 million. A 10% interest rate over a period of 7 years was assumed. The 7 years was estimated to account for testing, engineering, and construction, plus the 5-year life of the facility. The operating cost estimate was based on several items. A preliminary staffing schedule was developed; the labor costs for the staffing was based on a 1996 average mining wage survey, escalated by 5%. The wage survey for Holden was based on the results for the State of Washington. Other aspects of the operating costs were based on a 1998 study of a large mine/mill complex for zinc recovery. The figures in that study were adjusted with the following additional assumptions:

- The cost of reclaiming tailings would only be 20% of new mine costs.
- The labor in the study represented approximately 30% of total milling costs. The estimated Washington labor cost was divided by 0.36 to determine an estimated total milling cost.
- The values were also adjusted to account for the remote location of the Holden Mine tailings and need to utilize a combination of processing methods

Capital Costs

The capital cost estimate was developed based on a 1998 URS preliminary engineering study for a 220 DSTPD gold extraction plant. That budgetary capital cost estimate was $15 million. There are sufficient similarities between the two facilities to assume a similar cost escalated for the size difference between the 1998 study and the Holden Mine site. The similarities include the same methods of: 1) tailings reclaim; 2) storage of the tailings slurry and agitated tanks, and 3) grinding and classification of the tailings for particle size reduction. However, there are also significant differences between the gold extraction and the flotation in equipment types. Nevertheless, the gold extraction process was a complicated chemical process with multiple agitated reactors. For the purposes of this analysis, the 1998 costs were assumed to be approximately equivalent to the bulk and selective flotation costs for the Holden Mine site. In the gold project, the final tailings were thickened, filtered, treated with additives, and replaced in the old tailings area as fill material for use as a future light industrial facility and public park.

Using the $15 million estimated capital cost and escalating the cost by the ratio of the two plant sizes (4800 divided by 220) results in a capital cost without interest of $95.25 million. Using a 10% interest rate over 7 years the cost could escalate to $186 million. The capital cost values when related to dry short ton of tailings range in cost ($/DST) from $11.91/DST to $23.25/DST.

Operating Cost

The operating cost was approached in two ways: 1) the labor costs were calculated to operate the facility; and 2) a 1998 study of a large zinc mine/mill were used to develop an overall estimated operation cost. The preliminary staffing requirements to operate the facility were first estimated. The assessment of required labor resulted in an estimate of 11 people per shift for three shifts per day, for 7 days per week. By adding the required mechanical and electrical personnel and office support personnel, a total number of employees was estimated to be 57. Using 1996 average mining wages for the State of Washington and escalating that value ($37,889) base by 5% per year for inflation resulted in, based on 2080 hours per year, an hourly wage of $19.13. On a daily basis, this results in an estimated wage cost of approximately $6,144 per day or $1.28 per DSTPD based on 4,800 DSTPD.

The use of the 1998 study of a large zinc mine/mill complex resulted in an individual operating cost, based on a mining cost per dry short ton of tailings of $4.94, for milling of $4.62, and a management and overhead cost of $1.44. This is a total cost of $11 per DST for operating and $11.91 per DST for capital without interest charges. The total capital and operating estimated cost is $22.91 per DST.

Revenue

The metals contained in the tailings represent the gross dollar value after the flotation has been completed. The flotation products need to be further processed to recover metals. In the further processing of the copper and zinc concentrates there are some charges and losses. In general, the precious metals losses and charges attributed to concentrates are approximately 2% for gold and 4% for silver. The net value of copper in concentrate is generally 80% of the copper value, and 75%-80% of the zinc value. These reductions represent the cost for processing and losses in processing.

The total projected revenue, based on a unit basis of dollars per dry short ton, is estimated to be $7.94 per DST. The maximum probable revenue is estimated to be $9.28 per DST.

Net Anticipated Profit/Loss

Based on the above-mentioned analysis, the retreatment of Holden Mine tailings would result in a significant operating loss to complete. A summary of the operating costs and revenue are as follows:

- The maximum probable revenue based on 4th quarter 1999 metal prices indicates a contained value of $9.28 per DST. A more probable value for the metals after concentrate from concentrate to metals is $7.94 per DST of tailings.
- The estimated operating costs for the facility are $11 per DST of tailings

- The estimated capital cost without interest are $11.91 per DST of tailings
- The most likely scenario is that reprocessing the tailings will result in a cost of $14-$15 per ton of tailings over and above the possible revenue. This is an additional cost of approximately $112 million to $120 million above and beyond any revenue.

Discussion

Advantages
The potential advantages of tailings reprocessing include:

- Tailings reprocessing would likely remove a portion of the acid generating metal sulfide minerals from the tailings.

Disadvantages
The potential disadvantages of tailings reprocessing include:

- Not all of the acid generating potential would be removed from the tailings due to the large concentrations of iron sulfides.
- The reprocessing would take approximately 7 years and delay any other efforts to remedy the site conditions for that period of time.
- This option would require the construction and operation of a large reprocessing facility on site. The plant would require significant power and staff (possibly more than 50 people) for operation, and the power requirements may necessitate the construction of a conventional fuel-based power plant due to the limited power supply that could be derived through hydroelectric means during the low-flow seasons.
- The reprocessing of the tailings would generate a large volume of pyrite solids that would present a potential environmental problem because the concentrate can become pyrophoric, e.g. they can cause spontaneous combustion. It would be necessary to dispose of the concentrate, after proper treatment, in a RCRA landfill or potentially sell the materials off site. However, in North America, the sale of pyrite for the production of sulfuric acid is uncommon.
- Based on this preliminary capital and operating cost analysis that utilized the projected recovery data, it is anticipated that the net cost to reprocess the Holden Mine tailings would be approximately $112 million to $120 million above and beyond any potential revenue generated through the recovery of economic minerals. This cost is optimistic based on the assumptions utilized to develop the potential revenue, and the costs would likely be higher.
- One area of concern is that the gold and silver would only be recoverable if present in the sulfide minerals. If some of the gold and silver is present in the waste minerals, such as the silica, the likelihood of their recovery decreases significantly. In addition, some of the precious metals would be lost in the rougher concentrate tailings and in the iron pyrite tailings. With the gold and zinc concentrate representing approximately 85% of the potential revenues, the assumptions present a high degree of risk.

Summary

The tailings piles consist of the remains of the ore milling process conducted by Howe Sound Co. for the extraction of economic metal sulfide minerals. The metals that were removed during the operation of the mine included copper, zinc, gold and silver, and the efficiency of ore extraction/recovery varied for each metal. As a result, the existing tailings contain varying concentrations of both economic metal sulfide minerals and iron sulfides. The Agencies requested an evaluation of tailings reprocessing in the technology screening step of the FS as a means to potentially reduce the reactivity of the tailings and subsequent metals loading to surface water and groundwater at the Site.

Tailings reprocessing was evaluated for the potential to: 1) reduce metal sulfide concentrations, thereby reducing the acid-generating characteristics of the tailings; and 2) recover economic metal sulfides, and associated precious metals (gold and silver) to potentially offset the costs of reprocessing and site remediation.

Results of the evaluation indicate that reprocessing would likely remove a portion of the acid generating sulfide minerals from the tailings. However, not all of the acid generating potential would be removed from the tailings due to the large concentrations of iron sulfides. Additionally, a large volume of highly reactive pyrite solids would be produced through tailings reprocessing, and this material would require further treatment prior to disposal. Reprocessing would not provide a net reduction in the total volume of tailings, and the reprocessed tailings would still require handling and transportation prior to disposal at an on site or off site location.

A cost analysis was performed for this option based on current metal prices. The results indicate a net cost between $112 million to $120 million above any revenue that may be generated from the recovery of economic minerals. Additionally, preliminary analyses indicates that some of the gold and silver present in the tailings may be contained in minerals such as silica, which are not recoverable through reprocessing technologies. This may further reduce the potential revenue generated through reprocessing, as these two minerals represent a large portion of potential revenues.

Additional disadvantages of tailings reprocessing include:

- The construction and operation of a large reprocessing facility on site. The reprocessing plant would require significant power for operation, and the power requirements may necessitate the construction of a conventional fuel-based power plant due to the limited power supply that could be derived through hydroelectric means on a year-round basis. This would also involve the construction of additional roads and bridges, and clearing of a suitable area for facility construction.
- The transportation to the Site of large volumes of chemical reagents would be required. These chemicals would need to be transported from Chelan via barge, increasing the potential for accidental release to Lake Chelan.
- The process would take approximately 7 years to complete. This would delay other efforts to remedy Site conditions and may cause disruption to Holden Village operations for an extended time period.

Based on the above-mentioned findings, the reprocessing of the tailings was not carried through the detailed analysis.

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APPENDIX C
TABLE C-1
Estimated Tailings Volumes for Area A

Volume of tailings to be held in Area A

Height & Dimensions Calculation (for slope 1:2, V:H)

Area was calculated to be = 779,000 square feet.
Total volume of Mine Tailings (as calculated) = 230,529,600 cubic feet.

height (feet)	L1 (ft)	L2 (ft)	l1 (ft)	Base Area (ft^2)	Top Area (ft^2)	Side Area (ft^2)	Volume (ft ^3)
188	1,250	625	498	781,250	311,250	164,312	**102,695,000**

h, L1, and L2 numbers are applied manually
l1 = L1-4h
Base Area = L1*L2
Top Area = L2*l1
Side Area (as viewed from the North Side) = (L1+l1)*h/2
Volume = Side Area*L2

Height & Dimensions Calculation (for slope 1:3, V:H)

Area was calculated to be = 779,000 square feet.
Total volume of Mine Tailings (as calculated) = 230,529,600 cubic feet.

height (feet)	L1 (ft)	L2 (ft)	l1 (ft)	Base Area (ft^2)	Top Area (ft^2)	Side Area (ft^2)	Volume (ft ^3)
125	1,250	625	500	781,250	312,500	109,375	**68,359,375**

h, L1, and L2 numbers are applied manually
l1 = L1-6h
Base Area = L1*L2
Top Area = L2*l1
Side Area (as viewed from the North Side) = (L1+l1)*h/2
Volume = Side Area*L2

APPENDIX C
TABLE C-2
Estimated Tailings Volumes for Area B

Volume of tailings to be held in Area B

Height & Dimensions Calculation (for slope 1:2, V:H)

Area was calculated to be = 2,610,000 square feet.
Total volume of Mine Tailings (as calculated) = 230,529,600 cubic feet.

height (feet)	L1 (ft)	L2 (ft)	l1 (ft)	Base Area (ft^2)	Top Area (ft^2)	Side Area (ft^2)	Volume (ft ^3)
100	1,800	1,450	1,400	2,610,000	2,030,000	160,000	**232,000,000**

h, L1, and L2 numbers are applied manually
l1 = L1-4h
Base Area = L1*L2
Top Area = L2*l1
Side Area (as viewed from the North Side) = (L1+l1)*h/2
Volume = Side Area*L2

Height & Dimensions Calculation (for slope 1:3, V:H)

Area was calculated to be =2,610,000 square feet.
Total volume of Mine Tailings (as calculated) = 230,529,600 cubic feet.

height (feet)	L1 (ft)	L2 (ft)	l1 (ft)	Base Area (ft^2)	Top Area (ft^2)	Side Area (ft^2)	Volume (ft ^3)
108	1,800	1,450	1,152	2,610,000	1,670,400	159,408	**231,141,600**

h, L1, and L2 numbers are applied manually
l1 = L1-6h
Base Area = L1*L2
Top Area = L2*l1
Side Area (as viewed from the North Side) = (L1+l1)*h/2
Volume = Side Area*L2

APPENDIX C
TABLE C-3
Estimated Tailings Volumes for Area C

Volume of tailings to be held in Area C

Height & Dimensions Calculation (for slope 1:2, V:H)

Area was calculated to be =1,276,800 square feet.
Total volume of Mine Tailings (as calculated) = 230,529,600 cubic feet.

height (feet)	L1 (ft)	L2 (ft)	l1 (ft)	Base Area (ft^2)	Top Area (ft^2)	Side Area (ft^2)	Volume (ft ^3)
80	2,400	532	2,080	1,276,800	1,106,560	179,200	**95,334,400**

h, L1, and L2 numbers are applied manually
l1 = L1-4h — length of side slope (ft) = 179
Base Area = L1*L2 — Area of side slope (sqft) = 95167
Top Area = L2*l1 — Surface area for cap (sqft) = 1476094
Side Area (as viewed from the North Side) = (L1+l1)*h/2
Volume = Side Area*L2
** max height 80-feet

Height & Dimensions Calculation (for slope 1:3, V:H)

Area was calculated to be = 1,276,800 square feet.
Total volume of Mine Tailings (as calculated) = 230,529,600 cubic feet.

height (feet)	275.3	L2 (ft)	l1 (ft)	Base Area (ft^2)	Top Area (ft^2)	Side Area (ft^2)	Volume (ft ^3)
80	2,400	532	1,920	1,276,800	1,021,440	172,800	**91,929,600**

h, L1, and L2 numbers are applied manually
l1 = L1-6h — length of side slope (ft) = 253
Base Area = L1*L2 — Area of side slope (sqft) = 134587
Top Area = L2*l1 — Surface area for cap (sqft) = 1463413
Side Area (as viewed from the North Side) = (L1+l1)*h/2
Volume = Side Area*L2
** max height 80-feet

APPENDIX C
TABLE C-3 (Continued)
Estimated Tailings Volumes for Area C (2)

Volume of tailings to be held in Area C (2)

Height & Dimensions Calculation (for slope 1:2, V:H)

Area was calculated to be =1,276,800 square feet.
Total volume of Mine Tailings (as calculated) = 230,529,600 cubic feet.

height (feet)	L1 (ft)	L2 (ft)	l1 (ft)	Base Area (ft^2)	Top Area (ft^2)	Side Area (ft^2)	Volume (ft ^3)
221	2,400	532	1,514	1,276,800	805,658	433,326	**230,529,600**

h, L1, and L2 numbers are applied manually
l1 = L1-4h
Base Area = L1*L2
Top Area = L2*l1
Side Area (as viewed from the North Side) = (L1+l1)*h/2
Volume = Side Area*L2

Height & Dimensions Calculation (for slope 1:3, V:H)

Area was calculated to be = 1,276,800 square feet.
Total volume of Mine Tailings (as calculated) = 230,529,600 cubic feet.

height (feet)	275.3	L2 (ft)	l1 (ft)	Base Area (ft^2)	Top Area (ft^2)	Side Area (ft^2)	Volume (ft ^3)
275	2,400	532	748	1,276,800	398,142	433,326	**230,529,600**

h, L1, and L2 numbers are applied manually
l1 = L1-6h
Base Area = L1*L2
Top Area = L2*l1
Side Area (as viewed from the North Side) = (L1+l1)*h/2
Volume = Side Area*L2

APPENDIX C
TABLE C-4
Estimated Tailings Volumes for Area D

Volume of tailings to be held in Area D

Height & Dimensions Calculation (for slope 1:2, V:H)

Area was calculated to be = 2,770,000 square feet.
Total volume of Mine Tailings (as calculated) = 230,529,600 cubic feet.

height (feet)	L1 (ft)	L2 (ft)	l1 (ft)	Base Area (ft^2)	Top Area (ft^2)	Side Area (ft^2)	Volume (ft ^3)
92	2,000	1,385	1,632	2,770,000	2,260,320	167,072	**231,394,720**

h, L1, and L2 numbers are applied manually
l1 = L1-4h
Base Area = L1*L2
Top Area = L2*l1
Side Area (as viewed from the North Side) = (L1+l1)*h/2
Volume = Side Area*L2

length of side slope (ft) = 206
Area of side slope (sqft) = 284920
Surface area for cap (sqft) = 2997232

Height & Dimensions Calculation (for slope 1:3, V:H)

Area was calculated to be = 2,770,000 square feet.
Total volume of Mine Tailings (as calculated) = 230,529,600 cubic feet.

height (feet)	L1 (ft)	L2 (ft)	l1 (ft)	Base Area (ft^2)	Top Area (ft^2)	Side Area (ft^2)	Volume (ft ^3)
98	2,000	1,385	1,412	2,770,000	1,955,620	167,188	**231,555,380**

h, L1, and L2 numbers are applied manually
l1 = L1-6h
Base Area = L1*L2
Top Area = L2*l1
Side Area (as viewed from the North Side) = (L1+l1)*h/2
Volume = Side Area*L2

length of side slope (ft) = 310
Area of side slope (sqft) = 429216
Surface area for cap (sqft) = 2981240

APPENDIX C
TABLE C-5
Estimated Tailings Volumes for Area E

Volume of tailings to be held in Area E

Height & Dimensions Calculation (for slope 1:2, V:H)

Area was calculated to be = 892,000 square feet.
Total volume of Mine Tailings (as calculated) = 230,529,600 cubic feet.

height (feet)	L1 (ft)	L2 (ft)	l1 (ft)	Base Area (ft^2)	Top Area (ft^2)	Side Area (ft^2)	Volume (ft ^3)
125	1,000	892	500	892,000	446,000	93,750	**83,625,000**

h, L1, and L2 numbers are applied manually
l1 = L1-4h
Base Area = L1*L2
Top Area = L2*l1
Side Area (as viewed from the North Side) = (L1+l1)*h/2
Volume = Side Area*L2

length of side slope (ft) = 280
Area of side slope (sqft) = 249322
Surface area for cap (sqft) = 1038393

Height & Dimensions Calculation (for slope 1:3, V:H)

Area was calculated to be = 892,000 square feet.
Total volume of Mine Tailings (as calculated) = 230,529,600 cubic feet.

height (feet)	L1 (ft)	L2 (ft)	l1 (ft)	Base Area (ft^2)	Top Area (ft^2)	Side Area (ft^2)	Volume (ft ^3)
83	1,000	892	502	892,000	447,784	62,333	**55,601,036**

h, L1, and L2 numbers are applied manually
l1 = L1-6h
Base Area = L1*L2
Top Area = L2*l1
Side Area (as viewed from the North Side) = (L1+l1)*h/2
Volume = Side Area*L2

length of side slope (ft) = 262
Area of side slope (sqft) = 234122
Surface area for cap (sqft) = 978362

APPENDIX C
TABLE C-6
Estimated Costs for Relocation Area A

Description	Unit	Hourly Output	Quantity	Unit Cost	Total Cost
Mob/Demob[(a)]	ls			15%	$2,306,175.67
Site Clearing	ac	1.06	18	$548.39	$9,871
Rough Grading 14G-Single Pass	sy	187.5	86,567	$0.94	$81,373
Scraper, common earth, 3000' haul	cy	100	1,566,636	$8.00	$12,533,088
Temporary Road, gravel fill 4"	sy	100	1,000	$2.90	$2,900
Lime stabilization - dry	bcy	40.75	78,332	$20.95	$1,641,051
Dewatering - 4" contractor trash pump, 300GPM	day		244	$63.61	$15,521
General Area Cleanup	ac		18	$269.54	$4,852
Bentonite Liner	sf	1250	779,100	$0.39	$303,849
60-mil Geotextile Cap	sf	187.5	850,000	$0.92	$782,000
Subtotal Direct Capital					**$17,680,680**
Engineering Design/Planing				15%	$2,652,102.02
Construction Management				10%	$1,768,068.01
Project Management				4%	$707,227.21
Subtotal Capital Cost					**$22,808,077**
Contingency				40%	$9,123,231
TOTAL Capital Cost					**$32,000,000**

Note: These costs are order-of-magnitude costs consistent with the conceptual level of design for this process option and EPA guidance.

(a) Mob/demob costs include equipment and materials mobilization, man-camp construction and operation, general site improvements, and fuel containment area. Costs estimated at approximately 15% of direct capital costs.

APPENDIX C
TABLE C-7
Estimated Costs for Relocation Area B

Treatment	Unit	Hourly Output	Quantity	Unit Cost	Total Cost
Mob/Demob[(a)]	ls			10%	$8,096,122
Site Clearing	ac	1.06	60	$548.39	$32,903
Rough Grading 14G-Single Pass	sy	187.5	96,667	$0.94	$90,867
Scraper, common earth, 3000' haul	cy	100	8,500,000	$8.00	$68,000,000
Bridge, 100' span, 30' width	ea		1	$110,000	$110,000
Temporary Road, gravel fill 4"	sy	100	3,000	$2.90	$8,700
Lime stabilization - dry	bcy	40.75	425,000	$20.95	$8,903,750
Dewatering - 4" contractor trash pump, 300GPM	day		854	$63.61	$54,323
Tenmile Creek culvert	ls		1	$100,000	$100,000
General Area Cleanup	ac		60	$269.54	$16,172
Bentonite Liner	sf	1250	2,610,000	$0.39	$1,017,900
60-mil Geotextile Cap	sf	187.5	2,855,000	$0.92	$2,626,600
Subtotal Direct Capital					**$89,057,337**
Engineering Design/Planing				10%	$8,905,734
Construction Management				10%	$8,905,734
Project Management				4%	$3,562,293
Subtotal Capital Cost					**$110,431,098**
Contingency				40%	$44,172,439
TOTAL					**$155,000,000**

Note: These costs are order-of-magnitude costs consistent with the conceptual level of design for this process option and EPA guidance.

(a) Mob/demob costs include equipment and materials mobilization, man-camp construction and operation, general site improvements, & fuel containment area. Costs estimated at approx. 10% of direct capital costs.

APPENDIX C
TABLE C-8
Estimated Costs for Relocation Area C

Description	Unit	Hourly Output	Quantity	Unit Cost	Total Cost
Mob/Demob[(a)]	ls			10%	$3,373,889
Site Clearing	ac	1.06	30	$548.39	$16,452
Rough Grading 14G-Single Pass	sy	187.5	47,289	$0.94	$44,452
Scraper, common earth, 3000' haul	cy	100	3,500,000	$8.00	$28,000,000
Bridge, 100' span, 30' width	ea		1	$110,000	$110,000
Temporary Road, gravel fill 4"	sy	100	5,000	$2.90	$14,500
Lime stabilization - dry	bcy	40.75	175,000	$20.95	$3,666,250
Dewatering - 4" contractor trash pump, 300GPM	day		366	$63.61	$23,281
General Area Cleanup	ac		30	$269.54	$8,086
Bentonite Liner	sf	1250	1,276,800	$0.39	$497,952
60-mil Geotextile Cap	sf	187.5	1,476,000	$0.92	$1,357,920
Subtotal Direct Capital					**$37,112,782**
Engineering Design/Planing				15%	$5,566,917
Construction Management				10%	$3,711,278
Project Management				4%	$1,484,511
Subtotal Capital Cost					**$47,875,489**
Contingency				40%	$19,150,196
TOTAL					**$68,000,000**

Note: These costs are order-of-magnitude costs consistent with the conceptual level of design for this process option and EPA guidance.

(a) Mob/demob costs include equipment and materials mobilization, man-camp construction and operation, general site improvements, and fuel containment area. Costs estimated at approximately 10% of direct capital costs.

APPENDIX C
TABLE C-9
Estimated Costs for Relocation Area D

Treatment	Unit	Hourly Output	Quantity	Unit Cost	Total Cost
Mob/Demob[a]	ls			10%	$9,580,747
Site Clearing	ac	1.06	64	$548.39	$35,097
Rough Grading 14G-Double Pass	sy	187.5	615,556	$0.94	$578,622
Borrow subgrade, load, haul 5-miles	cy	194	8,500,000	$5.10	$43,350,000
Backfill with borrow mat'l	cy	70.88	8,500,000	$4.58	$38,930,000
Lime stabilization - dry	bcy	40.75	425,000	$20.95	$8,903,750
Dewatering - 4" contractor trash pump, 300GPM	day		2,440	$63.61	$155,208
General Area Cleanup	ac		64	$269.54	$17,251
Bentonite Liner	sf	1250	2,770,000	$0.39	$1,080,300
60-mil Geotextile Cap	sf	187.5	2,997,000	$0.92	$2,757,240
Subtotal Direct Capital					**$105,388,215**
Engineering Design/Planing				10%	$10,538,821
Construction Management				10%	$10,538,821
Project Management				4%	$4,215,529
Subtotal Capital Cost					**$130,681,387**
Contingency				40%	$52,272,555
TOTAL					**$183,000,000**

Note: These costs are order-of-magnitude costs consistent with the conceptual level of design for this process option and EPA guidance.

(a) Mob/demob costs include equipment and materials mobilization, man-camp construction and operation, general site improvements, and fuel containment area. Costs estimated at approximately 10% of direct capital costs.

APPENDIX C
TABLE C-10
Estimated Costs for Relocation Area E

Description	Unit	Hourly Output	Quantity	Unit Cost	Total Cost
Mob/Demob[(a)]	ls			15%	$5,199,035
Site Clearing	ac	1.06	21	$548.39	$11,242
Rough Grading 14G-Single Pass	sy	187.5	33,037	$0.94	$31,055
Tailings, load, haul 5-miles	cy	194	3,100,000	$5.10	$15,810,000
Backfill tailings	cy	70.88	3,100,000	$4.58	$14,198,000
Lime stabilization - dry	bcy	40.75	155,000	$20.95	$3,247,250
Dewatering - 4" contractor trash pump, 300GPM	day		854	$63.61	$54,323
General Area Cleanup	ac		21	$269.54	$5,526
Bentonite Liner	sf	1250	892,000	$0.39	$347,880
60-mil Geotextile Cap	sf	187.5	1,038,000	$0.92	$954,960
Subtotal Direct Capital					**$39,859,271**
Engineering Design/Planing				15%	$5,978,891
Construction Management				10%	$3,985,927
Project Management				4%	$1,594,371
Subtotal Capital Cost					**$51,418,459**
Contingency				40%	$20,567,384
TOTAL					**$72,000,000**

Note: These costs are order-of-magnitude costs consistent with the conceptual level of design for this process option and EPA guidance.

(a) Mob/demob costs include equipment and materials mobilization, man-camp construction and operation, general site improvements, and fuel containment area. Costs estimated at approximately 15% of direct capital costs.

APPENDIX C
TABLE C-11
Estimated Volume of Open Stopes

Parameter	Quantity	Source
Open Stope Volume 1500 Level to 1100 Level (ft^3)	25,656,000	D&M Calculation**
Total Stope Volume 1500 Level to 2500 Level (ft^3)	59,636,000	D&M Calculation**
Backfilled Stope Volume (ft^3)	45,208,000	D&M Calculation**
Open Stope Volume 1500 Level to 2500 Level (ft^3)	14,428,000	D&M Calculation**
Open Stope Volume 1100 Level to 300 Level (ft^3)	27,854,000	D&M Calculation**
Total Open Stope Volume*	**67,938,000**	

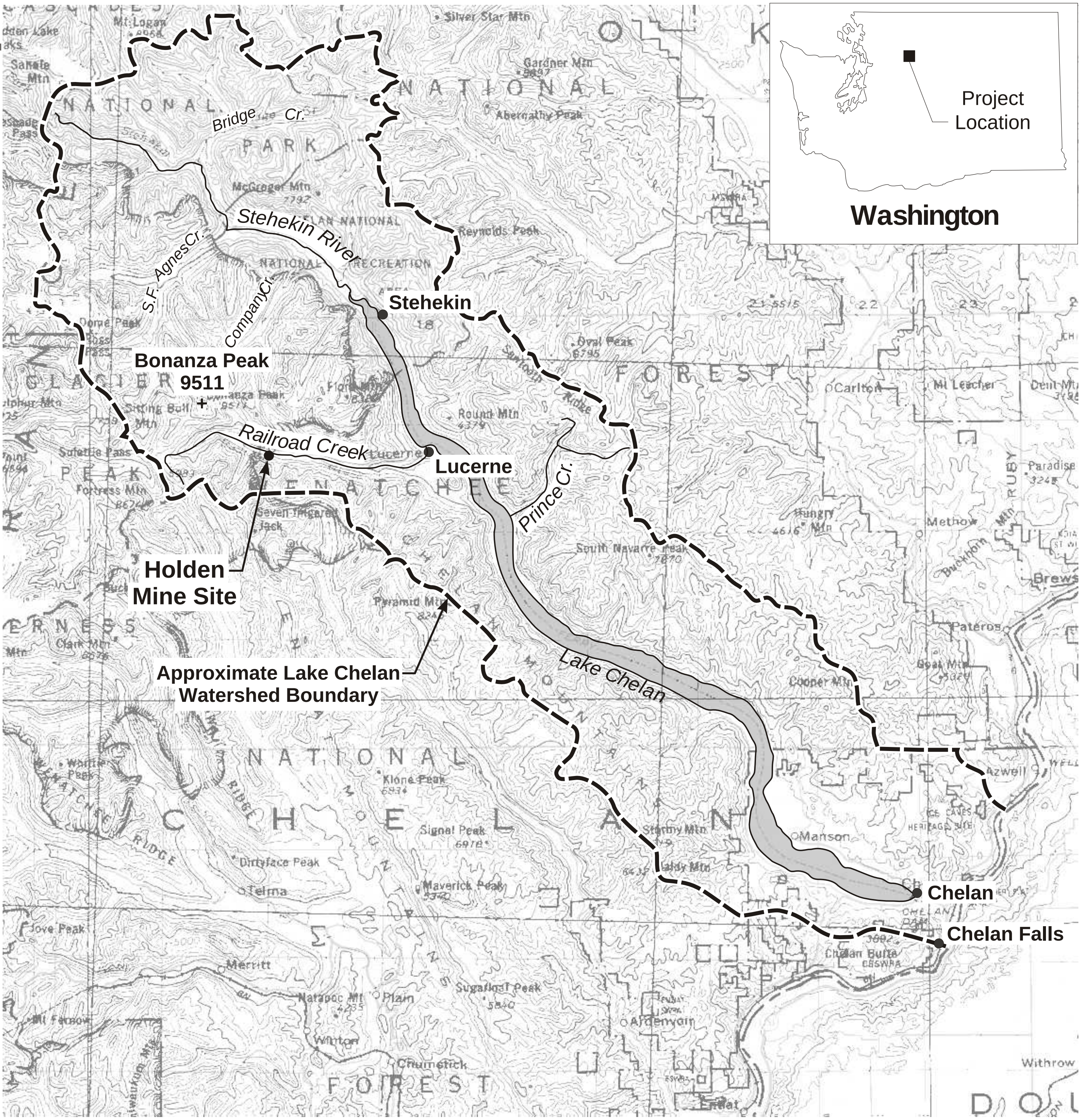
*Volume calculations performed for stopes only. Winzes and shafts not included.
**Vertical cross sectional area and widths calculated from drawings of mapped stopes. (Howe Sound Co., 1957, Holden Mine, East West Section and Assay Plans of Individual Levels)

APPENDIX C
TABLE C-12
Mine Backfill Process Option
Water Requirements For Tailings Slurry

	Standard Slurry (65% water)		Thickened Slurry (35% water)	
Total Volume of Tailings Backfilled*	67,938,000	ft^3	67,938,000	ft^3
Total Volume of Water Required	126,170,000	ft^3	36,580,000	ft^3
Flow required to complete in one field season**	32	cfs	9	cfs
	14,600	gpm	4,200	gpm
	21,024,000	gpd	6,048,000	gpd
Flow required to complete in two field seasons**	16	cfs	5	cfs
	7,300	gpm	2,100	gpm
	10,512,000	gpd	3,024,000	gpd
Flow required to complete in three field seasons**	11	cfs	3	cfs
	4,900	gpm	1,400	gpm
	7,056,000	gpd	2,016,000	gpd

*Assumes water is allowed to drain after placement
**Average field season assumed to be approximately 90 working days, 12 hrs per day (64,800 min)

Notes:
(1) The average flow in Railroad Creek from June-September is approximately 170 cfs
(2) A rule of thumb used for tailings placement in a tailings impoundment or dam is 10' of rise per year to allow water to drain, and obtain good settling within the pile. (for a standard slurry)
(3) Paste backfilling techniques would also require water usage similar to the thickened tailings slurry process, and would require dewatering after placement.



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

N

0 8 16

Scale in Miles

Figure C-1

Lake Chelan Watershed Map

Job No. 33750803

URS

Holden Mine RI/FS
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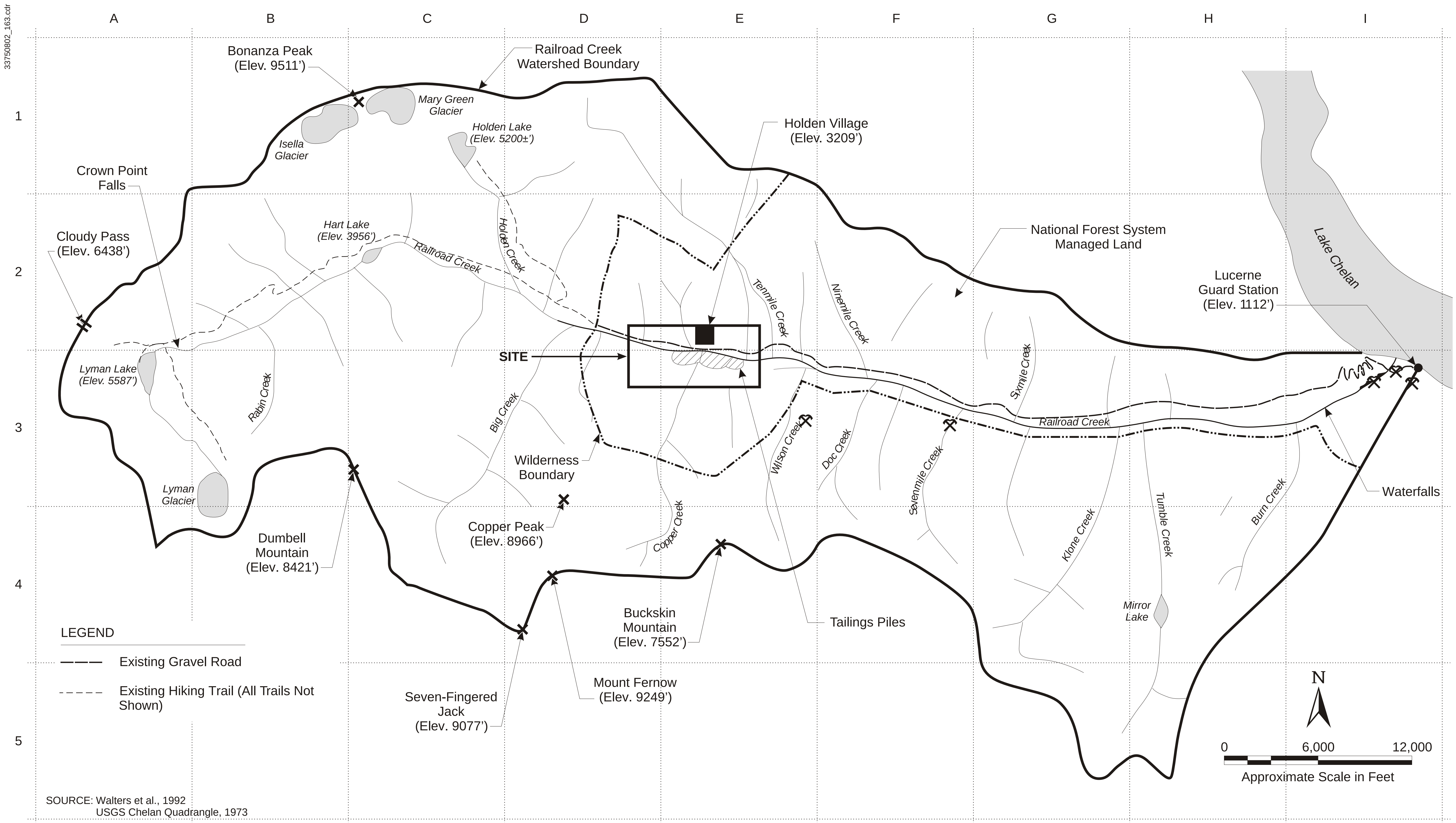
February 2004



Job No. 33750803

Figure C-2
Site Vicinity Map

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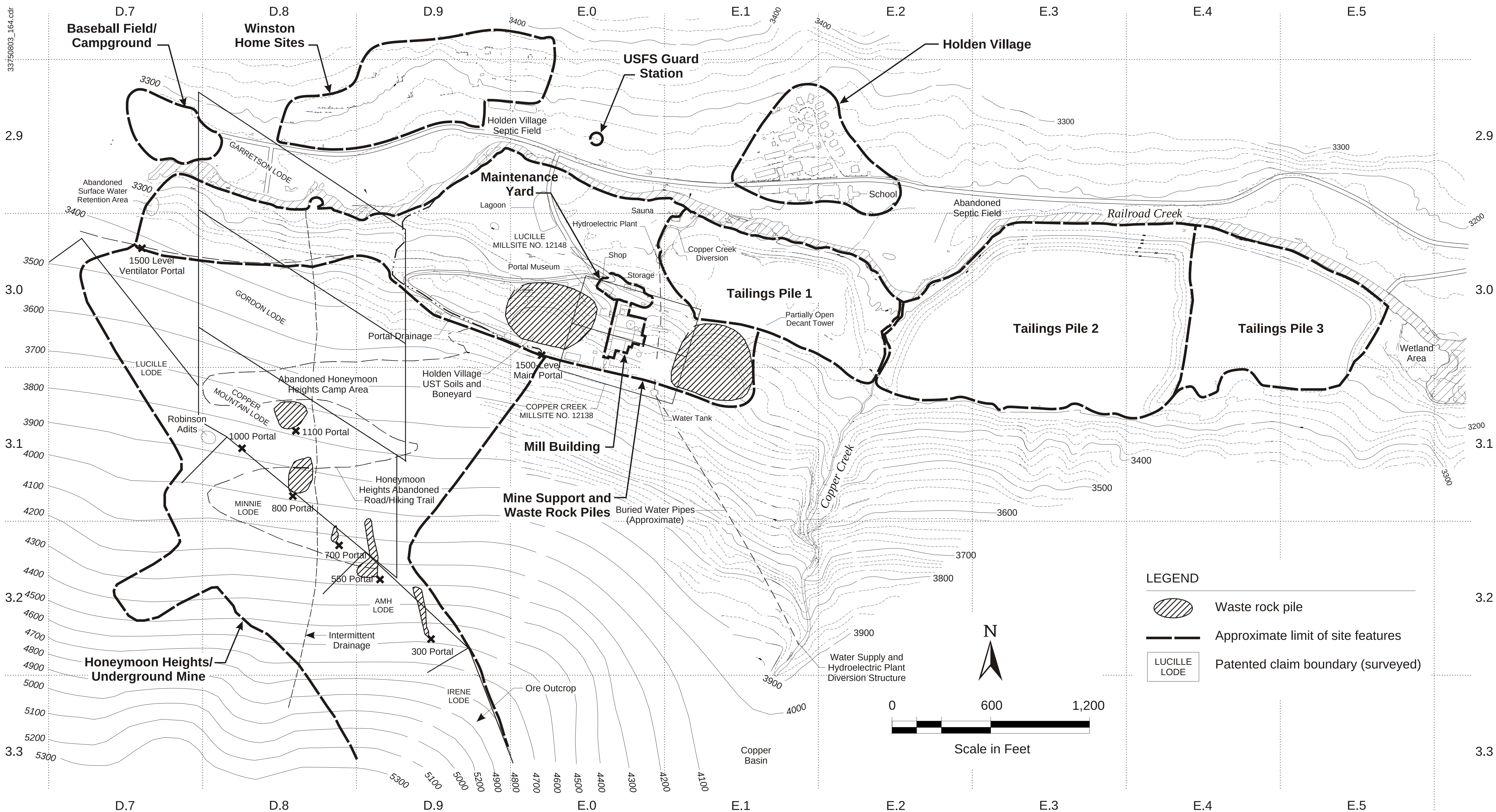

SOURCE: Base map information from USFS and Washington DNR, DEM CD ROM

Job No. 33750803

Figure C-3
Holden Mine Site Map

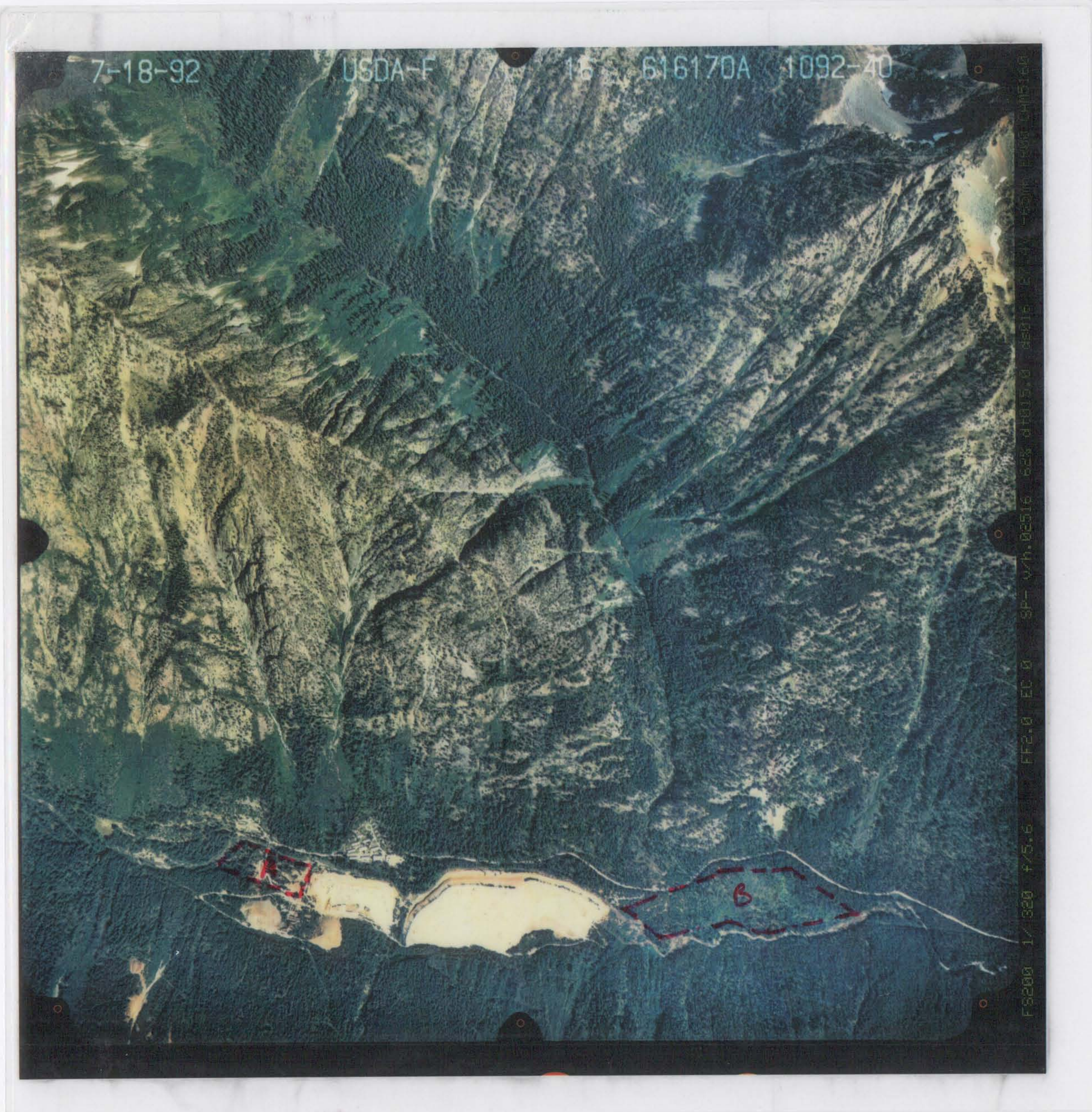

Figure C-4
AERIAL PHOTOGRAPH SHOWING
TAILINGS RELOCATION AREAS A & B

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Figure C-5
AERIAL PHOTOGRAPH SHOWING
TAILINGS RELOCATION AREA C

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Figure C-6
AERIAL PHOTOGRAPH SHOWING
TAILINGS RELOCATION AREAS D & E

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APPENDIX D
POST-REMEDIATION LOADING ANALYSIS

D-1 Short-term Post-remediation Loading Analysis Summary

D-2 Long-term Post-remediation Loading Analysis Summary

D-3 Short-term Post-remediation Loading and Uncertainty Calculations **(CD)**

D-4 Long-term Geochemical Trends Assumptions

D-5 Long-term Post-remediation Loading and Uncertainty Calculations **(CD)**

D-6 Long-term Post-remediation Sensitivity Analysis

Table D1-1
Alternative 2a - Water Management (Open Portal)
Short-Term Post Remediation Loading Analysis Summary

Source Area	Estimated Remedial Alternative Performance - Upgradient Controls and Downgradient Collection			Estimated Coefficients of Variation	
	Estimated Direct Precipitation Diverted (%)	Estimated Reduction in Metals Loading Due to Upgradient Controls(%), E[UG]	Downgradient Collection Efficiency (%), E[CE]	Upgradient Controls CV[UG]	Colletion CV[CE]
SP-26/Unaccounted (Groundwater) Load Upstream of RC-1	80%	50%	0%	0.1	0
SP-23/Honeymoon Heights	0%	0%	0%	0	0
Underground Mine [(a)]	0%	0%	0%	0	0
West Waste Rock Pile	15%	0%	0%	1	0
Mill Building [(b)]	50%	50%	0%	0.25	0
Other West Area Seeps (SP-9, 11, 25, 24) [(c)]	0%	25%	0%	1	0
West Area Seeps Downstream of RC-4 (SP-10W/10E) [(c)]	0%	25%	0%	1	0
East Waste Rock Pile [(b)]	15%	0%	0%	1	0
Copper Creek Diversion [(b)]	0%	95%	0%	0.05	0
Unaccounted Load - West Area [(c)]	0%	25%	0%	1	0
TP-1 Seeps & Flow Tubes[(d)]	80%	0%	0%	0	0
TP-2 Seeps & Flow Tubes (Upstream of RC-7) [(d)]	80%	0%	0%	0	0
TP2/3 Seeps & Flow Tubes (Downstream of RC-7) [(d)]	80%	0%	0%	0	0
Unaccounted Load - East Area [(d)]	80%	0%	0%	0	0
Loading Downstream of RC-2 (SP-21) [(d)]	80%	0%	0%	0	0
Loading downstream of RC-2 (Flow Tubes) [(d)]	80%	0%	0%	0	0

Notes:
(a) Air-flow restrictions installed in open mine adits.
(b) Assume tops of waste rock piles are regraded to min. infiltration (30% of the total surface area regraded and 50% of precipitation in that area will run
Assume impacted materials in the mill building are removed/covered; soils in the maintenance yard are capped with a concrete cap;
lagoon area soils are removed; and Copper Creek Diversion is placed in a culvert.
(c) Loading reductions from these areas expected due to the implementation of upgradient water and source controls.
(d) Help Model Scenario #2. Input parameters: 100% regrading and grass cover.
Approx. post remediation infiltration = 20%. (See Appendix G)

Table D1-2
Alternative 2b - Water Management (Hydrostatic Bulkheads)
Short-Term Post Remediation Loading Analysis Summary

Source Area	**Estimated Remedial Alternative Performance - Upgradient Controls and Downgradient Collection**			**Estimated Coefficients of Variation**	
	Estimated Direct Precipitation Diverted (%)	Estimated Reduction in Metals Loading Due to Upgradient Controls(%), E[UG]	Downgradient Collection Efficiency (%), E[CE]	Upgradient Controls CV[UG]	Colletion CV[CE]
SP-26/Unaccounted (Groundwater) Load Upstream of RC-1	80%	50%	0%	0.1	0
SP-23/Honeymoon Heights	0%	0%	0%	0	0
Underground Mine [(a)]	0%	0%	0%	0	0
West Waste Rock Pile [(b)]	15%	0%	0%	1	0
Mill Building [(b)]	50%	50%	0%	0.25	0
Other West Area Seeps (SP-9, 11, 25, 24) [(c)]	0%	25%	0%	1	0
West Area Seeps Downstream of RC-4 (SP-10W/10E) [(c)]	0%	25%	0%	1	0
East Waste Rock Pile [(b)]	15%	0%	0%	1	0
Copper Creek Diversion [(b)]	0%	95%	0%	0.05	0
Unaccounted Load - West Area [(c)]	0%	25%	0%	1	0
TP-1 Seeps & Flow Tubes[(d)]	80%	0%	0%	0	0
TP-2 Seeps & Flow Tubes (Upstream of RC-7) [(d)]	80%	0%	0%	0	0
TP2/3 Seeps & Flow Tubes (Downstream of RC-7) [(d)]	80%	0%	0%	0	0
Unaccounted Load - East Area [(d)]	80%	0%	0%	0	0
Loading Downstream of RC-2 (SP-21) [(d)]	80%	0%	0%	0	0
Loading downstream of RC-2 (Flow Tubes) [(d)]	80%	0%	0%	0	0

Notes:
(a) Air-flow restrictions installed in open mine adits. Hydrostatic bulkheads placed in 1500-level portals. Portal drainage concentrations ($E[C_{portal}]$) assumed t
equal to the "best estimates" due to flooding provided in Appendix E, Table 5 : Cd=0.1 mg/L, Cu=12 mg/L, Fe=2 mg/L, Zn=21 mg/L. $CV[C_{portal}]$s calculated based on the reasonable worst-case estimates due to mine flooding (Appendix E). Calculated $CV[C_{portal}]$s: Cd = 0.787, Cu = 0.39, Fe = 4.95, Zn = 1.1.
(b) Assume tops of waste rock piles are regraded to min. infiltration (30% of the total surface area regraded and 50% of precipitation in that area will runoff).
Assume impacted materials in the mill building are removed/covered; soils in the maintenance yard are capped with a concrete cap; lagoon area soils are removed; and Copper Creek Diversion is placed in a culvert.
(c) Loading reductions from these areas expected due to the implementation of upgradient water and source controls.
(d) Help Model Scenario #2. Input parameters: 100% regrading and grass cover.
Approx. post remediation infiltration = 20%. (See Appendix G)

Table D1-3
Alternative 3a - Water Management & Low-Energy West Area Treatment (Open Portal)
Short-Term Post Remediation Loading Analysis Summary

Source Area	Estimated Remedial Alternative Performance - Upgradient Controls and Downgradient Collection			Estimated Coefficients of Variation	
	Estimated Direct Precipitation Diverted (%)	Estimated Reduction in Metals Loading Due to Upgradient Controls(%), E[UG]	Downgradient Collection Efficiency (%), E[CE]	Upgradient Controls CV[UG]	Colletion Efficiency CV[CE]
SP-26/Unaccounted (Groundwater) Load Upstream of RC-1	80%	50%	0%	0.1	0
SP-23/Honeymoon Heights	0%	0%	90%	0	0.05
Underground Mine [(a)]	0%	0%	97%	0	0.05
West Waste Rock Pile [(b)]	15%	0%	90%	1	0.05
Mill Building [(b)]	50%	50%	90%	0.25	0.05
Other West Area Seeps (SP-9, 11, 25, 24) [(c)]	0%	75%	0%	0.2	0
West Area Seeps Downstream of RC-4 (SP-10W/10E) [(c)]	0%	75%	0%	0.2	0
East Waste Rock Pile [(b)]	15%	0%	90%	1	0.05
Copper Creek Diversion [(b)]	0%	95%	0%	0.05	0
Unaccounted Load - West Area [(c)]	0%	75%	0%	0.2	0
TP-1 Seeps & Flow Tubes[(d)]	80%	0%	0%	0	0
TP-2 Seeps & Flow Tubes (Upstream of RC-7) [(d)]	80%	0%	0%	0	0
TP2/3 Seeps & Flow Tubes (Downstream of RC-7) [(d)]	80%	0%	0%	0	0
Unaccounted Load - East Area [(d)]	80%	0%	0%	0	0
Loading Downstream of RC-2 (SP-21) [(d)]	80%	0%	0%	0	0
Loading downstream of RC-2 (Flow Tubes) [(d)]	80%	0%	0%	0	0

Treatment System	Estimated Treatment System Performance (mg/L)				Estimated Treatment System Coefficient of Variation			
	Cadmium $E[C_{Eff,Cd}]$	Copper $E[C_{Eff,Cu}]$	Iron $E[C_{Eff,Fe}]$	Zinc $E[C_{Eff,Zn}]$	Cadmium $CV[C_{Eff,Cd}]$	Copper $CV[C_{Eff,Cu}]$	Iron $CV[C_{Eff,Fe}]$	Zinc $CV[C_{Eff,Zn}]$
West Area	0.005	0.024	0.200	0.240	0.1	0.1	0.1	0.1
East Area, East of TP-3	NA	NA	NA	NA	NA	NA	NA	NA

West Area Groundwater Collection [(e)]		$E[Q_{GW}]$	$CV[Q_{GW}]$
Estimated Collection ($E[Q_{GW}]$,L/s) and Coefficient of Variation ($CV[Q_{GW}]$)	Spring	32	0.1
	Fall	18	0.1

Notes:
(a) Air-flow restrictions installed in open mine adits.
(b) Assume tops of waste rock piles are regraded to min. infiltration (30% of the total surface area regraded and 50% of precipitation in that area will runoff).
Assume impacted materials in the mill building are removed/covered; soils in the maintenance yard are capped with a concrete cap; lagoon area soils are removed; and Copper Creek Diversion is placed in a culvert.
(c) Loading reductions from these areas based on reduced loading to subsurface expected due to the installation of the upper West Area groundwater collection system and upgradient water and source controls.
(d) Help Model Scenario #2. Input parameters: 100% regrading and grass cover.
Approx. post remediation infiltration = 20%. (See Appendix G)
(e) Assume 90% collection of interecepted flows of 36 L/sec (spring) and 20 L/sec (fall).

Table D1-4
Alternative 3b - Water Management & Low-Energy West Area Treatment (Hydrostatic Bulkheads)
Short-Term Post Remediation Loading Analysis Summary

Source Area	Estimated Remedial Alternative Performance - Upgradient Controls and Downgradient Collection			Estimated Coefficients of Variation	
	Estimated Direct Precipitation Diverted (%)	Estimated Reduction in Metals Loading Due to Upgradient Controls(%), E[UG]	Downgradient Collection Efficiency (%), E[CE]	Upgradient Controls CV[UG]	Colletion Efficiency CV[CE]
SP-26/Unaccounted (Groundwater) Load Upstream of RC-1	80%	50%	0%	0.1	0
SP-23/Honeymoon Heights	0%	0%	90%	0	0.05
Underground Mine [(a)]	0%	0%	97%	0	0.05
West Waste Rock Pile [(b)]	15%	0%	90%	1	0.05
Mill Building [(b)]	50%	50%	90%	0.25	0.05
Other West Area Seeps (SP-9, 11, 25, 24) [(c)]	0%	75%	0%	0.2	0
West Area Seeps Downstream of RC-4(SP-10W/10E) [(c)]	0%	75%	0%	0.2	0
East Waste Rock Pile [(b)]	15%	0%	90%	1	0.05
Copper Creek Diversion [(b)]	0%	95%	0%	0.05	0
Unaccounted Load - West Area [(c)]	0%	75%	0%	0.2	0
TP-1 Seeps & Flow Tubes[(d)]	80%	0%	0%	0	0
TP-2 Seeps & Flow Tubes (Upstream of RC-7) [(d)]	80%	0%	0%	0	0
TP2/3 Seeps & Flow Tubes (Downstream of RC-7) [(d)]	80%	0%	0%	0	0
Unaccounted Load - East Area [(d)]	80%	0%	0%	0	0
Loading Downstream of RC-2 (SP-21) [(d)]	80%	0%	0%	0	0
Loading downstream of RC-2 (Flow Tubes) [(d)]	80%	0%	0%	0	0

Treatment System	Estimated Treatment System Performance (mg/L)				Estimated Treatment System Coefficient of Variation			
	Cadmium $E[C_{Eff,Cd}]$	Copper $E[C_{Eff,Cu}]$	Iron $E[C_{Eff,Fe}]$	Zinc $E[C_{Eff,Zn}]$	Cadmium $CV[C_{Eff,Cd}]$	Copper $CV[C_{Eff,Cu}]$	Iron $CV[C_{Eff,Fe}]$	Zinc $CV[C_{Eff,Zn}]$
West Area	0.005	0.024	0.200	0.240	0.1	0.1	0.1	0.1
East Area, East of TP-3	NA	NA	NA	NA	NA	NA	NA	NA

West Area Groundwater Collection [(e)]		$E[Q_{GW}]$	$CV[Q_{GW}]$
Estimated Collection ($E[Q_{GW}]$,L/s) and Coefficient of Variation ($CV[Q_{GW}]$)	Spring	32	0.1
	Fall	18	0.1

Notes:
(a) Air-flow restrictions installed in open mine adits. Hydrostatic bulkheads placed in 1500-level portals. Portal drainage concentrations ($E[C_{portal}]$) assumed to be equal to the "best estimates" due to flooding provided in Appendix E, Table 5 : Cd=0.1 mg/L, Cu=12 mg/L, Fe=2 mg/L, Zn=21 mg/L. $CV[C_{portal}]$s calculated based on the reasonable worst-case estimates due to mine flooding (Appendix E). Calculated $CV[C_{portal}]$s: Cd = 0.787, Cu = 0.39, Fe = 4.95, Zn = 1.1.
(b) Assume tops of waste rock piles are regraded to min. infiltration (30% of the total surface area regraded and 50% of precipitation in that area will runoff). Assume impacted materials in the mill building are removed/covered; soils in the maintenance yard are capped with a concrete cap; lagoon area soils are removed; and Copper Creek Diversion is placed in a culvert.
(c) Loading reductions from these areas based on reduced loading to subsurface expected due to the installation of the upper West Area groundwater collection system and upgradient water and source controls.
(d) Help Model Scenario #2. Input parameters: current conditions with 100% regrading and and grass cover. Approx. post remediation infiltration = 20%. (See Appendix G)
(e) Assume 90% collection of interecepted flows of 36 L/sec (spring) and 20 L/sec (fall).

Table D1-5
Alternative 4a - Water Management, Partial East Area Collection & Treatment
Short-Term Post Remediation Loading Analysis Summary

Source Area	Estimated Remedial Alternative Performance - Upgradient Controls and Downgradient Collection			Estimated Coefficients of Variation	
	Estimated Direct Precipitation Diverted (%)	Estimated Reduction in Metals Loading Due to Upgradient Controls(%), E[UG]	Downgradient Collection Efficiency (%), E[CE]	Upgradient Controls CV[UG]	Colletion Efficiency CV[CE]
SP-26/Unaccounted (Groundwater) Load Upstream of RC-1	80%	50%	0%	0.1	0
SP-23/Honeymoon Heights	0%	0%	0%	0	0
Underground Mine [(a)]	0%	0%	0%	0	0
West Waste Rock Pile [(b)]	15%	0%	0%	1	0
Mill Building [(b)]	50%	50%	0%	0.25	0
Other West Area Seeps (SP-9, 11, 25, 24) [(c)]	0%	25%	0%	1	0
West Area Seeps Downstream of RC-4 (SP-10W/10E) [(c)]	0%	25%	0%	1	0
East Waste Rock Pile [(b)]	15%	0%	0%	1	0
Copper Creek Diversion [(b)]	0%	95%	0%	0.05	0
Unaccounted Load - West Area [(c)]	0%	25%	0%	1	0
Intercepted TP-1 Seeps & Flow Tubes [(d)]	80%	0%	80%	0	0.25
Intercepted TP-2 Seeps & Flow Tubes (Upstream of RC-7) [(d)]	80%	0%	0%	0	0.25
Intercepted TP2/3 Seeps & Flow Tubes (Downstream of RC-7) [(d)]	80%	0%	80%	0	0.25
Unaccounted Load - East Area [(d)] [(e)]	80%	0%	20%	0	0.5
Loading downstream of RC-2 (SP-21) [(d)]	80%	0%	95%	0	0.05
Loading Downstream of RC-2 (Flow Tubes) [(d)]	80%	0%	90%	0	0.25

Treatment System	Estimated Treatment System Performance (mg/L)				Estimated Treatment System Coefficient of Variation			
	Cadmium $E[C_{Eff,Cd}]$	Copper $E[C_{Eff,Cu}]$	Iron $E[C_{Eff,Fe}]$	Zinc $E[C_{Eff,Zn}]$	Cadmium $CV[C_{Eff,Cd}]$	Copper $CV[C_{Eff,Cu}]$	Iron $CV[C_{Eff,Fe}]$	Zinc $CV[C_{Eff,Zn}]$
West Area	NA	NA	NA	NA	NA	NA	NA	NA
East Area, East of TP-3	0.005	0.035	0.200	0.350	0.1	0.1	0.1	0.1

East Area Groundwater Collection (other than intercepted flowtubes) [(f)]		$E[Q_{GW}]$	$CV[Q_{GW}]$
Estimated Collection ($E[Q_{GW}]$,L/s) and Coefficient of Variation ($CV[Q_{GW}]$)	Spring	14	1.4
	Fall	14	1.4

Notes:

(a) Air-flow restrictions installed in open mine adits. Hydrostatic bulkheads placed in 1500-level portals. Portal drainage concentrations ($E[C_{portal}]$) assumed to be equal to the "best estimates" due to flooding provided in Appendix E, Table 5 : Cd=0.1 mg/L, Cu=12 mg/L, Fe=2 mg/L, Zn=21 mg/L. $CV[C_{portal}]$s calculated based on the reasonable worst-case estimates due to mine flooding (Appendix E). Calculated $CV[C_{portal}]$s: Cd = 0.787, Cu = 0.39, Fe = 4.95, Zn = 1.1.

(b) Assume tops of waste rock piles are regraded to min. infiltration (30% of the total surface area regraded and 50% of precipitation in that area will runoff). Assume impacted materials in the mill building are removed/covered; soils in the maintenance yard are capped with a concrete cap; lagoon area soils are removed; and Copper Creek Diversion is placed in a culvert.

(c) Loading reductions from these areas expected due to the implementation of upgradient water and source controls.

(d) Help Model Scenario #2. Input parameters: 100% regrading and grass cover. Approx. post remediation infiltration = 20%. (See Appendix G)

(e) Assume 25% interception (Avg of TP-1, TP-2, & TP-3) @ 80% collection efficiency.

(f) Assume 80% collection of intercepted deep groundwater flow of 17 L/sec (spring and fall)

Table D1-6
Alternative 4b - Water Management, Extended East Area Collection & Treatment
Short-Term Post Remediation Loading Analysis Summary

Source Area	**Estimated Remedial Alternative Performance - Upgradient Controls and Downgradient Collection**			**Estimated Coefficients of Variation**	
	Estimated Direct Precipitation Diverted (%)	Estimated Reduction in Metals Loading Due to Upgradient Controls(%), E[UG]	Downgradient Collection Efficiency (%), E[CE]	Upgradient Controls CV[UG]	Colletion Efficiency CV[CE]
SP-26/Unaccounted (Groundwater) Load Upstream of RC-1	80%	50%	0%	0.1	0
SP-23/Honeymoon Heights	0%	0%	0%	0	0
Underground Mine [(a)]	0%	0%	0%	0	0
West Waste Rock Pile [(b)]	15%	0%	0%	1	0
Mill Building [(b)]	50%	50%	0%	0.25	0
Other West Area Seeps (SP-9, 11, 25, 24) [(c)]	0%	25%	0%	1	0
West Area Seeps Downstream of RC-4 (SP-10W/10E) [(c)]	0%	25%	0%	1	0
East Waste Rock Pile [(b)]	15%	0%	0%	1	0
Copper Creek Diversion [(b)]	0%	95%	0%	0.05	0
Unaccounted Load - West Area [(c)]	0%	25%	0%	1	0
Intercepted TP-1 Seeps & Flow Tubes [(d)]	80%	0%	80%	0	0.2
Intercepted TP-2 Seeps & Flow Tubes (Upstream of RC-7) [(d)]	80%	0%	80%	0	0.2
Intercepted TP2/3 Seeps & Flow Tubes (Downstream of RC-7) [(d)]	80%	0%	80%	0	0.2
Unaccounted Load - East Area [(d) (e)]	80%	0%	80%	0	0.2
Loading downstream of RC-2 (SP-21) [(d)]	80%	0%	95%	0	0.05
Loading Downstream of RC-2 (Flow Tubes) [(d)]	80%	0%	90%	0	0.2

Treatment System	**Estimated Treatment System Performance (mg/L)**				**Estimated Treatment System Coefficient of Variation**			
	Cadmium $E[C_{Eff,Cd}]$	Copper $E[C_{Eff,Cu}]$	Iron $E[C_{Eff,Fe}]$	Zinc $E[C_{Eff,Zn}]$	Cadmium $CV[C_{Eff,Cd}]$	Copper $CV[C_{Eff,Cu}]$	Iron $CV[C_{Eff,Fe}]$	Zinc $CV[C_{Eff,Zn}]$
West Area	NA	NA	NA	NA	NA	NA	NA	NA
East Area, East of TP-3	0.005	0.035	0.200	0.350	0.1	0.1	0.1	0.1

East Area Groundwater Collection (other than intercepted flowtubes) [(f)]		$E[Q_{GW}]$	$CV[Q_{GW}]$
Estimated Collection ($E[Q_{GW}]$,L/s) and Coefficient of Variation ($CV[Q_{GW}]$)	Spring	0	0
	Fall	0	0

Notes:
(a) Air-flow restrictions installed in open mine adits. Hydrostatic bulkheads placed in 1500-level portals. Portal drainage concentrations ($E[C_{portal}]$) assumed to be equal to the "best estimates" due to flooding provided in Appendix E, Table 5 : Cd=0.1 mg/L, Cu=12 mg/L, Fe=2 mg/L, Zn=21 mg/L. $CV[C_{portal}]$s calculated based on the reasonable worst-case estimates due to mine flooding (Appendix E). Calculated $CV[C_{portal}]$s: Cd = 0.787, Cu = 0.39, Fe = 4.95, Zn = 1.1.
(b) Assume tops of waste rock piles are regraded to min. infiltration (30% of the total surface area regraded and 50% of precipitation in that area will runoff). Assume impacted materials in the mill building are removed/covered; soils in the maintenance yard are capped with a concrete cap; lagoon area soils are removed; and Copper Creek Diversion is placed in a culvert.
(c) Loading reductions from these areas expected due to the implementation of upgradient water and source controls.
(d) Help Model Scenario #2. Input parameters: 100% regrading and grass cover. Approx. post remediation infiltration = 20%. (See Appendix G)
(e) Assume 100% interception @ 80% collection efficiency.
(f) Assume no deep groundwater collected by East Area barrier wall.

Table D1-7
Alternative 4c - Water Management, Extended Railroad Creek Relocation & East Area Treatment
Short-Term Post Remediation Loading Analysis Summary

Source Area	Estimated Remedial Alternative Performance - Upgradient Controls and Downgradient Collection			Estimated Coefficients of Variation	
	Estimated Direct Precipitation Diverted (%)	Estimated Reduction in Metals Loading Due to Upgradient Controls(%), E[UG]	Downgradient Collection Efficiency (%), E[CE]	Upgradient Controls CV[UG]	Colletion Efficiency CV[CE]
SP-26/Unaccounted (Groundwater) Load Upstream of RC-1	80%	50%	0%	0.1	0
SP-23/Honeymoon Heights	0%	0%	0%	0	0
Underground Mine [(a)]	0%	0%	0%	0	0
West Waste Rock Pile [(b)]	15%	0%	0%	1	0
Mill Building [(b)]	50%	50%	0%	0.25	0
Other West Area Seeps (SP-9, 11, 25, 24) [(c)]	0%	25%	0%	1	0
West Area Seeps Downstream of RC-4 (SP-10W/10E) [(c)]	0%	25%	0%	1	0
East Waste Rock Pile [(b)]	15%	0%	0%	1	0
Copper Creek Diversion [(b)]	0%	95%	0%	0.05	0
Unaccounted Load - West Area [(c)]	0%	25%	0%	1	0
Intercepted TP-1 Seeps & Flow Tubes [(d)]	80%	0%	80%	0	0.15
Intercepted TP-2 Seeps & Flow Tubes (Upstream of RC-7) [(d)]	80%	0%	80%	0	0.15
Intercepted TP2/3 Seeps & Flow Tubes (Downstream of RC-7) [(d)]	80%	0%	80%	0	0.15
Unaccounted Load - East Area [(d) (e)]	80%	0%	80%	0	0.15
Loading downstream of RC-2 (SP-21) [(d)]	80%	0%	95%	0	0.05
Loading Downstream of RC-2 (Flow Tubes) [(d)]	80%	0%	90%	0	0.15

Treatment System	Estimated Treatment System Performance (mg/L)				Estimated Treatment System Coefficient of Variation			
	Cadmium $E[C_{Eff,Cd}]$	Copper $E[C_{Eff,Cu}]$	Iron $E[C_{Eff,Fe}]$	Zinc $E[C_{Eff,Zn}]$	Cadmium $CV[C_{Eff,Cd}]$	Copper $CV[C_{Eff,Cu}]$	Iron $CV[C_{Eff,Fe}]$	Zinc $CV[C_{Eff,Zn}]$
West Area	NA	NA	NA	NA	NA	NA	NA	NA
East Area, East of TP-3	0.005	0.035	0.200	0.350	0.1	0.1	0.1	0.1

East Area Groundwater Collection (other than intercepted flowtubes) [(f)]		$E[Q_{GW}]$	$CV[Q_{GW}]$
Estimated Collection ($E[Q_{GW}]$,L/s) and Coefficient of Variation ($CV[Q_{GW}]$)	Spring	72	1.4
	Fall	46	1.4

Notes:
(a) Air-flow restrictions installed in open mine adits. Hydrostatic bulkheads placed in 1500-level portals. Portal drainage concentrations ($E[C_{portal}]$) assumed to be equal to the "best estimates" due to flooding provided in Appendix E, Table 5 : Cd=0.1 mg/L, Cu=12 mg/L, Fe=2 mg/L, Zn=21 mg/L. $CV[C_{portal}]$s calculated based on the reasonable worst-case estimates due to mine flooding (Appendix E). Calculated $CV[C_{portal}]$s: Cd = 0.787, Cu = 0.39, Fe = 4.95, Zn = 1.1.
(b) Assume tops of waste rock piles are regraded to min. infiltration (30% of the total surface area regraded and 50% of precipitation in that area will runoff). Assume impacted materials in the mill building are removed/covered; soils in the maintenance yard are capped with a concrete cap; lagoon area soils are removed; and Copper Creek Diversion is placed in a culvert.
(c) Loading reductions from these areas expected due to the implementation of upgradient water and source controls.
(d) Help Model Scenario #2. Input parameters: 100% regrading and grass cover. Approx. post remediation infiltration = 20%. (See Appendix G)
(e) Assume 100% interception @ 80% collection efficiency.
(f) Assume 80% collection of intercepted deep groundwater (11 L/sec spring and fall) and loss from relocated Railroad Creek (79 L/sec spring, 45 L/sec fall)

Table D1-8
Alternative 5a - Water Management, Partial East Area Collection, & East/West Area Treatment (Low-Energy WTP)
Short-Term Post Remediation Loading Analysis Summary

Source Area	Estimated Remedial Alternative Performance - Upgradient Controls and Downgradient Collection			Estimated Coefficients of Variation	
	Estimated Direct Precipitation Diverted (%)	Estimated Reduction in Metals Loading Due to Upgradient Controls(%), E[UG]	Downgradient Collection Efficiency (%), E[CE]	Upgradient Controls CV[UG]	Colletion Efficiency CV[CE]
SP-26/Unaccounted (Groundwater) Load Upstream of RC-1	80%	50%	0%	0.1	0
SP-23/Honeymoon Heights	0%	0%	90%	0	0.05
Underground Mine [(a)]	0%	0%	97%	0	0.025
West Waste Rock Pile [(b)]	15%	0%	90%	1	0.05
Mill Building [(b)]	50%	50%	90%	0.25	0.05
West Area Seeps (SP-9, 11, 25, 24) [(c)]	0%	75%	0%	0.2	0
West Area Seeps Downstream of RC-4 (SP-10W/10E) [(c)]	0%	75%	0%	0.2	0
East Waste Rock Pile [(b)]	15%	0%	90%	1	0.05
Copper Creek Diversion [(b)]	0%	95%	0%	0.05	0
Unaccounted Load - West Area & Flow Tube S1[(c)]	0%	75%	0%	0.2	0
Intercepted TP-1 Seeps & Flow Tubes[(d)]	80%	0%	80%	0	0.25
Intercepted TP-2 Seeps & Flow Tubes (Upstream of RC-7) [(d)]	80%	0%	0%	0	0.25
Intercepted TP-2/3 Seeps & Flow Tubes (Downstream of RC-7) [(d)]	80%	0%	80%	0	0.25
Unaccounted Load - East Area[(d) (e)]	80%	0%	20%	0	0.5
Loading Downstream of RC-2 (SP-21) [(d)]	80%	0%	95%	0	0.05
Loading Downstream of RC-2 (Flow Tubes, Fall Only) [(d)]	80%	0%	90%	0	0.25

Treatment System	Estimated Treatment System Performance (mg/L)				Estimated Treatment System Coefficient of Variation			
	Cadmium $E[C_{Eff,Cd}]$	Copper $E[C_{Eff,Cu}]$	Iron $E[C_{Eff,Fe}]$	Zinc $E[C_{Eff,Zn}]$	Cadmium $CV[C_{Eff,Cd}]$	Copper $CV[C_{Eff,Cu}]$	Iron $CV[C_{Eff,Fe}]$	Zinc $CV[C_{Eff,Zn}]$
West Area	0.005	0.024	0.200	0.240	0.1	0.1	0.1	0.1
East Area, East of TP-3	0.005	0.035	0.200	0.350	0.1	0.1	0.1	0.1

West Area Groundwater Collection [(f)]		$E[Q_{GW}]$	$CV[Q_{GW}]$
Estimated Collection ($E[Q_{GW}]$,L/s)	Spring	32	0.1
and Coefficient of Variation ($CV[Q_{GW}]$)	Fall	18	0.1
East Area Groundwater Collection (other than intercepted flowtubes) [(g)]		$E[Q_{GW}]$	$CV[Q_{GW}]$
Estimated Collection ($E[Q_{GW}]$,L/s)	Spring	14	1.4
and Coefficient of Variation ($CV[Q_{GW}]$)	Fall	14	1.4

Notes:
(a) Air-flow restrictions installed in open mine adits. Hydrostatic bulkheads placed in 1500-level portals. Portal drainage concentrations ($E[C_{portal}]$) assumed to be equal to the "best estimates" due to flooding provided in Appendix E, Table 5 : Cd=0.1 mg/L, Cu=12 mg/L, Fe=2 mg/L, Zn=21 mg/L. $CV[C_{portal}]$s calculated based on the reasonable worst-case estimates due to mine flooding (Appendix E). Calculated $CV[C_{portal}]$s: Cd = 0.787, Cu = 0.39, Fe = 4.95, Zn = 1.1.
(b) Assume tops of waste rock piles are regraded to min. infiltration (30% of the total surface area regraded and 50% of precipitation in that area will runoff). Assume impacted materials in the mill building are removed/covered; soils in the maintenance yard are capped with a concrete cap; lagoon area soils are removed; and Copper Creek Diversion is placed in a culvert.
(c) Loading reductions from these areas based on reduced loading to subsurface expected due to the installation of the upper West Area groundwater collection system and upgradient water and source controls.
(d) Help Model Scenario #2. Input parameters: 100% regrading and grass cover. Approx. post remediation infiltration = 20%. (See Appendix G)
(e) Assume 25% interception (Avg of TP-1, TP-2, & TP-3) @ 80% collection efficiency.
(f) Assume 90% collection of interecepted flows of 36 L/sec (spring) and 20 L/sec (fall).

Table D1-9
Alternative 5b - Water Management, Extended East Area Collection & East/West Area Treat. (Low-Energy WTP)
Short-Term Post Remediation Loading Analysis Summary

Source Area	Estimated Remedial Alternative Performance - Upgradient Controls and Downgradient Collection			Estimated Coefficients of Variation	
	Estimated Direct Precipitation Diverted (%)	Estimated Reduction in Metals Loading Due to Upgradient Controls(%), E[UG]	Downgradient Collection Efficiency (%), E[CE]	Upgradient Controls CV[UG]	Colletion Efficiency CV[CE]
SP-26/Unaccounted (Groundwater) Load Upstream of RC-1	80%	50%	0%	0.1	0
SP-23/Honeymoon Heights	0%	0%	90%	0	0.05
Underground Mine [(a)]	0%	0%	97%	0	0.025
West Waste Rock Pile [(b)]	15%	0%	90%	1	0.05
Mill Building [(b)]	50%	50%	90%	0.25	0.05
Other West Area Seeps (SP-9, 11, 25, 24) [(c)]	0%	75%	0%	0.2	0
West Area Seeps Downstream of RC-4 (SP-10W/10E) [(c)]	0%	75%	0%	0.2	0
East Waste Rock Pile [(b)]	15%	0%	90%	1	0.05
Copper Creek Diversion [(b)]	0%	95%	0%	0.05	0
Unaccounted Load - West Area & Flow Tube S1[(c)]	0%	75%	0%	0.2	0
Intercepted TP-1 Seeps & Flow Tubes[(d)]	80%	0%	80%	0	0.2
Intercepted TP-2 Seeps & Flow Tubes (Upstream of RC-7) [(d)]	80%	0%	80%	0	0.2
Intercepted TP-2/3 Seeps & Flow Tubes (Downstream of RC-7) [(d)]	80%	0%	80%	0	0.2
Unaccounted Load - East Area[(d) (e)]	80%	0%	80%	0	0.2
Loading Downstream of RC-2 (SP-21) [(d)]	80%	0%	95%	0	0.05
Loading Downstream of RC-2 (Flow Tubes, Fall Only) [(d)]	80%	0%	90%	0	0.2

Treatment System	Estimated Treatment System Performance (mg/L)				Estimated Treatment System Coefficient of Variation			
	Cadmium $E[C_{Eff,Cd}]$	Copper $E[C_{Eff,Cu}]$	Iron $E[C_{Eff,Fe}]$	Zinc $E[C_{Eff,Zn}]$	Cadmium $CV[C_{Eff,Cd}]$	Copper $CV[C_{Eff,Cu}]$	Iron $CV[C_{Eff,Fe}]$	Zinc $CV[C_{Eff,Zn}]$
West Area	0.005	0.024	0.200	0.240	0.1	0.1	0.1	0.1
East Area, East of TP-3	0.005	0.035	0.200	0.350	0.1	0.1	0.1	0.1

West Area Groundwater Collection [(f)]		$E[Q_{GW}]$	$CV[Q_{GW}]$
Estimated Collection ($E[Q_{GW}]$,L/s) and Coefficient of Variation ($CV[Q_{GW}]$)	Spring	32	0.1
	Fall	18	0.1
East Area Groundwater Collection (other than intercepted flowtubes) [(g)]		$E[Q_{GW}]$	$CV[Q_{GW}]$
Estimated Collection ($E[Q_{GW}]$,L/s) and Coefficient of Variation ($CV[Q_{GW}]$)	Spring	0	0
	Fall	0	0

Notes:
(a) Air-flow restrictions installed in open mine adits. Hydrostatic bulkheads placed in 1500-level portals. Portal drainage concentrations ($E[C_{portal}]$) assumed to be equal to the "best estimates" due to flooding provided in Appendix E, Table 5 : Cd=0.1 mg/L, Cu=12 mg/L, Fe=2 mg/L, Zn=21 mg/L. $CV[C_{portal}]$s calculated based on the reasonable worst-case estimates due to mine flooding (Appendix E). Calculated $CV[C_{portal}]$s: Cd = 0.787, Cu = 0.39, Fe = 4.95, Zn = 1.1.
(b) Assume tops of waste rock piles are regraded to min. infiltration (30% of the total surface area regraded and 50% of precipitation in that area will runoff). Assume impacted materials in the mill building are removed/covered; soils in the maintenance yard are capped with a concrete cap; lagoon area soils are removed; and Copper Creek Diversion is placed in a culvert.
(c) Loading reductions from these areas based on reduced loading to subsurface expected due to the installation of the upper West Area groundwater collection system and upgradient water and source controls.
(d) Help Model Scenario #2. Input parameters: 100% regrading and grass cover. Approx. post remediation infiltration = 20%. (See Appendix G)
(e) Assume 100% interception with 80% collection efficiency.
(f) Assume 90% collection of interecepted flows of 36 L/sec (spring) and 20 L/sec (fall).

Table D1-10
Alternative 5c - Water Management, Extended Railroad Creek Relocation & East/West Area Treat (Low-Energy WTP)
Short-Term Post Remediation Loading Analysis Summary

Source Area	Estimated Remedial Alternative Performance - Upgradient Controls and Downgradient Collection			Estimated Coefficients of Variation	
	Estimated Direct Precipitation Diverted (%)	Estimated Reduction in Metals Loading Due to Upgradient Controls(%), E[UG]	Downgradient Collection Efficiency (%), E[CE]	Upgradient Controls CV[UG]	Colletion Efficiency CV[CE]
SP-26/Unaccounted (Groundwater) Load Upstream of RC-1	80%	50%	0%	0.1	0
SP-23/Honeymoon Heights	0%	0%	90%	0	0.05
Underground Mine [a]	0%	0%	97%	0	0.025
West Waste Rock Pile [b]	15%	0%	90%	1	0.05
Mill Building [b]	50%	50%	90%	0.25	0.05
Other West Area Seeps (SP-9, 11, 25, 24) [c]	0%	75%	0%	0.2	0
West Area Seeps Downstream of RC-4 (SP-10W/10E) [c]	0%	75%	0%	0.2	0
East Waste Rock Pile [b]	15%	0%	90%	1	0.05
Copper Creek Diversion [b]	0%	95%	0%	0.05	0
Unaccounted Load - West Area & Flow Tube S1[c]	0%	75%	0%	0.2	0
Intercepted TP-1 Seeps & Flow Tubes[d]	80%	0%	80%	0	0.15
Intercepted TP-2 Seeps & Flow Tubes (Upstream of RC-7) [d]	80%	0%	80%	0	0.15
Intercepted TP-2/3 Seeps & Flow Tubes (Downstream of RC-7) [d]	80%	0%	80%	0	0.15
Unaccounted Load - East Area[d] [e]	80%	0%	80%	0	0.15
Loading Downstream of RC-2 (SP-21) [d]	80%	0%	95%	0	0.05
Loading Downstream of RC-2 (Flow Tubes) [d]	80%	0%	90%	0	0.15

Treatment System	Estimated Treatment System Performance (mg/L)				Estimated Treatment System Coefficient of Variation			
	Cadmium $E[C_{Eff,Cd}]$	Copper $E[C_{Eff,Cu}]$	Iron $E[C_{Eff,Fe}]$	Zinc $E[C_{Eff,Zn}]$	Cadmium $CV[C_{Eff,Cd}]$	Copper $CV[C_{Eff,Cu}]$	Iron $CV[C_{Eff,Fe}]$	Zinc $CV[C_{Eff,Zn}]$
West Area	0.005	0.024	0.200	0.240	0.1	0.1	0.1	0.1
East Area, East of TP-3	0.005	0.035	0.200	0.350	0.1	0.1	0.1	0.1

West Area Groundwater Collection [f]		$E[Q_{GW}]$	$CV[Q_{GW}]$
Estimated Collection ($E[Q_{GW}]$,L/s) and Coefficient of Variation ($CV[Q_{GW}]$)	Spring	32	0.1
	Fall	18	0.1
East Area Groundwater Collection (other than intercepted flowtubes) [g]		$E[Q_{GW}]$	$CV[Q_{GW}]$
Estimated Collection ($E[Q_{GW}]$,L/s) and Coefficient of Variation ($CV[Q_{GW}]$)	Spring	72	1.4
	Fall	46	1.4

Notes:
(a) Air-flow restrictions installed in open mine adits. Hydrostatic bulkheads placed in 1500-level portals. Portal drainage concentrations ($E[C_{portal}]$) assumed to be equal to the "best estimates" due to flooding provided in Appendix E, Table 5 : Cd=0.1 mg/L, Cu=12 mg/L, Fe=2 mg/L, Zn=21 mg/L. $CV[C_{portal}]$s calculated based on the reasonable worst-case estimates due to mine flooding (Appendix E). Calculated $CV[C_{portal}]$s: Cd = 0.787, Cu = 0.39, Fe = 4.95, Zn = 1.1.
(b) Assume tops of waste rock piles are regraded to min. infiltration (30% of the total surface area regraded and 50% of precipitation in that area will runoff). Assume impacted materials in the mill building are removed/covered; soils in the maintenance yard are capped with a concrete cap; lagoon area soils are removed; and Copper Creek Diversion is placed in a culvert.
(c) Loading reductions from these areas based on reduced loading to subsurface expected due to the installation of the upper West Area groundwater collection system and upgradient water and source controls.
(d) Help Model Scenario #2. Input parameters: 100% regrading and grass cover. Approx. post remediation infiltration = 20%. (See Appendix G)
(e) Assume 100% interception with 80% collection efficiency.
(f) Assume 90% collection of interecepted flows of 36 L/sec (spring) and 20 L/sec (fall).

Table D1-10a
Alternative 5d - Water Management, West Area Barrier Wall, Extended Railroad Creek Relocation & East/West Area Treat (Low-Energy WTP)
Short-Term Post Remediation Loading Analysis Summary

Source Area	Estimated Remedial Alternative Performance - Upgradient Controls and Downgradient Collection			Estimated Coefficients of Variation	
	Estimated Direct Precipitation Diverted (%)	Estimated Reduction in Metals Loading Due to Upgradient Controls(%), E[UG]	Downgradient Collection Efficiency (%), E[CE]	Upgradient Controls CV[UG]	Colletion Efficiency CV[CE]
SP-26/Unaccounted (Groundwater) Load Upstream of RC-1	80%	50%	0%	0.1	0
SP-23/Honeymoon Heights	0%	0%	90%	0	0.15
Underground Mine [(a)]	0%	0%	97%	0	0.025
West Waste Rock Pile [(b)]	15%	0%	90%	1	0.05
Mill Building [(b)]	50%	50%	90%	0.25	0.05
Other West Area Seeps (SP-9, 11, 25, 24) [(c)]	0%	75%	90%	0.2	0.15
West Area Seeps Downstream of RC-4 (SP-10W/10E) [(c)]	0%	75%	90%	0.2	0.15
East Waste Rock Pile [(b)]	15%	0%	90%	1	0.05
Copper Creek Diversion [(b)]	0%	95%	0%	0.05	0
Unaccounted Load - West Area & Flow Tube S1[(c)]	0%	75%	90%	0.2	0.15
Intercepted TP-1 Seeps & Flow Tubes[(d)]	80%	0%	80%	0	0.15
Intercepted TP-2 Seeps & Flow Tubes (Upstream of RC-7) [(d)]	80%	0%	80%	0	0.15
Intercepted TP-2/3 Seeps & Flow Tubes (Downstream of RC-7) [(d)]	80%	0%	80%	0	0.15
Unaccounted Load - East Area [(d) (e)]	80%	0%	80%	0	0.15
Loading Downstream of RC-2 (SP-21) [(d)]	80%	0%	95%	0	0.05
Loading Downstream of RC-2 (Flow Tubes) [(d)]	80%	0%	90%	0	0.15

Treatment System	Estimated Treatment System Performance (mg/L)				Estimated Treatment System Coefficient of Variation			
	Cadmium $E[C_{Eff,Cd}]$	Copper $E[C_{Eff,Cu}]$	Iron $E[C_{Eff,Fe}]$	Zinc $E[C_{Eff,Zn}]$	Cadmium $CV[C_{Eff,Cd}]$	Copper $CV[C_{Eff,Cu}]$	Iron $CV[C_{Eff,Fe}]$	Zinc $CV[C_{Eff,Zn}]$
West Area	0.005	0.024	0.200	0.240	0.1	0.1	0.1	0.1
East Area, East of TP-3	0.005	0.035	0.200	0.350	0.1	0.1	0.1	0.1

West Area Groundwater Collection (Upper Barrier Wall) [(f)]		$E[Q_{GW}]$	$CV[Q_{GW}]$
Estimated Collection ($E[Q_{GW}]$,L/s) and Coefficient of Variation ($CV[Q_{GW}]$)	Spring	32	0.1
	Fall	18	0.1
West Area Groundwater Collection (Lower Barrier Wall) [(g)]		$E[Q_{GW}]$	$CV[Q_{GW}]$
Estimated Collection ($E[Q_{GW}]$,L/s) and Coefficient of Variation ($CV[Q_{GW}]$)	Spring	3.3	0.1
	Fall	1.9	0.1
East Area Groundwater Collection (other than intercepted flowtubes) [(h)]		$E[Q_{GW}]$	$CV[Q_{GW}]$
Estimated Collection ($E[Q_{GW}]$,L/s) and Coefficient of Variation ($CV[Q_{GW}]$)	Spring	72	1.4
	Fall	46	1.4

Notes:
(a) Air-flow restrictions installed in open mine adits. Hydrostatic bulkheads placed in 1500-level portals. Portal drainage concentrations ($E[C_{portal}]$) assumed to be equal to the "best estimates" due to flooding provided in Appendix E, Table 5 : Cd=0.1 mg/L, Cu=12 mg/L, Fe=2 mg/L, Zn=21 mg/L. $CV[C_{portal}]$s calculated based on the reasonable worst-case estimates due to mine flooding (Appendix E). Calculated $CV[C_{portal}]$s: Cd = 0.787, Cu = 0.39, Fe = 4.95, Zn = 1.1.
(b) Assume tops of waste rock piles are regraded to min. infiltration (30% of the total surface area regraded and 50% of precipitation in that area will runoff). Assume impacted materials in the mill building are removed/covered; soils in the maintenance yard are capped with a concrete cap; lagoon area soils are removed; and Copper Creek Diversion is placed in a culvert.
(c) Loading reductions from these areas based on reduced loading to subsurface expected due to the installation of the upper West Area groundwater collection system and upgradient water and source controls.
(d) Help Model Scenario #2. Input parameters: 100% regrading and grass cover. Approx. post remediation infiltration = 20%. (See Appendix G)
(e) Assume 100% interception with 80% collection efficiency.
(f) Assume 90% collection of interecepted flows of 36 L/sec (spring) and 20 L/sec (fall) for upper West Area barrier wall. Collected groundwater conveyed to West Area treatment system.
(g) Assume 90% collection of intercepted flows of 3.7 L/sec (spring) and 2.1 L/sec (fall) for lower West Area barrier wall. Collected groundwater conveyed to East Area treatment system.
(h) Assume 80% collection of intercepted deep groundwater (11 L/sec spring and fall) and loss from relocated Railroad Creek (79 L/sec spring, 45 L/sec fall)

Table D1-11
Alternative 6a - Water Management, Extended Railroad Creek Relocation & East/West Area Treat (Mechanical West Area WTP)
Short-Term Post Remediation Loading Analysis Summary

Source Area	Estimated Remedial Alternative Performance - Upgradient Controls and Downgradient Collection			Estimated Coefficients of Variation	
	Estimated Direct Precipitation Diverted (%)	Estimated Reduction in Metals Loading Due to Upgradient Controls(%), E[UG]	Downgradient Collection Efficiency (%), E[CE]	Upgradient Controls CV[UG]	Colletion Efficiency CV[CE]
SP-26/Unaccounted (Groundwater) Load Upstream of RC-1	80%	50%	80%	0.1	0.15
SP-23/Honeymoon Heights	0%	0%	90%	0	0.15
Underground Mine [(a)]	0%	0%	97%	0	0.025
West Waste Rock Pile [(b)]	15%	0%	90%	1	0.05
Mill Building [(b)]	50%	50%	90%	0.25	0.05
Other West Area Seeps (SP-9, 11, 25, 24) [(c)]	0%	75%	90%	0.2	0.15
West Area Seeps Downstream of RC-4 (SP-10W/10E) [(c)]	0%	75%	90%	0.2	0.15
East Waste Rock Pile [(b)]	15%	0%	90%	1	0.05
Copper Creek Diversion [(b)]	0%	95%	0%	0.05	0
Unaccounted Load - West Area & Flow Tube S1 [(c)]	0%	75%	90%	0.2	0.15
TP-1 Seeps & Flow Tubes[(d)]	80%	0%	80%	0	0.15
TP-2 Seeps & Flow Tubes (Upstream of RC-7) [(d)]	80%	0%	80%	0	0.15
TP2/3 Seeps & Flow Tubes (Downstream of RC-7) [(d)]	80%	0%	80%	0	0.15
Unaccounted Load - East Area [(d) (e)]	80%	0%	80%	0	0.15
Loading Downstream of RC-2 (SP-21) [(d)]	80%	0%	95%	0	0.05
Loading Downstream of RC-2 (Flow Tubes) [(d)]	80%	0%	90%	0	0.15

Treatment System	Estimated Treatment System Performance (mg/L)				Estimated Treatment System Coefficient of Variation			
	Cadmium $E[C_{Eff,Cd}]$	Copper $E[C_{Eff,Cu}]$	Iron $E[C_{Eff,Fe}]$	Zinc $E[C_{Eff,Zn}]$	Cadmium $CV[C_{Eff,Cd}]$	Copper $CV[C_{Eff,Cu}]$	Iron $CV[C_{Eff,Fe}]$	Zinc $CV[C_{Eff,Zn}]$
West Area	0.005	0.024	0.200	0.240	0.1	0.1	0.1	0.1
East Area, East of TP-3	0.005	0.035	0.200	0.350	0.1	0.1	0.1	0.1

West Area Groundwater Collection Upper Barrier Wall (90% E[CE]) [(f)]		$E[Q_{GW}]$	$CV[Q_{GW}]$
Estimated Collection ($E[Q_{GW}]$,L/s) and Coefficient of Variation ($CV[Q_{GW}]$)	Spring	32	0.1
	Fall	18	0.1
West Area Groundwater Collection Lower Barrier Wall (90% E[CE] P-5 to RC-4; 80% E[CE] SP-26 to P-5) [(g)]		$E[Q_{GW}]$	$CV[Q_{GW}]$
Estimated Collection ($E[Q_{GW}]$,L/s) and Coefficient of Variation ($CV[Q_{GW}]$)	Spring	22	0.1
	Fall	12	0.1
East Area Groundwater Collection (other than intercepted flowtubes) [(h)]		$E[Q_{GW}]$	$CV[Q_{GW}]$
Estimated Collection ($E[Q_{GW}]$,L/s) and Coefficient of Variation ($CV[Q_{GW}]$)	Spring	72	1.4
	Fall	46	1.4

Notes:
(a) Air-flow restrictions installed in open mine adits.
(b) Assume tops of waste rock piles are regraded to min. infiltration (30% of the total surface area regraded and 50% of precipitation in that area will runoff).
Assume impacted materials in the mill building are removed/covered; soils in the maintenance yard are capped with a concrete cap;
lagoon area soils are removed; and Copper Creek Diversion is placed in a culvert.
(c) Loading reductions from these areas based on reduced loading to subsurface expected due to the installation of the upper West Area groundwater collection system and upgradient water and source controls.
(d) Help Model Scenario #3. Input parameters: 100% regrading and grass cover.
Approx. post remediation infiltration = 20%. (See Appendix G)
(e) Assume 100% interception with 80% collection efficiency.
(f) Assume 90% collection of interecepted flows of 36 L/sec (spring) and 20 L/sec (fall) for upper West Area barrier wall. Collected groundwater conveyed to West

Table D1-12
Alternative 6b - Water Management, Extended Railroad Creek Relocation & East/West Area Treat (Mechanical West Area WTP with Bulkhea
Short-Term Post Remediation Loading Analysis Summar

Source Area	Estimated Remedial Alternative Performance - Upgradient Controls and Downgradient Collection			Estimated Coefficients of Variation	
	Estimated Direct Precipitation Diverted (%)	Estimated Reduction in Metals Loading Due to Upgradient Controls(%), E[UG]	Downgradient Collection Efficiency (%), E[CE]	Upgradient Controls CV[UG]	Colletion Efficiency CV[CE]
SP-26/Unaccounted (Groundwater) Load Upstream of RC-1	80%	50%	80%	0.1	0.15
SP-23/Honeymoon Heights	0%	0%	90%	0	0.15
Underground Mine[a]	0%	0%	97%	0	0.025
West Waste Rock Pile [b]	15%	0%	90%	1	0.05
Mill Building[b]	50%	50%	90%	0.25	0.05
Other West Area Seeps (SP-9, 11, 25, 24) [c]	0%	75%	90%	0.2	0.15
West Area Seeps Downstream of RC-4 (SP-10W/10E) [c]	0%	75%	90%	0.2	0.15
East Waste Rock Pile [b]	15%	0%	90%	1	0.05
Copper Creek Diversion[b]	0%	95%	0%	0.05	0
Unaccounted Load - West Area & Flow Tube S1[c]	0%	75%	90%	0.2	0.15
Intercepted TP-1 Seeps & Flow Tubes[d]	80%	0%	80%	0	0.15
Intercepted TP-2 Seeps & Flow Tubes (Upstream of RC-7)[d]	80%	0%	80%	0	0.15
Intercepted TP2/3 Seeps & Flow Tubes (Downstream of RC-7) [d]	80%	0%	80%	0	0.15
Unaccounted Load - East Area[d] [e]	80%	0%	80%	0	0.15
Loading Downstream of RC-2 (SP-21) [d]	80%	0%	95%	0	0.05
Loading Downstream of RC-2 (Flow Tubes)[d]	80%	0%	90%	0	0.15

Treatment System	Estimated Treatment System Performance (mg/L)				Estimated Treatment System Coefficient of Variation			
	Cadmium $E[C_{Eff,Cd}]$	Copper $E[C_{Eff,Cu}]$	Iron $E[C_{Eff,Fe}]$	Zinc $E[C_{Eff,Zn}]$	Cadmium $CV[C_{Eff,Cd}]$	Copper $CV[C_{Eff,Cu}]$	Iron $CV[C_{Eff,Fe}]$	Zinc $CV[C_{Eff,Zn}]$
West Area	0.005	0.024	0.200	0.240	0.1	0.1	0.1	0.1
East Area, East of TP-3	0.005	0.035	0.200	0.350	0.1	0.1	0.1	0.1

West Area Groundwater Collection Upper Barrier Wall (90% E[CE])[f]		$E[Q_{GW}]$	$CV[Q_{GW}]$
Estimated Collection ($E[Q_{GW}]$,L/s)	Spring	32	0.1
and Coefficient of Variation ($CV[Q_{GW}]$)	Fall	18	0.1
West Area Groundwater Collection Lower Barrier Wall (90% E[CE] P-5 to RC-4; 80% E[CE] SP-26 to P-5)[g]		$E[Q_{GW}]$	$CV[Q_{GW}]$
Estimated Collection ($E[Q_{GW}]$,L/s)	Spring	22	0.1
and Coefficient of Variation ($CV[Q_{GW}]$)	Fall	12	0.1
East Area Groundwater Collection (other than intercepted flowtubes)[h]		$E[Q_{GW}]$	$CV[Q_{GW}]$
Estimated Collection ($E[Q_{GW}]$,L/s)	Spring	72	1.4
and Coefficient of Variation ($CV[Q_{GW}]$)	Fall	46	1.4

Notes:
(a) Air-flow restrictions installed in open mine adits. Hydrostatic bulkheads placed in 1500-level portals. Portal drainage concentrations ($E[C_{portal}]$) assumed to be equal to the "best estimates" due to flooding provided in Appendix E, Table 5 : Cd=0.1 mg/L, Cu=12 mg/L, Fe=2 mg/L, Zn=21 mg/L. $CV[C_{portal}]$s calculated based on the reasonable worst-case estimates due to mine flooding (Appendix E). Calculated $CV[C_{portal}]$s: Cd = 0.787, Cu = 0.39, Fe = 4.95, Zn = 1.1.
(b) Assume tops of waste rock piles are regraded to min. infiltration (30% of the total surface area regraded and 50% of precipitation in that area will runoff). Assume impacted materials in the mill building are removed/covered; soils in the maintenance yard are capped with a concrete cap; lagoon area soils are removed; and Copper Creek Diversion is placed in a culvert.
(c) Loading reductions from these areas based on reduced loading to subsurface expected due to the installation of the upper West Area groundwater collection system and upgradient water and source controls.
(d) Help Model Scenario #3. Input parameters: 100% regrading and grass cover. Approx. post remediation infiltration = 20%. (See Appendix G)
(e) Assume 100% interception with 80% collection efficiency.
(f) Assume 90% collection of interecepted flows of 36 L/sec (spring) and 20 L/sec (fall) for upper West Area barrier wall. Collected groundwater conveyed to West

Table D1-13
Alternative 7 - Capping, Consolidation, Water Management, & West Area Treatment (Low-Energy WTP)
Short-Term Post Remediation Loading Analysis Summary

Source Area	Estimated Remedial Alternative Performance - Upgradient Controls and Downgradient Collection			Estimated Coefficients of Variation	
	Estimated Direct Precipitation Diverted (%)	Estimated Reduction in Metals Loading Due to Upgradient Controls(%), E[UG]	Downgradient Collection Efficiency (%), E[CE]	Upgradient Controls CV[UG]	Colletion Efficiency CV[CE]
SP-26/Unaccounted (Groundwater) Load Upstream of RC-1	80%	50%	0%	0.1	0
SP-23/Honeymoon Heights	0%	0%	90%	0	0.05
Underground Mine [(a)]	0%	0%	97%	0	0.025
West Waste Rock Pile [(b)]	27%	0%	90%	1	0.05
Mill Building [(b)]	50%	50%	90%	0.25	0.05
Other West Area Seeps (SP-9, 11, 25, 24) [(c)]	0%	75%	0%	0.2	0
West Area Seeps Downstream of RC-4 (SP-10W/10E) [(c)]	0%	75%	0%	0.2	0
East Waste Rock Pile [(b)]	27%	0%	90%	1	0.05
Copper Creek Diversion [(b)]	0%	95%	0%	0.05	0
Unaccounted Load - West Area & Flow Tube S1 [(c)]	0%	75%	0%	0.2	0
TP-1 Seeps & Flow Tubes [(d) (e)]	95%	90%	0%	0.05	0
TP-2 Seeps & Flow Tubes (Upstream of RC-7) [(d)]	95%	0%	0%	0	0
TP2/3 Seeps & Flow Tubes (Downstream of RC-7) [(d)]	95%	0%	0%	0	0
Unaccounted Load - East Area [(d)]	95%	0%	0%	0	0
Loading Downstream of RC-2 (SP-21) [(d)]	95%	0%	0%	0	0
Loading Downstream of RC-2 (Flow Tubes) [(d)]	95%	0%	0%	0	0

Treatment System	Estimated Treatment System Performance (mg/L)				Estimated Treatment System Coefficient of Variation			
	Cadmium $E[C_{Eff,Cd}]$	Copper $E[C_{Eff,Cu}]$	Iron $E[C_{Eff,Fe}]$	Zinc $E[C_{Eff,Zn}]$	Cadmium $CV[C_{Eff,Cd}]$	Copper $CV[C_{Eff,Cu}]$	Iron $CV[C_{Eff,Fe}]$	Zinc $CV[C_{Eff,Zn}]$
West Area	0.005	0.024	0.200	0.240	0.1	0.1	0.1	0.1
East Area, East of TP-3	NA	NA	NA	NA	NA	NA	NA	NA

West Area Groundwater Collection [(f)]		$E[Q_{GW}]$	$CV[Q_{GW}]$
Estimated Collection ($E[Q_{GW}]$,L/s) and Coefficient of Variation ($CV[Q_{GW}]$)	Spring	32	0.1
	Fall	18	0.1

Notes:
(a) Air-flow restrictions installed in open mine adits. Hydrostatic bulkheads placed in 1500-level portals. Portal drainage concentrations ($E[C_{portal}]$) assumed to be equal to the "best estimates" due to flooding provided in Appendix E, Table 5 : Cd=0.1 mg/L, Cu=12 mg/L, Fe=2 mg/L, Zn=21 mg/L. $CV[C_{portal}]$s calculated based on the reasonable worst-case estimates due to mine flooding (Appendix E). Calculated $CV[C_{portal}]$s: Cd = 0.787, Cu = 0.39, Fe = 4.95, Zn = 1.1.
(b) Assume tops of waste rock piles are regraded to min. infiltration (30% of the total surface area regraded and covered).
Assume impacted materials in the mill building are removed/covered; soils in the maintenance yard are capped with a concrete cap; lagoon area soils are removed; and Copper Creek Diversion is placed in a culvert.
(c) Loading reductions from these areas based on reduced loading to subsurface expected due to the installation of the upper West Area groundwater collection system and upgradient water and source controls.
(d) Help Model Scenario #4. Input parameters: regrading and geosynthetic cover.
Approx. post remediation infiltration = 2%. (See Appendix G)
(e) Estimated loading reduction due to consolidation of TP-1 onto consolidated tailings pile.

Table D1-14
Alternative 8 - Source Control & East/West Area Treatment
Short-Term Post Remediation Loading Analysis Summary

Source Area	Estimated Remedial Alternative Performance - Upgradient Controls and Downgradient Collection: Estimated Direct Precipitation Diverted (%)	Estimated Reduction in Metals Loading Due to Upgradient Controls(%), E[UG]	Downgradient Collection Efficiency (%), E[CE]	Estimated Coefficients of Variation: Upgradient Controls CV[UG]	Colletion Efficiency CV[CE]
SP-26/Unaccounted (Groundwater) Load Upstream of RC-1	80%	50%	0%	0.1	0
SP-23/Honeymoon Heights	0%	0%	90%	0	0.05
Underground Mine [(a)]	0%	0%	97%	0	0.025
West Waste Rock Pile [(b)]	95%	90%	0%	1	0.05
Mill Building [(b)]	50%	50%	90%	0.25	0.05
Other West Area Seeps (SP-9, 11, 25, 24) [(c)]	0%	80%	0%	0.2	0
West Area Seeps Downstream of RC-4 (SP-10W/10E) [(c)]	0%	80%	0%	0.2	0
East Waste Rock Pile [(b)]	95%	90%	0%	1	0.05
Copper Creek Diversion [(b)]	0%	95%	0%	0.05	0
Unaccounted Load - West Area & Flow Tube S1 [(c)]	0%	80%	0%	0.2	0.15
TP-1 Seeps & Flow Tubes[(d) (e)]	95%	90%	0%	0.05	0
Intercepted TP-2 Seeps & Flow Tubes (Upstream of RC-7) [(d)]	95%	0%	80%	0	0.2
Intercepted TP2/3 Seeps & Flow Tubes (Downstream of RC-7) [(d)]	95%	0%	80%	0	0.2
Unaccounted Load - East Area [(d) (f)]	95%	0%	80%	0	0.2
Loading Downstream of RC-2 (SP-21) [(d)]	95%	0%	95%	0	0.05
Loading Downstream of RC-2 (Flow Tubes) [(d)]	95%	0%	90%	0	0.2

Treatment System	Estimated Treatment System Performance (mg/L): Cadmium $E[C_{Eff,Cd}]$	Copper $E[C_{Eff,Cu}]$	Iron $E[C_{Eff,Fe}]$	Zinc $E[C_{Eff,Zn}]$	Estimated Treatment System Coefficient of Variation: Cadmium $CV[C_{Eff,Cd}]$	Copper $CV[C_{Eff,Cu}]$	Iron $CV[C_{Eff,Fe}]$	Zinc $CV[C_{Eff,Zn}]$
West Area	0.005	0.024	0.200	0.240	0.1	0.1	0.1	0.1
East Area, East of TP-3	0.005	0.035	0.200	0.350	0.1	0.1	0.1	0.1

West Area Groundwater Collection [(g)]		$E[Q_{GW}]$	$CV[Q_{GW}]$
Estimated Collection ($E[Q_{GW}]$,L/s) and Coefficient of Variation ($CV[Q_{GW}]$)	Spring	0	0
	Fall	0	0
East Area Groundwater Collection (other than intercepted flowtubes) [(h)]		$E[Q_{GW}]$	$CV[Q_{GW}]$
Estimated Collection ($E[Q_{GW}]$,L/s) and Coefficient of Variation ($CV[Q_{GW}]$)	Spring	0	0
	Fall	0	0

Notes:
(a) Air-flow restrictions installed in open mine adits. Hydrostatic bulkheads placed in 1500-level portals. Portal drainage concentrations ($E[C_{portal}]$) assumed to be equal to the "best estimates" due to flooding provided in Appendix E, Table 5 : Cd=0.1 mg/L, Cu=12 mg/L, Fe=2 mg/L, Zn=21 mg/L. $CV[C_{portal}]$s calculated based on the reasonable worst-case estimates due to mine flooding (Appendix E). Calculated $CV[C_{portal}]$s: Cd = 0.787, Cu = 0.39, Fe = 4.95, Zn = 1.1.
(b) Assume waste rock piles are consolidated onto consolidated tailings pile.
Assume impacted materials in the mill building are removed/covered; soils in the maintenance yard are capped with a concrete cap; lagoon area soils are removed; and Copper Creek Diversion is placed in a culvert.
(c) Loading reductions from these areas based on reduced loading to subsurface expected due to the installation of the upper West Area groundwater collection system and upgradient water and source controls.
(d) Help Model Scenario #4. Input parameters: regrading and geosynthetic cover.
Approx. post remediation infiltration = 2%. (See Appendix G)
(e) Estimated loading reduction due to consolidation of TP-1 onto consolidated tailings pile.
(f) Assume 100% interception with 80% collection efficiency.

Table D2-1
Alternative 2a - Water Management (Open Portal)
Long-Term Post Remediation Loading Analysis Summary

Source Area	**Estimated Remedial Alternative Performance - Upragient Controls and Downgradient Collection**			**Estimated Coefficients of Variation**	
	Estimated Direct Precipitation Diverted (%)	Estimated Reduction in Metals Loading Due to Upgradient Controls(%), E[UG]	Downgradient Collection Efficiency (%), E[CE]	Upgradient Controls CV[UG]	Colletion CV[CE]
SP-26/Unaccounted (Groundwater) Load Upstream of RC-1	80%	60%	0%	0.1	0
SP-23/Honeymoon Heights	0%	0%	0%	0	0
Underground Mine [(a)]	0%	0%	0%	1	0
West Waste Rock Pile	15%	0%	0%	1	0
Mill Building [(b)]	50%	60%	0%	0.25	0
Other West Area Seeps (SP-9, 11, 25, 24) [(c)]	0%	30%	0%	1	0
West Area Seeps Downstream of RC-4 (SP-10W/10E) [(c)]	0%	30%	0%	1	0
East Waste Rock Pile [(b)]	15%	0%	0%	1	0
Copper Creek Diversion [(b)]	0%	95%	0%	0.05	0
Unaccounted Load - West Area [(c)]	0%	30%	0%	1	0
TP-1 Seeps & Flow Tubes[(d)]	80%	0%	0%	0	0
TP-2 Seeps & Flow Tubes (Upstream of RC-7) [(d)]	80%	0%	0%	0	0
TP2/3 Seeps & Flow Tubes (Downstream of RC-7) [(d)]	80%	0%	0%	0	0
Unaccounted Load - East Area [(d)]	80%	0%	0%	0	0
Loading Downstream of RC-2 (SP-21) [(d)]	80%	0%	0%	0	0
Loading downstream of RC-2 (Flow Tubes) [(d)]	80%	0%	0%	0	0

Notes:
(a) Air-flow restrictions installed in open mine adits.
(b) Assume tops of waste rock piles are regraded to min. infiltration (30% of the total surface area regraded and 50% of precipitation in that area will runoff).
Assume impacted materials in the mill building are removed/covered; soils in the maintenance yard are capped with a concrete cap;
lagoon area soils are removed; and Copper Creek Diversion is placed in a culvert.
(c) Loading reductions from these areas expected due to the implementation of upgradient water and source controls.
(d) Help Model Scenario #2. Input parameters: 100% regrading and grass cover.
Approx. post remediation infiltration = 20%. (See Appendix G)

Table D2-2
Alternative 2b - Water Management (Hydrostatic Bulkheads)
Long-Term Post Remediation Loading Analysis Summary

Source Area	**Estimated Remedial Alternative Performance - Upragient Controls and Downgradient Collection**			**Estimated Coefficients of Variation**	
	Estimated Direct Precipitation Diverted (%)	Estimated Reduction in Metals Loading Due to Upgradient Controls(%), E[UG]	Downgradient Collection Efficiency (%), E[CE]	Upgradient Controls CV[UG]	Colletion CV[CE]
SP-26/Unaccounted (Groundwater) Load Upstream of RC-1	80%	60%	0%	0.1	0
SP-23/Honeymoon Heights	0%	0%	0%	0	0
Underground Mine [(a)]	0%	(a)	0%	0	0
West Waste Rock Pile [(b)]	15%	0%	0%	1	0
Mill Building [(b)]	50%	60%	0%	0.25	0
Other West Area Seeps (SP-9, 11, 25, 24) [(c)]	0%	30%	0%	1	0
West Area Seeps Downstream of RC-4 (SP-10W/10E) [(c)]	0%	30%	0%	1	0
East Waste Rock Pile [(b)]	15%	0%	0%	1	0
Copper Creek Diversion [(b)]	0%	95%	0%	0.05	0
Unaccounted Load - West Area [(c)]	0%	30%	0%	1	0
TP-1 Seeps & Flow Tubes[(d)]	80%	0%	0%	0	0
TP-2 Seeps & Flow Tubes (Upstream of RC-7) [(d)]	80%	0%	0%	0	0
TP2/3 Seeps & Flow Tubes (Downstream of RC-7) [(d)]	80%	0%	0%	0	0
Unaccounted Load - East Area [(d)]	80%	0%	0%	0	0
Loading Downstream of RC-2 (SP-21) [(d)]	80%	0%	0%	0	0
Loading downstream of RC-2 (Flow Tubes) [(d)]	80%	0%	0%	0	0

Notes:
(a) Air-flow restrictions installed in open mine adits. Hydrostatic bulkheads placed in 1500-level portals. Portal drainage concentrations assumed to be equal to baseline spring and fall concentrations.
(b) Assume tops of waste rock piles are regraded to min. infiltration (30% of the total surface area regraded and 50% of precipitation in that area will runoff). Assume impacted materials in the mill building are removed/covered; soils in the maintenance yard are capped with a concrete cap; lagoon area soils are removed; and Copper Creek Diversion is placed in a culvert.
(c) Loading reductions from these areas expected due to the implementation of upgradient water and source controls.
(d) Help Model Scenario #2. Input parameters: 100% regrading and grass cover.
Approx. post remediation infiltration = 20%. (See Appendix G)

Table D2-3
Alternative 3a - Water Management & Low-Energy West Area Treatment (Open Portal)
Long-Term Post Remediation Loading Analysis Summary

Source Area	Estimated Remedial Alternative Performance - Upragient Controls and Downgradient Collection			Estimated Coefficients of Variation	
	Estimated Direct Precipitation Diverted (%)	Estimated Reduction in Metals Loading Due to Upgradient Controls(%), E[UG]	Downgradient Collection Efficiency (%), E[CE]	Upgradient Controls CV[UG]	Colletion Efficiency CV[CE]
SP-26/Unaccounted (Groundwater) Load Upstream of RC-1	80%	60%	0%	0.1	0
SP-23/Honeymoon Heights	0%	0%	90%	0	0.05
Underground Mine [(a)]	0%	0%	97%	1	0.05
West Waste Rock Pile [(b)]	15%	0%	90%	1	0.05
Mill Building [(b)]	50%	60%	90%	0.25	0.05
Other West Area Seeps (SP-9, 11, 25, 24) [(c)]	0%	85%	0%	0.2	0
West Area Seeps Downstream of RC-4 (SP-10W/10E) [(c)]	0%	85%	0%	0.2	0
East Waste Rock Pile [(b)]	15%	0%	90%	1	0.05
Copper Creek Diversion [(b)]	0%	95%	0%	0.05	0
Unaccounted Load - West Area [(c)]	0%	85%	0%	0.2	0
TP-1 Seeps & Flow Tubes[(d)]	80%	0%	0%	0	0
TP-2 Seeps & Flow Tubes (Upstream of RC-7) [(d)]	80%	0%	0%	0	0
TP2/3 Seeps & Flow Tubes (Downstream of RC-7) [(d)]	80%	0%	0%	0	0
Unaccounted Load - East Area [(d)]	80%	0%	0%	0	0
Loading Downstream of RC-2 (SP-21) [(d)]	80%	0%	0%	0	0
Loading downstream of RC-2 (Flow Tubes) [(d)]	80%	0%	0%	0	0

Treatment System	Estimated Treatment System Performance (mg/L)				Estimated Treatment System Coefficient of Variation			
	Cadmium $E[C_{Eff,Cd}]$	Copper $E[C_{Eff,Cu}]$	Iron $E[C_{Eff,Fe}]$	Zinc $E[C_{Eff,Zn}]$	Cadmium $CV[C_{Eff,Cd}]$	Copper $CV[C_{Eff,Cu}]$	Iron $CV[C_{Eff,Fe}]$	Zinc $CV[C_{Eff,Zn}]$
West Area	0.005	0.024	0.200	0.240	0.1	0.1	0.1	0.1
East Area, East of TP-3	NA	NA	NA	NA	NA	NA	NA	NA

West Area Groundwater Collection [(e)]		$E[Q_{GW}]$	$CV[Q_{GW}]$
Estimated Collection ($E[Q_{GW}]$,L/s) and Coefficient of Variation ($CV[Q_{GW}]$)	Spring	32	0.1
	Fall	18	0.1

Notes:
(a) Air-flow restrictions installed in open mine adits.
(b) Assume tops of waste rock piles are regraded to min. infiltration (30% of the total surface area regraded and 50% of precipitation in that area will runoff).
Assume impacted materials in the mill building are removed/covered; soils in the maintenance yard are capped with a concrete cap;
lagoon area soils are removed; and Copper Creek Diversion is placed in a culvert.
(c) Loading reductions from these areas based on reduced loading to subsurface expected due to the installation of the upper West Area groundwater collection system and upgradient water and source controls.
(d) Help Model Scenario #2. Input parameters: 100% regrading and grass cover.
Approx. post remediation infiltration = 20%. (See Appendix G)
(e) Assume 90% collection of interecepted flows of 36 L/sec (spring) and 20 L/sec (fall).

Table D2-4
Alternative 3b - Water Management & Low-Energy West Area Treatment (Hydrostatic Bulkheads)
Long-Term Post Remediation Loading Analysis Summary

Source Area	Estimated Remedial Alternative Performance - Upragient Controls and Downgradient Collection			Estimated Coefficients of Variation	
	Estimated Direct Precipitation Diverted (%)	Estimated Reduction in Metals Loading Due to Upgradient Controls(%), E[UG]	Downgradient Collection Efficiency (%), E[CE]	Upgradient Controls CV[UG]	Colletion Efficiency CV[CE]
SP-26/Unaccounted (Groundwater) Load Upstream of RC-1	80%	60%	0%	0.1	0
SP-23/Honeymoon Heights	0%	0%	90%	0	0.05
Underground Mine [(a)]	0%	(a)	97%	0	0.05
West Waste Rock Pile [(b)]	15%	0%	90%	1	0.05
Mill Building [(b)]	50%	60%	90%	0.25	0.05
Other West Area Seeps (SP-9, 11, 25, 24) [(c)]	0%	85%	0%	0.2	0
West Area Seeps Downstream of RC-4 (SP-10W/10E) [(c)]	0%	85%	0%	0.2	0
East Waste Rock Pile [(b)]	15%	0%	90%	1	0.05
Copper Creek Diversion [(b)]	0%	95%	0%	0.05	0
Unaccounted Load - West Area [(c)]	0%	85%	0%	0.2	0
TP-1 Seeps & Flow Tubes[(d)]	80%	0%	0%	0	0
TP-2 Seeps & Flow Tubes (Upstream of RC-7) [(d)]	80%	0%	0%	0	0
TP2/3 Seeps & Flow Tubes (Downstream of RC-7) [(d)]	80%	0%	0%	0	0
Unaccounted Load - East Area [(d)]	80%	0%	0%	0	0
Loading Downstream of RC-2 (SP-21) [(d)]	80%	0%	0%	0	0
Loading downstream of RC-2 (Flow Tubes) [(d)]	80%	0%	0%	0	0

Treatment System	Estimated Treatment System Performance (mg/L)				Estimated Treatment System Coefficient of Variation			
	Cadmium $E[C_{Eff,Cd}]$	Copper $E[C_{Eff,Cu}]$	Iron $E[C_{Eff,Fe}]$	Zinc $E[C_{Eff,Zn}]$	Cadmium $CV[C_{Eff,Cd}]$	Copper $CV[C_{Eff,Cu}]$	Iron $CV[C_{Eff,Fe}]$	Zinc $CV[C_{Eff,Zn}]$
West Area	0.005	0.024	0.200	0.240	0.1	0.1	0.1	0.1
East Area, East of TP-3	NA	NA	NA	NA	NA	NA	NA	NA

West Area Groundwater Collection [(e)]		$E[Q_{GW}]$	$CV[Q_{GW}]$
Estimated Collection ($E[Q_{GW}]$,L/s) and Coefficient of Variation ($CV[Q_{GW}]$)	Spring	32	0.1
	Fall	18	0.1

Notes:
(a) Air-flow restrictions installed in open mine adits. Hydrostatic bulkheads placed in 1500-level portals. Portal drainage concentrations assumed to be equal to baseline spring and fall concentrations.
(b) Assume tops of waste rock piles are regraded to min. infiltration (30% of the total surface area regraded and 50% of precipitation in that area will runoff). Assume impacted materials in the mill building are removed/covered; soils in the maintenance yard are capped with a concrete cap; lagoon area soils are removed; and Copper Creek Diversion is placed in a culvert.
(c) Loading reductions from these areas based on reduced loading to subsurface expected due to the installation of the upper West Area groundwater collection system and upgradient water and source controls.
(d) Help Model Scenario #2. Input parameters: 100% regrading and grass cover. Approx. post remediation infiltration = 20%. (See Appendix G)
(e) Assume 90% collection of interecepted flows of 36 L/sec (spring) and 20 L/sec (fall).

Table D2-5
Alternative 4a - Water Management, Partial East Area Collection & Treatment
Long-Term Post Remediation Loading Analysis Summary

Source Area	Estimated Remedial Alternative Performance - Upragient Controls and Downgradient Collection			Estimated Coefficients of Variation	
	Estimated Direct Precipitation Diverted (%)	Estimated Reduction in Metals Loading Due to Upgradient Controls(%), E[UG]	Downgradient Collection Efficiency (%), E[CE]	Upgradient Controls CV[UG]	Colletion Efficiency CV[CE]
SP-26/Unaccounted (Groundwater) Load Upstream of RC-1	80%	60%	0%	0.1	0
SP-23/Honeymoon Heights	0%	0%	0%	0	0
Underground Mine [(a)]	0%	(a)	0%	0	0
West Waste Rock Pile [(b)]	15%	0%	0%	1	0
Mill Building [(b)]	50%	60%	0%	0.25	0
Other West Area Seeps (SP-9, 11, 25, 24) [(c)]	0%	30%	0%	1	0
West Area Seeps Downstream of RC-4 (SP-10W/10E) [(c)]	0%	30%	0%	1	0
East Waste Rock Pile [(b)]	15%	0%	0%	1	0
Copper Creek Diversion [(b)]	0%	95%	0%	0.05	0
Unaccounted Load - West Area [(c)]	0%	30%	0%	1	0
Intercepted TP-1 Seeps & Flow Tubes[(d)]	80%	0%	80%	0	0.25
Intercepted TP-2 Seeps & Flow Tubes (Upstream of RC-7) [(d)]	80%	0%	0%	0	0.25
Intercepted TP2/3 Seeps & Flow Tubes (Downstream of RC-7) [(d)]	80%	0%	80%	0	0.25
Unaccounted Load - East Area [(d) (e)]	80%	0%	20%	0	0.5
Loading downstream of RC-2 (SP-21) [(d)]	80%	0%	95%	0	0.05
Loading Downstream of RC-2 (Flow Tubes) [(d)]	80%	0%	90%	0	0.25

Treatment System	Estimated Treatment System Performance (mg/L)				Estimated Treatment System Coefficient of Variation			
	Cadmium $E[C_{Eff,Cd}]$	Copper $E[C_{Eff,Cu}]$	Iron $E[C_{Eff,Fe}]$	Zinc $E[C_{Eff,Zn}]$	Cadmium $CV[C_{Eff,Cd}]$	Copper $CV[C_{Eff,Cu}]$	Iron $CV[C_{Eff,Fe}]$	Zinc $CV[C_{Eff,Zn}]$
West Area	NA	NA	NA	NA	NA	NA	NA	NA
East Area, East of TP-3	0.005	0.035	0.200	0.350	0.1	0.1	0.1	0.1

East Area Groundwater Collection (other than intercepted flowtubes) [(f)]		$E[Q_{GW}]$	$CV[Q_{GW}]$
Estimated Collection ($E[Q_{GW}]$,L/s) and Coefficient of Variation ($CV[Q_{GW}]$)	Spring	14	1.4
	Fall	14	1.4

Notes:
(a) Air-flow restrictions installed in open mine adits. Hydrostatic bulkheads placed in 1500-level portals. Portal drainage concentrations assumed to be equal to baseline spring and fall concentrations.
(b) Assume tops of waste rock piles are regraded to min. infiltration (30% of the total surface area regraded and 50% of precipitation in that area will runoff). Assume impacted materials in the mill building are removed/covered; soils in the maintenance yard are capped with a concrete cap; lagoon area soils are removed; and Copper Creek Diversion is placed in a culvert.
(c) Loading reductions from these areas expected due to the implementation of upgradient water and source controls.
(d) Help Model Scenario #2. Input parameters: 100% regrading and grass cover. Approx. post remediation infiltration = 20%. (See Appendix G)
(e) Assume 25% interception (Avg of TP-1, TP-2, & TP-3) @ 80% collection efficiency.
(f) Assume 80% collection of intercepted deep groundwater flow of 17 L/sec (spring and fall)

Table D2-6
Alternative 4b - Water Management, Extended East Area Collection & Treatment
Long-Term Post Remediation Loading Analysis Summary

Source Area	**Estimated Remedial Alternative Performance - Upragient Controls and Downgradient Collection**			**Estimated Coefficients of Variation**	
	Estimated Direct Precipitation Diverted (%)	Estimated Reduction in Metals Loading Due to Upgradient Controls(%), E[UG]	Downgradient Collection Efficiency (%), E[CE]	Upgradient Controls CV[UG]	Colletion Efficiency CV[CE]
SP-26/Unaccounted (Groundwater) Load Upstream of RC-1	80%	60%	0%	0.1	0
SP-23/Honeymoon Heights	0%	0%	0%	0	0
Underground Mine [(a)]	0%	(a)	0%	0	0
West Waste Rock Pile [(b)]	15%	0%	0%	1	0
Mill Building [(b)]	50%	60%	0%	0.25	0
Other West Area Seeps (SP-9, 11, 25, 24) [(c)]	0%	30%	0%	1	0
West Area Seeps Downstream of RC-4 (SP-10W/10E) [(c)]	0%	30%	0%	1	0
East Waste Rock Pile [(b)]	15%	0%	0%	1	0
Copper Creek Diversion [(b)]	0%	95%	0%	0.05	0
Unaccounted Load - West Area [(c)]	0%	30%	0%	1	0
Intercepted TP-1 Seeps & Flow Tubes[(d)]	80%	0%	80%	0	0.3
Intercepted TP-2 Seeps & Flow Tubes (Upstream of RC-7) [(d)]	80%	0%	80%	0	0.3
Intercepted TP2/3 Seeps & Flow Tubes (Downstream of RC-7) [(d)]	80%	0%	80%	0	0.3
Unaccounted Load - East Area [(d) (e)]	80%	0%	80%	0	0.3
Loading downstream of RC-2 (SP-21) [(d)]	80%	0%	95%	0	0.05
Loading Downstream of RC-2 (Flow Tubes) [(d)]	80%	0%	90%	0	0.3

Treatment System	**Estimated Treatment System Performance (mg/L)**				**Estimated Treatment System Coefficient of Variation**			
	Cadmium $E[C_{Eff,Cd}]$	Copper $E[C_{Eff,Cu}]$	Iron $E[C_{Eff,Fe}]$	Zinc $E[C_{Eff,Zn}]$	Cadmium $CV[C_{Eff,Cd}]$	Copper $CV[C_{Eff,Cu}]$	Iron $CV[C_{Eff,Fe}]$	Zinc $CV[C_{Eff,Zn}]$
West Area	NA	NA	NA	NA	NA	NA	NA	NA
East Area, East of TP-3	0.005	0.035	0.200	0.350	0.1	0.1	0.1	0.1

East Area Groundwater Collection (other than intercepted flowtubes) [(f)]		$E[Q_{GW}]$	$CV[Q_{GW}]$
Estimated Collection ($E[Q_{GW}]$,L/s) and Coefficient of Variation ($CV[Q_{GW}]$)	Spring	0	0
	Fall	0	0

Notes:
(a) Air-flow restrictions installed in open mine adits. Hydrostatic bulkheads placed in 1500-level portals. Portal drainage concentrations assumed to be equal to baseline spring and fall concentrations.
(b) Assume tops of waste rock piles are regraded to min. infiltration (30% of the total surface area regraded and 50% of precipitation in that area will runoff). Assume impacted materials in the mill building are removed/covered; soils in the maintenance yard are capped with a concrete cap; lagoon area soils are removed; and Copper Creek Diversion is placed in a culvert.
(c) Loading reductions from these areas expected due to the implementation of upgradient water and source controls.
(d) Help Model Scenario #2. Input parameters: 100% regrading and grass cover. Approx. post remediation infiltration = 20%. (See Appendix G)
(e) Assume 100% interception @ 80% collection efficiency.
(f) Assume no deep groundwater collected by East Area barrier wall.

Table D2-7
Alternative 4c - Water Management, Extended Railroad Creek Relocation & East Area Treatment
Long-Term Post Remediation Loading Analysis Summary

Source Area	Estimated Remedial Alternative Performance - Upragient Controls and Downgradient Collection			Estimated Coefficients of Variation	
	Estimated Direct Precipitation Diverted (%)	Estimated Reduction in Metals Loading Due to Upgradient Controls(%), E[UG]	Downgradient Collection Efficiency (%), E[CE]	Upgradient Controls CV[UG]	Colletion Efficiency CV[CE]
SP-26/Unaccounted (Groundwater) Load Upstream of RC-1	80%	60%	0%	0.1	0
SP-23/Honeymoon Heights	0%	0%	0%	0	0
Underground Mine [(a)]	0%	(a)	0%	0	0
West Waste Rock Pile [(b)]	15%	0%	0%	1	0
Mill Building [(b)]	50%	60%	0%	0.25	0
Other West Area Seeps (SP-9, 11, 25, 24) [(c)]	0%	30%	0%	1	0
West Area Seeps Downstream of RC-4 (SP-10W/10E) [(c)]	0%	30%	0%	1	0
East Waste Rock Pile [(b)]	15%	0%	0%	1	0
Copper Creek Diversion [(b)]	0%	95%	0%	0.05	0
Unaccounted Load - West Area [(c)]	0%	30%	0%	1	0
Intercepted TP-1 Seeps & Flow Tubes[(d)]	80%	0%	80%	0	0.15
Intercepted TP-2 Seeps & Flow Tubes (Upstream of RC-7) [(d)]	80%	0%	80%	0	0.15
Intercepted TP2/3 Seeps & Flow Tubes (Downstream of RC-7) [(d)]	80%	0%	80%	0	0.15
Unaccounted Load - East Area [(d) (e)]	80%	0%	80%	0	0.15
Loading downstream of RC-2 (SP-21) [(d)]	80%	0%	95%	0	0.05
Loading Downstream of RC-2 (Flow Tubes) [(d)]	80%	0%	90%	0	0.15

Treatment System	Estimated Treatment System Performance (mg/L)				Estimated Treatment System Coefficient of Variation			
	Cadmium $E[C_{Eff,Cd}]$	Copper $E[C_{Eff,Cu}]$	Iron $E[C_{Eff,Fe}]$	Zinc $E[C_{Eff,Zn}]$	Cadmium $CV[C_{Eff,Cd}]$	Copper $CV[C_{Eff,Cu}]$	Iron $CV[C_{Eff,Fe}]$	Zinc $CV[C_{Eff,Zn}]$
West Area	NA	NA	NA	NA	NA	NA	NA	NA
East Area, East of TP-3	0.005	0.035	0.200	0.350	0.1	0.1	0.1	0.1

East Area Groundwater Collection (other than intercepted flowtubes) [(f)]		$E[Q_{GW}]$	$CV[Q_{GW}]$
Estimated Collection ($E[Q_{GW}]$,L/s) and Coefficient of Variation ($CV[Q_{GW}]$)	Spring	72	1.4
	Fall	46	1.4

Notes:
(a) Air-flow restrictions installed in open mine adits. Hydrostatic bulkheads placed in 1500-level portals. Portal drainage concentrations assumed to be equal to baseline spring and fall concentrations.
(b) Assume tops of waste rock piles are regraded to min. infiltration (30% of the total surface area regraded and 50% of precipitation in that area will runoff). Assume impacted materials in the mill building are removed/covered; soils in the maintenance yard are capped with a concrete cap; lagoon area soils are removed; and Copper Creek Diversion is placed in a culvert.
(c) Loading reductions from these areas expected due to the implementation of upgradient water and source controls.
(d) Help Model Scenario #2. Input parameters: 100% regrading and grass cover. Approx. post remediation infiltration = 20%. (See Appendix G)
(e) Assume 100% interception @ 80% collection efficiency.
(f) Assume 80% collection of intercepted deep groundwater (11 L/sec spring and fall) and loss from relocated Railroad Creek (79 L/sec spring, 45 L/sec fall)

Table D2-8
Alternative 5a - Water Management, Partial East Area Collection, & East/West Area Treatment (Low-Energy WTP)
Long-Term Post Remediation Loading Analysis Summary

Source Area	Estimated Remedial Alternative Performance - Upragient Controls and Downgradient Collection			Estimated Coefficients of Variation	
	Estimated Direct Precipitation Diverted (%)	Estimated Reduction in Metals Loading Due to Upgradient Controls(%), E[UG]	Downgradient Collection Efficiency (%), E[CE]	Upgradient Controls CV[UG]	Colletion Efficiency CV[CE]
SP-26/Unaccounted (Groundwater) Load Upstream of RC-1	80%	60%	0%	0.1	0
SP-23/Honeymoon Heights	0%	0%	90%	0	0.05
Underground Mine [(a)]	0%	(a)	97%	0	0.025
West Waste Rock Pile [(b)]	15%	0%	90%	1	0.05
Mill Building [(b)]	50%	60%	90%	0.25	0.05
West Area Seeps (SP-9, 11, 25, 24) [(c)]	0%	85%	0%	0.2	0
West Area Seeps Downstream of RC-4 (SP-10W/10E) [(c)]	0%	85%	0%	0.2	0
East Waste Rock Pile [(b)]	15%	0%	90%	1	0.05
Copper Creek Diversion [(b)]	0%	95%	0%	0.05	0
Unaccounted Load - West Area & Flow Tube S1 [(c)]	0%	85%	0%	0.2	0
Intercepted TP-1 Seeps & Flow Tubes [(d)]	80%	0%	80%	0	0.25
Intercepted TP-2 Seeps & Flow Tubes (Upstream of RC-7) [(d)]	80%	0%	0%	0	0.25
Intercepted TP-2/3 Seeps & Flow Tubes (Downstream of RC-7) [(d)]	80%	0%	80%	0	0.25
Unaccounted Load - East Area [(d)] [(e)]	80%	0%	20%	0	0.5
Loading Downstream of RC-2 (SP-21) [(d)]	80%	0%	95%	0	0.05
Loading Downstream of RC-2 (Flow Tubes, Fall Only) [(d)]	80%	0%	90%	0	0.25

Treatment System	Estimated Treatment System Performance (mg/L)				Estimated Treatment System Coefficient of Variation			
	Cadmium $E[C_{Eff,Cd}]$	Copper $E[C_{Eff,Cu}]$	Iron $E[C_{Eff,Fe}]$	Zinc $E[C_{Eff,Zn}]$	Cadmium $CV[C_{Eff,Cd}]$	Copper $CV[C_{Eff,Cu}]$	Iron $CV[C_{Eff,Fe}]$	Zinc $CV[C_{Eff,Zn}]$
West Area	0.005	0.024	0.200	0.240	0.1	0.1	0.1	0.1
East Area, East of TP-3	0.005	0.035	0.200	0.350	0.1	0.1	0.1	0.1

West Area Groundwater Collection [(f)]		$E[Q_{GW}]$	$CV[Q_{GW}]$
Estimated Collection ($E[Q_{GW}]$,L/s) and Coefficient of Variation ($CV[Q_{GW}]$)	Spring	32	0.1
	Fall	18	0.1
East Area Groundwater Collection (other than intercepted flowtubes) [(g)]		$E[Q_{GW}]$	$CV[Q_{GW}]$
Estimated Collection ($E[Q_{GW}]$,L/s) and Coefficient of Variation ($CV[Q_{GW}]$)	Spring	14	1.4
	Fall	14	1.4

Notes:
(a) Air-flow restrictions installed in open mine adits. Hydrostatic bulkheads placed in 1500-level portals. Portal drainage concentrations assumed to be equal to baseline spring and fall concentrations.
(b) Assume tops of waste rock piles are regraded to min. infiltration (30% of the total surface area regraded and 50% of precipitation in that area will runoff). Assume impacted materials in the mill building are removed/covered; soils in the maintenance yard are capped with a concrete cap; lagoon area soils are removed; and Copper Creek Diversion is placed in a culvert.
(c) Loading reductions from these areas based on reduced loading to subsurface expected due to the installation of the upper West Area groundwater collection system and upgradient water and source controls.
(d) Help Model Scenario #2. Input parameters: 100% regrading and grass cover. Approx. post remediation infiltration = 20%. (See Appendix G)
(e) Assume 25% interception (Avg of TP-1, TP-2, & TP-3) @ 80% collection efficiency.
(f) Assume 90% collection of interecepted flows of 36 L/sec (spring) and 20 L/sec (fall).
(g) Assume 80% collection of intercepted deep groundwater flow of 17 L/sec (spring and fall)

Table D2-9
Alternative 5b - Water Management, Extended East Area Collection & East/West Area Treat. (Low-Energy WTP)
Long-Term Post Remediation Loading Analysis Summary

Source Area	Estimated Remedial Alternative Performance - Upragient Controls and Downgradient Collection			Estimated Coefficients of Variation	
	Estimated Direct Precipitation Diverted (%)	Estimated Reduction in Metals Loading Due to Upgradient Controls(%), E[UG]	Downgradient Collection Efficiency (%), E[CE]	Upgradient Controls CV[UG]	Colletion Efficiency CV[CE]
SP-26/Unaccounted (Groundwater) Load Upstream of RC-1	80%	60%	0%	0.1	0
SP-23/Honeymoon Heights	0%	0%	90%	0	0.05
Underground Mine [(a)]	0%	(a)	97%	0	0.025
West Waste Rock Pile [(b)]	15%	0%	90%	1	0.05
Mill Building [(b)]	50%	60%	90%	0.25	0.05
Other West Area Seeps (SP-9, 11, 25, 24) [(c)]	0%	85%	0%	0.2	0
West Area Seeps Downstream of RC-4 (SP-10W/10E) [(c)]	0%	85%	0%	0.2	0
East Waste Rock Pile [(b)]	15%	0%	90%	1	0.05
Copper Creek Diversion [(b)]	0%	95%	0%	0.05	0
Unaccounted Load - West Area & Flow Tube S1[(c)]	0%	85%	0%	0.2	0
Intercepted TP-1 Seeps & Flow Tubes[(d)]	80%	0%	80%	0	0.3
Intercepted TP-2 Seeps & Flow Tubes (Upstream of RC-7) [(d)]	80%	0%	80%	0	0.3
Intercepted TP-2/3 Seeps & Flow Tubes (Downstream of RC-7) [(d)]	80%	0%	80%	0	0.3
Unaccounted Load - East Area[(d) (e)]	80%	0%	80%	0	0.3
Loading Downstream of RC-2 (SP-21) [(d)]	80%	0%	95%	0	0.05
Loading Downstream of RC-2 (Flow Tubes, Fall Only) [(d)]	80%	0%	90%	0	0.3

Treatment System	Estimated Treatment System Performance (mg/L)				Estimated Treatment System Coefficient of Variation			
	Cadmium $E[C_{Eff,Cd}]$	Copper $E[C_{Eff,Cu}]$	Iron $E[C_{Eff,Fe}]$	Zinc $E[C_{Eff,Zn}]$	Cadmium $CV[C_{Eff,Cd}]$	Copper $CV[C_{Eff,Cu}]$	Iron $CV[C_{Eff,Fe}]$	Zinc $CV[C_{Eff,Zn}]$
West Area	0.005	0.024	0.200	0.240	0.1	0.1	0.1	0.1
East Area, East of TP-3	0.005	0.035	0.200	0.350	0.1	0.1	0.1	0.1

West Area Groundwater Collection [(f)]		$E[Q_{GW}]$	$CV[Q_{GW}]$
Estimated Collection ($E[Q_{GW}]$,L/s) and Coefficient of Variation ($CV[Q_{GW}]$)	Spring	32	0.1
	Fall	18	0.1
East Area Groundwater Collection (other than intercepted flowtubes) [(g)]		$E[Q_{GW}]$	$CV[Q_{GW}]$
Estimated Collection ($E[Q_{GW}]$,L/s) and Coefficient of Variation ($CV[Q_{GW}]$)	Spring	0	0
	Fall	0	0

Notes:
(a) Air-flow restrictions installed in open mine adits. Hydrostatic bulkheads placed in 1500-level portals. Portal drainage concentrations assumed to be equal to baseline spring and fall concentrations.
(b) Assume tops of waste rock piles are regraded to min. infiltration (30% of the total surface area regraded and 50% of precipitation in that area will runoff). Assume impacted materials in the mill building are removed/covered; soils in the maintenance yard are capped with a concrete cap; lagoon area soils are removed; and Copper Creek Diversion is placed in a culvert.
(c) Loading reductions from these areas based on reduced loading to subsurface expected due to the installation of the upper West Area groundwater collection system and upgradient water and source controls.
(d) Help Model Scenario #2. Input parameters: 100% regrading and grass cover. Approx. post remediation infiltration = 20%. (See Appendix G)
(e) Assume 100% interception with 80% collection efficiency.
(f) Assume 90% collection of interecepted flows of 36 L/sec (spring) and 20 L/sec (fall).
(g) Assume no deep groundwater collected by East Area barrier wall.

Table D2-10
Alternative 5c - Water Management, Extended Railroad Creek Relocation & East/West Area Treat (Low-Energy WTP)
Long-Term Post Remediation Loading Analysis Summary

Source Area	Estimated Remedial Alternative Performance - Upragient Controls and Downgradient Collection: Estimated Direct Precipitation Diverted (%)	Estimated Reduction in Metals Loading Due to Upgradient Controls(%), E[UG]	Downgradient Collection Efficiency (%), E[CE]	Estimated Coefficients of Variation: Upgradient Controls CV[UG]	Colletion Efficiency CV[CE]
SP-26/Unaccounted (Groundwater) Load Upstream of RC-1	80%	60%	0%	0.1	0
SP-23/Honeymoon Heights	0%	0%	90%	0	0.05
Underground Mine [(a)]	0%	(a)	97%	0	0.025
West Waste Rock Pile [(b)]	15%	0%	90%	1	0.05
Mill Building [(b)]	50%	60%	90%	0.25	0.05
Other West Area Seeps (SP-9, 11, 25, 24) [(c)]	0%	85%	0%	0.2	0
West Area Seeps Downstream of RC-4 (SP-10W/10E) [(c)]	0%	85%	0%	0.2	0
East Waste Rock Pile [(b)]	15%	0%	90%	1	0.05
Copper Creek Diversion [(b)]	0%	95%	0%	0.05	0
Unaccounted Load - West Area & Flow Tube S1[(c)]	0%	85%	0%	0.2	0
Intercepted TP-1 Seeps & Flow Tubes[(d)]	80%	0%	80%	0	0.15
Intercepted TP-2 Seeps & Flow Tubes (Upstream of RC-7) [(d)]	80%	0%	80%	0	0.15
Intercepted TP-2/3 Seeps & Flow Tubes (Downstream of RC-7) [(d)]	80%	0%	80%	0	0.15
Unaccounted Load - East Area [(d) (e)]	80%	0%	80%	0	0.15
Loading Downstream of RC-2 (SP-21) [(d)]	80%	0%	95%	0	0.05
Loading Downstream of RC-2 (Flow Tubes) [(d)]	80%	0%	90%	0	0.15

Treatment System	Estimated Treatment System Performance (mg/L)				Estimated Treatment System Coefficient of Variation			
	Cadmium $E[C_{Eff,Cd}]$	Copper $E[C_{Eff,Cu}]$	Iron $E[C_{Eff,Fe}]$	Zinc $E[C_{Eff,Zn}]$	Cadmium $CV[C_{Eff,Cd}]$	Copper $CV[C_{Eff,Cu}]$	Iron $CV[C_{Eff,Fe}]$	Zinc $CV[C_{Eff,Zn}]$
West Area	0.005	0.024	0.200	0.240	0.1	0.1	0.1	0.1
East Area, East of TP-3	0.005	0.035	0.200	0.350	0.1	0.1	0.1	0.1

West Area Groundwater Collection [(f)]		$E[Q_{GW}]$	$CV[Q_{GW}]$
Estimated Collection ($E[Q_{GW}]$,L/s) and Coefficient of Variation ($CV[Q_{GW}]$)	Spring	32	0.1
	Fall	18	0.1
East Area Groundwater Collection (other than intercepted flowtubes) [(g)]		$E[Q_{GW}]$	$CV[Q_{GW}]$
Estimated Collection ($E[Q_{GW}]$,L/s) and Coefficient of Variation ($CV[Q_{GW}]$)	Spring	72	1.4
	Fall	46	1.4

Notes:
(a) Air-flow restrictions installed in open mine adits. Hydrostatic bulkheads placed in 1500-level portals. Portal drainage concentrations assumed to be equal to baseline spring and fall concentrations.
(b) Assume tops of waste rock piles are regraded to min. infiltration (30% of the total surface area regraded and 50% of precipitation in that area will runoff). Assume impacted materials in the mill building are removed/covered; soils in the maintenance yard are capped with a concrete cap; lagoon area soils are removed; and Copper Creek Diversion is placed in a culvert.
(c) Loading reductions from these areas based on reduced loading to subsurface expected due to the installation of the upper West Area groundwater collection system and upgradient water and source controls.
(d) Help Model Scenario #2. Input parameters: 100% regrading and grass cover. Approx. post remediation infiltration = 20%. (See Appendix G)
(e) Assume 100% interception with 80% collection efficiency.
(f) Assume 90% collection of interecepted flows of 36 L/sec (spring) and 20 L/sec (fall).
(g) Assume 80% collection of intercepted deep groundwater (11 L/sec spring and fall) and loss from relocated Railroad Creek (79 L/sec spring, 45 L/sec fall)

Table D2-10a
Alternative 5d - Water Management, West Area Barrier Wall, Extended Railroad Creek Relocation & East/West Area Treat (Low-Energy WTF
Long-Term Post Remediation Loading Analysis Summary

Source Area	Estimated Remedial Alternative Performance - Upragient Controls and Downgradient Collection			Estimated Coefficients of Variation	
	Estimated Direct Precipitation Diverted (%)	Estimated Reduction in Metals Loading Due to Upgradient Controls(%), E[UG]	Downgradient Collection Efficiency (%), E[CE]	Upgradient Controls CV[UG]	Colletion Efficiency CV[CE]
SP-26/Unaccounted (Groundwater) Load Upstream of RC-1	80%	60%	0%	0.1	0
SP-23/Honeymoon Heights	0%	0%	90%	0	0.15
Underground Mine[(a)]	0%	0%	97%	0	0.025
West Waste Rock Pile [(b)]	15%	0%	90%	0	0.05
Mill Building[(b)]	50%	60%	90%	0.25	0.05
Other West Area Seeps (SP-9, 11, 25, 24) [(c)]	0%	85%	90%	0.2	0.15
West Area Seeps Downstream of RC-4 (SP-10W/10E) [(c)]	0%	85%	90%	0.2	0.15
East Waste Rock Pile [(b)]	15%	0%	90%	0	0.05
Copper Creek Diversion[(b)]	0%	95%	0%	0.05	0
Unaccounted Load - West Area & Flow Tube S1[(c)]	0%	85%	90%	0.2	0.15
Intercepted TP-1 Seeps & Flow Tubes[(d)]	80%	0%	80%	0	0.15
Intercepted TP-2 Seeps & Flow Tubes (Upstream of RC-7) [(d)]	80%	0%	80%	0	0.15
Intercepted TP-2/3 Seeps & Flow Tubes (Downstream of RC-7) [(d)]	80%	0%	80%	0	0.15
Unaccounted Load - East Area[(d) (e)]	80%	0%	80%	0	0.15
Loading Downstream of RC-2 (SP-21) [(d)]	80%	0%	95%	0	0.05
Loading Downstream of RC-2 (Flow Tubes)[(d)]	80%	0%	90%	0	0.15

Treatment System	Estimated Treatment System Performance (mg/L)				Estimated Treatment System Coefficient of Variation			
	Cadmium $E[C_{Eff,Cd}]$	Copper $E[C_{Eff,Cu}]$	Iron $E[C_{Eff,Fe}]$	Zinc $E[C_{Eff,Zn}]$	Cadmium $CV[C_{Eff,Cd}]$	Copper $CV[C_{Eff,Cu}]$	Iron $CV[C_{Eff,Fe}]$	Zinc $CV[C_{Eff,Zn}]$
West Area	0.005	0.024	0.200	0.240	0.1	0.1	0.1	0.1
East Area, East of TP-3	0.005	0.035	0.200	0.350	0.1	0.1	0.1	0.1

West Area Groundwater Collection (Upper Barrier Wall)[(f)]		$E[Q_{GW}]$	$CV[Q_{GW}]$
Estimated Collection ($E[Q_{GW}]$,L/s)	Spring	32	0.1
and Coefficient of Variation ($CV[Q_{GW}]$)	Fall	18	0.1
West Area Groundwater Collection (Lower Barrier Wall)[(g)]		$E[Q_{GW}]$	$CV[Q_{GW}]$
Estimated Collection ($E[Q_{GW}]$,L/s)	Spring	3.3	0.1
and Coefficient of Variation ($CV[Q_{GW}]$)	Fall	1.9	0.1
East Area Groundwater Collection (other than intercepted flowtubes)[(h)]		$E[Q_{GW}]$	$CV[Q_{GW}]$
Estimated Collection ($E[Q_{GW}]$,L/s)	Spring	72	1.4
and Coefficient of Variation ($CV[Q_{GW}]$)	Fall	46	1.4

Notes:
(a) Air-flow restrictions installed in open mine adits. Hydrostatic bulkheads placed in 1500-level portals. Portal drainage concentrations assumed to be equal to baseline spring and fall concentrations.
(b) Assume tops of waste rock piles are regraded to min. infiltration (30% of the total surface area regraded and 50% of precipitation in that area will runoff). Assume impacted materials in the mill building are removed/covered; soils in the maintenance yard are capped with a concrete cap; lagoon area soils are removed; and Copper Creek Diversion is placed in a culvert.
(c) Loading reductions from these areas based on reduced loading to subsurface expected due to the installation of the upper West Area groundwater collection system and upgradient water and source controls.
(d) Help Model Scenario #2. Input parameters: 100% regrading and grass cover. Approx. post remediation infiltration = 20%. (See Appendix G)
(e) Assume 100% interception with 80% collection efficiency.
(f) Assume 90% collection of interecepted flows of 36 L/sec (spring) and 20 L/sec (fall) for upper West Area barrier wall. Collected groundwater conveyed to West Area treatment system.
(g) Assume 90% collection of intercepted flows of 3.7 L/sec (spring) and 2.1 L/sec (fall) for lower West Area barrier wall. Collected groundwater conveyed to East Area treatment system.
(h) Assume 80% collection of intercepted deep groundwater (11 L/sec spring and fall) and loss from relocated Railroad Creek (79 L/sec spring, 45 L/sec fall)

Table D2-11
Alternative 6a - Water Management, Extended Railroad Creek Relocation & East/West Area Treat (Mechanical West Area WTP)
Long-Term Post Remediation Loading Analysis Summary

Source Area	Estimated Remedial Alternative Performance - Upragient Controls and Downgradient Collection			Estimated Coefficients of Variation	
	Estimated Direct Precipitation Diverted (%)	Estimated Reduction in Metals Loading Due to Upgradient Controls(%), E[UG]	Downgradient Collection Efficiency (%), E[CE]	Upgradient Controls CV[UG]	Colletion Efficiency CV[CE]
SP-26/Unaccounted (Groundwater) Load Upstream of RC-1	80%	60%	80%	0.1	0.15
SP-23/Honeymoon Heights	0%	0%	90%	0	0.15
Underground Mine [(a)]	0%	0%	97%	1	0.025
West Waste Rock Pile [(b)]	15%	0%	90%	1	0.05
Mill Building [(b)]	50%	60%	90%	0.25	0.05
Other West Area Seeps (SP-9, 11, 25, 24) [(c)]	0%	85%	90%	0.2	0.15
West Area Seeps Downstream of RC-4 (SP-10W/10E) [(c)]	0%	85%	90%	0.2	0.15
East Waste Rock Pile [(b)]	15%	0%	90%	1	0.05
Copper Creek Diversion [(b)]	0%	95%	0%	0.05	0
Unaccounted Load - West Area [(c)]	0%	85%	90%	0.2	0.15
TP-1 Seeps & Flow Tubes[(d)]	80%	0%	80%	0	0.15
TP-2 Seeps & Flow Tubes (Upstream of RC-7) [(d)]	80%	0%	80%	0	0.15
TP2/3 Seeps & Flow Tubes (Downstream of RC-7) [(d)]	80%	0%	80%	0	0.15
Unaccounted Load - East Area [(d) (e)]	80%	0%	80%	0	0.15
Loading Downstream of RC-2 (SP-21) [(d) (e)]	80%	0%	95%	0	0.05
Loading Downstream of RC-2 (Flow Tubes) [(d) (e)]	80%	0%	90%	0	0.15

Treatment System	Estimated Treatment System Performance (mg/L)				Estimated Treatment System Coefficient of Variation			
	Cadmium $E[C_{Eff,Cd}]$	Copper $E[C_{Eff,Cu}]$	Iron $E[C_{Eff,Fe}]$	Zinc $E[C_{Eff,Zn}]$	Cadmium $CV[C_{Eff,Cd}]$	Copper $CV[C_{Eff,Cu}]$	Iron $CV[C_{Eff,Fe}]$	Zinc $CV[C_{Eff,Zn}]$
West Area	0.005	0.024	0.200	0.240	0.1	0.1	0.1	0.1
East Area, East of TP-3	0.005	0.035	0.200	0.350	0.1	0.1	0.1	0.1

West Area Groundwater Collection Upper Barrier Wall (90% E[CE]) [(f)]		$E[Q_{GW}]$	$CV[Q_{GW}]$
Estimated Collection ($E[Q_{GW}]$,L/s) and Coefficient of Variation ($CV[Q_{GW}]$)	Spring	32	0.1
	Fall	18	0.1
West Area Groundwater Collection Lower Barrier Wall (90% E[CE] P-5 to RC-4; 80% E[CE] SP-26 to P-5) [(g)]		$E[Q_{GW}]$	$CV[Q_{GW}]$
Estimated Collection ($E[Q_{GW}]$,L/s) and Coefficient of Variation ($CV[Q_{GW}]$)	Spring	22	0.1
	Fall	12	0.1
East Area Groundwater Collection (other than intercepted flowtubes) [(h)]		$E[Q_{GW}]$	$CV[Q_{GW}]$
Estimated Collection ($E[Q_{GW}]$,L/s) and Coefficient of Variation ($CV[Q_{GW}]$)	Spring	72	1.4
	Fall	46	1.4

Notes:
(a) Air-flow restrictions installed in open mine adits.
(b) Assume tops of waste rock piles are regraded to min. infiltration (30% of the total surface area regraded and 50% of precipitation in that area will runoff). Assume impacted materials in the mill building are removed/covered; soils in the maintenance yard are capped with a concrete cap; lagoon area soils are removed; and Copper Creek Diversion is placed in a culvert.
(c) Loading reductions from these areas based on reduced loading to subsurface expected due to the installation of the upper West Area groundwater collection system and upgradient water and source controls.
(d) Help Model Scenario #2. Input parameters: 100% regrading and grass cover. Approx. post remediation infiltration = 20%. (See Appendix G)
(e) Assume 100% interception with 80% collection efficiency.
(f) Assume 90% collection of interecepted flows of 36 L/sec (spring) and 20 L/sec (fall) for upper West Area barrier wall. Collected groundwater conveyed to West Area treatment system.
(g) Assume 90% collection of intercepted flows of 3.7 L/sec (spring) and 2.1 L/sec (fall) for lower West Area barrier wall from P-5 to RC-4 and 80% collection of 23 L/sec (spring) and 13 L/sec (fall) for lower West Area barrier wall from SP-26 to P-5. Collected groundwater conveyed to East Area treatment system.
(h) Assume 80% collection of intercepted deep groundwater (11 L/sec spring and fall) and loss from relocated Railroad Creek (79 L/sec spring, 45 L/sec fall)

Table D2-12
Alternative 6b - Water Management, Extended Railroad Creek Relocation & East/West Area Treat (Mechanical West Area WTP with Bulkhea
Long-Term Post Remediation Loading Analysis Summar

Source Area	Estimated Remedial Alternative Performance - Upragient Controls and Downgradient Collection			Estimated Coefficients of Variation	
	Estimated Direct Precipitation Diverted (%)	Estimated Reduction in Metals Loading Due to Upgradient Controls(%), E[UG]	Downgradient Collection Efficiency (%), E[CE]	Upgradient Controls CV[UG]	Colletion Efficiency CV[CE]
SP-26/Unaccounted (Groundwater) Load Upstream of RC-1	80%	60%	80%	0.1	0.15
SP-23/Honeymoon Heights	0%	0%	90%	0	0.15
Underground Mine[(a)]	0%	(a)	97%	0	0.025
West Waste Rock Pile [(b)]	15%	0%	90%	1	0.05
Mill Building[(b)]	50%	60%	90%	0.25	0.05
Other West Area Seeps (SP-9, 11, 25, 24)[(c)]	0%	85%	90%	0.2	0.15
West Area Seeps Downstream of RC-4 (SP-10W/10E) [(c)]	0%	85%	90%	0.2	0.15
East Waste Rock Pile [(b)]	15%	0%	90%	1	0.05
Copper Creek Diversion[(b)]	0%	95%	0%	0.05	0
Unaccounted Load - West Area [(c)]	0%	85%	90%	0.2	0.15
Intercepted TP-1 Seeps & Flow Tubes[(d)]	80%	0%	80%	0	0.15
Intercepted TP-2 Seeps & Flow Tubes (Upstream of RC-7) [(d)]	80%	0%	80%	0	0.15
Intercepted TP2/3 Seeps & Flow Tubes (Downstream of RC-7) [(d)]	80%	0%	80%	0	0.15
Unaccounted Load - East Area[(d) (e)]	80%	0%	80%	0	0.15
Loading Downstream of RC-2 (SP-21)[(d)]	80%	0%	95%	0	0.05
Loading Downstream of RC-2 (Flow Tubes)[(d)]	80%	0%	90%	0	0.15

Treatment System	Estimated Treatment System Performance (mg/L)				Estimated Treatment System Coefficient of Variation			
	Cadmium $E[C_{Eff,Cd}]$	Copper $E[C_{Eff,Cu}]$	Iron $E[C_{Eff,Fe}]$	Zinc $E[C_{Eff,Zn}]$	Cadmium $CV[C_{Eff,Cd}]$	Copper $CV[C_{Eff,Cu}]$	Iron $CV[C_{Eff,Fe}]$	Zinc $CV[C_{Eff,Zn}]$
West Area	0.005	0.024	0.200	0.240	0.1	0.1	0.1	0.1
East Area, East of TP-3	0.005	0.035	0.200	0.350	0.1	0.1	0.1	0.1

West Area Groundwater Collection Upper Barrier Wall (90% E[CE])[(f)]		$E[Q_{GW}]$	$CV[Q_{GW}]$
Estimated Collection ($E[Q_{GW}]$,L/s) and Coefficient of Variation ($CV[Q_{GW}]$)	Spring	32	0.1
	Fall	18	0.1
West Area Groundwater Collection Lower Barrier Wall (90% E[CE] P-5 to RC-4; 80% E[CE] SP-26 to P-5)[(g)]		$E[Q_{GW}]$	$CV[Q_{GW}]$
Estimated Collection ($E[Q_{GW}]$,L/s) and Coefficient of Variation ($CV[Q_{GW}]$)	Spring	22	0.1
	Fall	12	0.1
East Area Groundwater Collection (other than intercepted flowtubes)[(h)]		$E[Q_{GW}]$	$CV[Q_{GW}]$
Estimated Collection ($E[Q_{GW}]$,L/s) and Coefficient of Variation ($CV[Q_{GW}]$)	Spring	72	1.4
	Fall	46	1.4

Notes:
(a) Air-flow restrictions installed in open mine adits. Hydrostatic bulkheads placed in 1500-level portals. Portal drainage concentrations assumed to be equal to baseline spring and fall concentrations.
(b) Assume tops of waste rock piles are regraded to min. infiltration (30% of the total surface area regraded and 50% of precipitation in that area will runoff). Assume impacted materials in the mill building are removed/covered; soils in the maintenance yard are capped with a concrete cap; lagoon area soils are removed; and Copper Creek Diversion is placed in a culvert.
(c) Loading reductions from these areas based on reduced loading to subsurface expected due to the installation of the upper West Area groundwater collection system and upgradient water and source controls.
(d) Help Model Scenario #3. Input parameters: 100% regrading and grass cover. Approx. post remediation infiltration = 20%. (See Appendix G)
(e) Assume 100% interception with 80% collection efficiency.
(f) Assume 90% collection of interecepted flows of 36 L/sec (spring) and 20 L/sec (fall) for upper West Area barrier wall. Collected groundwater conveyed to West Area treatment system.
(g) Assume 90% collection of intercepted flows of 3.7 L/sec (spring) and 2.1 L/sec (fall) for lower West Area barrier wall from P-5 to RC-4 and 80% collection of 23 L/sec (spring) and 13 L/sec (fall) for lower West Area barrier wall from SP-26 to P-5. Collected groundwater conveyed to East Area treatment system.
(h) Assume 80% collection of intercepted deep groundwater (11 L/sec spring and fall) and loss from relocated Railroad Creek (79 L/sec spring, 45 L/sec fall)

Table D2-13
Alternative 7 - Capping, Consolidation, Water Management, & West Area Treatment (Low-Energy WTP)
Long-Term Post Remediation Loading Analysis Summary

Source Area	Estimated Remedial Alternative Performance - Upragient Controls and Downgradient Collection			Estimated Coefficients of Variation	
	Estimated Direct Precipitation Diverted (%)	Estimated Reduction in Metals Loading Due to Upgradient Controls(%), E[UG]	Downgradient Collection Efficiency (%), E[CE]	Upgradient Controls CV[UG]	Colletion Efficiency CV[CE]
SP-26/Unaccounted (Groundwater) Load Upstream of RC-1	80%	60%	0%	0.1	0
SP-23/Honeymoon Heights	0%	0%	90%	0	0.05
Underground Mine [(a)]	0%	(a)	97%	0	0.025
West Waste Rock Pile [(b)]	27%	0%	90%	1	0.05
Mill Building [(b)]	50%	60%	90%	0.25	0.05
Other West Area Seeps (SP-9, 11, 25, 24) [(c)]	0%	85%	0%	0.2	0
West Area Seeps Downstream of RC-4 (SP-10W/10E) [(c)]	0%	85%	0%	0.2	0
East Waste Rock Pile [(b)]	27%	0%	90%	1	0.05
Copper Creek Diversion [(b)]	0%	95%	0%	0.05	0
Unaccounted Load - West Area [(c)]	0%	85%	0%	0.2	0
TP-1 Seeps & Flow Tubes[(d) (e) (f)]	95%	90%	0%	0.05	0
TP-2 Seeps & Flow Tubes (Upstream of RC-7) [(d) (e)]	95%	0%	0%	0	0
TP2/3 Seeps & Flow Tubes (Downstream of RC-7) [(d) (e)]	95%	0%	0%	0	0
Unaccounted Load - East Area [(d) (e)]	95%	0%	0%	0	0
Loading Downstream of RC-2 (SP-21) [(d) (e)]	95%	0%	0%	0	0
Loading Downstream of RC-2 (Flow Tubes) [(d) (e)]	95%	0%	0%	0	0

Treatment System	Estimated Treatment System Performance (mg/L)				Estimated Treatment System Coefficient of Variation			
	Cadmium $E[C_{Eff,Cd}]$	Copper $E[C_{Eff,Cu}]$	Iron $E[C_{Eff,Fe}]$	Zinc $E[C_{Eff,Zn}]$	Cadmium $CV[C_{Eff,Cd}]$	Copper $CV[C_{Eff,Cu}]$	Iron $CV[C_{Eff,Fe}]$	Zinc $CV[C_{Eff,Zn}]$
West Area	0.005	0.024	0.200	0.240	0.1	0.1	0.1	0.1
East Area, East of TP-3	NA	NA	NA	NA	NA	NA	NA	NA

West Area Groundwater Collection [(g)]		$E[Q_{GW}]$	$CV[Q_{GW}]$
Estimated Collection ($E[Q_{GW}]$,L/s)	Spring	32	0.1
and Coefficient of Variation ($CV[Q_{GW}]$)	Fall	18	0.1

Notes:
(a) Air-flow restrictions installed in open mine adits. Hydrostatic bulkheads placed in 1500-level portals. Portal drainage concentrations assumed to be equal to baseline spring and fall concentrations.
(b) Assume tops of waste rock piles are regraded to min. infiltration (30% of the total surface area regraded and covered).
Assume impacted materials in the mill building are removed/covered; soils in the maintenance yard are capped with a concrete cap; lagoon area soils are removed; and Copper Creek Diversion is placed in a culvert.
(c) Loading reductions from these areas based on reduced loading to subsurface expected due to the installation of the upper West Area groundwater collection system and upgradient water and source controls.
(d) Help Model Scenario #4. Input parameters: regrading and geosynthetic cover.
Approx. post remediation infiltration = 2%. (See Appendix G)
(e) Estimated loading reductions due to consolidation and capping are incorporated into the long-term time-trend geochemical loading reductions.
(f) Estimated loading reduction due to consolidation of TP-1 onto consolidated tailings pile.
(f) Assume 90% collection of interecepted flows of 36 L/sec (spring) and 20 L/sec (fall).

Table D2-14
Alternative 8 - Source Control & East/West Area Treatment
Long-Term Post Remediation Loading Analysis Summary

Source Area	Estimated Remedial Alternative Performance - Upragient Controls and Downgradient Collection: Estimated Direct Precipitation Diverted (%)	Estimated Reduction in Metals Loading Due to Upgradient Controls(%), E[UG]	Downgradient Collection Efficiency (%), E[CE]	Estimated Coefficients of Variation: Upgradient Controls CV[UG]	Colletion Efficiency CV[CE]
SP-26/Unaccounted (Groundwater) Load Upstream of RC-1	80%	60%	0%	0.1	0
SP-23/Honeymoon Heights	0%	0%	90%	0	0.05
Underground Mine [(a)]	0%	0%	97%	0	0.025
West Waste Rock Pile [(b)]	95%	90%	0%	0.05	0.05
Mill Building [(b)]	50%	60%	90%	0.25	0.05
Other West Area Seeps (SP-9, 11, 25, 24) [(c)]	0%	90%	0%	0.15	0
West Area Seeps Downstream of RC-4 (SP-10W/10E) [(c)]	0%	90%	0%	0.15	0
East Waste Rock Pile [(b)]	95%	90%	0%	0.05	0.05
Copper Creek Diversion [(b)]	0%	95%	0%	0.05	0
Unaccounted Load - West Area [(c)]	0%	90%	0%	0.15	0
TP-1 Seeps & Flow Tubes[(d) (e) (f)]	95%	90%	0%	0.05	0
TP-2 Seeps & Flow Tubes (Upstream of RC-7) [(d) (e) (g)]	95%	0%	80%	0	0.2
TP2/3 Seeps & Flow Tubes (Downstream of RC-7) [(d) (e) (g)]	95%	0%	80%	0	0.2
Unaccounted Load - East Area [(d) (e) (h)]	95%	0%	80%	0	0.2
Loading Downstream of RC-2 (SP-21) [(d) (e)]	95%	0%	95%	0	0.05
Loading Downstream of RC-2 (Flow Tubes) [(d) (e)]	95%	0%	90%	0	0.2

Treatment System	Estimated Treatment System Performance (mg/L)				Estimated Treatment System Coefficient of Variation			
	Cadmium $E[C_{Eff,Cd}]$	Copper $E[C_{Eff,Cu}]$	Iron $E[C_{Eff,Fe}]$	Zinc $E[C_{Eff,Zn}]$	Cadmium $CV[C_{Eff,Cd}]$	Copper $CV[C_{Eff,Cu}]$	Iron $CV[C_{Eff,Fe}]$	Zinc $CV[C_{Eff,Zn}]$
West Area	0.005	0.024	0.200	0.240	0.1	0.1	0.1	0.1
East Area, East of TP-3	0.005	0.035	0.200	0.350	0.1	0.1	0.1	0.1

West Area Groundwater Collection [(i)]		$E[Q_{GW}]$	$CV[Q_{GW}]$
Estimated Collection ($E[Q_{GW}]$,L/s) and Coefficient of Variation ($CV[Q_{GW}]$)	Spring	0	0.1
	Fall	0	0.1
East Area Groundwater Collection (other than intercepted flowtubes) [(j)]		$E[Q_{GW}]$	$CV[Q_{GW}]$
Estimated Collection ($E[Q_{GW}]$,L/s) and Coefficient of Variation ($CV[Q_{GW}]$)	Spring	0	0
	Fall	0	0

Notes:
(a) Air-flow restrictions installed in open mine adits. Hydrostatic bulkheads placed in 1500-level portals. Portal drainage concentrations assumed to be equal to baseline spring and fall concentrations.
(b) Assume waste rock piles are concsolidated onto the consolidated tailings pile.
Assume impacted materials in the mill building are removed/covered; soils in the maintenance yard are capped with a concrete cap; lagoon area soils are removed; and Copper Creek Diversion is placed in a culvert.
(c) Loading reductions from these areas based on reduced loading to subsurface expected due to the installation of the upper West Area groundwater collection system and upgradient water and source controls.
(d) Help Model Scenario #4. Input parameters: regrading and geosynthetic cover.
Approx. post remediation infiltration = 2%. (See Appendix G)
(e) Estimated loading reductions due to consolidation and capping are incorporated into the long-term time-trend geochemical loading reductions.
(f) Estimated loading reduction due to consolidation of TP-1 onto consolidated tailings pile.
(g) A reduction factor of 94% is applied to collected flows from tailings materials to account for decreased discharge due to long term draindown effects.
(h) Assume 100% interception with 80% collection efficiency.
(i) Assume no diffuse groundwater collection in West Area.
(j) Assume no deep groundwater collected by East Area barrier wall.

Appendix D-3

Short-term Post-remediation Loading and Uncertainty Calculations

Appendix D-3 is included on separate compact disc included in Volume 2 of the Draft Final Feasibility Study Report.

Table D4
Long-term Geochemical Trend Assumptions
Holden Mine RI/FS

Table D4-1 - Long-term Tailings Loading (as a Percentage of 1997 Baseline Loading)

Date	2030	2055	2082	2157	2232	2262	2307	2382	2457	2582	2707	3082	3457	3800	3957	4457
Time (years)	25	50	77	152	227	257	302	377	452	577	702	1077	1452	1795	1952	2452
Time (weeks)	1304	2609	4018	7931	11845	13410	15758	19671	23585	30107	36629	56196	75763	93661	101853	127942
Long-term Loading from Tailings - Current Tailings Pile Configuration (% of Baseline Loading)																
Cadmium	129%	10%	19%	17%	17%	20%	16%	20%	11%	64%	12%	9%	10%	30%	1%	1%
Copper	129%	10%	18%	16%	17%	19%	16%	20%	10%	64%	11%	9%	10%	30%	1%	1%
Iron	97%	72%	90%	64%	51%	48%	48%	55%	32%	58%	46%	33%	28%	30%	26%	26%
Zinc	93%	85%	104%	73%	57%	53%	54%	62%	36%	55%	56%	40%	34%	33%	32%	32%
Long-term Loading from Tailings - Reslope and Placement of a Gravel Cover (% of Baseline Loading)																
Cadmium	104%	11%	23%	17%	16%	15%	14%	18%	10%	58%	11%	8%	10%	24%	1%	1%
Copper	104%	10%	22%	16%	16%	15%	14%	18%	10%	58%	11%	8%	10%	24%	1%	1%
Iron	76%	66%	83%	57%	45%	41%	42%	48%	28%	45%	42%	30%	26%	25%	24%	24%
Zinc	91%	82%	103%	71%	55%	51%	52%	59%	35%	53%	54%	38%	33%	31%	30%	30%
Long-term Loading from Tailings - Consolidation and Capping (% of Baseline Loading)																
Cadmium	0.5%	0.7%	0.8%	1.3%	1.3%	0.8%	1.4%	1.0%	1.3%	1.4%	2.0%	2.3%	2.3%	3.8%	5.9%	9.4%
Copper	0.5%	0.7%	0.8%	1.3%	1.3%	0.8%	1.4%	1.0%	1.3%	1.4%	2.0%	2.3%	2.3%	3.8%	5.9%	9.4%
Iron	1.1%	1.4%	1.4%	2.2%	2.3%	1.3%	2.4%	2.2%	2.6%	2.6%	3.2%	3.8%	2.9%	4.3%	4.8%	7.5%
Zinc	1.3%	1.6%	1.6%	2.6%	2.9%	1.6%	3.0%	2.7%	3.2%	3.2%	3.9%	4.8%	3.7%	5.5%	6.1%	9.4%

Table D4-2 - Long-term Waste Rock & Underground Mine Loading Decay Rate Constants (k, $week^{-1}$)

Waste Rock	-0.0001
Underground Mine	-0.0001

Assume that year 2000 = time zero for exponential decay calcs

Table D4-3 - Background Metals Concentrations (mg/L)

		Cd	Cu	Fe	Zn
HV-3	6/9/1997	0.0001	0.003	0.01	0.006
	9/20/97 *	0.0001	0.001	0.025	0.0045
	11/18/2001	0.00002	0.0032	0.025	0.003
HV-3 Average	Spring	0.00007	0.00240	0.02000	0.00450
	Fall	0.00007	0.00240	0.02000	0.00450

* Result reported is the average of the primary sample and the field duplicate.

Underlined concentrations represent non-detects. One-half the reporting is limit is shown.

Table D4-4 - Baseline West Area Diffuse GW Concentrations (mg/L)

		Cd	Cu	Fe	Zn	Source
Spring	UBW/LBW *	0.04	5.25	0.03	4.75	FS Table 6-4 (Blended Spring Seep Conc)
	SP-26 to P5 BW	0.00007	0.0024	0.02	0.0045	Background metals concentrations (well HV-3); Table D4-3, above
Fall	UBW/LBW *	0.04	5.25	0.03	4.75	FS Table 6-4 (Blended Spring Seep Conc)
	SP-26 to P5 BW	0.00007	0.0024	0.02	0.0045	Background metals concentrations (well HV-3); Table D4-3, above

* UBW/LBW = Groundwater collected by upper barrier wall & lower barrier wall in the west area. Note that metals loading from these areas are assumed to decrease at the same rate as waste rock-type sources.

Table D4-5 - Baseline East Area Non-flowtube GW Concentrations (mg/L)

		Cd	Cu	Fe	Zn	Source
Spring	Deep GW *	0.0007	0.002	0.025	0.086	Average concentrations from DS-3D and DS-4D
	N Side former RRC Channel	Post-remediation RC-4 Concentration				Post-remediation RC-4 Concentration
Fall	Deep GW *	0.0007	0.002	0.025	0.086	Average concentrations from DS-3D and DS-4D
	N Side former RRC Channel	Post-remediation RC-4 Concentration				Post-remediation RC-4 Concentration

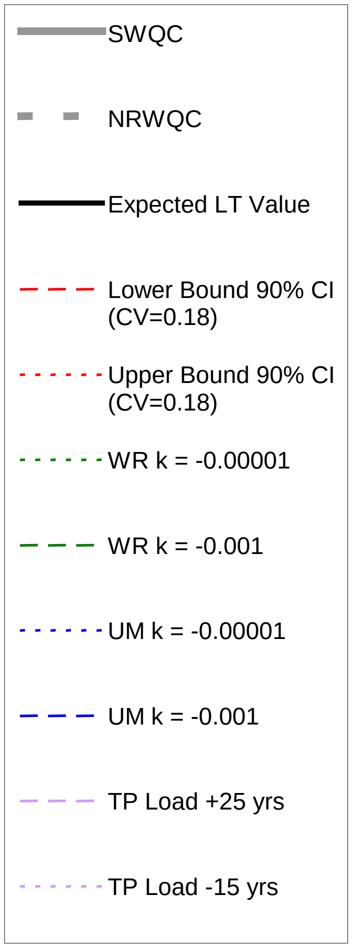
* Deep GW loading assumed to decrease at same rate as long-term tailings loading (Table D4-1, above).

Appendix D-5

Long-term Post-remediation Loading and Uncertainty Calculations

Appendix D-5 is included on separate compact disc included in Volume 2 of the Draft Final Feasibility Study Report.

Appendix D6 – Long-term Post-remediation Sensitivity Analysis
Annotated Legend



SWQC – State of Washington hardness adjusted surface water quality criteria

NRWQC – 2002 National Recommended Water Quality Criteria

Expected LT Value – Estimated (expected) long-term metal concentration as calculated in Appendix D5 and presented in Tables 7-5 through 7-12

Lower Bound 90% CI – Lower bound of approximate 90% confidence interval for expected long-term metal concentration. Assumes same coefficient of variation (CV) for post-remediation metal concentration as calculated for short term (Table 7-5).

Upper Bound 90% CI - Upper bound of approximate 90% confidence interval for expected long-term metal concentration. Assumes same coefficient of variation (CV) for post-remediation metal concentration as calculated for short term (Table 7-5).

WR k = -0.00001 – Estimated long-term metal concentrations calculated with a waste rock exponential decay constant (k) of –0.00001. Note that the expected waste rock decay constant used in the Appendix D5 long-term loading calculations is –0.0001.

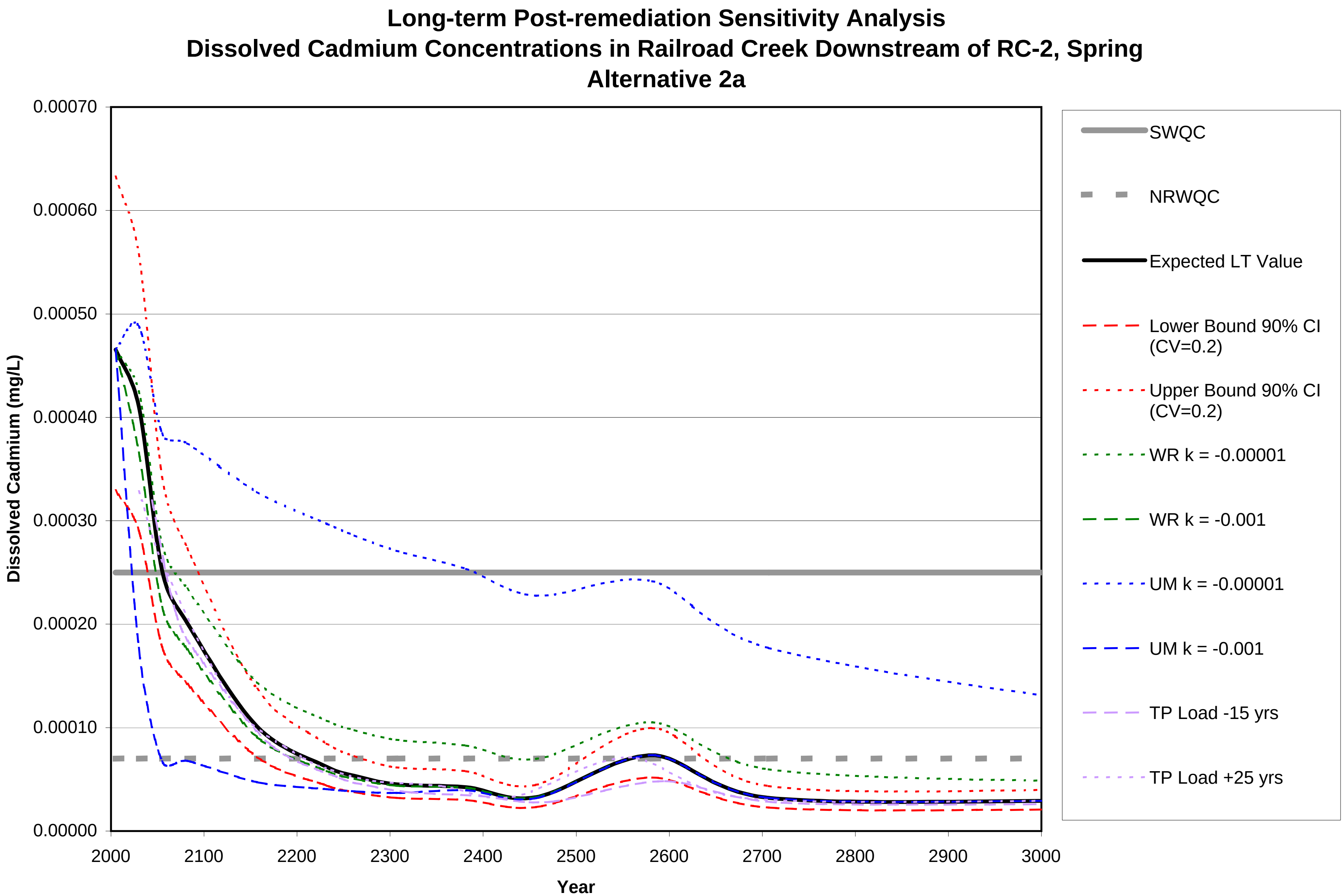
WR k = -0.001 – Estimated long-term metal concentrations calculated with a waste rock exponential decay constant (k) of –0.001.

UM k = -0.00001 - Estimated long-term metal concentrations calculated with an underground mine exponential decay constant (k) of –0.00001. Note that the expected underground mine decay constant used in the Appendix D5 long-term loading calculations is –0.0001.

UM k = -0.001 - Estimated long-term metal concentrations calculated with an underground mine exponential decay constant (k) of –0.001.

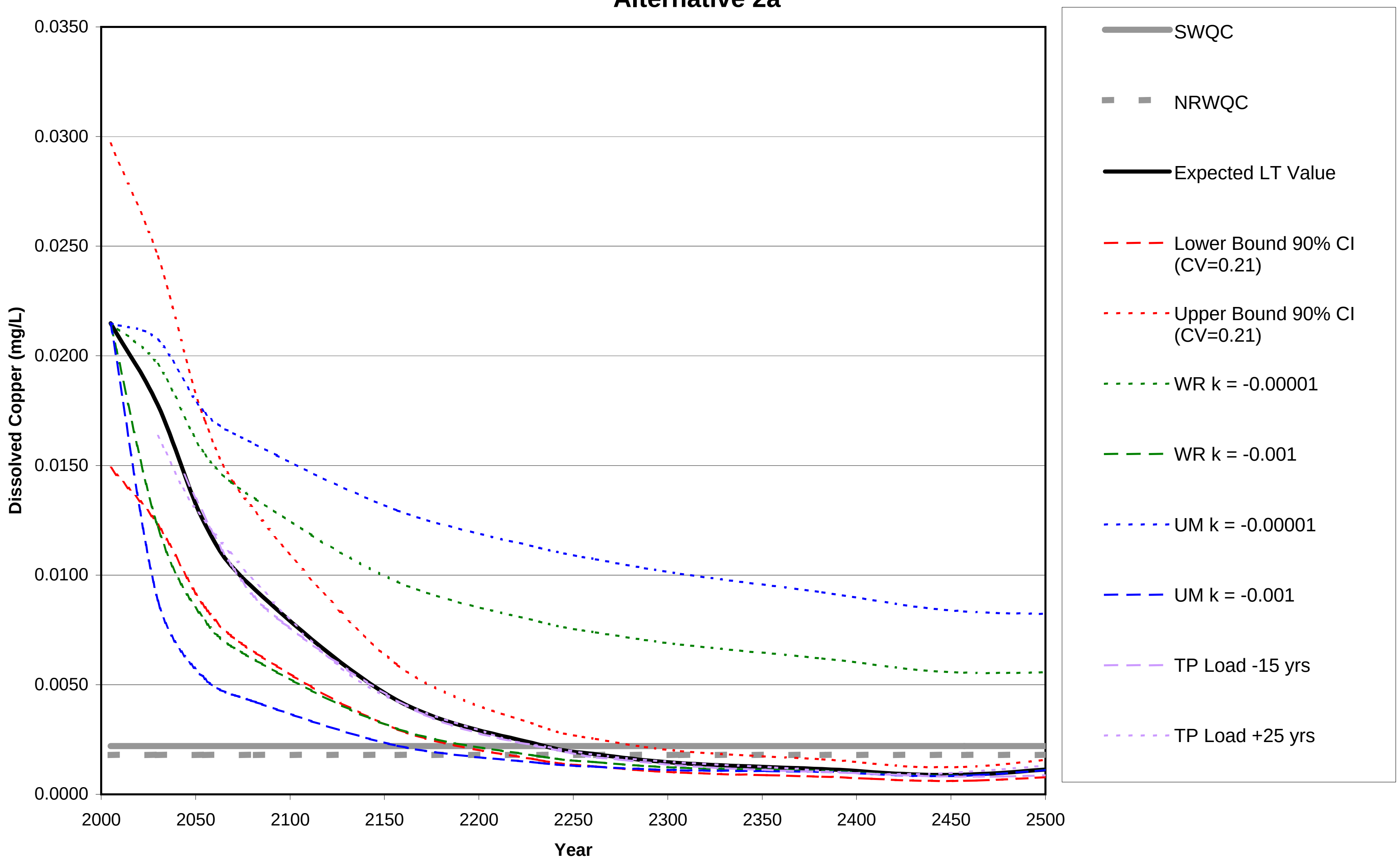
TP Load +25 yrs – Predicted long-term metals concentrations assuming that current conditions correspond to approximately year 2030 on the loading trend graphs (as presented on Table 14 of Appendix E - Analysis and Prediction of Long Term Trends in Chemical Loading, SRK 2003)

TP Load -15 yrs – Predicted long-term metals concentrations assuming that current conditions correspond to approximately year 1990 on the loading trend graphs (as presented on Table 14 of Appendix E - Analysis and Prediction of Long Term Trends in Chemical Loading, SRK 2003)

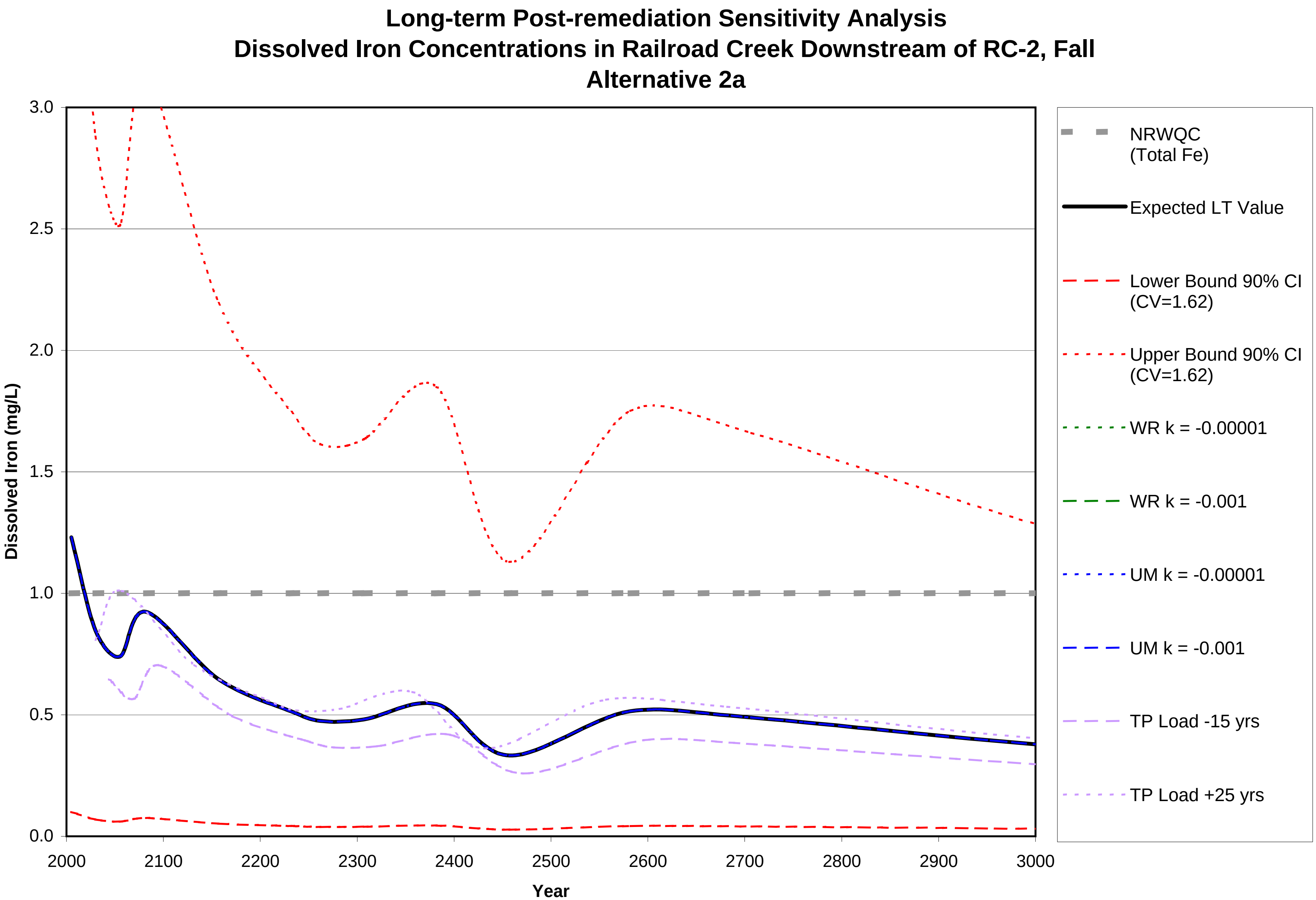


Appendix D6-1
Alternative 2a - Cadmium
Long-term Post-remediation Sensitivity Analysis
Draft Final FS Report February 2004

Long-term Post-remediation Sensitivity Analysis
Dissolved Copper Concentrations in Railroad Creek Downstream of RC-2, Spring
Alternative 2a

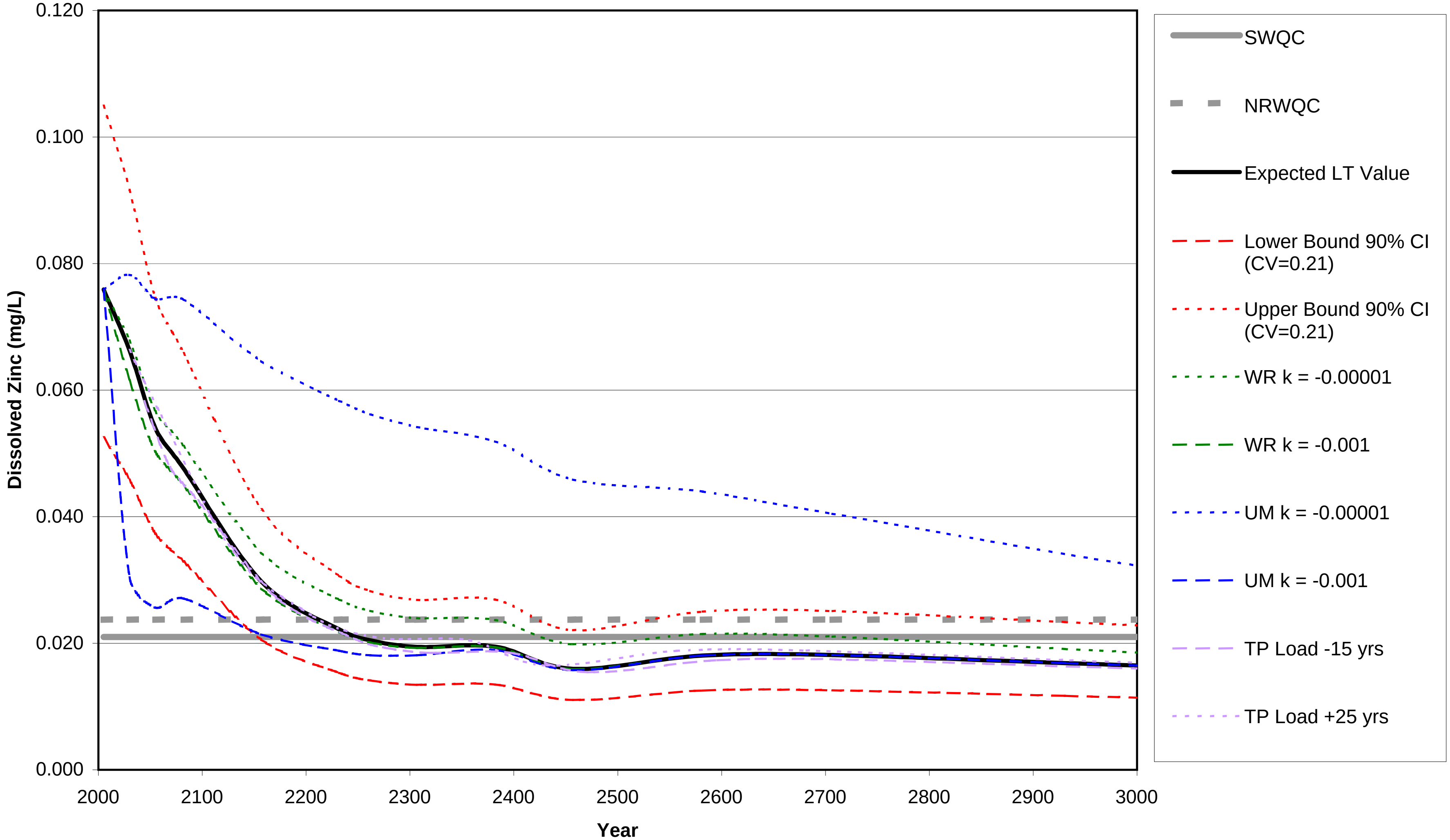


Appendix D6-1
Alternative 2a - Copper
Long-term Post-remediation Sensitivity Analysis

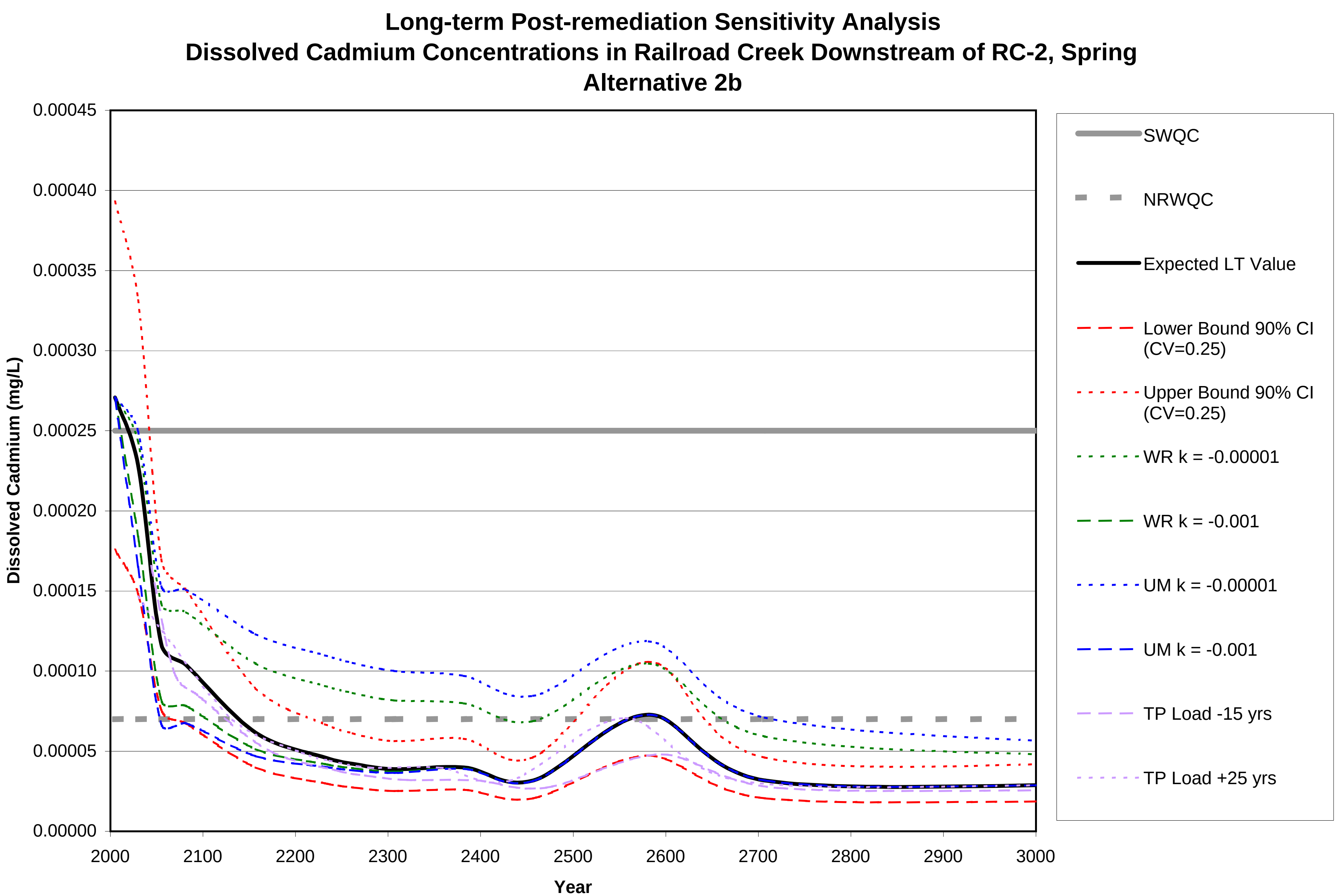


Appendix D6-1
Alternative 2a - Iron
Long-term Post-remediation Sensitivity Analysis
Draft Final FS Report February 2004

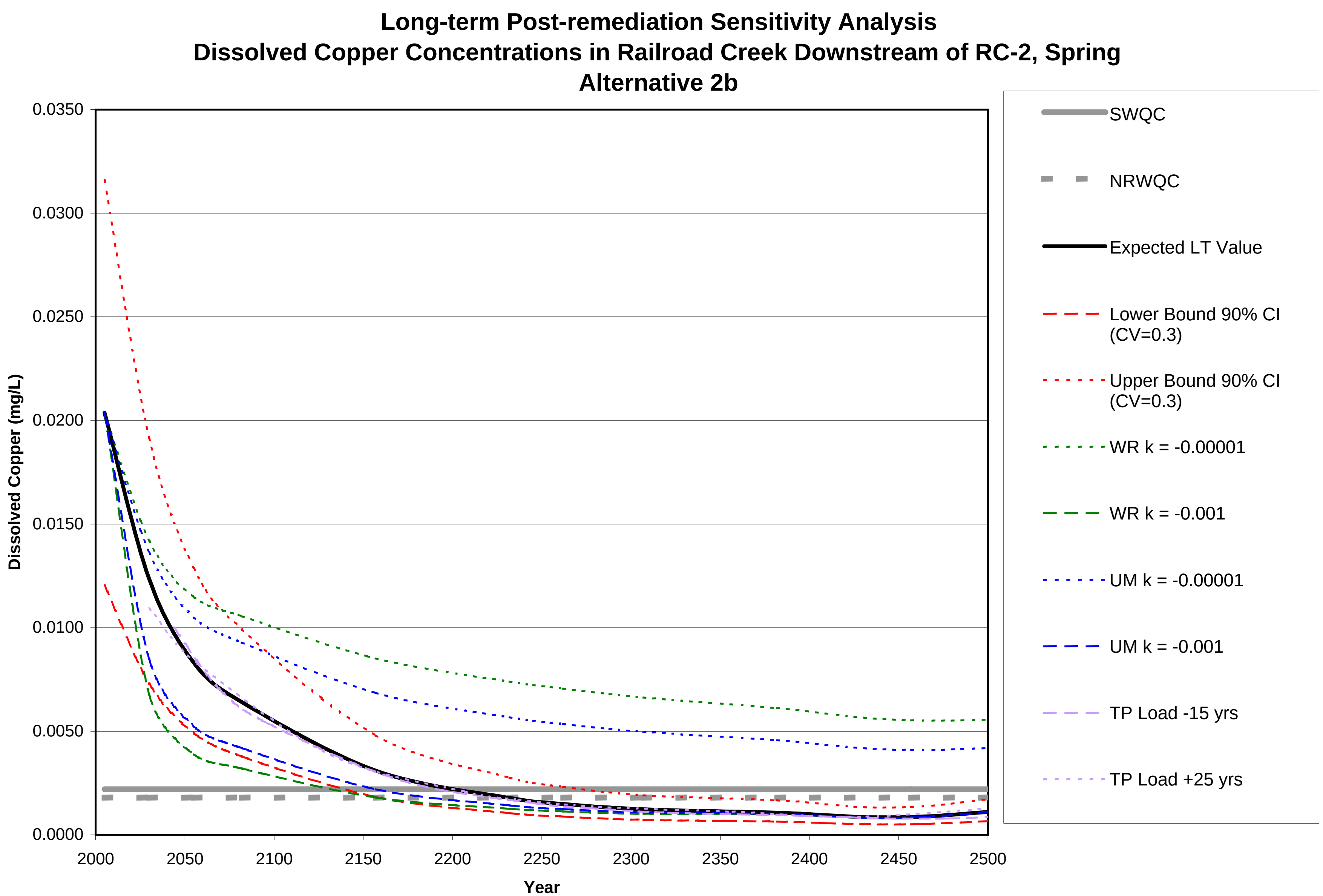
Long-term Post-remediation Sensitivity Analysis
Dissolved Zinc Concentrations in Railroad Creek Downstream of RC-2, Spring
Alternative 2a

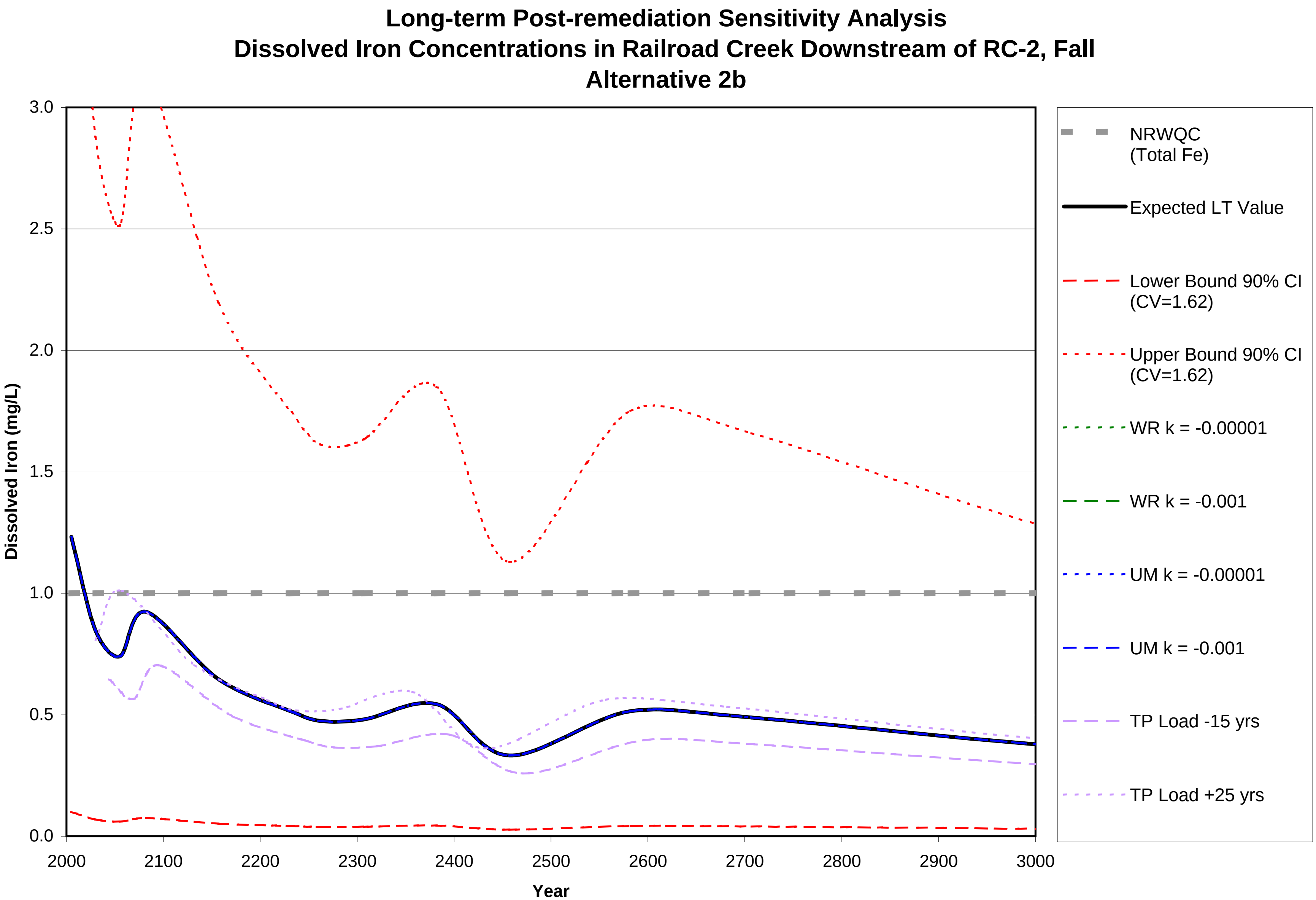


Appendix D6-1
Alternative 2a - Zinc
Long-term Post-remediation Sensitivity Analysis
Draft Final FS Report February 2004



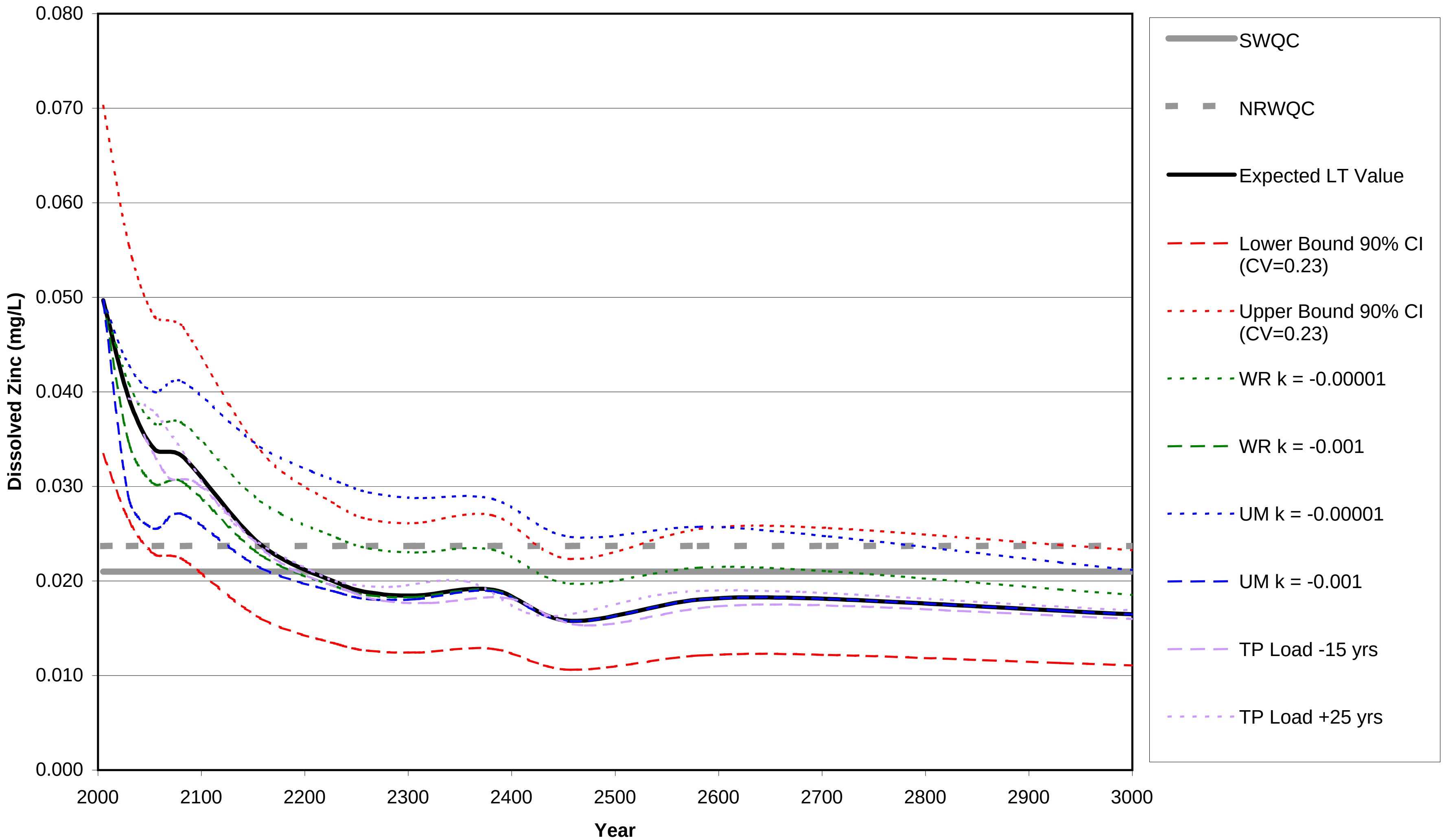
Long-term Post-remediation Sensitivity Analysis
Dissolved Cadmium Concentrations in Railroad Creek Downstream of RC-2, Spring
Alternative 2b
Dissolved Cadmium (mg/L)
0.00045
0.00040
0.00035
0.00030
0.00025
0.00020
0.00015
0.00010
0.00005
0.00000
2000
2100
2200
2300
2400
2500
2600
2700
2800
2900
3000
Year
SWQC
NRWQC
Expected LT Value
Lower Bound 90% CI (CV=0.25)
Upper Bound 90% CI (CV=0.25)
WR k = -0.00001
WR k = -0.001
UM k = -0.00001
UM k = -0.001
TP Load -15 yrs
TP Load +25 yrs


Long-term Post-remediation Sensitivity Analysis
Dissolved Copper Concentrations in Railroad Creek Downstream of RC-2, Spring
Alternative 2b
Dissolved Copper (mg/L)
0.0350
0.0300
0.0250
0.0200
0.0150
0.0100
0.0050
0.0000
2000
2050
2100
2150
2200
2250
2300
2350
2400
2450
2500
Year
SWQC
NRWQC
Expected LT Value
Lower Bound 90% CI (CV=0.3)
Upper Bound 90% CI (CV=0.3)
WR k = -0.00001
WR k = -0.001
UM k = -0.00001
UM k = -0.001
TP Load -15 yrs
TP Load +25 yrs



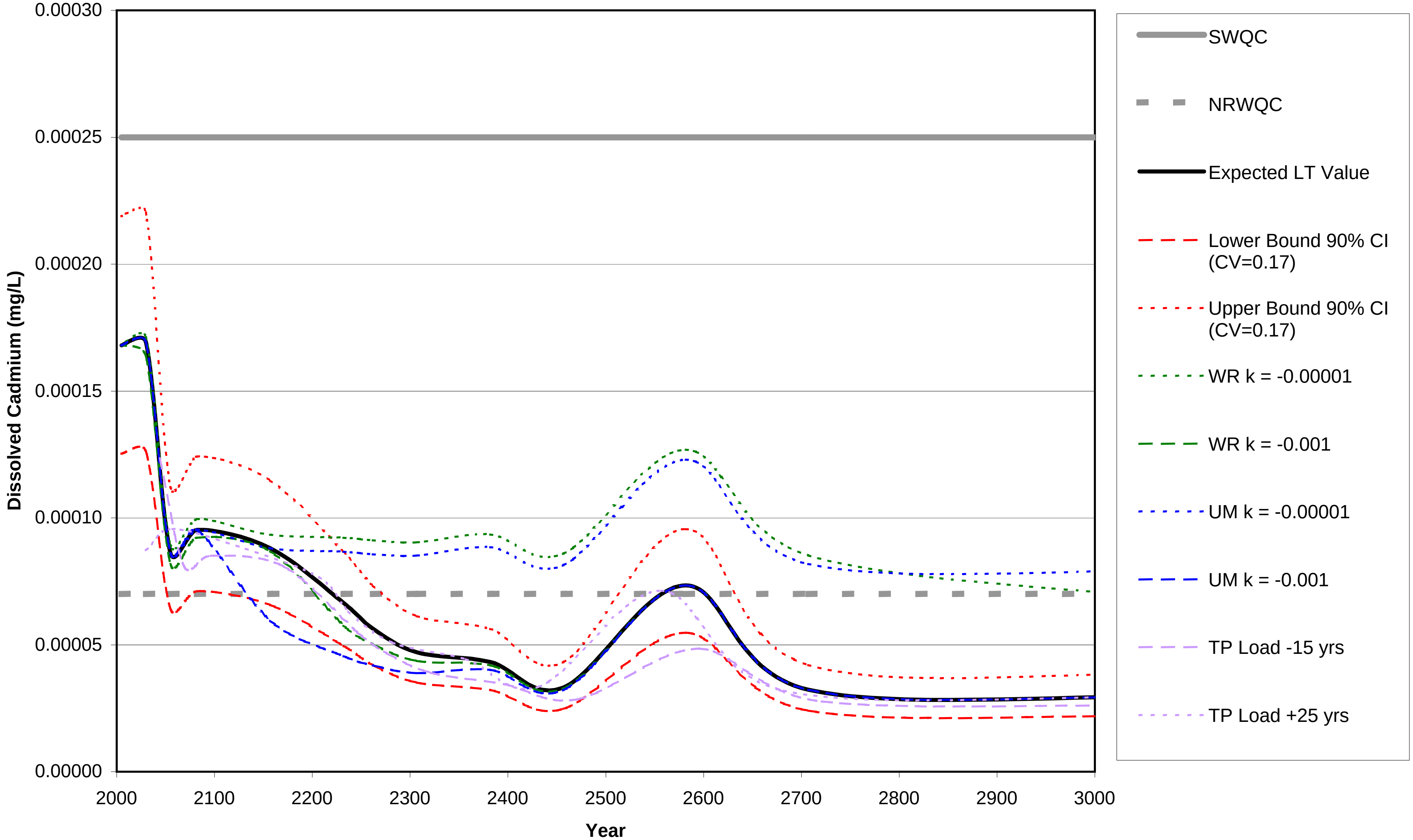
Appendix D6-2
Alternative 2b - Iron
Long-term Post-remediation Sensitivity Analysis
Draft Final FS Report February 2004

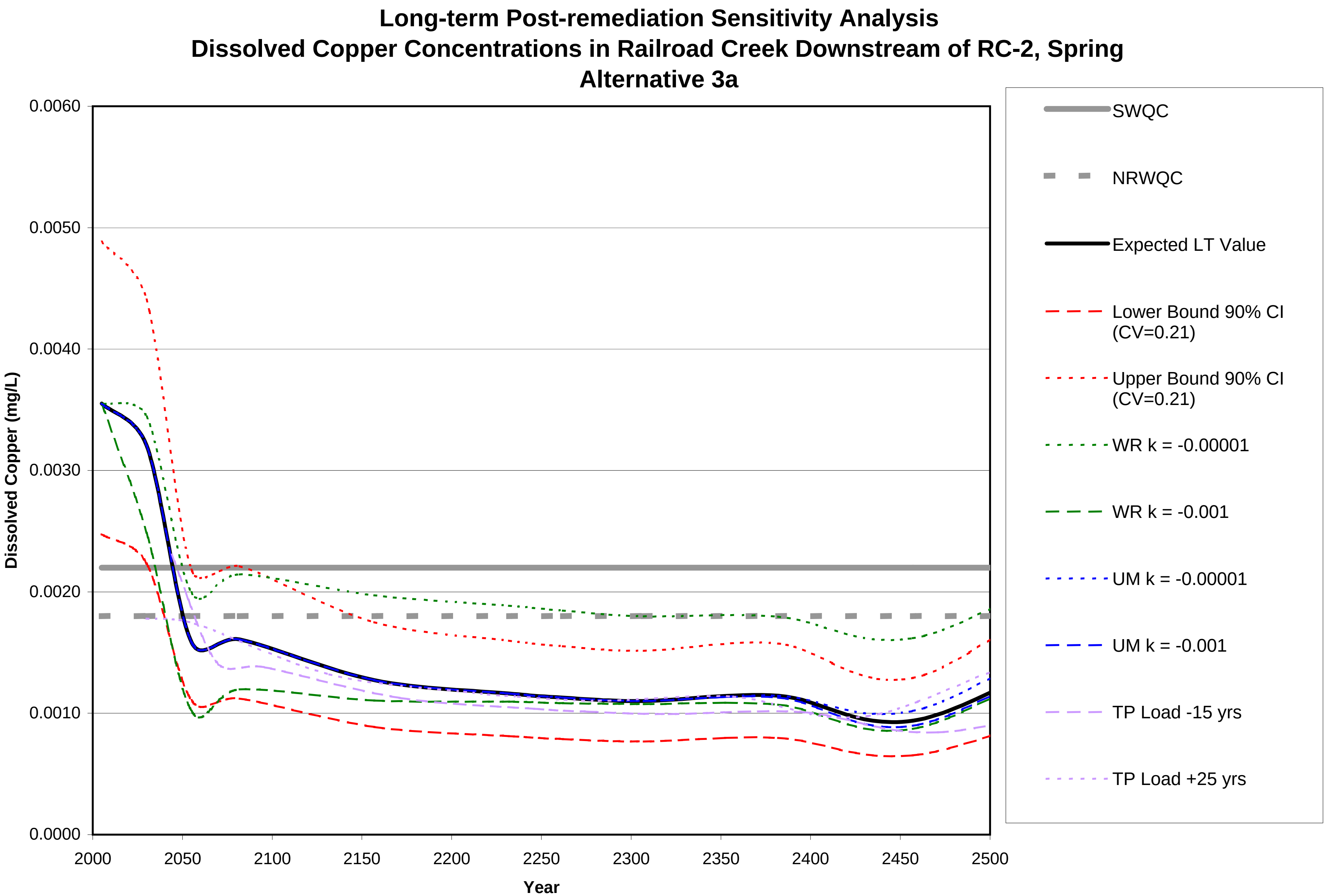
Long-term Post-remediation Sensitivity Analysis
Dissolved Zinc Concentrations in Railroad Creek Downstream of RC-2, Spring
Alternative 2b



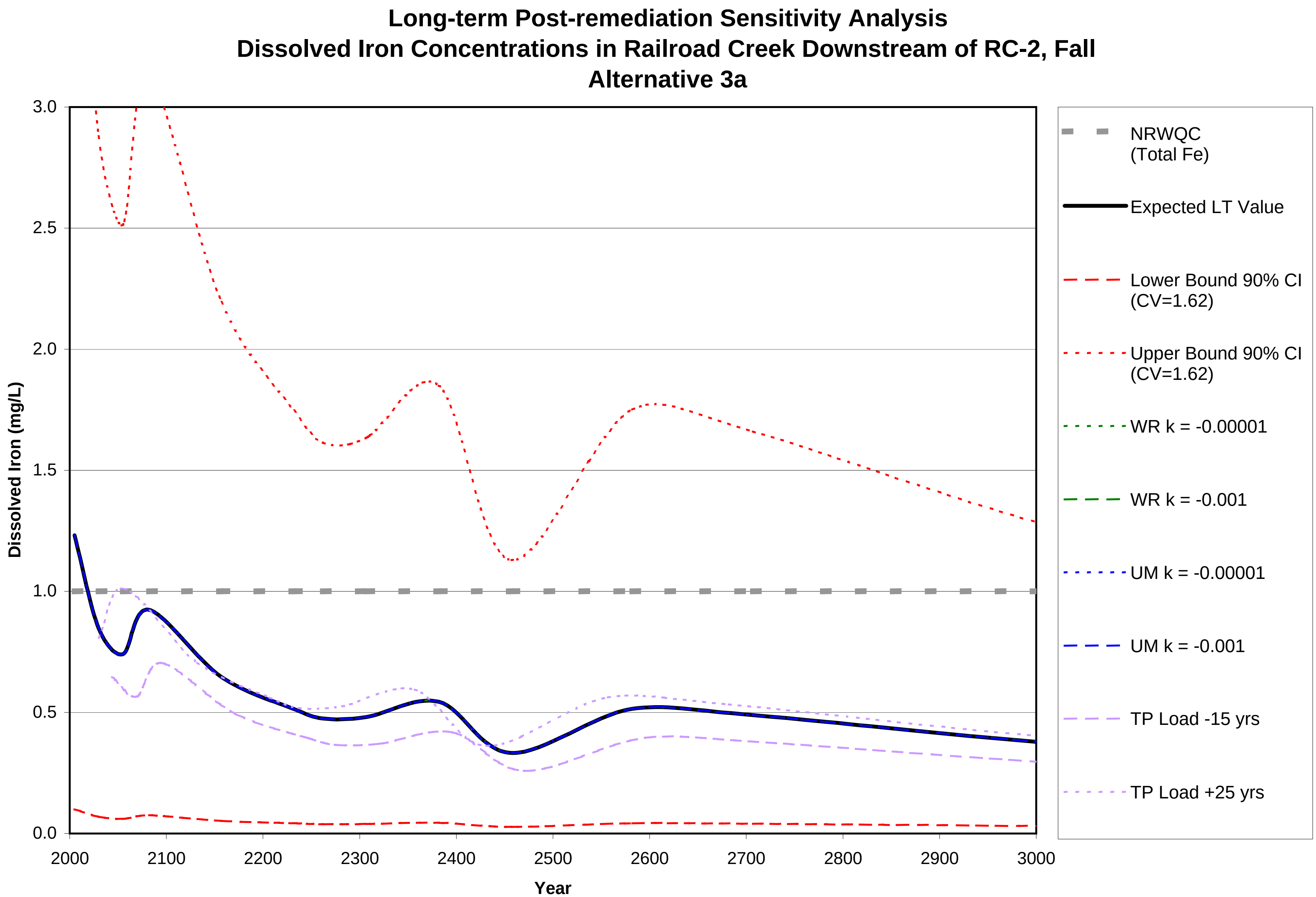
Appendix D6-2
Alternative 2b - Zinc
Long-term Post-remediation Sensitivity Analysis
Draft Final FS Report February 2004

Long-term Post-remediation Sensitivity Analysis
Dissolved Cadmium Concentrations in Railroad Creek Downstream of RC-2, Spring
Alternative 3a



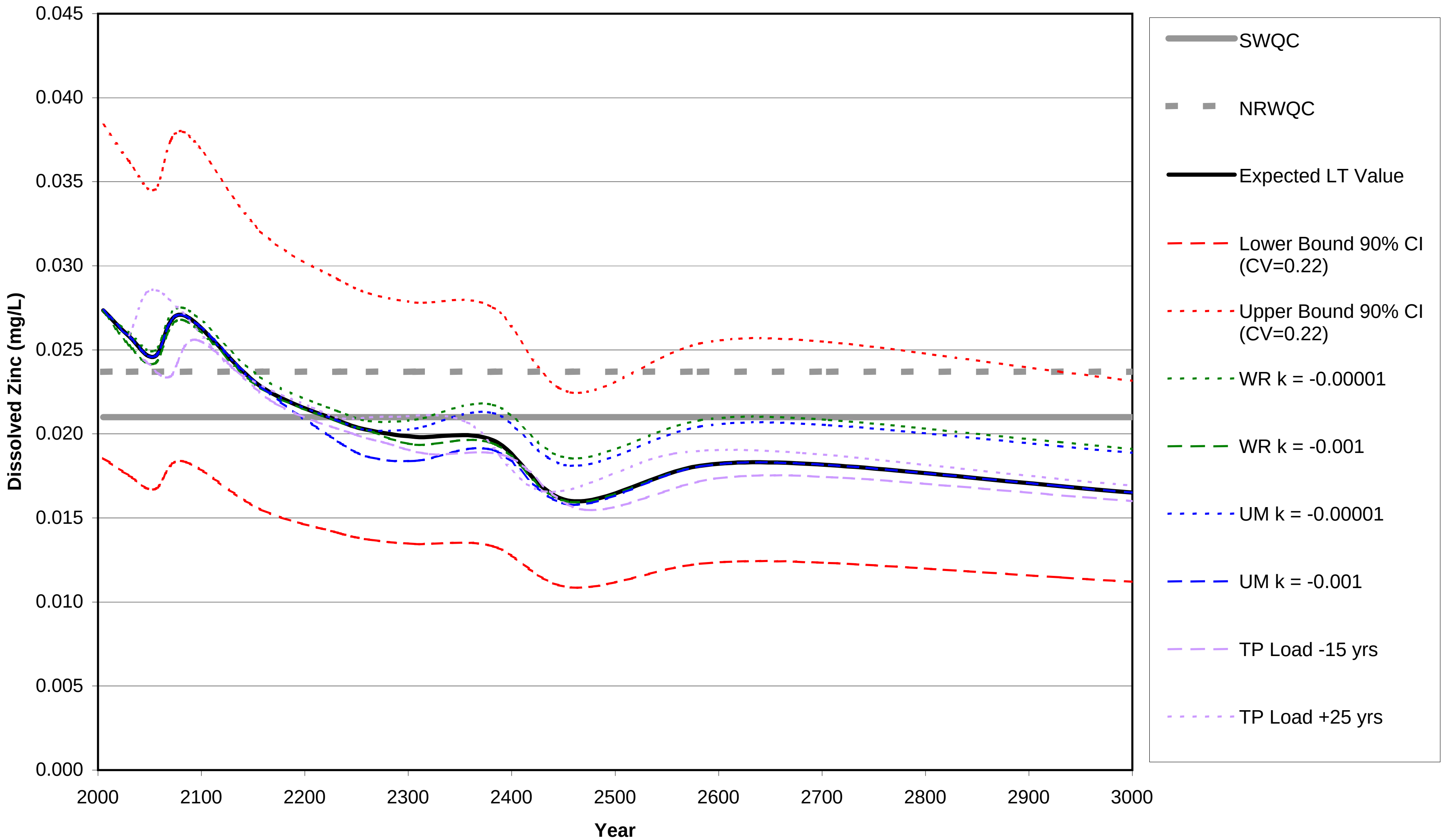


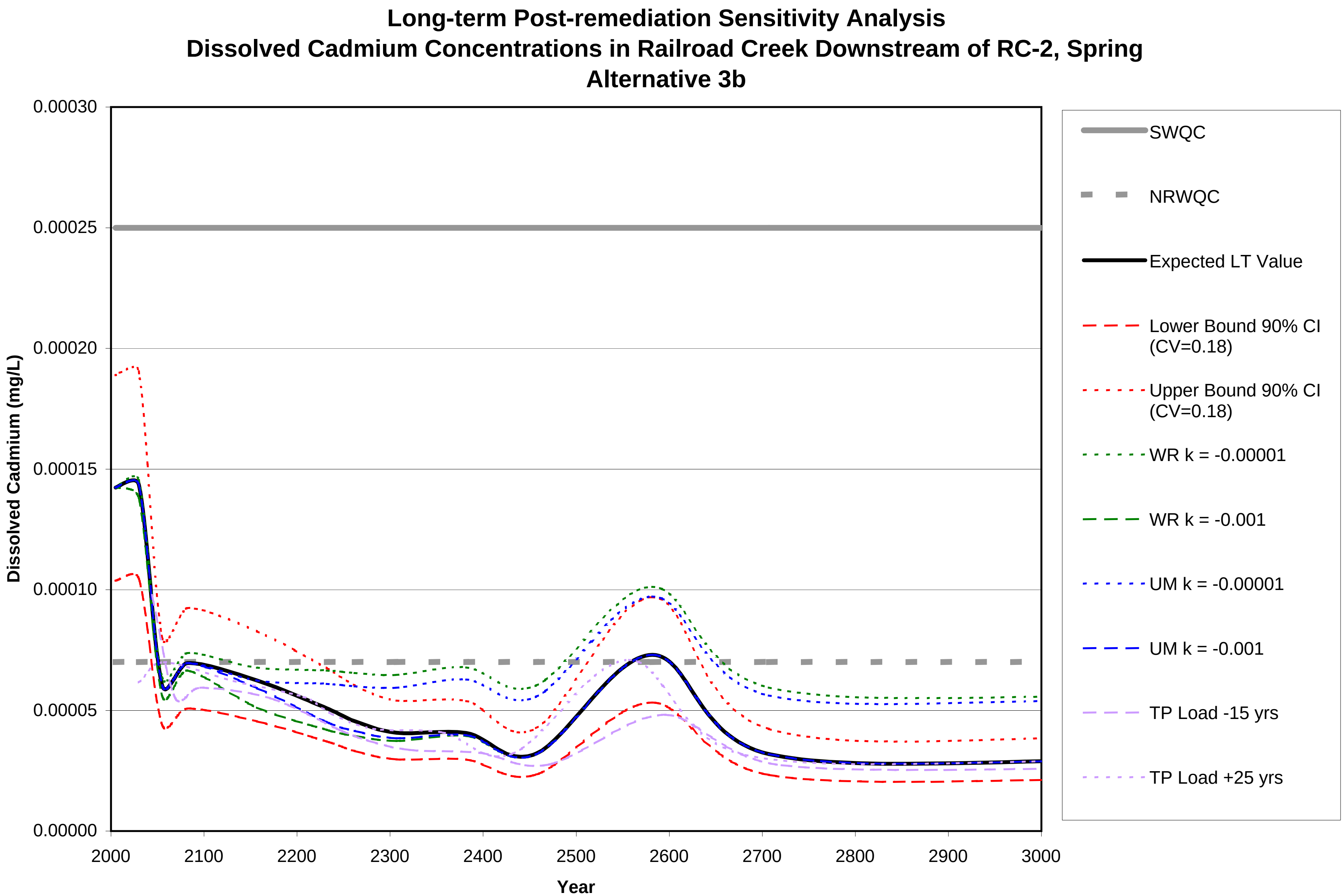
Long-term Post-remediation Sensitivity Analysis
Dissolved Copper Concentrations in Railroad Creek Downstream of RC-2, Spring
Alternative 3a
Dissolved Copper (mg/L)
0.0060
0.0050
0.0040
0.0030
0.0020
0.0010
0.0000
2000
2050
2100
2150
2200
2250
2300
2350
2400
2450
2500
Year
SWQC
NRWQC
Expected LT Value
Lower Bound 90% CI (CV=0.21)
Upper Bound 90% CI (CV=0.21)
WR k = -0.00001
WR k = -0.001
UM k = -0.00001
UM k = -0.001
TP Load -15 yrs
TP Load +25 yrs

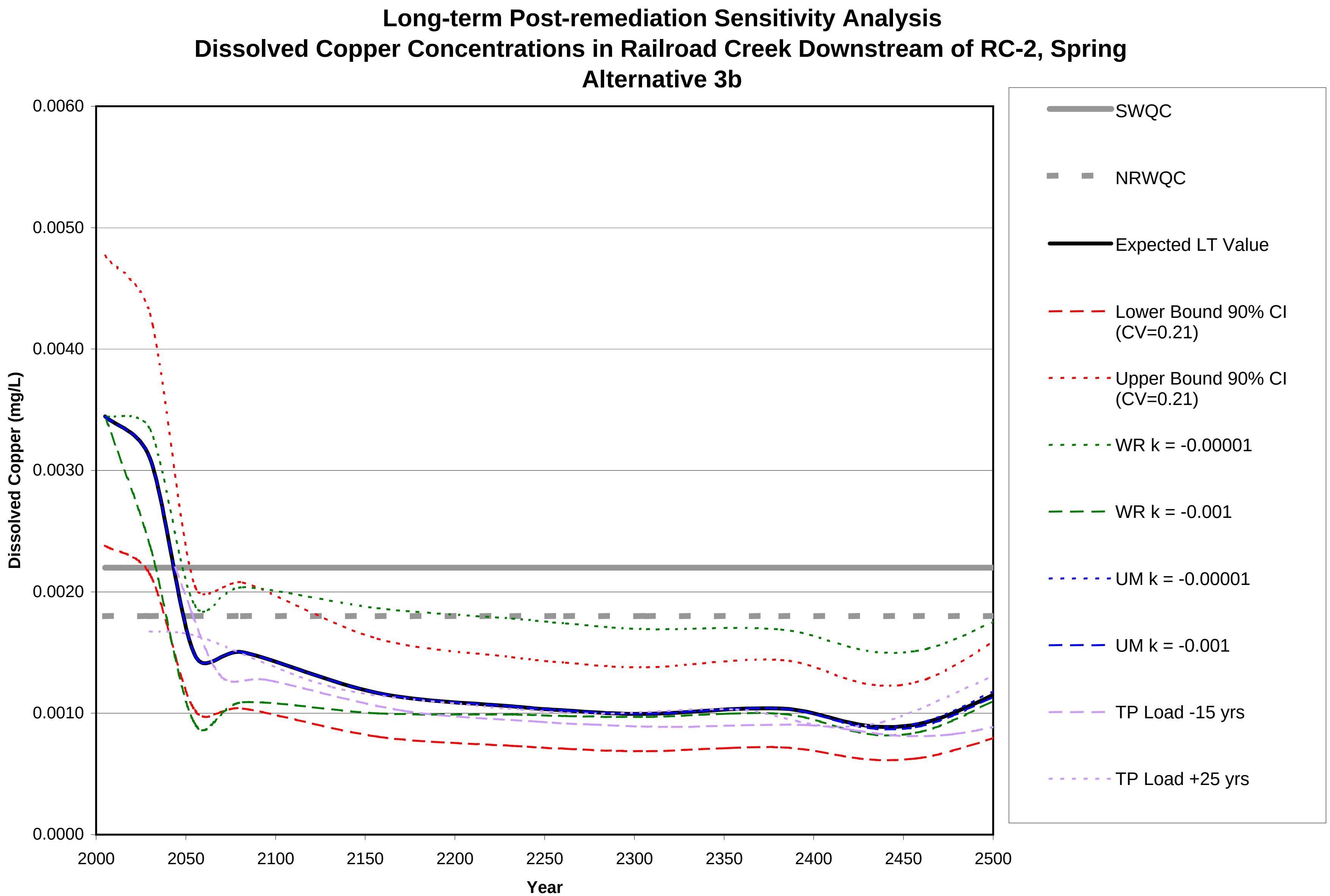


Appendix D6-3
Alternative 3a - Iron
Long-term Post-remediation Sensitivity Analysis

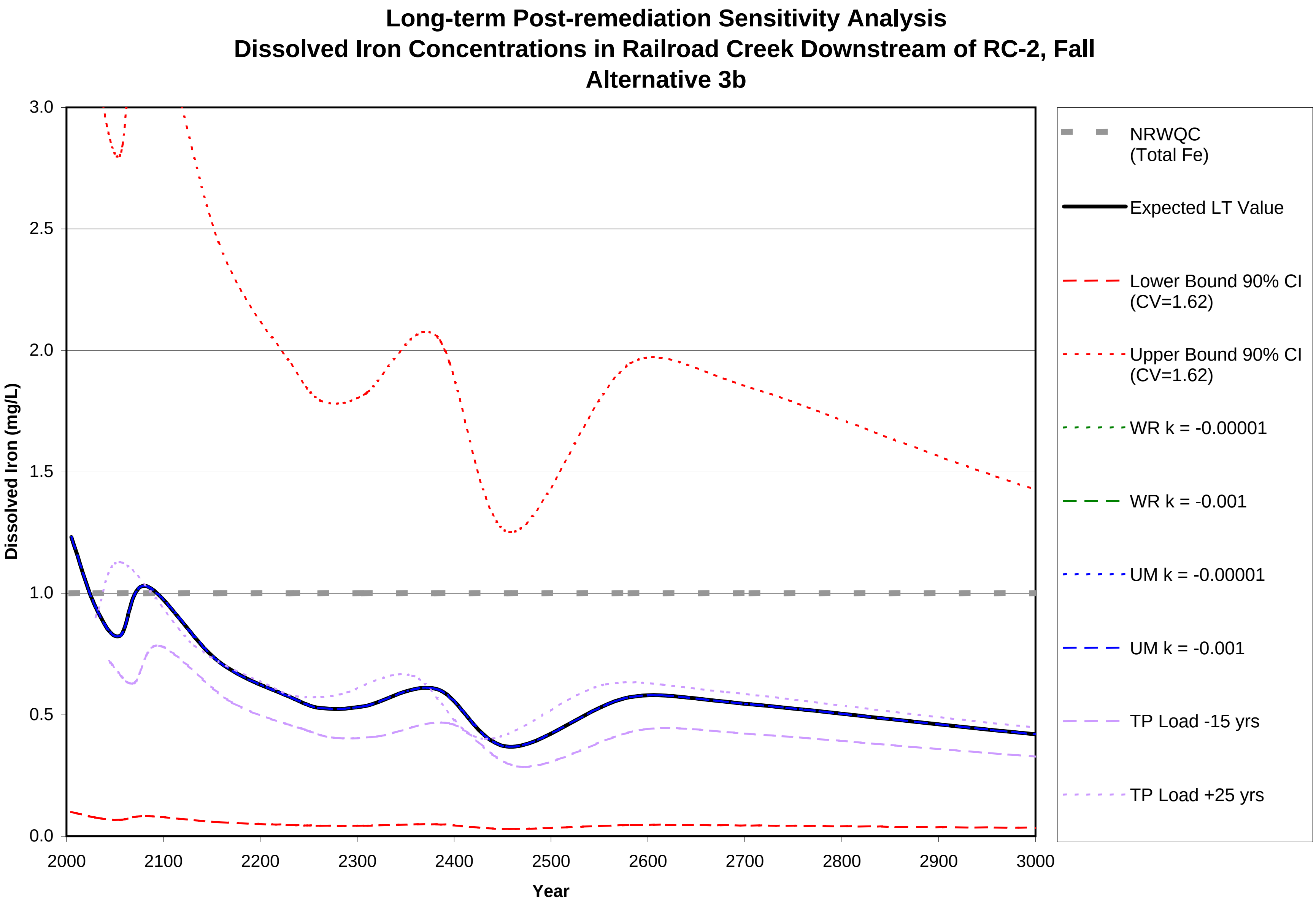
Long-term Post-remediation Sensitivity Analysis
Dissolved Zinc Concentrations in Railroad Creek Downstream of RC-2, Spring
Alternative 3a




Long-term Post-remediation Sensitivity Analysis
Dissolved Cadmium Concentrations in Railroad Creek Downstream of RC-2, Spring
Alternative 3b
Dissolved Cadmium (mg/L)
0.00030
0.00025
0.00020
0.00015
0.00010
0.00005
0.00000
2000
2100
2200
2300
2400
2500
2600
2700
2800
2900
3000
Year
SWQC
NRWQC
Expected LT Value
Lower Bound 90% CI (CV=0.18)
Upper Bound 90% CI (CV=0.18)
WR k = -0.00001
WR k = -0.001
UM k = -0.00001
UM k = -0.001
TP Load -15 yrs
TP Load +25 yrs

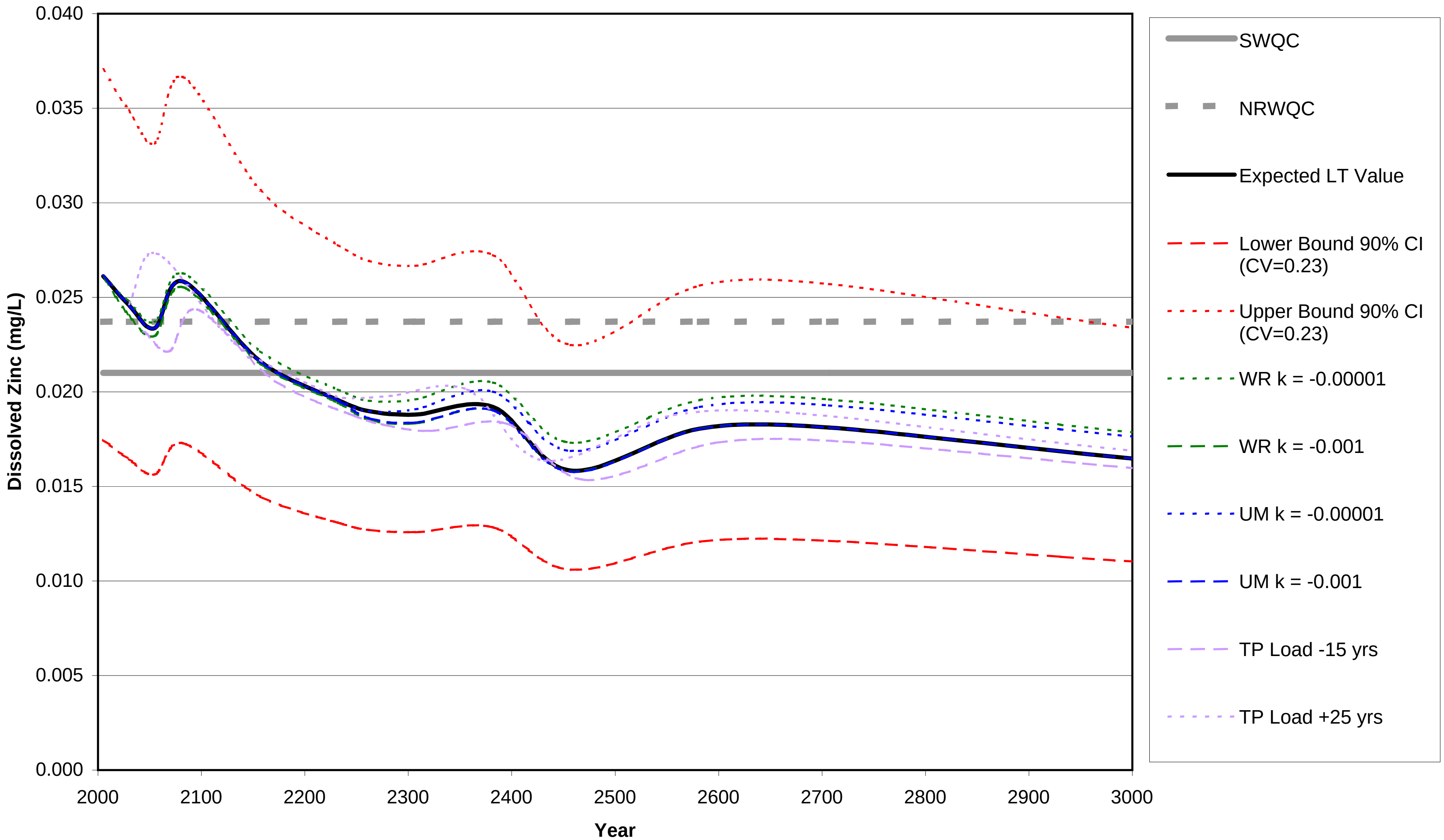


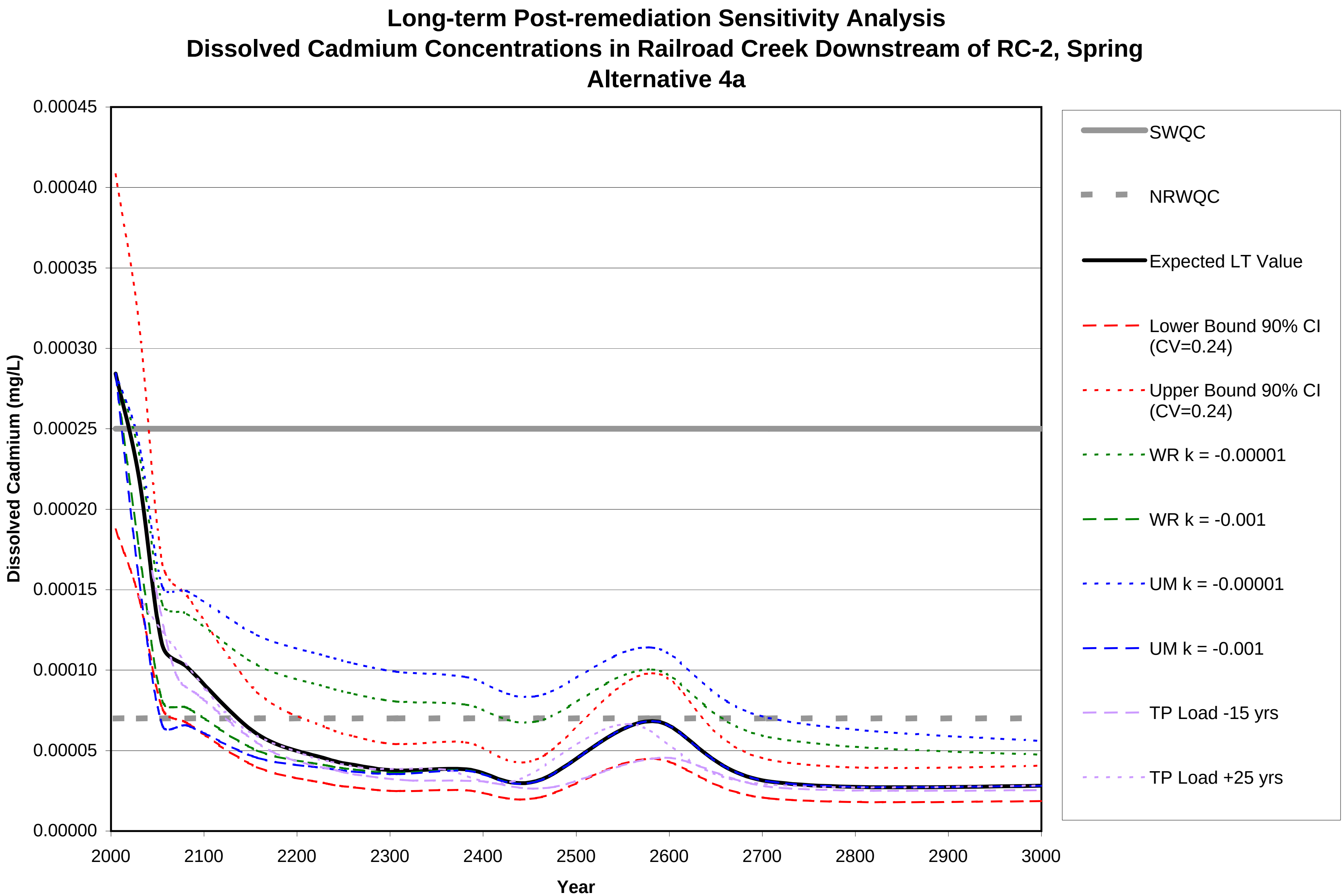
Appendix D6-4
Alternative 3b - Copper
Long-term Post-remediation Sensitivity Analysis
Draft Final FS Report February 2004



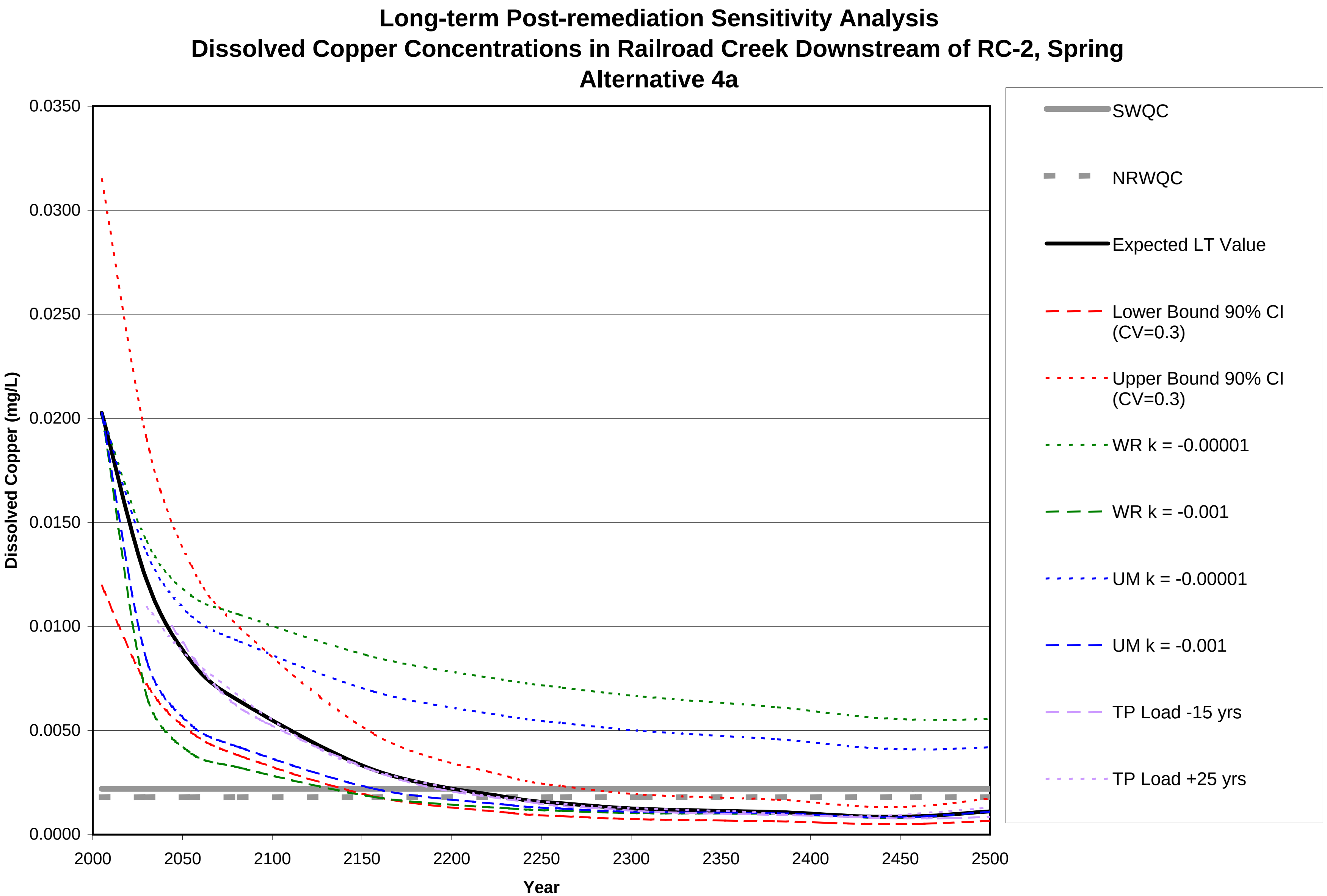
Appendix D6-4
Alternative 3b - Iron
Long-term Post-remediation Sensitivity Analysis

Long-term Post-remediation Sensitivity Analysis
Dissolved Zinc Concentrations in Railroad Creek Downstream of RC-2, Spring
Alternative 3b



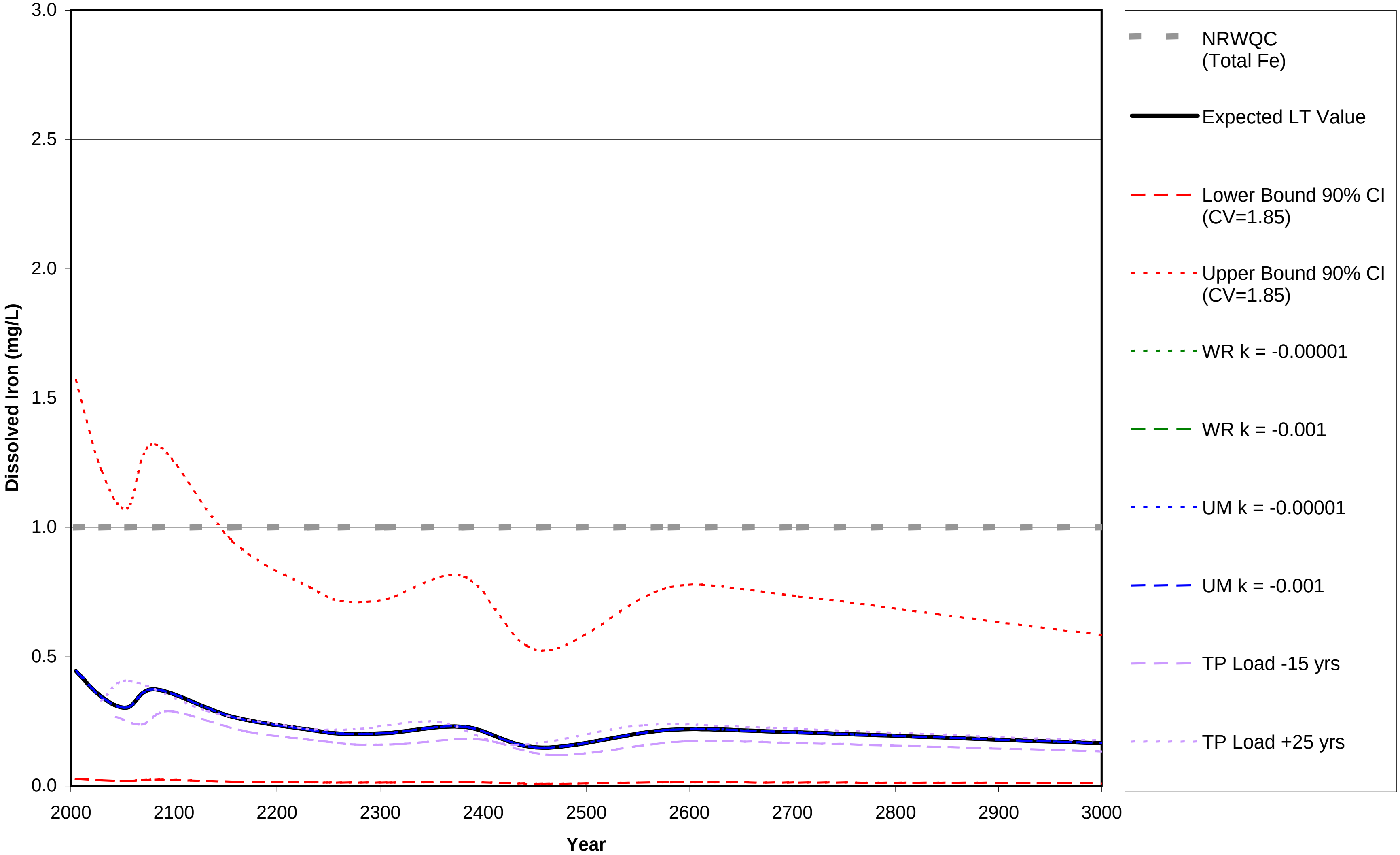


Appendix D6-5
Alternative 4a - Cadmium
Long-term Post-remediation Sensitivity Analysis
Draft Final FS Report February 2004

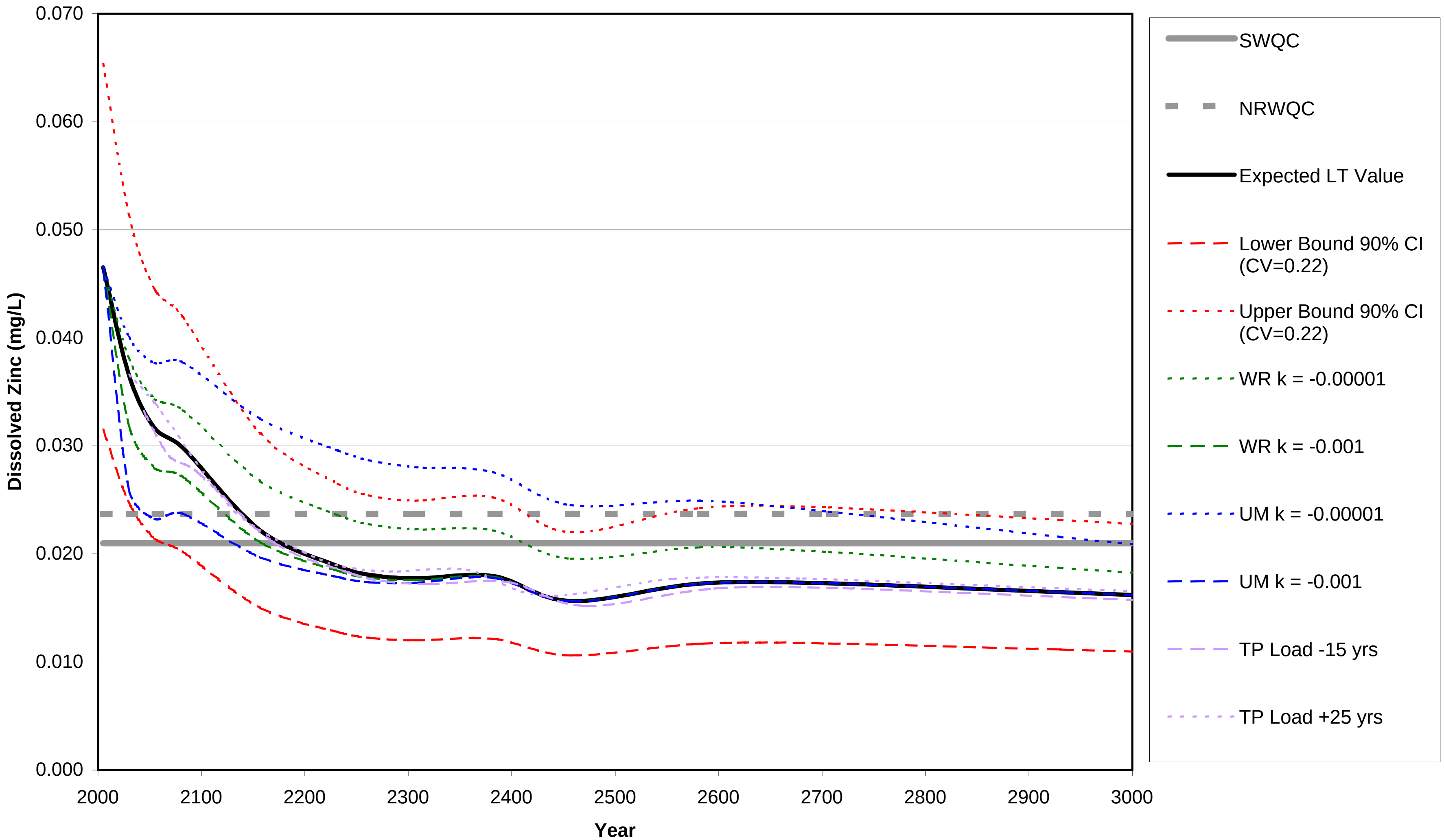


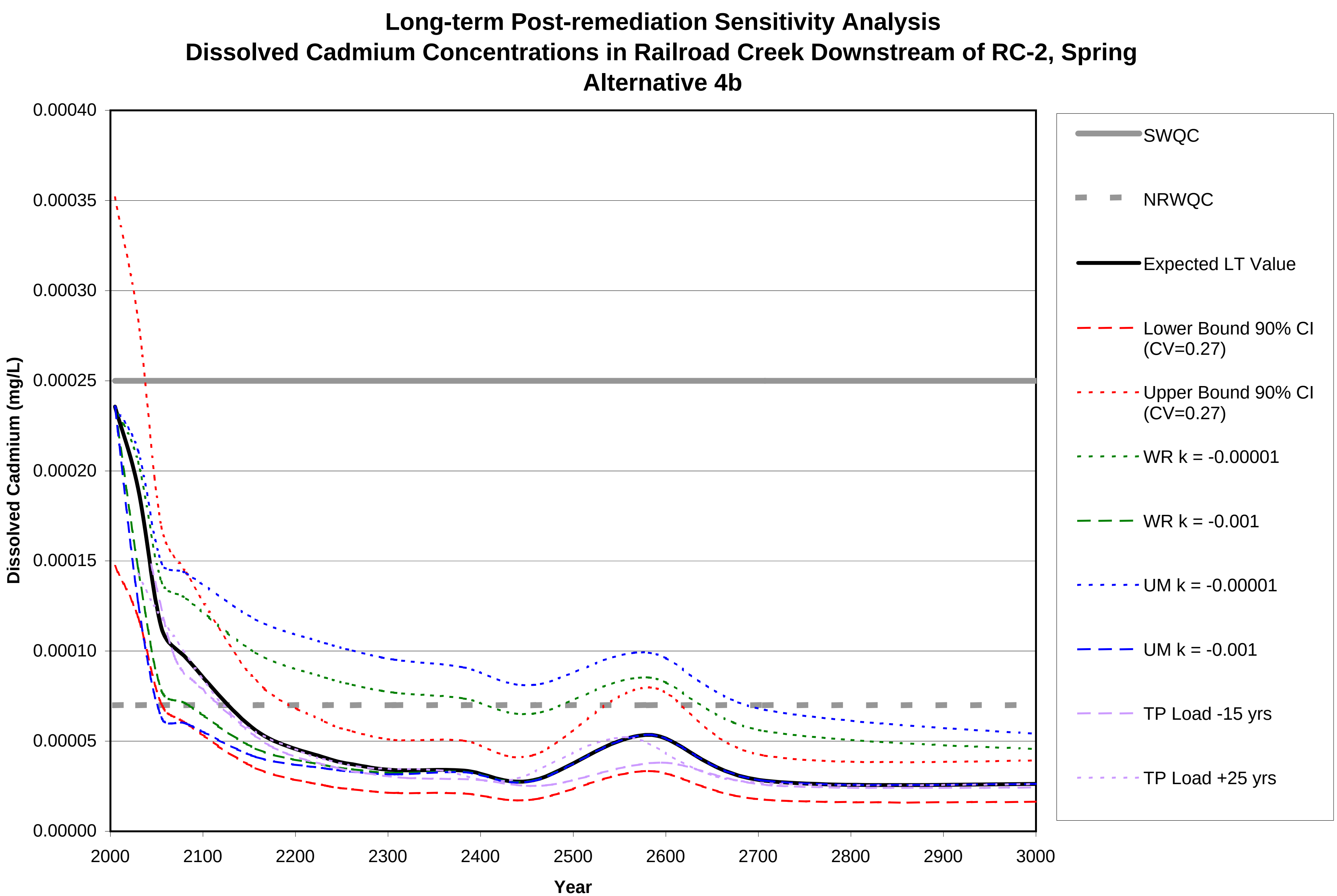
Long-term Post-remediation Sensitivity Analysis
Dissolved Copper Concentrations in Railroad Creek Downstream of RC-2, Spring
Alternative 4a
Dissolved Copper (mg/L)
0.0350
0.0300
0.0250
0.0200
0.0150
0.0100
0.0050
0.0000
2000
2050
2100
2150
2200
2250
2300
2350
2400
2450
2500
Year
SWQC
NRWQC
Expected LT Value
Lower Bound 90% CI (CV=0.3)
Upper Bound 90% CI (CV=0.3)
WR k = -0.00001
WR k = -0.001
UM k = -0.00001
UM k = -0.001
TP Load -15 yrs
TP Load +25 yrs

Long-term Post-remediation Sensitivity Analysis
Dissolved Iron Concentrations in Railroad Creek Downstream of RC-2, Fall
Alternative 4a

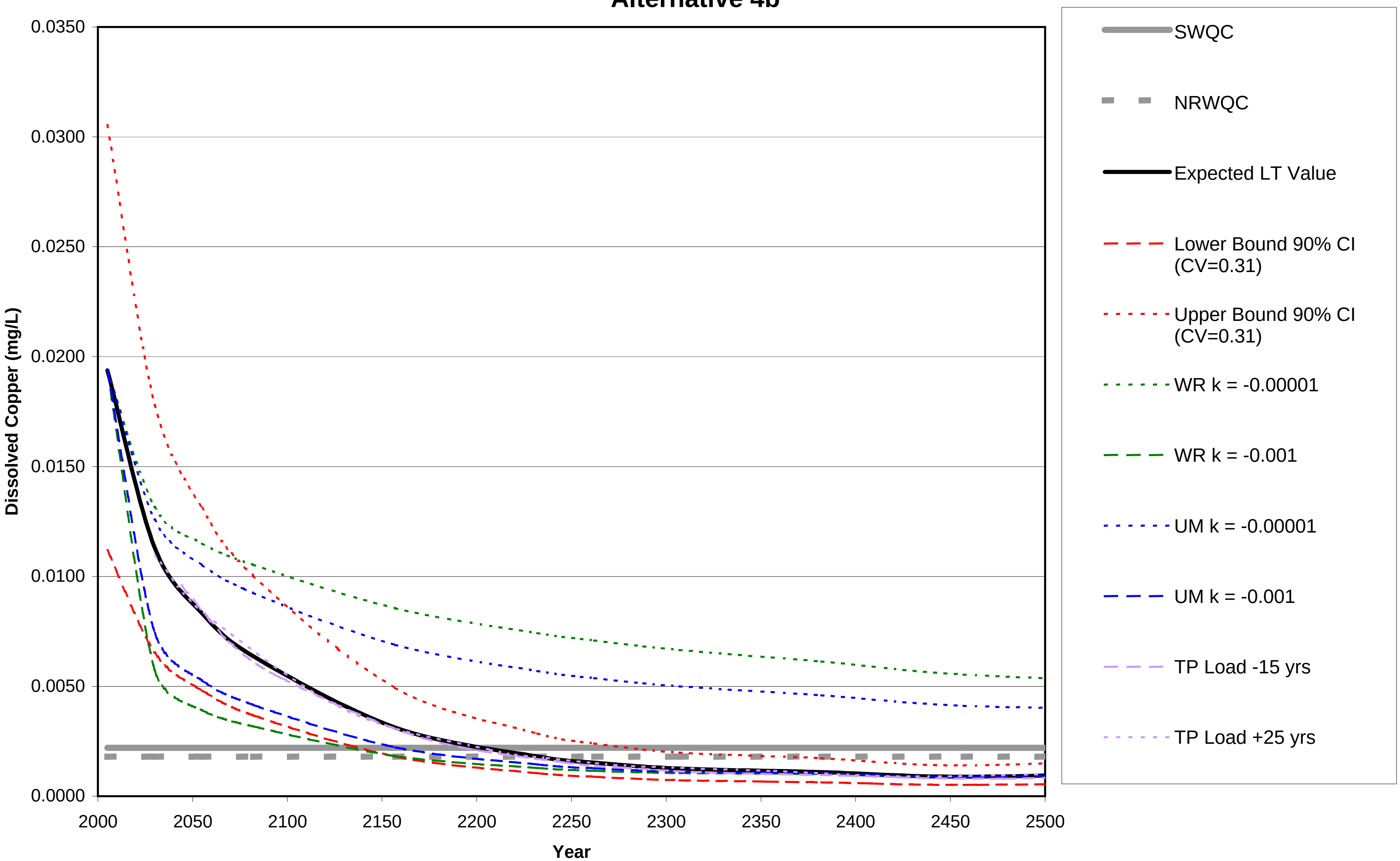


Long-term Post-remediation Sensitivity Analysis
Dissolved Zinc Concentrations in Railroad Creek Downstream of RC-2, Spring
Alternative 4a

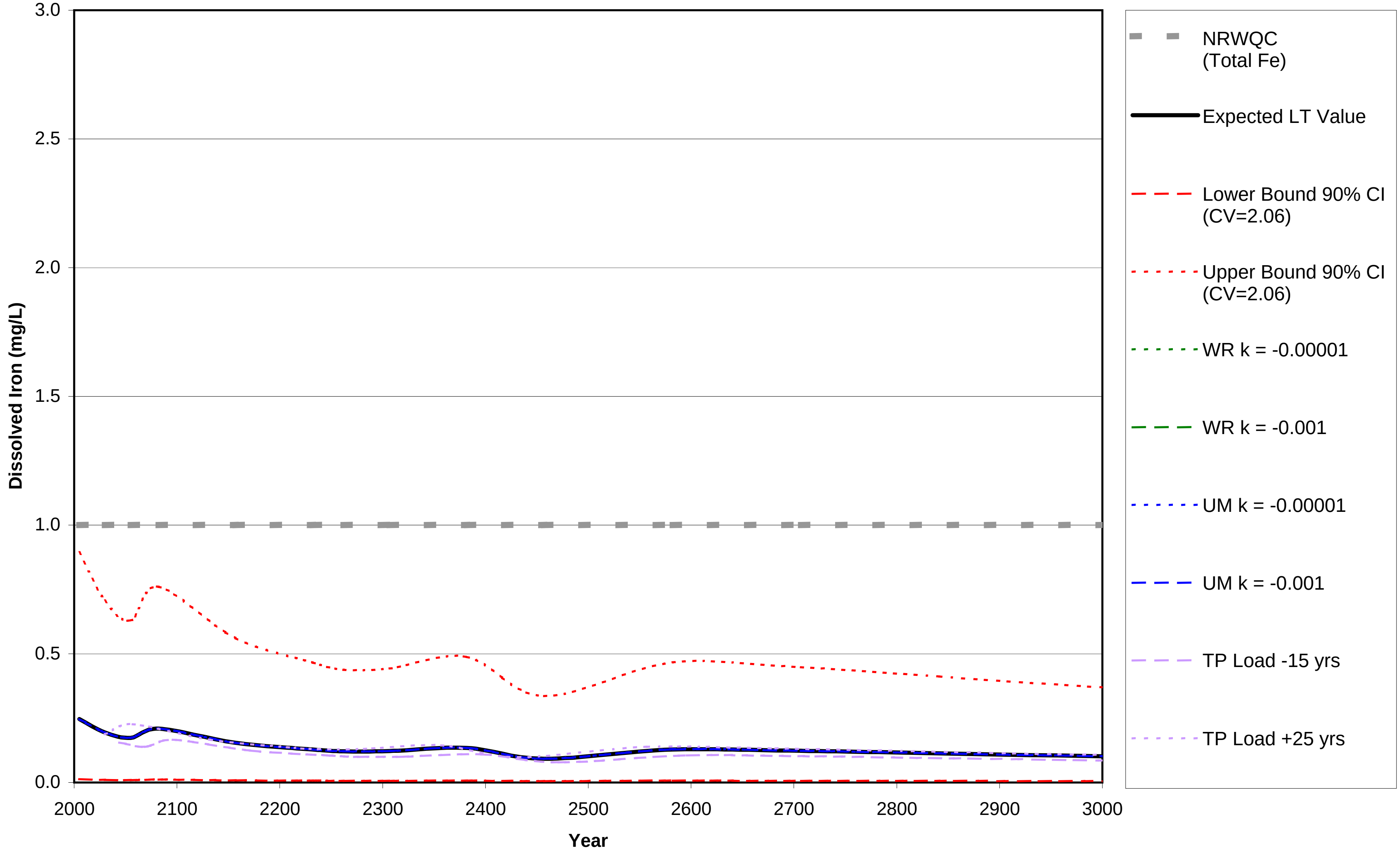



Long-term Post-remediation Sensitivity Analysis
Dissolved Cadmium Concentrations in Railroad Creek Downstream of RC-2, Spring
Alternative 4b
Dissolved Cadmium (mg/L)
0.00040
0.00035
0.00030
0.00025
0.00020
0.00015
0.00010
0.00005
0.00000
2000
2100
2200
2300
2400
2500
2600
2700
2800
2900
3000
Year
SWQC
NRWQC
Expected LT Value
Lower Bound 90% CI (CV=0.27)
Upper Bound 90% CI (CV=0.27)
WR k = -0.00001
WR k = -0.001
UM k = -0.00001
UM k = -0.001
TP Load -15 yrs
TP Load +25 yrs

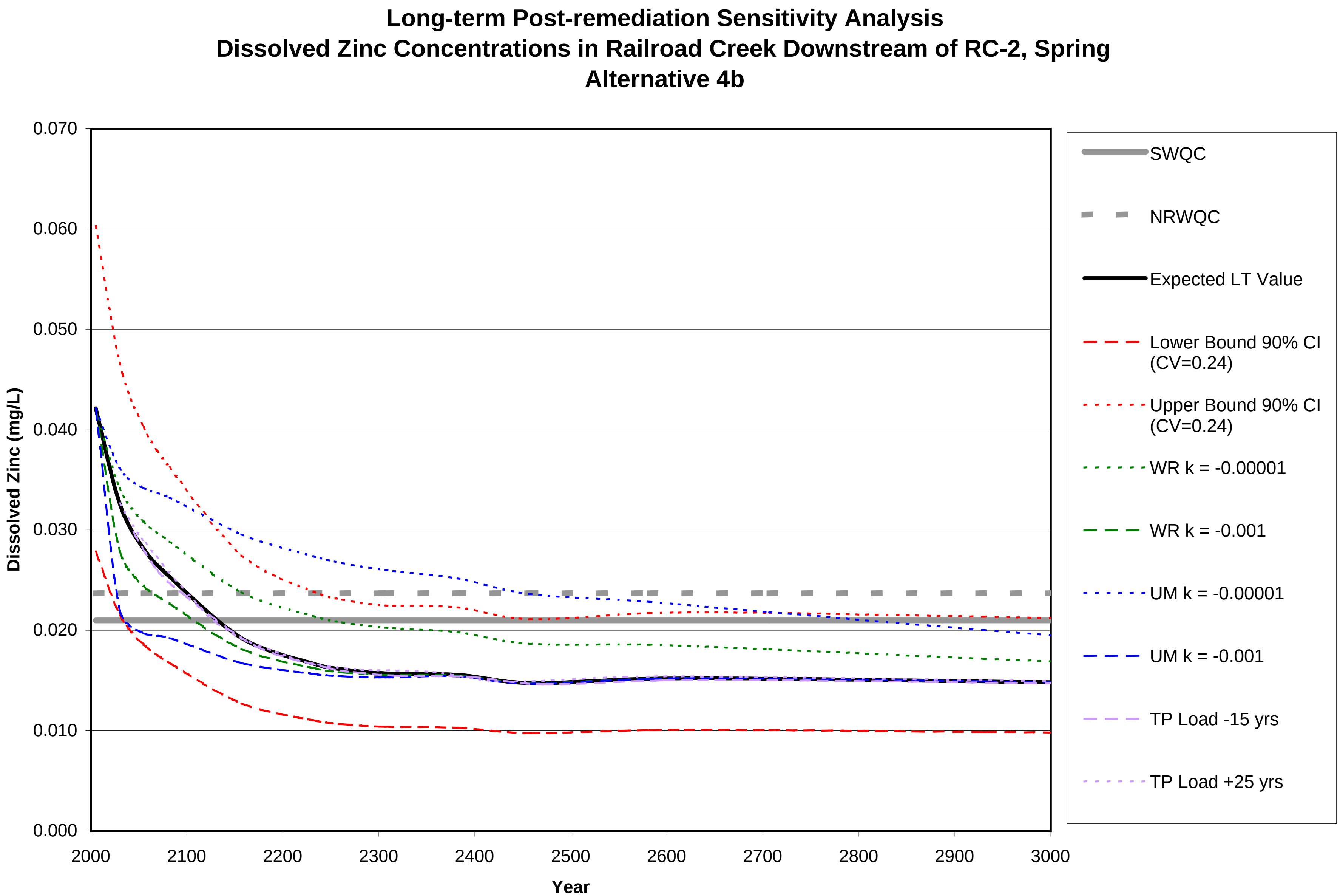
Long-term Post-remediation Sensitivity Analysis
Dissolved Copper Concentrations in Railroad Creek Downstream of RC-2, Spring
Alternative 4b



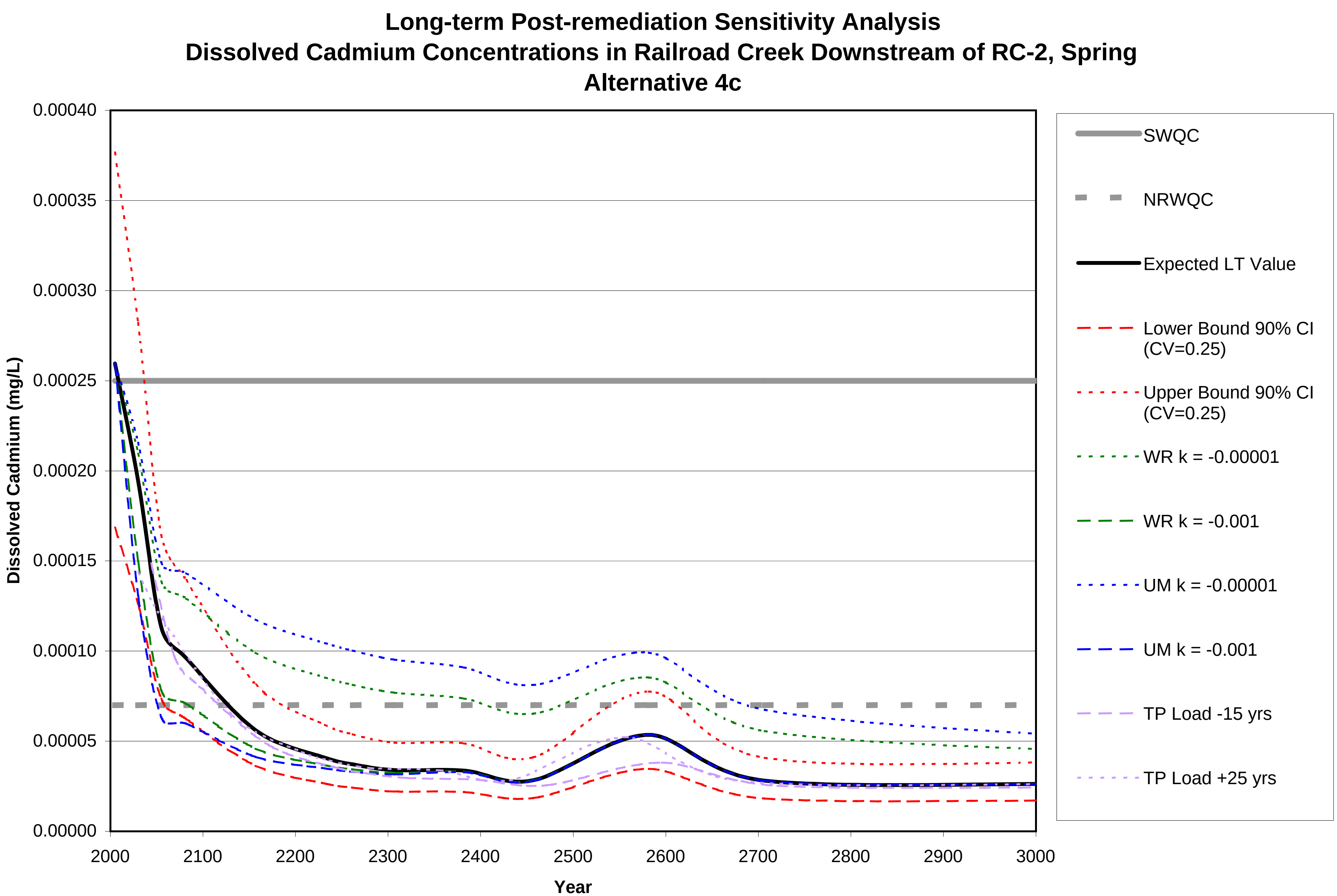
Long-term Post-remediation Sensitivity Analysis
Dissolved Iron Concentrations in Railroad Creek Downstream of RC-2, Fall
Alternative 4b



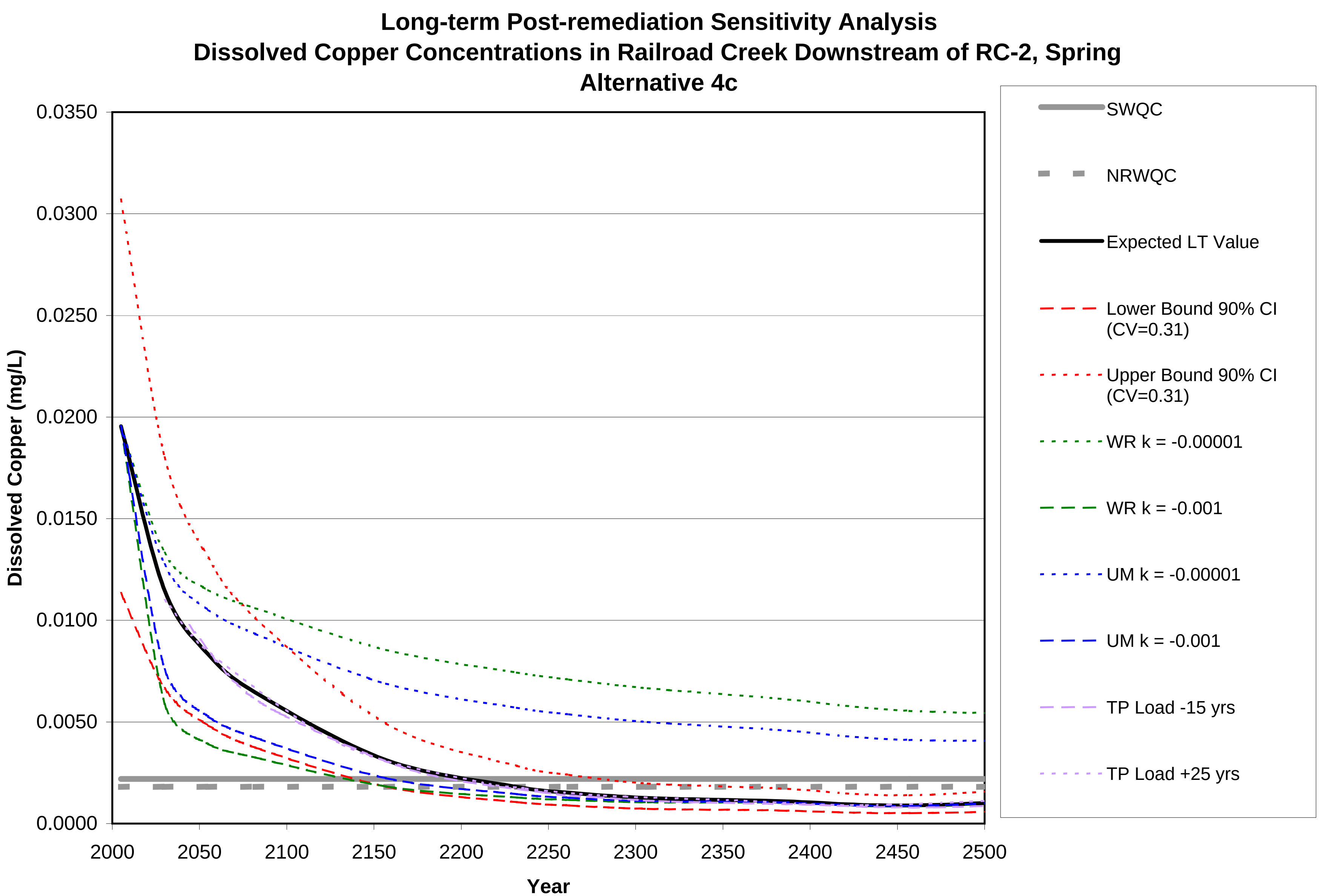
Appendix D6-6
Alternative 4b - Iron
Long-term Post-remediation Sensitivity Analysis
Draft Final FS Report February 2004

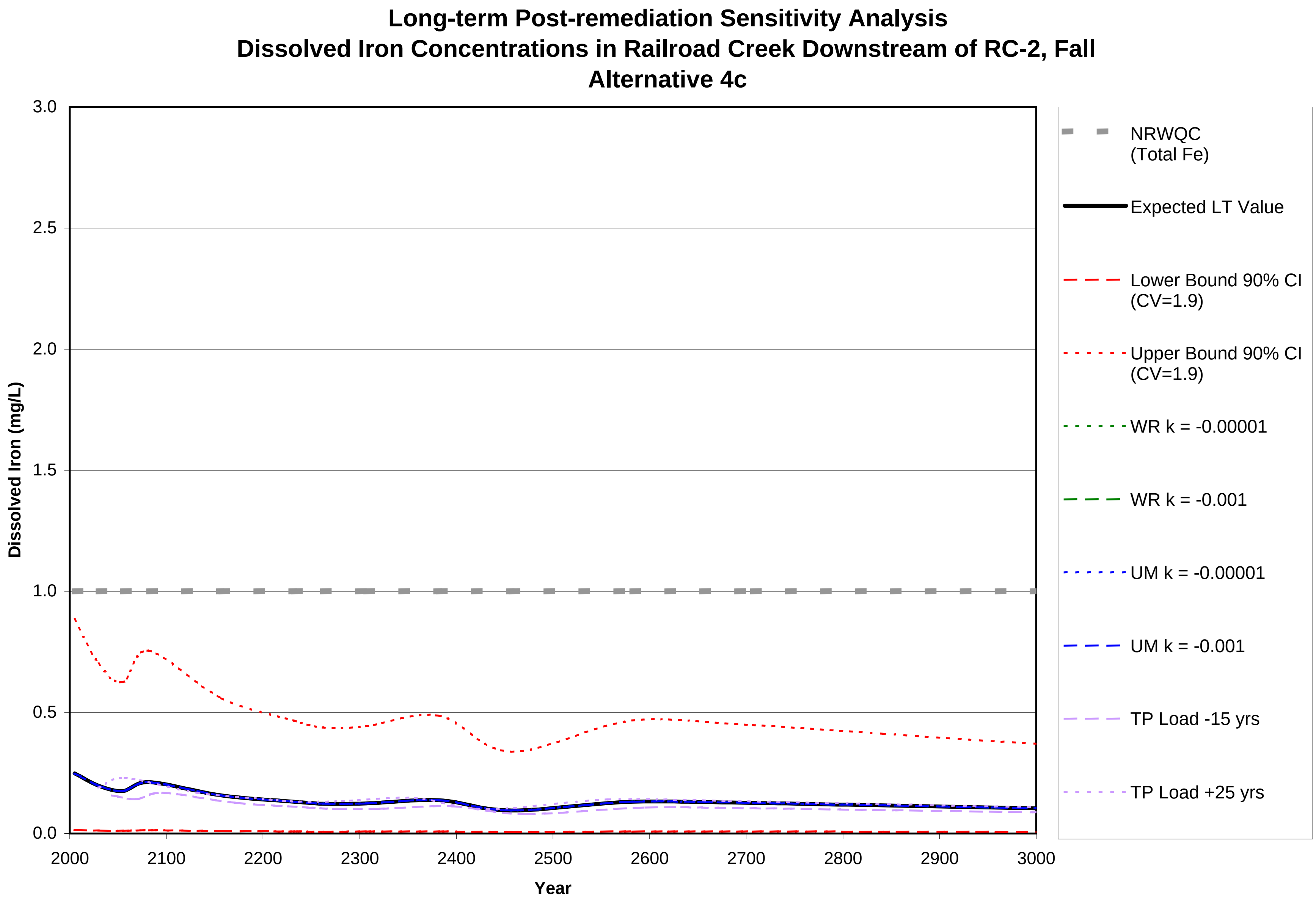


Appendix D6-6
Alternative 4b - Zinc
Long-term Post-remediation Sensitivity Analysis
Draft Final FS Report February 2004

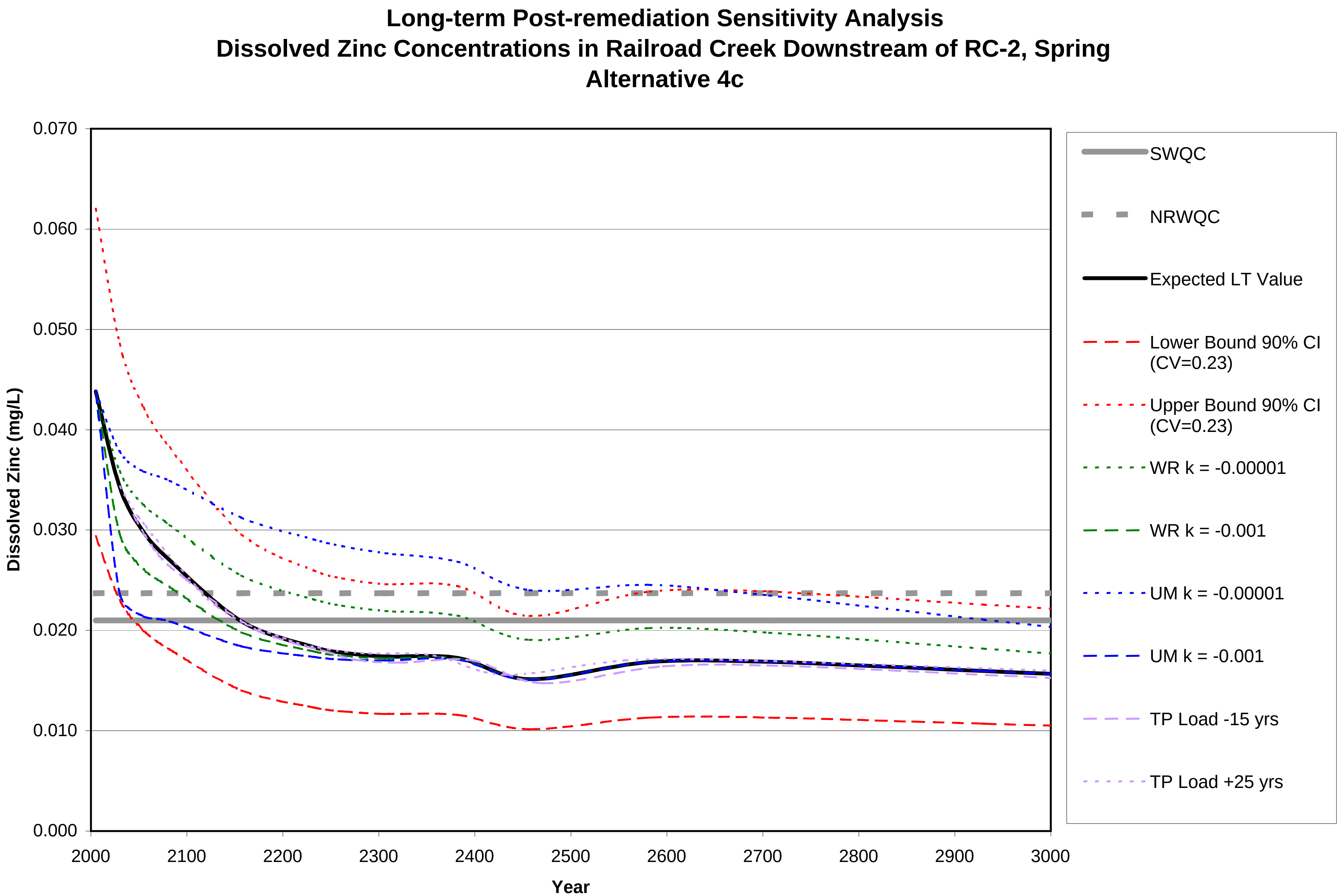


Appendix D6-7
Alternative 4c - Cadmium
Long-term Post-remediation Sensitivity Analysis
Draft Final FS Report February 2004


Long-term Post-remediation Sensitivity Analysis
Dissolved Copper Concentrations in Railroad Creek Downstream of RC-2, Spring
Alternative 4c
Dissolved Copper (mg/L)
0.0350
0.0300
0.0250
0.0200
0.0150
0.0100
0.0050
0.0000
2000
2050
2100
2150
2200
2250
2300
2350
2400
2450
2500
Year
SWQC
NRWQC
Expected LT Value
Lower Bound 90% CI (CV=0.31)
Upper Bound 90% CI (CV=0.31)
WR k = -0.00001
WR k = -0.001
UM k = -0.00001
UM k = -0.001
TP Load -15 yrs
TP Load +25 yrs

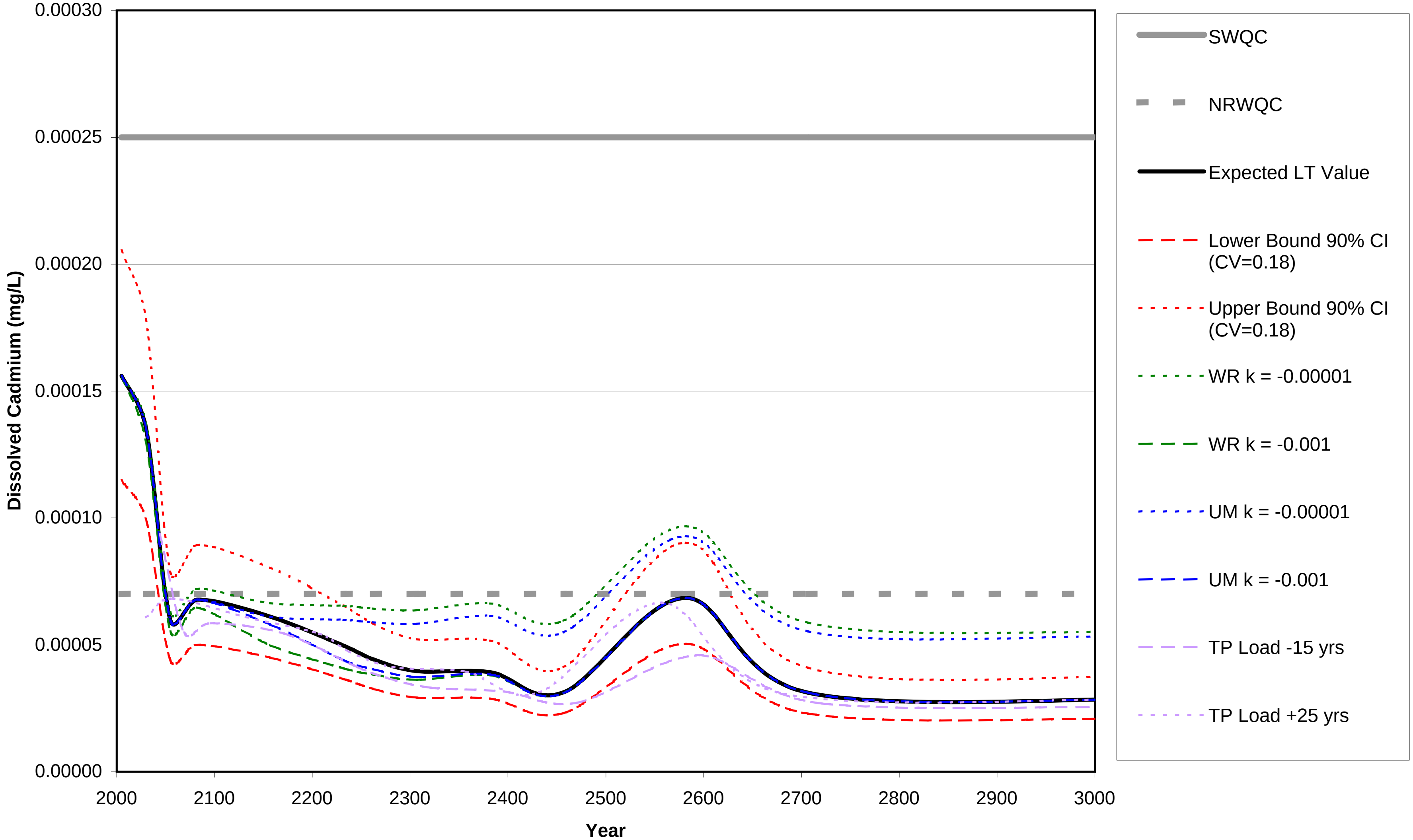


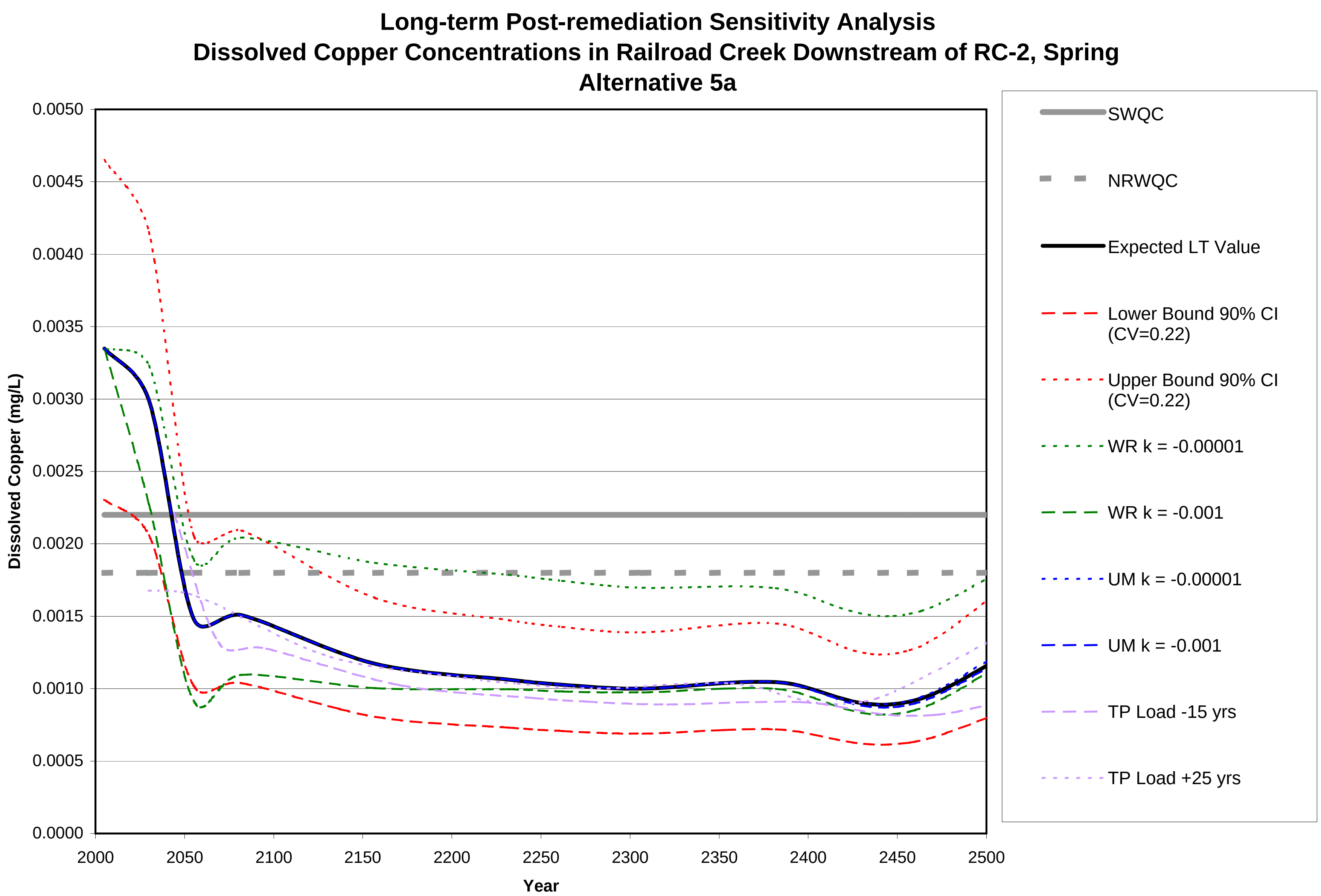
Appendix D6-7
Alternative 4c - Iron
Long-term Post-remediation Sensitivity Analysis
Draft Final FS Report February 2004



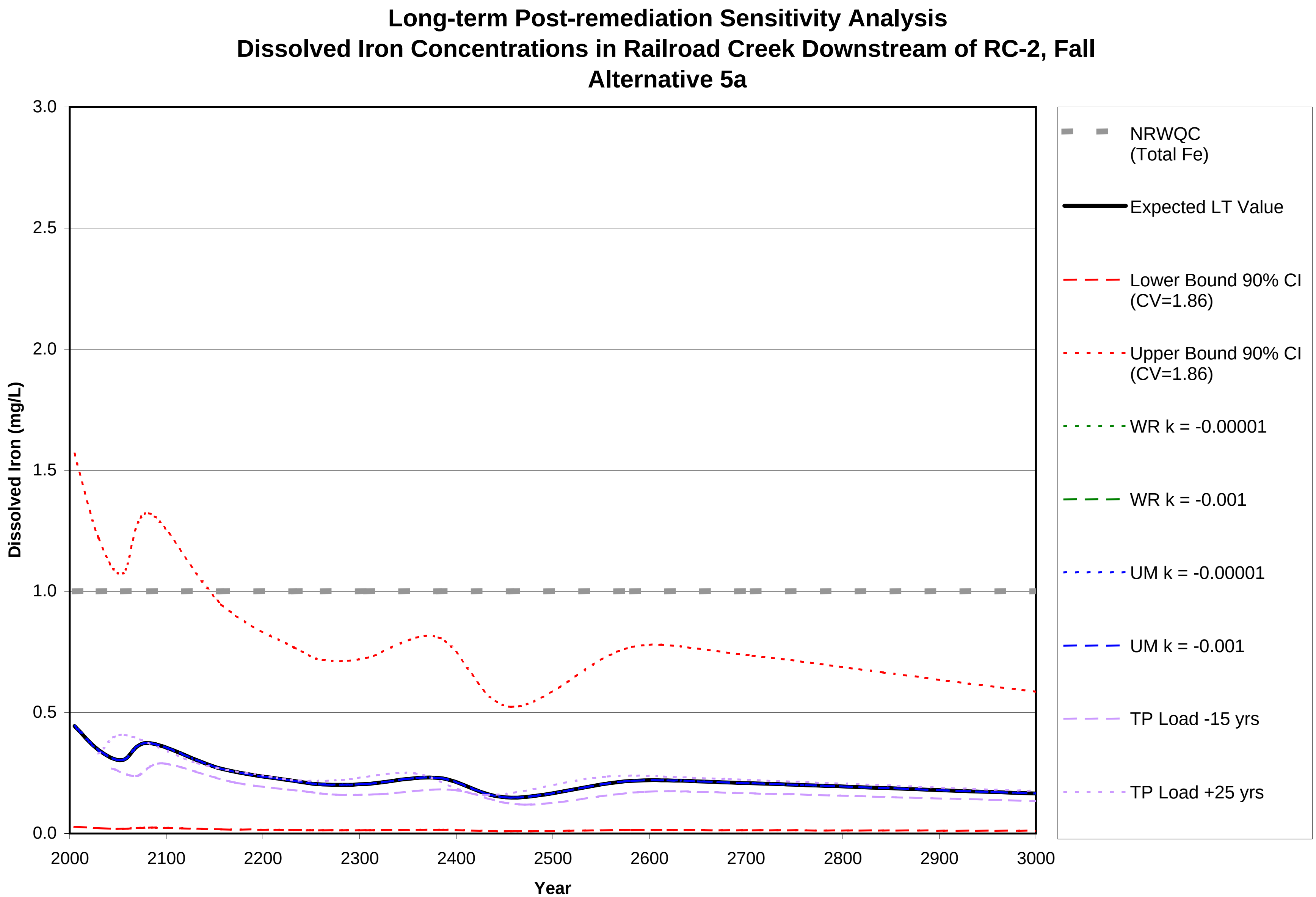
Appendix D6-7
Alternative 4c - Zinc
Long-term Post-remediation Sensitivity Analysis
Draft Final FS Report February 2004

Long-term Post-remediation Sensitivity Analysis
Dissolved Cadmium Concentrations in Railroad Creek Downstream of RC-2, Spring
Alternative 5a



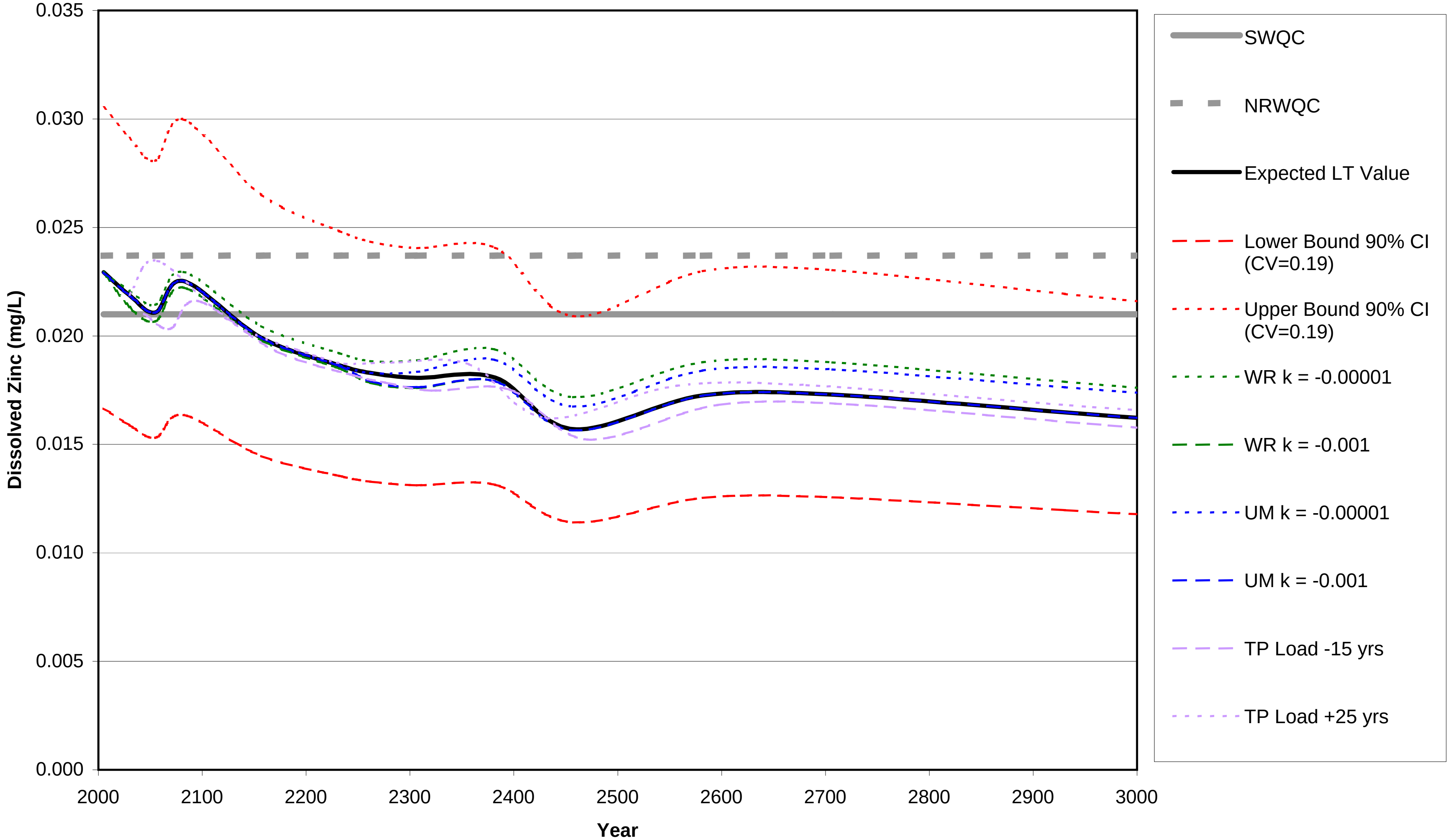


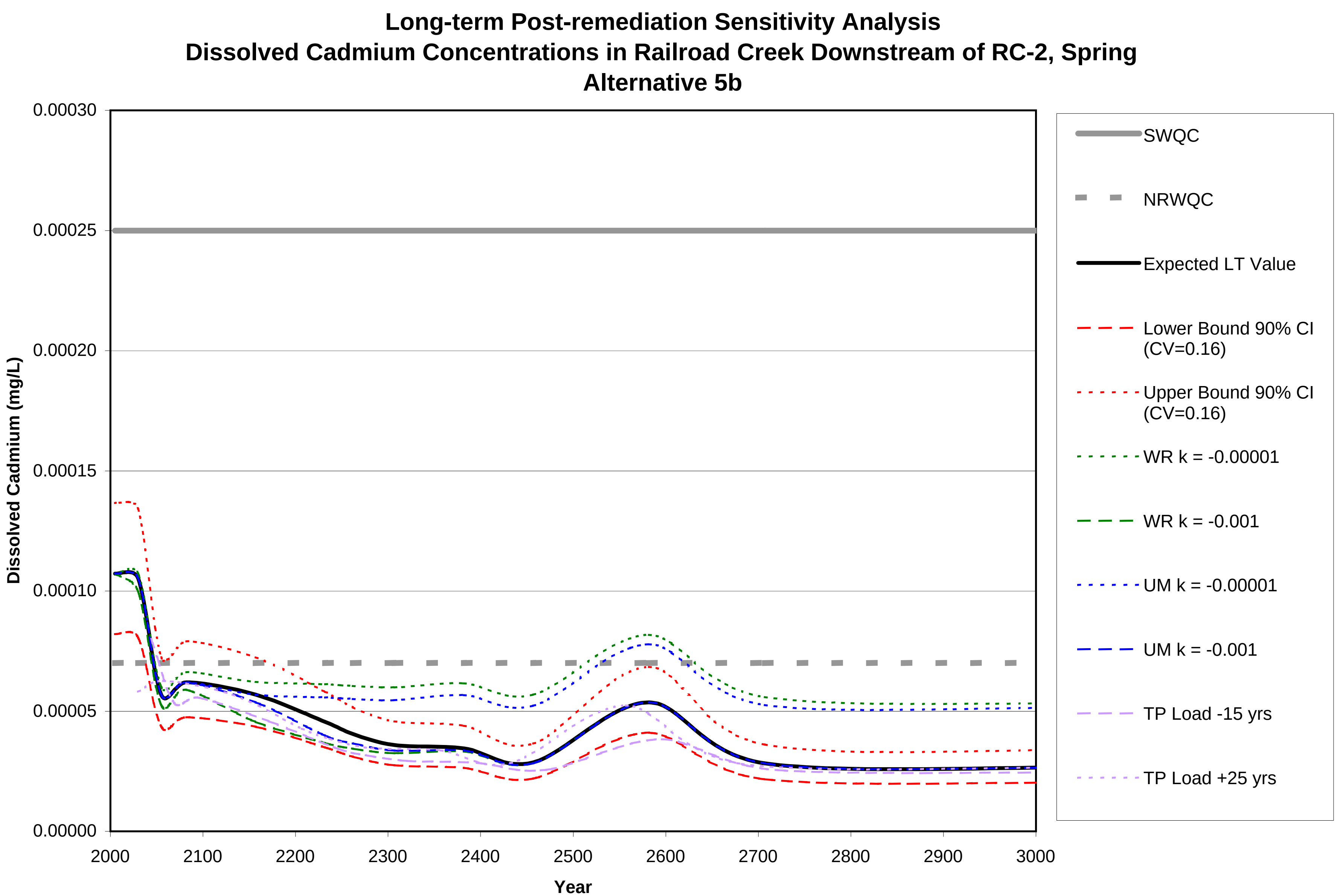
Long-term Post-remediation Sensitivity Analysis
Dissolved Copper Concentrations in Railroad Creek Downstream of RC-2, Spring
Alternative 5a
Dissolved Copper (mg/L)
0.0050
0.0045
0.0040
0.0035
0.0030
0.0025
0.0020
0.0015
0.0010
0.0005
0.0000
2000
2050
2100
2150
2200
2250
2300
2350
2400
2450
2500
Year
SWQC
NRWQC
Expected LT Value
Lower Bound 90% CI (CV=0.22)
Upper Bound 90% CI (CV=0.22)
WR k = -0.00001
WR k = -0.001
UM k = -0.00001
UM k = -0.001
TP Load -15 yrs
TP Load +25 yrs



Appendix D6-8
Alternative 5a - Iron
Long-term Post-remediation Sensitivity Analysis
Draft Final FS Report February 2004

Long-term Post-remediation Sensitivity Analysis
Dissolved Zinc Concentrations in Railroad Creek Downstream of RC-2, Spring
Alternative 5a




Long-term Post-remediation Sensitivity Analysis
Dissolved Cadmium Concentrations in Railroad Creek Downstream of RC-2, Spring
Alternative 5b
Dissolved Cadmium (mg/L)
0.00030
0.00025
0.00020
0.00015
0.00010
0.00005
0.00000
2000
2100
2200
2300
2400
2500
2600
2700
2800
2900
3000
Year
SWQC
NRWQC
Expected LT Value
Lower Bound 90% CI (CV=0.16)
Upper Bound 90% CI (CV=0.16)
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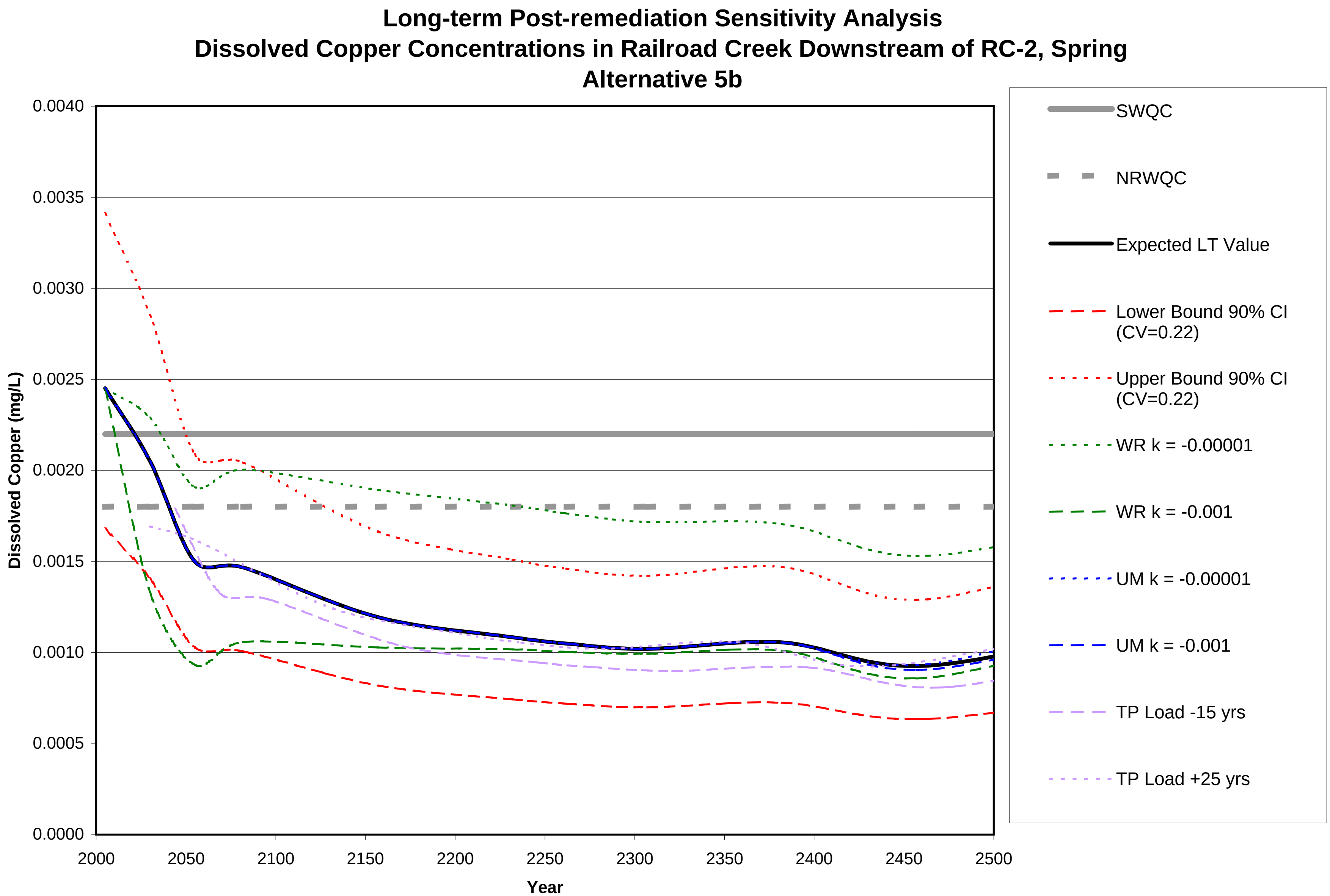
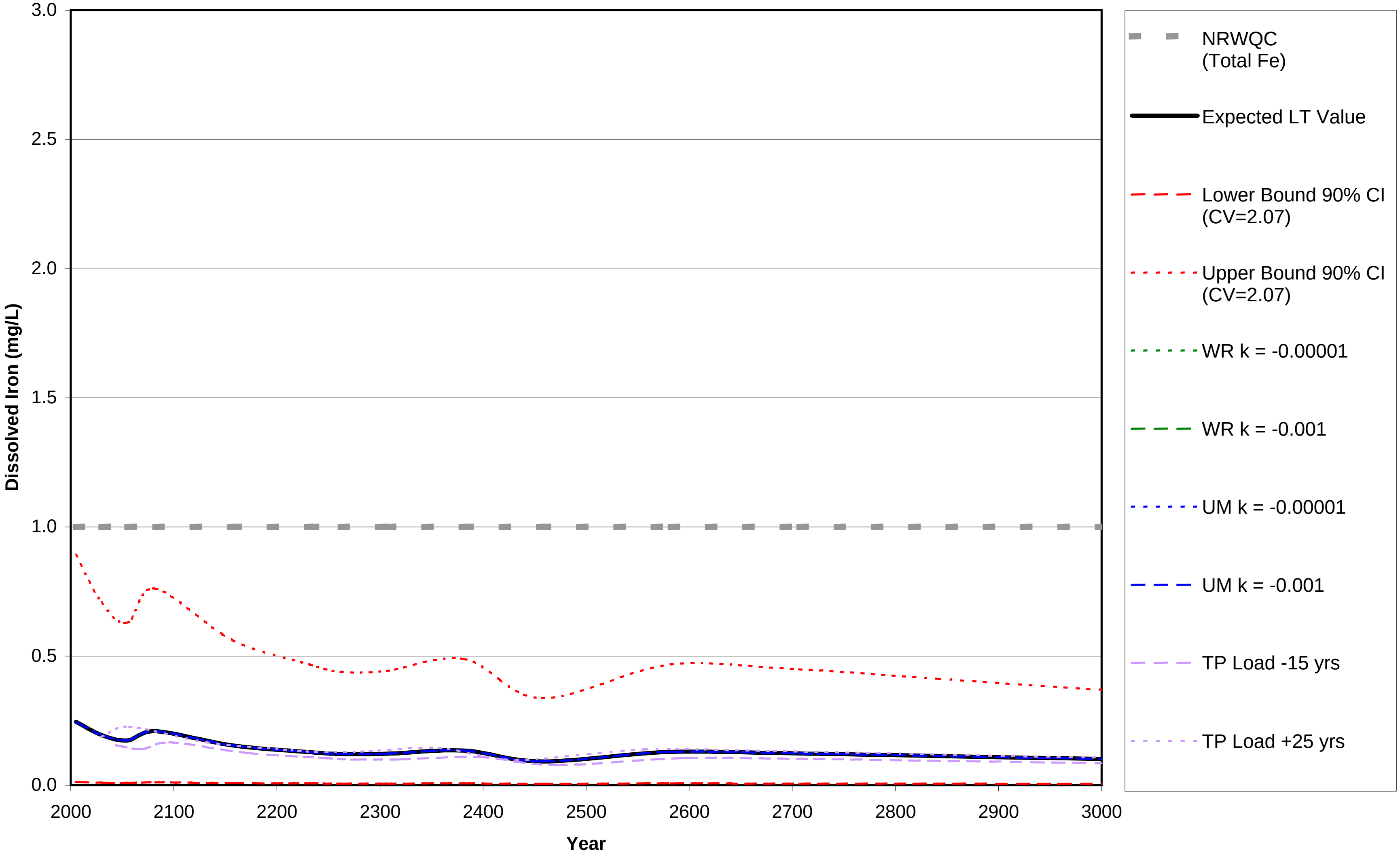
WR k = -0.001
UM k = -0.00001
UM k = -0.001
TP Load -15 yrs
TP Load +25 yrs



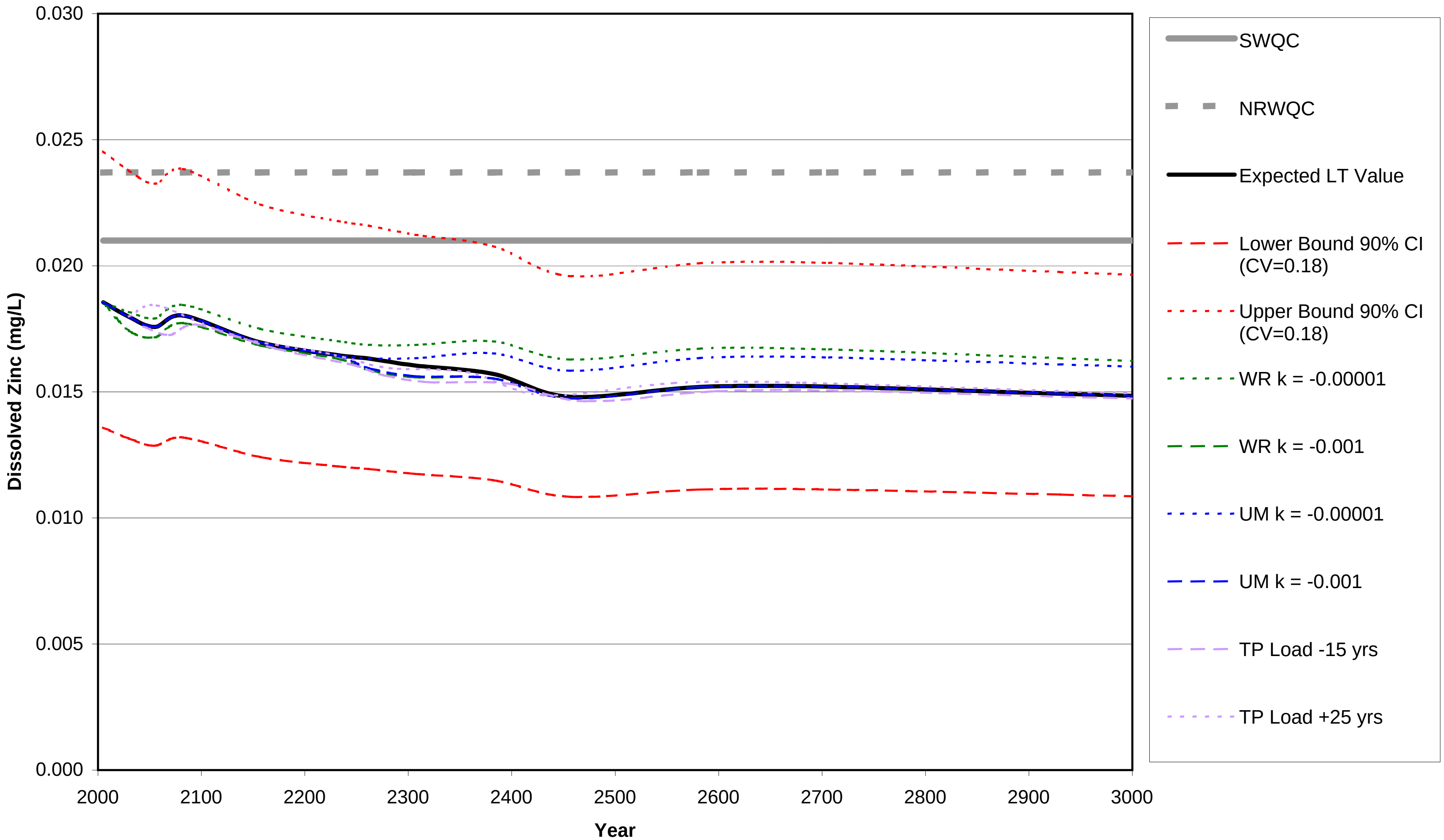
Appendix D6-9
Alternative 5b - Copper
Long-term Post-remediation Sensitivity Analysis
Draft Final FS Report February 2004

Long-term Post-remediation Sensitivity Analysis
Dissolved Iron Concentrations in Railroad Creek Downstream of RC-2, Fall
Alternative 5b

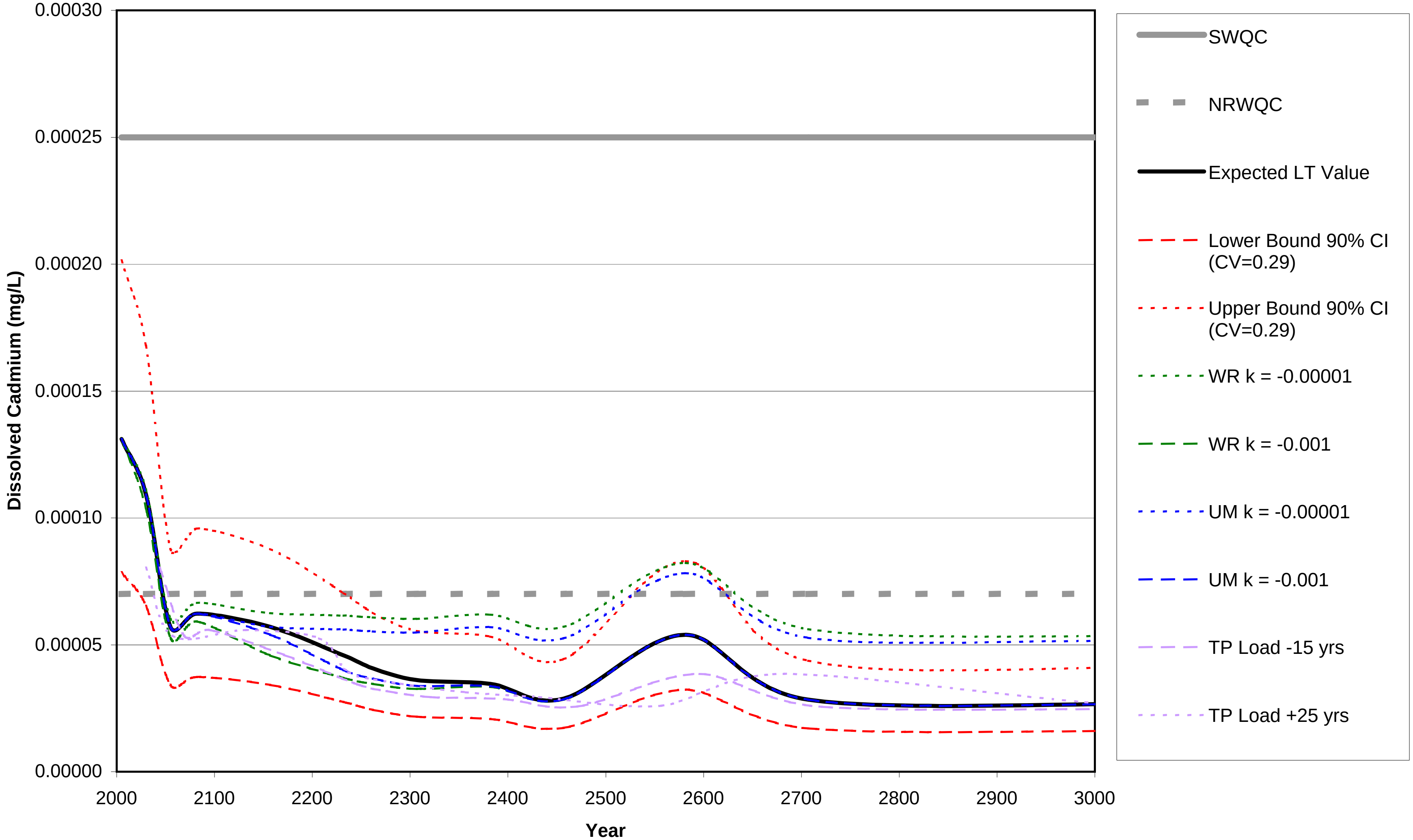


Appendix D6-9
Alternative 5b - Iron
Long-term Post-remediation Sensitivity Analysis
Draft Final FS Report February 2004

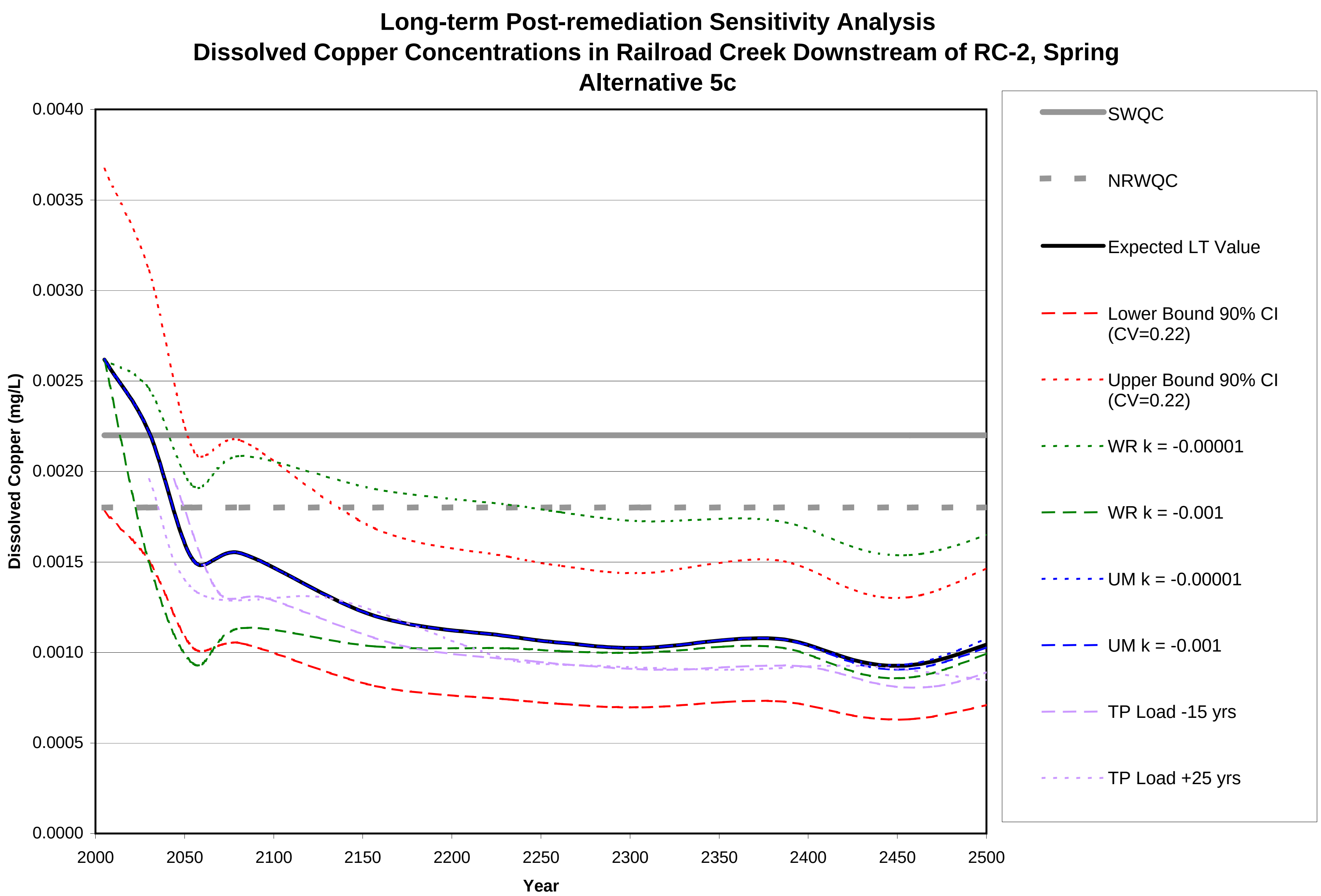
Long-term Post-remediation Sensitivity Analysis
Dissolved Zinc Concentrations in Railroad Creek Downstream of RC-2, Spring
Alternative 5b



Long-term Post-remediation Sensitivity Analysis
Dissolved Cadmium Concentrations in Railroad Creek Downstream of RC-2, Spring
Alternative 5c

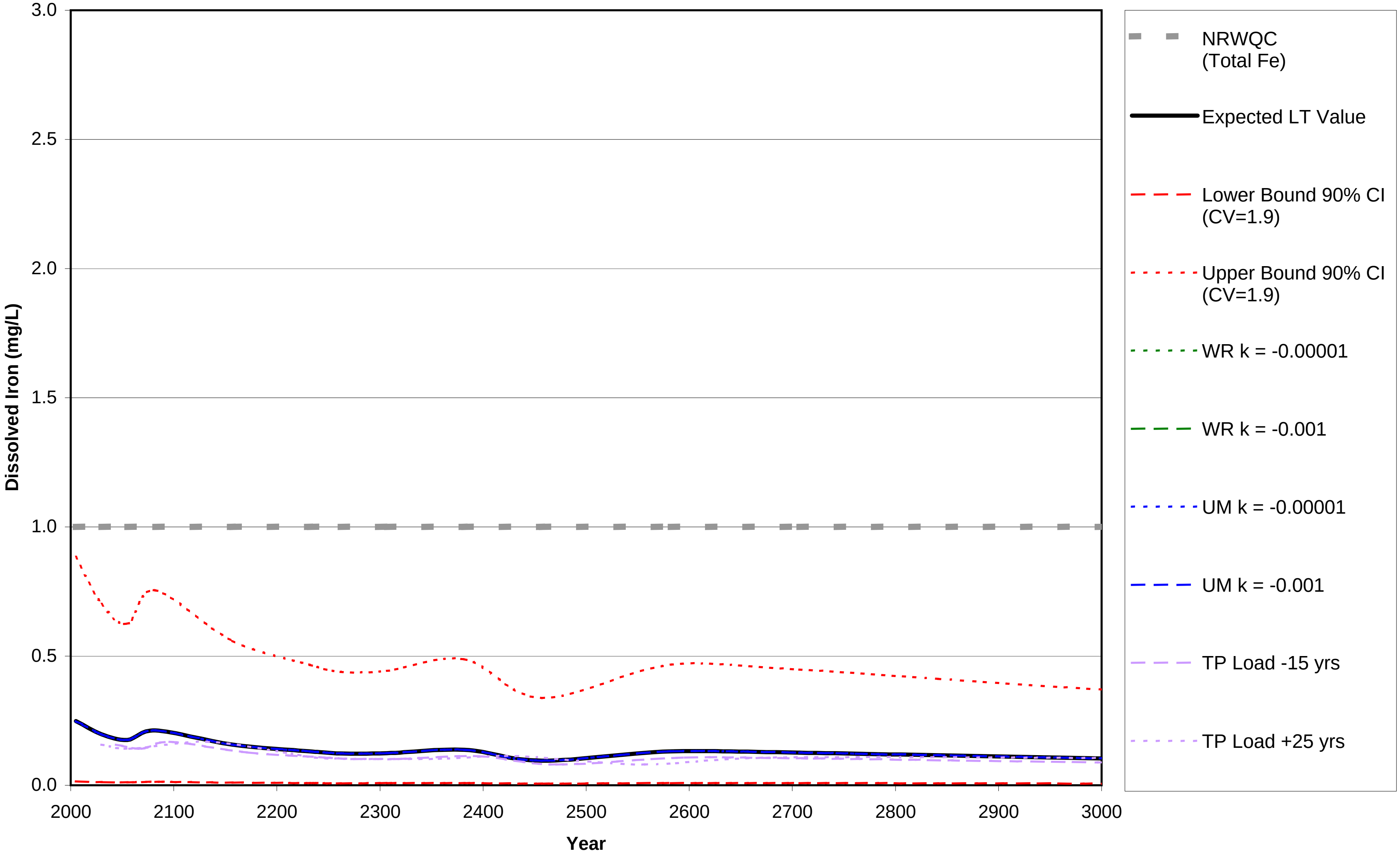


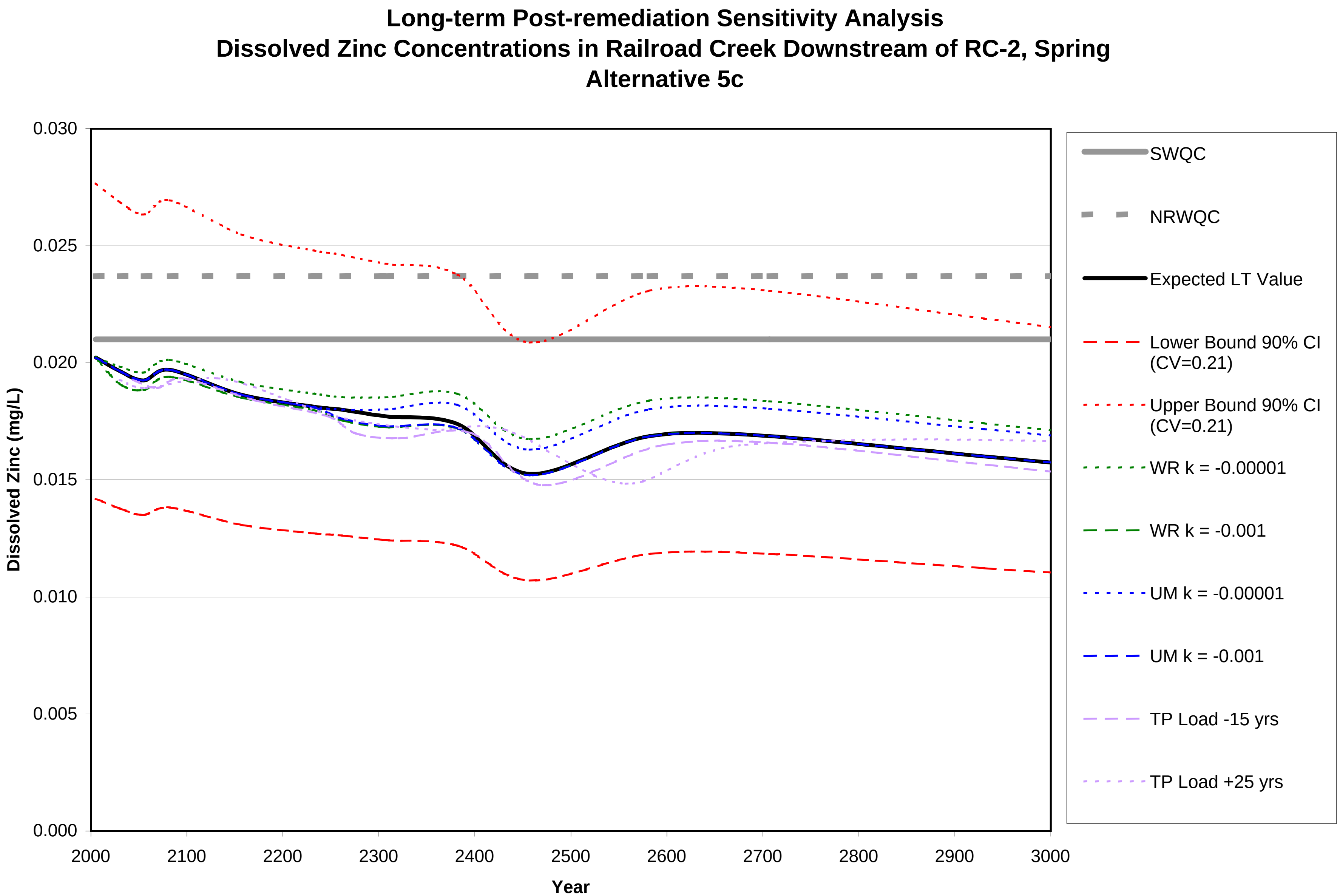
Appendix D6-10
Alternative 5c - Cadmium
Long-term Post-remediation Sensitivity Analysis
Draft Final FS Report February 2004



Appendix D6-10
Alternative 5c - Copper
Long-term Post-remediation Sensitivity Analysis
Draft Final FS Report February 2004

Long-term Post-remediation Sensitivity Analysis
Dissolved Iron Concentrations in Railroad Creek Downstream of RC-2, Fall
Alternative 5c





Long-term Post-remediation Sensitivity Analysis
Dissolved Zinc Concentrations in Railroad Creek Downstream of RC-2, Spring
Alternative 5c
Dissolved Zinc (mg/L)
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0.025
0.020
0.015
0.010
0.005
0.000
2000
2100
2200
2300
2400
2500
2600
2700
2800
2900
3000
Year
SWQC
NRWQC
Expected LT Value
Lower Bound 90% CI (CV=0.21)
Upper Bound 90% CI (CV=0.21)
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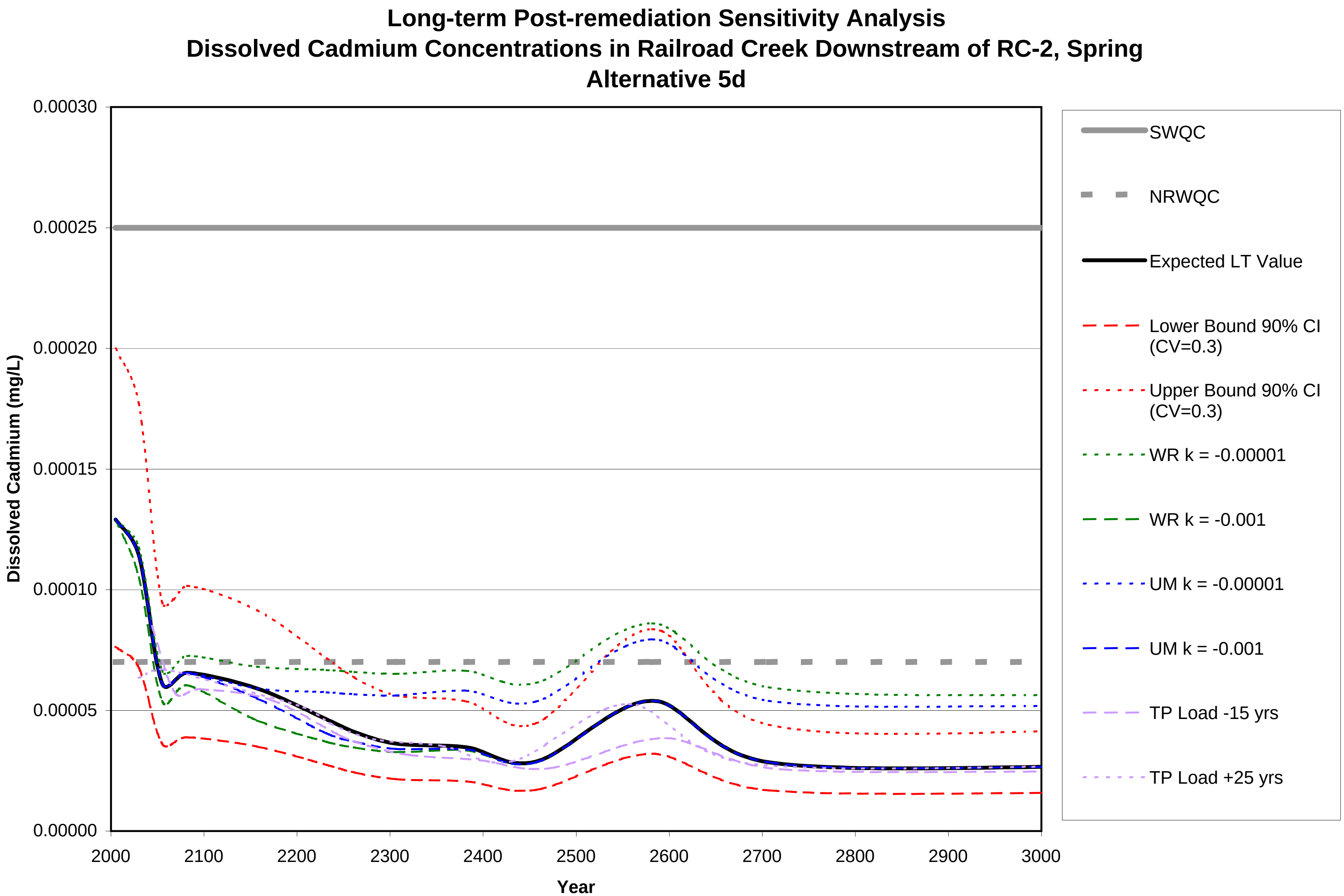
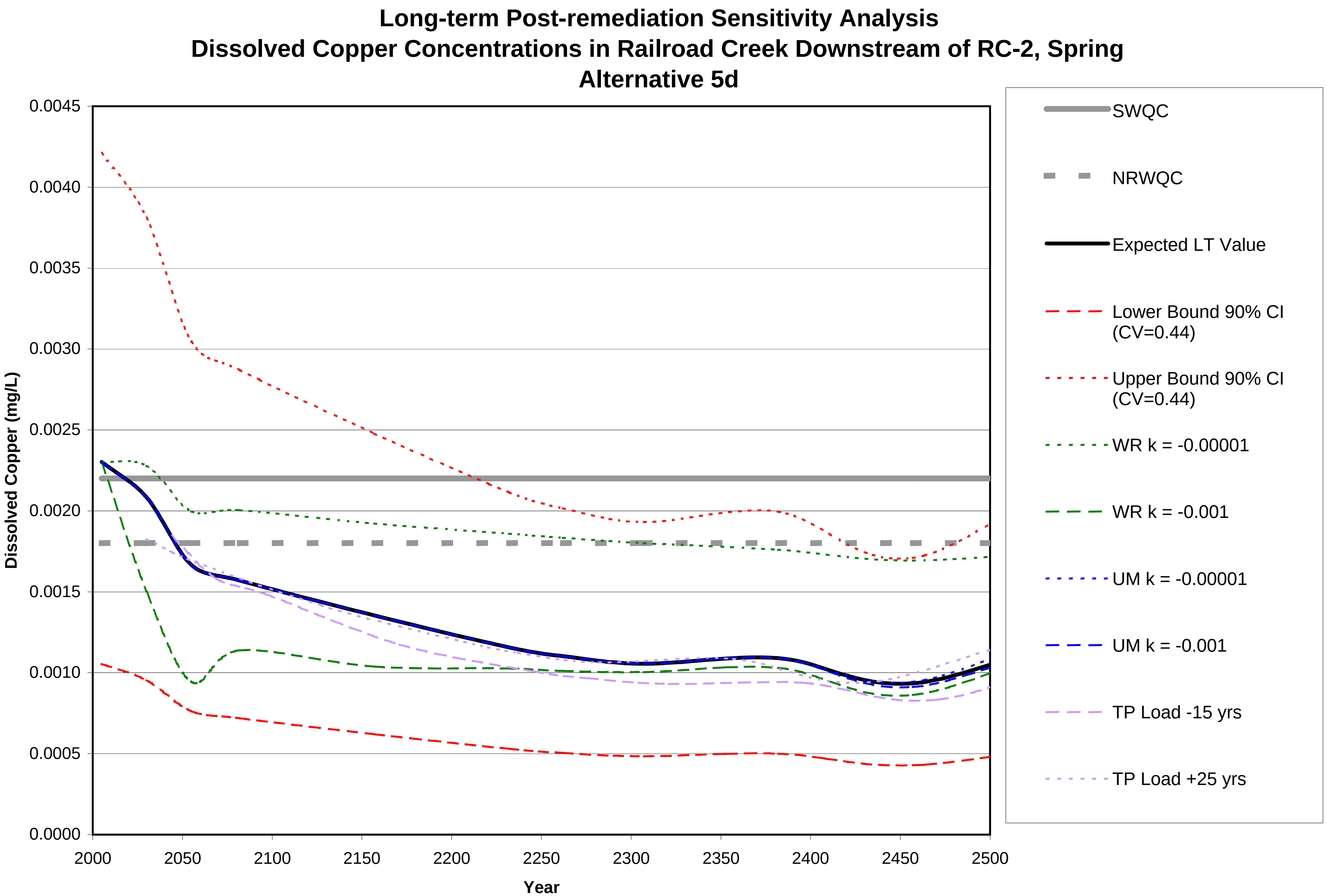
WR k = -0.001
UM k = -0.00001
UM k = -0.001
TP Load -15 yrs
TP Load +25 yrs



Appendix D6-10a
Alternative 5d - Cadmium
Long-term Post-remediation Sensitivity Analysis
Draft Final FS Report February 2004



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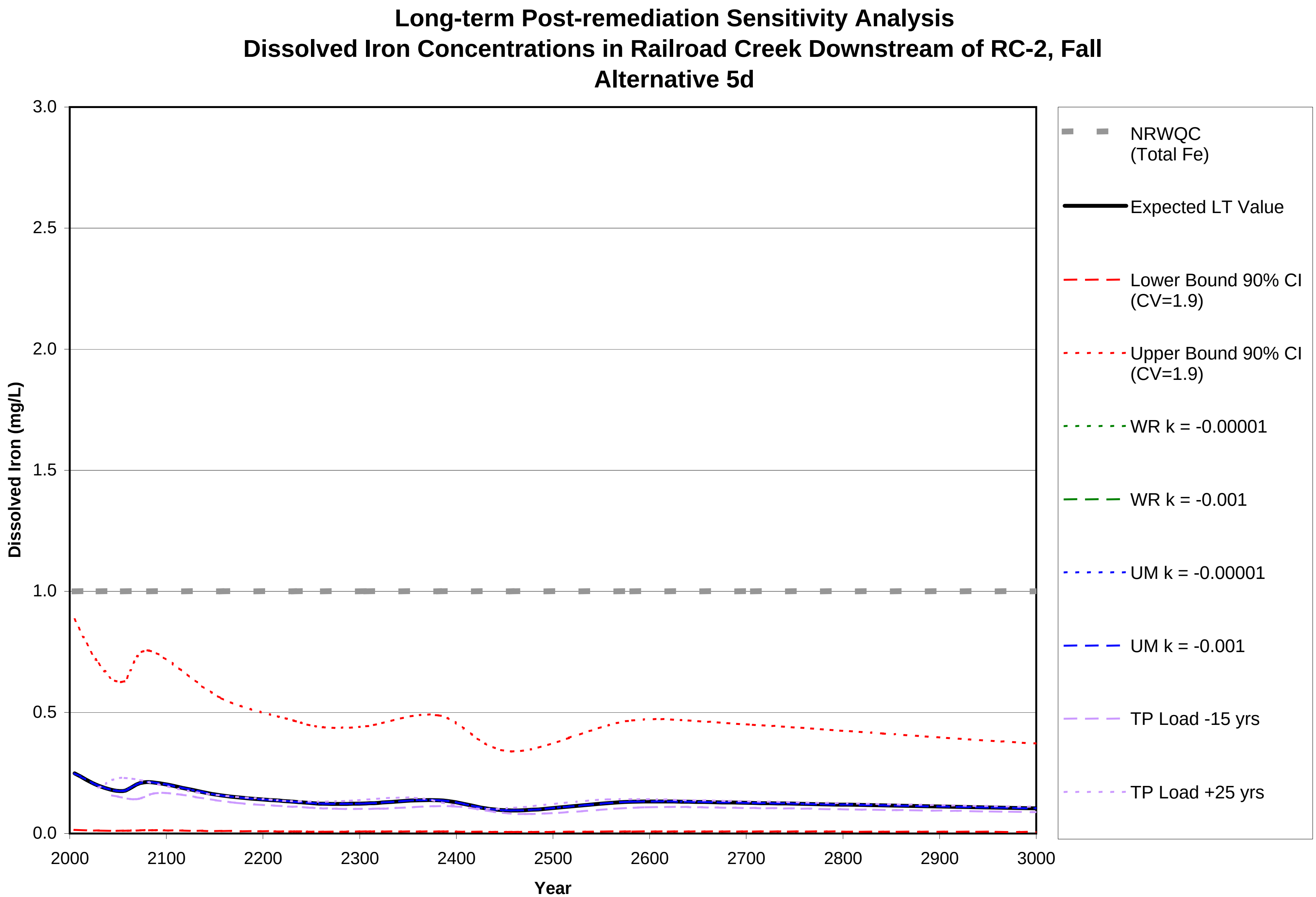
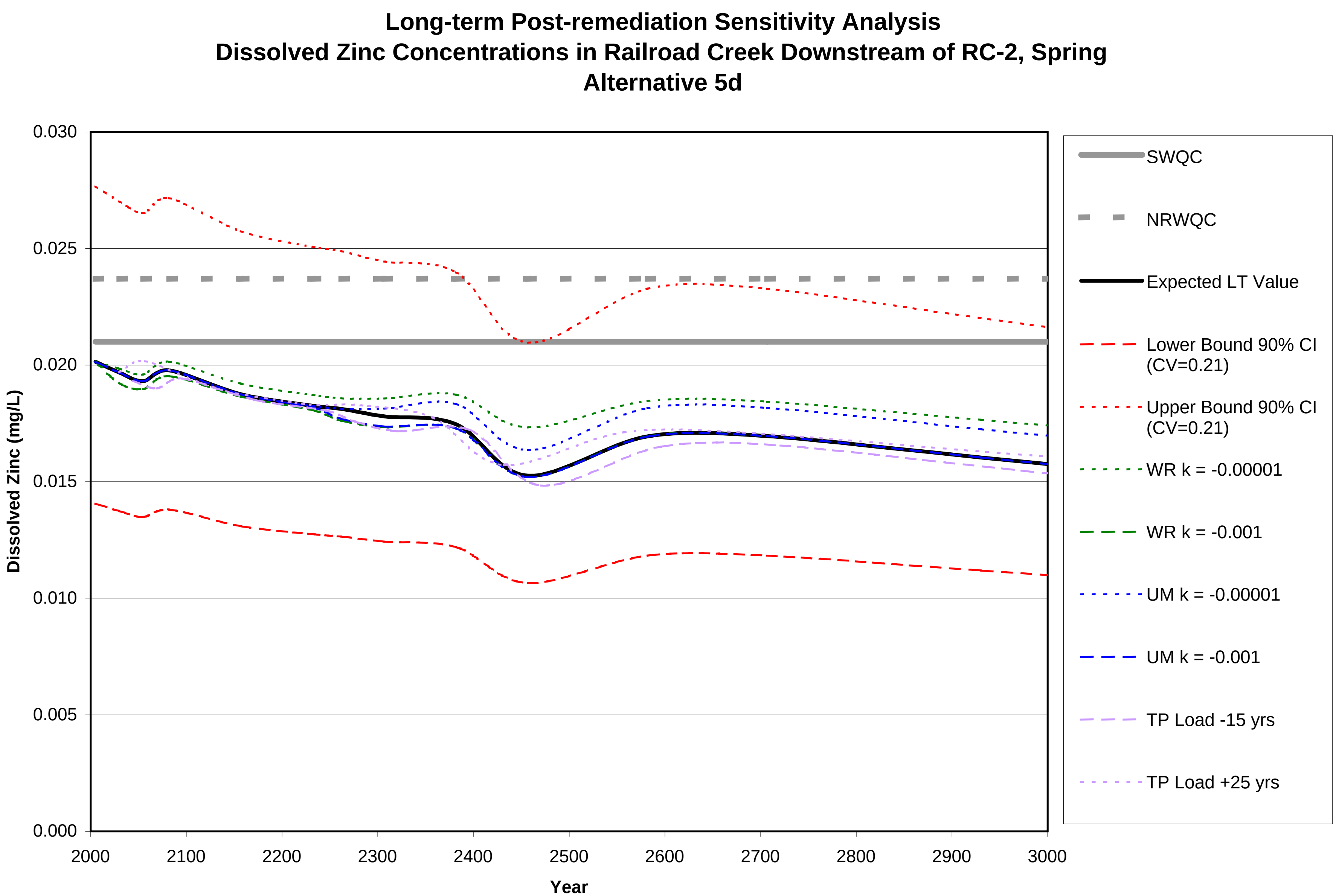
Alternative 5d - Copper
Long-term Post-remediation Sensitivity Analysis

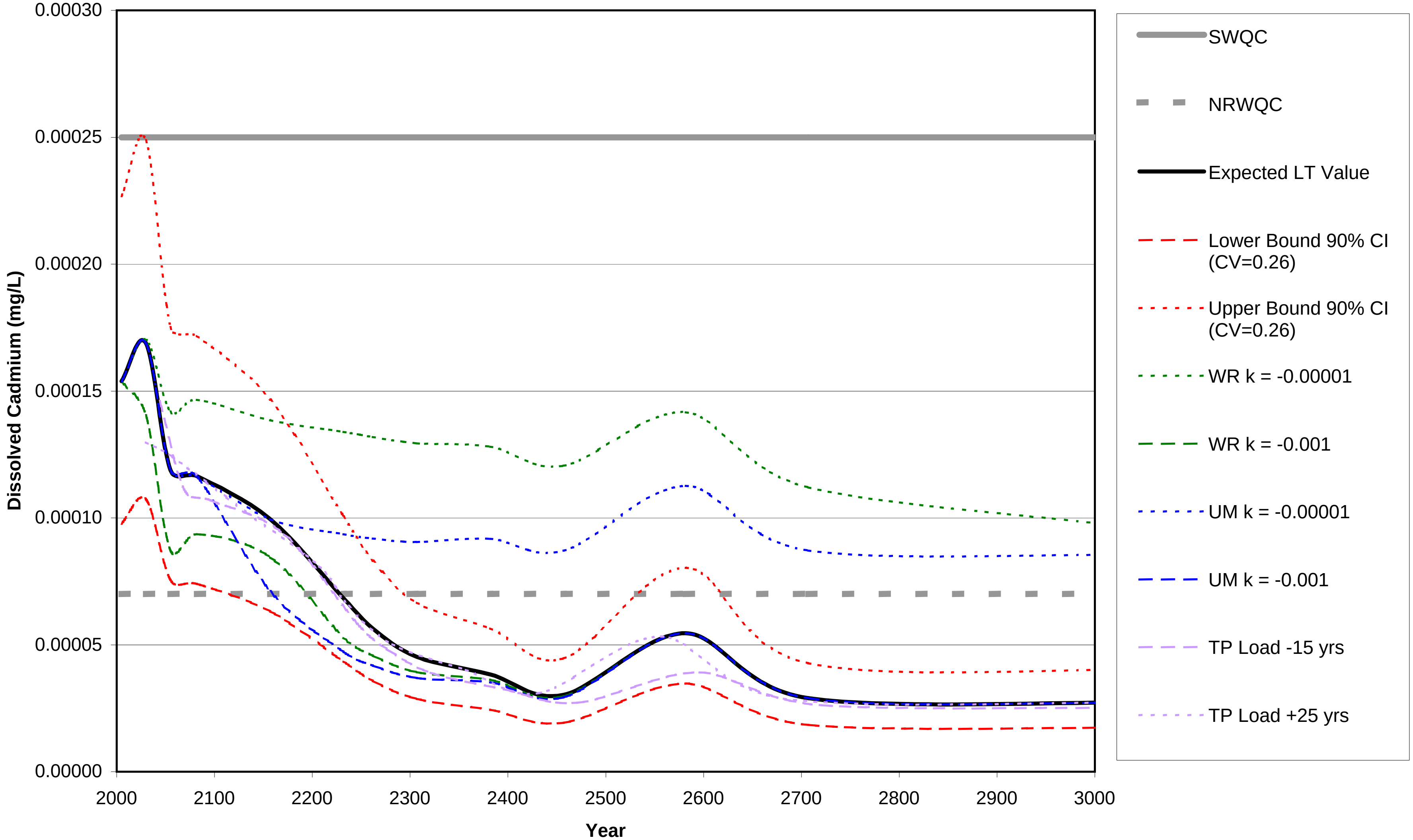


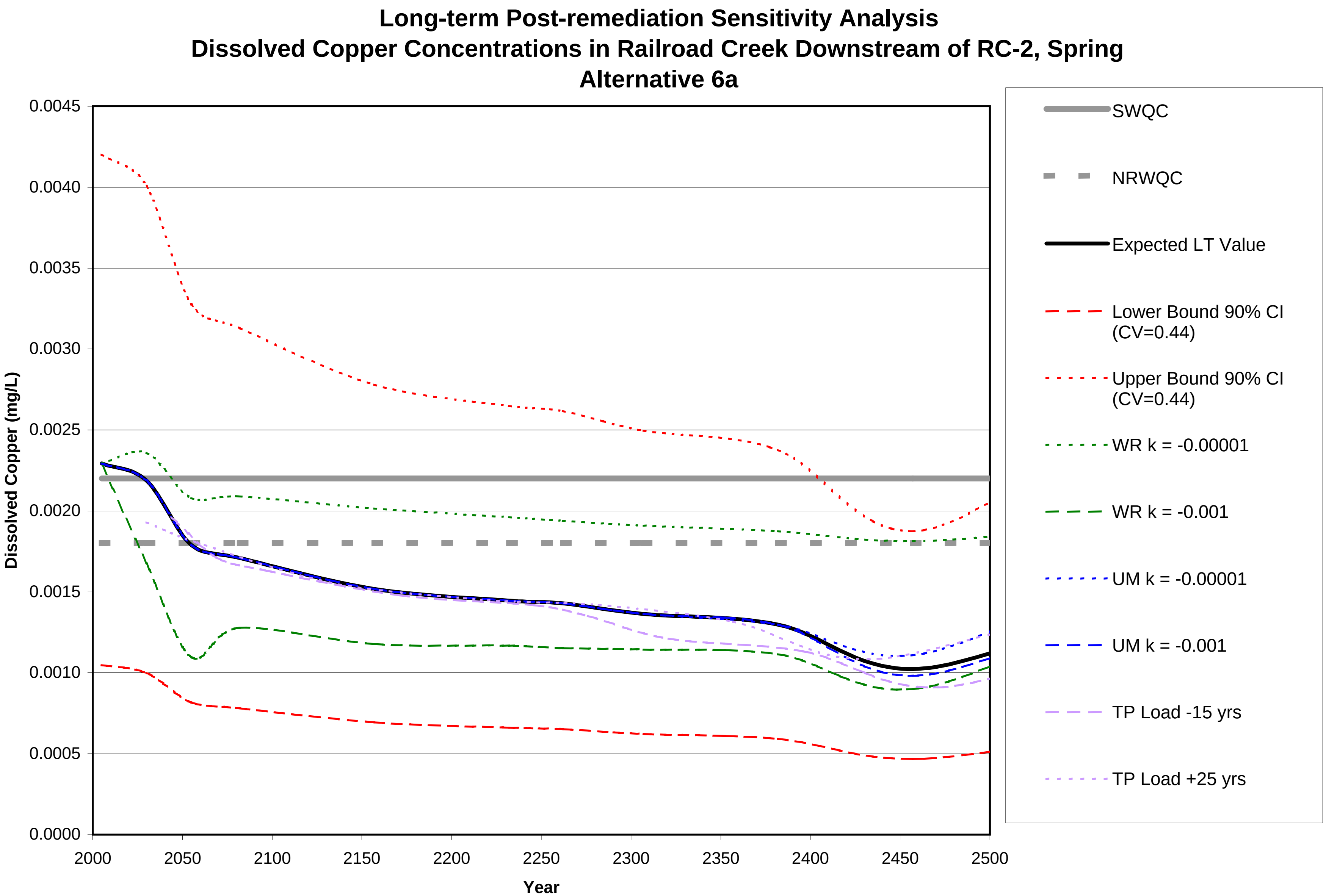
Appendix D6-10a
Alternative 5d - Iron
Long-term Post-remediation Sensitivity Analysis
Draft Final FS Report February 2004



Appendix D6-10a
Alternative 5d - Zinc
Long-term Post-remediation Sensitivity Analysis
Draft Final FS Report February 2004

Long-term Post-remediation Sensitivity Analysis
Dissolved Cadmium Concentrations in Railroad Creek Downstream of RC-2, Spring
Alternative 6a





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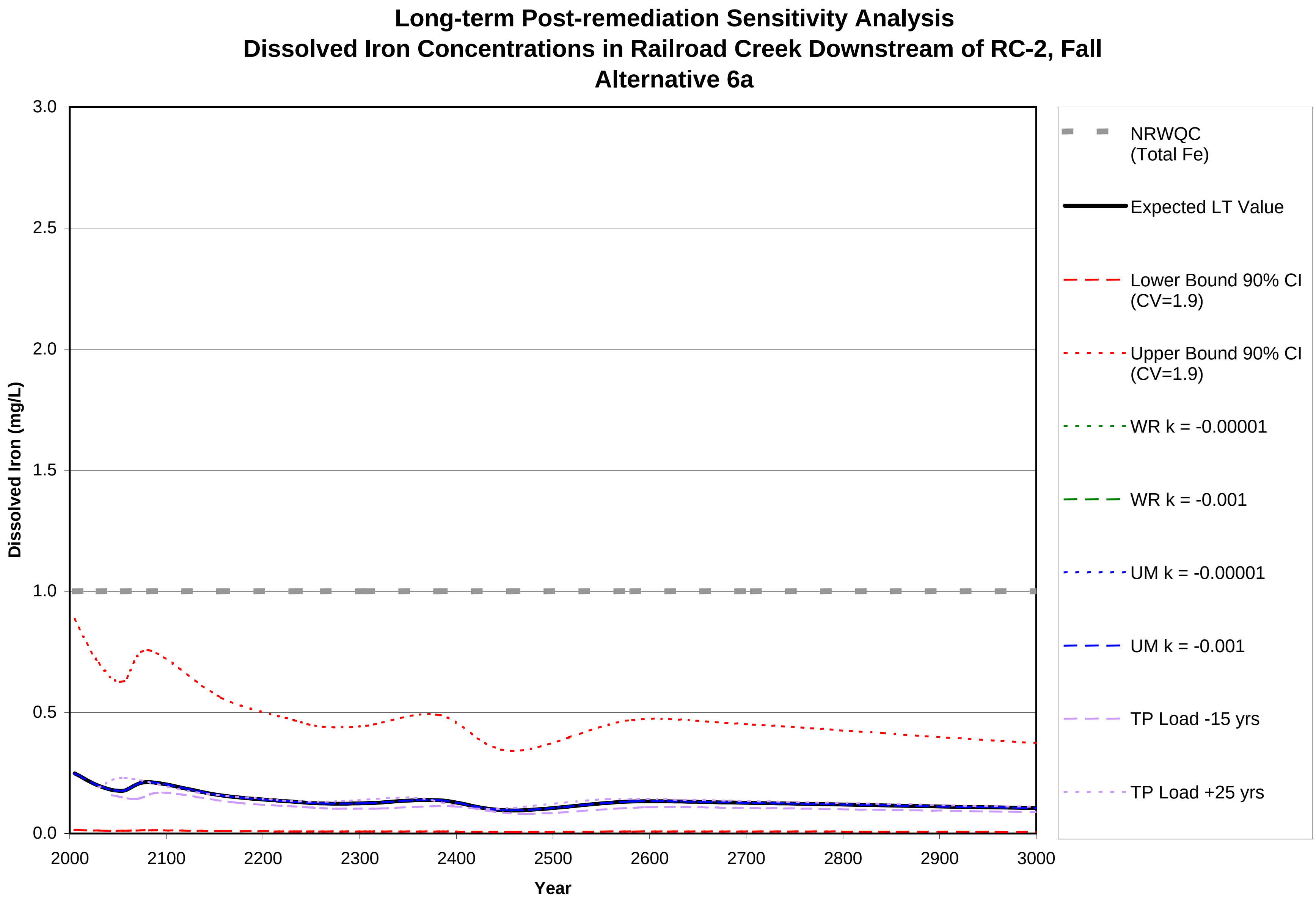
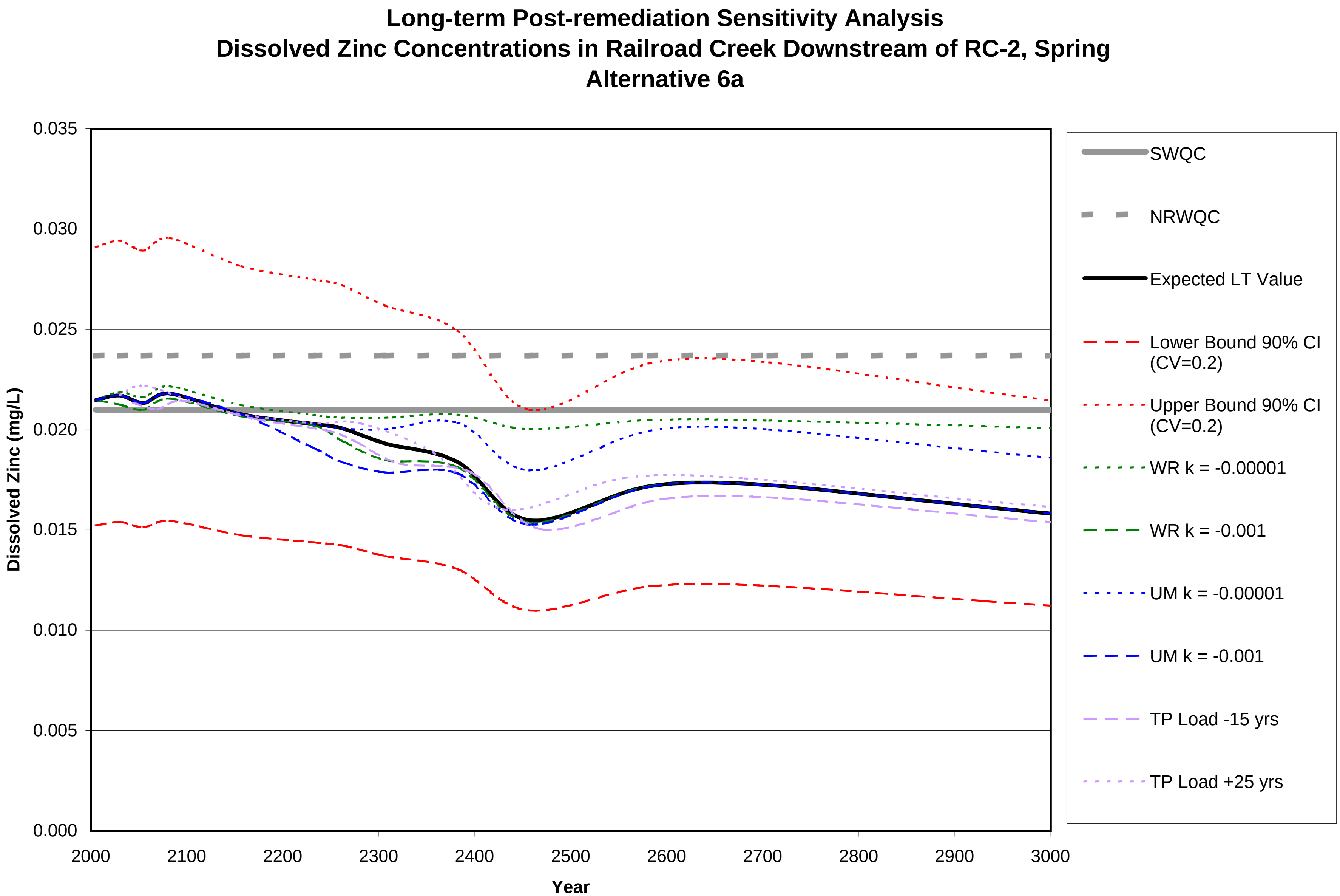
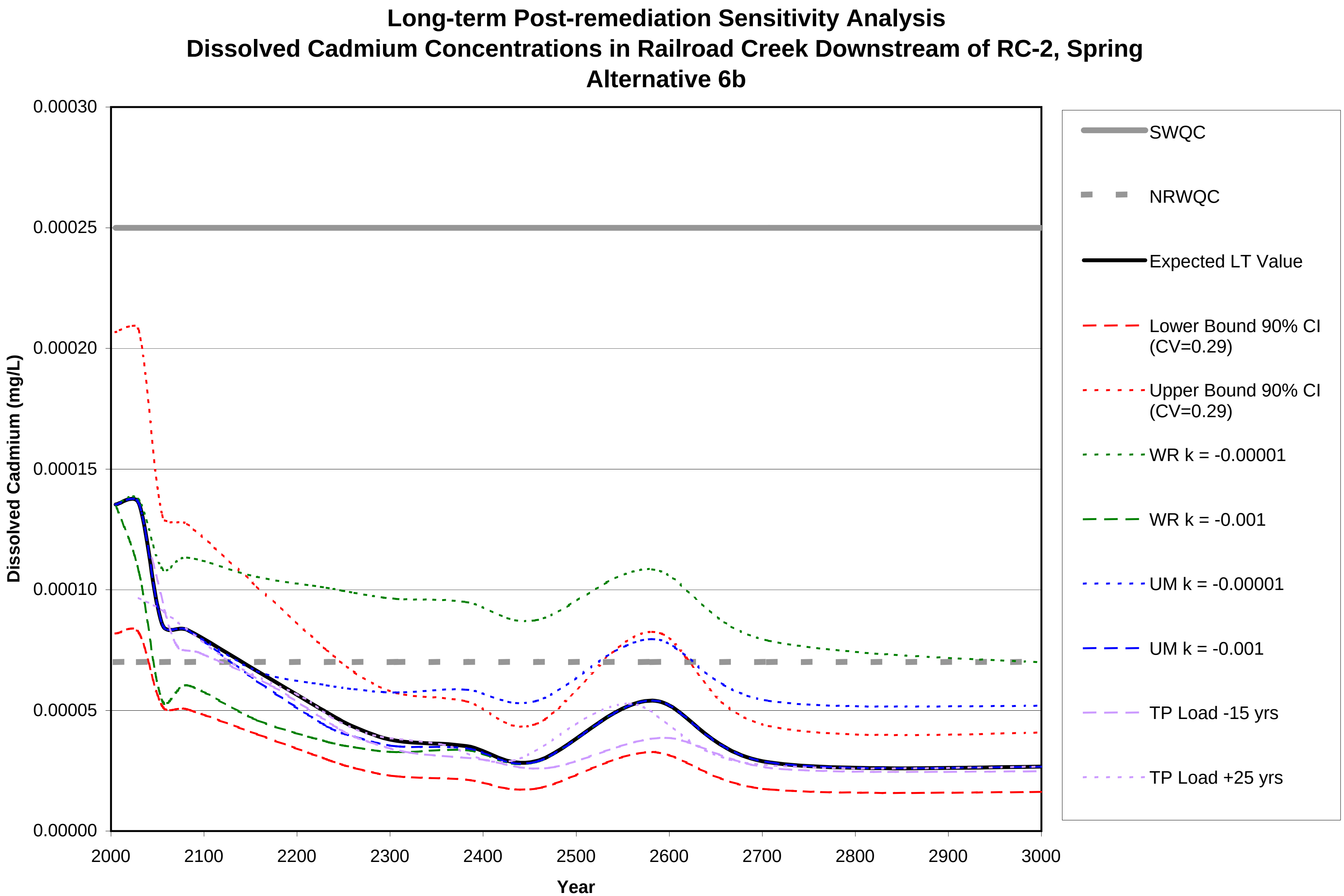
Alternative 6a - Copper
Long-term Post-remediation Sensitivity Analysis
Draft Final FS Report February 2004



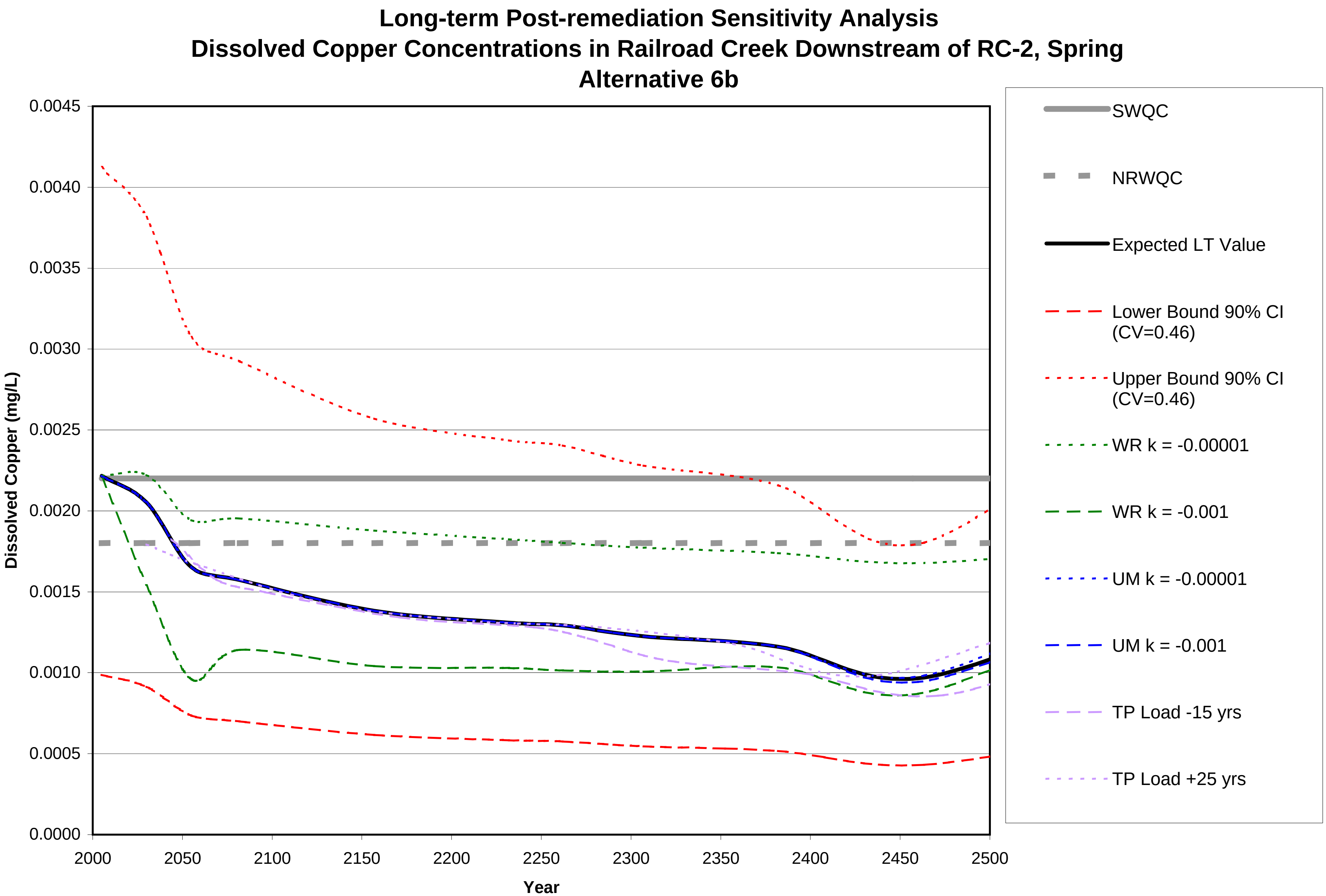
Appendix D6-11
Alternative 6a - Iron
<u>Long-term Post-remediation Sensitivity Analysis</u>
Draft Final FS Report February 2004



Appendix D6-11
Alternative 6a - Zinc
<u>Long-term Post-remediation Sensitivity Analysis</u>

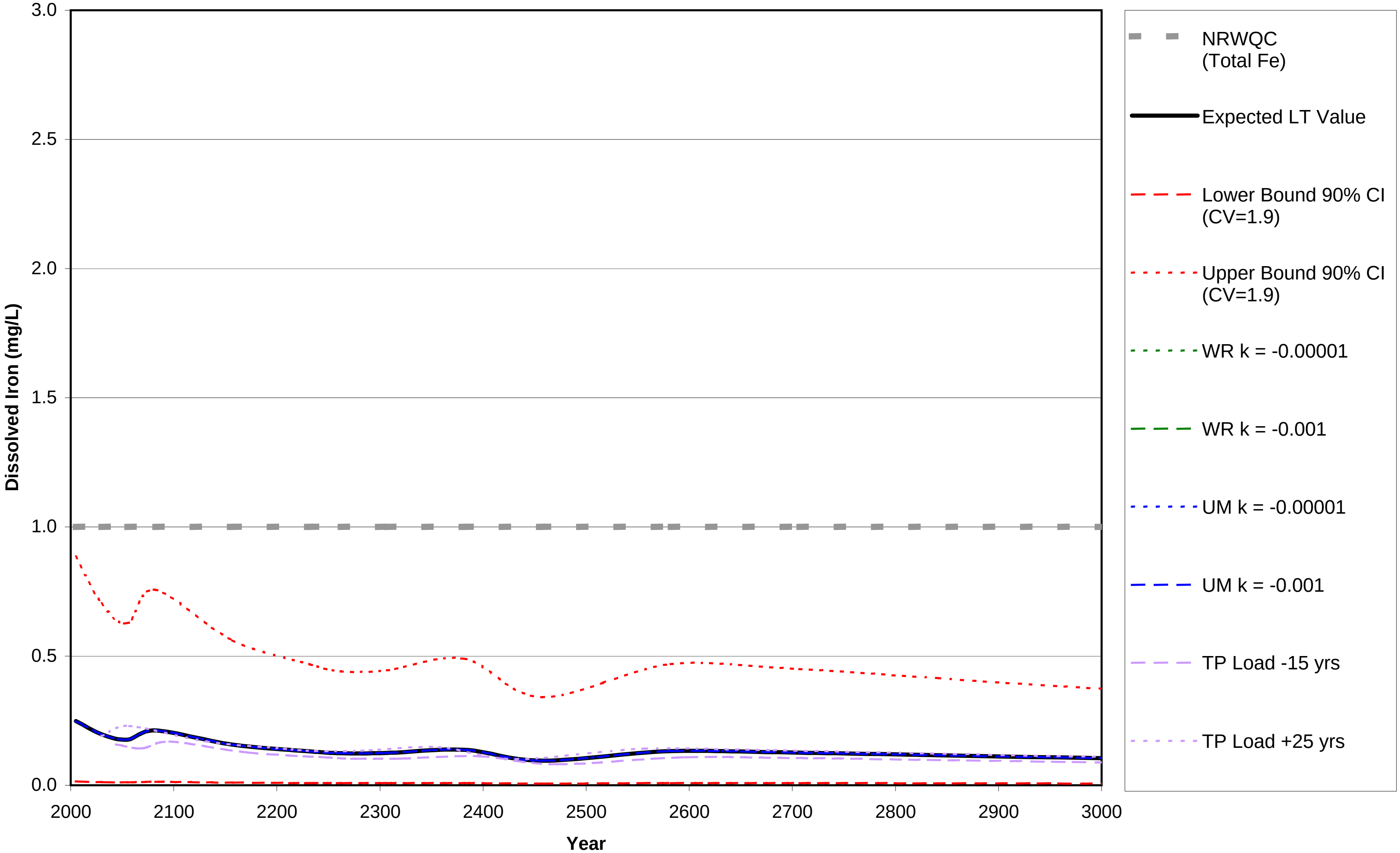


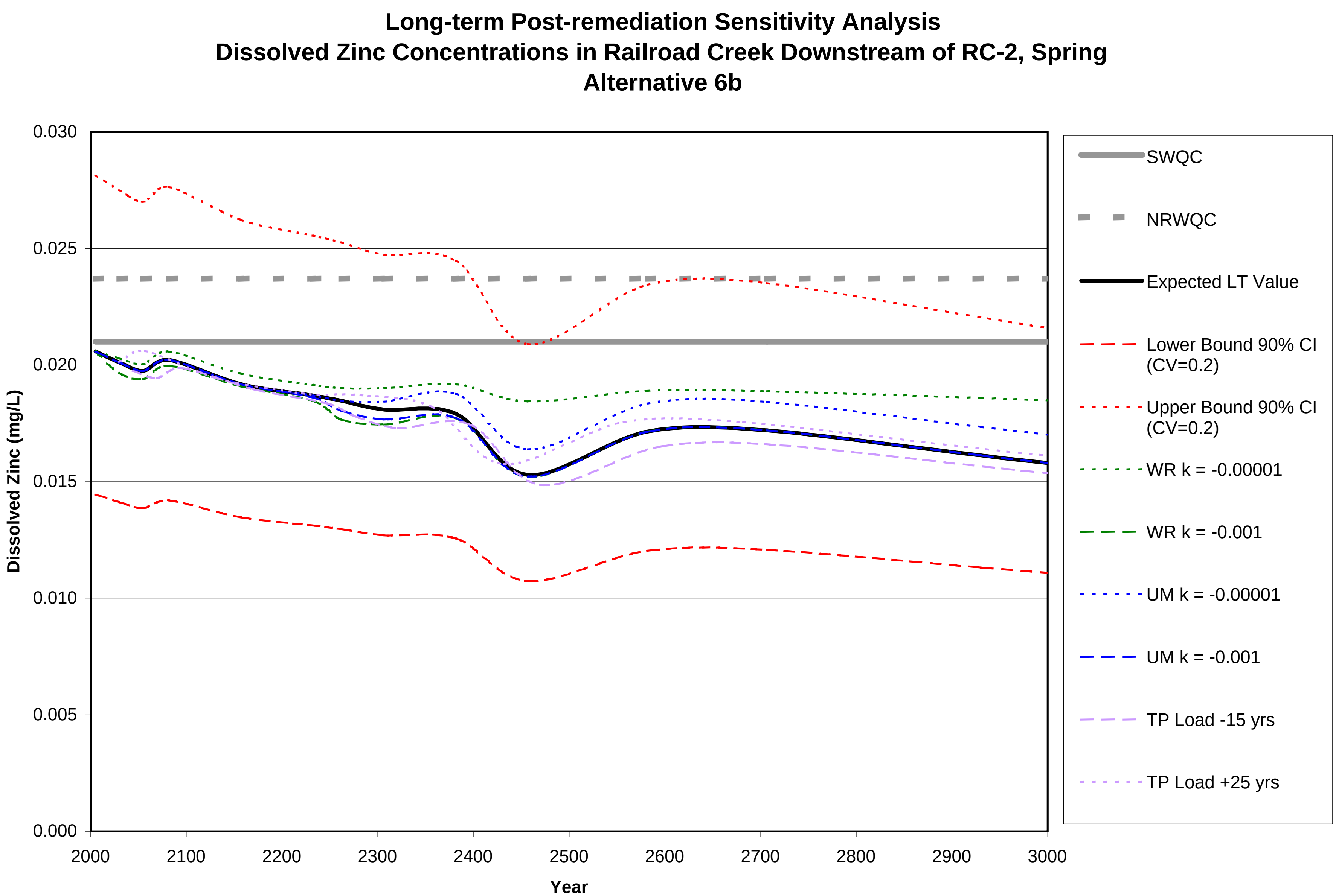
Appendix D6-12
Alternative 6b - Cadmium
Long-term Post-remediation Sensitivity Analysis
Draft Final FS Report February 2004



Appendix D6-12
Alternative 6b - Copper
Long-term Post-remediation Sensitivity Analysis
Draft Final FS Report February 2004

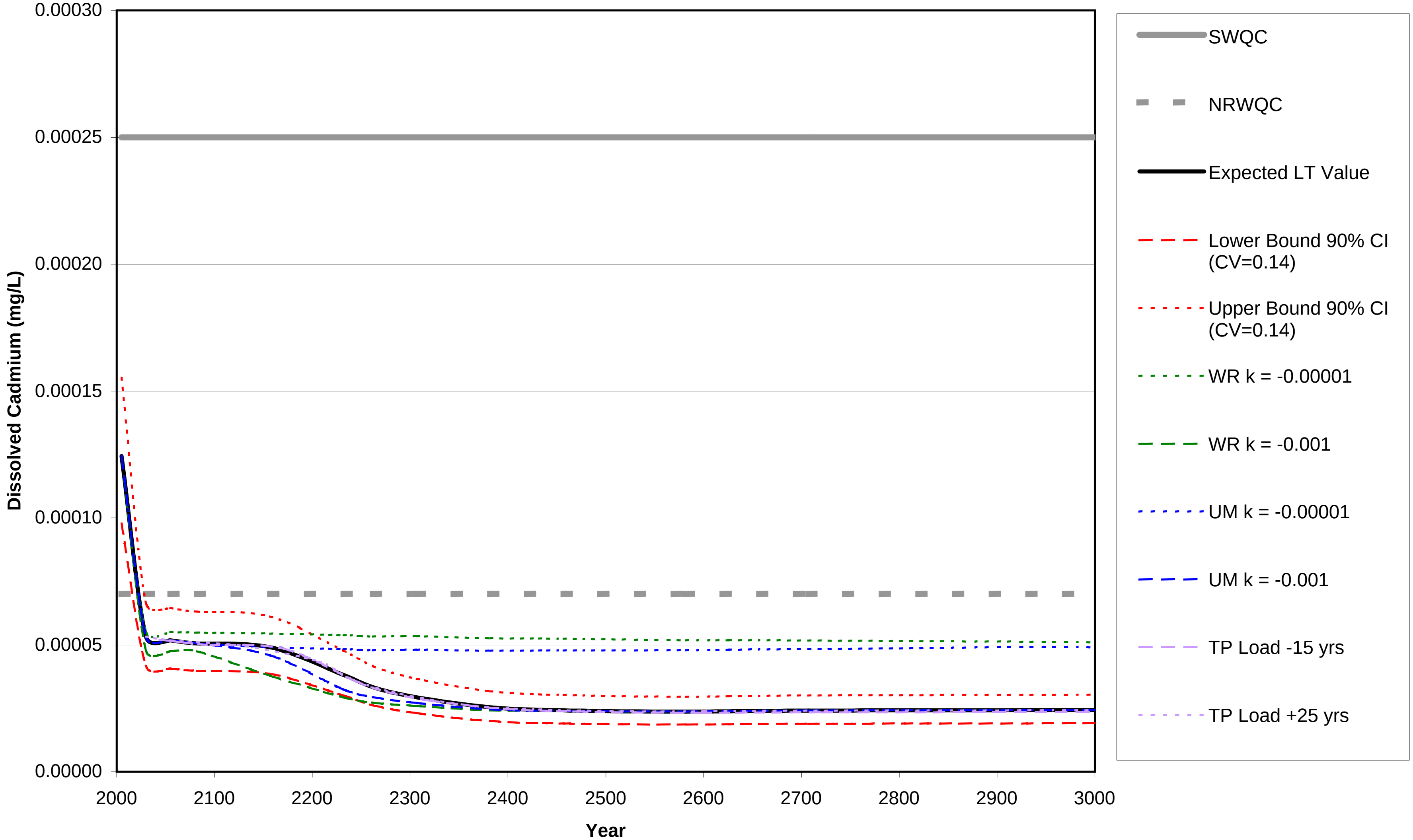
Long-term Post-remediation Sensitivity Analysis
Dissolved Iron Concentrations in Railroad Creek Downstream of RC-2, Fall
Alternative 6b



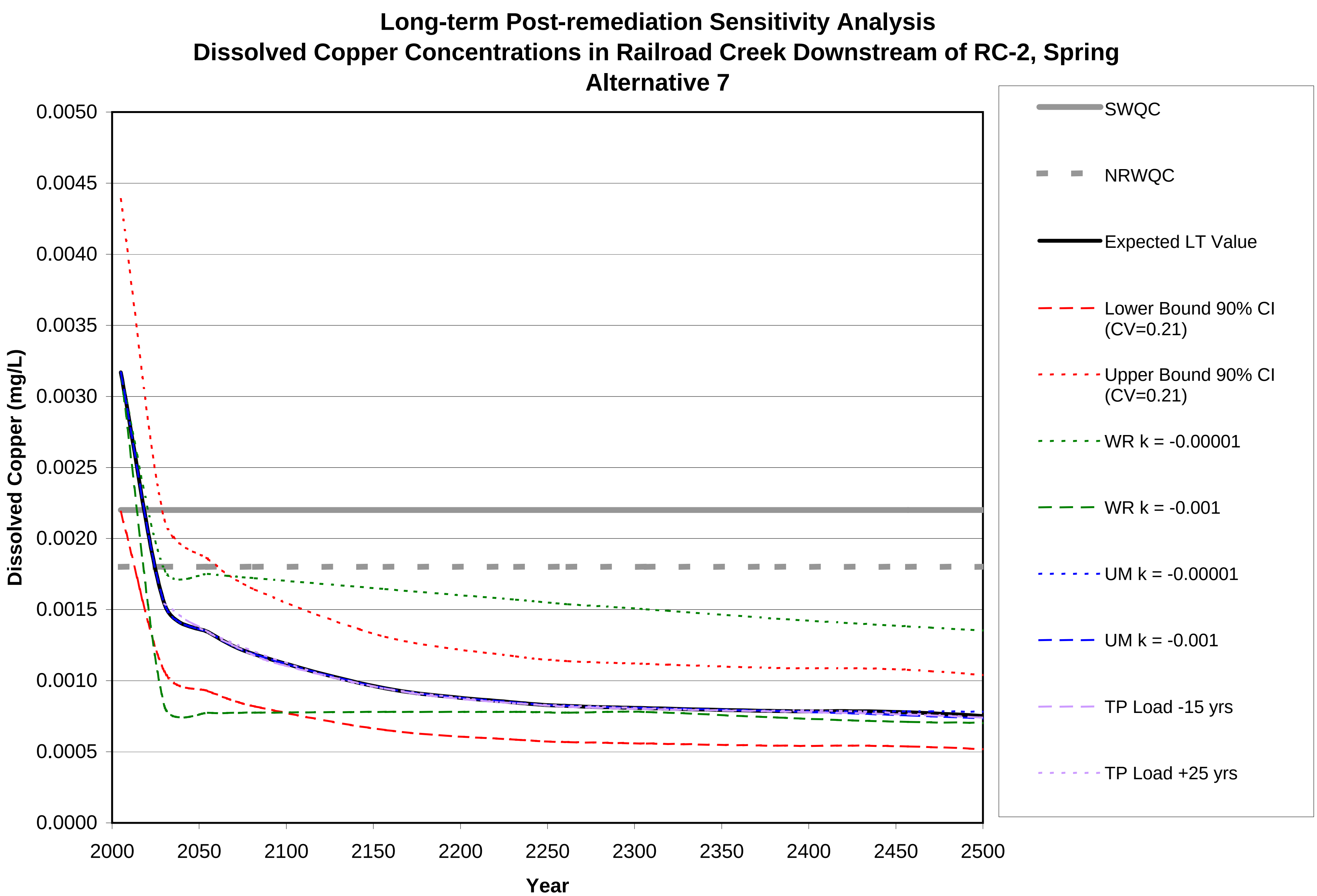


Appendix D6-12
Alternative 6b - Zinc
Long-term Post-remediation Sensitivity Analysis
Draft Final FS Report February 2004

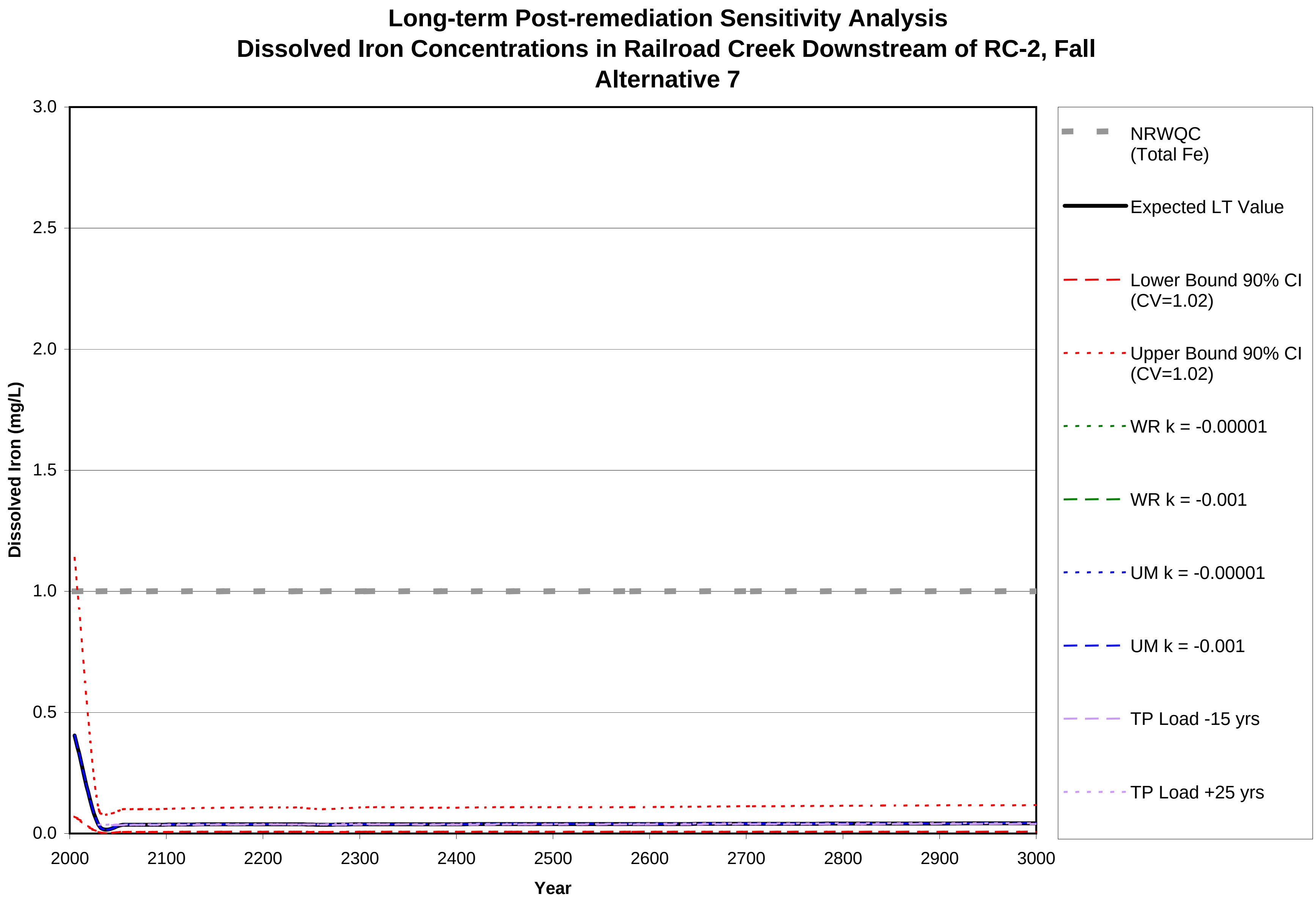
Long-term Post-remediation Sensitivity Analysis
Dissolved Cadmium Concentrations in Railroad Creek Downstream of RC-2, Spring
Alternative 7



Appendix D6-13
Alternative 7 - Cadmium
Long-term Post-remediation Sensitivity Analysis
Draft Final FS Report February 2004

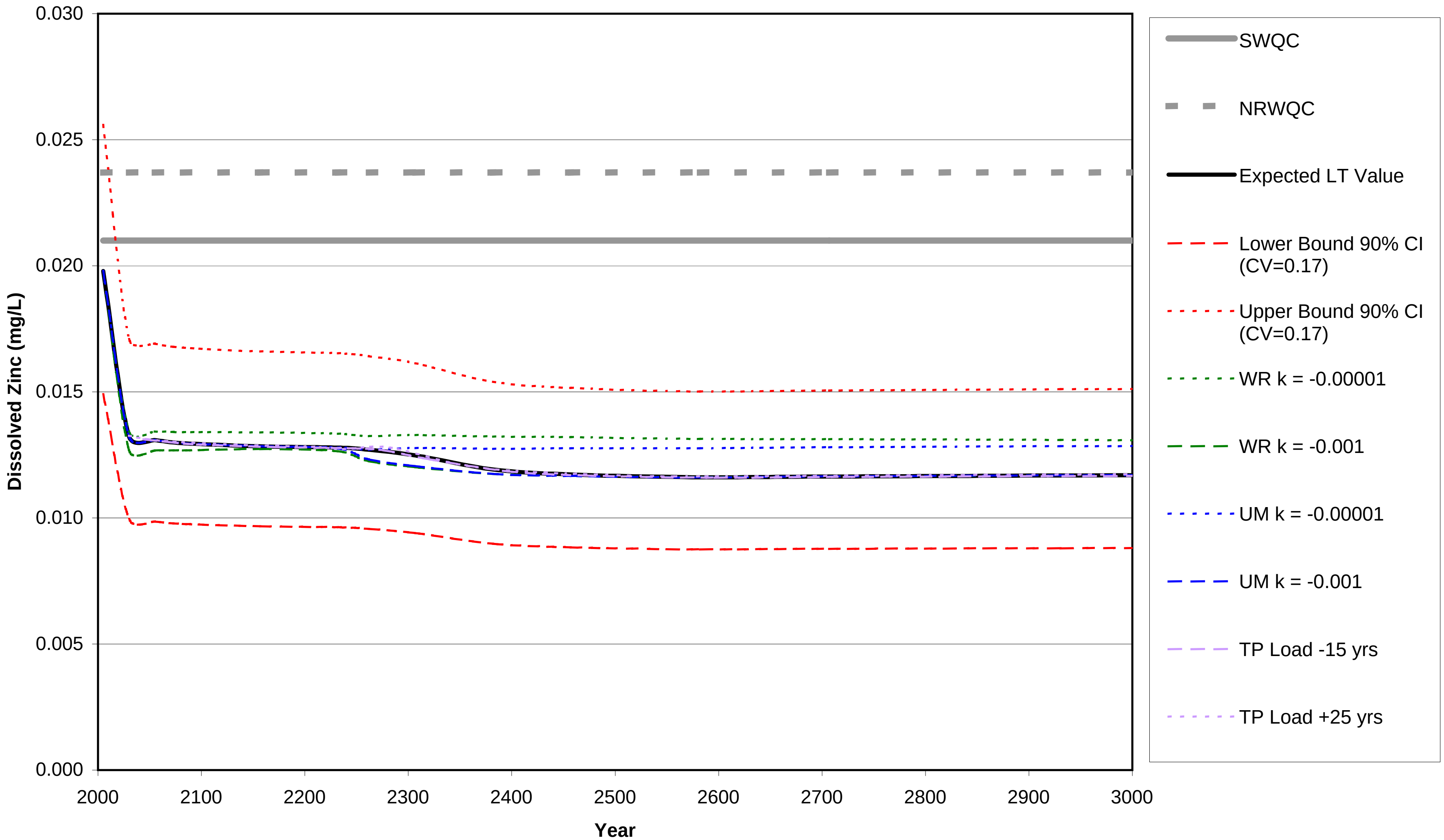


Appendix D6-13
Alternative 7 - Copper
Long-term Post-remediation Sensitivity Analysis
Draft Final FS Report February 2004

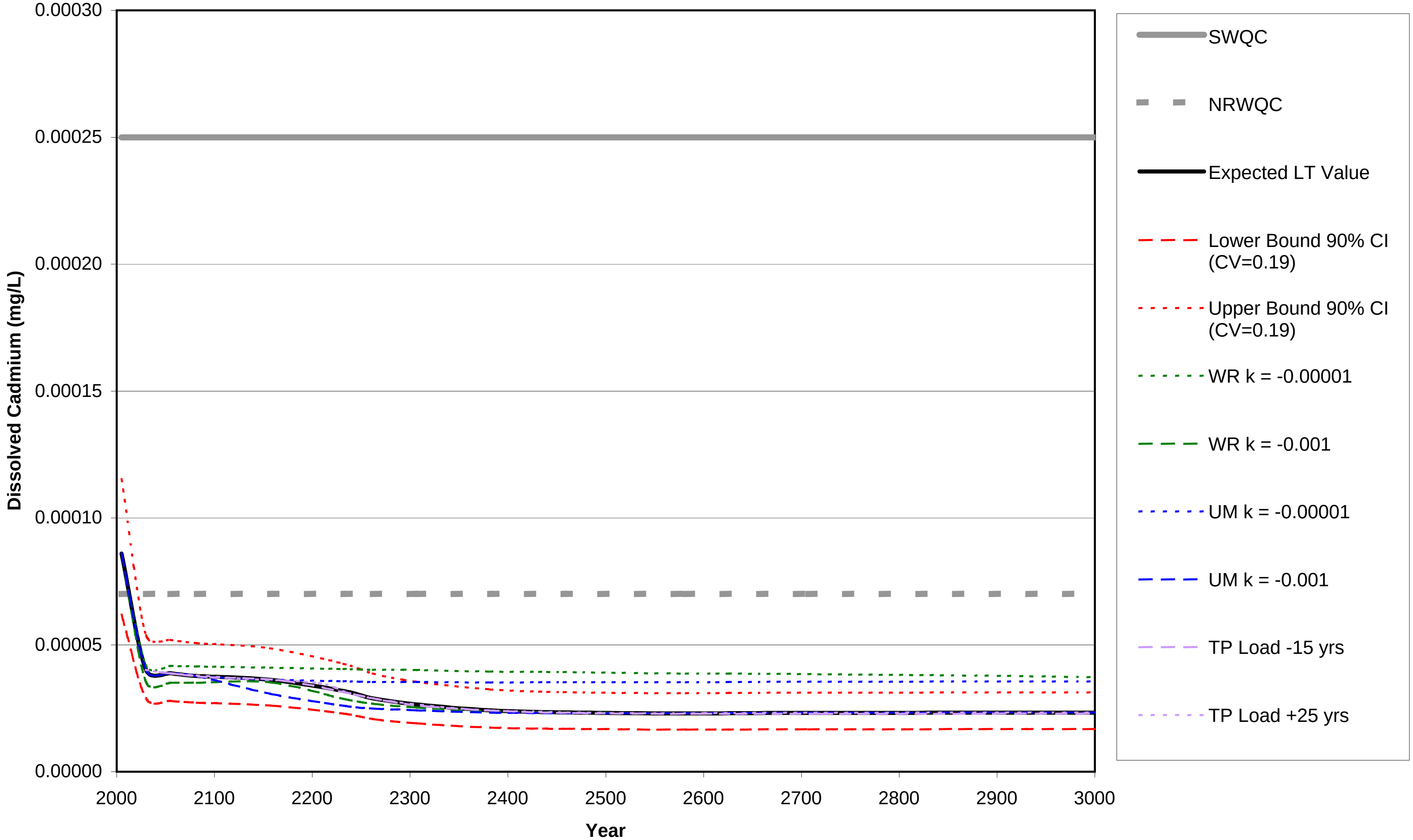


Appendix D6-13
Alternative 7 - Iron
Long-term Post-remediation Sensitivity Analysis
Draft Final FS Report February 2004

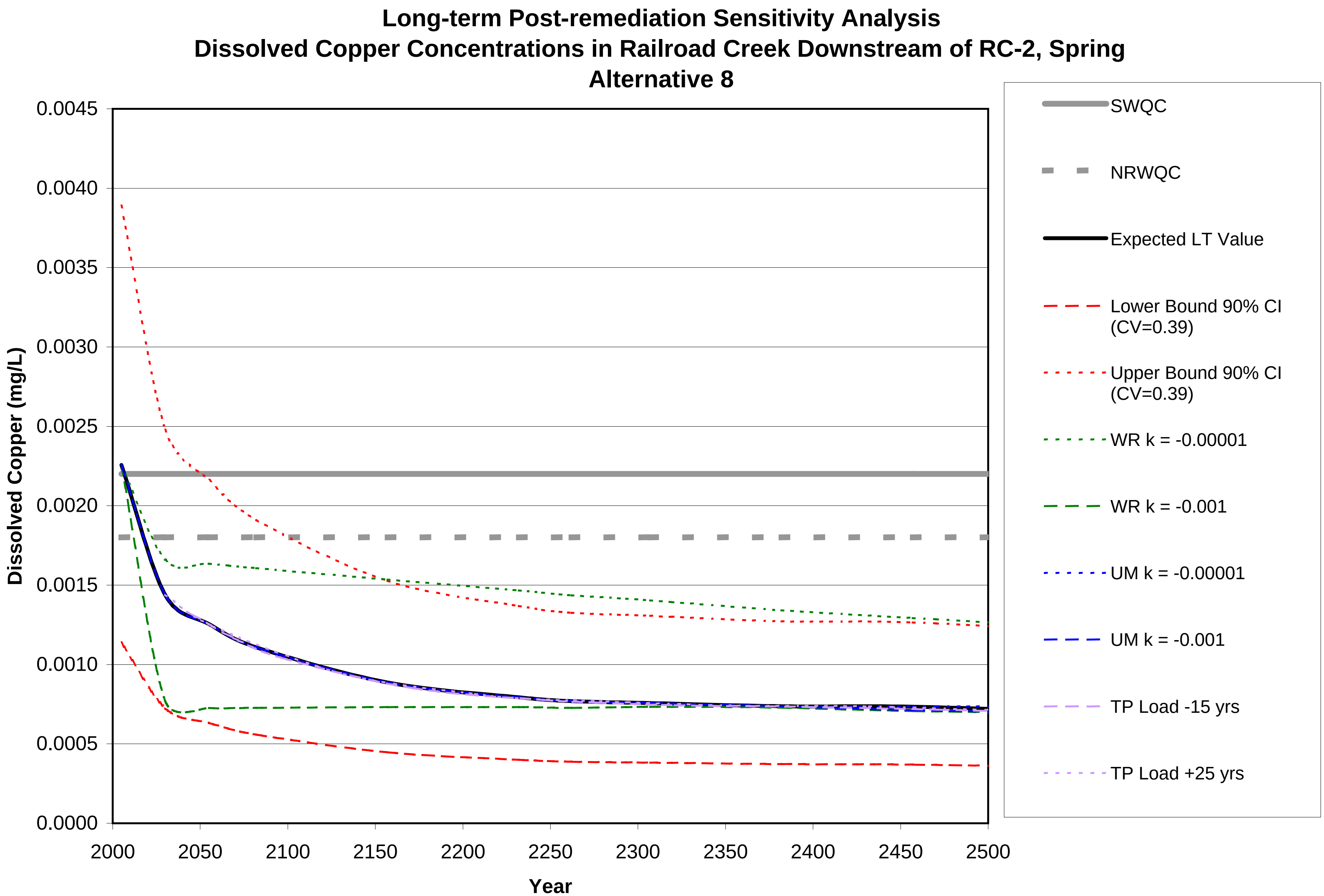
Long-term Post-remediation Sensitivity Analysis
Dissolved Zinc Concentrations in Railroad Creek Downstream of RC-2, Spring
Alternative 7



Long-term Post-remediation Sensitivity Analysis
Dissolved Cadmium Concentrations in Railroad Creek Downstream of RC-2, Spring
Alternative 8

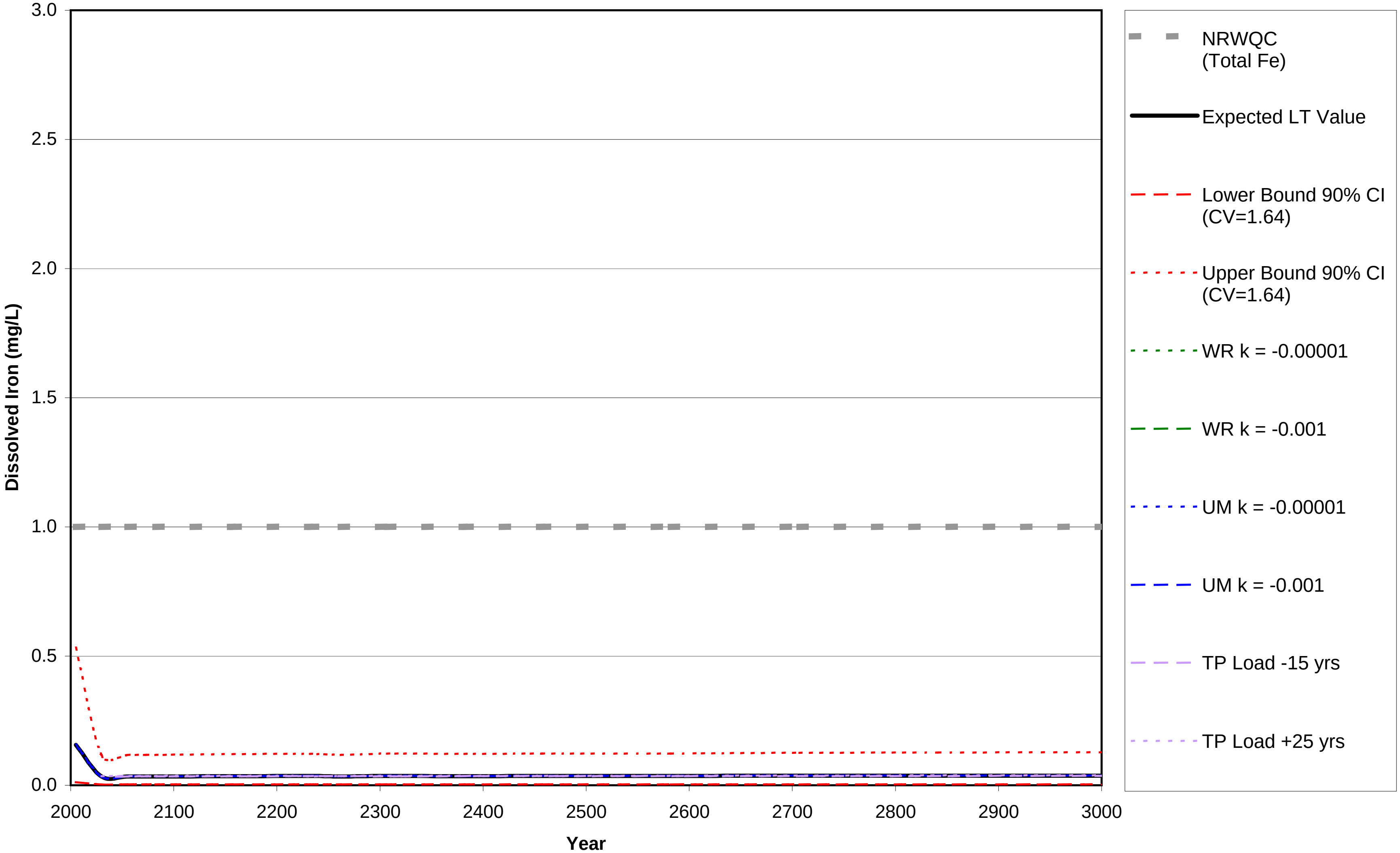


Appendix D6-14
Alternative 8 - Cadmium
<u>Long-term Post-remediation Sensitivity Analysis</u>
Draft Final FS Report February 2004

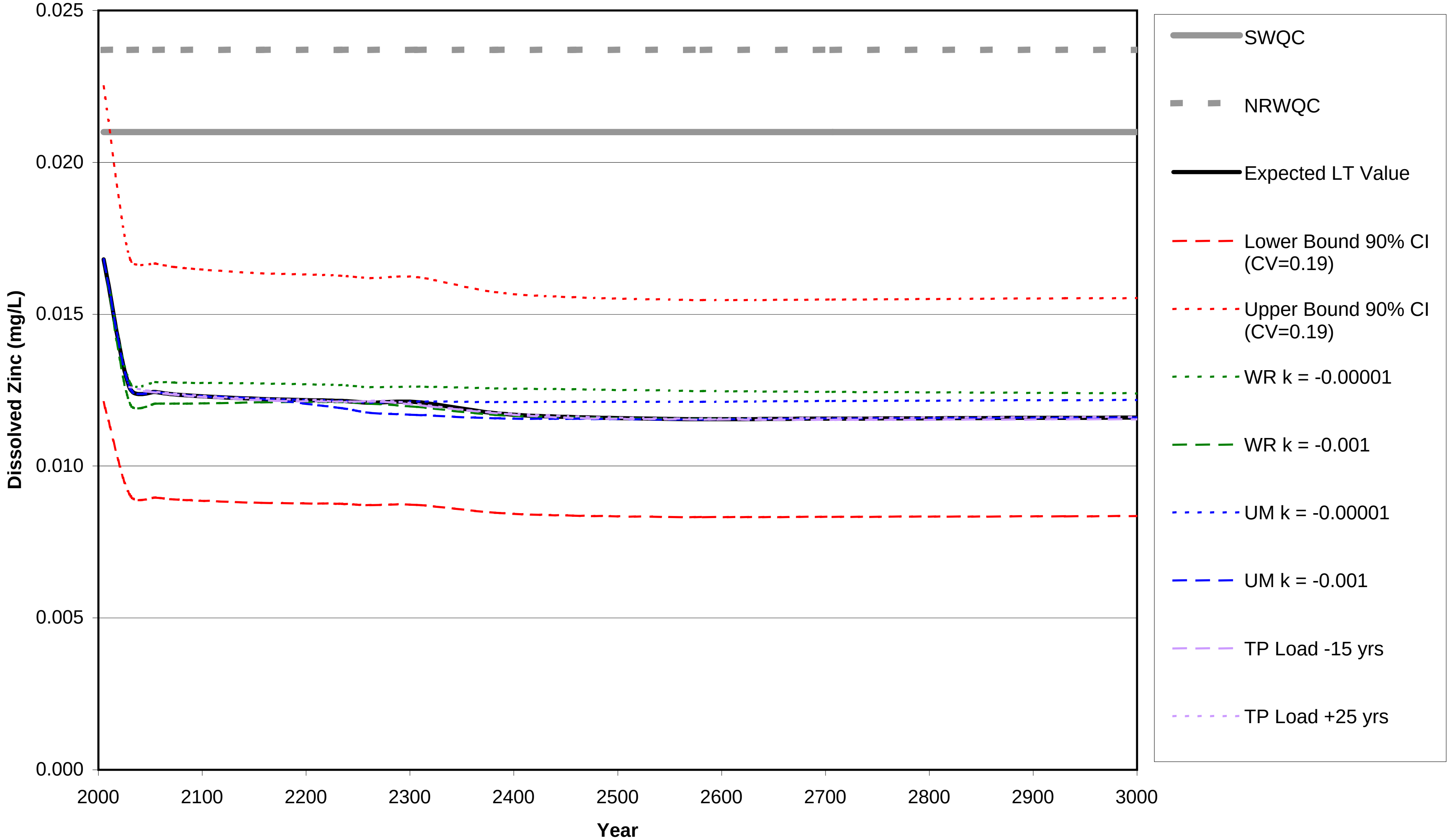


Appendix D6-14
Alternative 8 - Copper
Long-term Post-remediation Sensitivity Analysis
Draft Final FS Report February 2004

Long-term Post-remediation Sensitivity Analysis
Dissolved Iron Concentrations in Railroad Creek Downstream of RC-2, Fall
Alternative 8



Long-term Post-remediation Sensitivity Analysis
Dissolved Zinc Concentrations in Railroad Creek Downstream of RC-2, Spring
Alternative 8



APPENDIX E
SUPPORTING GEOCHEMICAL EVALUATIONS

Steffen, Roberstson and Kirsten (SRK – Canada) Inc, 2004a. *Analysis and Prediction of Long-Term Attenuation of Metal Loadings, Holden Mine, Washington State.* Report prepared for URS Corporation. February 2004**.**

Steffen, Roberstson and Kirsten (SRK – Canada) Inc, 2004b. *Supporting Geochemical Calculations – Feasibility Study, Holden Mine, Washington State.* Report prepared for URS Corporation. February 2004.

ANALYSIS AND PREDICTION OF LONG TERM ATTENUATION OF METAL LOADINGS

HOLDEN MINE, WASHINGTON STATE

Report Prepared for

URS Corporation

Report Prepared by

SRK Consulting
Engineers and Scientists

February 2004

ANALYSIS AND PREDICTION OF LONG TERM ATTENUATION OF METAL LOADINGS

HOLDEN MINE, WASHINGTON STATE

URS Corporation

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Seattle, WA 98101-1616
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SRK Project Number 1UU003.00.400

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February 2004

Compiled by:

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Authors: John Chapman
Stephen Day

Executive Summary

As a result of natural geochemical processes, the release of metals constituents from waste rock, the underground mine workings and tailings at the Holden Mine site are expected to decrease over time. The long term natural attenuation of potential contaminants of concern is an undisputed fact resulting from a chemical process causing the depletion of the sources of acidity and metals. This technical memorandum provides a site-specific analysis based on established geochemical principles to predict decreases in metal loadings to groundwater and surface water over time. The findings of this analysis will be used in the long term post-remediation loading analysis, included in the Feasibility Study to evaluate potential contaminant of concern (PCOC) concentrations in Railroad Creek and expected restoration time frames.

Long term attenuation of metal loadings from the waste rock piles (East and West, and Honeymoon Heights) were predicted using decay trends reported in the literature for testwork conducted at a variety of scales and on several different types of mineralized rock from other sites. These data established that long term attenuation is a documented phenomenon, and that the timescale of attenuation is the main variable. The calculations indicated that metal loadings from the waste rock piles would be attenuated by approximately 50% over the next 50 to 75 years. The diversion of upgradient water around mine features, such as the waste rock piles was evaluated to reduce the contact between clean water and potential sources of metals loadings. Using conservative assumptions, the upgradient controls under consideration are not predicted to result in increased attenuation over the base case.

A similar conclusion was reached for attenuation of metal loadings from the underground mine at the Holden Mine site under the current configuration based on comparison with long term monitoring results for the Britannia Mine in southwestern British Columbia. This non-operational mine is similar in many respects to the Holden Mine. Long term attenuation trends for the Holden Mine site are conservatively predicted to be similar for all the remedial alternatives under consideration (air flow restrictions and hydrostatic bulkheads).

Attenuation in metal loadings from the tailings piles was predicted using a quantitative modeling approach based on the geochemical characteristics of the tailings, the diffusion of oxygen into the tailings, and chemical reactions in the tailings. The long term trend for all metals is a gradual reduction in loadings with cadmium and copper decreasing to approximately 20% of current loadings within approximately 100 years, and aluminum, zinc and iron decreasing to approximately 60% or less of current loadings within approximately 200 years. Over the long term, acid breakthrough at the base of the fine tailings in each pile is predicted to result in temporary increases in loadings. However, during these periods, loadings of all metals are predicted to remain below approximately 60% of current loadings. The effect of re-grading and re-vegetation of the tailings is expected to be minimal for cadmium, copper and zinc, but could produce a substantial reduction iron loadings. Predicted loadings for consolidation and capping are very low primarily because the volume of water entering the consolidated pile would be very low.

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1 Introduction

1.1 Background

As a result of natural geochemical processes, the release of metals constituents from waste rock, the underground mine workings and tailings at the Holden Mine site are expected to decrease over time. This technical memorandum provides a site-specific analysis of these geochemical processes and the expected attenuation of metals loading to site groundwater and surface water over time. The findings of this analysis will be used in the long term post-remediation loading analysis, included in the Feasibility Study to evaluate potential contaminant of concern (PCOC) concentrations in Railroad Creek and expected restoration time frames.

The analyses presented in this technical memorandum build on a number of other analyses and reports completed for this site. These include:

- Discussion of Geochemical Data Collected from Holden Mine - November 2000. Prepared by SRK Consulting, January 19, 2001.
- Discussion of Geochemical Data Collected from Holden Mine - April and May 2001. Prepared by SRK Consulting, July 26, 2001.
- Geochemical Characterization of Tailings at the Holden Mine. Prepared by SRK Consulting, March 2002.
- Results of Humidity Cell Testing on Tailings - Holden Mine. Prepared by SRK Consulting, July 2003.
- Supporting Geochemical Calculations - Feasibility Study - Holden Mine, Washington State. Prepared by SRK Consulting, February 2004.

The Holden Mine site was developed and operated from the late 1930's through the 1950's for the primary production of copper, zinc, silver, and gold. As described in the Draft Final Remedial Investigation Report (URS 1999) and Draft FS (URS 2002) there are three primary sources of metals loading to site groundwater and surface water related to acid rock drainage (ARD) at the site (Figure 1):

- **Waste Rock** – Two large waste rock piles (referred to as the East and West waste rock piles) were generated primarily from the development of the 1500-level portals and workings, and are located on either side of the mill building near the 1500-level main portal. Several smaller waste rock piles were also generated by small scale exploration and mining activities in the higher levels of the mine (referred to as Honeymoon Heights). Seepage from the waste rock piles contributes primarily cadmium, copper, and zinc to groundwater and Railroad Creek, which runs adjacent to the site.

- **Underground Mine** – Approximately 60 miles of underground mine workings were developed during the period of operation. The majority of the mine openings below the 1500-level were backfilled with tailings. Following mine closure, the underground mine workings eventually flooded, resulting in the discharge of groundwater from the main portal of the mine. The portal drainage contributes primarily cadmium, copper, and zinc to groundwater and Railroad Creek.

- **Tailings** – Approximately 8 million tons of tailings were generated at the site and placed in three tailings piles covering an area of approximately 90 acres. Groundwater seepage from the three piles contributes primarily iron, and some cadmium, copper, and zinc to groundwater and Railroad Creek.

The attenuation of ARD and associated metals loadings is well-documented in the literature. ARD is generally formed as a result of the oxidation of sulfide minerals in the presence of moisture. As the mass of available sulfide minerals declines over time, the associated release of acidic water and metals also declines until background conditions are reached. Therefore, there is no doubt that ARD generated from tailings, waste rock and the underground mine at the Holden site will substantially decline from current levels, even without remediation. This document addresses the time frame of the decline.

1.2 Objective and Overall Approach

In this report, SRK has used a combination of site-specific geochemical modeling, available site data, and scientific literature to evaluate the potential attenuation of metals loadings from waste rock, the underground mine and tailings over time. The geochemical analyses described in this report are based on established geochemical principles that govern the attenuation of ARD. Similar approaches for evaluating ARD attenuation over time have been used at, for example, the Coeur d’Alene sites (URS Greiner 2001).

Uncertainties in the estimates, based on the inherent limitation of applying data from other sites and geochemical data from the Holden Mine site are considered in this report. In general, the overall approach taken for evaluation of waste rock, the underground mine and tailings is conservative.

1.3 Organization of Report

This report describes geochemical modeling undertaken to predict the long term attenuation of metals from sources at the Holden Mine site.

Overall, the report is divided into sections to reflect the differences between coarse and fine mineral wastes (i.e., waste rock and tailings). The waste rock piles and residual ore in the underground stopes, collapsed voids and rock fill in the underground workings are weathering under conditions that are generally not expected to be oxygen-limited. In contrast, the tailings are finely-crushed and partly-saturated materials that are weathering under oxygen-limited conditions controlled by diffusion from the outer surfaces.

Section 2 provides a general overview of the geochemical processes that contribute to the release of metals from mining sites. Sections 3 and 4 provide an evaluation of long-term loading predictions for the waste rock and underground mine because the predictive approach was similar and relied on information primarily available in the literature supported by site observations.

Section 5 provides a summary of long-term predictions for the tailings which were developed using a coupled modeling approach with inputs from laboratory testwork and site data.

2 Geochemical Processes at Mine Sites

2.1 General

Most hard rock metal mines, like Holden, involve excavation and processing of buried rock (ore) to extract useful metals (eg. copper and zinc) contained in minerals. The minerals may be smelted on site to produce the metals, or, as in the case of the Holden, the minerals were smelted off-site. As it is not economically practical to recover all the minerals (particularly those containing iron), they remain on site in: (a) the walls of the excavations (mine openings); (b) in rock removed to access the ore (waste rock); and (c) in residues remaining from processing the ore (tailings).

The metal-containing minerals were formed under conditions in the earth's crust that were very different from the atmosphere. Some major differences include, pressure and temperature (both greater in the crust), and water and oxygen abundance (both greater in the atmosphere). Because of these differences, the minerals remaining on site after mining are unstable in the atmosphere and they begin to breakdown, releasing the metals they contain to flowing water. 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 significantly modifies the water chemistry. The mine waters may be acidic and contain high concentrations of dissolved sulfur. This type of water is referred to as acid rock drainage (ARD), and it forms specifically because reaction of minerals containing iron and sulfur with oxygen produces a weak form of sulfuric acid. This reaction can be written in words as:

Iron sulfide + Water + Air → Sulfuric acid + Dissolved Iron + Heat

The dissolved iron may also react with water and air to produce iron oxide, which resembles rust

Dissolved Iron + Water + Air → Iron Oxide ("rust")

The progress of both of the above reactions is enhanced by common naturally-occurring bacteria. The oxidation of sulfide minerals also releases other metals in addition to iron (for example, cadmium, copper and zinc) which dissolve in water. ARD therefore often contains high concentrations of other metals.

As the acidic waters flow away from their source, the acid may be removed by contact with acid neutralizing minerals, or mixing with acid-neutralizing water. Both processes result in water with less acidity and sulfate. The latter is the product of neutralization of sulfuric acid. The removal of acidity also removes metals from solution resulting in precipitation of sludge. Metals are also precipitated by contact of the water with other minerals.

Over time, the continual reaction of iron sulfide with water and air causes the particles of the mineral to decrease in size and become coated by iron oxide. As this process occurs on the surface of the minerals, the resulting decrease in the available surface over time causes the rate of release of acid and metals to decrease, or attenuate.

The long term attenuation of potential contaminants of concern is an undisputed fact resulting from chemical and biological processes causing the depletion of the sources of acidity and metals. The purpose of this memorandum is to document the timeframe of attenuation.

2.2 Waste Rock

The processes described above operate in waste rock piles produced, at Holden Mine, primarily by development of tunnels to access the ore. Waste rock is extracted by blasting, which results in mostly large rocks with some fine material. The actual variation of particle size depends on the excavation method, and the tendency of the rock to breakdown during excavation and after the rock is placed in a rock pile.

An important characteristic of waste rock is that the relative large size of the particles allows oxygen to move freely inside the pile. Air may be drawn into the pile by the reaction of oxygen with the rock, and vented from the pile by upward movement driven by heat generation. Changes in atmospheric pressure and external temperatures can also cause air to move into and out of the rock pile.

A second important feature of waste rock piles is that they remain unsaturated, and flow within the unsaturated rock mass from rainfall and snowmelt occurs in channels around the large rocks. As a result, water does not contact the whole rock mass, and a significant part of the rock may never come into contact with water. These “dry” parts of the rock nevertheless continue to react with air and water vapor in the air, resulting in storage of sulfuric acid and metals. If this rock is subsequently moved or immersed in water, the acidity may be released.

2.3 Underground Mines

Underground mining typically results in an extensive network of tunnels in which the walls and ceilings are largely designed to be free of loose material for safety reasons. Extraction of ore occurs by blasting, creating broken material that is then loaded into trucks or trams and taken to surface for processing to extract the ore minerals. This process is not perfectly efficient, and residual broken ore (or “muck”) remains in certain parts of the mine. At Holden, the ore bodies were extracted by a common method that resulted in the muck falling by gravity to low points (referred to as “drawpoints”) where it was then loaded into trams. The resulting large voids or “stopes” inside the mine probably contain residual ore. Underground mines can therefore be considered as a type of

waste rock facility which includes residual ore, rock or tailings used to fill chambers in the workings, and broken rock caused by collapse of tunnels. These materials contain sulfide minerals which are subject to the same oxidation processes described in Section 2.1.
After underground mines cease operation, they commonly become partially flooded by inflowing groundwater. The workings are typically well-aerated above the flood level. This ensures that oxygen is available in excess above the water level and limited in availability below the water level. Air movement may be driven by heat differences within the mine caused by geothermal effects or sulfide mineral oxidation. The difference between external and internal temperatures can also cause strong drafts that may reverse on a daily or seasonal basis.

Like waste rock, water flow within underground workings occurs on a few flow paths depending on where water enters the workings, how this water is channeled through mined out areas, and the direction of flow engineered by the mine operators to manage water. Large parts of the workings may not be contacted by water under normal free-draining conditions.

2.4 Tailings

Tailings are the fine residues produced by crushing and processing of ore to extract ore minerals. Tailings contain the same major minerals as the ore but with lesser amounts of minerals containing metals of economic value, like zinc and copper. Tailings can therefore react with the atmosphere to produce ARD much like waste rock.

However, unlike underground mine workings and waste rock piles, oxygen access to the tailings is limited by the fine grained nature of the material. Except at the immediate surface exposed to the atmosphere, this limitation is typically sufficient to control the rate of oxidation of iron sulfide minerals in the tailings.

The fine-grained nature of tailings allows uniform movement of water through the tailings by infiltration from the exposed surfaces. It also allows water to be retained in the pores of the material resulting in a high degree of water saturation and the possible presence of a water table depending on the configuration of the deposit. The presence of water in the pores also serves to limit the movement of oxygen into the tailings. Typically, acidic conditions form near the surface first then propagate downwards as any acid-neutralizing minerals are removed.

3 Waste Rock Predictions

3.1 Site Geochemical Model

3.1.1 Geological Background

The East and West Waste Rock Piles were generated primarily by development of the 1500 Level access tunnels. Small waste rock piles located in the Honeymoon Heights area were generated by small scale mining activity in the higher levels of the mine prior to the development of the 1500-level portal. Based on historical mining records and site geology, the larger waste rock piles can be expected to be composed primarily of Buckskin Schists mixed with minor amounts of marble and sulfide wastes from near the ore zones. A higher proportion of sulfide material is expected for the Honeymoon Heights piles because the ore was nearer to the surface in these areas.

3.1.2 Current Conditions

The current chemistry of seepage from both types of waste rock probably reflects acid generated by oxidation of sulfide-bearing wastes, and partial to complete neutralization by reaction of the acidic water with marble and reactive silicates in the schists. Seepage from the waste rock piles is moderately acidic (pH>4) with relatively low TDS (less than 300 mg/L) dominated by sulfate and calcium. Zinc and copper concentrations in the 1 to 10 mg/L range confirm the influence of oxidation of zinc and copper sulfides. Similar levels of aluminum, along with potassium, sodium and magnesium indicate reaction of acidic waters with silicates such as biotite.

Using current seepage chemistry collected in 1997 from SP-8 (East Waste Rock Pile), and SP-15E and 15W (West Waste Rock Pile), the equilibrium geochemical model MINTEQA2 (Allison et al. 1991) showed that the solubility of iron and aluminum minerals are probably controlling the concentrations of these elements in the seepage. This is a common observation for waste rock seepage. Similar mineralogical controls were not apparent for concentrations of elements such as cadmium, copper and zinc.

Examination of the seepage data also indicates that metal concentrations did not vary significantly with flow, and that variations in concentrations appeared to be related to pH. For example, within the typical pH range observed in the spring, copper concentrations were between 3.5 and 4.9 mg/L. When the pH increased to 7 at SP-15E in July 1997, copper concentrations decreased to 0.9 mg/L. A possible explanation for these observations is that metal concentrations (particularly copper) are limited by mineral solubility as a function of pH. MINTEQA2 may not predict this effect due to a lack of thermodynamic data in the program database, or dilution of the seepage within the waste rock. The stable sulfate concentrations also possibly indicate this effect. Candidates for copper mineralogical controls are the mixed aluminum, copper and sulfate minerals observed in the underground workings (SRK 2001a).

3.1.3 Long Term Effects

In the long term, several stages in the processes that control release of acidity and metals are anticipated (Figure 2). In the first stage, pore waters in the waste rock piles are dominantly pH neutral due to buffering by carbonate minerals. The oxidation rate under these conditions is relatively low and metals released by oxidation are largely precipitated as oxides and carbonates. As the carbonate minerals are consumed, pH drops and oxidation accelerates. Intermediate buffering steps may be observed as alumino-silicates are dissolved and aluminum is released. As pH drops further, the solubility of metal carbonates and oxides increases and metal release accelerates, probably exceeding the rate at which the metals are released by oxidation of sulfide minerals. A peak oxidation rate is typically reached after which the supply of readily available sulfide minerals decreases and oxidation rates decay. In the long term, pH typically starts to increase very slowly but will remain low (typically below 4). Metal release attenuates as the supply of soluble minerals is exhausted. Over the long term, the rate of metal leaching is expected to be equivalent to the oxidation rate as the two processes come to equilibrium. It should be noted however, that this would only apply to flow paths within the piles. Oxidation products could continue to accumulate in areas not subject to leaching. Therefore, if the waste rock piles were disturbed in the future, release of metals loads would be expected to increase due to flushing of stored oxidation products.

The trends shown in Figure 2 are documented in small-scale laboratory and field tests in which the material being weathered is homogenous (Norecol Dames & Moore 1994). At larger scales, the timing of events has been observed to vary for different locations in the waste rock according to rock type and construction history, and seepage chemistry reflects overlapping effects. It is SRK's opinion that at Holden, the initial carbonate buffering stage was brief due to the low concentrations of carbonate in the rock (except for minor occurrences of marble). Therefore, the overall stage for the Holden waste rock piles is expected to be on the right side of the diagram in which oxidation rates and metal release are decreasing. Long term trends in metal release (i.e., the decay rates) will depend on the availability of sulfides and the oxidation rate.

3.2 Remediation Scenarios

The base case scenario discussed in Section 3.3 assumes that the waste rock piles remain in their current condition. Section 3.4 considers the effect of upgradient water controls to minimize water infiltration.

3.3 Scenario 1 - Current Configuration

3.3.1 Approach Used to Predict Long Term Loading Attenuation

A review of water chemistry trends observed in long-term laboratory experiments and field tests reported in the literature was selected as the method for evaluating future attenuation in metals loading from waste rock at the Holden Mine site. Data are available in the literature related to waste rock seepage, and these data are useful for understanding potential long-term attenuation at Holden.

3.3.2 Review and Application of Long Term Trends in the Literature

Data are available in the literature for long term small-scale tests such as humidity cells and small test waste rock piles. The following paragraphs demonstrate that:

- Metal loadings from waste rock pilesdecrease with time; and
- Results of testing at other sites can be applied to predictions of metal loading attenuation at Holden.

A multi-year study of three scales of test work, including humidity cells, leach columns and test piles was conducted for the Cinola Gold Project located in the Queen Charlotte Islands, British Columbia (Norecol, Dames & Moore 1994). The project was supported by the Canadian Mine Environment Neutral Drainage (MEND) program. Gold mineralization at Cinola Gold is hosted in sedimentary rocks containing fine-grained pyrite (ferrous sulfide).

All types of testing showed the basic trend of acceleration of oxidation (indicated by sulfate release) followed by pH depression (to below 4) and deceleration of oxidation rates. Once low pH conditions were reached, metal release was strongly correlated with sulfate release. The decay portion of the sulfate release curve could typically be approximated by a straight line of the form (Norecol, Dames & Moore, 1994):

$$Log_{10}R_{SO4} = kt + c$$

Where R_{SO4} is the rate of release of sulfate, which is proportional to concentration, k is referred to as the decay constant (in $weeks^{-1}$) and is negative, t is the time elapsed (in weeks[1]), and c is a constant. The two constants (k and c) are estimated empirically by fitting a regression equation to the data.

Results of monitoring from the Cinola Gold project are shown in Figure 3, and values of k for each type of testing estimated by Norecol Dames & Moore (1994) are provided in Table 1. For humidity cells and leach columns in the laboratory, k tended to be more negative than -0.01[2] $week^{-1}$ (to a maximum of -0.034 $week^{-1}$). Waste rock pads containing 30 tonnes of rock had k values less negative than -0.006 $week^{-1}$ (when considering the statistical uncertainty) indicating a slower decay. The waste rock pad data were affected by seasonal variations (highest release rates in summer) as shown in Figure 3b, but the decay over five years was apparent due to the high frequency of sampling.

[1] The time-scale used is weeks because it is the typical operating unit for laboratory tests such as humidity cells.
[2] In the following discussion, individual small numbers are shown in decimal format (for example -0.01) whereas small numbers representing an order of magnitude are shown in shown in scientific notation (-10^{-2}). In this example, -10^{-2} is the same as -0.01, and -10^{-3} is the same as -0.001. The term "of the order of 10^{-2}" means numbers between 0.01 and 0.09 (ie numbers with two figures to the right of the decimal place).

The k values obtained from humidity cell tests conducted for two other projects are similar to the values obtained during the Cinola Gold project, although the tests were conducted with rock containing different mineralization (see Table 1). The site for reference 2 (SRK 2003b) is Huckleberry Mine located in northern British Columbia. The copper-molybdenum porphyry mineralization at this mine is hosted by andesitic volcanic rocks. Pyrite occurs throughout the host rocks as disseminations and veinlets. The site for reference 3 (SRK 2003d) is the Red Dog Mine in Alaska. Mineralization at this site is quite different from Cinola and Huckleberry. Fine to coarse-grained zinc and lead sulfides are contained in black shales. The similarity of k-values for similar types of tests from vastly different mineral deposit types suggests that decay constants are reasonably well constrained and can be extrapolated to other sites[3].

Monitoring data for drainage from the underground Britannia Mine discussed subsequently in Section 4.3 indicate a k-value of -0.0005 week^{-1} for very long term copper release from the mine. These data indicate decay rates for a larger scale facility containing waste rock. Copper release is correlated with sulfate release because both processes occur as a result of sulfide mineral oxidation (Morin et al 1995; Norecol Dames & Moore, 1996). The k value of -0.0005 week^{-1} is of the order of -10^{-4} week^{-1} and is one order-of-magnitude smaller than the small scale field tests which are about -10^{-3} week^{-1}. Comparison of the Britannia Mine drainage data with results of smaller scale testing shown in Table 1 demonstrate that k-values decrease as the size of the waste rock mass increases and indicates k-values of the order of -10^{-4} week^{-1} are appropriate for the East and West Waste Rock Piles at the Holden Mine site.

In summary, the following order-of-magnitude k-values are suggested by values in the literature:

- Laboratory small and medium scale: -10^{-2} week^{-1}
- Small scale field tests: -10^{-3} week^{-1}
- Full scale (Britannia Mine site): -10^{-4} week^{-1}

[3] The data for Cinola indicate that scale of testing may partly explain the variation in k-values among types of tests. For the small-scale humidity cells, k values were typically of the order of -10^{-2} week^{-1} but for the waste rock pads this decreased to -10^{-3} week^{-1}. Two significant differences between laboratory and field scale tests include operating temperature and degree of flushing. The laboratory tests are operated under warmer conditions which results in faster weathering than observed under field conditions. Also, the laboratory tests are flushed thoroughly during leaching resulting in little storage of oxidation products, so that oxidation products are detected in leachate very soon after they are produced. Under site conditions, oxidation products are produced rapidly initially but are not completely flushed. As time progresses, sulfide oxidation decreases but flushing of the stored oxidation products maintains the sulfate concentrations above those produced by oxidation. Together, these effects flatten the decay curves resulting in lower k-values

Table 1. Comparison of Decay Constants

Type of Test and Site	Mass of Test Material kg	Decay Constant (k) for Indicated Parameter						Ref.
		Parameter	n	Average k week^{-1}	Average $t_{1/2}$ Years	r^2	k Confidence Limits	
Humidity Cells (Small Laboratory Scale)								
Cinola Gold	0.2	Sulfate	-	-0.01	0.6	-	-	1
Cinola Gold	0.2	Sulfate	-	-0.02	0.3	-	-	1
Cinola Gold	0.2	Sulfate	-	-0.02	0.3	-	-	1
Cinola Gold	0.2	Sulfate	-	-0.03 to -0.01	0.2 to 0.6	-	-	1
Huckleberry Mine	0.8	Sulfate	18	-0.03	0.2	0.81	-0.04 to -0.02	2
Red Dog Mine	1	Sulfate	17	-0.007	0.8	0.42	-0.01 to -0.003	3
Leach Columns (Medium Laboratory Scale)								
Cinola Gold*	17	Sulfate	-	-0.03 to -0.009	0.2 to 0.6	-	-	1
Waste Rock Piles (Small Field Scale)								
Cinola Gold Pad 1‡	30000	Sulfate	57	-0.002	3	0.26	-0.002 to -0.0009	1
Cinola Gold Pad 2‡	30000	Sulfate	56	-0.005	1	0.32	-0.006 to -0.003	1
Cinola Gold Pad 3‡	30000	Sulfate	56	-0.004	1	0.30	-0.005 to -0.003	1
Cinola Gold Pad 4‡	30000	Sulfate	54	-0.004	1	0.31	-0.005 to -0.002	1

Notes:

n - number of observations in the decay trend used to calculate k. "-" indicates that the number was not reported in the reference.
Average k – the average slope of the decay of the curve. A single value indicates the slope from one test. A range of values indicates the range of decay slopes obtained for several tests.
Average $t_{1/2}$ = Half-life calculated from average k. A range of values corresponds to the range of k values.
r^2 - Square of Pearson linear correlation coefficient for regression equation for single tests..
k confidence limits – Calculated at 95% confidence for single tests.
"-" indicates that the statistics were not reported. The ranges of k indicated for some tests were from several tests. Statistics for waste rock pads were re-calculated from the raw data and vary slightly from reported values.
* Data for these tests are shown in Figure 3a.
‡ Data for these tests are shown in Figure 3b.

References:

1 = Norecol Dames & Moore 1994
2 = SRK (2003b)
3 = SRK (2003d)

3.3.3 Application to Waste Rock at Holden

The similarity of the decay constants (k) in Table 1 for similar scales of testing representing a wide range of mineral deposit types hosted by different types of mineralization indicates that it is reasonable to evaluate these constants for application to the waste rock piles at the Holden Mine site. The ratio of current sulfate release ($R_{SO4,t}$) to initial sulfate release ($R_{SO4,o}$) is given by:

$$\text{Log}_{10}(R_{SO4,t}/R_{SO4,o}) = kt$$

Curves illustrating this relationship are shown in Figure 4(a) for k representing the highest humidity cell value in Table 1 (-0.03 $week^{-1}$), a lower humidity cell value (-0.01 $week^{-1}$) and lowest k indicated by the 95% confidence limits (-0.0009 $week^{-1}$) and a nominal value of -0.0001 $week^{-1}$ for a full scale facility. A material with a rapid decay (high negative k) can be expected to be oxidizing at a very low rate after a few years. As k decreases, a longer period of time is required for rates to become negligible. For example, for k=-0.0001 $week^{-1}$, rates would decrease by 50% after approximately 60 years, and 90% after 200 years. All curves indicate that release rates decrease in the long term.

For Holden, the current conditions do not reflect t=0 but roughly t=50 years (2609 weeks). Therefore, the decay of current release rates is given by:

$$Log_{10}(R_{SO4,t}/R_{SO4,t=2615}) = k(t-2609)$$

Figure 4(b) shows the curves with k values of -0.0009 and -0.0001 $week^{-1}$ referenced to t=50 years. The curves depict estimated past and future loadings relative to current loadings (t=50 yrs).

For Holden, k has not been documented in test work or by site monitoring. Therefore, based on a review of the data summarized above, a k of -0.0001 $week^{-1}$ was selected to evaluate long-term trends in metals loading from the Holden Mine East and West Waste Rock Piles. This value is an order-of-magnitude lower than the lowest documented value reported in Table 1 to account for the large scale and low temperature effects suggested by the literature and discussed in Section 3.3.2.

In this context, the removal of metals from water by the formation of chemical precipitates (for example, the common white-colored precipitates observed at the Holden Mine site) controls the concentrations of metals although a decrease in the rate of metals release continues to occur. The use of a conservative low k-value is appropriate to account for these effects because precipitate formation flattens the decay curve.

For the much smaller waste rock piles located in the Honeymoon Heights area of the site, k values between -10^{-3} and -10^{-4} $week^{-1}$ are probably appropriate due to the size and observed relatively higher sulfide content of the rock. The latter in particular would be expected to result in more rapid depletion of metals than the East and West Waste rock piles. Selection of a k-value of 0.0001 $week^{-1}$ is therefore conservative.

3.4 Scenario 2 – Effect of Upgradient Controls

The diversion of upgradient water around mine features, such as the waste rock piles, is being evaluated under all of the remedial alternatives in the FS to reduce the contact between clean water and potential sources of metals loadings. All of the alternatives being evaluated include upgradient water diversion around site source areas, and one of the candidate alternatives, Alternative 7, also includes the placement of an engineered cover on the top, flat portions of the waste rock piles.

The evaluation of Scenario 2 considered only the effect of upgradient controls on the East and West Waste Rock Piles. The small piles in the Honeymoon Heights area were not evaluated.

The overall conservative assumption is that these controls will potentially reduce the volume of infiltration but have no affect on oxygen availability. Furthermore, it is assumed that the diversions and/or covers will not result in a reduction in load because MINTEQA2 predicts that there is no limit to the solubility of cadmium, copper, and zinc under these pH conditions. If there are solubility limits for these metals, any reduction in flow would produce a proportional reduction in loading. Therefore, the assumption that solubility controls are not effective is conservative.

MINTEQA2 was used to estimate seepage chemistry assuming the maximum estimated reduction in the infiltration of precipitation and upgradient run-on due to water diversion and cover installation (25%), and assuming that aluminum concentrations are controlled by the mineral $AlOHSO_4$. No iron control was used because the iron concentrations were very low and the oxidation speciation is not easily defined under these conditions. Table 2 shows West Waste Rock Pile estimates based on seepage analyzed on June 9, 1997 as the base case. The maximum reduction of water infiltration assumed in the FS was estimated to be approximately 25%. This was estimated based on the approximate coverage achieved by a cap placed on the top flat waste rock pile surfaces and upgradient water diversion. The effect of lesser flow reductions could be obtained according to the flow (i.e. assuming constant load). The results of the evaluation indicate that most concentrations in Table 2 are simply increased according to the decrease in flow. However, aluminum concentrations are shown to decrease due to the effect of the aluminum sulfate control.

The same calculation was performed for SP-8 (May 21, 1997) for the East Waste Rock Pile (Table 2). The limited data available for SP-8 reduces the ability to estimate the effect of upgradient water controls for this pile. However, due to the apparent similarities in mineralization between the two piles, the effects of upgradient controls would be expected to be similar.

Table 2. Waste Rock Piles - Effect of Flow Reductions

Parameter	Unit	West Pile		East Pile	
		Base (SP-15E)	25% Reduction in Infiltration	Base (SP-8)	25% Reduction in Infiltration
pH	s.u.	5.11	4.97	4.61	4.47
Al	mg/L	2.24	0.61	9.62	1.36
Ba	mg/L	0.04	0.05	0.02	0.03
Cd	mg/L	0.06	0.08	0.09	0.12
Ca	mg/L	38.30	52.50	56.50	77.43
Cu	mg/L	3.95	5.36	7.88	10.80
Fe	mg/L	0.08	0.11	0.03	0.04
Mg	mg/L	5.82	7.97	5.38	7.37
K	mg/L	3.91	5.36	3.98	5.45
Na	mg/L	3.01	4.12	2.44	3.34
Zn	mg/L	7.21	9.88	11.20	15.31
SO_4	mg/L	140	183	240.00	286.75
Mn	mg/L	0.20	0.27	0.42	0.57
Ni	mg/L	0.02	0.02	0.05	0.06

Based on the calculations described above, the implementation of upgradient water controls are not assumed to reduce metals loading from waste rock seepage or groundwater in related DFFS evaluations. Long term loading decay would likely be comparable to the current configuration.

3.5 Conclusions Related to Long-Term Metals Loading from Waste Rock Piles

The main finding of the waste rock geochemical modeling is that attenuation of metal load release from waste rock is a documented phenomenon, and follows logically from the depletion of reactive waste rock components. Long term release under field conditions probably occurs relatively slowly spanning time frames in the order of a few centuries. Using a decay constant of -0.0001 week^{-1}, below the lowest value found in the literature, is reasonable and conservative for the Holden Mine site and indicates that current metals loading from the waste rock piles on site would decrease by approximately 50% in the next 50 to 75 years.

Upgradient controls are not expected to have a significant effect on metal loadings from the waste rock piles. Loading from these sources would be expected to follow a similar long term decay as seen without the controls.

4 Underground Mine Predictions

4.1 Site Geochemical Model

The geochemical model for the underground workings, demonstrated by observations made during underground investigations conducted in 2000 and 2001 indicates that the workings above the 1500 Level are a source of acidic water (pH<4) and metals through contact with mineralized rock (SRK 2001a,b). This water then mixes with alkaline water upwelling from the No. 2 Shaft and discharges from the 1500 Level Main Portal. Due to seasonal variations in flows from the upper workings caused by snow melt, the chemistry of the 1500 Level portal discharge varies widely. During spring and summer, the drainage reflects the influence of the acidic water and has pHs buffered below 5 by the precipitation of aluminum. In the fall and winter, the No. 2 shaft water is dominant and results in pH near 7. Metal loadings in the discharge are influenced by these processes. The increase in pH and dominance of No.2 shaft water result in lower concentrations of cadmium, copper and zinc in the fall.

Overall, the long-term attenuation of metal loads from the mine will be controlled by depletion of metals from residual ore and waste rock remaining in the workings above the 1500 Level. The presence of acidic water with pH less than 4 flowing down raises towards the 1500 Level indicates that oxidation is probably advanced in the workings and that conditions are well to the right of the peaks shown conceptually in Figure 2.

4.2 Remediation Scenarios

The base case scenario discussed in Section 4.3 assumes that the underground mine remains in the current condition. Sections 4.4 and 4.5 consider the effects of:

- **Airflow Restrictions**. Restriction of airflow to reduce the availability of oxygen for oxidation of sulfide waste rock in the mine.
- **Hydrostatic bulkheads**. Flooding of the workings to equalize seasonally influenced portal drainage flows. This would also potentially exclude gaseous oxygen from sulfide waste rock below the flood level, depending on the depth of water maintained within the mine.

4.3 Scenario 1 - Current Configuration

4.3.1 Approach Used to Predict Long Term Loading Trends

The approach used is comparable to that applied to the waste rock (Section 3.3.1) with the additional consideration of trends in the Holden Mine monitoring data collected over the past 20 years.

Available monitoring data for the 1500-level portal discharge illustrate the strong seasonal effects which obscure any long-term trends in water chemistry (Figure 5). The limited number and timing of the sampling events further constrains discernment of long-term water quality trends. For example, the zinc peak in 1998 (27.8 mg/L) coincides with the lowest pH (4.3) for which metal concentrations were determined. At other times, pHs were 4.4 and higher. Sulfate concentrations are also not useful for evaluating water quality trends because they are greater in the upwelling No. 2 shaft water. The lack of trends observed in the monitoring data is likely a result of seasonal effects and the low frequency of sampling, but could also indicate that load release is not decaying at a noticeable rate due to metals precipitation or other effects.

4.3.2 Review and Application of Long Term Trends in the Literature

The waste rock decay constants discussed previously are useful for evaluating future portal drainage trends because residual ore and waste rock is believed to be the primary source of metal load in the 1500-level Main Portal discharge.

SRK is aware of only one example of a very long term monitoring record for an underground mine (SRK 2003a). The Britannia Mine located near Vancouver, B.C. has bi-monthly monitoring data for copper concentrations discharging from the 2200 Level beginning in 1930 through to 1956 as a result of operation of a copper cementation plant. No other parameters were monitored. Monitoring resumed in 1995 and is ongoing. The data are for monitoring of the 2200 portal drainage which collects water from a high grade portion of the mine. This part of the mine was worked during the early decades of the 20th century. There are significant similarities between Britannia Mine and Holden Mine, including:

- **Geological**. The Britannia Mine extracted ore from steeply dipping massive sulfide ore bodies hosted by silicate rocks.
- **Topographical.** The Britannia Mine is located in the Coast Mountains of British Columbia, which is the northern continuation of the Cascade Mountains of Washington State. The mountain relief in the Britannia Mine area is approximately 4000 feet.
- **Geometric**. The Britannia Mine consists of numerous levels with access to surface by adits. Levels are numbered downwards. The majority of levels are internally free-draining, with final mine drainage at a single location (the 4100 level). Mine levels below the 4100 level to the 5700 Level became flooded at closure.
- **Climatic.** Precipitation in the upland areas of the Britannia Mine area is very high (120 inches) with winter precipitation at levels above 3000 feet occurring primarily as snow. Snow packs typically build to 10 feet.

- **Hydrogeological.** Water balance estimates for the Britannia Mine indicate that 75% of flow through the mine originates as snowmelt and precipitation. The balance originates as upwelling groundwater.

- **Mining.** Copper, and later zinc ores were extracted. Open stoping occurred, with backfill by tailings in the latter part of the operation in the lower levels of the mine below the stable flood level.

The monitoring data for the 2200 Level discharge indicate a consistent steady decreasing trend with initial copper concentrations near 2 g/L and recent concentrations below 100 mg/L (Figure 6). The calculated decay trend for the 1930s to 1956 data is:

$Log_{10}Cu$ (mg/L) = -0.00048 t (weeks) + 3.1

The extrapolation of this trend fits the 1990s data very well with a correlation coefficient of 0.97 (Figure 6). The 95% confidence limits for the k value are -0.00049 to 0.00047 week^{-1}. It should be noted that similar to Holden, the results are strongly affected by season; nonetheless, an excellent decay trend is apparent. The reason for the strong decay trend for copper is that the mine water has pH below 4. At these pHs, copper concentrations are controlled by highly soluble copper sulfate. Sorption effects are expected to be minimal.
The rate constant for the Britannia Mine data is estimated to be -0.00048 week^{-1} which is at the low end of decay curves indicated for waste rock (Table 1). Given that this trend was derived directly from long term underground mine drainage monitoring, it provides a sound basis for the evaluation of metals loading attenuation at the Holden Mine site.

4.3.3 Application to the Underground Mine at Holden

As indicated in Section 4.3.1, the monitoring data for the Holden Mine drainage does not visually indicate decay in copper concentrations. The regression equation fit to the data is:

$Log_{10}Cu$ (mg/L) = -0.00027 t (weeks) + 0.16

The 95% confidence limits for k in this equation are -0.0008 to 0.0004 week^{-1}. This range includes the Britannia k of -0.00048 week^{-1}. Based on the similarity of Holden Mine and Britannia Mine the k value representing attenuation of metals at the acidic sources in the Holden Mine is likely to be similar to Britannia Mine. However, the effect of chemical precipitate formation is expected to be more significant at the Holden Mine due to the upwelling of alkaline water from the No.2 Shaft and resultant fluctuation of drainage pH. The actual decay constant is expected to be lower than -0.0005 week^{-1}, and the value derived for waste rock (-0.0001 week^{-1}) was chosen to account for formation of precipitates for the same reasons given in Section 3.3.3. The underlying conclusion is that release of metal loadings at source will decrease at a rate of the order of -10^{-4} week^{-1} and that precipitate formation may mask these effects in the short term. Therefore, a decay rate of -0.0001 $week^{-1}$ was conservatively selected at the low end of the -10^{-4} $week^{-1}$ range.

4.4 Scenario 2 – Effect of Airflow Restrictions

4.4.1 Approach

In general, the success of air exclusion depends on the rate at which sulfides in the mine are oxidizing. These rates cannot be determined directly because most of the workings are inaccessible.

Therefore, to estimate oxygen demand, sulfate load currently emerging from the mine was used as an indicator of the rate of oxidation along contacted flow paths.

4.4.2 Comparison of Oxygen Demand and Volume of Workings

Oxygen demand was estimated by calculating the sulfate load in drainage from the 1500 Level. This assumes that all sulfate originates from oxidation of sulfide minerals. This conservatively under-estimates actual oxidation rates within the workings because large parts of the workings are probably not flushed by water. There is also a potential that this assumption over-estimates actual oxidation rates if sulfate minerals are present that were not formed by oxidation of sulfide minerals (e.g. gypsum). However, the second factor was considered in the calculation as discussed below in Step 2.

Steps and result of the calculation were as follows:

- The total sulfate load in the 1500 Level drainage was estimated based on seasonal flow rates and sulfate concentrations provided in the Revised DRI (Dames & Moore, 1999). Annual sulfate load in the drainage was estimated to be approximately **127 tonnes/year**.

- The sulfate load in waters upwelling from the #2 Shaft was then estimated because it is likely that this sulfate load represents slow leaching of oxidation products generated prior to flooding of the workings below the 1500 Level and not through the ongoing oxidation of sulfide minerals in the upper mine workings. Part of this sulfate load may actually originate as downward moving load from the workings above the 1500 level or natural sulfate minerals in the host rocks. However, the assumption that this load represents oxidation products from sources below the 1500-level was maintained to minimize the potential to overestimate actual oxidation rates. Based on measured sulfate concentrations and flowrates, the estimated upwelling load is approximately **53 tonnes/year**.

- The estimated sulfate load originating above the 1500 level (127 – 53 = 74 tonnes/year) was converted to equivalent moles of oxygen using the conventional pyrite oxidation reaction (15/8 moles of O_2 per mole of sulfate) – resulting in approximately **$1.4x10^6$ moles of O_2 per year**.

- The estimated volume of the workings ($2.6x10^7$ ft^3) (Dames & Moore, 1999), the density of air (~ 1 g/L) and the proportion of oxygen in air (21%) were used to estimate the total quantity of oxygen in the workings – **$4.8x10^6$ moles of O_2.**

The above calculation indicates that the mass of oxygen consumed by oxidation is of the same order-of-magnitude as the mass of oxygen contained in the stopes. This indicates that oxygen could be depleted in a few years if the workings could be perfectly (i.e. 100% airflow exclusion) sealed.

4.4.3 Comparison of Oxygen Demand and Airflow

A limited number of airflow measurements were obtained in April 2001 (provided in FS). Outflow velocities of up to 4.5 miles per hour were measured in the 1500 level and inflow of 5 miles per hour were measured at the 1100 level portal. However, flow rates were highly variable. Within a day, the rate at the 1100 level was measured to be much lower (0.5 mph). This range of airflows was used in the estimates.

The air supply was estimated based on a tunnel cross sectional area of 60 ft^2 (i.e. about 10 ft by 6 ft).

Based on estimated air flow velocities between 0.5 and 4.5 mph, and a tunnel cross-sectional area of 60 ft^2, the estimated oxygen supply rate is between $2.7x10^8$ and $2.7x10^9$ moles/year, compared to the estimated $1.4x10^6$ moles of O_2 per year consumed through oxidation reactions as reflected by sulfate concentrations in the 1500 level drainage.

These calculations indicate that the rate of supply exceeds the demand by two to three orders-of-magnitude, and that the efficiency of plugging would need to be better than 99.5% (low airflow) to 99.95% (high airflow) to limit the air flow to the amount required to sustain the oxidation reactions. Further reductions above these levels would theoretically result in reduced oxidation reactions within the mine, which would be expected to result in metal loading reductions.

4.4.4 Effect of Dissolved Oxygen in Mine Inflow

Water flow into the workings will also carry an oxygen load, which is estimated to be about $1/10^{th}$ of the oxygen currently consumed in the workings to generate sulfate loads observed in mine drainage. The calculation assumed that the inflow rate to the mine ($4.2x10^8$ L) is comparable to discharge and is oxygen saturated at 10 mg/L. The value of 10 mg/L is conservative because processes in soils on surface above the mine will remove oxygen from water before it enters the workings. This calculation indicates that dissolved oxygen could sustain up to about 10% of the current oxidation rate and loading from the mine.

4.4.5 Summary of the Evaluation of Airflow Restrictions

Based on the calculations, it is concluded that:

- If all airflow into the workings could be stopped (i.e. 100% plugging efficiency), oxygen could be depleted in a few years.
- Based on the limited number of airflow measurements at the mine entrance, a plug or plugs would possibly need to reduce airflow by at least 99.5% to limit oxygen demand to less than that needed to sustain current estimates of oxidation rates.
- Oxygen dissolved in water infiltrating into the mine places an upper bound on possible load reduction at 10% of the current load.
- Because the actual efficiency of future air-flow restrictions at the Holden Mine is not known, the conservative assumption is to assume zero effect of air flow restrictions on metal loads from the mine.

4.5 Scenario 3 – Effect of Flooding

4.5.1 General Background

In general, it is expected that flooding of the Holden mine workings using a water tight bulkhead would initially result in acidic leaching of soluble primary and secondary minerals (i.e. acid sulfate salts) from the fractured mine walls, backfill in the stopes and remaining ore in the stope drawpoints and ore passes. Dissolution of these minerals is not instantaneous, and it can be expected that over time, dissolved metal concentrations will slowly decrease due to flushing out with repeated flooding. Additionally, some regeneration of salts would be expected due to oxidation of the rock surfaces re-exposed during annual draw down cycles.

In the long term, reducing conditions may eventually develop in parts of the mine that remain perpetually flooded. This may result in reductive dissolution, a process by which minerals formed under oxidizing conditions (for example, iron oxyhydroxides) become unstable. However, these effects are not expected to be significant if the workings are drained on an annual basis.

The worst case for water chemistry during flooding is that sufficient oxidation products will be present to result in dissolved metal concentrations close to the solubility limits of the oxidation products. Actual concentrations may be lower than the solubility limits due to the effects of kinetics of mineral dissolution and dilution.

4.5.2 Holden Mine Background

The option under consideration would include annual flooding and drain down of the workings between the 1500 and 1100 levels to equalize seasonal flows. The mine ceased operations in 1957, therefore the workings above the 1500 Level have been exposed to weathering for at least 45 years.

Inspections of portions of the 1500 Level, 1100 Level and 300 Level indicate the following features (SRK 2001a):

- Red-brown precipitates have formed downstream of the #2 Shaft in the 1500 Level.
- White-blue precipitates from the 1100 Level were tentatively identified as the basic copper aluminum sulfate minerals woodwardite and chalcoalumite. Similar precipitates were observed at other locations.
- Amorphous orange brown precipitates described as "limonite" were observed as deposits from flowing fractures in the 1100 Level.
- Lowest pH water (3.4) was observed in drainage from raises in the 1500 level. These waters were dominated by sulfate, aluminum, calcium, magnesium and zinc. Iron concentrations were relatively low.

MINTEQA2 (Allison *et al* 1991) modeling of these waters indicated that solution chemistry is probably controlled by formation of basic aluminum sulfates and ferric hydroxides. Near neutral pH waters containing elevated copper concentrations in the 1100 level also indicated that basic copper carbonates and sulfates were possibly also present.

Large deposits of acid sulfate salts were not observed. The inability to access most of the workings does not preclude the presence of these salts in unleached portions of the workings.

The above observations indicate that water flooding the workings will interact with a variety of different minerals, though mostly of types that would be expected to be buffer pH above 4.

4.5.3 Mine Flooding Data from Other Sites

Case Studies

The primary relevant data source for comparison to the proposed flooding of the Holden Mine is the Britannia Mine located near Vancouver, British Columbia, Canada. As described in Section 4.3.2, this mine has similar geological, topographical, geometric, climatic and hydrogeological features to the Holden Mine.

In 2001, the Province of British Columbia initiated a project to remediate acid rock drainage from the mine which currently discharges directly without treatment to Howe Sound. This project included a proposal to use the mine workings to equalize strongly seasonal flows and optimize the sizing of a water treatment plant in a similar fashion to that proposed for Holden. As part of the investigations of this proposal, a flooding trial was designed to evaluate the stability of an existing concrete plug; to predict the available water storage volume in the workings; and to predict the effects of flooding on portal drainage water quality.

To prepare for permitting of the flooding trial, available information was gathered from other mines where the workings had been flooded. The primary purpose of the review was to find datasets that indicated mineralogical controls on water chemistry. The data obtained are summarized in Tables 3 and 4, and include an earlier flooding trial of the Britannia Mine completed in 1983.

The principle sources of monitoring data on mine flooding, other than Britannia Mine are shown in Table 3. Some of the more relevant case studies include:

- **The Løkken Mine, Norway**. This massive sulfide copper mine was allowed to flood by installation of plugs inside the workings (SRK 1991). Water in a shaft in the flooded part of the mine was monitored in the 1980s and early 1990s. The data are not analogous to repeated flooding and drain down because the water has remained in the shaft.

  The earliest flooding data from the Løkken Mine showed that deeper water in the shaft was generally strongly acidic (pHs as low as 2.3) with high sulfate, aluminum and ferrous iron concentrations (SRK 1991). MINTEQA2 calculated near chemical saturation for H-jarosite (K and Na were not reported), melanterite, gypsum and basic aluminum sulfates for the most concentrated waters. Maximum copper and zinc concentrations (157 mg/L and 4130 mg/L, respectively) did not indicate chemical saturation. Long term monitoring has shown increase in pH (minima of 4.3) and slow decrease in sulfate, iron, aluminum, copper and zinc concentrations (Arnesen et al. 1991).

- **Coal mines in the Pittsburgh Seam**. Flooded workings were monitored at several locations over a period of up to 14 years (Perry 2001 and Donovan et al 1991). The data provide indications of the effects of flooding and the onset of reducing conditions after prolonged flooding. Again, the workings were not drawn down at this site.

  Monitoring of flooded coal mines in the Pittsburgh Seam showed that mine pool waters were initially acidic ($pH<5$) and oxidizing (average Eh 511 mV).

  Long term monitoring reported by Perry (2001) indicated near neutral pH and low Eh (-170 mV). Sulfate and iron concentrations increased, and MINTEQA2 indicated that iron occurred completely (>>99.9%) in the ferrous form. Donovan et al (1991) reported that pH also increased to 6.6 (on average) but that concentrations of major components (including iron) decreased.

Table 3. Available Water Quality Data from Flooded Mines

		Løkken Mine Shaft			Keystone Coal Mine[3]		Lily/Orphan Boy Shaft[4]	Kings's Mine[5]	Pittsburg Seam Mines[6]		Pittsburg Seam Mines[7]	
		1986[1]		1991[2]	West French Drain	Voids			Juvenile	Mature	1 Year	14 Years
		Minimum	Maximum	490 Level	Median	Median			Average	Average	Average	Average
pH		5.35	2.3	4.29	3.99	3.31	3	2.73	3.3	7.3	4.4	6.6
Eh	mV	-	-	-	-	-	-	-	511	-170	-	-
Sp. Cond	µS/cm	-	-	2856	-	-	-	-	-	-	-	-
Sulphate	mg/L	340	74200	56000	1074	840	277	1044	2050	3185	7000	1445
Al	mg/L	323	1362	708	12.6	9.6	9.69	39.7	30	0.04	20.6	0.2
As	mg/L	-	-	-	-	-	1.07	-	-	-	-	-
Cd	mg/L	0.0044	0.72	0.15	-	-	0.33	0.07	-	-	-	-
Ca	mg/L	88	600	475	224	162	-	51.7	340	305	371	142
Cu	mg/L	0.31	157	0.42	-	-	0.32	16.4	-	-	-	-
Fe	mg/L	1.63	25700	19800	69.4	60.3	27.7	166	45	138	931	87
K	mg/L	-	-	-	-	-	-	-	6	13	12	5.6
Pb	mg/L	-	-	-	-	-	-	-	-	-	-	-
Mg	mg/L	17.5	3100	2520	69.5	53.8	-	42.9	134	103	200	49
Mn	mg/L	-	-	-	12.8	5.9	6.21	1.45	-	-	15.8	1.3
Na	mg/L	-	-	-	8.2	13.1	-	-	139	1330	2007	774
Zn	mg/L	1.54	4130	2994	-	-	26.1	37	-	-	-	-

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Table 4. Water Quality Data for the Britannia Mine

Parameter	Unit	1995 to 2001 Drainage from 4100 Level (Unflooded)		Mine Flooding 1983 Peak Concentrations		Mine Flooding 2002 Peak Concentrations	
		Average	Max	September	December	April/May[1]	June to August
pH	s.u.	3.8	3.2	3.1	3.5	3.3	3.1
Eh	mV	-	-	-	-	660/815[2]	565/730
Sp. Cond	µS/cm	2062	3180	-	2500	3150	3440
Sulphate	mg/L	1441	1660	-	1700	1790	2780
Al	mg/L	26.6	40.3	35.3	30.6	52.2	84.6
As	mg/L	-	-	-	-	<0.05	0.06
Cd	mg/L	0.09	0.15	0.11	0.14	0.135	0.133
Ca	mg/L	387	517	478	419	444	496
Cu	mg/L	17.1	25.4	22.5	18.3	41.4	64.2
Fe	mg/L	4.4	12.7	56.1	17.1	12.8	72.4
K	mg/L	1.2	3	-	-	3	3
Pb	mg/L	0.15	0.6	0.09	0.22	0.06	0.11
Mg	mg/L	69	100	115	83.4	110	193
Mn	mg/L	4.2	6.3	9.2	7.52	8.09	14.2
Na	mg/L	9.4	13	-	-	13.6	22.7
Zn	mg/L	20.6	29.8	27.3	28.1	29.4	28.3

Notes
1. The first sample collected during this drain down period had lower pH and higher acidity than all other samples in the first flooding. The results are not included because they were believed to have originated from flooding of a ore pass near the plug.
2. Eh values are minimum and maximum values

Britannia Mine

- **Background**

  Production at the Britannia Mine ceased in the 1970s. A concrete plug was installed in the lowest draining mine level in the late 1970s. In the early and mid-1980s, the water level was raised several times; flooding the lower workings, and water quality was monitored sporadically. Through the 1990s and early 2000s, the mine was free-draining. Access to the mine workings is very limited.

  Recent drainage from the Britannia Mine under free-draining conditions has had a consistent pH of less than 4 (Table 4). Water chemistry is dominated by sulfate and calcium. Other significant components are aluminum, magnesium, zinc and copper. Drainage chemistry prior to flooding of the lower workings was complicated by operational pumping of workings below sea level and engineered efforts to re-direct all mine water to the lowest level. MINTEQA2 indicates that current sulfate concentrations are probably controlled by the dissolution of gypsum which is a component of the mineralization. Aluminum concentrations indicate that basic aluminum sulfate precipitates are probably present in the workings along with ferric hydroxides.

- **1980s Flooding**

  Flooding in the 1980s resulted in decrease in pH and small increases in several elements (Table 4). The exception was iron, which at peak concentrations during flooding was an order-of-magnitude greater than the recent concentrations shown in Table 4.

- **2002 Flooding**

  The 2002 flooding trial was conducted in two phases. The first phase was designed to partially flood the workings mainly to test the monitoring systems and collect geochemical data under slow flooding conditions prior to snowmelt. The workings were flooded to an elevation of approximately 102 m (335 feet) above the concrete plug in the 4100 Level of the mine. The second phase was started after the peak flow conditions had passed in late May. Although not originally intended, the workings had to be partially drained in late June due to a heavy rainfall warning and lower than expected storage capacity. Flooding resumed in mid-July and a final flood level of 250 m (820 feet) above the 4100 Level was reached in mid-August. Final draindown was completed by late September.

  Water samples were collected every other day during the draindown periods of each flooding trial. A consistent pattern emerged during all three flood and draindown cycles in 2002 (Figure 7). During draindown, pH decreased, and sulfate and metal concentrations increased. Metal and sulfate typically reached peak concentrations then decreased. The pattern was consistent with a conceptual model developed prior to flooding which predicted that water quality produced during draindown would worsen with the arrival of water affected by contact with residual broken ore in the stopes. Maximum concentrations of metals and sulfates were observed when water from the highest workings arrived at the plug.

Detailed examination of the draindown chemistry indicated that iron showed the highest maximum concentrations relative to average pre-flood conditions (72 mg/L compared to 4.4 mg/L) , followed by copper (64 mg/L cf. 17 mg/L), aluminum (85 mg/L cf. 27 mg/L) and manganese (14 mg/L cf. 4 mg/L). Iron concentrations generally increased as oxidation-reduction potential decreased. The increase in sulfate and calcium was apparently limited by the solubility of gypsum. Zinc and cadmium concentrations increased only slightly possibly because the occurrence of sphalerite is limited in some areas of the workings.

The overall conclusion from monitoring of flooding trials was that the observed effects of pH depression and increases in sulfate and metal concentrations were consistent with the expected leaching of acidic salts produced by oxidation of sulfide wastes. The results also showed that severe water quality of the type observed in some flooded mines (for example, Løkken Mine) is not likely, probably due to the large volume of the workings, dilution effects and limited contact time.

A limitation of the project was that the effects of repeated flooding and draindown, as would likely occur during operation of the water treatment plant at Holden, could not be evaluated. It was speculated that sulfate, aluminum, iron and manganese concentrations would persist for several years or even decades because the solubility of these ions in the workings is probably controlled by secondary minerals. Copper concentrations were expected to decrease in a few years, although collapse caused by repeated flooding and draindown could result in higher concentrations due to exposure of fresh mineral surfaces to oxidation. As shown in Figure 7, the flooding did not have a significant effect on zinc concentrations. Concentrations of both zinc and cadmium were expected to remain stable due to the similar geochemical behaviour of these metals.

4.5.4 Prediction of Effects of Flooding at the Holden Mine

Initial Flush Water Chemistry

The conservative approach to prediction of water chemistry for the flooding of the Holden Mine is to assume that readily soluble sulfate salts are present and will dissolve during flooding, as observed at Britannia Mine. Water quality was estimated using the method described below then compared to the poorest quality water observed in the Holden Mine. Low pH (3.4) water was observed flowing at a low rate down a raise into the 1500 Level.

The overall equation used to develop water quality estimates for peak solute concentrations in the Holden Mine ($C_{Holden,peak}$) during flooding using the Britannia Mine data is:

$$C_{Holden,peak} = C_{Holden,baseline}(1+t_{Holden}.A_{Britannia})$$

Where: $C_{Holden,baseline}$ = Concentrations in free-draining flow from the mine.
t_{Holden} = duration of exposure of Holden workings since mining (57 years).
$A_{Britannia}$ = Annual accumulation rate estimated from flooding of the Britannia workings given by:

$$A_{Britannia} = (C_{Britannia,peak} - C_{Britannia,baseline})/(t_{Britannia} . C_{Britannia,baseline})$$

In other words, the rate of accumulation indicated by the increase in concentrations observed during flooding of the Britannia Mine is applied to Holden Mine. Two different episodes of flooding have occurred in the Britannia Mine:

- Flooding the Britannia Mine in the 1980s occurred four year after the mine stopped operating and a concrete plug was installed in the lowest free draining level ($t_{Britannia}$ = 4 years)
- The two 2002 flooding trials inundated the workings previously flooded in 1983 ($t_{Britannia}$ = 19 years – 1983 to 2002)

Table 4 shows that peak concentrations of most parameters were greater during the Britannia Mine 2002 flooding trial than they were in the 1980s. However for most parameters the estimated rates of accumulation for the 2002 data were lower. Although this outcome was predicted because the accumulation period was better defined for the 2002 data, the actual rates of accumulation are subject to significant uncertainties. The estimated higher accumulation rates for copper and aluminum in 2002 may imply that these metals are subject to mineralogical solubility controls, which would be consistent with the formation of copper-aluminum minerals of the types that have been found in the Holden Mine workings.

The results of using the 1980s and 2002 Britannia Mine flooding trial data to predict concentrations in the Holden Mine workings are shown in Table 5. Two predictions were completed.

The "Best Estimate" was based on the first flooding peak in the Britannia Mine in April and May 2002. The flood level reached for the first peak in 2002 (102 m) was partially to completely inundated four times in the 1980s. This indicates that the mine surfaces were thoroughly flushed in the 1980s. Using the 2002 data resulted in generally lower concentrations than those predicted using the 1980s data (with the exception of copper which was slightly higher). With the exception of sulfate, estimated concentrations were similar to those observed in the Holden Mine Raise Water.

Table 5. Summary of Estimates for Flooding Water Chemistry Using Different Sources

		Britannia Mine Flooding Trials Monitoring Data						Holden Mine						
		1980s		April and May 2002		June to August 2002		Typical 1500 Level Baseline	Flooding Concentration Estimates Using Britannia Data			Holden Mine 1500 Level Raise Water	Recommended Estimated Concentrations During Flooding	
Parameter		Peak minus Baseline[1]	Peak-Baseline (% per year) over 4 years	Peak minus Baseline[1]	Peak-Baseline (% per year) over 19 years	Peak minus Baseline[1]	Peak-Baseline (% per year) over 19 years	P1 (May 9, 2001)	1980s Flooding	April and May 2002 Peak	June to August 2002 Peak		Best Estimate	Reasonable Worst Case
pH	s.u.							4.9				3.4	3.4	3.4
Sulphate	mg/L	259	4%	349	1%	1339	5%	420	1269	720	1570	480	720	1570
Al	mg/L	8.7	8%	26	5%	58	11%	4	21	17	33	30	17	33
Cd	mg/L	0.02	6%	0.046	3%	0.044	3%	0.05	0.18	0.13	0.12	0.172	0.1	0.17
Ca	mg/L	91	6%	57	1%	109	1%	79	287	113	144	99.7	113	144
Cu	mg/L	5.4	8%	24	7%	47	14%	2.2	10	12	20	8.3	12	20
Fe	mg/L	51.7	294%	8	10%	68	81%	0.3	41	2	14	1.8	2	14
Mg	mg/L	46	17%	41	3%	124	9%	9.4	80	26	59	22	26	59
Mn	mg/L	5	30%	4	5%	10	13%	0.44	6	2	4	1.04	2	4
Zn	mg/L	6.7	8%	9	2%	8	2%	9	44	21	20	33	21	33
Calculated Acidity	$mgCaCO_3/L$	-	-			-	-	41	305	135	277	223	135	277

Notes:
1. Britannia base line in all cases was the 1995 to 2001 monitoring data indicated in Table 4

The “Reasonable Worst Case” was calculated using the second (June and August) 2002 flooding peak in the Britannia Mine and the concentrations measured in the Holden Mine Raise Water. The higher of the two concentrations is shown as the Reasonable Worst Case in Table 5. The flood level reached in the second flooding of Britannia Mine was inundated twice in the 1980s and therefore probably represents considerably more than 19 years accumulation of salts due to incomplete flushing of salts in the 1980s. In this case, predicted concentrations of some parameters are somewhat higher than the Raise Water with the exception of cadmium and zinc. These elements occur together in sphalerite, which may have be more abundant at Holden Mine than at Britannia Mine.

Long Term Effects

The effect of long term filling and drain down should be to remove oxidation products accumulated prior to initial flooding. Eventual stable conditions should reflect oxidation of the workings during the periodic exposure between filling cycles.

No actual examples of this type of approach with useful monitoring data are available. The Britannia Mine was subjected to a series of cycles in the 1980s but monitoring did not include major parameters such as iron. After the first two flooding cycles, pH remained depressed. Subsequent flooding cycles did not flood to the same elevation and pH reached current levels after a few years.

The Løkken Mine has shown slow recovery, though probably because the water is only slowly being flushed. A better indication is perhaps provided by the Pittsburgh Seam coal mines. After 14 years, mine water was non-acidic, and iron concentrations had decreased by an order of magnitude. This suggests that the time frame for flushing of acidity and high metal loads and return to pre-flooding conditions should be of the order of years, rather then decades.

Although flooding cycles would be expected to release additional oxidation products generated between floods, these products are expected to be removed by interaction with the rock walls and formation of secondary minerals. Long term attenuation effects are expected to be similar to that estimated for Scenario 1. If the periodic flooding results in leaching of pockets of reactive sulfide minerals that are not currently on a flow path, intermediate-term chemistry may be worse than currently observed. Based on the ore removal methods used at Holden and the lack of tailings backfill above the 1500 Level, this effect seems unlikely.

4.5.5 Summary of the Mine Flooding Evaluation

Recommended best estimates of the chemistry of the initial flush of the Holden Mine workings are shown in Table 5.

Based on a review of data available in the literature, metals concentrations in the 1500-level drainage are expected to recover to current levels over a period of several years.

4.6 Conclusions Related to Long-Term Metals Loading from the Underground Mine

The geology and geochemistry of the Britannia Mine is similar to that of the Holden Mine, and an evaluation of monitoring data from Britannia is useful in evaluating long term attenuation of metals for the underground workings at the Holden Mine site. The observed decay in release of copper load from the Britannia Mine is consistent with scale effects observed for laboratory and field testing.

Based on a review of available data, a conservative decay constant of -0.0001 $week^{-1}$ was selected for metals loading in the Holden Mine portal drainage. Using this decay constant, current metal loads discharging from the workings may are predicted to decrease by 50% over the next 60 years.

Consideration of the two remedial alternatives indicated the following:

- **Airflow Restrictions**. Plugging of the workings to reduce oxygen availability would need to be very efficient (99.5% or better) to reduce oxygen levels below that required to sustain the oxidation reactions. Dissolved oxygen in water flowing into the mine is estimated to be capable of sustaining about 10% of the current load discharging from the mine.
- **Hydrostatic Bulkheads.** A review of the literature on mine flooding indicates that metal loadings would likely increase in the short term due to flushing of soluble salts; however, concentrations of metals in drainage would probably decrease to current levels in a few years.
- Long term attenuation of metal loads is predicted to follow the same general trend regardless of the remedial alternative (airflow restrictions and hydrostatic bulkheads).

5 Tailings Piles Predictions

5.1 Site Geochemical Model

5.1.1 Introduction

The Holden tailings contain elevated sulfur concentrations mostly in the form of pyrite. Laboratory testing performed in 2001 and 2002 as part of a comprehensive geochemical investigation indicated that the tailings piles are already acidic, or are potentially acid generating. The acid buffering capacity of the tailings is also very low (SRK 2002 and 2003c). In kinetic tests on potentially acid generating tailings, acid generation was observed to occur rapidly within weeks of exposure to atmospheric oxygen and water (SRK 2003c).

Due to the configuration of the tailings piles, oxygen access to the tailings primarily occurs by diffusion along the exposed surfaces, which include the top and side slopes. As a result, oxidation occurs along a front roughly parallel to these surfaces. The rate of progression of the oxidation front is controlled by a number of factors, the most important of which are the grain size distribution, the degree of saturation and the reactivity of the tailings.

In particular, grain size varies in the Holden tailings piles and this, in part controls the saturation profile in the tailings. The margins of the piles served as containment dikes and are composed of the coarsest fraction of the tailings. Within the piles, considerably finer-grained tailings ("slimes") were deposited.

For the purpose of modeling, the general assumption is that the overall mineralogical characteristics of the different piles are similar. The similarity of features, such as the depth of oxidation in the piles discussed in the following sections supports this assumption.

5.1.2 Field Observations

Three distinctive geochemical layers were observed in 18 test pits within the tailings piles during the 2001 geochemical investigation (Figure 8):

- **"Oxidized Layer"**. In this layer, shallow surface tailings are stained orange by oxidized iron and contain very low concentrations of pyrite. The lower boundary of this layer is defined as the oxidation front. Undisturbed tailings typically showed about 2 to 3 ft of strongly oxidized tailings in fine sand and silty tailings. Strongly oxidized tailings of up to 7 ft were encountered in test pits located near the perimeter embankments of coarser tailings. The pH of these tailings was below 4.0.

- **"Acidic Layer"**. Deeper mostly unoxidized grey tailings are acidic due to acid produced along the oxidation front. Acid neutralizing minerals have largely been depleted and sulfide minerals have not been oxidized in this layer. The lower boundary is defined as the acid front. The 2001 investigation showed that the acid front extends to a depth of about 15 ft in the fine tailings. The median pH for samples from this layer was 5.0.

- **"Neutral Layer"**. Deep unoxidized tailings are not acidic due to residual acid neutralization potential (carbonate minerals) and the sulfide minerals have not been oxidized in this layer. The layer is referred to as the 'neutral layer'. Where this third layer exists, the lower boundary is at the base of the tailings. The median pH of this layer was 6.6.

In the coarse tailings, located along the downstream edges of the tailings piles, the depths of the oxidation and acid fronts are deeper than in the finer-grained material due to greater oxygen penetration. The acid front in these areas is expected to have penetrated to the base of the tailings, which results in acidic seepage from these portions of the tailings piles.

In the fine tailings, the acid front has probably only penetrated to the base of the tailings along the southern or upgradient margins of the piles adjacent to the valley sides where the tailings are relatively shallow. The majority of the total tailings contained in the piles are currently non-acidic.

Based on the field observations, three principal processes are expected to control the long-term release of metals loads from the tailings:

- the breakthrough of the acid front to the base of coarse tailings;
- a gradual slowing of the progression of the oxidation and acid fronts and release of metals due to oxygen diffusion rate limitations in the fine tailings; and
- the subsequent similar breakthrough effect within the fine tailings.

The conceptual site geochemical model described below synthesises overall observations from the site and laboratory testing and provides a basis for the subsequent quantification of effects and prediction of long term attenuation of loadings.

5.1.3 Conceptual Geochemical Model

The results from the field and laboratory investigations suggests that sulfide mineral oxidation in the Oxidized Layer occurs according to the following reaction:

$$2FeS_2(s) + {}^{15}/_{2}\,O_2 + H_2O \rightarrow Fe_2(SO_4)_3 + H_2SO_4\,(aq)$$

This reaction indicates that pyrite is oxidized to a soluble ferric iron sulfate salt and sulfuric acid rather than an insoluble ferric hydroxide ($Fe(OH)_3$).

Trace element sulfide minerals such as sphalerite also are oxidized concurrently as follows:

$$ZnS + 2O_2 \rightarrow ZnSO_4(aq)$$

Acid generated from sulfide oxidation migrates out of the Oxidized Layer into the unoxidized tailings below where it reacts with and dissolves any available acid buffering minerals. The zone of depleted buffering minerals is the Acidic Layer. Below this layer, acid buffering minerals remain and the pH of the tailings is near neutral.

Under the acidic conditions in the Oxidized and Acidic Layers, the solubility of some components (such as copper and aluminium) is at their highest due to the strong control exerted by pH. This means that when leached from the upper two layers, these metals migrate only as far as the current location of the acid front and then precipitate as secondary mineral phases in the Neutral Layer. As the acid front migrates downward, the stored secondary minerals are re-dissolved and precipitated at greater depth below the acid front. This mechanism results in low concentrations of these components in seepage under current conditions because they are attenuated within the tailings. However, when the Acid Front breaks through the base of the tailings, the stored metal load is released rapidly due to the lack of downstream attenuation capacity. An implication of this process is that greater loads are likely to be released by acid breakthrough from thicker piles, and therefore that the geometry of the piles is an important consideration for modelling.

In summary, metal release from the tailings piles occurs through the following processes:

- **Oxygen Entry**. Oxygen enters the pores of the tailings from the atmosphere by diffusion.
- **Oxidation of Sulfide Minerals**. Sulfide minerals in the tailings are oxidized by oxygen in the air. As the oxygen reacts with the minerals, it is depleted from the pore gases. The depth of oxygen penetration determines the depth of the oxidation front at any time.
- **Acid and Metal Release**. Oxidation of iron pyrite produces acidic iron sulfate salts. Metal sulfates are also released by oxidation of trace cadmium, copper and zinc sulfide constituents.
- **Transport of Acidity and Metals**. Infiltrating water dissolves the metal sulfate salts and transports the acid, sulfate and metals to deeper tailings which contain acid neutralizing minerals. The acid neutralizing minerals are dissolved by the acid. The acid front represents the point of transition from acidic porewater to neutral pH porewater. As acid neutralizing minerals are removed the acid front advances to greater depth
- **Precipitation of Secondary Minerals**. The change in pore water pH caused by reaction with acid buffering minerals results in the formation of secondary minerals (hydroxides and carbonates) that accumulate below the acid front.

- **Re-Dissolution of Secondary Minerals**. The secondary minerals are re-dissolved as the acid front progresses downward.

- **Acid Front Breakthrough**. When the acid front reaches the base of the tailings, a rapid increase in metal loads occurs due to the lack of a neutral zone to precipitate the metals.

5.2 Overall Approach Used to Predict Long Term Trends

The purpose of this section is to provide an overview of the modeling steps in the context of the conceptual geochemical model presented in the previous section. The approach involved coupling of a number of different calculations or models to simulate the different processes. The overall modeling approach is shown in Figure 9. The subsequent section provides more technical detail on the modeling methods and the various inputs.

Step 1. Infiltration Modeling

The geochemical processes are driven by the influx of oxygen by diffusion, which is controlled primarily by the degree of saturation of the tailings. That is, the more water in the tailings pore space, the slower the rate at which oxygen can enter the tailings. Therefore, it was necessary to first calculate the moisture content profile through the tailings to predict the penetration of oxygen into the tailings. This modeling is performed using commercial software (HYDRUS-2D) which used as inputs:

- daily precipitation data;
- evapo-transpiration;
- stratigraphy; and
- hydraulic conductivity of the tailings.

The infiltration to, and moisture content profiles of, the coarse and fine tailings were assumed to be different due to the difference in their hydraulic conductivities. The coarse and fine tailings were assessed separately.

The outputs from this step are moisture content profiles of the coarse and fine tailings.

Step 2. Oxygen Transport and Prediction of Sulfide Mineral Depletion

The moisture content profiles derived in Step 1 were used to calculate the effective oxygen diffusion coefficient, which is the ratio of the rate of oxygen transport into the tailings compared to the rate of diffusion in stagnant air. The oxygen diffusion calculation indicates the rate at which oxygen can be delivered to the sulfide grains and take part in oxidation reactions. It therefore determines the location of oxidation front, which in turn allows the rate of depletion of sulfide minerals to be estimated.

In addition to the oxygen diffusion coefficient inputs to the calculation include:

- a parameter indicating the rate of sulfide oxidation (reaction rate constant); and
- the initial sulfide content of the tailings.

The oxygen transport calculations for the coarse and fine tailings were assessed separately due to the differences in their moisture content profiles.

The output from this step is the rate of oxidation of sulfide minerals.

Step 3. Acid Generation Rate and Release of Metals

The rate of oxidation allows the rate of acid generation to be calculated from the ideal chemical reaction for the oxidation of iron sulfide. Metal release rates are estimated based on the ratio of metal release to acid generation observed in laboratory tests. The results of both calculations are loads rather than concentrations. The concentrations of acidity and metals in the pore water are obtained by dividing the loads release by the rate of infiltration. The resulting water quality is referred to as 'acidic water' or in the following discussions as Type A water.

Once the sulfide minerals have been depleted from the oxidation layer, it is assumed that the porewater would revert to circum-neutral pH. This water is referred to as Type D.

The output from this step is the chemistry of acidic water originating from the oxidized layer.

Step 4. Progression of the Acid Front

The acid generated in the oxidized layer dissolves the acid neutralization potential in the underlying tailings as it moves downward. In addition to results from the previous step, the calculation requires the average available neutralization potential of the 'fresh' (unoxidized and unreacted) tailings.

The output from this step is the position of the acid front at any time.

Step 5. Neutralization of Acidic Water and Precipitation of Metals

Below the acid front, the pH of the pore waters increases to neutral conditions. As a result, metals in the pore water are precipitated as secondary minerals and the metal concentrations in the solution decrease. This process is modeled partly using chemical equilibrium software (MINTEQA2), which calculates the resulting metal concentrations. Observed metal concentrations in groundwater monitoring wells were also used to indicate pH neutral groundwater. The resultant porewater quality calculated by this step is referred to as 'neutralized pore water' or Type B water.

Step 6. Accumulation of Precipitated Metals Below the Acid Front

The difference in the concentration between the acidic water (Type A) and the neutralized pore water (Type B) is the amount of metal that is precipitated as secondary minerals. These minerals are generally less soluble at neutral pH, than under acidic conditions. Therefore, as the acid front progressively moves down, these minerals are assumed to completely re-dissolve. The resulting acidic water with higher metal concentrations than Type A is referred to as Type C.

Once the acid front has 'passed through' the base of the tailings column, the concentrations revert to Type A Acidic Water.

Step 7. Solute Release from the Tailings Piles

In summary, the calculations described above result in four different categories or types of water as illustrated in Figure 10. These are as follows:

- **Type A** is acidic water released from the active oxidation front. The rate at which metals are released from this front is equal to the rate at which they are generated by progression of the oxidation front.

- **Type B** is pH neutral water released from the base of the pile in the area where neither the acid or oxidation fronts have broken through.

- **Type C** is acidic water containing metals dissolved by the acidic water as it re-dissolves stored secondary minerals. This water is observed as the acid front breaks through the base of the tailings.

- **Type D** is neutral pH water from the oxidized layer that no longer contains sulfide minerals.

The above calculations are completed for columns of tailings representing a unit surface area, i.e. 1 ft^2 columns extending the depth of the tailings pile. The piles have different overall heights, and the depth of tailings varies within each pile according to the original natural topography. To account for this effect in the modeling, curves were developed to indicate the area of the piles with a given thickness. These curves allow the volume of each type of water to he calculated and combined to yield the total loading from all three piles.

As indicated above, the difference in grain size for the fine and coarse tailings resulted in different moisture content profiles. The above steps were carried through separately for the two types of tailings but the modeling approach is identical.

5.3 Detailed Description of Modeling Methods and Inputs

5.3.1 Step 1 - Infiltration Modeling

The documented physical characteristics of the Holden Mine tailings and the site meteorological record were used to estimate infiltration and the degree of saturation of the tailings. The HYDRUS-2D model (Simunek et al., 1999) was used to evaluate the saturation profile for base case conditions. The HYDRUS-2D model is an accepted model widely used for analysis of water flow and solute transport in variably saturated porous media. The saturation profiles developed respectively for the fine and coarse tailings were then adopted for all other scenarios. The initial infiltration modeling was undertaken by URS, using the USEPA HELP Model (URS 2002).

Precipitation

The average annual precipitation for Holden Village is 38.6 inches as indicated by URS, which is based on data collected between 1962 and 1997. Information available on the internet (http://www.wrcc.dri.edu/cgi-bin/cliMAIN.pl?wahold) indicated an average annual precipitation of 40.27 inches. Since the HYDRUS-2D model required daily data as an input, available data from 1982 was selected as being closest to representing an average year for precipitation. It had 42.26 inches of precipitation.

Evaporation and transpiration

The HYDRUS-2D simulations were carried out using the potential evapo-transpiration of 17.86 inches provided by URS.

Stratigraphy and physical properties

The stratigraphy consists of 6 inches of sandy gravel overlying the tailings. The hydraulic properties of both materials are based on the laboratory testing (SRK 2002). The hydraulic properties were fitted to the Van Genuchten functions used in HYDRUS-2D. The properties of the tailings are based on sample “URS-TP1-tp4 4.0 ft” and the sandy gravel on “TP1-tp3 3in”. The saturated hydraulic conductivity was assumed to be 10^{-5} m/s for the sandy gravel and two values (10^{-6} and 10^{-7} m/s) were used for the tailings.

The coarse nature of the surface sandy gravel would probably cause reduced quantities of runoff to occur, thus favouring infiltration.

Infiltration

A range of infiltration values can be estimated simply by using the annual averages of precipitation and potential evaporation:

- If it is assumed that the potential evaporation is 100% effective, the infiltration would be in the order of 24 inches per year (0.6 m/year or 1.7 mm/day).
- If it is assumed that there is no runoff and that evapo-transpiration represents 17% of the total precipitation (URS HELP modelling predictions), the infiltration would be in the order of 35 inches per year (0.9 m/year or 2.4 mm/day).
- If it is assumed that 9% of the precipitation is lost to runoff and 17% to evapo-transpiration, the infiltration would be in the order of 30 inches per year (0.8 m/year or 2.2 mm/day).

Those approximations indicate that the average annual infiltration would likely be greater than 24 inches and could reach 35 inches.

The HYDRUS-2D simulations which included evaporation showed that infiltration would be in the order of 32 inches per year with a saturated hydraulic conductivity of 10^{-6} m/s for the coarser tailings and 30 inches per year with a saturated hydraulic conductivity of 10^{-7} m/s for the finer tailings. The corresponding average moisture content profiles are shown in Figure 11.

5.3.2 Step 2 - Oxygen Transport and Prediction of Sulfide Mineral Depletion

The rate of oxygen transport into the tailings by diffusion is governed by Fick's law. Integrating the one-dimensional form of Fick's Law and incorporating a first order oxygen consuming reaction leads to the conservation equation:

$$\frac{dC}{dt} = \frac{dC}{dx}\left(D \frac{dC}{dx}\right) - rC$$

where C is the oxygen concentration, t is time, D is the effective diffusion coefficient, x is depth and r is the reaction rate constant. A numerical solution for this equation was coded in Visual Basic in an Excel spreadsheet.

The effective diffusion coefficients were estimated using the equation presented by Erberling *et al.* (1993) and assuming saturations of 60 % and 85 % respectively for the coarser and finer tailings. The corresponding estimated effective diffusion constants are 2.4×10^{-7} m^2/s and 7.8×10^{-9} m^2/s respectively.

As noted previously, oxygen and water are required for oxidation of the sulfide minerals (pyrite) in the tailings to produce acid. Oxygen is expected to enter the tailings primarily through molecular diffusion. The rate of oxygen diffusion also depends on the rate at which the gas is consumed by sulfide mineral oxidation, which is described by the reaction:

$$2FeS_2(s) + {}^{15}/_{2}\, O_2 + H_2O \rightarrow Fe_2(SO4)_3\,(s) + H_2SO_4\,(aq)$$

The consumption of oxygen within the piles was estimated using the above equation and data obtained from the fall 2001 humidity cell testing data (SRK 2003c).

The average reaction rate constant for grey tailings was calculated from the humidity cell tests as $4.2 \times 10^{-6}\ s^{-1}$. An initial sulfide content of 3.1 % was assumed (SRK 2002). Using these starting conditions, the sulfide oxidation in the tailings with time was calculated.

Conservatively, the oxygen flux rates estimated for current conditions were used to project the solute release rates and water quality for future changes. The calculations are discussed below.

5.3.3 Step 3 – Acid Generation Rate and Release of Metals

The rate of release of metals, relative to sulfur oxidation, was estimated from the fall 2001 humidity cell testing results (SRK 2003c). The metals load released and the estimated infiltration rate were then used to estimate past and future metals concentrations in tailings pile seepage.

Briefly, the calculations for oxidation and release of metals from sulfides are as follows:

- Assuming that all the oxygen that enters the tailings is consumed by sulfide oxidation (according to the stoichiometry given in the above pyrite oxidation reaction), the total sulfate generated is calculated for a period of one year, using the current estimated rate of oxygen flux into the tailings

- The average and maximum molar solute ratios calculated from the humidity cell test results (sulfate generated to metals released), as shown in Table 6 are then used to estimate the corresponding metal release from the total sulfur oxidation. These estimated values are then checked against the total mass of metal available for release. The estimated quantity of metals released are then adjusted, if necessary, so as to not exceed the total mass available.

This calculation yields the total mass of solutes generated from oxidation.

Table 6. Summary of Molar Ratios of Metals Release

Parameter	Units	Oxidation (Orange) Tailings	Shallow Grey Tailings	Deep Grey Tailings
Aluminum	mol Al/mol S	$4.2x10^{-2}$	$2.4x10^{-1}$	$3.9x10^{-2}$
Arsenic	mol As/mol S	$1.3x10^{-4}$	$3.4x10^{-6}$	$8.7x10^{-6}$
Cadmium	mol Cd/mol S	$1.9x10^{-4}$	$4.2x10^{-5}$	$9.9x10^{-5}$
Calcium	mol Ca/mol S	$5.4x10^{-1}$	$7.0x10^{-2}$	$4.2x10^{-1}$
Copper	mol Cu/mol S	$2.4x10^{-3}$	$5.0x10^{-4}$	$5.4x10^{-4}$
Iron	mol Fe/mol S	$3.4x10^{-2}$	$7.9x10^{-2}$	$1.6x10^{-1}$
Lead	mol Pb/mol S	$2.6x10^{-4}$	$6.1x10^{-6}$	$1.7x10^{-5}$
Magnesium	mol Mg/mol S	$2.2x10^{-1}$	$3.1x10^{-2}$	$7.8x10^{-2}$
Manganese	mol Mn/mol S	$1.8x10^{-2}$	$1.7x10^{-3}$	$6.5x10^{-3}$
Nickel	mol Ni/mol S	$1.8x10^{-3}$	$5.3x10^{-5}$	$1.4x10^{-4}$
Potassium	mol K/mol S	$2.5x10^{-1}$	$3.6x10^{-2}$	$9.1x10^{-2}$
Sodium	mol Na/mol S	$1.1x10^{0}$	$1.4x10^{-2}$	$4.2x10^{-2}$
Zinc	mol Zn/mol S	$6.7x10^{-2}$	$4.1x10^{-1}$	$5.8x10^{-2}$

It should be noted that the molar release ratios for the oxidized tailings tend to be high due to the relatively low sulfate concentrations. The deeper tailings released high concentrations of sulfate due to oxidation of sulfide minerals.

The sulfate and metal release is calculated in the previous step is then “dissolved” in the total annual infiltration. As noted before, all the calculations are completed on a unit surface area basis.

5.3.4 Step 4 - Progression of the Acid Front

The quantity of acid generated in the oxidized layer calculated in the previous step is used to dissolve the neutralization potential (NP) in the underlying tailings as the acid front moves downward through the pile. The assumed initial NP of the ‘fresh’ (unoxidized and unreacted) tailings is 19 kg $CaCO_3$/t (SRK 2002). Analysis of oxidized tailings showed that NP was 4.5 kg $CaCO_3$/t, which indicated that this amount remains in the tailings when the tailings have become acidic. This indicates that this portion of the NP (i.e. 4.5/19 = 24%) is not available because it is not in a naturally reactive form. The initial NP used in the calculations was therefore reduced from 19 kg $CaCO_3$/t to 14.5 kg $CaCO_3$/t to account for this observation.

5.3.5 Steps 5 and 6 – Neutralization of Acidic Water and Accumulation of Precipitated Metals Below the Acid Front

Storage of metals in the lower tailings precipitated by neutralization of acid water below the acid front was estimated based on observed metal concentrations in groundwater in contact with tailings. Metals concentrations measured in site monitoring wells during the RI (URS, 1998) that showed neutral pH conditions were used for this analysis. These stored metals were assumed to be released when the tailings were predicted by the long-term model to be fully acidified. Upper bounds on iron solubility were established using the MINTEQA2 geochemical speciation model. The controlling phases that were adopted for iron solubility included melanterite, sodium jarosite and ferrihydrite. Other solubility controlling phases included $Al(OH)SO_4$ and gypsum. No solubility controls were indicated for zinc at the calculated concentrations for neutral or acidic conditions. However, copper and cadmium were found to be solubility controlled at neutral pH conditions.

The difference between the solute release from the acidic zone and that from the neutralized zones is summed, and accumulated for the time it takes for the acid front to break through. This means that the accumulated mass increases progressively with the depth from surface of the tailings. For example, when the acid front passes through a depth of 6 ft, the mass of accumulated solute that would be released per unit surface area would be approximately double that released at a depth of 3 ft.

It should be noted that the likely sorption of solute loads in native soils beneath the tailings was not considered as part of this modeling. Therefore, loading peaks predicted for the tailings are conservative and probably over-estimate actual loading peaks that would be observed in Railroad Creek.

5.3.6 Step 7 - Solute Release from the Tailings Piles

The final step is to calculate stored solute loadings (releasing Type C water) breakthrough at the base of the tailings piles and the loadings associated with other types of waters. From the cross-sectional profiles of the tailings deposits it is evident that vertical thickness of the tailings varies from very shallow at the upstream side of the valley, to its maximum at the downstream crest. As the oxidation and acid fronts move progressively into the tailings, the surface area intersected at the base of the piles progressively increases. Since the volume of infiltration to the tailings is proportional to the surface area in plan, the volume of acidic water would be proportional to the 'upstream' surface area (in plan) that exists between acid front and the oxidation front as shown in Figure 10. To relate these to loadings (i.e. infiltration), the planimetric surface area of the base of each the three piles as a function of the depth from surface was determined. The base surface areas were corrected to the same surface elevation to allow the base surface areas of the piles to be summed to provide a total surface area. The results are shown in Figure 12. The figure contains two curves, representing the fine and coarse tailings respectively. For the development of the coarse tailings curve it was assumed that the coarse tailings zone extends inward about 10 ft from the crest of the perimeter embankments.

Using this graph, the surface area of the acid front 'exposed' at the base all three piles can be determined readily. For example, if the oxidation front in the fine tailings is at 10 ft at some time in the future. The surface area associated with the oxidation front would be about 55,000 ft^2. The infiltration associated with this area is multiplied by the Type D water quality to yield the associated solute loadings.

When the oxidation front is at 10 ft, the acid front will be at a depth of about 60 ft. The surface area at the base of the fine tailings deposit that would be acidic is equal to 1,000,000 ft^2 less 55,000 ft^2 = 945,000 ft^2. The loading from the acidic zone is then calculated by multiplying the volume of infiltration associated with this area with the solute concentrations estimated for the Type A water.

By subtraction, (i.e. total surface area less acidic and oxidation zones = 3,042,000 – 945,000-55,000= 2,042,000 ft^2) the surface area of the neutral (Type B) water is determined and used to calculate the corresponding loading.

The solute release from accumulated oxidation products at the acid front is calculated from the annualized rate of change of the acid front surface area. The annualized rate of change at a depth of 60 ft is about 20,000 ft^2 per year. This yields the surface area associated with the Type C water quality to enable calculation of the associated solute loadings.

The sum of these four estimates yields the total loading of solutes combined from the base of the three tailings piles.

5.3.7 Verification of Oxygen Transport and Reaction Rate Calculations

The calculated progress of the oxidation front can be compared to field observations of the thickness of the oxidized layer (SRK 2002) to verify the oxygen transport and reaction rate constant calculations.

The calculated progress of the oxidation front in the fine and coarse tailings is given in Figure 13. At 45 years (i.e. corresponding to 2002), sulfide is calculated to be depleted to a depth of about 3 ft in the fine tailings. This correlates well with the observed sulfide depletion in the tailings and suggests that the model may be used to predict oxygen flux in the future (Table 7). The oxygen uptake rate over the same period was predicted to decrease from about 2.7×10^{-5} to about 7.4×10^{-6} mol $O_2/m^2/s$, i.e. the current rate of oxygen flux is about 5 % of the initial rate.

The calculations completed for the coarse tailings indicate that the sulfide minerals would be depleted to depth of about 10 ft from 1957 to 2002. This ‘depth’ also applies to the face of the piles, i.e. from the perimeter face perpendicular to the surface. The oxygen uptake rate into the coarse tailings decreased from about 4.9×10^{-5} to 1.1×10^{-6} mol $O_2/m^2/s$.

Table 7. Summary of Observed Oxidation Depths in 2001

TP1			TP2			TP3		
Location	**Position**	**Oxidation Depth feet**	**Location**	**Position**	**Oxidation Depth feet**	**Location**	**Position**	**Oxidation Depth feet**
B1	Center	5.0	B1	Edge	4.5	TP1	Edge	4.9
TP1	Center	3.0	B2	Center	3.0	TP2	Edge	6.2
TP2	Center	1.0	TP1	Edge	3.1	TP3	Edge	5.3
TP3	Edge	2.7	TP2	Center	2.5	TP4	Center	2.0
TP4	Edge	2.2	TP3	Edge	3.6	TP5	Center	2.5
TP5	Center	7.5	TP4	Center	2.5	TP6	Center	2.0
TP6	Center	1.5	TP5	Center	2.5			
			TP6	Edge	4.9			

5.4 Description of Modeling Scenarios

5.4.1 Introduction

As part of their evaluation, URS identified the following potential closure scenarios for further consideration in the FS:

- **Scenario 1 (Base Case)**. The tailings are left in their current configuration;

- **Scenario 2**. The tailings are resloped to provide a gradient of approximately 3% or greater to improve runoff and reduce infiltration to about 20% of mean annual precipitation, and the current gravel cover is replaced to mitigate the windblown transport of tailings; and

- **Scenario 3**. All the tailings are consolidated within the approximate footprint of Tailings Pile #2 and capped with an engineered cover, including a top soil layer to provide frost protection and a growth medium. Under this alternative, infiltration is further reduced to approximately 5% of mean annual precipitation. In detail, the components of the cover assumed for the purpose of the SRK's work include the following:

  - Topsoil/vegetative layer - 6 inches thick.
  - Cover soil layer - 18 inches thick.
  - Infiltration collection layer - two-sided geocomposite.
  - Barrier layer - 60-mil thick, linear low density (LLDPE) geomembrane, textured on both sides.
  - Seepage control layer - two-sided geocomposite.
  - Graded tailings subgrade.

The implications with respect to acid generation and contaminant release from the tailings for Scenarios 2 and 3 compared to the Scenario 1 are provided in the following sections.

5.4.2 Scenario 2 – Re-Slope and Gravel Cover

Based on the infiltration modeling described below, the reduction in the rate of infiltration to the tailings under Scenario 2 is not expected to significantly affect the moisture content profile beyond a depth of about 12 to 18 inches from the surface of the tailings. This means that the rate of oxygen entry by diffusion may possibly increase marginally, but overall is not expected to be significantly different to that observed for Scenario 1. Since the rate of oxidation is expected to remain the same, the reduced rate of infiltration is expected to result in increased solute concentrations in the pore water of the acidic zone. As a result, the total metals loadings are not expected to change significantly.

5.4.3 Scenario 3 – Consolidation and Capping

There are three significant long-term effects that could result from consolidation of the tailings and capping:

- The face of Tailings Pile 2 would be flattened by removal of coarse tailings from this location. These tailings are likely to be either mixed with finer tailings, or layered within the bulk of the consolidated pile, which would reduce the size of the coarse tailings zone.

- Fresh and oxidized, fine and coarse, tailings relocated from Tailings Piles 1 and 3 would be mixed. The blended tailings could be considered "fresh" due to the fact that the bulk of the tailings would still be unoxidized and non-acidic. Furthermore, the unoxidized neutral tailings at depth would likely be placed last on the consolidated pile; therefore near surface tailings would be fresh.

- The cover membrane would have a significant impact on both oxygen diffusion and infiltration rates. The lower rate of oxygen diffusion, together with organics from vegetation at the surface could lead to reducing conditions within the tailings pile that may increase solubility of the stored oxidation products containing iron. However, under this alternative, the lower infiltration rates would effectively limit solute transport out of the tailings pile. It should be noted that these are long-term effects that could result following completion of consolidation and cover installation. The potential short-term effects of this scenario, consisting primarily of draindown, are not evaluated in this report.

5.5 Summary of Results

5.5.1 Scenario 1 – Current Conditions

The main results for the base case are summarized in Figures 13 and 14. Figure 13 shows the predicted progress of the oxidation and acid fronts in the coarse and fine tailings extrapolated to Year 4500 (i.e., roughly 2400 years from the present day). As described in Section 5.4.1, the modeling was found to accurately predict the current depth of oxidation, observed during the 2001 geochemical investigation.

As shown on Figure 13(a), both coarse and fine tailings are expected to show initially (i.e., between cessation of mining operations and today) rapid growth in the thickness of the oxidized layer. Figure 13(a) shows that the oxidation front in the coarse tailings is expected to result in complete oxidation to the base of the tailings piles. In contrast, the oxidation front in the fine tailings was predicted to stabilize at a depth of about 20 feet in the very long term, indicating that most of the fine tailings would not be affected by oxidation in the time frame of tens of thousands of years. This occurs because oxygen penetrates the tailings from surface by diffusion, and as the distance of the front from the surface increases, the availability of oxygen at the front also decreases. At a depth of about 20 feet, the model predicts that oxidation occurs very slowly and the front moves imperceptibly.

Figure 13(b) shows that the acid front is predicted to progress rapidly in the coarse tailings. These results indicate that the coarse tailings are currently partially acidic and are expected to become fully acidic within decades. The modeling results also indicate that the acid front will continue to propagate to the base of the fine tailings, but less rapidly, indicating that the tailings piles would be fully acidic within the current millennium.

Figure 14 provides predicted past and future loads as a ratio of the predicted current conditions (in 2003). Because the modeling predicts relative variations in metals loading over time, the results are shown as a ratio rather than absolute loads. Figure 14(a) shows the variations in predicted load released from the tailings piles over the next 200 years. Figure 14(b) shows the model output extended to year 4500. The shorter-term detail provided in Figure 14(a) shows loading peaks that correspond to break through of the acid front in the coarse tailings within each of the three tailings piles. Figure 14(a) also provides an indication of the range of uncertainty in these predictions, primarily due to uncertainty in the variation in actual tailings thicknesses throughout the three piles. The two vertical black lines show ±15 years on 2003, which roughly represents the uncertainty associated with the assumptions adopted for the modeling. Uncertainty within the model indicates that current conditions may be on the decreasing trend of the peak associated with breakthrough of the acid front in the coarse tailings in Pile 1, or the increasing trend of the copper and cadmium peak associated with Pile 3. Since the modeling coincidentally predicted that current (i.e. 2003) conditions are near a low point for most parameters, the curves shown in Figure 15 represent the most conservative estimate of load reductions in the future and actual load reductions may be greater than indicated.

Overall, the predictions indicate that future loads should generally be no greater than current loads with the possible exception of short-term (next few decades) increases in copper and cadmium loads associated with breakthrough of the acid front in the coarse tailings of Pile 3 and zinc and aluminum loads associated with breakthrough in the coarse tailings of Pile 2 as shown in Figure 15(a). The uncertainty in predicting current conditions (i.e. current position on the graph) determines the degree of increase that might be expected. In the worst case, the model indicates a potential load increase of 10% for cadmium and copper in the short term. However, within 200 years, cadmium and copper loadings are expected to decrease by approximately 80%, and would be expected to remain below 20% of current loadings for a majority of the time. Iron, zinc, aluminum and sulfate loadings are predicted to follow the same general trend as cadmium, and copper, with loadings below approximately 60% of predicted current loads within 200 years.

All future loadings beyond year 2100 are predicted to be lower than current conditions. However, within this decreasing trend, three periods of increased loading are predicted for the long term due to acid break through in the fine tailings deposits in each of the three piles (Figure 14(b)). While the acid front is continually progressing downward, the piles have relatively flat bases. Hence the peaks represent a large area of breakthrough over a relatively short time period, as is diagrammatically shown in Figure 10. The sequence of breakthrough is determined by the relative thickness of the three tailings piles. During these possible periods of increased loading, aluminum, cadmium, copper, iron, and zinc loads are predicted to remain at or below approximately 60% of the current estimated load. The model also indicates that in the long term, cadmium and copper loadings are expected to decrease by 95% to less than 5% of current loadings, and aluminum, iron, sulfate and zinc are expected to decrease to less than approximately 30% of current levels.

5.5.2 Scenario 2 – Re-Slope and Gravel Cover

The predicted long-term loading trends for Scenario 2 are shown on Figures 15(a) and 15(b). Under this scenario, it was assumed that the rate of oxygen diffusion would be unchanged from the base case. The surface infiltration was assumed to decrease to about 20% of mean annual precipitation, as indicated by the HELP modeling undertaken by URS.

The modeling results for Scenario 2 indicate that the predicted future cadmium, copper and zinc loadings would remain relatively unchanged from the base case, because they would not exceed solubility limits at the lower infiltration rates. As described for Scenario 1, the predicted long-term sulfate and metals loadings are expressed as a ratio of the predicted current loadings.

The reduced infiltration to the coarser tailings may result in ‘drier’ tailings in the oxidation zone. This may result in slightly higher oxygen concentrations in the tailings which would increase the redox conditions. The field water quality monitoring results indicated that the redox range from about 165 mV to 500 mV, with and average of about 340 mV. The laboratory test results indicated a redox of about 300 mV for the strongly oxidizing tailings. The redox conditions will affect primarily the dissolved iron concentration through the formation of ferric iron which would precipitate as iron oxy-hydroxides. Because of these potential effects, a sensitivity analysis to redox conditions was completed in the assessment of this scenario. The base condition was assumed to be 300 mV, and to demonstrate the effect of redox, this was doubled to 600 mV (more oxidizing) in a second model run.

The effect of estimated redox conditions within the tailings piles for Scenario 2 are shown in Figure 15. Figure 15(a) shows the results when it is assumed that the redox in the coarse and fine tailings would remain at approximately 300 mV, (i.e., the current condition and redox used in Scenario 1). The results shown in Figure 15(b) were derived assuming that the average redox in the coarse tailings increases to 600 mV, due to an increase in oxygen diffusion under less-saturated conditions. Cadmium, copper, and zinc, however, would not be impacted by a change in redox conditions. The net effect of the increased redox conditions is that ferrous iron would be oxidized to ferric iron, which would more readily form insoluble secondary minerals phases. This would reduce the dissolved iron concentration and thus the loading. It is probable that conditions somewhere between 300 and 600 mV could develop in the pile. The results presented in Figure 15(a) could therefore be considered as a probable upper bound, and that in Figure 15(b) as a probable lower bound of future loadings for this scenario.

The results shown on Figure 15 assume the remedy would be implemented by 2005. Consistent with Scenario 1, the modeling results indicate that future loads should generally be no greater than current loads with the possible exception of short term (next few decades) increases associated with breakthrough of the acid front in the coarse tailings of Piles 2 and 3 as shown in Figure 15. Also, as described previously, the uncertainty in predicting current conditions determines the degree of increases and decreases that might be expected. As shown for Scenario 1, the model indicates that in the long term, cadmium and copper loading is expected to decrease by 95%, to less than 5% of current loading under this scenario. Sulfate and iron loads were predicted to be higher than copper and cadmium on a similar trend, but in the long term, loads were predicted to decrease by 70%, to below approximately 30% of current loads. Zinc loads would decrease by 65%, to about 35% of current loadings; however, these estimates may be conservative for the previously mentioned reason.

5.5.3 Scenario 3 – Consolidation and Capping

The modeling results for Scenario 3 are provided on Figures 16 and 17. Under this scenario, the oxygen transport modeling was revised to accommodate the effect of the engineered cover; however, the potential effect of a top soil layer (over the cover membrane) was conservatively neglected in the calculations. The effects of the topsoil on oxygen transport will depend on the level of saturation and the integrity of the layer. Therefore, its effect is likely to vary seasonally, and may limit oxygen entry during wet periods. However, it will also likely be affected by root penetration which could reduce its effectiveness as an oxygen barrier. Since the effects of root penetration cannot easily be predicted the effects of the soil cover was neglected.

The predicted progress of the oxidation and acid fronts is illustrated in Figure 16. No distinction between coarse and fine tailings was made under this scenario since it is assumed that the 'coarse zones' have effectively been eliminated. Note also that the time scale commences once the consolidation and capping has been completed and does not take into account the time for existing water within the tailings piles to drain down to the toe of the consolidated pile. This evaluation assumes that the cover is effectively maintained indefinitely. If the integrity of the cover is compromised in the future, the geochemical processes described previously would be initiated. This would include development of oxidation and acid fronts in the tailings resulting in increases in solute loads as the acid front breaks through the base of the tailings.

The estimated solute loadings for this scenario are provided in Figure 17. As for the previous scenarios, the predicted future loadings are expressed as a ratio of the predicted base case loadings. The results indicate that consolidation and capping would result in reduction in metals loadings following the drain down of existing water within the piles. However, future loadings are predicted to potentially increase slightly as the oxidation and acid fronts progress deeper into the tailings, albeit at a greatly reduced rate.

The effects of redox conditions may impact iron loading as described for Scenario 2. The tailings have already been subjected to partial oxidation, and it is known that significant amounts of stored oxidation products exist within the tailings. A change in redox conditions could impact their stability. Potential effects have however not been modeled. For example, establishing a vegetation cover could introduce organic acids and organic compounds that could lead to reducing conditions in the tailings pile. This could lead to the reduction of ferric iron to ferrous iron, which would result in the dissolution of stored iron oxy-hydroxides already present in the tailings.

The results shown on Figure 17 are based on an assumed average redox of about 300 mV in the porewater. This value represents the oxidizing conditions observed within the piles.

The modeling results for Scenario 3 indicate long-term cadmium, copper, iron, sulfate, and zinc loadings would be reduced to below 5% of current loadings for approximately 1500 years (Figure 14). Subsequently, a potential gradual increase in loading is predicted due to the progression of the acid and oxidation fronts deeper into the pile. Due to the low estimated infiltration rate, concentrations are likely to be solubility limited in the long term and loadings are not expected to increase above the indicated levels. As stated previously, the results do not take into account the time for existing water within the tailings piles to drain down to the toe following consolidation and capping, and assumes that the cap is maintained indefinitely to limit infiltration of surface water to less than 5% of mean annual precipitation.

5.6 Conclusions Related to Long-Term Metals Loading from the Tailings Piles

It is concluded that if the tailings are left in their current configurations (Scenario 1):

- Within approximately 100 years, concentrations of cadmium and copper are expected to decrease by 80% to below approximately 20% of current loadings for a majority of the time. Over the longer term, acid breakthrough at the base of the fine tailings in each pile is predicted to result in temporary increases in loadings. During these periods of potentially increased loading, concentrations are predicted to be at or below approximately 60% of the current load.

- Within approximately 200 years, concentrations of iron are expected to decrease by 45% to below approximately 55% of current loadings for a majority of the time, with subsequent periods of increased loading corresponding to acid breakthrough from the base of each of the three piles. During these periods of potentially increased loading, iron loads are predicted to remain below 60% of the current load.

- Aluminum, zinc and sulfate loadings are predicted to follow the same general trend as cadmium, copper, and iron, with long-term loadings at or below approximately 60% of predicted current loads within 200 years.

- Loads of all parameters are expected to continue to decrease and remain below about 5% of current loads for copper and cadmium, 25% of current loads for iron, and 30% of current loads for aluminum, sulfate and zinc within approximately 2000 years.

- Evaluation of the uncertainty associated with the long-term modeling of current conditions indicates that the reported modeling results represent conservative estimates of loading reductions because current conditions were predicted to represent a low point in load release.

- Actual load reductions could be greater than indicated due to the effect of metal sorption processes occurring as tailings pore waters mix with groundwater and react with natural unconsolidated soils beneath the tailings deposits.

If the tailings piles were regraded to reduce surface infiltration (Scenario 2), the modeling results indicate that:

- The long-term loadings of aluminum, cadmium, copper, and zinc would remain relatively unchanged from those predicted for the base case.

- Loads of sulfate and iron are expected to decrease below the loadings projected for the Scenario 1 in the short term. In the long term, loadings of these constituents are predicted to be similar to the base case. The decrease in predicted short-term iron and sulfate loads is due to solubility constraints predicted by the model for the reduced infiltration rates.

- Iron loadings could be strongly affected by the redox conditions that develop after the tailings piles have been regraded. Due to the decrease in infiltration, and a potential decrease in the level of saturation of the tailings, more oxidizing conditions could especially develop in the coarse tailings. This could lead to increase ferrous oxidation to ferric and formation of iron oxyhydroxides which would result in decreased loadings. The results indicate that if the redox conditions were to increase from 300 mV to 600 mV (more oxidizing), iron loadings could decrease by in excess of 90 percent.

If the tailings were consolidated and capped, the modeling results indicate that:

- Reduction in all parameters is predicted after draindown of existing pore water occurs. This draindown period was not incorporated into SRK's model. In the long term, loadings may increase marginally as the oxidation and acid fronts progress deeper into the tailings, albeit at a very much reduced rate.

- Long term loadings for all parameters are expected to be below 10% current loads. This assumes the cap is constructed and indefinitely maintained to reduce surface infiltration to below 5% of mean annual precipitation.

6 Overall Conclusions

It is expected, and supported by observations reported in the literature, that release of metals from mine waste storage facilities will attenuate over time as a result of depletion of the source of the metals, which are in most cases sulfide minerals. Provided that no further decreases in pH are predicted to occur, metal loading attenuation occurs rapidly at first then decelerates following a decreasing exponential-type trend.

Data in the literature for waste rock tests were applied to prediction of the rate of decay of metal loadings from the waste rock piles at the Holden Mine site. The calculations indicate that current metal loadings would be attenuated by approximately 50% over the next 50 to 75 years. Using conservative assumptions, the upgradient controls are expected to result in similar attenuate rates.

A similar conclusion was reached for attenuation of metal loadings from the underground mine at the Holden Mine site under the current configuration. Similar long term attenuation trends are expected regardless of the remedial alternative selected (air flow restrictions and hydrostatic bulkheads)

Attenuation in metal loadings from the tailings piles was predicted using a quantitative modeling approach based on the geochemical characteristics of the tailings, the diffusion of oxygen into the tailings, and chemical reactions in the tailings. The long term trend for all metals is a gradual reduction in loadings with cadmium and copper decreasing to approximately 20% of current loadings within approximately 100 years, and aluminum, zinc and iron decreasing to approximately 60% or less of current loadings within approximately 200 years. Over the long term, acid breakthrough at the base of the fine tailings in each pile is predicted to result in temporary increases in loadings. However, during these periods, loadings of all metals are predicted to remain below approximately 60% of current loadings. The effect of re-grading and re-vegetation of the tailings is expected to be minimal for cadmium, copper and zinc, but could produce a substantial reduction in iron loadings. Predicted future loads for consolidation and capping are very low primarily because the volume of water entering the consolidated pile is estimated to be very low.

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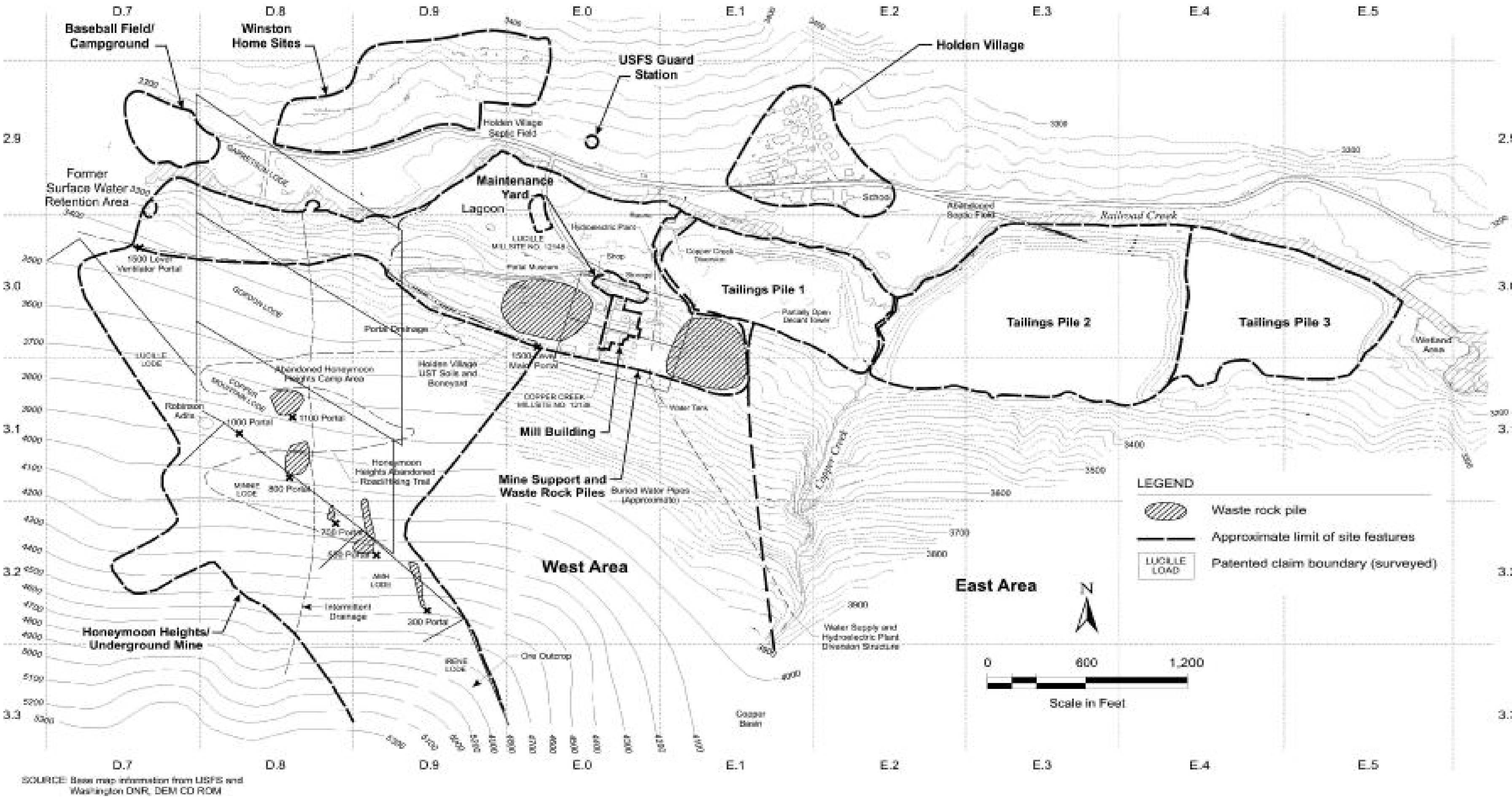

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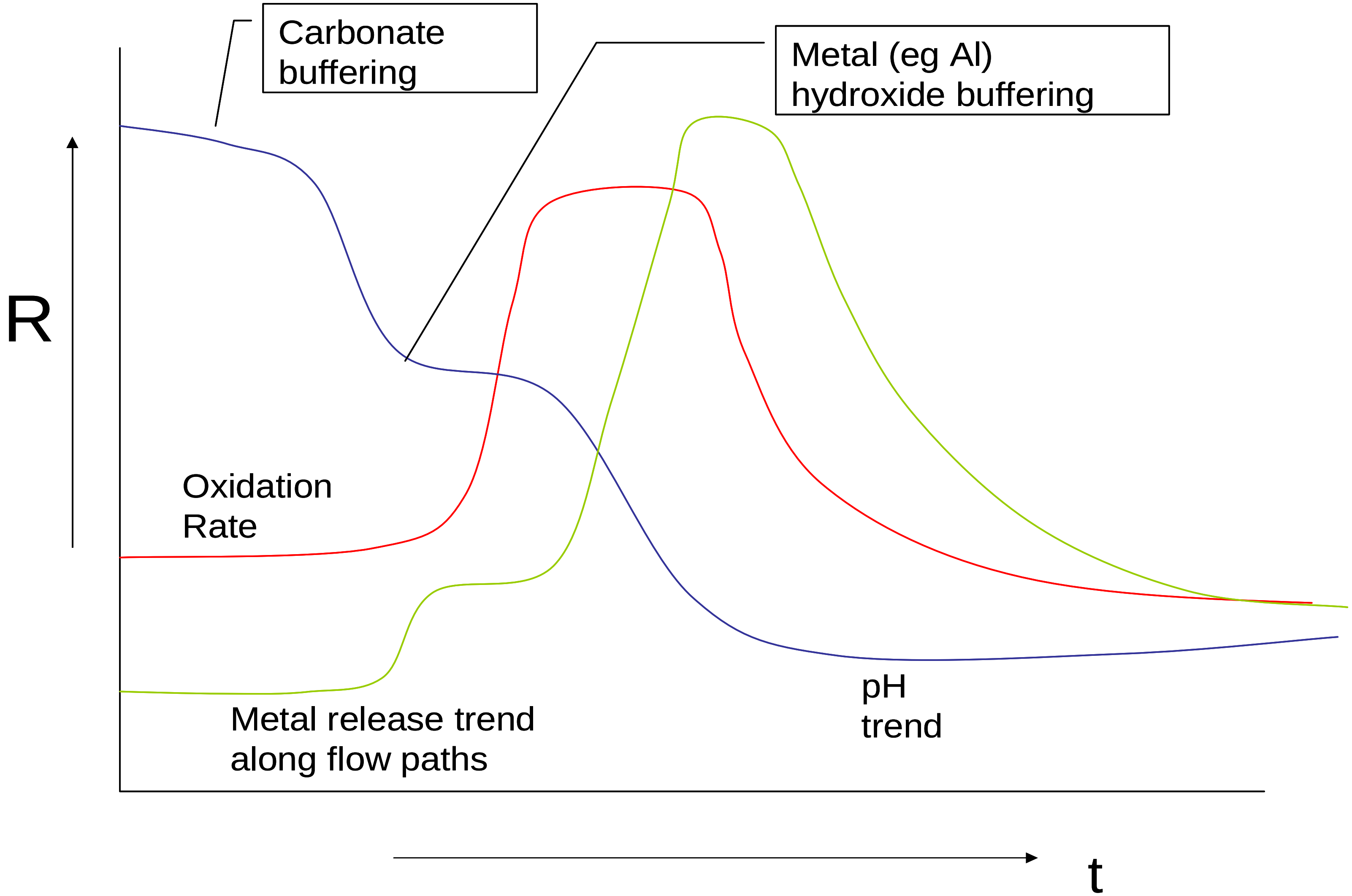
DISCUSSION OF LONG TERM TRENDS IN CHEMICAL LOADINGS - HOLDEN MINE

Layout of Holden Mine Site

Project	Date	Approved	Figure
1UU003.00	Feb-04		1



Note: R is the rate of release or the pH. The axis is relative.

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General Trends for Acid Generating Waste Rock

Project	Date	Approved	Figure
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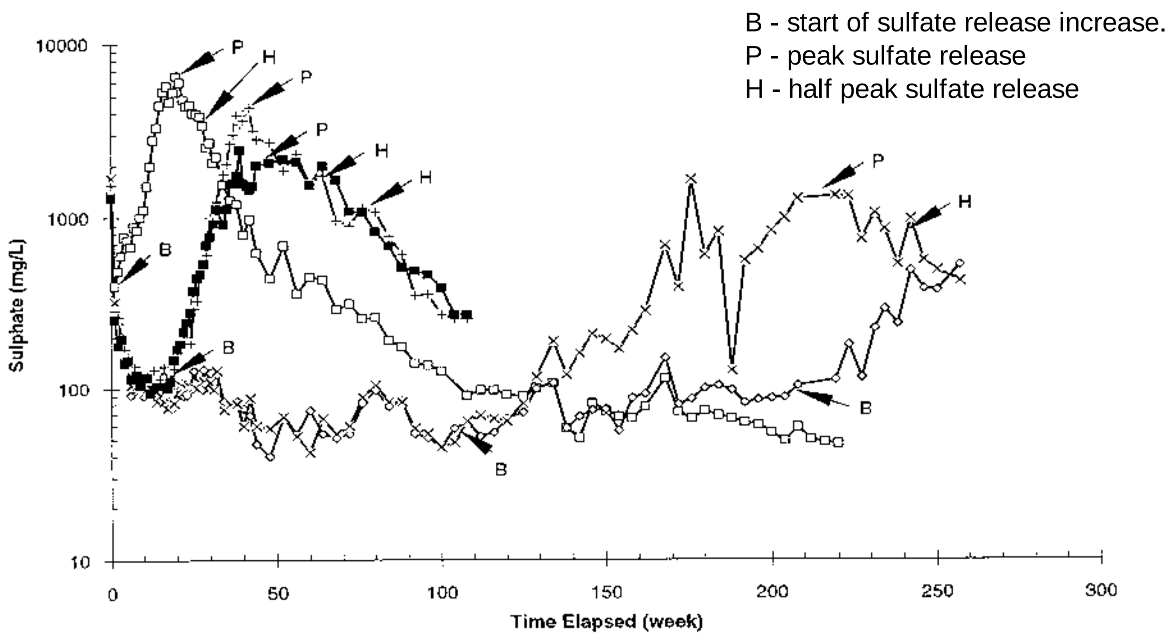
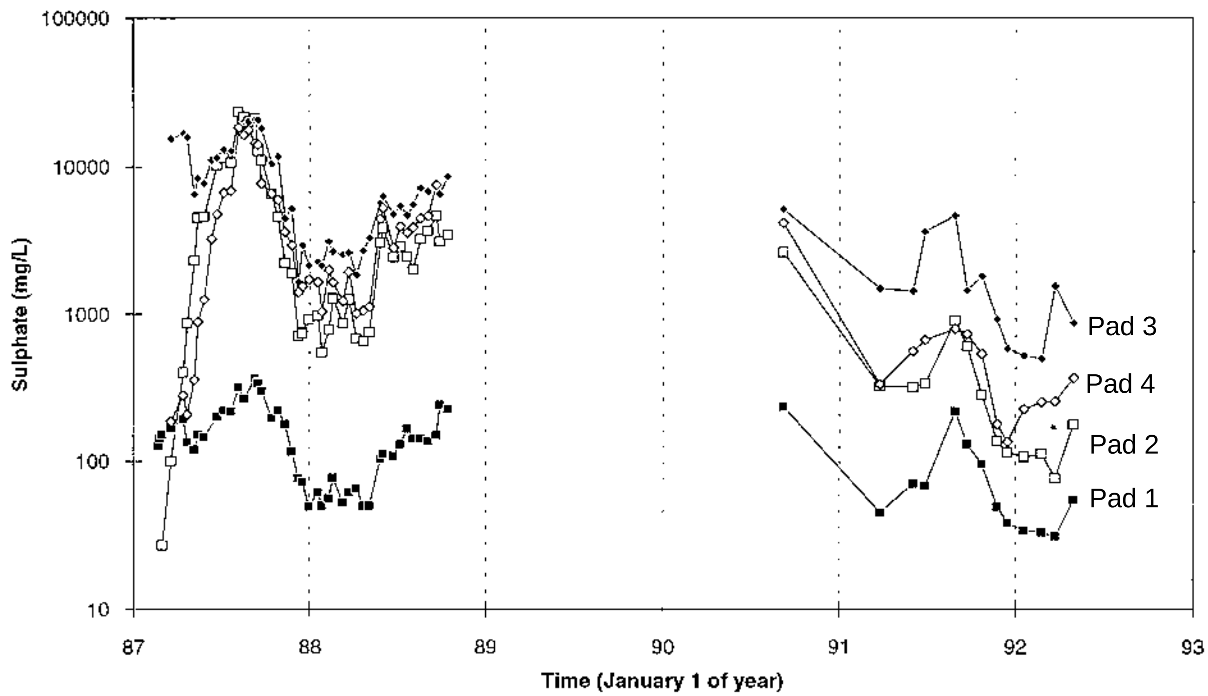
(a) Leach Columns (P - Peak, H - 50% of peak)



(b) Waste Rock Pads



Extracted from Norecol, Dames & Moore, 1994

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Examples of Long Term Test Results for the Cinola Gold Project

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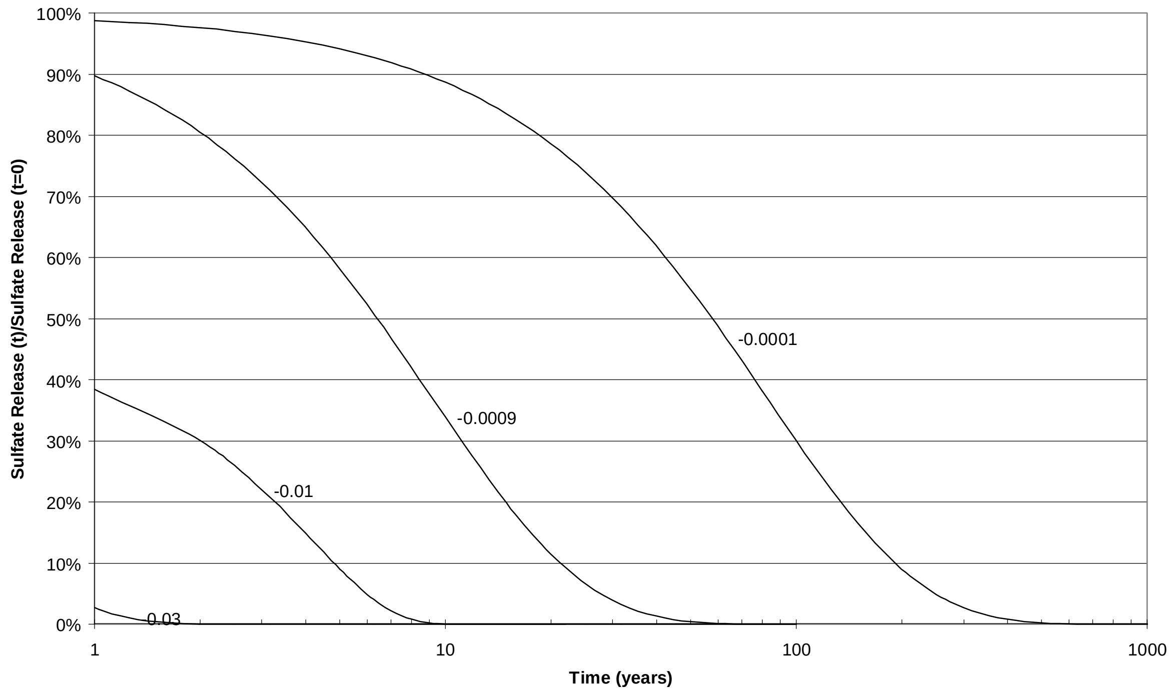
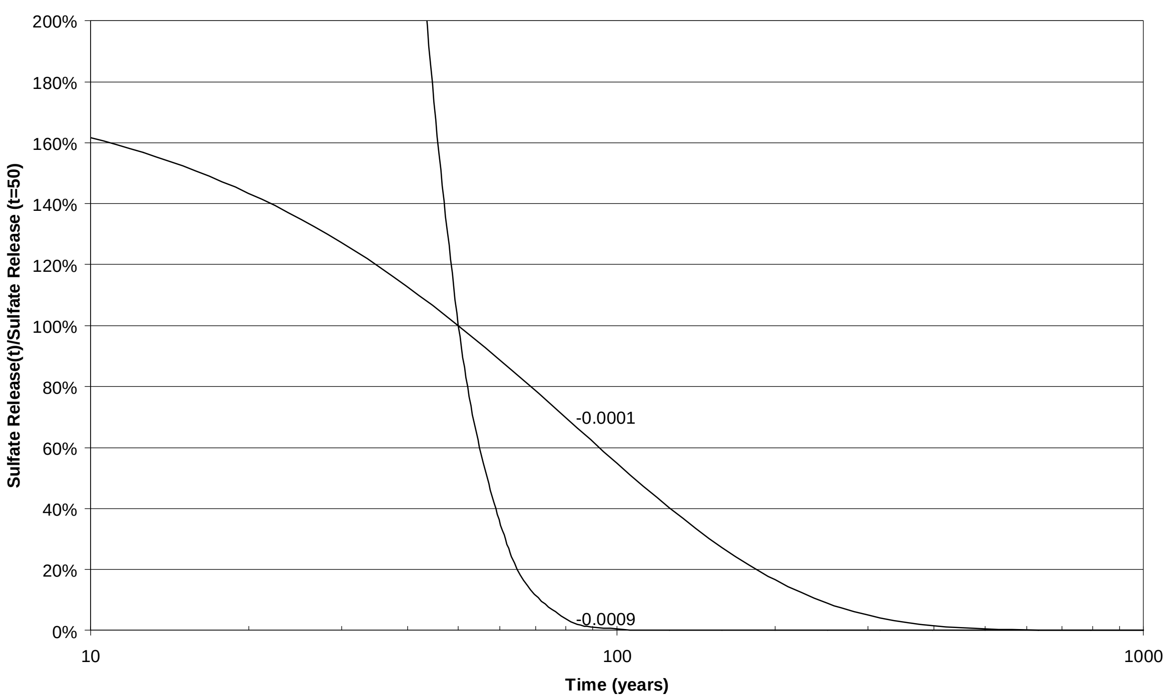
(a) Decay Curves for Indicated k-values, starting at t=0



(b) Decay Curves for Indicated k-values, referenced to t=50 years



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Examples of Decay Curves for Various Values of k for Waste Rock

Project	Date	Approved	Figure
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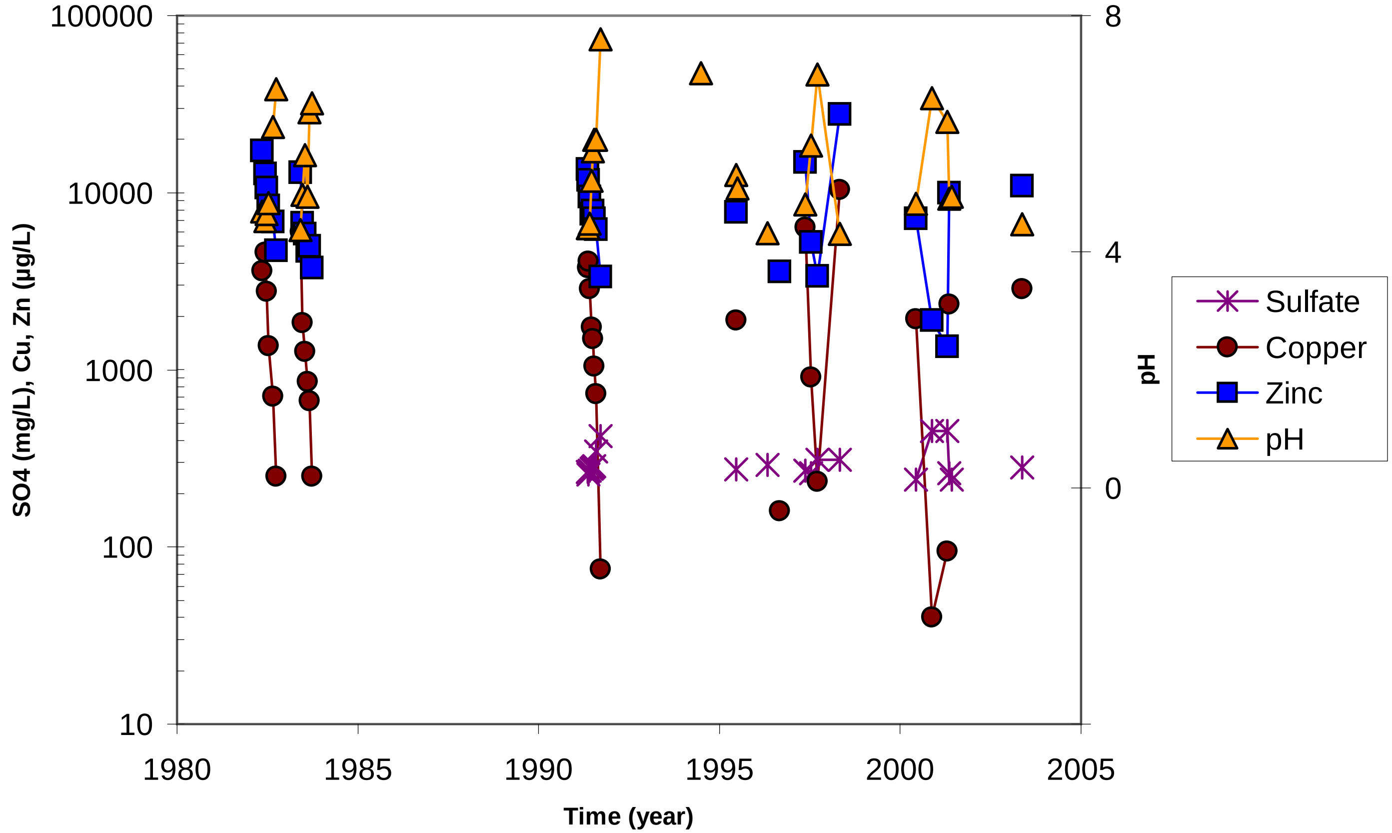

Note. Connecting lines are only shown between results from samples collected in the same field season

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	P1 Monitoring Results - Holden Mine		
Project	Date	Approved	Figure
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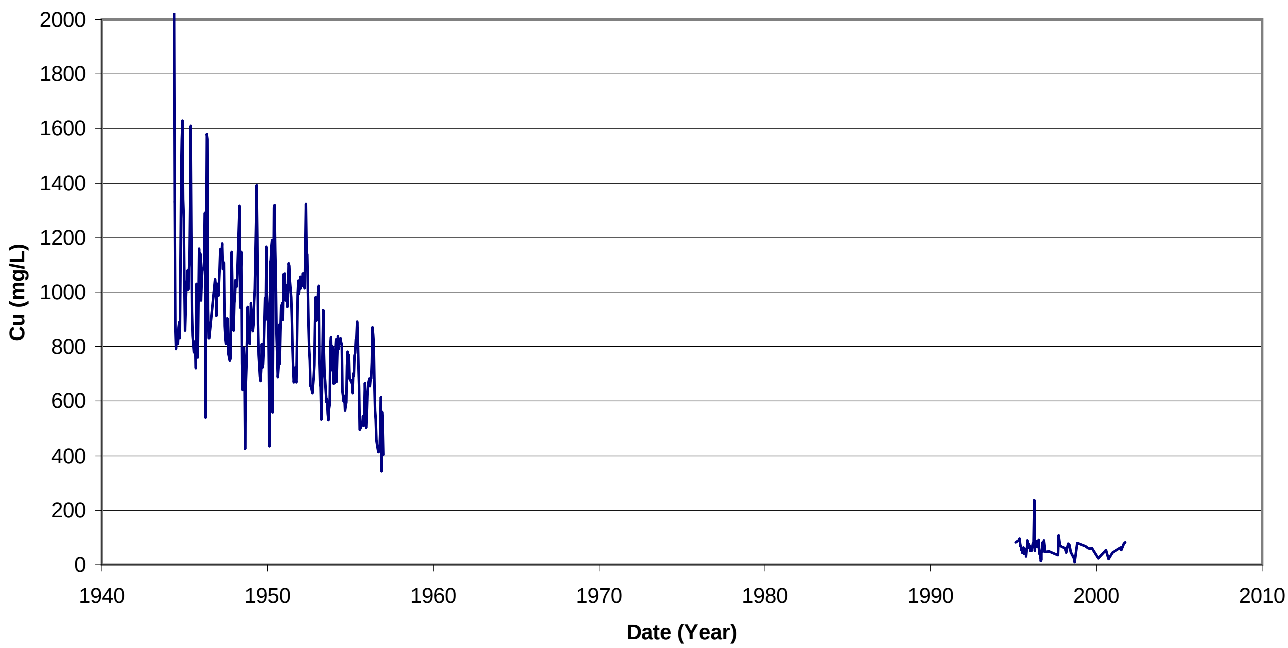
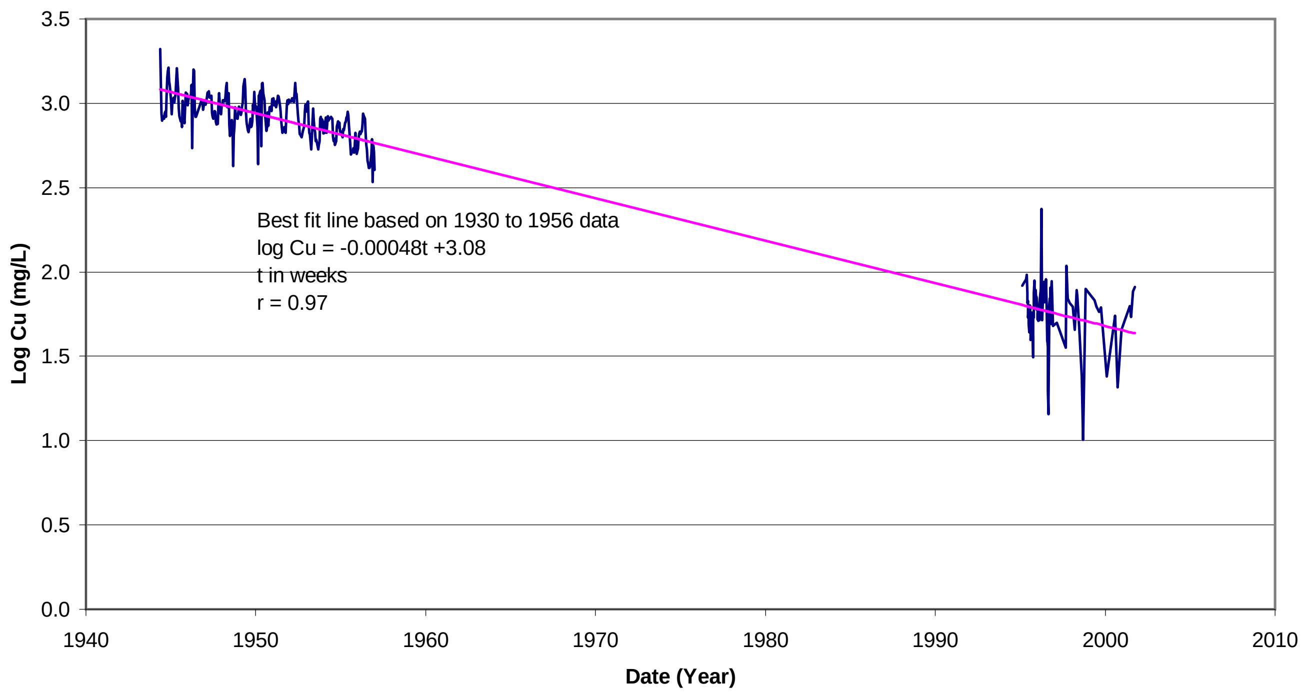
(a) Britannia Mine 2200 Level Discharge Copper Concentrations



(b) Log Linear Fit to Copper Concentrations



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Monitoring Data for 2200 Level Discharge - Britannia Mine

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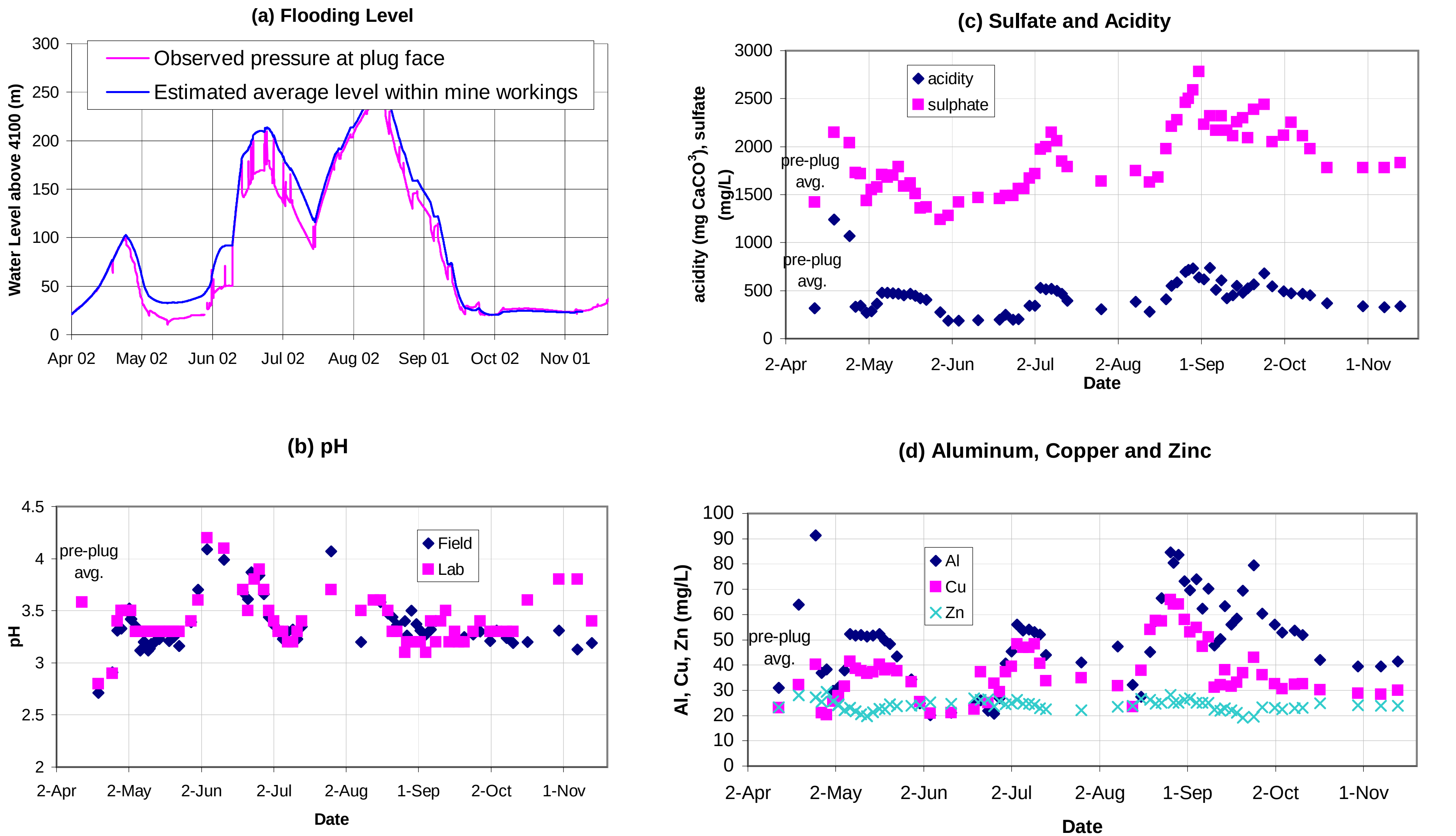

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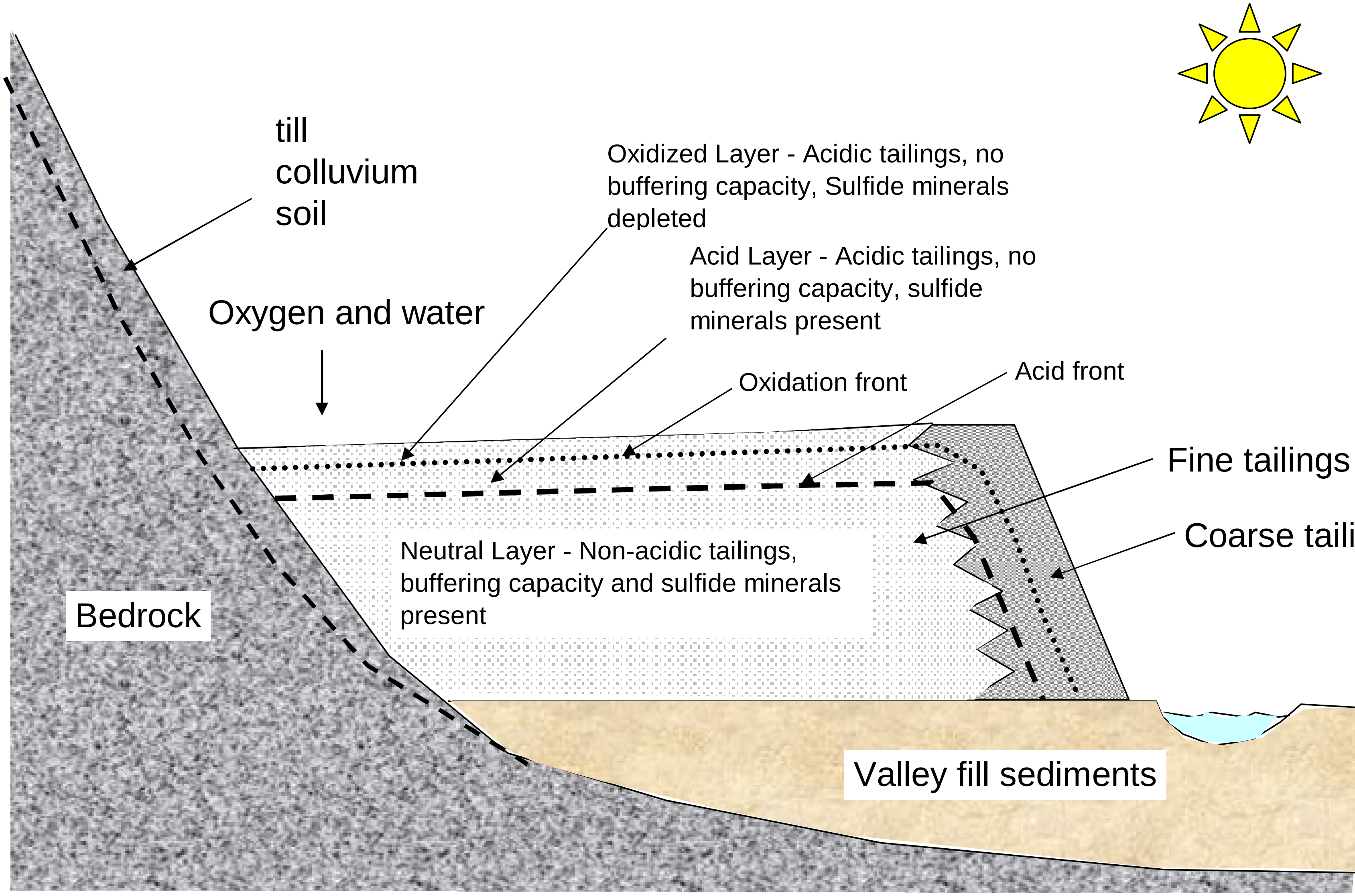
Monitoring Results for Flooding of the Britannia Mine in 2002

Project	Date	Approved	Figure
1UU003.00	Feb-04		7



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Conceptual Tailings Pile Section

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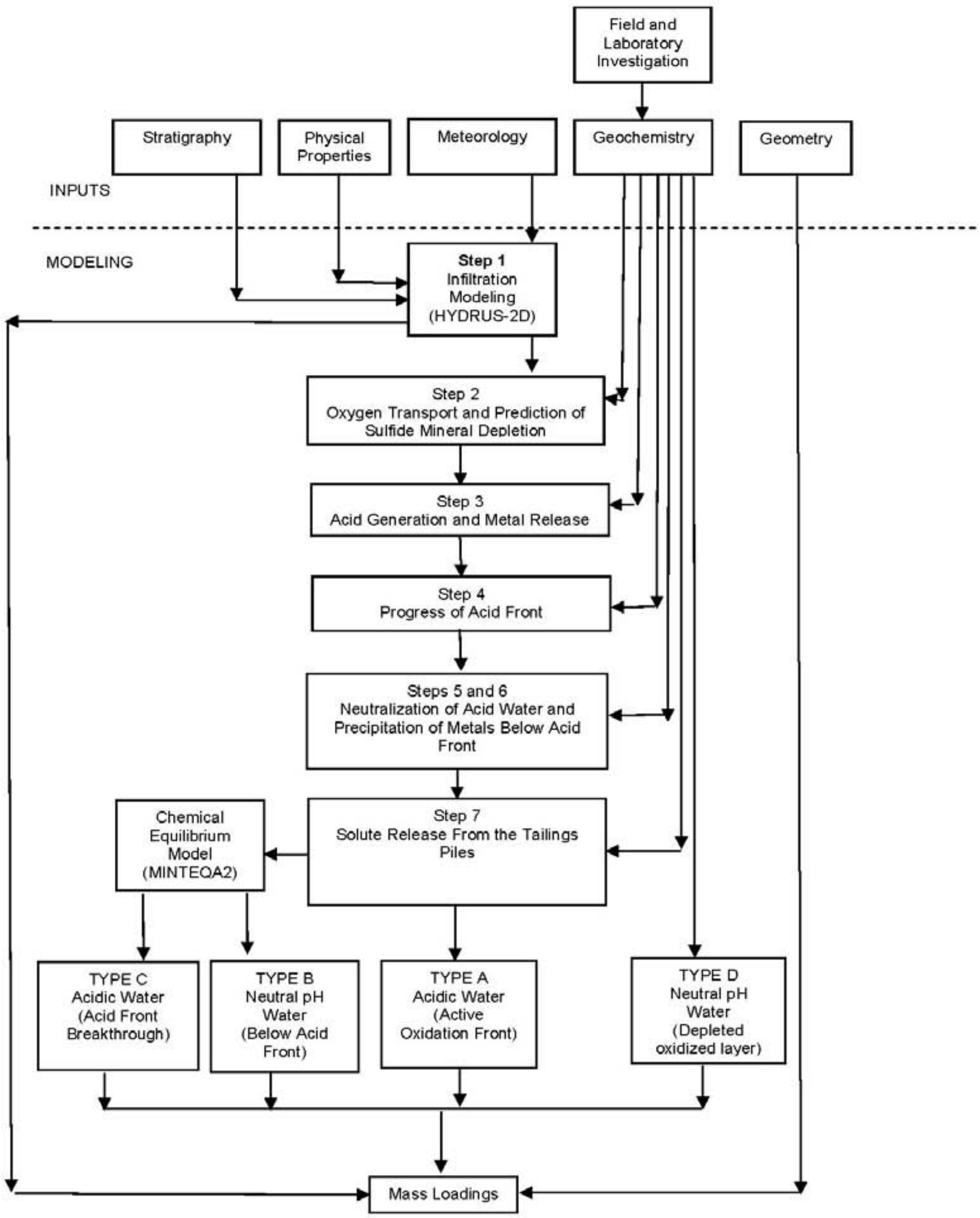

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Overall Tailings Modeling Approach

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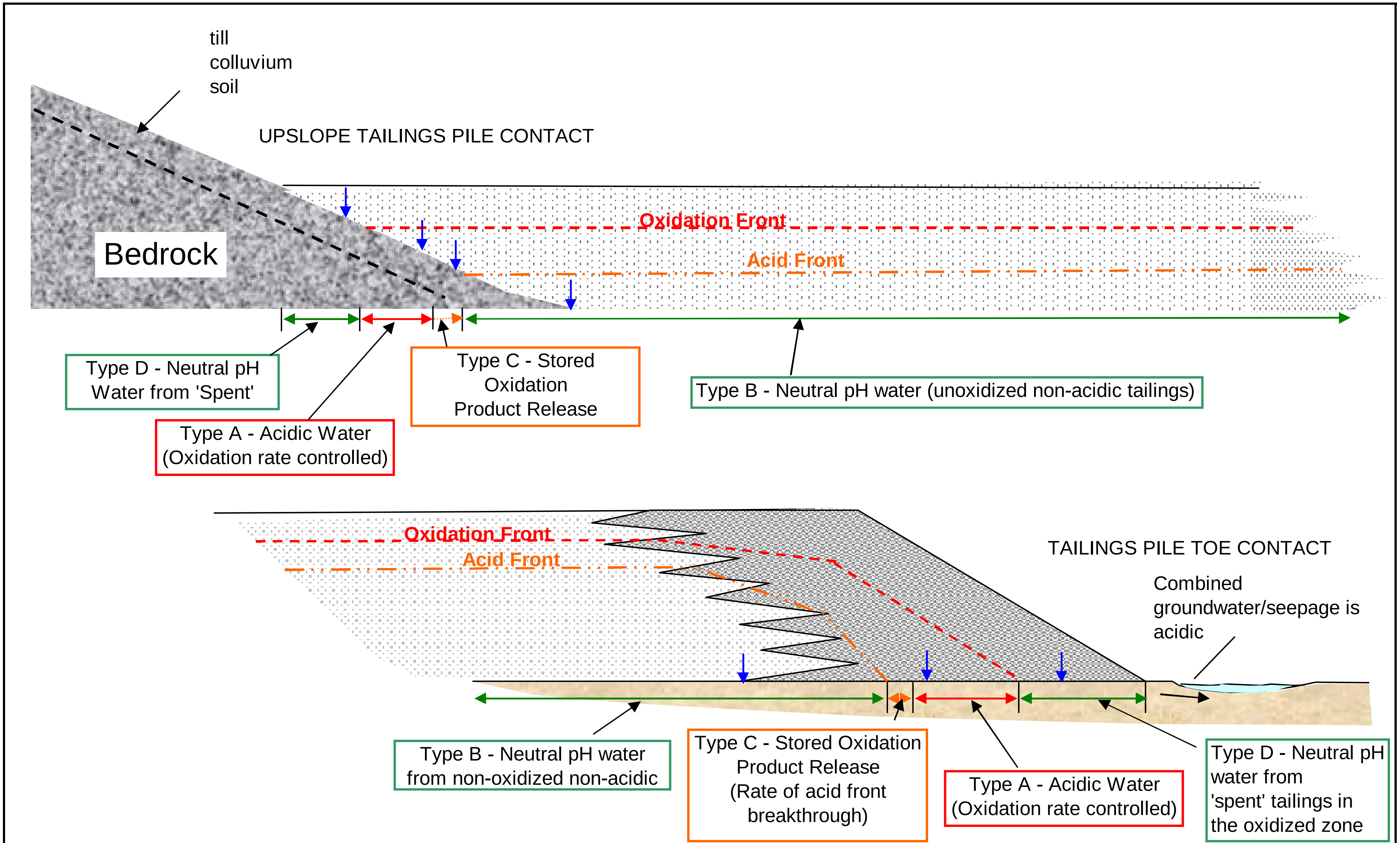

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Simplified Water Quality Model for Tailings Piles

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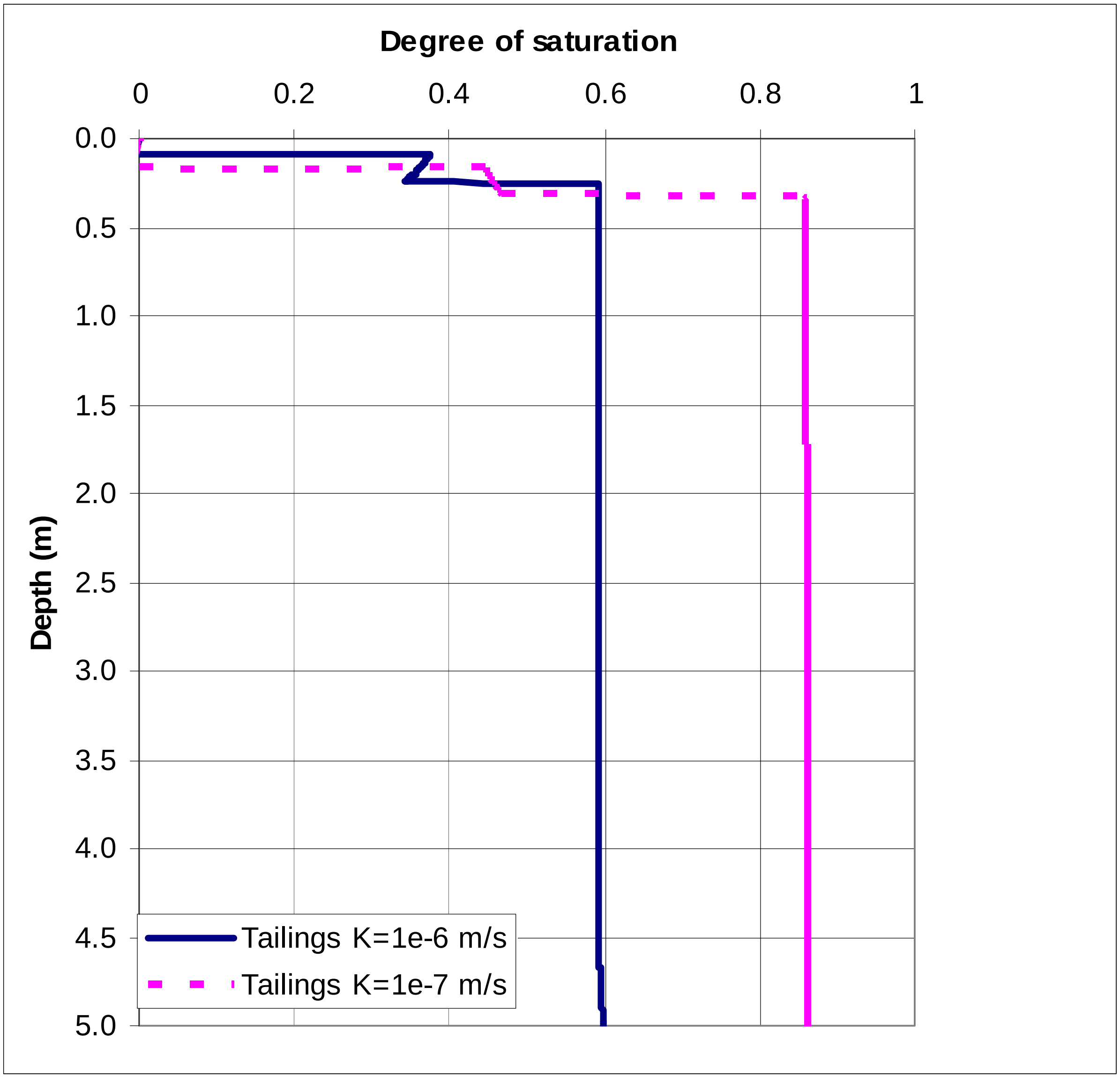

Fine Tailings K = 1x10-7m/s; Coarse Tailings K = 1x10-6 m/s

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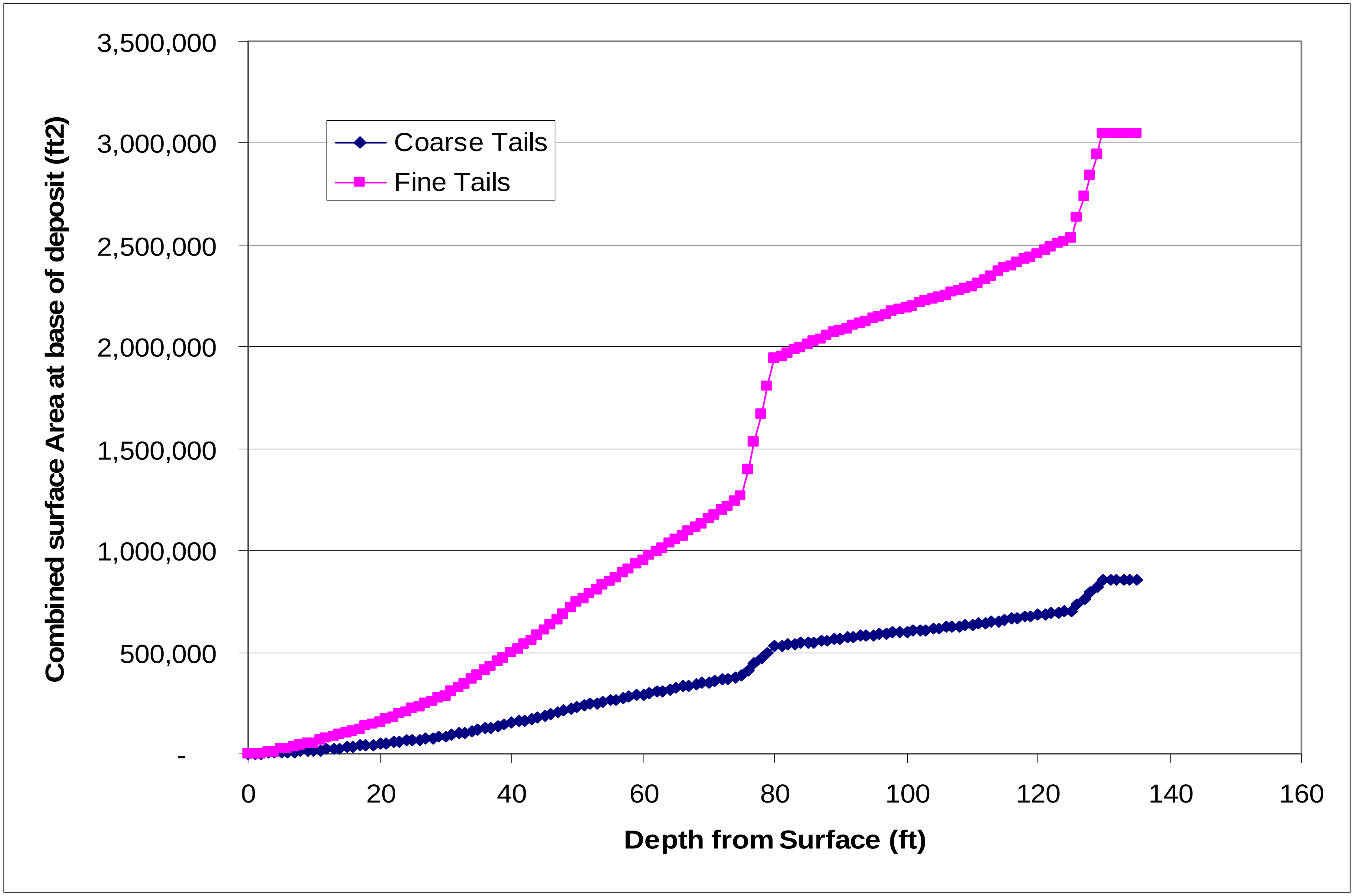
Saturation Profiles Estimated by HYDRUS-2D			
Project	Date	Approved	Figure
1UU003.00	Feb-04		11



Note: Corrected to the Same Surface Elevation

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Planimetric Surface Area at the Base of the Combined Tailings Piles

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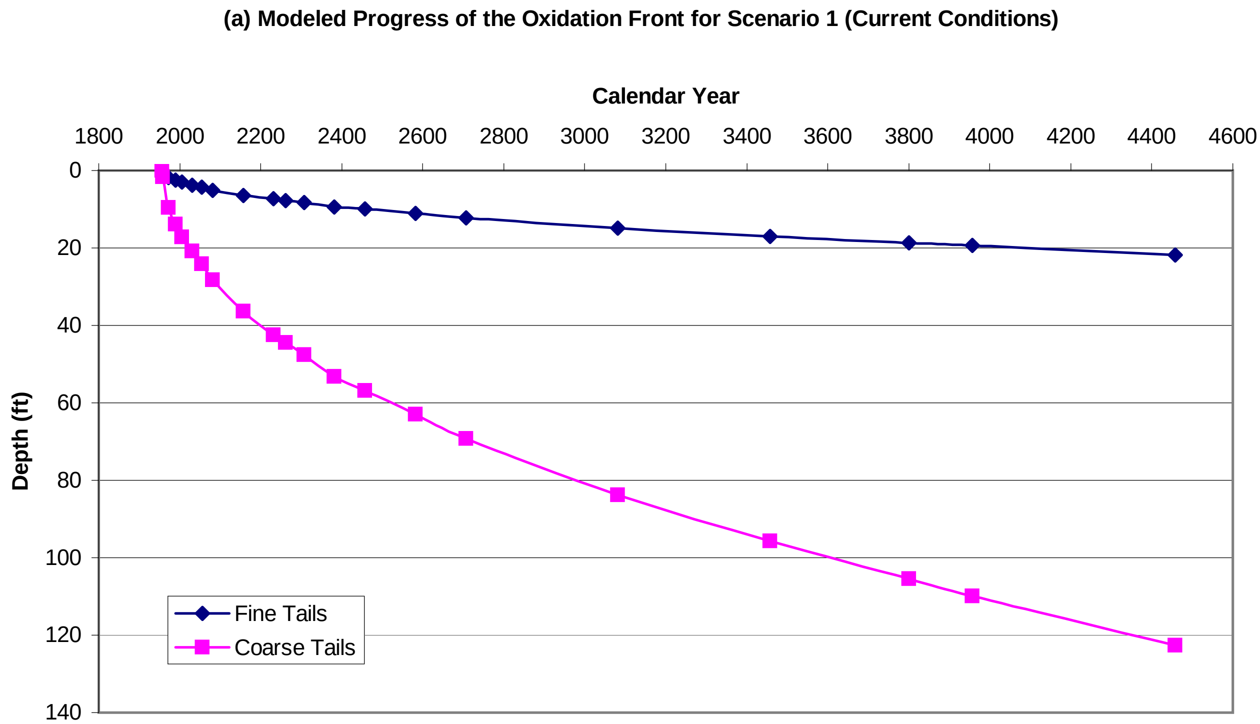
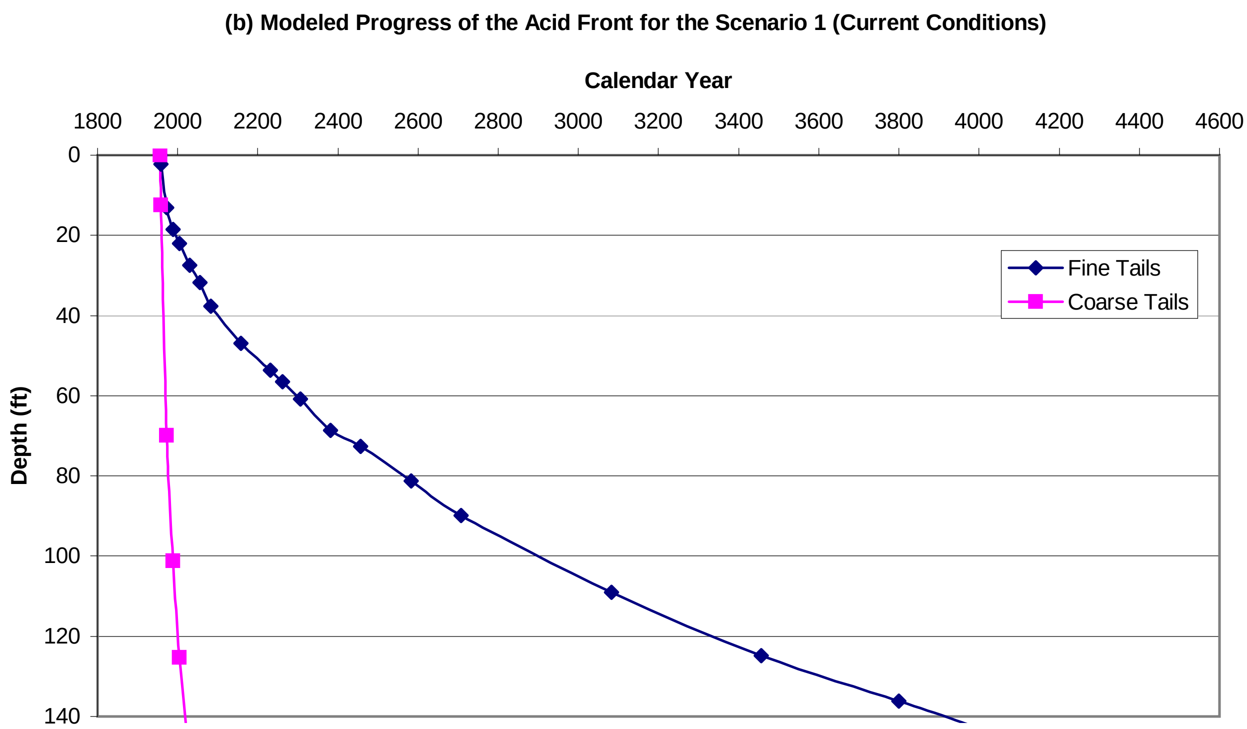
1UU003.00	Feb-04		12





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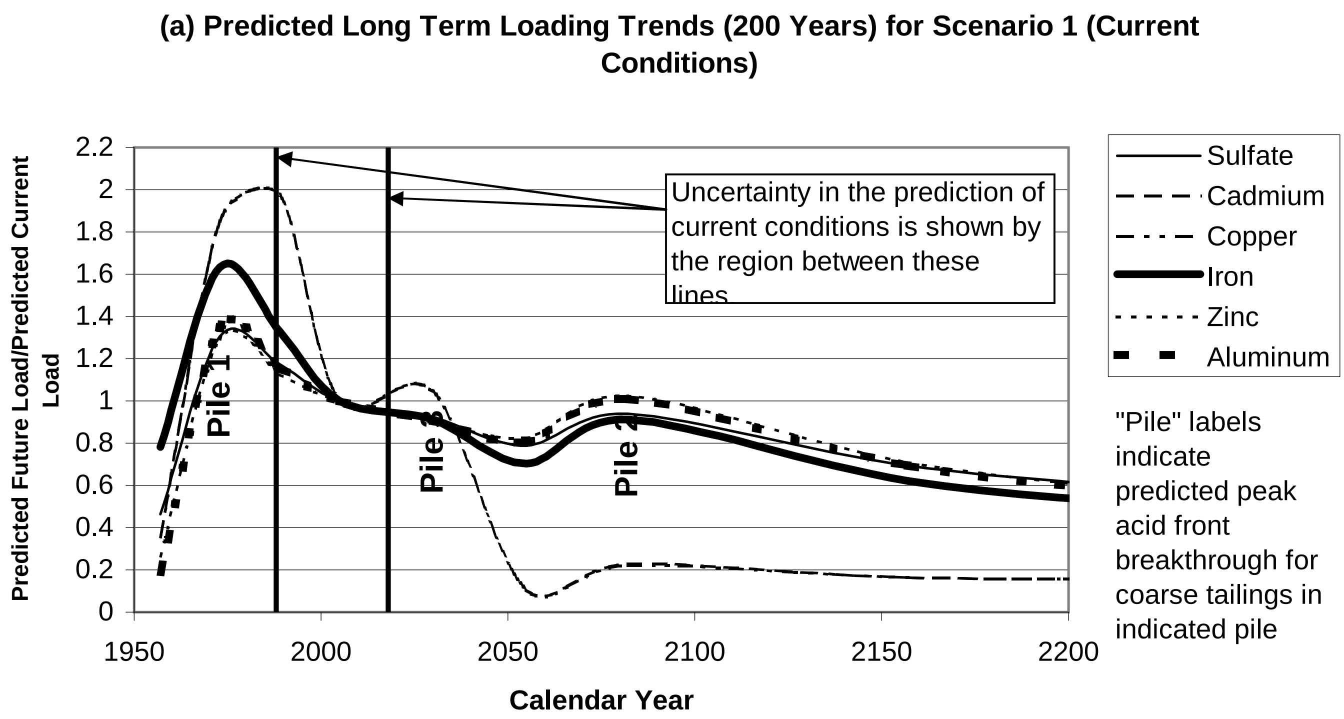
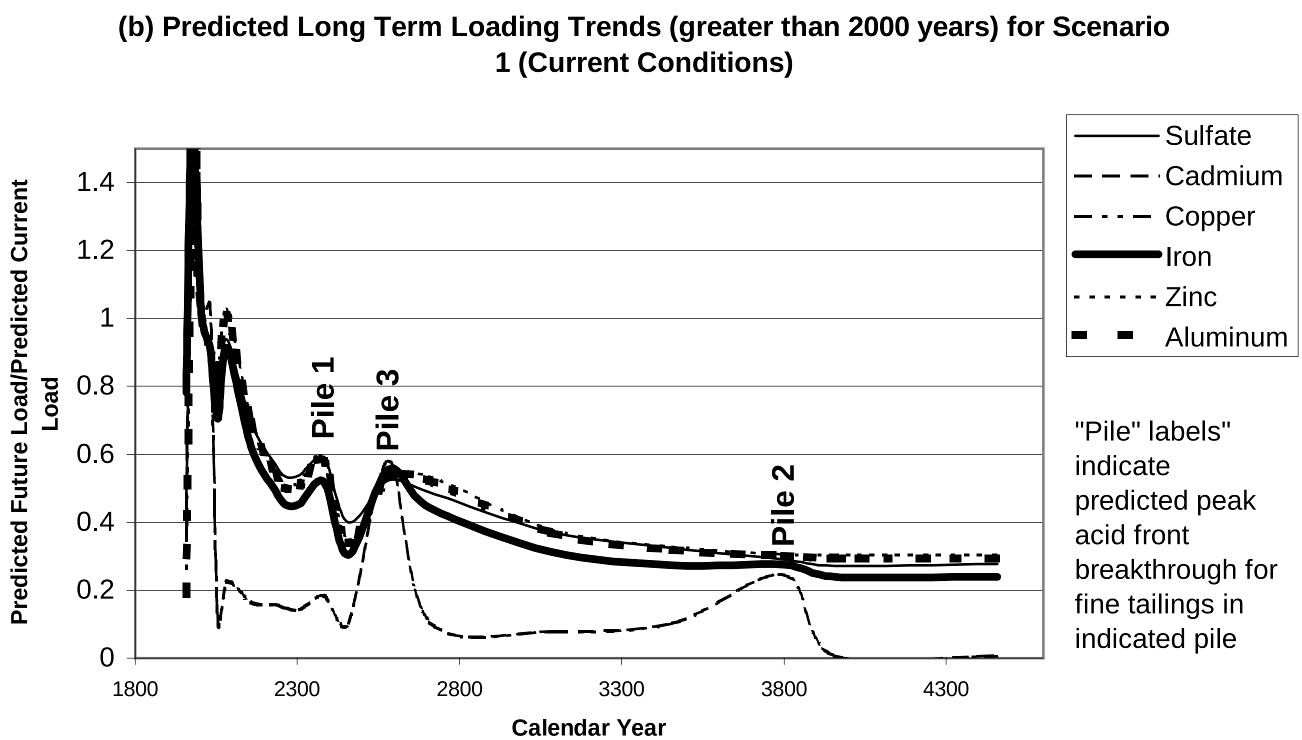
DISCUSSION OF LONG TERM TRENDS IN CHEMICAL LOADINGS - HOLDEN MINE

Modeled Progress of Oxidation and Acid Fronts in Coarse and Fine Tailings for Base Case

Project	Date	Approved	Figure
1UU003.00	Feb-04		13





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DISCUSSION OF LONG TERM TRENDS IN CHEMICAL LOADINGS - HOLDEN MINE

Predicted Long-Term Loading Trends (Scenario 1)

Project	Date	Approved	Figure
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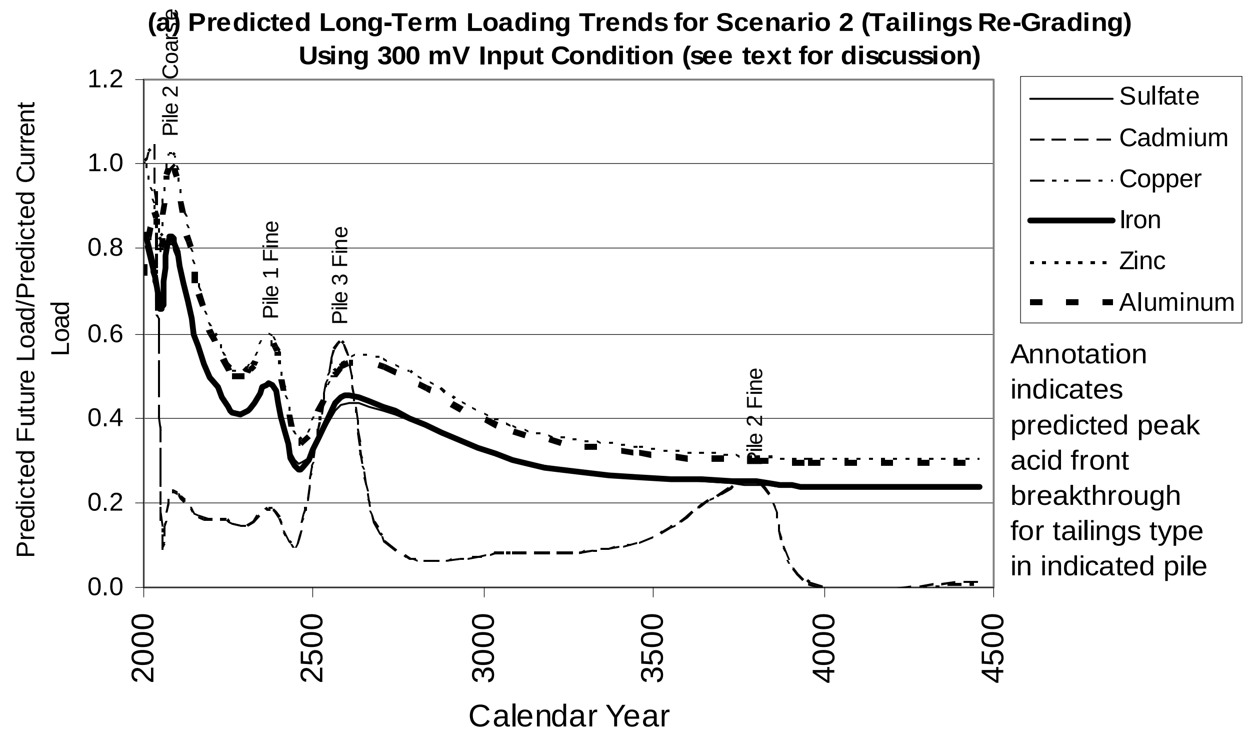

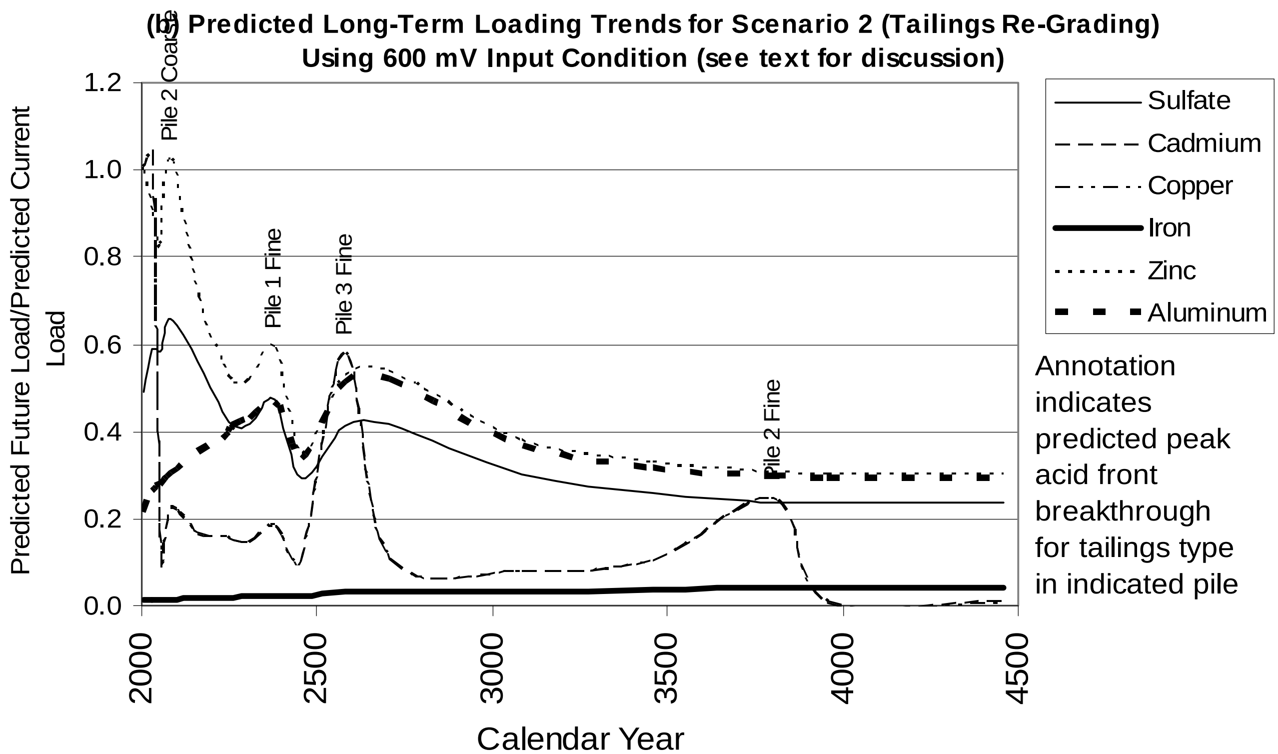

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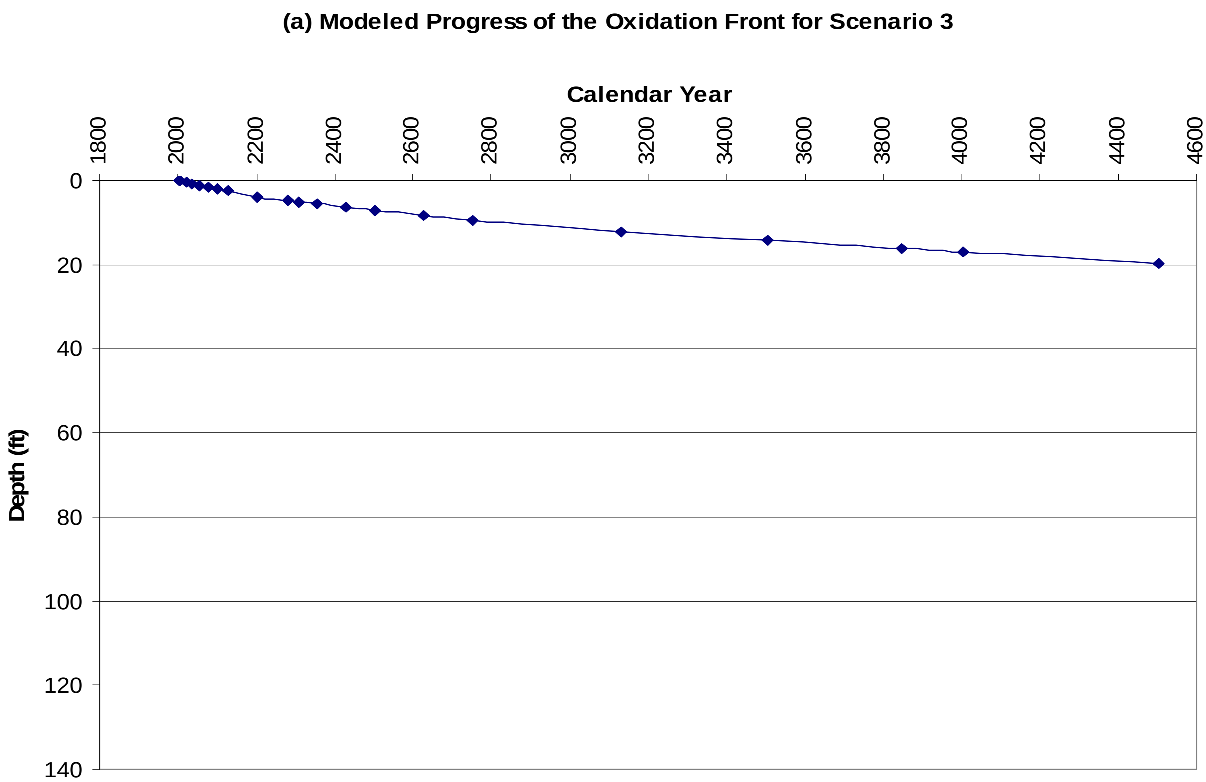
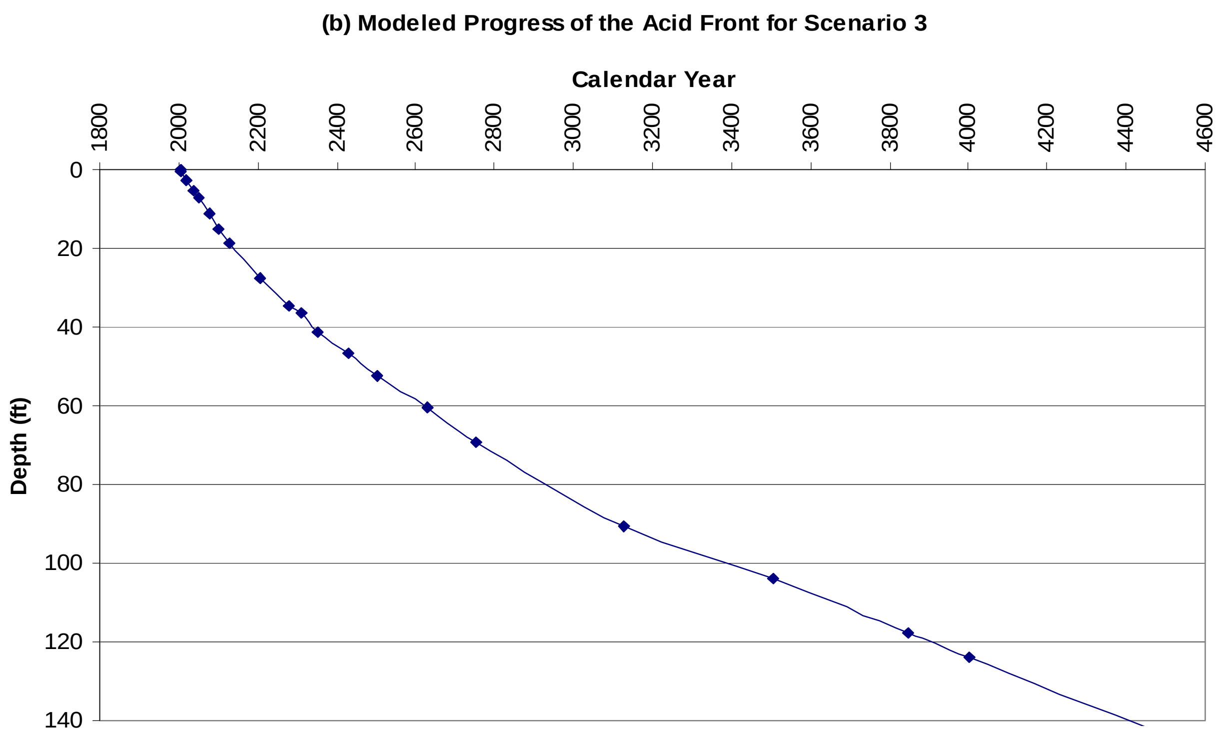
DISCUSSION OF LONG TERM TRENDS IN CHEMICAL LOADINGS - HOLDEN MINE

Predicted Long-Term Loading Trends (Scenario 2)

Project	Date	Approved	Figure
1UU003.00	Feb-04		15





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DISCUSSION OF LONG TERM TRENDS IN CHEMICAL LOADINGS - HOLDEN MINE

Scenario 3 Progress of Oxidation and Acid Fronts in Coarse and Fine Tailings

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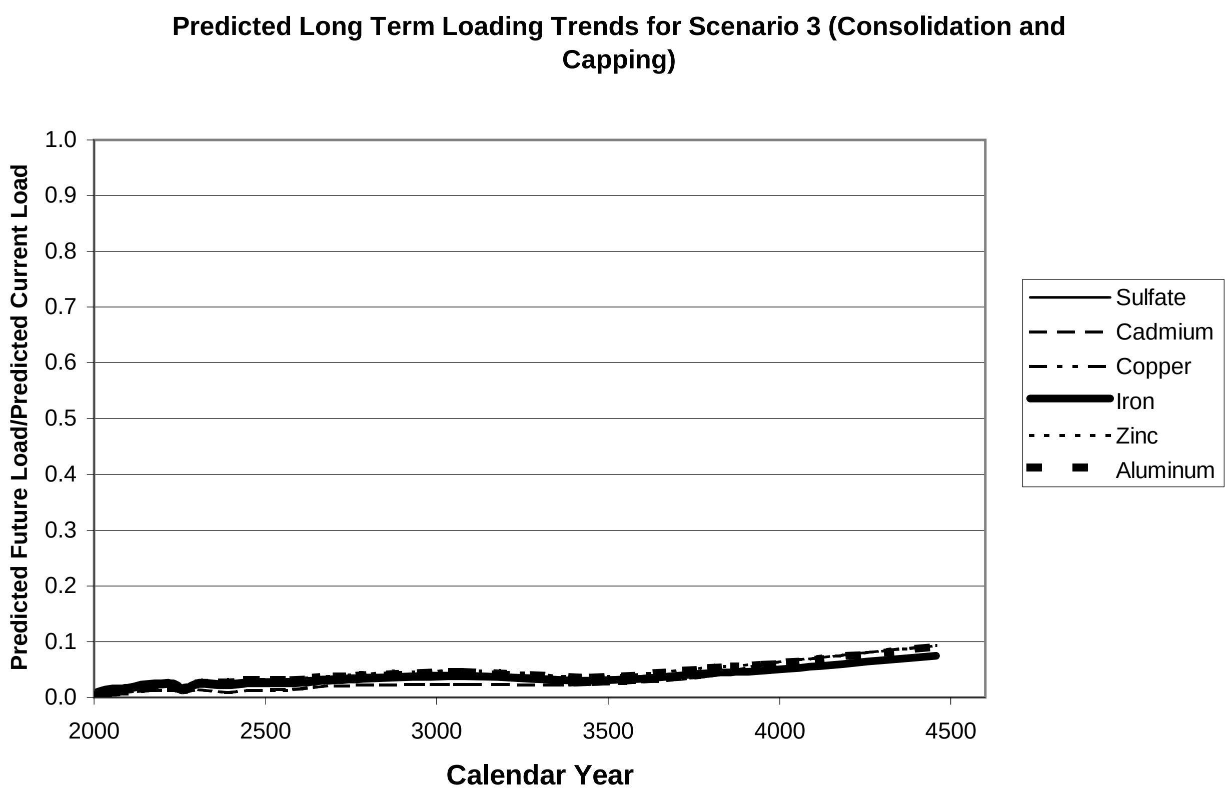
1UU003.00	Feb-04		16



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Predicted Long-Term Loading Trends (Scenario 3)			
Project	Date	Approved	Figure
1UU003.00	Feb-04		17

SUPPORTING GEOCHEMICAL CALCULATIONS

FEASIBILITY STUDY

HOLDEN MINE, WASHINGTON STATE

Report Prepared for

URS Corporation

Report Prepared by

SRK Consulting
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SUPPORTING GEOCHEMICAL CALCULATIONS FEASIBILITY STUDY

HOLDEN MINE, WASHINGTON STATE

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1 INTRODUCTION

1.1 Background and Scope

URS Corporation (URS) developed a list of seven candidate site-wide remedial alternatives for the Holden Mine Site. The alternatives are forming the basis for a Feasibility Study (FS) currently in preparation.

A component of the FS is an evaluation of the potential effectiveness of the various remedial alternatives towards the overall objective of reducing metal loads to site groundwater and Railroad Creek. URS Corp retained SRK Consulting (SRK) to provide estimates of the potential loading effects associated with several remedial actions included within the seven candidate site wide remedial alternatives being evaluated in the FS. This report describes the following aspects:

- The possible use of the mine workings below the 1500 Level for passive treatment of mine water acidity and metal loadings.
- The incremental benefits of a low permeability cap compared to tailings re-vegetation as documented in the literature.
- The potential short term effects on runoff water chemistry of re-grading Tailings Piles 1, 2 and 3.
- The potential short-term effects on runoff water chemistry resulting from consolidation of Tailings Piles 1, 2 and 3.

The overall approach to these calculations and evaluations has been to provide conservative worst case estimates of the potential effects. The estimates rely on the site-specific information developed for the Revised Draft Remedial Investigation (DRI) dated July 28, 1999 and Draft Feasibility Study (FS) dated June 12, 2002 rather than theoretical assumptions and complex modeling. The evaluations presented herein may be revised in the future based on additional site data or agency comments.

A separate report (SRK 2004) provides evaluation of the long term effects of the remedial alternatives.

1.2 Information Sources

This report is primarily based on information provided in the DRI, the FS and data transmittals on investigations of the underground mine (SRK 2001a,b) and the tailings piles (SRK 2002). A complete reference list is provided in Section 3.

2 RESULTS

2.1 Internal Treatment of Mine Water

2.1.1 Background

One concept of in-mine treatment currently being evaluated for the Holden Mine would involve construction of structures inside the mine to route seasonally acidic drainage from the workings above the 1500 Level to the flooded workings below the 1500 Level. The purpose of this would be to take advantage of alkaline groundwater and/or chemically reducing conditions observed in water upwelling from the lower workings to increase the pH and/or reduce dissolved metals concentrations in the drainage from the upper mine workings.

2.1.2 Passive Neutralization of Alkalinity

The potential to neutralize acidity in seasonally variable water draining from the workings above the 1500 level by mixing with the more consistent flows of upwelling water observed at the No.2 Shaft was generally evaluated using data collected during the underground investigations conducted in 2000 and 2001 (SRK, 2001 a,b).

The estimated acidity load discharged from the 1500 Level during the spring freshet was compared to the alkalinity load discharged during the balance of the year to determine if the alkalinity load significantly exceeded the acidity load. Inputs to the calculation are shown in Table 1. The weighted metal concentrations (C) were calculated as follows:

$$C = (C_{,n}.Q_n.N_n + C_l.Q_l.N_l)/(Q_n.N_n + Q_l.N_l)$$

Where:

$C_{,n}$ – Metal concentration under neutral pH conditions
$C_{,l}$ – Metal concentration under low pH conditions
Q_n – Flow under neutral pH conditions
Ql – Flow under neutral pH conditions
N_n – Number of neutral pH months
N_l – Number of low pH months

Acidity was not determined directly but estimated from aluminum, iron, copper and manganese concentrations, assuming that these metals are oxidized and precipitated as their respective hydroxides and oxides:

$$\text{Acidity (mg } CaCO_3\text{/L)} = 50.\Sigma\ (C.x)/M$$

Where x is the charge on metal ion (x_{Al} = 3; x_{Fe}=3; x_{Cu} = 2; x_{Mn}=2) and M is the atomic weight of the metal. The factor of 50 converts the sum to equivalent calcium carbonate units.

Net alkalinity is the difference between alkalinity and acidity.

Table 1: Calculation of Net Alkalinity Assuming Near Neutral pH Drainage for 10 Months

	Flow L/s	Alk $mgCaCO_3/L$	Al mg/L	Cu mg/L	Fe mg/L	Mn mg/L	Calc Acidity $mgCaCO_3/L$	Net Alk $mgCaCO_3/L$
Near neutral pH for 10 months in summer, fall and winter	4	23	0.02	0.6	0.02	0.40	2	21
Low pH for 2 months in spring)	31	0	6.1	3.5	0.34	0.44	40	-40
Average for 12 months	9	9	3.6	2.3	0.21	0.42	25	-15

The calculation assumes that the drainage is near pH neutral for 10 months (ie N_l= 10). This assumption is based on available seasonal portal drainage sampling data. The resulting calculated net alkalinity, based on the available monitoring data is -15 $mgCaCO_3$ eq/L because the total estimated acid load during the two months when the mine drainage is acidic significantly exceeds the estimated alkalinity load available for the remaining 10 months of the year. Therefore, there is probably insufficient alkalinity to internally neutralize the acid load released during the spring freshet. This indicates that in order for neutralization of acidity to occur, additional alkalinity would need to be added, for example, by using lime.

2.1.3 Optimization of Reducing Conditions

Groundwater upwelling from the No.2 shaft has neutral pH with a field measured redox potential of about 300 mV at the top of the shaft on the 1500 Level. At 60 m depth (the deepest point sampled), the redox potential is much lower (about 80 mV). At 27 m depth, the dissolved oxygen was 0.45 mg/L and remained relatively constant below this point. Iron concentrations in the shaft water were about 6 mg/L, which is consistent with the reducing conditions observed in the shaft. It is possible that much stronger reducing conditions exist at greater depths, and if sufficient, these could be removing metals from water by bacterially mediated formation of sulfides. Redox potential at depth would need to be below -100 mV to precipitate copper sulfide. Strongly reducing conditions can be attained in underground coal mines (Aljoe 1994; Perry 2001) because there is abundant organic carbon in coal seams and carbonaceous host rocks. In rocks with low carbon content, such as at Holden, a carbon source is needed and would need to be injected separately. Further investigation would be needed to determine if reducing conditions exist at depth and whether these would need to be enhanced to promote sulfate reduction and formation of metal sulfides.

A secondary consideration would be the hydrogeological conditions in the flooded mine. Acidic water from above the 1500 Level would need to be routed to ensure that it encounters reducing conditions. This water would also carry a dissolved oxygen load which would need sufficient retention time to be consumed before sulfide formation could occur. If the oxygenated water were to find a short cut through the workings it could prevent the development of anoxic conditions.

Enhancement of reduction has been implemented at the small Lilly/Orphan Boy Mine in Montana (Canty 2000) with partial success. The Lilly/Orphan mine is an abandoned hard-rock mine, and to promote reducing conditions, an organic substrate was introduced into a shaft and tunnel. The system neutralized acidity and precipitated metals (aluminum, cadmium, copper and zinc) at low flows but was overwhelmed by oxygenated water during the spring freshet. Also, the reducing conditions caused arsenic and iron to be mobilized due to de-stabilization of ferric iron oxyhydroxides. This is a significant consideration at Holden where the 1500 level contains deposits of ferric iron sludges.

2.1.4 Conclusions

It is concluded that in situ neutralization of acidity is probably not likely to occur because the acid load released during the spring exceeds the alkalinity load available in the baseflow from the No.2 Shaft.

Monitoring of the No.2 shaft showed that reducing conditions are present at depth (60 m) but the oxidation-reduction potential was not low enough to allow reduction of sulfate to sulfide. Additional monitoring would be needed to determine if conditions below this level are sufficient to precipitate metals as sulfides.

2.2 Low Permeability Covers Compared to Re-Vegetation

2.2.1 Background

Two remediation alternatives under consideration in the Draft Final FS are the application of a low-permeability engineered cover, such as a geosynthetic cover, to the tailings to provide a barrier to both oxygen and precipitation infiltration and enhancement of existing vegetation on the piles to reduce precipitation infiltration.

The Canadian Mine Environment Neutral Drainage (MEND) program recently issued a component of the MEND Manual on these control approaches in February 2001 (MEND 2001). This document contains a comprehensive review of the status of research on tailings covers and is the primary source document for the evaluation provided below.

One example of installation of a geosynthetic cover on tailings to achieve the same metal loading reduction objectives identified for Holden was described in the 2001 MEND document for the Poirier Site located in northern Québec (Lewis et al 2000).

The following sections provide a review of the potential benefits of a vegetative cover, followed by a description of the above case history.

2.2.2 Covers for Growth Medium

MEND (2001) describes simple covers (i.e., those designed primarily to act as sustainable growth medium) as the “base method” for covers. It notes that some reduction in net precipitation infiltration may occur but that these types of covers are not typically expected to provide a beneficial effect on reactive wastes. However, the base method may be varied by increasing the thickness of the cover to decrease net precipitation infiltration by increasing the available moisture storage capacity.

As a result of this philosophy, few comparative studies on the relative performance of simple vs. engineered soil covers have been completed. The usual comparison is between uncovered and covered tailings. Gardiner et al. (1997) and O’Kane et al. (1999) described a comparison of the performance of simple and complex soil covers (consisting of glacial till and gravel) at the Sullivan Mine and concluded that the engineering soil cover provided negligible additional benefit in terms of oxidation/reduction compared to the simple cover. This finding was a result of the unfavorable physical characteristics of the complex soil cover.

SRK recently reviewed data for a mine site where soil covers have been placed on waste rock dumps for the purpose of re-vegetation about 10 years ago. Monitoring data showed no difference in water quality before and after cover placement. SRK is also aware of a number of sites where non-engineered covers were placed in 1970s in an effort to improve water quality. Although these were not documented, it was apparent that water quality had not improved.

2.2.3 Effect of Mature Vegetation

Development of mature vegetation is theoretically desirable because it produces an organic soil layer (“duff”) on the cover. This layer should consume oxygen by organic decay. A potential secondary benefit of a mature vegetative cover would be a reduction in the infiltration of direct precipitation by enhancement of evapotranspiration.

Some research has been conducted on “oxygen-consuming” covers. These are intended to create reducing conditions by application of carbon-rich materials such as pulp mill waste, municipal solid waste or peat. Results of the research have been ambiguous, and no full scale applications have been documented.

Another approach is the development of wetlands on tailings. This results in both a saturated soil cover and an organic layer.

The natural analogue to a long term unsaturated cover with mature vegetation is a sandy soil profile above the water table. These profiles continue to oxidize due to delivery of oxygen via numerous rootlets. The presence of an organic layer in this case is not an effective barrier to oxygen transport.

A cover consisting of mature vegetation may reduce the volume of direct precipitation that infiltrates the tailings piles at the Holden Mine site. A reduction in precipitation infiltration has been well documented for mature alpine forests through mechanisms such as evapotranspiration. SRK (2003b) present modeling results that demonstrate a metal loadings maybe reduced as a result of reduced infiltration into the Holden tailings piles.

2.2.4 Poirier Site

Lewis et al (2000) described reclamation of the Poirier Mine site in northern Québec. The project involved relocation, grading and capping of 5 million tonnes of acid generating tailings produced between 1965 and 1975 from milling of copper and zinc ore. The sulfur content of the tailings ranged from 7 to 20% and typical toe seepage had pH of 3.2, sulfate of 38,600 mg/L and iron of 17,300 mg/L.

Three alternatives were considered:

- A 1-m clay cover
- Geomembrane with soil protection cover (0.5 m of clay, 1.5 m of till)
- Clay cover with frost protection (1 m of clay, 1.5 m of till).

It was concluded that due to the extensive oxidation in the piles, that placement of an oxygen barrier would be unlikely to result in observable benefits for decades or centuries, and therefore the overall objective was to reduce infiltration.

Based on the significant expected reduction in loadings expected with Alternative 2 compared to Alternatives 1 and 3 (1 mm/year infiltration rate was assumed), this alternative was implemented in 2000. The tailings basin had several ideal features including underlying clay rich-soils and a lack of groundwater inflow sources. The cover selected was 60 mil of unspecified type.

No details on long term performance of cover or maintenance requirements are currently available.

2.2.5 Conclusions

The overall conclusion is that application of soil covers to achieve a vegetative cover has not historically shown a significant benefit in terms of reduction of oxygen transport into tailings piles and/or improvement in seepage water quality. In the case studies evaluated, a simple cover may reduce infiltration but not to a significant degree. A cover consisting of mature vegetation may reduce the volume of direct precipitation that infiltrates the tailings piles at the Holden Mine site. Specific modeling for Holden shows that this may result in a reduction in metal loads.

Theoretically, a more impermeable cover material such as a geosynthetic liner would likely have a substantial benefit on metal loadings from the tailings piles by significantly reducing precipitation infiltration as predicted for the Poirier Site. Oxygen reduction might be a marginal and less significant benefit for highly oxidized tailings because the infiltrating water, although minimal, would continue to leach stored oxidation products. However, metals loadings from unoxidized tailings would be expected to be significantly reduced though the reduction in precipitation infiltration. These effects have been evaluated for the Holden Mine site by SRK (2003b). Water flows not affected by the cover (such as groundwater recharge from the valley sides and down valley flow) would presumably not be affected by the cover and would be expected to continue to leach at the same rate after cover placement.

2.3 Short Term Water Chemistry Effects for Re-Graded Tailings

2.3.1 Background

Re-grading of the tailings piles is being considered under a number of candidate alternatives to enhance slope stability and minimize the potential release of tailings during a seismic event. This will involve excavation and re-location of both near surface oxidized orange tailings and deeper gray tailings.

As described by SRK (2002), the orange and gray tailings have distinctive characteristics. The orange tailings are characterized by much lower sulfur and metal concentrations than the gray tailings. In the gray tailings, sulfur occurs dominantly in the form of sulfide, whereas the orange tailings are characterized by dominantly sulfate-sulfur. In extraction tests (SRK 2002), the orange tailings had typical pHs less than 4, with elevated leachable aluminum, and copper compared to the gray tailings. The gray tailings had typical leachate pHs between 5 and 6, with elevated iron and zinc concentrations compared to the oxidized tailings.

Two effects can be expected from exposure of the tailings during re-grading:

- An immediate effect can be expected as a result of leaching of soluble components of the tailings including weathering products.

- A subsequent effect can be expected as oxidation of sulfide minerals occurs. Humidity cell testing indicates that oxidation will begin after approximately four weeks when pH decreases to less than 4 and sulfide oxidation accelerates (SRK 2003).

2.3.2 Estimation of Water Quality Effects

Effect of Leaching of Stored Oxidation Products

Estimation of this effect requires that the secondary or weathering mineralogy be established. SRK (2002) reported that the orange tailings contained goethite and jarosite. Modeling performed using MINTEQA2 (Allison et al 1991) on pore waters and leachate extractions indicated that jarosite, gypsum, and $AlOHSO_4$ may be present. Scanning Electron Microscopy (SEM) suggested that the jarosite might be copper-bearing. It is expected that runoff from orange tailings exposed during re-grading will be acidic (pH<4) with copper being the most significant metal leached.

SRK (2002) found that goethite is present in the shallow gray tailings. Iron carbonate has also been tentatively identified. MINTEQA2 modeling showed that at least gypsum and $AlOHSO_4$ may be present. Iron concentrations were assumed to be dominantly (>99%) ferrous iron at the moderately acidic pHs observed. This assumption was required by the absence of widespread limonite. MINTEQA2 predicted that ferric hydroxide, jarosite and possibly Na-jarosite should be present, but this is sensitive to the proportion of ferric iron. Iron carbonate was not identified as a potential secondary phase because the pH and alkalinity of the leachates and pore waters as measured are low. MINTEQA2 did not indicate the presence of any secondary minerals of copper, zinc, cadmium or lead. The main finding is that the gray tailings are in a reducing condition compared to the surface tailings, contain very little pore water alkalinity and elevated iron concentrations. Exposure of these tailings during re-grading will result in oxidation of the tailings and the pore water. Due to the low alkalinity of the pore waters, oxidation of iron and formation ferric hydroxide will cause pH to decrease probably to less than 4 or 3. The effect of water with pH below 4 in contact with the gray and orange tailings may be to release metals. This effect was not simulated in the laboratory tests.

The approach taken to provide an initial estimate of the short term chemistry of runoff due to leaching of existing oxidation products from the disturbed tailings was:

- Estimate the leachable load from each type of tailings using the average concentrations observed in leaching tests and the 3:1 leachate (deionized water) to sample ratio.

- Based on the quantities estimated to be disturbed during re-grading and re-sloping (FS), the total leachable load was calculated.

- The concentrations produced by dissolution of the total leachable load during precipitation events defined by URS on the disturbed areas were estimated. The precipitation events were:
  - A one inch storm rain fall event.
  - Snow melt producing 9.9 x 10^{-6} cm/s for 31 days (about 10 inches).
- The resulting concentrations were input into MINTEQA2 to evaluate the effects of equilibration and were also compared to maximum concentrations in leach tests and pore waters.

Table 2 provides the results of the estimates of these effects. It is apparent that leaching of exposed tailings by a 1 inch storm event could produce poor quality water. MINTEQA2 output indicated that the mineral jarosite would be expected to form along with an aluminum sulfate. Re-equilibration with these minerals present resulted in the chemistry shown in Table 2. The pH of runoff could be very low (possibly less than 2) as a result of release of stored iron, and would contain high concentrations of zinc and iron. The chemistry estimates shown are approximate and depend on the iron concentration and the estimate of the oxidation-reduction potential of the runoff.

In comparison, snow melt would be expected to be more dilute and have a pH between 2 and 3. Concentrations were estimated to be comparable to current seepage with the exception of zinc.

Table 2: Estimates of Runoff Chemistry for Re-Graded Tailings

Parameter	Unit	Orange Tailings		Grey Tailings			Tailings Seepage	Leaching of Pre-Existing Oxidation Products				Leaching of Sulfide Oxidation Products				
		Extraction Leachate		Extraction Leachate		Pore Water		Storm Event		Snow Melt		Storm Event (MINTEQA2 Corrected)				Snowmelt
		Oxidized	Max URS-TP3-tp1-7'	Median	Max URS-TP1-tp2-2'	Max URS-TP1-tp5-12'	SP-2 July 12, 1997	Calculated	MINTEQA2 Corrected	Calculated	MINTEQA2 Corrected	After 1 Month	After 2 Month	After 3 Month	After 4 Month	
pH	s.u.	3.8	3.96	5.5	5.15	4.15	2.9	4.8	1.4	4.8	2.4	2.2	1.9	1.8	1.7	2.9
SO_4	mg/L	45	1510	223	2180	3660	3800	25688	23654	2461	2767	12163	24634	35395	47635	2629
Alk	mg/L	-	-	<1	<1	-		104	-	9.9	-	-	-	-	-	-
Aluminum	mg/L	1.65	10.6	0.02	0.45	102	115	97	86	9	194	471	745	1065	1369	44
Arsenic	mg/L	<0.0006	0.00078	<0.006	<0.0012	-0.010	<0.005	-0.656	0.693	-0.063	0.064	0.071	0.14	0.21	0.29	0.020
Cadmium	mg/L	0.002	0.013	0.002	0.0034	0.032	0.009	0.32	0.34	0.03	0.03	0.70	1.4	2.2	3.0	0.15
Calcium	mg/L	4.55	543	13.9	508	380	241	1701	2490	163	228	432	1226	599	574	132
Copper	mg/L	0.145	6.6	0.003	0.0042	0.3	0.79	8.6	9.1	0.8	0.8	4.8	9.8	15	21	1.1
Total Iron	mg/L	0.08	0.1	167	142	672	1180	17311	905	1658	45	101	127	226	344	3
Lead	mg/L	0.005	0.016	<0.005	0.0074	0.052	<0.01	-0.23	0.24	-0.02	0.02	0.27	0.54	0.82	0.11	0.060
Magnesium	mg/L	1.9	5.7	3.2	17.7	204	153	440	463	42	42	113	232	355	483	3
Manganese	mg/L	0.11	0.3	0.23	0.72	7.2	8.57	30	32	3	3	14	30	45	62	3
Potassium	mg/L	2.85	4.6	8.4	7.9	8.6	9.64	1034	411	99	1	199	430	698	983	72
Sodium	mg/L	1.55	2.1	2	4.9	34.9	23.3	296	884	28	80	69	403	617	840	43
Zinc	mg/L	0.255	0.69	15.1	246	5.2	4.12	1579	1417	151	130	3536	6166	9449	12862	665

Notes:
1. Assumes that ferrihydrite and jarosite are precipitated. Calculated ion balances are <1% for chemistry shown.

Effects of Sulfide Mineral Oxidation

Longer term effects potentially result from the oxidation of freshly exposed sulfide minerals in the gray tailings. These effects were estimated from humidity cell data as follows:

- Humidity cell release rates for sulfate and metals were expressed as mg/m^2/week, where the area factor is the cross-sectional area of the humidity cell.
- Concentrations were calculating using the areas of exposed tailings and runoff scenarios indicated by URS. These scenarios were similar to the ones used for the oxidation effects with additional consideration of the exposure period:
  - A 1 inch storm event after tailings had been exposed for 1 month, 2 months, 3 months and 4 months.
  - Snow melt producing 9.9×10^{-6} cm/s for 31 days (about 10 inches) after the tailings were thoroughly leached by rainfall in the fall then been covered with snow for six months of winter. Release rates were reduced by a factor of 3 to account for lower oxidation rates at lower temperatures.
- Concentrations were input into MINTEQA2 to evaluate effects of mineral precipitation

Table 2 provides the results of these calculations. All four storm event scenarios indicated that the pH of runoff could be expected to be near 2, with elevated concentrations of zinc and sulfate. Due to the high ionic strengths of these waters and the associated uncertainty in the input of pH and oxidation-reduction potential, there is significant uncertainty around the estimated concentrations. The main conclusions from these estimates are that runoff can be expected to be strongly acidic, and as the duration of exposure increases, the pH of runoff can be expected to decrease and concentrations of ions increase.

The spring snowmelt event scenario produced much lower concentrations and higher pH than the storm events due to the effect of slower release rates over the winter and the higher volumes of water involved.

Comparison of Predictions

As noted in Section 2.3.1, the period over which the initial effects might be observed is a few weeks after the tailings are exposed during re-grading. However, the calculations indicated the characteristics of runoff produced by leaching of stored oxidation products and fresh products of sulfide mineral oxidation are probably indistinguishable. Both types of runoff are expected to be very strongly acidic with elevated sulfate and zinc concentrations, and elevated aluminum and iron concentrations. This type of runoff has been observed at other sites in tailings areas composed of sulfide tailings.

Effect on Seepage Chemistry

As described previously by SRK (2003b), the conceptual geochemical model indicates that acidity and metals generated in the surface tailings is attenuated by contact with alkalinity in the deeper gray tailings. Iron is also reduced in the tailings but produces acidity when oxidized and hydrolyzed at the toe seeps. Acid and metals produced by oxidation of the exposed gray tailings should be attenuated in the deep gray tailings and have a negligible affect on seepage originating from deep within the tailings mass.

2.3.3 Implications to Remedial Activities

The following general comments can be made related to tailings pile regrading:

- Exposure of oxidized and gray tailings during re-grading would likely result in acidic runoff from precipitation events that will be unsuitable for direct discharge to the environment. As a result, this water may need to be collected and treated. At the Poirier Site described in Section 2.2.4, runoff water was managed during construction activities.

- Exposure of gray tailings should be minimized due to their high reactivity and potential to generate long term acidic runoff.

- Excavated oxidized tailings should be placed on top of gray tailings to mimic the current configuration, as possible. This may reduce exposure of gray tailings to oxidation, while possibly attenuating acidity and metals leached from the oxidized tailings by reaction with the gray tailings.

2.3.4 Conclusions

Runoff chemistry is likely to be controlled by the dissolution of weathering products from the near surface oxidized layer and acidification of gray tailings by oxidation and precipitation of iron. Table 2 indicates estimated metal concentrations that can be expected for both processes.

2.4 Short Term Effect of Consolidation Activities

Alternatives 7 and 8 involve moving all of Tailings Pile 1 and the majority of Tailings Pile 3 onto Tailings Pile 2. The final pile would be reconfigured for seismic stability and covered with geosynthetic material or other low permeability material.

The short term effects of consolidation would be comparable to those described above for re-grading (Section 2.3.2, Table 2). Exposure of both oxidized tailings and gray tailings containing high concentrations of stored leachable iron would result in acidic runoff. Runoff chemistry was estimated using results from humidity cells (SRK 2003). The same runoff scenarios were used to estimate flow volumes.

The main difference between re-grading and consolidation is that consolidation will involve exposure of a greater quantity of tailings, and deeper gray tailings that contain some residual alkalinity which will provide some delay in the onset of strongly acidic conditions. For the purpose of the calculations, the following approximations were made:

- 80% of the tailings are deep gray tailings; and
- the gray tailings will oxidize at rates indicated for pH>4 in the humidity cell test on this material (SRK 2003).

The calculated pHs of potential runoff (Table 3) were less severe than indicated for the re-graded tailings in Section 2.3 due to the presence of deeper unoxidized tailings but were nonetheless strongly acidic with pHs less than 3 for the storm runoff scenarios and pH less than 4 for snowmelt. The acidity of the runoff is expected to overwhelm the small amount of alkalinity still present in the deep gray tailings.

Table 3: Prediction of Runoff Chemistry for Consolidated Tailings

Parameter	Unit	Months Exposed Before Storm Event				Snowmelt
		1	2	3	4	
pH		2.6	2.3	2.3	2.1	3.3
SO_4	mg/L	4964	8724	12557	16522	1557
Aluminum	mg/L	134	248	358	466	19
Arsenic	mg/L	0.035	0.071	0.11	0.14	0.008
Cadmium	mg/L	0.69	1.4	2.1	2.8	0.20
Calcium	mg/L	483	443	411	403	270
Copper	mg/L	2	4.4	6.6	8.9	0.5
Total Fe	mg/L	281	608	941	1304	54
Ferrous Fe	mg/L	265	565	865	1191	52
Lead	mg/L	0.26	0.54	0.81	1.1	0.060
Magnesium	mg/L	135	274	415	559	30
Manganese	mg/L	25	50	75	101	5
Potassium	mg/L	237	488	744	1010	51
Sodium	mg/L	67	134	136	274	15
Zinc	mg/L	755	1524	2037	3112	167
Acidity	mg $CaCO_3$/L	2461	4928	6998	9973	471

The implications to remediation described in Section 2.3 for re-grading also apply to consolidation.

3 Conclusions

Conclusions from these calculations are summarized as follows:

- There is probably insufficient dissolved alkalinity upwelling from the No.2 Shaft to offset the acidity in drainage from the upper workings. Reducing conditions in the No.2 Shaft are not sufficient to cause sulfide mineral precipitation; however, more strongly reducing conditions may exist at depth.

- Simple soil covers are probably not effective for reducing oxidation of tailings; however, improved evapotranspiration by vegetation may reduce infiltration. A geosynthetic liner would result in substantial decrease in infiltration and would also reduce the oxidation rate of gray tailings.

- Short term runoff from freshly graded or consolidated tailings can be expected to be acidic and carry elevated concentrations of dissolved metals.

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SRK Consulting 2001b. Discussion of Geochemical Data Collected from Holden Mine - April and May 2001. SRK Project 1UD005.00. Prepared for Dames & Moore, July 26, 2001.

SRK Consulting, 2002. Geochemical Characterization of Tailings at the Holden Mine. Prepared for URS Corp. SRK Project 1UD005.00. March 2002.

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URS Corporation, 2002. Draft Feasibility Study – Holden Mine Site. Prepared for Intalco. June 12, 2002.

APPENDIX F
ACID DRAINAGE TREATMENT PLANT PERFORMANCE DATA

Summary of Available Low-energy and Mechanical ARD Treatment System Performance Data

ATTACHMENT F-1

Elbow Creek Engineering, 2004. *Detailed Examination of Acid Drainage Treatment Plant Performance.* February 13, 2004.

SUMMARY OF LOW-ENERGY TREATMENT SYSTEM PERFORMANCE DATA
APPENDIX F

SITE, LOCATION: **Crystal Mine, Montana, North America**

MINING PRODUCTS: Not available

GENERAL TREATMENT TYPE: Low-energy lime precipitation: full-scale study

PRIMARY SYSTEM COMPONENTS: Quicklime neutralization with an AquaFix water-powered lime feeder, aeration using rip rap channels, two settling ponds in series. Flow transferred through the system by gravity, with minimal system control or oversight at the inactive and remote location (semi-passive).

PERIOD OF OPERATION: Two year pilot test from September 1994 through June 1996

AVERAGE TREATMENT DATA

TREATMENT FLOW (gpm)	PARAMETER	INFLUENT	EFFLUENT
20 – 100	pH	3.04	11.4
	Cd (mg/L)	0.86	0.005
	Cu (mg/L)	14.7	0.04
	Fe (mg/L)	50	0.02
	Zn (mg/L)	65	0.4

*Average treatment data under proper operating conditions
* Data provided as total metals

INFLUENT/EFFLUENT VARIATION DATA

TREATMENT FLOW (gpm)	PARAMETER	INFLUENT MIN – MAX	EFFLUENT MIN - MAX
20 - 100	pH	2.54 – 3.44	9.28 – 12.7
	Cd (mg/L)	0.67 – 1.05	0.003 – 0.020
	Cu (mg/L)	7.7 – 27	0.002 – 0.37
	Fe (mg/L)	25 - 110	0.01 – 0.03
	Zn (mg/L)	51 - 81	0.01 – 2.4

*Min and max concentrations obtained during proper operating conditions
* Data provided as total metals

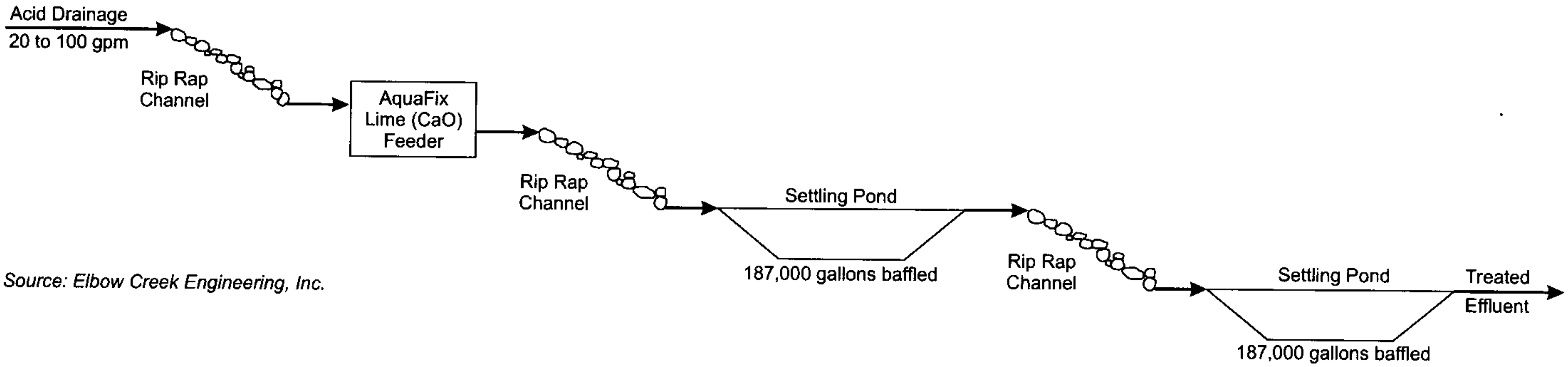
POTENTIAL REASON(S) CITED FOR VARIATION: Treatment flow varied due to spring snow melt. The effluent water quality varied for several reasons; lack of knowledge by the operational staff, plugging of the alkaline reagent within the throat of the AQUA-FIX, and collapse of portal which clogged process train and acidic water to bypass.

Crystal Mine, Montana, North America (Continued)

REFERENCE

Elbow Creek Engineering, 2004. *Detailed Examination of Acid Drainage Treatment Plant Performance.* February 13, 2004.

MSE Technology Applications, Inc. *Final Report-Remote Mine Site Demonstration Project.* Prepared for EPA. March 1998



Source: Elbow Creek Engineering, Inc.

SITE, LOCATION: **Confidential, North America (Elbow Creek Site 4)**

MINING PRODUCTS: Not available

GENERAL TREATMENT TYPE: Low-energy lime precipitation: full-scale operation

PRIMARY SYSTEM COMPONENTS: Automated hydrated lime addition/mixing with flocculant addition and removal of suspended solids in two 3-million gallon settling ponds (baffled). Solids dredged from within the ponds once per year and disposed in lined containment onsite.

PERIOD OF OPERATION: Mid 1990's to current

AVERAGE TREATMENT DATA

TREATMENT FLOW (gpm)	PARAMETER	INFLUENT	EFFLUENT
200 –6,000	pH	5.0 – 6.0	7.0 – 8.0
	Cd (mg/L)	0.015	0.0003
	Cu (mg/L)	0.30	0.004
	Fe (mg/L)	30.8	0.29
	Zn (mg/L)	0.90	0.05

* Data provided as total metals
* Influent quality similar to estimated blended concentrations in water collected from the Holden Mine East Area.

INFLUENT/EFFLUENT VARIATION DATA: Not available

REFERENCE

Elbow Creek Engineering, 2004. *Detailed Examination of Acid Drainage Treatment Plant Performance.* February 13, 2004.

SUMMARY OF MECHANICAL TREATMENT SYSTEM PERFORMANCE DATA
APPENDIX F

SITE, LOCATION: **Bunker Hill Mine, Kellogg, Idaho**

MINING PRODUCTS: Lead and zinc

GENERAL TREATMENT TYPE: Mechanical low density sludge (LDS) process (full-scale) with pilot-scale filtration study

PRIMARY SYSTEM COMPONENTS: Based on the results of full-scale and pilot-scale treatability testing, lime precipitation (HDS) operated at a pH of 9.5 followed by tri-media filtration (garnet, sand, and anthracite) was recommended for use at the site in the Proposed Plan (EPA 2001). Data obtained from the full-scale lime precipitation system (LDS) and pilot scale filtration tests are provided below. Note that the system is currently operated as a LDS system, but will be modified to operate as a HDS system in the future.

The attached figure provides a process schematic for the lime precipitation system and pilot-scale filtration tests. Note that sulfide was not added during the tests summarized below.

PERIOD OF SYSTEM OPERATION: The Bunker Hill mine was operated from 1885 into the 1980s. Small-scale mining operations continue currently. The central AMD treatment plant (CTP) currently operates as a lime precipitation (LDS) system. The CTP was built in 1974 and is currently in operation (EPA, 2001).

AVERAGE TREATMENT DATA

The following summarizes average influent and effluent dissolved metals data from full-scale AMD treatment in the CTP by lime precipitation (LDS) followed by pilot-scale tri-media filtration (garnet, sand, and anthracite). The tests were conducted August 14 – 18, 2000. The CTP effluent was "spiked" with sludge from the thickener underflow to simulate higher TSS concentrations expected during future plant operations as a HDS system. (URS Griener/CH2M Hill, 2000).

FULL-SCALE TREATMENT FLOW (gpm)	PARAMETER	FULL-SCALE LIME PRECIPITATION (LDS)		PILOT-SCALE TRI-MEDIA FILTRATION	
		INFLUENT	EFFLUENT	INFLUENT[b]	EFFLUENT
NA	pH	3.1	9.2	7.2	NA
	Cd (mg/L)	0.11	0.0003	0.0024	0.0002
	Cu (mg/L)	0.10	NA	NA	a
	Fe (mg/L)	79.2	NA	NA	a
	Zn (mg/L)	75.7	0.065	1.44	0.028

* Concentration data are for dissolved metals
* NA: Not Available
a: Avg total metals results for cu = 0.049 mg/Land fe = 0.030 mg/L.
b: Influent to filter test consisted of effluent from LDS system spiked with sludge from system underflow to simulate higher TSS concentrations.

Bunker Hill Mine, Kellogg, Idaho (Continued)

INFLUENT/EFFLUENT VARIATION DATA

The following summarizes total metals data from two trial runs of full-scale lime precipitation in the CTP followed by bench-scale sludge spiking and tri-media filtration (garnet, sand, and anthracite) (URS Griener/CH2M HILL, 2000). The following data is from tests conducted in July and August of 2000.

FULL-SCALE TREATMENT FLOW (gpm)	PARAMETER	FULL-SCALL LIME PRECIPITATION		PILOT-SCALE TRI-MEDIA FILTRATION
		INFLUENT	EFFLUENT	EFFLUENT
UK	pH	NA	8.6 – 9.3	NA
	Cd (mg/L)	0.16 – 0.22	0.00023 – 0.0022	0.00011 – 0.0012
	Cu (mg/L)	NA	NA	< 0.0037 –0.093
	Fe (mg/L)	NA	NA	0.022 – 0.073
	Zn (mg/L)	93 – 113	0.061 – 0.40	0.014 – 0.055

* Concentration data are total metals
* NA: Not Available

POTENTIAL REASON(S) CITED FOR VARIATION: An episode of a lime pump failure resulted in insufficient pH reduction and elevated metals concentrations for a period of time during the first trial run. Copper and iron were not the focus of the study and not addressed specifically in available reports.

REFERENCES

EPA. "Proposed Plan for the Bunker Hill Superfund Site, Bunker Hill Mine Water Management, Kellogg, Idaho". July 2001.

Hart Crowser. "Agencies Direction for Preparing the Holden Mine Site Draft Final Feasibility Study". January 2003.

URS Greiner in association with CH2M HILL. "Phase 2 Testing Results Bunker Hill Mine Water Treatability Study". November 2000.

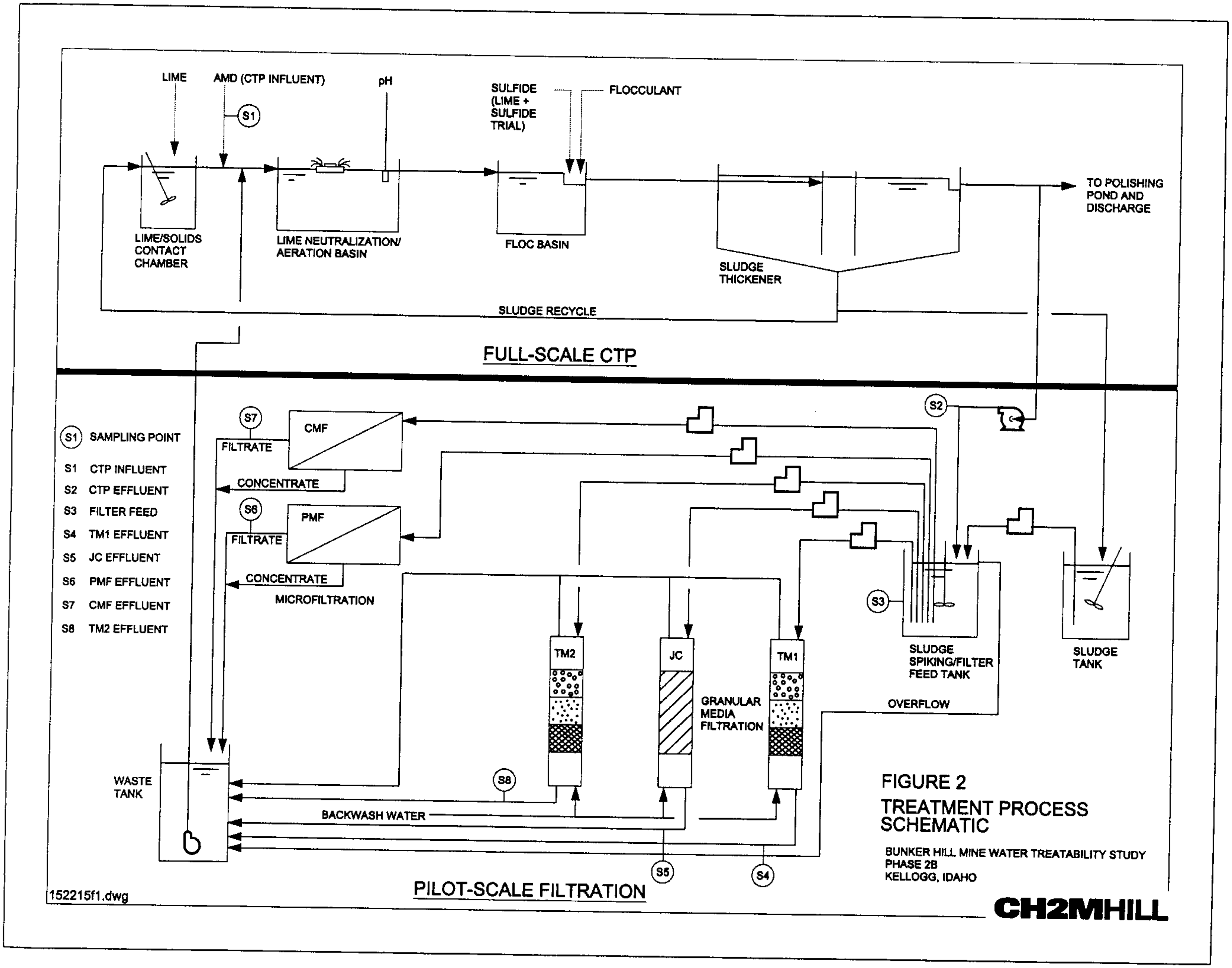


FIGURE 2
TREATMENT PROCESS SCHEMATIC

BUNKER HILL MINE WATER TREATABILITY STUDY
PHASE 2B
KELLOGG, IDAHO

CH2MHILL

SITE, LOCATION: **Confidential, North America (Elbow Creek Site 1)**

MINING PRODUCTS: Not available

GENERAL TREATMENT TYPE: Mechanical high density sludge (HDS) process: full-scale operation

PRIMARY SYSTEM COMPONENTS: Mechanical lime and recycled sludge neutralization in HDS system to pH 9.3 followed by mechanical clarification. The attached figure provides the general process configuration.

PERIOD OF OPERATION: Detailed water quality data are from plant operations for the period of 1992 though 2001

AVERAGE TREATMENT DATA

TREATMENT FLOW (gpm)	PARAMETER	INFLUENT		EFFLUENT	
		AVG	95%	AVG	95%
3,800	pH	4.0	4.9	9.2	9.5
	Cd (mg/L)	0.075	0.16	<0.002	< 0.005
	Cu (mg/L)	0.18	0.51	0.008	0.02
	Fe (mg/L)	190	384	0.02	0.05
	Zn (mg/L)	40	75	0.02	0.04

* Concentration data are dissolved metals
* Average and 95th percentile data from 1992 – 2001 generated from over 4,500 data for each parameter

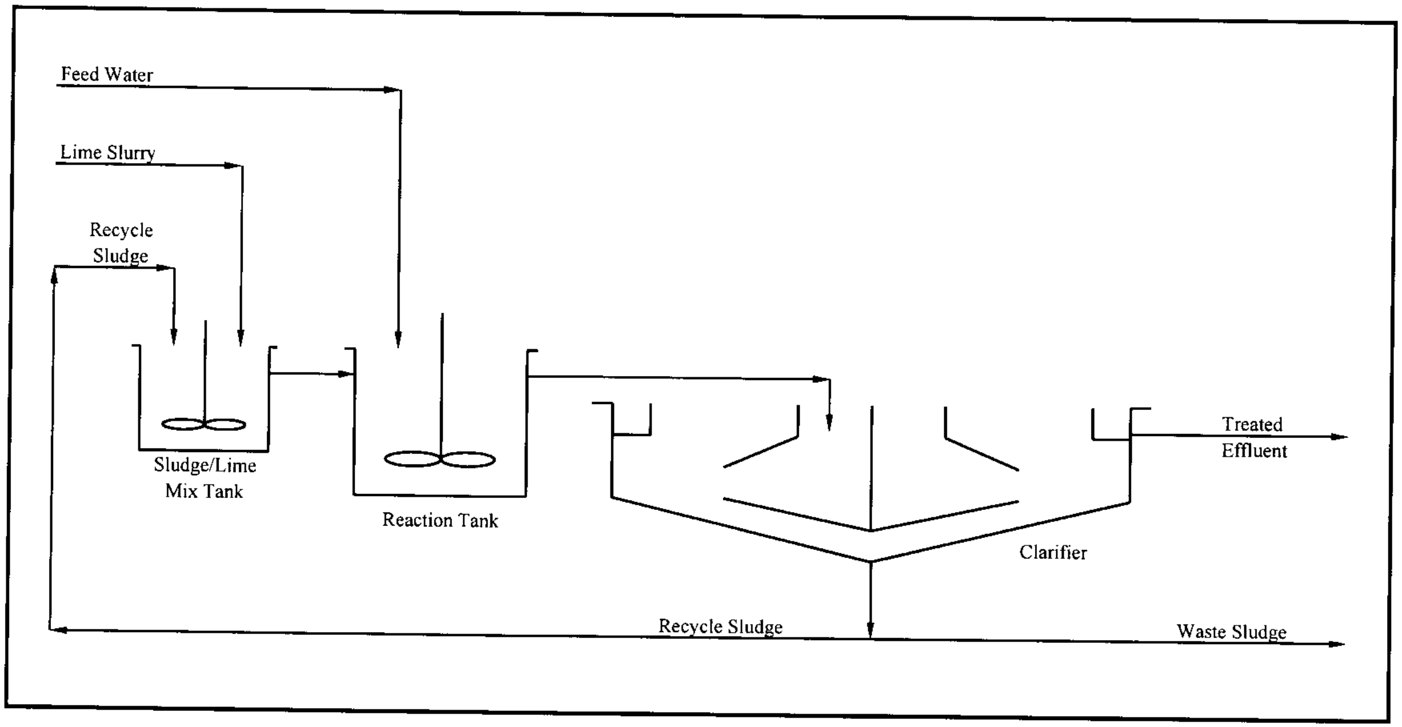
INFLUENT/EFFLUENT VARIATION DATA

TREATMENT FLOW (gpm)	PARAMETER	REG. CRITERIA (Monthly Avg.)	INFLUENT MIN – MAX (Monthly Avg.)	EFFLUENT MIN – MAX (Monthly Avg.)
0 – 6,300	pH	8.0 – 10.0	3.6 – 4.6	9.1 – 9.4
	Cd (mg/L)	NA	0.045 – 0.11	<0.002
	Cu (mg/L)	<0.15	0.04 – 0.28	0.002 – 0.020
	Fe (mg/L)	<0.6	84 – 140	0.02 – 0.05
	Zn (mg/L)	<0.3	20 - 44	0.01 – 0.03

* Concentration data are dissolved metals
* Concentration data from Jan. – Dec. 2001
* NA: Not Available

REFERENCE

Elbow Creek Engineering, 2004. *Detailed Examination of Acid Drainage Treatment Plant Performance.* February 13, 2004.



Site No. 1
Acid Drainage Treatment Plant
General Process Configuration
High Density Sludge

SITE, LOCATION: **Confidential, North America (Elbow Creek Site 3)**

MINING PRODUCTS: Not available

GENERAL TREATMENT TYPE: Mechanical lime precipitation with sludge recycle: full-scale operation

PRIMARY SYSTEM COMPONENTS: Mechanical lime neutralization with sludge recycle to pH 8.9 followed by mechanical clarification. The attached figure provides the general process configuration

PERIOD OF OPERATION: Late 1990's to current. Detailed water quality data are from plant operations for the period of 1999 though 2001

AVERAGE TREATMENT DATA

TREATMENT FLOW (gpm)	PARAMETER	INFLUENT		EFFLUENT	
		AVG	95%	AVG	95%
1000	pH	3.2	3.7	8.9	9.3
	Cd (mg/L)	NA	NA	NA	NA
	Cu (mg/L)	32	57	0.07	0.16
	Fe (mg/L)	140	265	0.19	0.48
	Zn (mg/L)	13	20	0.05	0.08

* Concentration data are total metals

* Average and 95th percentile data from 1999 – 2001 generated from over 4,100 data for pH, Cu, Fe, and Zn

* NA: Not Available

INFLUENT/EFFLUENT VARIATION DATA

TREATMENT FLOW (gpm)	PARAMETER	REG. CRITERIA (Monthly Avg.)	INFLUENT MIN – MAX (Monthly Avg.)	EFFLUENT MIN – MAX (Monthly Avg.)
400 – 1,100	pH	6.5 – 9.0	2.8 – 3.4	8.8 – 9.4
	Cd (mg/L)	NA	NA	NA
	Cu (mg/L)	0.1	21 - 60	0.45 – 0.66
	Fe (mg/L)	50	270 - 87	0.16 – 0.24
	Zn (mg/L)	None	8 - 20	0.03 – 0.04

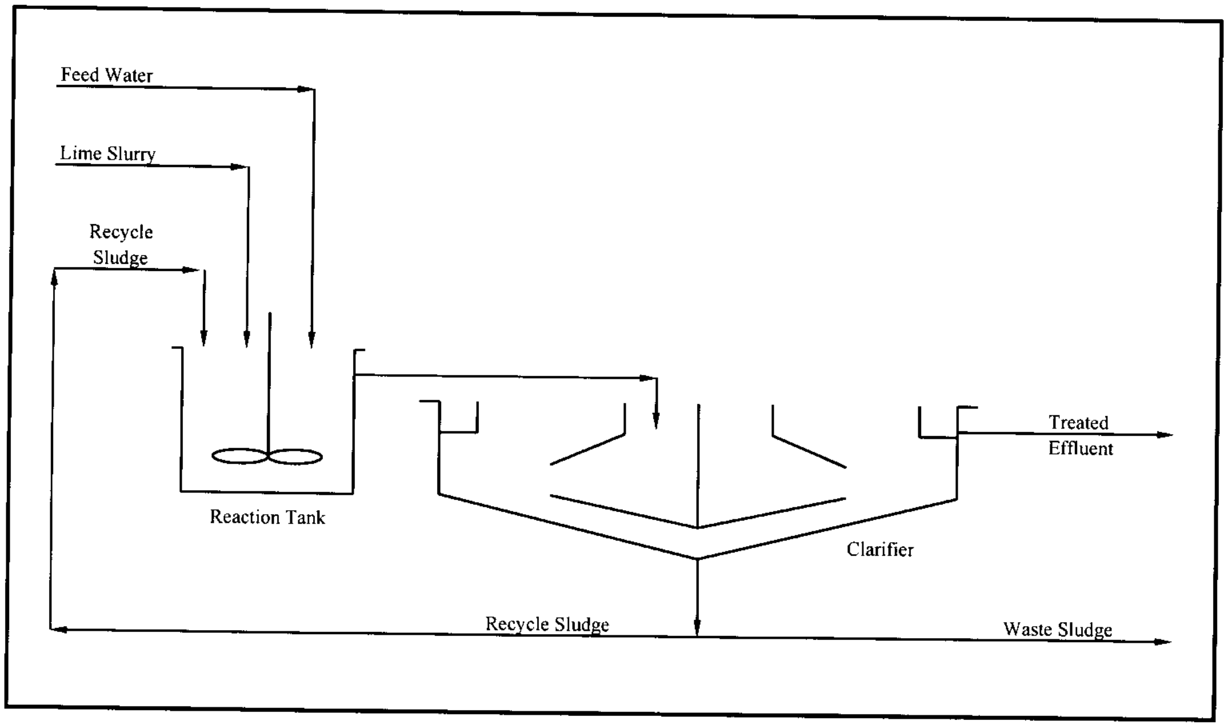
* Concentration data are total metals

* Concentration data from Apr. – Oct. 2002

* NA: Not Available

REFERENCES

Elbow Creek Engineering, 2004. *Detailed Examination of Acid Drainage Treatment Plant Performance.* February 13, 2004.



Site No. 3
Acid Drainage Treatment Plant
General Process Configuration
Lime Neutralization with Sludge Recycle

SITE, LOCATION: **Confidential, North America (Elbow Creek Site 2)**

MINING PRODUCTS: Not available

GENERAL TREATMENT TYPE: Mechanical HDS process: full-scale operation

PRIMARY SYSTEM COMPONENTS: Lime neutralization in HDS system to pH 10.0 followed by mechanical clarification, and gravity sand filtration. The attached figure provides the general process configuration.

PERIOD OF OPERATION: Late 1980's to current. Detailed water quality data are from plant operations for the period of 1998 though 2001

AVERAGE TREATMENT DATA

TREATMENT FLOW (gpm)	PARAMETER	INFLUENT		EFFLUENT	
		AVG	95%	AVG	95%
5,000 – 15,000	pH	~5.5	NA	~9.8	NA
	Cd (mg/L)	2.7	3.7	0.003	0.004
	Cu (mg/L)	0.087	0.30	0.002	0.007
	Fe (mg/L)	9.3	20	0.21	1.6
	Zn (mg/L)	265	329	0.06	0.09

* Concentration data are total metals

* Average and 95th percentile data from 1998 – 2001 generated from over 580 data points for Cd, Cu, Fe, and Zn

INFLUENT/EFFLUENT VARIATION DATA

TREATMENT FLOW (gpm)	PARAMETER	REG. CRITERIA (Monthly Avg.)	INFLUENT MIN – MAX (Monthly Avg.)	EFFLUENT MIN – MAX (Monthly Avg.)
5,000 – 15,000	pH	NA	~5.5	~9.8
	Cd (mg/L)	0.002	1.8 – 3.6	0.001 – 0.003
	Cu (mg/L)	0.015	0.04 – 0.31	0.002 – 0.004
	Fe (mg/L)	None	3.4 - 18	0.36 – 1.6
	Zn (mg/L)	0.12	207 - 342	0.04 – 0.06

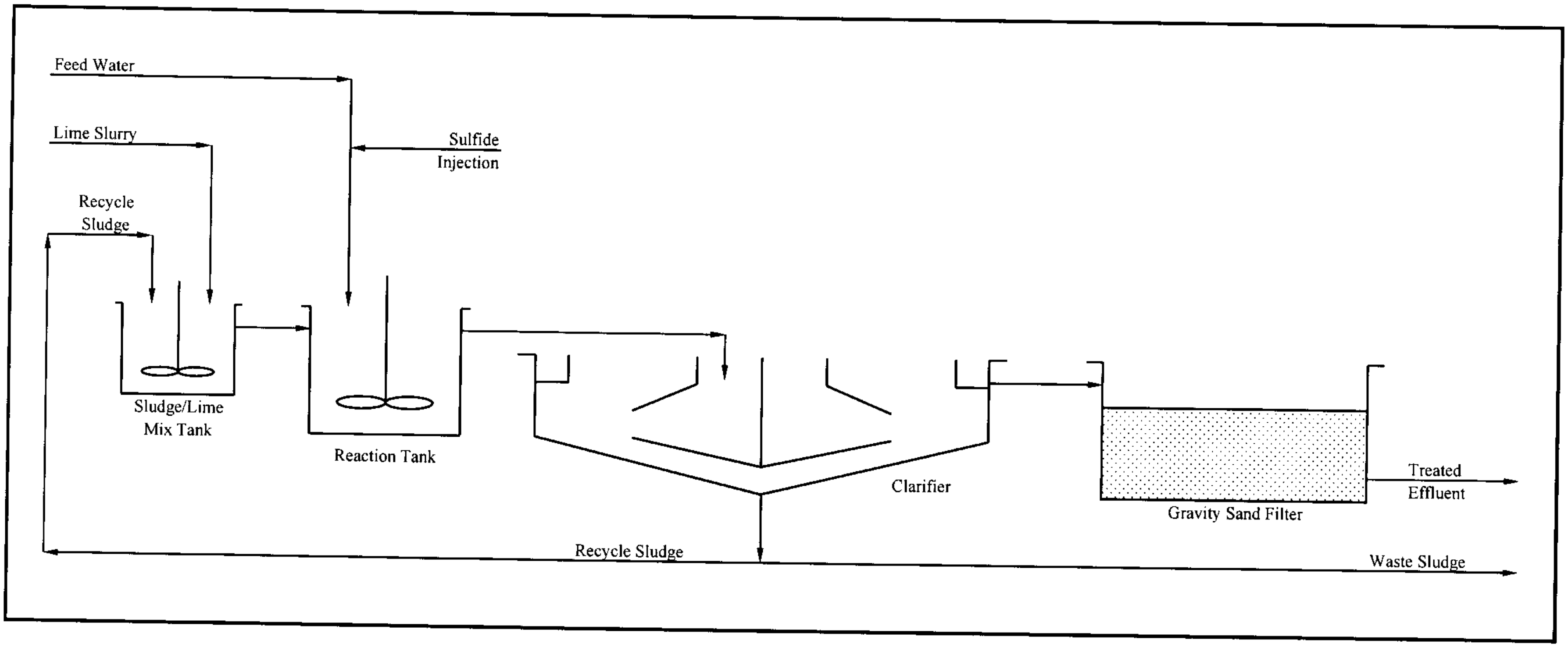
* Concentration data are total metals

* Concentration data from May – Oct. 2000

* NA: Not Available

REFERENCES

Elbow Creek Engineering, 2004. *Detailed Examination of Acid Drainage Treatment Plant Performance.* February 13, 2004.



Site No. 2
Acid Drainage Treatment Plant
General Process Configuration
High Density Sludge with Sulfide Injection and Filtration

ELBOW CREEK ENGINEERING, INC.

ELBOW CREEK ENGINEERING, INC.
67 GOOSE LANE
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MEMORANDUM

DATE: February 13, 2004

TO: David Jackson, David E. Jackson & Associates, Inc.
Jennifer Deters, URS Corporation

FROM: Mike Botz, Elbow Creek Engineering, Inc.

COPY: John Clairmont, UniField Engineering, Inc.

RE: Examination of Acid Drainage Treatment Plant Performance

This memorandum was prepared to support the evaluation of site-wide remedial alternatives presented in the Feasibility Study for the Holden Mine site in Washington. Candidate remedial alternatives under consideration for the site include the collection and treatment of acid drainage originating in underground mine workings, waste rock piles and tailings piles located in the West and East Areas of the site. Both low-energy and conventional mechanical water treatment systems are being considered for treatment of acid drainage at the site. This memorandum provides an examination of influent and effluent water quality observed from several pilot and full-scale acid drainage treatment plants that may be considered in relation to alternatives being considered for the Holden Mine site. Treatment systems referenced in this memorandum include several mechanical alkaline precipitation processes, a low-energy process using automated chemical addition and mixing equipment, and a process utilizing a water-powered lime feeder.

For purposes of preparing the Feasibility Study for the Holden Mine site, the untreated water chemistry and the effluent goals summarized in Table 1 have been assumed for the East and West Areas.

Table 1
Intalco Holden Mine Site Untreated Water Chemistry and Assumed Effluent Goals

Constituent	West Area		East Area	
	Untreated Water (1)	Assumed Effluent Goal (2,3)	Untreated Water (1)	Assumed Effluent Goal (2,3)
Cadmium, mg/L	0.02 to 0.05	0.005	0.002 to 0.04	0.005
Copper, mg/L	2 to 10	0.024	0.03 to 0.50	0.035
Iron, mg/L	0.5 to 1.0	0.2	21 to 443	0.2
Zinc, mg/L	2 to 15	0.24	0.3 to 7.0	0.35

Notes: (1) Estimated ranges taken from Section 7 of the February 2003 Draft Final Feasibility Study.
(2) Assumed effluent goals for both low-energy and conventional mechanical treatment systems.
(3) Dissolved concentrations.

Over the past several years, the authors have collected published and unpublished performance data from several pilot and full-scale acid drainage treatment plants in North America. These plants treated mine waters ranging in chemistry from heavily-impacted acidic waters to lightly-impacted relatively clean waters. A summary of maximum, average and minimum effluent concentrations for cadmium, copper, iron and zinc in these plants is provided in Table 2. These data were taken from a total of 21 treatment plants utilizing lime neutralization processes, which in some cases included sulfide precipitation and filtration polishing steps. All the treatment processes in these 21 plants are of conventional design and widely utilized for acid drainage treatment. The magnitude of variation in effluent quality indicated in Table 2 is typical of that observed with acid drainage treatment plants. In general, effluent goals assumed in the Feasibility Study (Table 1) are within the ranges of concentrations listed in Table 2.

Table 2
Summary of Effluent Quality from Acid Drainage Treatment Plants

Constituent	Effluent Concentrations (1)		
	Maximum	Average	Minimum
Cadmium, mg/L	0.08	0.012	<0.0003
Copper, mg/L	0.12	0.031	<0.0004
Iron, mg/L	5.45	0.53	0.02
Zinc, mg/L	1.62	0.25	0.01

Notes: (1) Data taken from 21 North American pilot and full-scale acid drainage treatment plants.

Detailed water quality databases were obtained for three of the full-scale acid drainage treatment plants included in Table 2 with the intent of generating statistical performance summaries for influent and effluent pH and the concentrations of cadmium, copper, iron, zinc and sulfate. These three treatment plants are anonymously numbered 1 through 3 since the associated performance data is not in the public domain. Brief descriptions of these treatment plants are provided below, while more detailed information is provided in Attachments A through C.

Included in Attachments A through C for the three treatment plants are the following:

- Treatment plant process flow diagram
- Annual summaries and statistics for untreated and treated water qualities
- Indications of total versus dissolved constituent analyses
- Timeline plots forconcentrations of various constituents in treated effluent
- Site effluent limitations (where applicable)

Site No. 1: The acid drainage treatment plant at Site No. 1 is configured as a high density sludge system to treat about 3,800 gpm on a year round basis. The pH of the acid drainage is adjusted with lime from about 4.0 up to about 9.3 and suspended solids are removed from treated water in a clarifier before discharge to surface water. Details regarding the configuration of this treatment plant and detailed water quality data for the period 1992 through 2001 are provided in Attachment A. As indicated in Attachment A, the statistical summary was generated from over 4,500 individual analyses of influent and effluent water samples for pH, cadmium, copper, iron, zinc and sulfate. In addition to the annual statistical summaries for the years 1992 through 2001, monthly statistical summaries are also provided for the year 2001.

Site No. 2: The acid drainage treatment plant at Site No. 2 is configured as a high density sludge system with sulfide injection and effluent filtration to treat about 5,000 to 15,000 gpm on a seasonal basis. The pH of the acid drainage is adjusted with lime from about 5.5 up to about 10.0 and suspended solids are removed from treated water in a clarifier and gravity sand filter before discharge to surface water. Details regarding the configuration of this treatment plant and detailed water quality data for the period 1998 through 2001 are provided in Attachment B. As indicated in Attachment B, the statistical summary was generated from over 580 individual analyses of influent and effluent water samples for cadmium, copper, iron, zinc and sulfate. In addition to the annual statistical summaries for the years 1998 through 2001, monthly statistical summaries are also provided for the year 2000.

Site No. 3: The acid drainage treatment plant at Site No. 3 is configured as a lime neutralization system with sludge recycle to treat about 1,000 gpm on a seasonal basis. The pH of the acid drainage is adjusted with lime from about 3.2 up to about 8.9 and suspended solids are removed from treated water in a clarifier before discharge to surface water. Details regarding the configuration of this treatment plant and detailed water quality data for the period 1999 through 2001 are provided in Attachment C. As indicated in Attachment C, the statistical summary was generated from over 4,100 individual analyses of influent and effluent water samples for pH, copper, iron and zinc. In addition to the annual statistical summaries for the years 1999 through 2001, monthly statistical summaries are also provided for the year 2002.

An overall summary of the data presented in Attachments A through C for these three sites is provided in Table 3. Reference Attachments A through C for descriptions of total versus dissolved constituent analyses and the type of treatment process employed.

Table 3
Summary of Full-Scale Acid Drainage Treatment Plant Performance

Parameter		**Influent**			**Effluent**		
		Site No. 1	**Site No. 2**	**Site No. 3**	**Site No. 1**	**Site No. 2**	**Site No. 3**
Flow, gpm	Typical	3,800	5,000 to 15,000	1,000	3,800	5,000 to 15,000	1,000
pH	Average	3.98	~5.5	3.18	9.22	~9.8	8.87
	Median	4.00	--	3.18	9.30	--	8.85
	99th Percentile	5.14	--	3.77	9.64	--	9.44
	95th Percentile	4.90	--	3.65	9.50	--	9.33
Cadmium, mg/L	Average	0.075	2.71	--	<0.002	0.003	--
	Median	0.070	2.76	--	<0.002	0.001	--
	99th Percentile	0.19	3.76	--	<0.005	0.036	--
	95th Percentile	0.16	3.70	--	<0.005	0.004	--
Copper, mg/L	Average	0.18	0.087	32	0.008	0.002	0.070
	Median	0.12	0.050	34	0.006	0.003	0.059
	99th Percentile	1.07	0.31	62	0.041	0.009	0.22
	95th Percentile	0.51	0.30	57	0.020	0.007	0.16
Iron, mg/L	Average	190	9.3	135	0.02	0.21	0.19
	Median	162	5.0	111	0.02	0.08	0.15
	99th Percentile	734	87	290	0.08	1.8	0.76
	95th Percentile	384	20	265	0.05	1.6	0.48
Zinc, mg/L	Average	40	265	13	0.02	0.06	0.05
	Median	37	265	13	0.01	0.05	0.03
	99th Percentile	99	345	21	0.06	0.10	0.30
	95th Percentile	75	329	20	0.04	0.09	0.08
Sulfate, mg/L	Average	2,058	2,273	--	1,876	2,106	--
	Median	1,968	2,210	--	1,835	2,050	--
	99th Percentile	3,533	3,861	--	2,759	2,998	--
	95th Percentile	2,995	3,569	--	2,541	2,549	--

Statistical data in Table 3 and Attachments A through C include the following:

Average: Direct average of relevant data, with one-half of the detection limit used for those values reported below a specific level of detection. Average values can be influenced by the presence of outlier data, therefore median, 99^{th} percentile and 95^{th} percentile values were also generated.

Median: Median value of relevant data, with one-half of the data being greater than the median value and one-half of the data being less than the median value. The median value is the same as the 50^{th} percentile value and is less influenced by outlier data.

99^{th} Percentile: The 99^{th} percentile is the value at which 99% of the data are less than the indicated value and 1% of the data are greater than the indicated value. The 99^{th} percentile value is useful for evaluating the long-term performance capability of a particular treatment system.

95^{th} Percentile: The 95^{th} percentile is the value at which 95% of the data are less than the indicated value and 5% of the data are greater than the indicated value. The 95^{th} percentile value is useful for evaluating the long-term performance capability of a particular treatment system.

Data presented in Table 3 and Attachments A through C are consistent with performance ranges presented in Table 2. However, these additional data provide examples of the variability that is normally observed in treatment plant performance with respect to metals removal. These performance variabilities are illustrated by the concentration versus time graphs provided in Attachments A through C for effluent cadmium, copper, iron and zinc. The performance variabilities shown on these graphs are typical of many water treatment plants where variability arises due to the following:

- Error and/or variation resulting from sample collection, preservation and analysis.
- Variation in neutralization pH due to variable lime additions.
- Variations in the effectiveness of suspended solids removal in a clarifier and/or filter.
- Interruptions or variations in the rate of reagent additions.
- Intermittent plant activities that may impact treatment functions, such as periodic clarifier sludge pumping or filter backwashing.
- Changes in plant operating parameters, such as the rate of sludge recycle.
- Changes in the chemistry and/or flow of influent water.
- The level of iron in influent water, where higher iron concentrations have generally been found to improve the final quality of treated water through adsorptive and co-precipitation reactions that take place.

The combination of the above factors results in a statistical range of treatment plant performance that is characteristic of a given treatment system. For a proposed water treatment application, the preferred approach to estimating the achievable level of treatment and the variability that may be observed in a full-scale plant is by completing a comprehensive site-specific laboratory and pilot testing program. In general, treatment plant performance at one site can not be extrapolated or assumed to apply at another site and for this reason site-specific water treatability testing is required.

Performance data for another full-scale acid drainage treatment plant (Site 4) not included in the above data is summarized in Table 4. This plant is utilized for treatment of surface runoff which varies seasonally in flow from about 200 to 6,000 gpm, with the higher flows encountered for about three months each year during spring runoff. Treatment is affected through automated hydrated lime addition into agitated tanks for pH neutralization followed by suspended solids removal in two settling ponds. Treated water is decanted from the settling ponds and discharged from the site under an NPDES permit. The acid drainage at this site is lightly impacted as indicated by the feed water pH of 5.0 to 6.0, but treatment is effective at lowering the concentrations of metals. The settling ponds normally reduce the total suspended solids (TSS) levels in discharged water to less than about 5 mg/L with the aid of flocculant added in the treatment plant.

Table 4
Summary of Influent and Effluent Quality from a Full-Scale Low-Energy Acid Drainage Treatment Plant

Parameter		**Site 4 (1)**
Flow, gpm		200 to 6,000
pH	Influent Effluent	5.0 to 6.0 7.0 to 8.0
Cadmium	Influent, mg/L Effluent, mg/L	0.015 0.0003
Copper	Influent, mg/L Effluent, mg/L	0.30 0.004
Iron	Influent, mg/L Effluent, mg/L	30.8 0.29
Zinc	Influent, mg/L Effluent, mg/L	0.90 0.05
Sulfate	Influent, mg/L Effluent, mg/L	-- --
Years Operated		Mid 1990's to current

Notes: (1) Full-scale acid drainage treatment plant utilizing lime neutralization followed by suspended solids removal in two settling ponds. Effluent concentrations are three-year averages while influent concentrations are maximum values.

Site 4 utilizes baffled settling ponds for suspended solids removal rather than a conventional mechanical clarifier. The two ponds are each about three million gallons in size, with the actual volume available for solids setting varying throughout the year as solids accumulate at the bottom of the ponds. Once per year, accumulated solids are dredged from the ponds and transferred to an on-site lined surface impoundment for permanent disposal. Final effluent from this treatment system is of high quality provided that adequate pH control is maintained, flocculant is added to waters entering the ponds and suitable volume is available in the ponds for solids settling.

In general, the effluent concentrations presented in Table 4 for Site 4 are similar to the effluent goals assumed in the Feasibility Study (Table 1) and are comparable to effluent concentrations summarized in Tables 2 and 3 for conventional mechanical treatment systems.

Data from a two-year pilot study of an acid drainage treatment system utilizing an AquaFix water-powered lime feeder in conjunction with aeration channels and settling ponds was presented by the USEPA in 1998. The study was performed at an inactive and remote Western US mine site to treat acid drainage at a rate of about 20 to 100 gpm. The purpose of the pilot study was to evaluate the feasibility of using a system requiring relatively little electrical energy to treat acid drainage.

A schematic illustrating the layout of this treatment system is presented in Figure 1 and included the following:

- Gravity collection of 20 to 100 gpm of acid drainage from underground mine workings.
- Flow of acid drainage through a rip rap channel for aeration.
- Addition of quicklime (CaO) with an AquaFix feeder (pH was not controlled).
- Flow of acid drainage through a rip rap channel for aeration.
- Settling of solids in a 187,000 gallon lined pond.
- Flow of acid drainage through a rip rap channel for aeration.
- Settling of solids in a 187,000 gallon lined pond.
- Discharge of treated effluent.

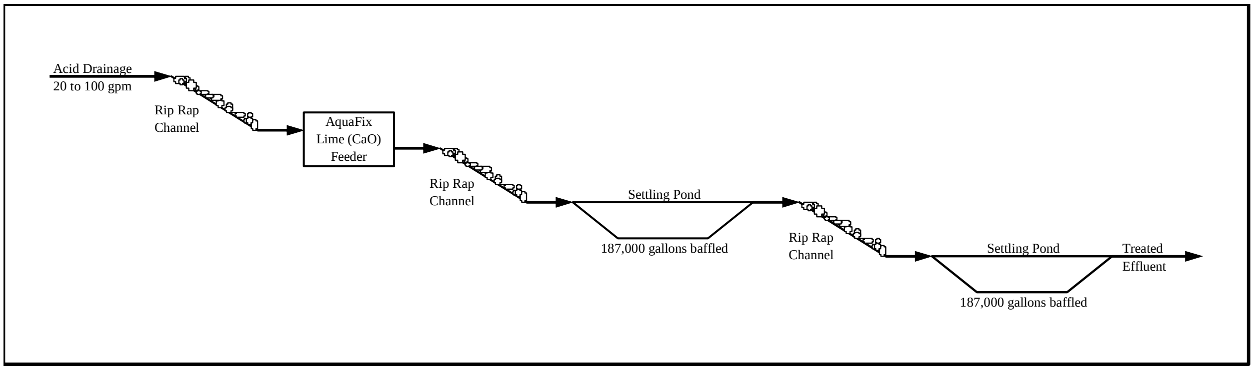


Figure 1
AquaFix Treatment System

Acid drainage at this site was heavily impacted, with a pH of about 2.0 to 4.0 and elevated concentrations of several metals, as indicated in Table 5.

Table 5
Acid Drainage Chemistry for AquaFix Pilot Testing (Untreated)

Constituent	Base Flow Conditions	Peak Flow Conditions
pH	2 to 4	2 to 4
Cadmium, mg/L	0.8	1.0
Copper, mg/L	13	94
Iron, mg/L	50	350
Zinc, mg/L	60	90

Effluent from the treatment system was monitored weekly over the two-year operating period. Final effluent normally contained less than 30 mg/L of total suspended solids (TSS) and frequently less than 10 mg/L. This indicates that the settling ponds were adequately sized and baffled to provide suitable conditions for settling of solids.

During proper system operation, treated effluent was of high quality and on average was near the effluent goals assumed in the Feasibility Study for the Holden Mine site. Effluent data from this system for periods of proper system operation are summarized in Table 6. For approximately one-third of the operating time, this treatment system did not operate properly as a result of human error or equipment malfunction, and during these periods effluent quality was significantly poorer than indicated in Table 6.

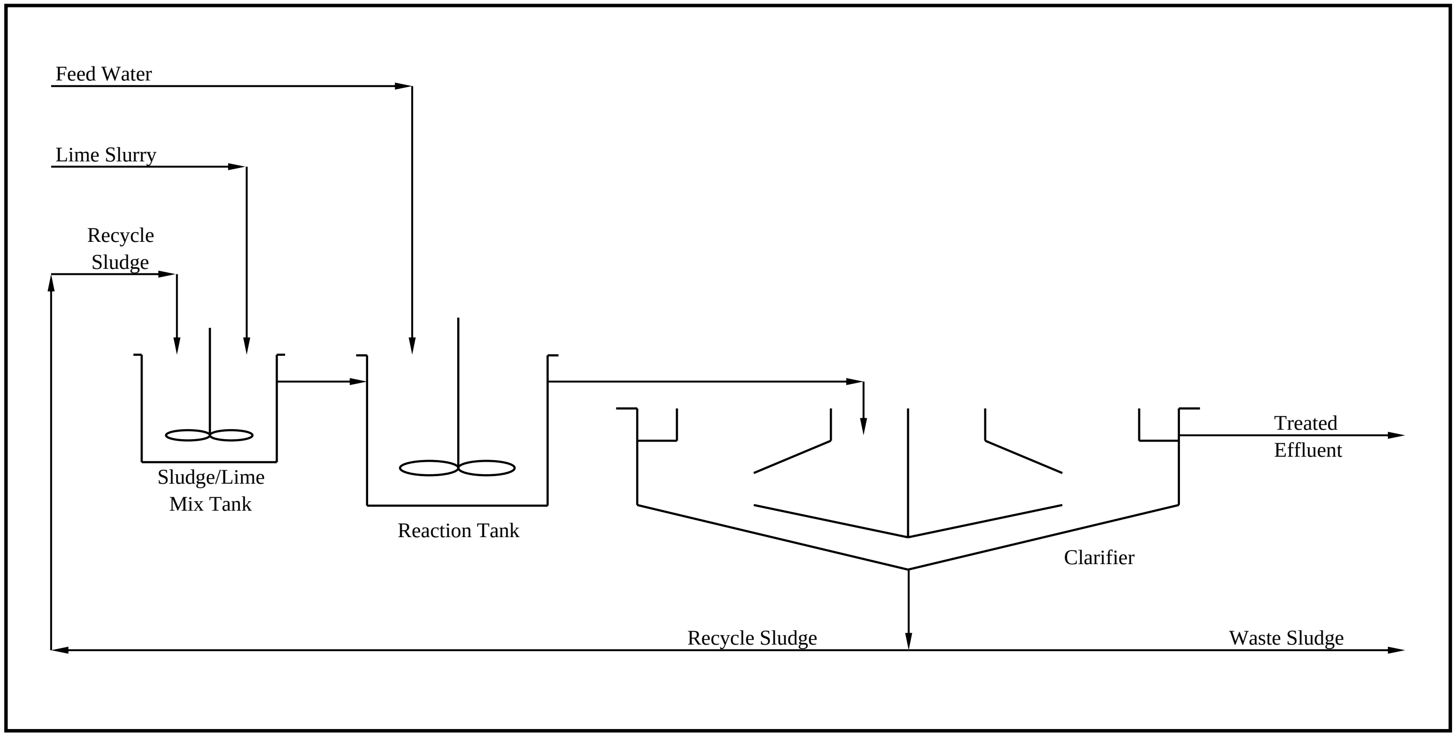
Table 6
Pilot Testing Data from Acid Drainage Treatment System Utilizing an AquaFix Lime Feeder

Proper Operating Conditions						
Constituent	**Average**		**Maximum**		**Minimum**	
	Influent	**Effluent**	**Influent**	**Effluent**	**Influent**	**Effluent**
pH	3.04	11.41	3.44	12.7	2.54	9.28
Cadmium, mg/L	0.86	0.005	1.05	0.020	0.67	0.003
Copper, mg/L	14.7	0.040	27	0.37	7.7	0.002
Iron, mg/L	50	0.02	110	0.03	25	0.01
Zinc, mg/L	65	0.4	81	2.4	51	0.01

ATTACHMENT A

ACID DRAINAGE TREATMENT PLANT – SITE NO. 1

DETAILED PERFORMANCE DATA



Site No. 1
Acid Drainage Treatment Plant
General Process Configuration
High Density Sludge

Site No. 1
Acid Drainage Treatment Plant - High Density Sludge Configuration
Summary of Influent and Effluent Water Quality
All Concentrations Dissolved

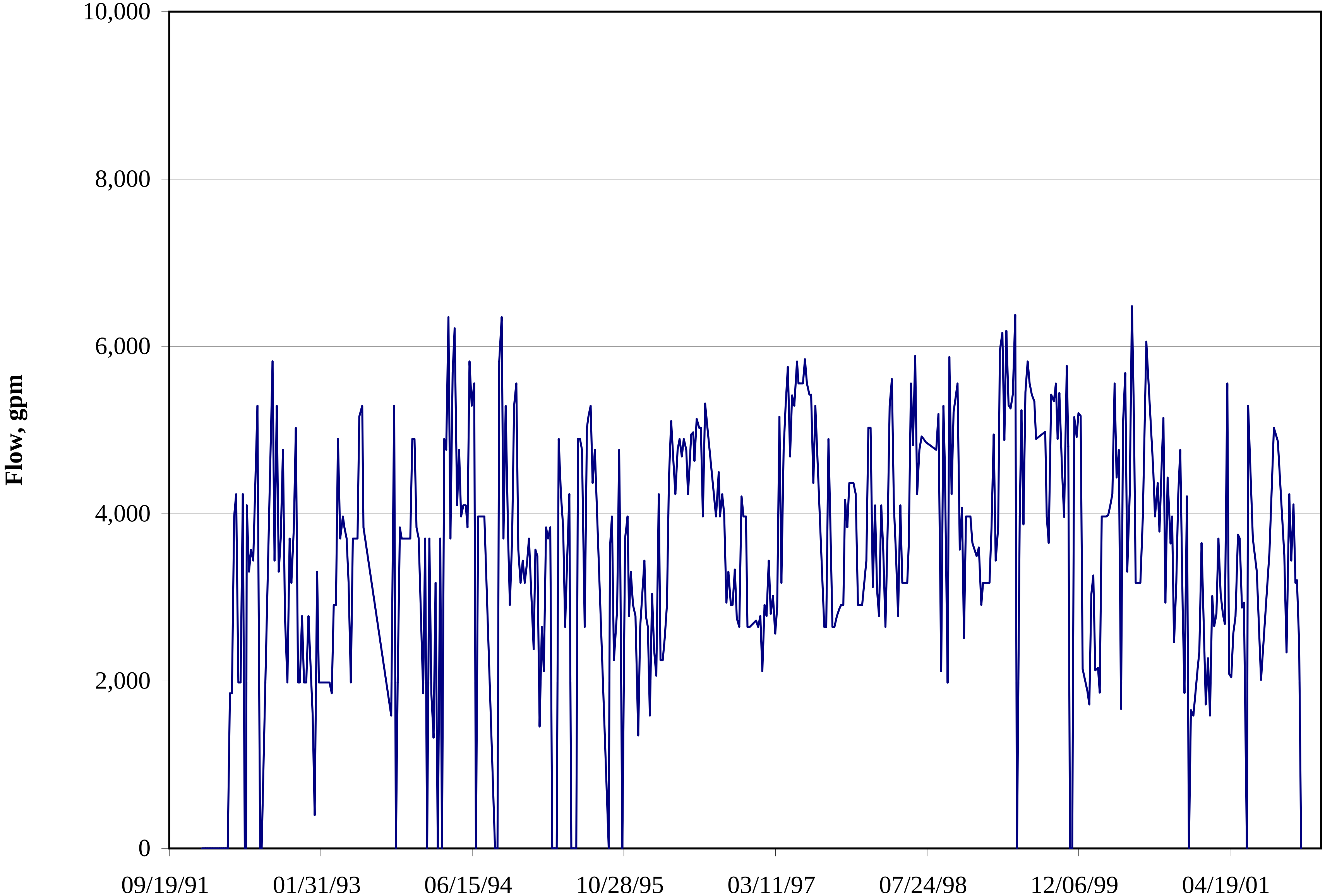
Year	Yearly Average											
	pH		Cd (mg/L)		Cu (mg/L)		Fe (mg/L)		Zn (mg/L)		Sulfate (mg/L)	
	Influent	Effluent	Influent	Effluent	Influent	Effluent	Influent	Effluent	Influent	Effluent	Influent	Effluent
1992	3.88	9.20	--	--	0.26	0.012	152	0.02	32	0.02	2,396	2,191
1993	4.19	9.35	--	--	0.13	0.014	155	0.02	26	0.01	--	--
1994	3.91	9.22	--	--	0.16	0.008	203	0.02	32	0.01	--	1,766
1995	3.78	8.97	--	--	0.18	0.010	209	0.03	36	0.02	--	--
1996	3.70	9.12	--	--	0.26	0.010	242	0.02	49	0.02	--	--
1997	3.64	9.21	0.082	<0.005	0.28	0.005	330	0.03	56	0.02	2,671	2,262
1998	3.94	9.33	0.048	<0.002	0.15	0.005	164	0.03	35	0.01	1,916	1,791
1999	4.11	9.30	0.070	<0.002	0.10	0.002	163	0.03	47	0.02	2,006	1,883
2000	4.41	9.26	0.093	<0.002	0.14	0.005	154	0.02	48	0.02	2,012	1,861
2001	4.33	9.23	0.083	<0.002	0.14	0.008	106	0.03	37	0.02	1,616	1,516

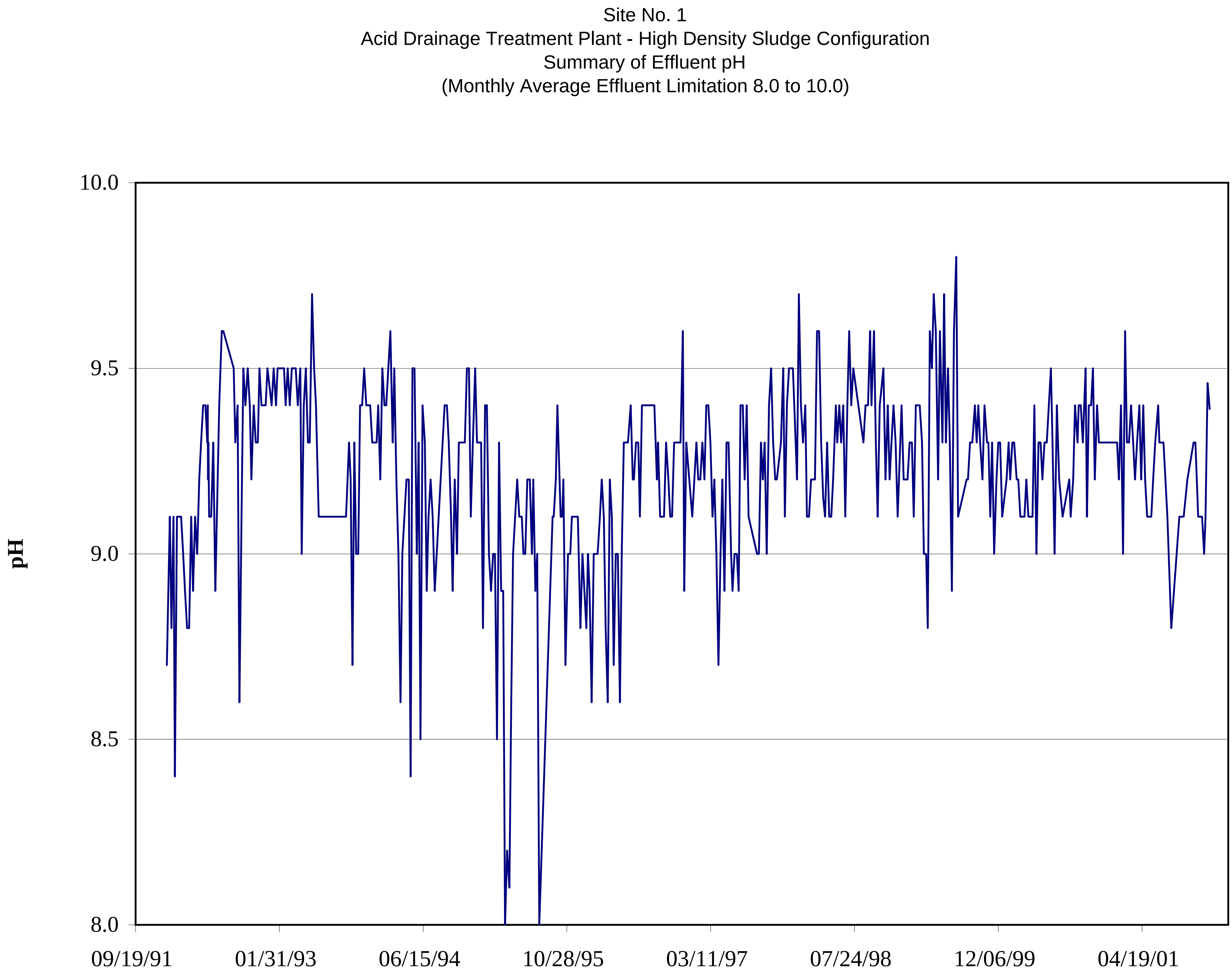
Average	3.98	9.22	0.075	<0.002	0.18	0.008	190	0.02	40	0.02	2,058	1,876
Median	4.00	9.30	0.070	<0.002	0.12	0.006	162	0.02	37	0.01	1,968	1,835
Maximum	5.90	9.80	0.230	--	2.80	0.085	1120	0.16	121	0.58	4,574	3,091
Minimum	2.80	8.00	0.010	--	0.01	0.002	50	0.002	8	0.002	905	865
Standard Deviation	0.63	0.24	0.041	--	0.25	0.008	120	0.02	18	0.03	548	393
Number Observations	458	458	223	223	458	457	458	458	458	458	232	234
99th Percentile	5.14	9.64	0.19	<0.005	1.07	0.041	734	0.08	99	0.06	3,533	2,759
95th Percentile	4.90	9.50	0.16	<0.005	0.51	0.020	384	0.05	75	0.04	2,995	2,541

2001	Monthly Average											
	pH		Cd (mg/L)		Cu (mg/L)		Fe (mg/L)		Zn (mg/L)		Sulfate (mg/L)	
	Influent	Effluent	Influent	Effluent	Influent	Effluent	Influent	Effluent	Influent	Effluent	Influent	Effluent
January	4.38	9.28	0.084	<0.002	0.28	0.011	138	0.02	41	0.01	1,783	1,728
February	4.80	9.33	0.060	<0.002	0.07	0.012	118	0.02	33	0.01	1,650	1,535
March	4.23	9.30	0.073	<0.002	0.21	0.016	126	0.02	35	0.01	1,533	1,409
April	4.40	9.30	0.102	<0.002	0.16	0.009	107	0.02	44	0.01	1,636	1,546
May	4.30	9.13	0.100	<0.002	0.15	0.004	88	0.03	41	0.02	1,649	1,486
June	3.93	9.33	0.097	<0.002	0.11	0.004	109	0.02	40	0.01	1,786	1,746
July	3.63	9.07	0.080	<0.002	0.06	0.003	85	0.04	35	0.02	1,508	1,391
August	4.30	9.10	0.070	<0.002	0.05	0.002	126	0.05	34	0.02	2,026	1,923
September	4.60	9.15	0.045	<0.002	0.04	0.004	87	0.03	23	0.02	1,372	1,355
October	4.53	9.23	0.067	<0.002	0.06	0.004	89	0.04	36	0.03	1,515	1,428
November	4.35	9.08	0.113	<0.002	0.18	0.004	84	0.03	42	0.02	1,501	1,482
December	4.45	9.43	0.055	<0.002	0.09	0.020	111	0.03	20	0.02	1,515	1,150

Average	4.33	9.23	0.083	<0.002	0.14	0.008	106	0.03	37	0.02	1,616	1,516
Median	4.35	9.30	0.080	<0.002	0.09	0.004	102	0.02	36	0.02	1,588	1,486
Maximum	5.00	9.60	0.170	--	1.01	0.025	164	0.06	66	0.04	2,219	2,250
Minimum	3.50	8.80	0.040	--	0.02	0.002	57	0.004	14	0.002	905	865
Standard Deviation	0.39	0.15	0.029	--	0.18	0.006	27	0.01	10	0.01	308	279
Number Observations	40	40	40	40	40	39	40	40	40	40	40	40
99th Percentile	4.96	9.55	0.16	<0.002	0.84	0.023	161	0.06	63	0.04	2,182	2,161
95th Percentile	4.90	9.40	0.13	<0.002	0.35	0.020	156	0.04	58	0.04	2,069	1,976

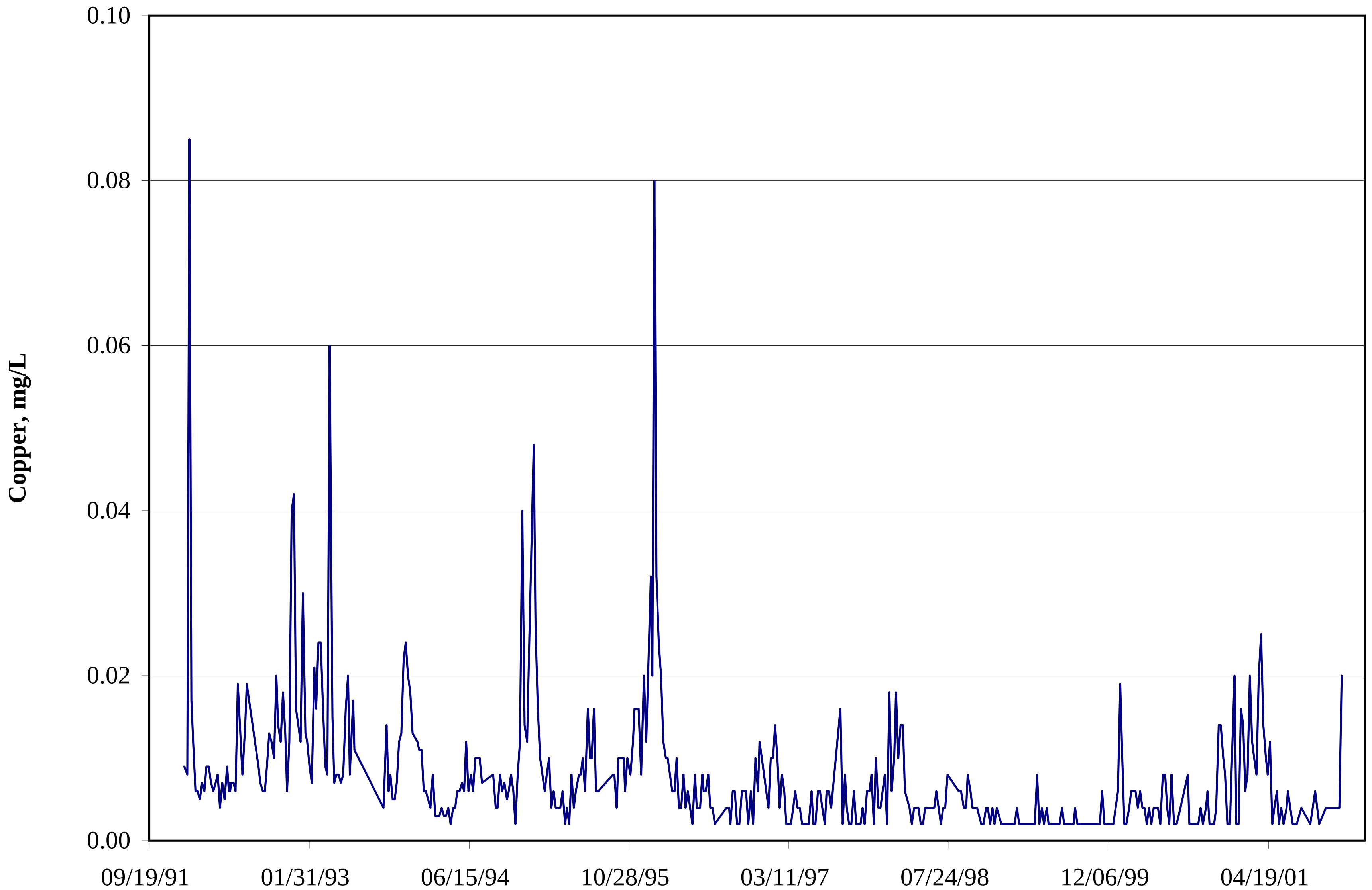
Site No. 1
Acid Drainage Treatment Plant - High Density Sludge Configuration
Summary of Treatment Plant Flow Rate



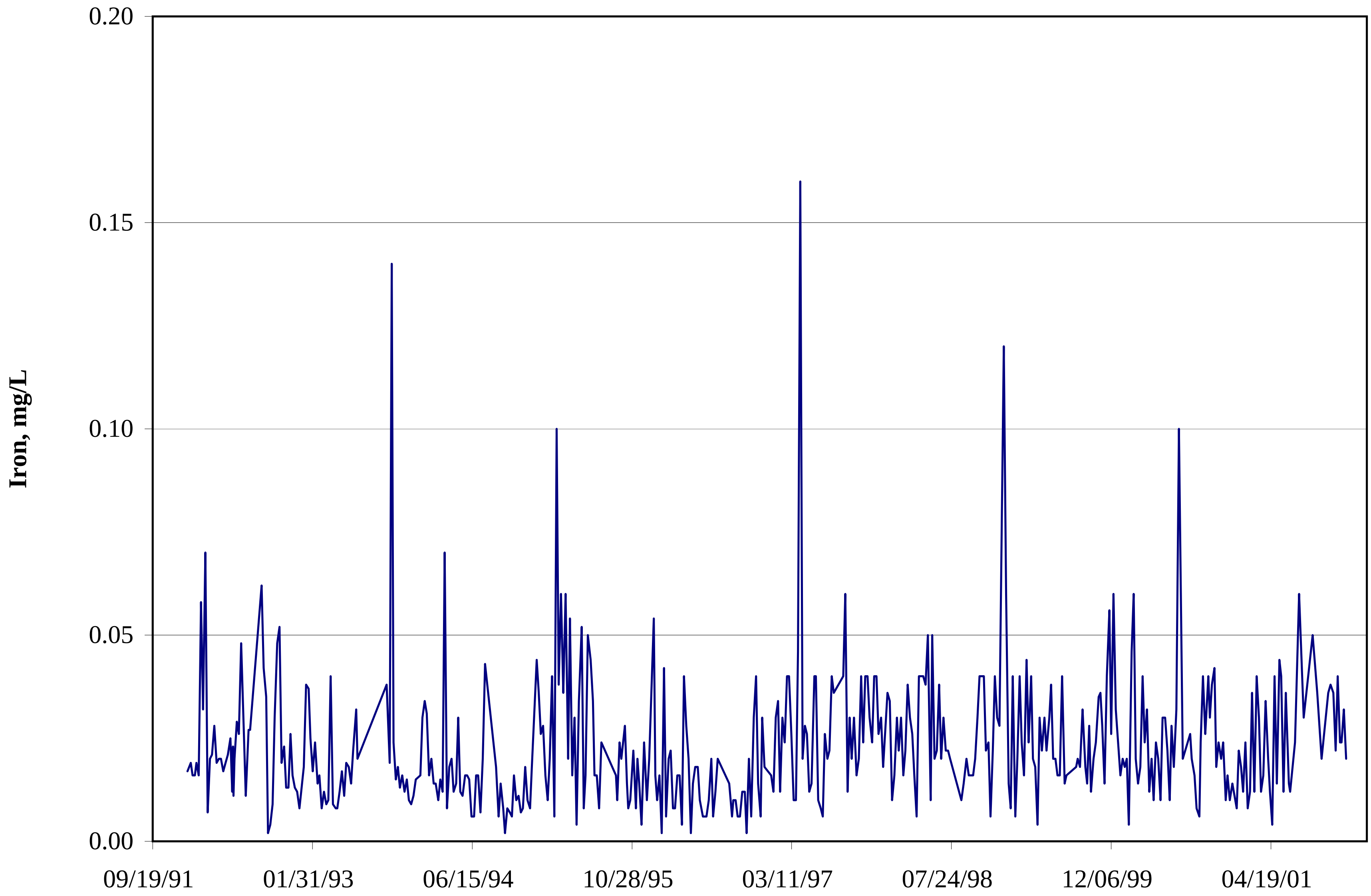


Site No. 1
Acid Drainage Treatment Plant - High Density Sludge Configuration
Summary of Effluent pH
(Monthly Average Effluent Limitation 8.0 to 10.0)
pH
10.0
9.5
9.0
8.5
8.0
09/19/91
01/31/93
06/15/94
10/28/95
03/11/97
07/24/98
12/06/99
04/19/01

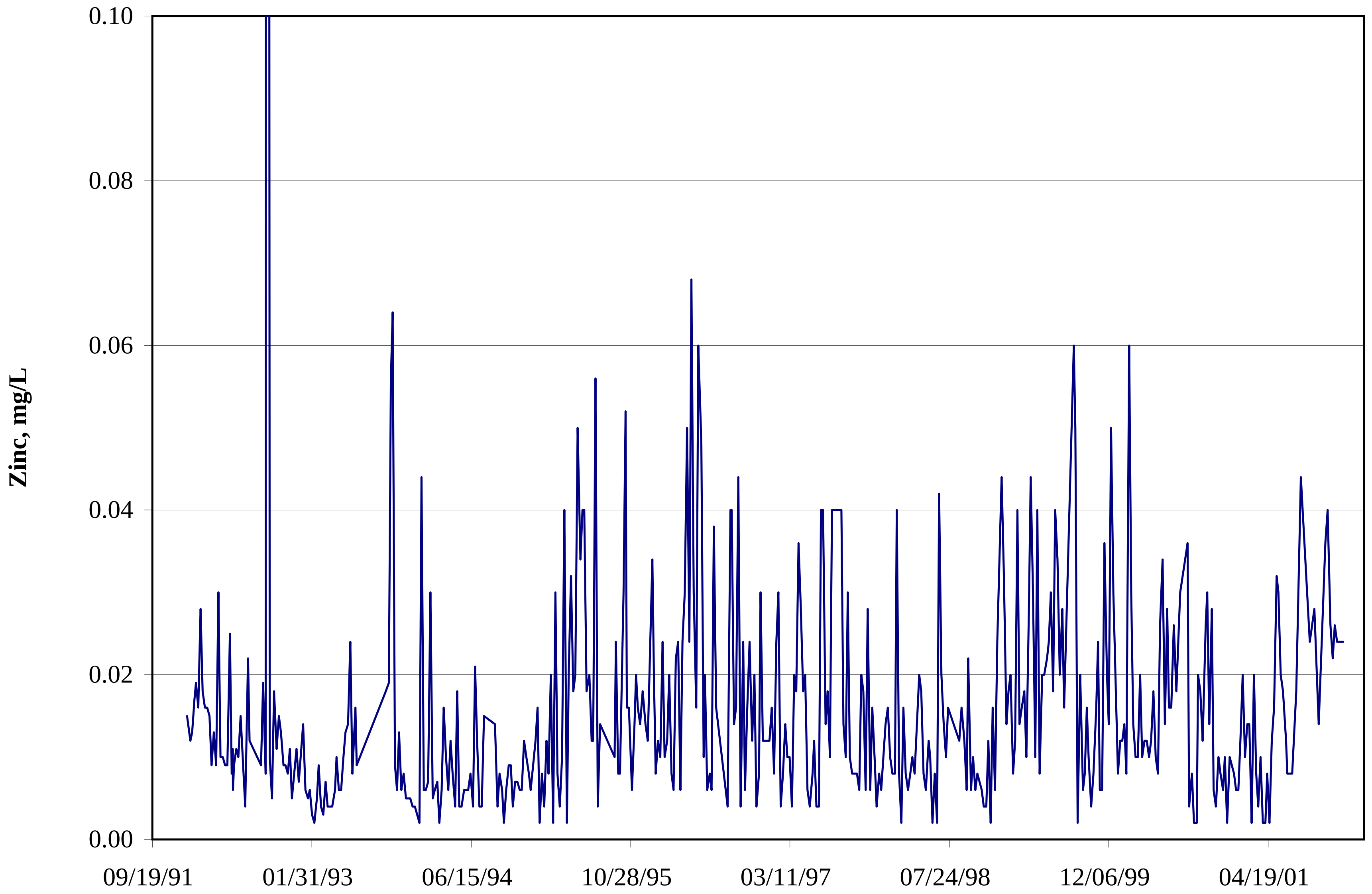
Site No. 1
Acid Drainage Treatment Plant - High Density Sludge Configuration
Summary of Effluent Copper Concentrations
All Concentrations Dissolved
(Monthly Average Effluent Limitation 0.15 mg/L)



Site No. 1
Acid Drainage Treatment Plant - High Density Sludge Configuration
Summary of Effluent Iron Concentrations
All Concentrations Dissolved
(Monthly Average Effluent Limitation 0.6 mg/L)



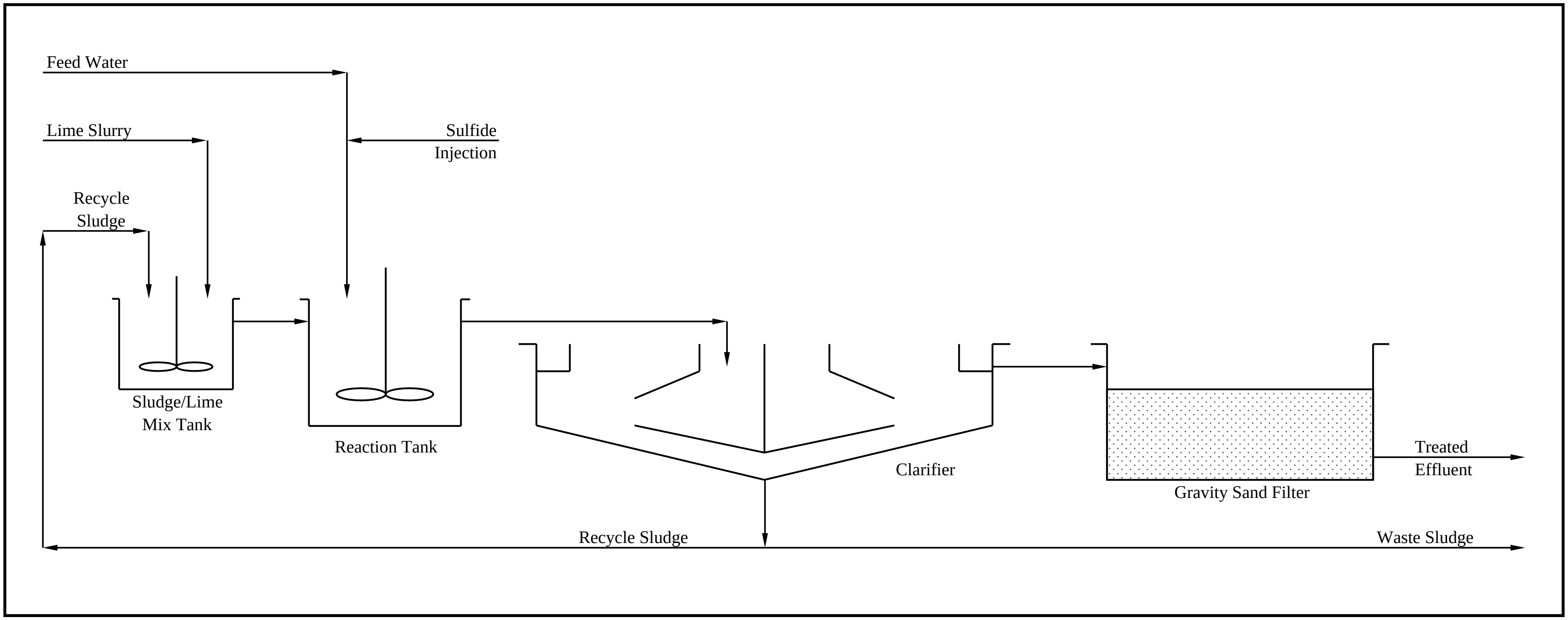
Site No. 1
Acid Drainage Treatment Plant - High Density Sludge Configuration
Summary of Effluent Zinc Concentrations
All Concentrations Dissolved
(Monthly Average Effluent Limitation 0.3 mg/L)



ATTACHMENT B

ACID DRAINAGE TREATMENT PLANT – SITE NO. 2

DETAILED PERFORMANCE DATA



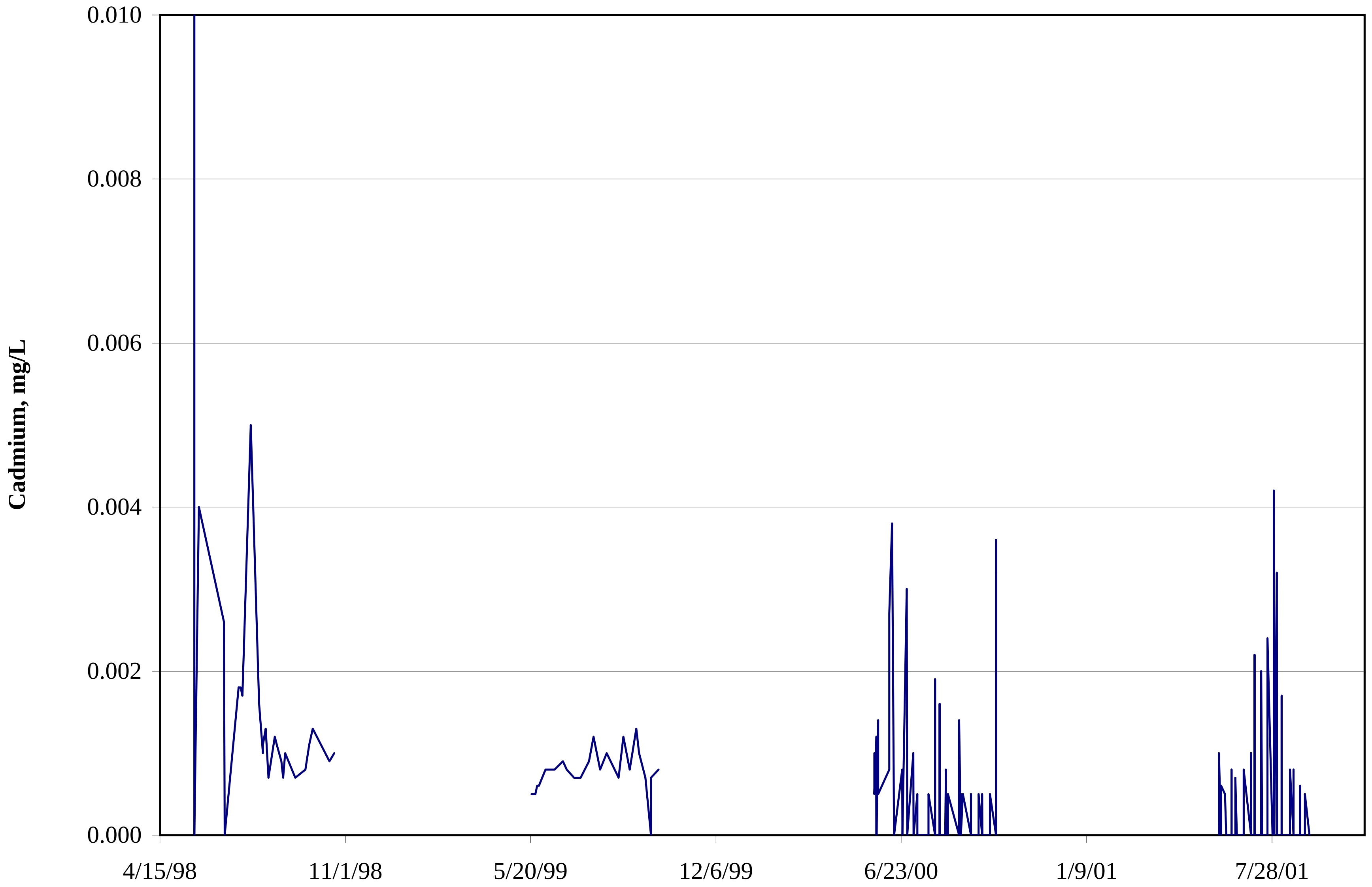
Site No. 2
Acid Drainage Treatment Plant
General Process Configuration
High Density Sludge with Sulfide Injection and Filtration

Site No. 2
Acid Drainage Treatment Plant - High Density Sludge Configuration with Sulfide Injection and Filtration
Summary of Influent and Effluent Water Quality
All Concentrations Total

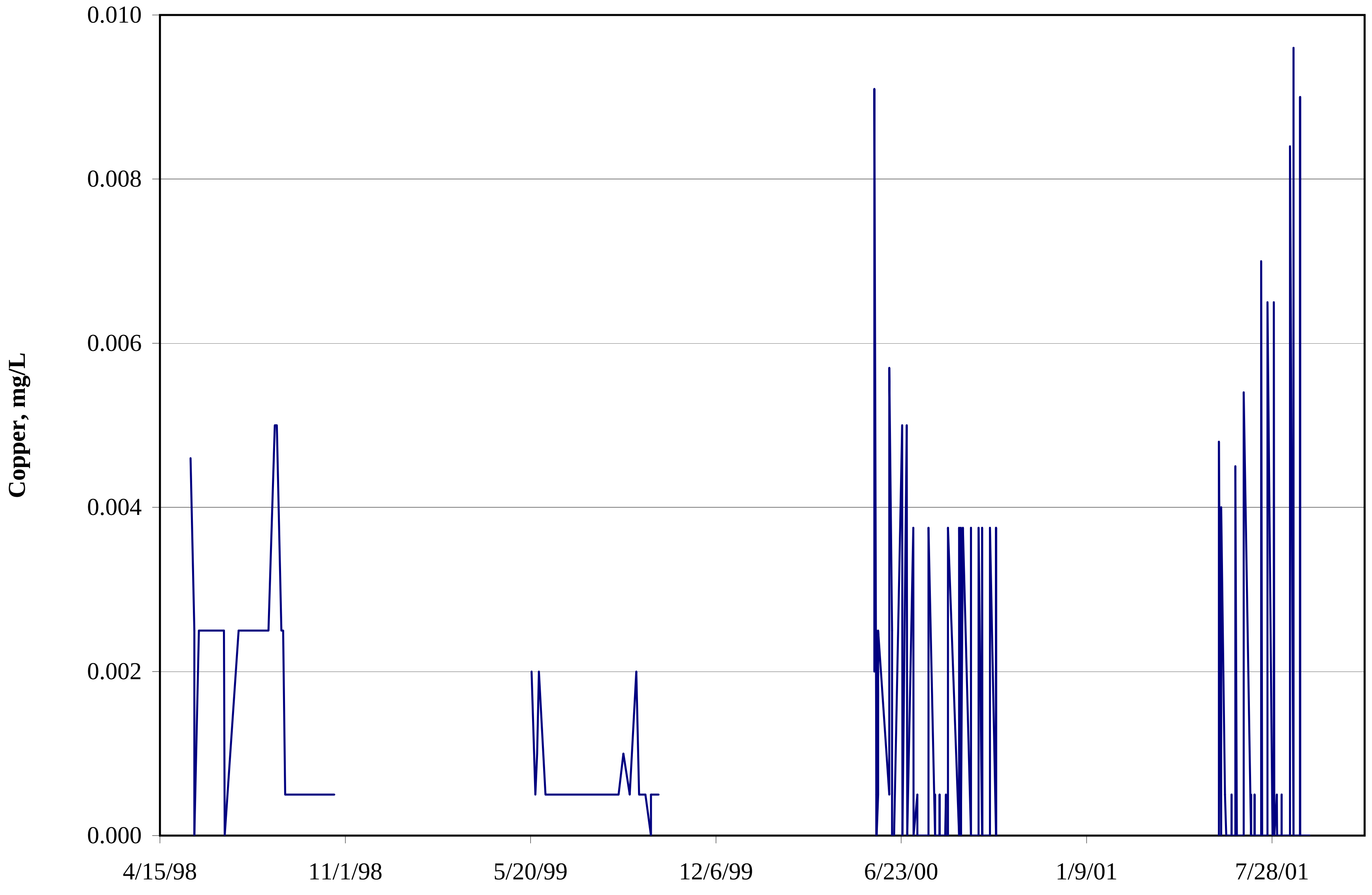
Year	Yearly Average									
	Cd (mg/L)		Cu (mg/L)		Fe (mg/L)		Zn (mg/L)		Sulfate (mg/L)	
	Influent	Effluent	Influent	Effluent	Influent	Effluent	Influent	Effluent	Influent	Effluent
1998	3.19	0.006	--	<0.005	5.9	0.08	278	0.06	2,006	1,916
1999	2.64	0.001	0.042	<0.001	16	0.08	262	0.06	2,551	2,003
2000	2.37	0.001	0.11	0.003	7.1	0.65	255	0.05	2,450	2,344
2001	--	0.001	--	0.004	--	0.06	--	0.04	--	2,237
Average	2.71	0.003	0.087	0.002	9.3	0.21	265	0.06	2,273	2,106
Median	2.76	0.001	0.050	0.003	5.0	0.08	265	0.05	2,210	2,050
Maximum	3.78	0.088	0.31	0.010	114	1.9	352	0.11	3,960	3,450
Minimum	1.33	0.001	0.005	0.001	0.04	0.01	189	0.01	1,160	1,480
Standard Deviation	0.65	0.010	0.10	0.002	18	0.43	38	0.02	616	307
Number Observations	44	93	26	89	46	58	46	89	32	59
99th Percentile	3.76	0.036	0.31	0.009	87	1.8	345	0.10	3,861	2,998
95th Percentile	3.70	0.004	0.30	0.007	20	1.6	329	0.09	3,569	2,549

2000	Monthly Average									
	Cd (mg/L)		Cu (mg/L)		Fe (mg/L)		Zn (mg/L)		Sulfate (mg/L)	
	Influent	Effluent	Influent	Effluent	Influent	Effluent	Influent	Effluent	Influent	Effluent
May	1.75	0.001	0.04	0.003	3.4	0.09	226	0.05	1,615	2,195
June	1.80	0.002	0.05	0.004	7.1	1.6	230	0.04	2,160	1,930
July	1.90	0.001	0.05	0.002	7.9	1.2	207	0.06	2,300	2,195
August	2.59	0.001	0.16	0.003	6.7	0.64	239	0.06	--	2,285
September	2.75	0.001	0.31	0.004	18	0.36	282	0.05	--	2,840
October	3.62	0.003	0.27	0.004	14	0.37	342	0.05	3,360	2,510
Average	2.37	0.001	0.11	0.003	7.1	0.65	255	0.05	2,450	2,344
Median	2.36	0.001	0.05	0.004	6.7	0.32	242	0.05	2,300	2,280
Maximum	3.73	0.004	0.31	0.009	20.8	1.9	352	0.10	3,510	3,450
Minimum	1.65	0.001	0.01	0.001	0.04	0.01	191	0.03	1,590	1,830
Standard Deviation	0.62	0.001	0.11	0.002	5.8	0.73	41	0.01	761	364
Number Observations	17	28	17	26	17	14	17	26	7	17
99th Percentile	3.69	0.004	0.31	0.008	19.9	1.9	349	0.10	3,501	3,325
95th Percentile	3.55	0.004	0.31	0.006	16.1	1.8	335	0.08	3,465	2,826

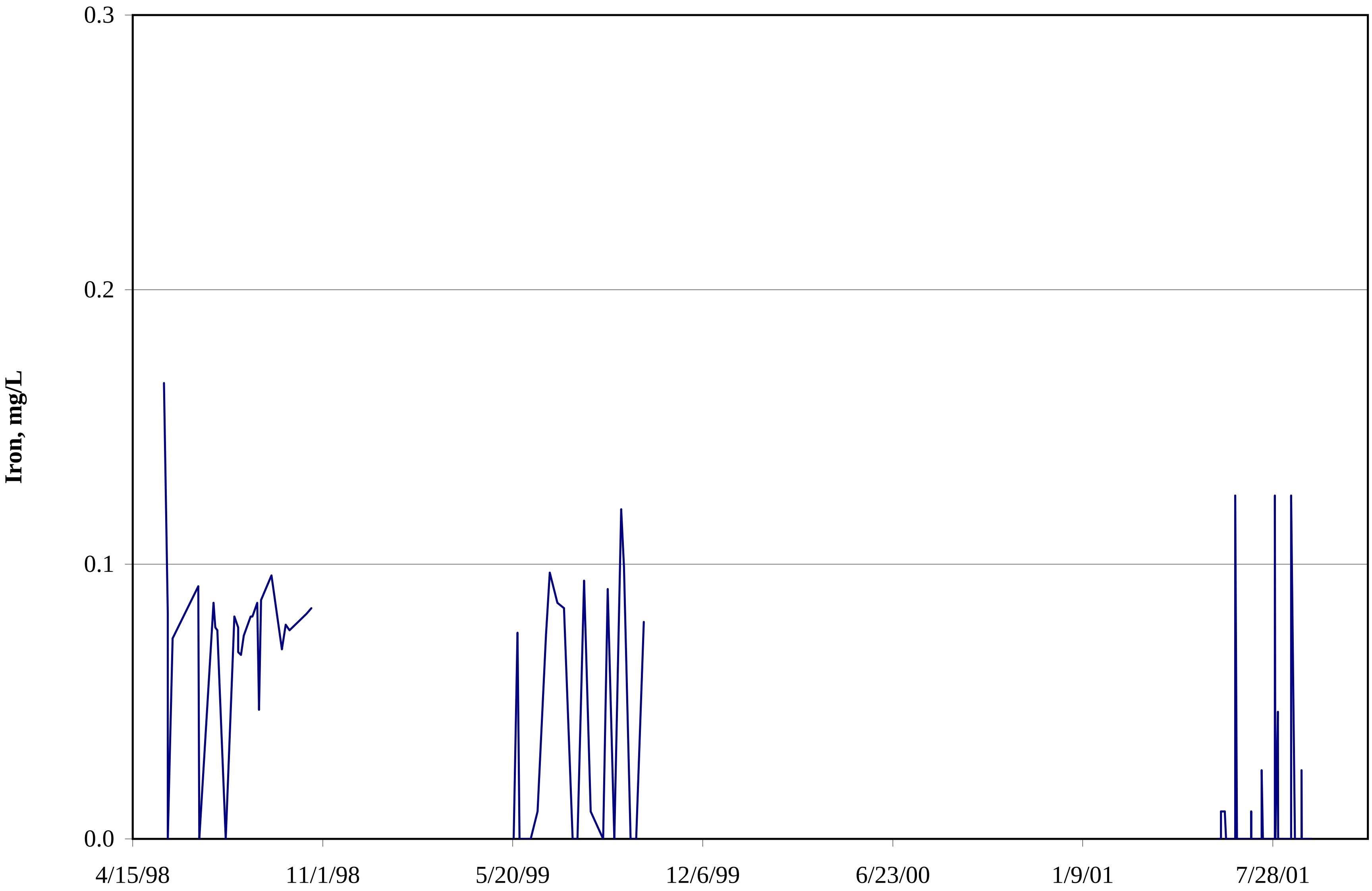
Site No. 2
Acid Drainage Treatment Plant - High Density Sludge Configuration with Sulfide Injection and Filtration
Summary of Effluent Cadmium Concentrations
All Concentrations Total
(Monthly Average Effluent Limitation 0.002 mg/L)



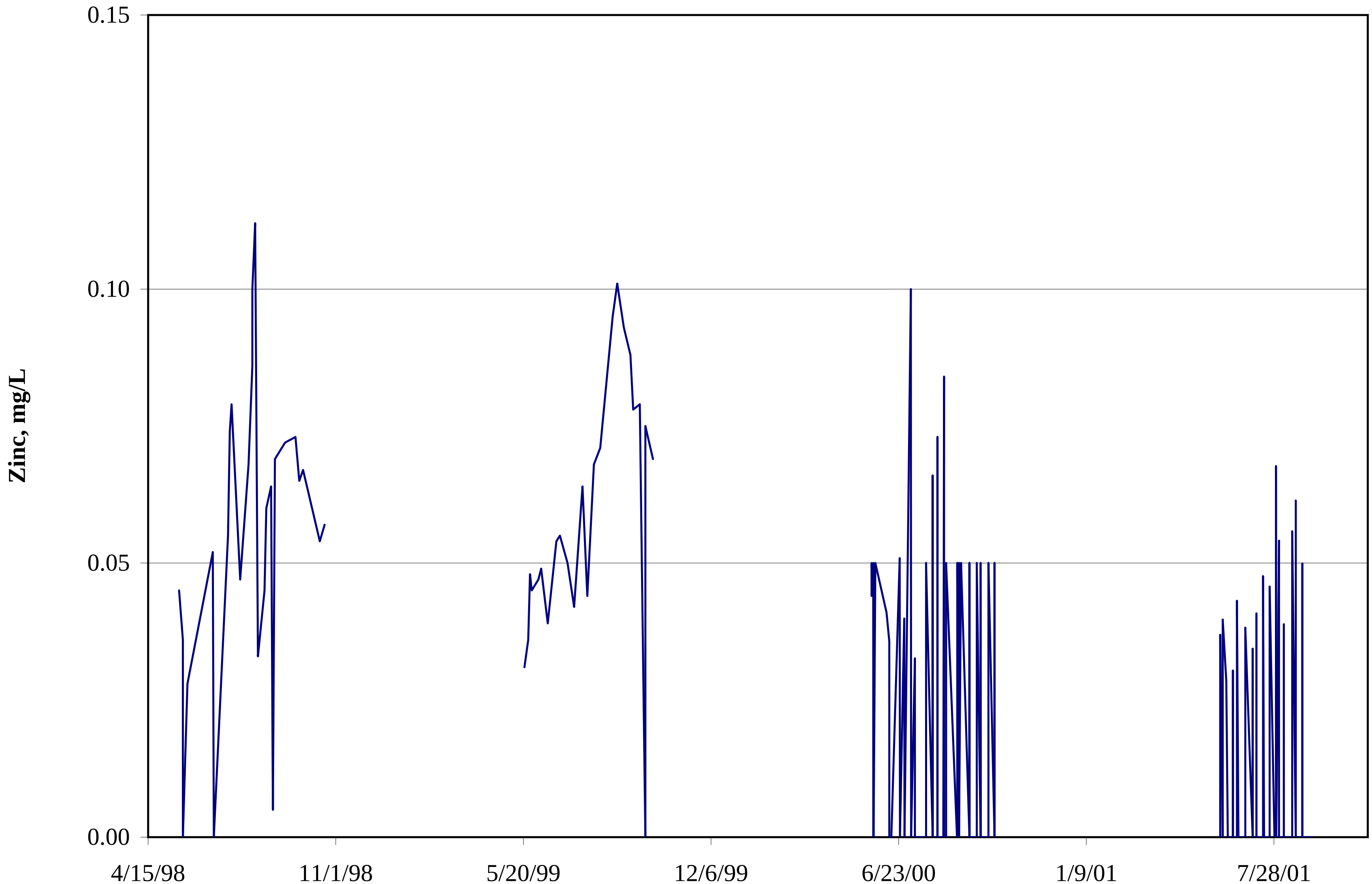
Site No. 2
Acid Drainage Treatment Plant - High Density Sludge Configuration with Sulfide Injection and Filtration
Summary of Effluent Copper Concentrations
All Concentrations Total
(Monthly Average Effluent Limitation 0.015 mg/L)



Site No. 2
Acid Drainage Treatment Plant - High Density Sludge Configuration with Sulfide Injection and Filtration
Summary of Effluent Iron Concentrations
All Concentrations Total
(No Effluent Limitation)



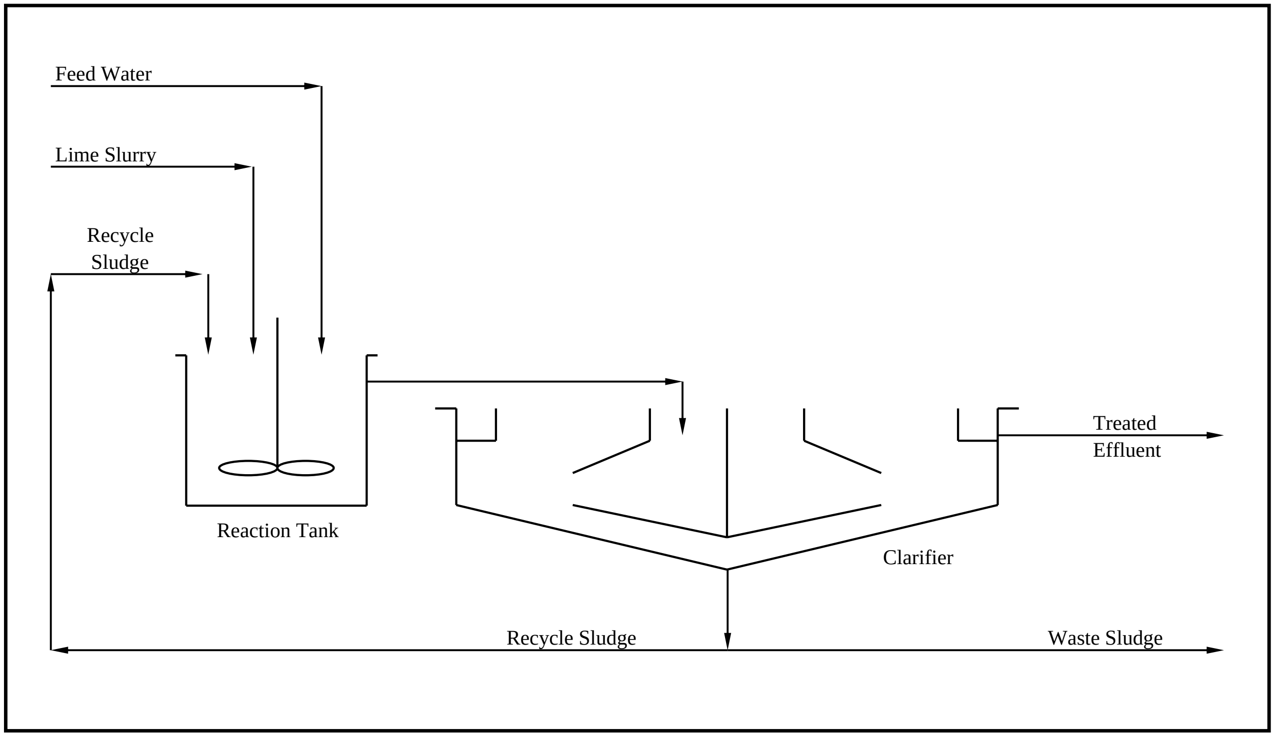
Site No. 2
Acid Drainage Treatment Plant - High Density Sludge Configuration with Sulfide Injection and Filtration
Summary of Effluent Zinc Concentrations
All Concentrations Total
(Monthly Average Effluent Limitation 0.12 mg/L)



ATTACHMENT C

ACID DRAINAGE TREATMENT PLANT – SITE NO. 3

DETAILED PERFORMANCE DATA



Site No. 3
Acid Drainage Treatment Plant
General Process Configuration
Lime Neutralization with Sludge Recycle

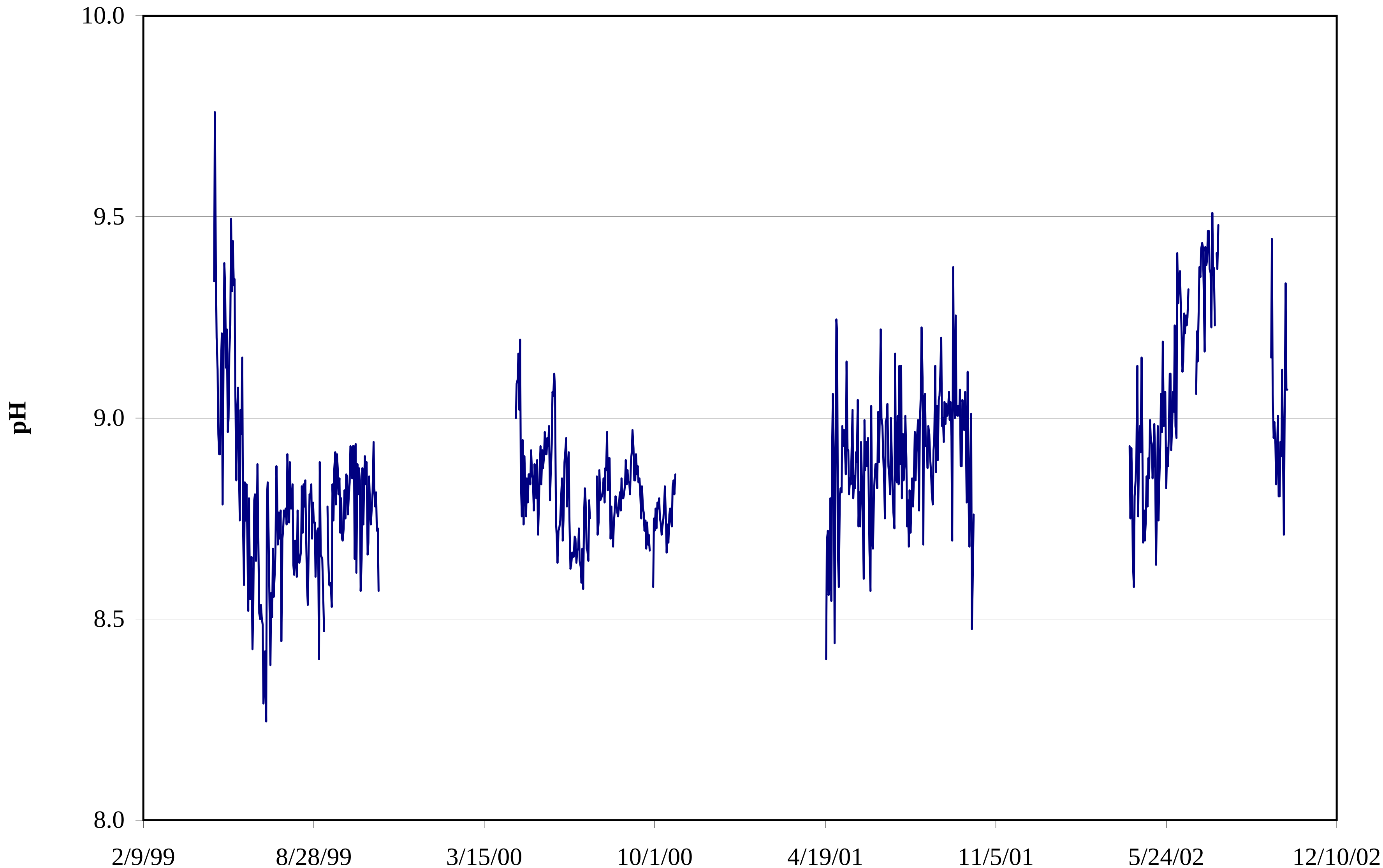
Site No. 3
Acid Drainage Treatment Plant - Lime Neutralization with Sludge Recycle
Summary of Influent and Effluent Water Quality
All Concentrations Total

Year	Yearly Average							
	pH		Cu (mg/L)		Fe (mg/L)		Zn (mg/L)	
	Influent	Effluent	Influent	Effluent	Influent	Effluent	Influent	Effluent
1999	3.02	8.79	30	0.069	--	0.16	--	--
2000	3.43	8.81	30	0.10	--	0.28	--	--
2001	3.18	8.90	30	0.053	107	0.13	11	0.06
2002	3.06	9.07	41	0.055	176	0.21	15	0.03
Average	3.18	8.87	32	0.070	135	0.19	13	0.05
Median	3.18	8.85	34	0.059	111	0.15	13	0.03
Maximum	3.84	9.76	64	0.82	297	0.89	21	2.1
Minimum	2.68	8.25	8	0.010	46	0.01	3	0.01
Standard Deviation	0.25	0.21	13	0.049	63	0.13	5	0.13
Number Observations	659	660	657	656	288	647	288	287
99th Percentile	3.77	9.44	62	0.22	290	0.76	21	0.30
95th Percentile	3.65	9.33	57	0.16	265	0.48	20	0.08

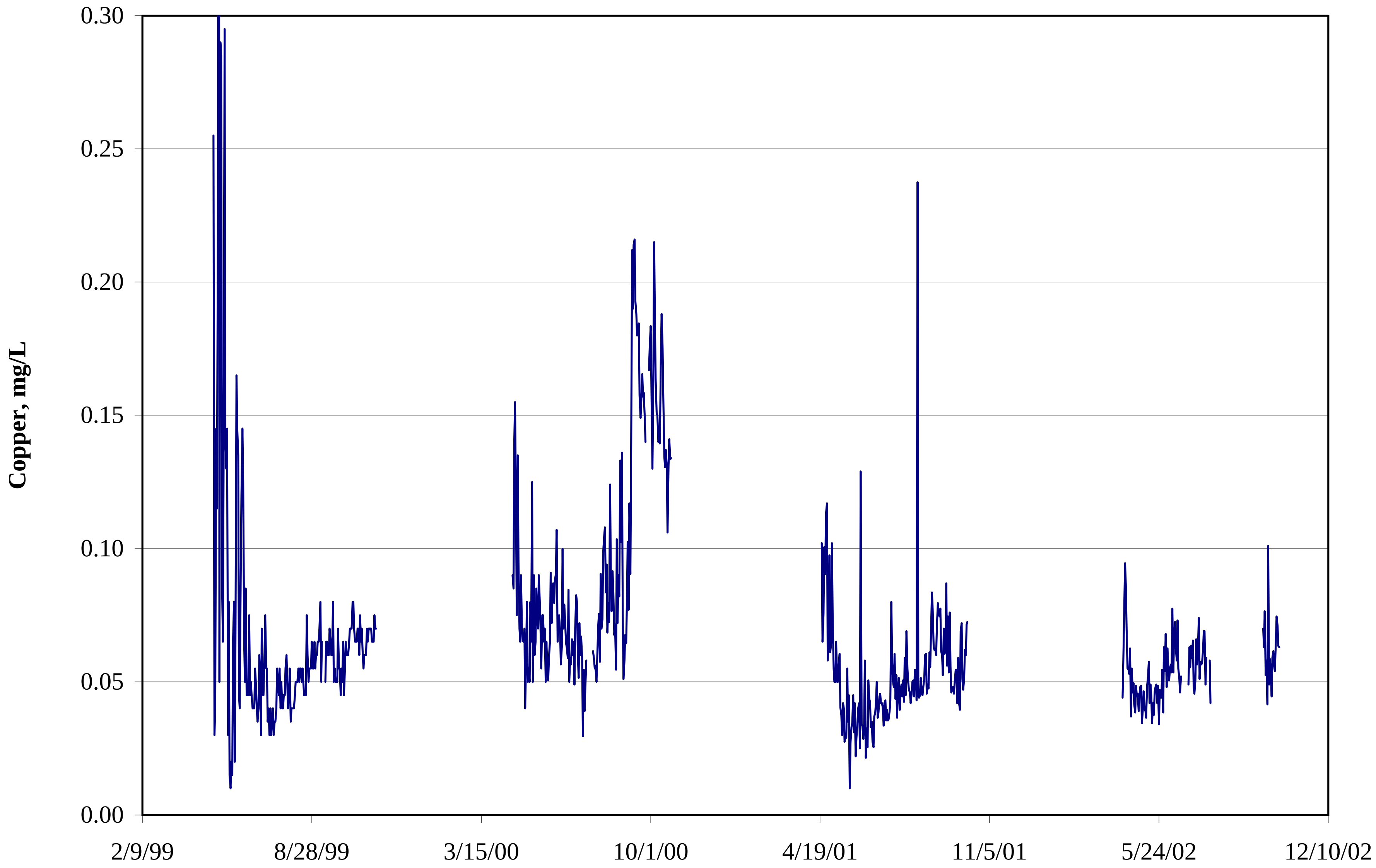
2002	Monthly Average							
	pH		Cu (mg/L)		Fe (mg/L)		Zn (mg/L)	
	Influent	Effluent	Influent	Effluent	Influent	Effluent	Influent	Effluent
April	3.44	8.84	21	0.055	87	0.19	8	0.03
May	3.20	8.93	31	0.045	153	0.23	12	0.03
June	2.92	9.20	55	0.059	269	0.24	19	0.04
July	2.85	9.37	60	0.058	227	0.16	20	0.03
August	--	--	--	--	--	--	--	--
September	2.84	9.05	46	0.066	170	0.24	17	0.04
October	2.89	8.97	43	0.060	135	0.19	16	0.03
Average	3.06	9.07	41	0.055	176	0.21	15	0.03
Median	3.00	9.01	43	0.054	171	0.19	16	0.03
Maximum	3.57	9.51	64	0.10	297	0.48	21	0.07
Minimum	2.74	8.58	17	0.034	64	0.10	7	0.02
Standard Deviation	0.25	0.23	16	0.012	71	0.07	5	0.01
Number Observations	117	116	115	114	115	114	115	114
99th Percentile	3.54	9.48	63	0.093	293	0.42	21	0.06
95th Percentile	3.51	9.43	62	0.074	274	0.35	21	0.05

Site No. 3
Acid Drainage Treatment Plant - Lime Neutralization with Sludge Recycle
Summary of Treatment Plant Flow Rate

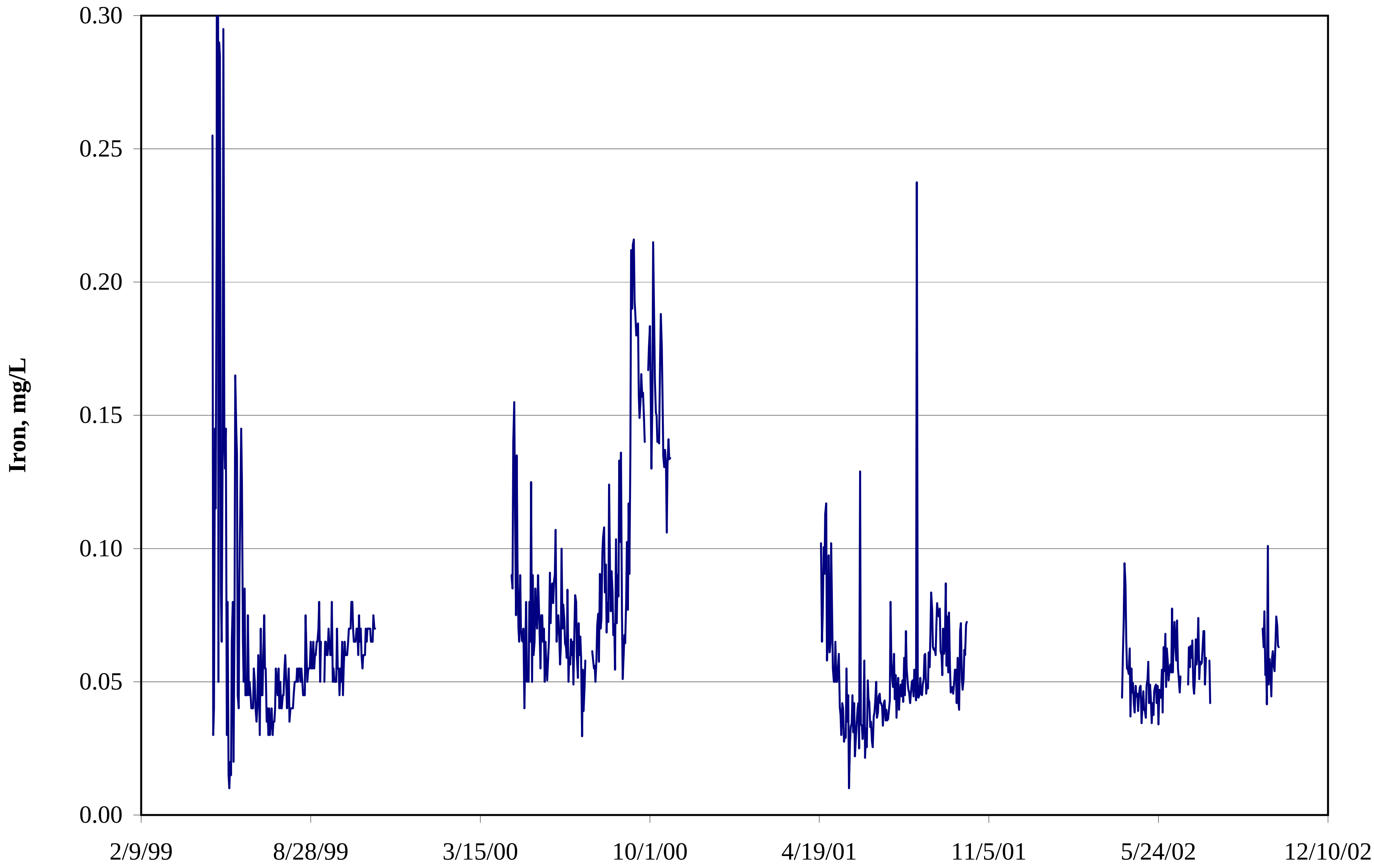
Site No. 3
Acid Drainage Treatment Plant - Lime Neutralization with Sludge Recycle
Effluent pH
(Monthly Average Effluent Limitation 6.5 to 9.0 - Exceedances Allowed with Regulatory Approval)



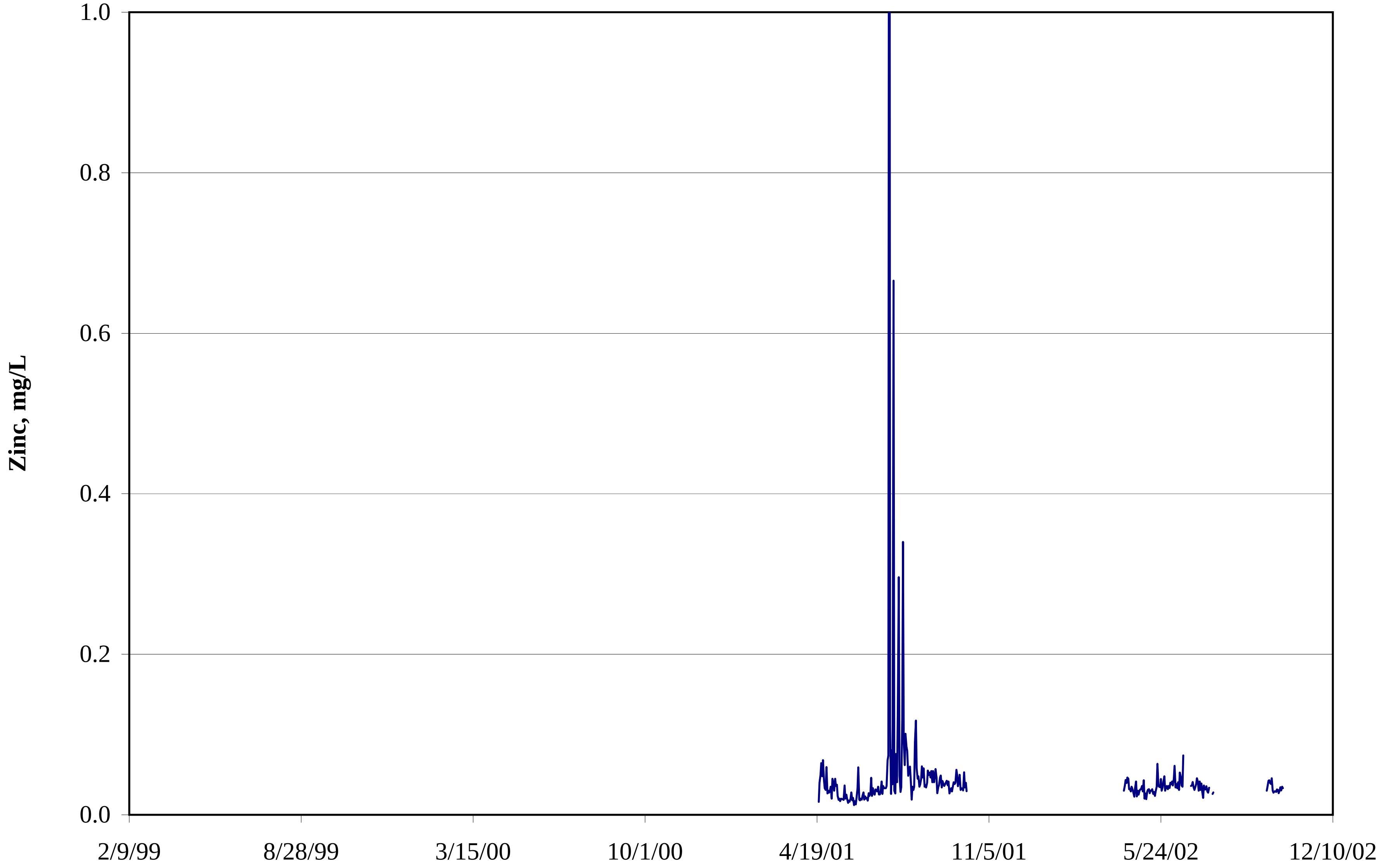
Site No. 3
Acid Drainage Treatment Plant - Lime Neutralization with Sludge Recycle
Effluent Copper Concentrations
All Concentrations Total
(Monthly Average Effluent Limitation 0.1 mg/L)



Site No. 3
Acid Drainage Treatment Plant - Lime Neutralization with Sludge Recycle
Effluent Iron Concentrations
All Concentrations Total
(Monthly Average Effluent Limitation 50 mg/L)



Site No. 3
Acid Drainage Treatment Plant - Lime Neutralization with Sludge Recycle
Effluent Zinc Concentrations
All Concentrations Total
(No Effluent Limitation)



APPENDIX G
HYDRAULIC EVALUATION OF LANDFILL PERFORMANCE (HELP) MODELING

APPENDIX G
HYDRAULIC PERFORMANCE MODEL

Objective

The objective is to use the HELP Version 3 Model (The Hydrologic Evaluation of Landfill Performance – EPA/600/R-94/168b) to conduct a water balance analysis of three mine tailings piles at Holden Mine, Washington. The model is also used to determine how the water system will react under different model conditions.

Introduction

The Hydrologic Evaluation of Landfill Performance (HELP) model was developed to help landfill designers and regulators evaluate the hydrologic performance of proposed landfill designs. The model accepts weather, soil and design data and uses solution techniques that account for the effects of surface storage, snowmelt, runoff, infiltration, evapotranspiration, vegetative growth, soil moisture storage, lateral subsurface drainage, leachate recirculation, unsaturated vertical drainage, and leakage through soil, geomembrane or composite liners. Landfill systems including various combinations of vegetation, cover soils, lateral drain layers, low permeability barrier soils, and geomembrane liners may be modeled. Results are expressed as daily, monthly, annual and long-term average water budgets.

Assumptions

Model assumptions include:

1. Latitude = 48.12º

2. Evaporative depth = 8” (from HELP users guide, average zone for sand/silt)

3. Maximum Leaf Index = 2.0 (HELP users guide, ratio of actively transpiring vegetation to surface area of land that is consistent with area around Holden)

4. Growing season/wind speed/relative humidity – HELP default values for Stampede Pass, WA (closest (proximity) HELP default values to Holden, data for Holden not available – judged to be an appropriate approximation)

5. Precipitation – data from NOAA climatological data for Holden Village, 1962 – 1997, Monthly mean data spread randomly within each month. Average precipitation of 38.6 inches assumed. (Source: Table 4.3-2 in the DRI Report).

6. Temperature – data from NOAA climatological data for Holden Village, 1962 – 1997, Monthly average temperature given to each day of corresponding month. Values obtained from Table 4.3-3 in the DRI Report.

7. Solar Radiation (Langleys) - HELP default values for Stampede Pass, WA (closest (proximity) HELP default values to Holden, data for Holden not available)

8. Landfill Area – from Revised DRI Holden Mine Site Map

   - Tailings Pile 1 – 25 acres
   - Tailings Pile 2 – 45 acres
   - Tailings Pile 3 – 22 acres

9. Available runoff (sloped) area = 5%

10. Runoff area grade = 58% (30°)

11. Slope length

    - Tailings Pile 1 – 75 feet
    - Tailings Pile 2 – 125 feet
    - Tailings Pile 3 – 100 feet

12. Bare ground conditions (HELP Default #1) unless otherwise noted.

The model was run separately for each of the three tailings piles. For each pile, the model was run under four scenarios. Each scenario was used to determine how the system would react under different conditions. The model was changed to allow different soil conditions, precipitation conditions, re-grading, re-vegetating, and combinations thereof.

The HELP Model uses a layering system to differentiate how water flows through the different soils. There are 4 layer types: 1. vertical percolation; 2. lateral movement; 3. barrier soil layer; and 4. flexible membrane liner. The soil layers and other inputs for each modeled scenario are as follows:

Scenario 1 - Current Conditions/Average Precipitation

Layer 1: Type 1, 3-inches, gravel, k = 3.0 x 10-1 cm/sec (HELP Default #21)

Layer 2: Type 2, 3-inches, gravel, k = 3.0 x 10-1 cm/sec (HELP Default #21)

Layer 3: Type 3, 3-inches, sandy loam, k = 1.7 x 10-3 cm/sec (HELP Default #4)

Layer 4: Type 1, 237-inches, sandy loam, k = 1.7 x 10-3 cm/sec (HELP Default #4)

Scenario 2 - Regrading to Average 3% Slope – Average Precipitation

Layer 1: Type 1, 3-inches, gravel K=3.0 x 10-1 cm/sec (HELP Default #21)

Layer 2: Type 2, 3-inches, gravel K=3.0 x 10-1 cm/sec (HELP Default #21)

Layer 3: Type 3, 3-inches, sandy loam, K=1.7 x 10-3 cm/sec (HELP Default #4)

Layer 4: Type 1, 237-inches, sandy loam, K=1.7 x 10-3 cm/sec (HELP Default #4)

Available runoff (sloped) area = 100%

Runoff area grade = 3%

Slope length – TP-1 600’, TP-2 900’, TP-3 650’

Model not able to incorporate 2 sloped areas of varying grade, therefore the steep side slope areas (assumed to be 5% of total area) were ignored.

Scenario 3 - Revegetation and Regrading (as Scenario 2 with "good" grass - HELP default #4)

No Gravel

Layer 1: Type 1, 6-inches, sandy loam, k = 1.7 x 10-3 cm/sec (HELP Default #4)

Layer 2: Type 2, 6-inches, sandy loam, k = 1.7 x 10-3 cm/sec (HELP Default #4)

Layer 3: Type 3, 3-inches, sandy loam, k = 1.7 x 10-3 cm/sec (HELP Default #4)

Layer 4: Type 1, 225-inches, sandy loam, k = 1.7 x 10-3 cm/sec (HELP Default #4)

Scenario 4 – Regrading with geosynthetic cover

Layer 1: Type 1, 6-Inches, Gravel K=3.0 X 10-1 Cm/Sec (HELP Default #21)

Layer 2: Type 2, 24-inches, sandy loam, K=1.7 x 10-3 cm/sec (HELP Default #4)

Layer 3: Type 4, Geosynthetic (0.6 cm) (HELP Default #17) K = 3.0 x 10-9 cm/sec, 1 pin-hole/acre, 4 defaults/acre, "good" installation (HELP Default #3)

Layer 4: Type 1, 240-inches, sandy loam, K=1.7 x 10-3 cm/sec (HELP Default #4)

Regrading as described in Scenario 2

No Vegetation

Results

Results obtained using the HELP model for each of the four scenarios described above are provided in Table G-1.

TABLE G-1
HELP Model Results Summary
Holden Mine Site Tailings Piles 1, 2, & 3
Annual Totals

Scenario Number	Percent of Total Precipitation			
	Description of Layers	**Evapotrans-piration**	**Runoff**	**Infiltration Through Lowest Layer**
1	Current Conditions/Avg. Precip: 6" gravel: k=3.0 x 10^{-1} cm/s 20' sandy loam: k=1.7 x 10^{-3} cm/s No regrading - tops of piles are flat with 5% of area sloped to runoff. No vegetation	17%	9%	74%
2	Regrading/Avg. Precip: Scenario 2 layers with: Regrading (100% area regraded) Slope grade = 1 - 3% No vegetation	17%	64%	19%
3	Regrading/Revegetation/Avg Precip: Scenario 2 layers with: HELP Model default for good grass No gravel	21%	67%	12%
4	Regrading/Geosynthetic Cover/Avg Precip: 6" gravel: k=3.0 x 10^{-1}cm/s 24" sandy loam: k=1.7 x 10^{-3} cm/s 0.6 cm geosynthetic: k=3.0x10^{-9}cm/s 20' sandy loam: k=1.7 x 10^{-3} cm/s Regrading (100% area regraded) Slope grade = 1 - 3% No vegetation	19%	79%	2%

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**              HYDROLOGIC EVALUATION OF LANDFILL PERFORMANCE               **
**                HELP MODEL VERSION 3.07  (1 NOVEMBER 1997)                **
**                  DEVELOPED BY ENVIRONMENTAL LABORATORY                   **
**                    USAE WATERWAYS EXPERIMENT STATION                     **
**              FOR USEPA RISK REDUCTION ENGINEERING LABORATORY             **
**                                                                          **
**                                                                          **
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PRECIPITATION DATA FILE:     G:\CRAIG\HELP3\HOLDEN4.D4
TEMPERATURE DATA FILE:       g:\craig\help3\HOLDEN7.D7
SOLAR RADIATION DATA FILE:   g:\craig\help3\HOLDEN13.D13
EVAPOTRANSPIRATION DATA:     g:\craig\help3\HOLDEN11.D11
SOIL AND DESIGN DATA FILE:   g:\craig\help3\SCEN2P1.D10
OUTPUT DATA FILE:            G:\CRAIG\HELP3\scen2p1.OUT


TIME:  15:19     DATE:  10/ 7/1999


******************************************************************************

     TITLE:  Holden Mine Tailings Pile 1 - Scenario 1

******************************************************************************


     NOTE:  INITIAL MOISTURE CONTENT OF THE LAYERS AND SNOW WATER WERE
              COMPUTED AS NEARLY STEADY-STATE VALUES BY THE PROGRAM.


                                   LAYER  1
                                   --------

                       TYPE 1 - VERTICAL PERCOLATION LAYER
                           MATERIAL TEXTURE NUMBER  21
           THICKNESS                  =        3.00   INCHES
           POROSITY                   =        0.3970 VOL/VOL
           FIELD CAPACITY             =        0.0320 VOL/VOL
           WILTING POINT              =        0.0130 VOL/VOL
           INITIAL SOIL WATER CONTENT =        0.0593 VOL/VOL
           EFFECTIVE SAT. HYD. COND.  =  0.300000012000       CM/SEC
       NOTE:  SATURATED HYDRAULIC CONDUCTIVITY IS MULTIPLIED BY  3.00
                FOR ROOT CHANNELS IN TOP HALF OF EVAPORATIVE ZONE.
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LAYER 2

TYPE 2 - LATERAL DRAINAGE LAYER
MATERIAL TEXTURE NUMBER 21

THICKNESS	=	3.00	INCHES
POROSITY	=	0.3970	VOL/VOL
FIELD CAPACITY	=	0.0320	VOL/VOL
WILTING POINT	=	0.0130	VOL/VOL
INITIAL SOIL WATER CONTENT	=	0.0559	VOL/VOL
EFFECTIVE SAT. HYD. COND.	=	0.300000012000	CM/SEC
SLOPE	=	58.00	PERCENT
DRAINAGE LENGTH	=	20.5	FEET

LAYER 3

TYPE 3 - BARRIER SOIL LINER
MATERIAL TEXTURE NUMBER 4

THICKNESS	=	3.00	INCHES
POROSITY	=	0.4370	VOL/VOL
FIELD CAPACITY	=	0.1050	VOL/VOL
WILTING POINT	=	0.0470	VOL/VOL
INITIAL SOIL WATER CONTENT	=	0.4370	VOL/VOL
EFFECTIVE SAT. HYD. COND.	=	0.170000002000E-02	CM/SEC

LAYER 4

TYPE 1 - VERTICAL PERCOLATION LAYER
MATERIAL TEXTURE NUMBER 4

THICKNESS	=	237.00	INCHES
POROSITY	=	0.4370	VOL/VOL
FIELD CAPACITY	=	0.1050	VOL/VOL
WILTING POINT	=	0.0470	VOL/VOL
INITIAL SOIL WATER CONTENT	=	0.1762	VOL/VOL
EFFECTIVE SAT. HYD. COND.	=	0.170000002000E-02	CM/SEC

GENERAL DESIGN AND EVAPORATIVE ZONE DATA

NOTE: SCS RUNOFF CURVE NUMBER WAS COMPUTED FROM DEFAULT SOIL DATA BASE USING SOIL TEXTURE #21 WITH BARE GROUND CONDITIONS, A SURFACE SLOPE OF 58.% AND

A SLOPE LENGTH OF 75. FEET.

SCS RUNOFF CURVE NUMBER	=	75.00	
FRACTION OF AREA ALLOWING RUNOFF	=	5.0	PERCENT
AREA PROJECTED ON HORIZONTAL PLANE	=	25.000	ACRES
EVAPORATIVE ZONE DEPTH	=	6.0	INCHES
INITIAL WATER IN EVAPORATIVE ZONE	=	0.346	INCHES
UPPER LIMIT OF EVAPORATIVE STORAGE	=	2.382	INCHES
LOWER LIMIT OF EVAPORATIVE STORAGE	=	0.078	INCHES
INITIAL SNOW WATER	=	12.815	INCHES
INITIAL WATER IN LAYER MATERIALS	=	43.420	INCHES
TOTAL INITIAL WATER	=	56.235	INCHES
TOTAL SUBSURFACE INFLOW	=	0.00	INCHES/YEAR

EVAPOTRANSPIRATION AND WEATHER DATA

NOTE: EVAPOTRANSPIRATION DATA WAS OBTAINED FROM
Holden WASHINGTON

STATION LATITUDE	=	48.12	DEGREES
MAXIMUM LEAF AREA INDEX	=	2.00	
START OF GROWING SEASON (JULIAN DATE)	=	183	
END OF GROWING SEASON (JULIAN DATE)	=	245	
EVAPORATIVE ZONE DEPTH	=	6.0	INCHES
AVERAGE ANNUAL WIND SPEED	=	9.10	MPH
AVERAGE 1ST QUARTER RELATIVE HUMIDITY	=	89.00	%
AVERAGE 2ND QUARTER RELATIVE HUMIDITY	=	78.00	%
AVERAGE 3RD QUARTER RELATIVE HUMIDITY	=	71.00	%
AVERAGE 4TH QUARTER RELATIVE HUMIDITY	=	88.00	%

NOTE: PRECIPITATION DATA FOR Holden Washington
WAS ENTERED BY THE USER.

NOTE: TEMPERATURE DATA FOR Holden Washington
WAS ENTERED BY THE USER.

NOTE: SOLAR RADIATION DATA WAS SYNTHETICALLY GENERATED USING
COEFFICIENTS FOR STAMPEDE PASS WASHINGTON
AND STATION LATITUDE = 47.17 DEGREES

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ANNUAL TOTALS FOR YEAR 1999

	INCHES	CU. FEET	PERCENT
PRECIPITATION	38.60	3502951.000	100.00
RUNOFF	1.245	112959.312	3.22
EVAPOTRANSPIRATION	6.619	600640.000	17.15
DRAINAGE COLLECTED FROM LAYER 2	2.3730	215353.594	6.15
PERC./LEAKAGE THROUGH LAYER 3	28.363609	2573997.500	73.48
AVG. HEAD ON TOP OF LAYER 3	0.0039		
PERC./LEAKAGE THROUGH LAYER 4	25.067959	2274917.250	64.94
CHANGE IN WATER STORAGE	3.296	299080.969	8.54
SOIL WATER AT START OF YEAR	43.420	3940359.000	
SOIL WATER AT END OF YEAR	46.716	4239440.000	
SNOW WATER AT START OF YEAR	12.815	1162944.120	33.20
SNOW WATER AT END OF YEAR	12.815	1162944.120	33.20
ANNUAL WATER BUDGET BALANCE	0.0000	-0.346	0.00

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ANNUAL TOTALS FOR YEAR 1998

	INCHES	CU. FEET	PERCENT
PRECIPITATION	38.60	3502951.000	100.00
RUNOFF	1.245	112959.320	3.22
EVAPOTRANSPIRATION	6.602	599125.000	17.10
DRAINAGE COLLECTED FROM LAYER 2	2.3660	214714.187	6.13
PERC./LEAKAGE THROUGH LAYER 3	28.387342	2576151.250	73.54
AVG. HEAD ON TOP OF LAYER 3	0.0039		
PERC./LEAKAGE THROUGH LAYER 4	28.379025	2575396.500	73.52
CHANGE IN WATER STORAGE	0.008	754.681	0.02
SOIL WATER AT START OF YEAR	46.716	4239440.000	

SOIL WATER AT END OF YEAR	46.724	4240194.500	
SNOW WATER AT START OF YEAR	12.815	1162944.120	33.20
SNOW WATER AT END OF YEAR	12.815	1162944.120	33.20
ANNUAL WATER BUDGET BALANCE	0.0000	1.212	0.00

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ANNUAL TOTALS FOR YEAR 1997

	INCHES	CU. FEET	PERCENT
PRECIPITATION	38.60	3502951.000	100.00
RUNOFF	1.245	112959.336	3.22
EVAPOTRANSPIRATION	6.631	601738.000	17.18
DRAINAGE COLLECTED FROM LAYER 2	2.3705	215118.359	6.14
PERC./LEAKAGE THROUGH LAYER 3	28.354101	2573134.750	73.46
AVG. HEAD ON TOP OF LAYER 3	0.0039		
PERC./LEAKAGE THROUGH LAYER 4	28.380142	2575498.000	73.52
CHANGE IN WATER STORAGE	-0.026	-2362.358	-0.07
SOIL WATER AT START OF YEAR	46.724	4240194.500	
SOIL WATER AT END OF YEAR	46.698	4237832.000	
SNOW WATER AT START OF YEAR	12.815	1162944.120	33.20
SNOW WATER AT END OF YEAR	12.815	1162944.120	33.20
ANNUAL WATER BUDGET BALANCE	0.0000	-0.346	0.00

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ANNUAL TOTALS FOR YEAR 1996

	INCHES	CU. FEET	PERCENT
PRECIPITATION	38.60	3502951.000	100.00

RUNOFF	1.245	112959.898	3.22
EVAPOTRANSPIRATION	6.662	604563.625	17.26
DRAINAGE COLLECTED FROM LAYER 2	2.3697	215046.031	6.14
PERC./LEAKAGE THROUGH LAYER 3	28.328079	2570773.250	73.39
AVG. HEAD ON TOP OF LAYER 3	0.0039		
PERC./LEAKAGE THROUGH LAYER 4	28.358572	2573540.500	73.47
CHANGE IN WATER STORAGE	-0.035	-3161.177	-0.09
SOIL WATER AT START OF YEAR	46.698	4237832.000	
SOIL WATER AT END OF YEAR	46.667	4235064.500	
SNOW WATER AT START OF YEAR	12.815	1162944.120	33.20
SNOW WATER AT END OF YEAR	12.810	1162550.620	33.19
ANNUAL WATER BUDGET BALANCE	0.0000	2.077	0.00

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ANNUAL TOTALS FOR YEAR 1995

	INCHES	CU. FEET	PERCENT
PRECIPITATION	38.60	3502951.000	100.00
RUNOFF	1.249	113371.094	3.24
EVAPOTRANSPIRATION	6.480	588032.875	16.79
DRAINAGE COLLECTED FROM LAYER 2	2.3693	215010.875	6.14
PERC./LEAKAGE THROUGH LAYER 3	28.497425	2586141.250	73.83
AVG. HEAD ON TOP OF LAYER 3	0.0039		
PERC./LEAKAGE THROUGH LAYER 4	28.439911	2580922.000	73.68
CHANGE IN WATER STORAGE	0.062	5613.543	0.16
SOIL WATER AT START OF YEAR	46.667	4235064.500	
SOIL WATER AT END OF YEAR	46.725	4240284.500	
SNOW WATER AT START OF YEAR	12.810	1162550.620	33.19

SNOW WATER AT END OF YEAR	12.815	1162944.120	33.20
ANNUAL WATER BUDGET BALANCE	0.0000	0.692	0.00

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AVERAGE MONTHLY VALUES IN INCHES FOR YEARS 1999 THROUGH 1995

	JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
PRECIPITATION						
TOTALS	6.62	4.74	2.81	1.60	0.93	1.11
	0.76	1.11	1.62	3.41	6.50	7.39
STD. DEVIATIONS	0.00	0.00	0.00	0.00	0.00	0.00
	0.00	0.00	0.00	0.00	0.00	0.00
RUNOFF						
TOTALS	0.000	0.000	0.158	1.087	0.000	0.000
	0.000	0.000	0.000	0.000	0.000	0.000
STD. DEVIATIONS	0.000	0.000	0.010	0.010	0.000	0.000
	0.000	0.000	0.000	0.000	0.000	0.000
EVAPOTRANSPIRATION						
TOTALS	0.248	0.173	0.048	0.058	0.681	0.846
	0.915	0.952	0.999	1.008	0.375	0.295
STD. DEVIATIONS	0.042	0.000	0.002	0.013	0.048	0.049
	0.044	0.028	0.035	0.045	0.005	0.002
LATERAL DRAINAGE COLLECTED FROM LAYER 2						
TOTALS	0.0000	0.0000	0.0418	2.2721	0.0001	0.0002
	0.0001	0.0000	0.0085	0.0466	0.0003	0.0000
STD. DEVIATIONS	0.0000	0.0000	0.0049	0.0066	0.0001	0.0002
	0.0001	0.0000	0.0005	0.0039	0.0000	0.0000
PERCOLATION/LEAKAGE THROUGH LAYER 3						
TOTALS	0.0000	0.0000	3.1894	21.5762	0.0903	0.1633
	0.0988	0.0428	0.6547	2.2800	0.2907	0.0000
STD. DEVIATIONS	0.0000	0.0000	0.2004	0.2162	0.0230	0.0462

0.0438	0.0240	0.0256	0.0284	0.0066	0.0000

PERCOLATION/LEAKAGE THROUGH LAYER 4

TOTALS	0.8988	0.7167	0.6790	3.6728	11.7084	3.3528
	1.9739	1.4125	0.9742	0.5988	0.7014	1.0357
STD. DEVIATIONS	0.3065	0.1810	0.1283	0.8816	0.3474	0.0417
	0.0407	0.0218	0.0165	0.0098	0.0060	0.0040

AVERAGES OF MONTHLY AVERAGED DAILY HEADS (INCHES)

DAILY AVERAGE HEAD ON TOP OF LAYER 3

AVERAGES	0.0000	0.0000	0.0045	0.0365	0.0001	0.0002
	0.0001	0.0001	0.0011	0.0037	0.0004	0.0000
STD. DEVIATIONS	0.0000	0.0000	0.0003	0.0003	0.0000	0.0001
	0.0001	0.0000	0.0001	0.0002	0.0000	0.0000

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AVERAGE ANNUAL TOTALS & (STD. DEVIATIONS) FOR YEARS 1999 THROUGH 1995

	INCHES		CU. FEET	PERCENT
PRECIPITATION	38.60	(0.013)	3502951.0	100.00
RUNOFF	1.246	(0.0020)	113041.79	3.227
EVAPOTRANSPIRATION	6.599	(0.0700)	598819.94	17.095
LATERAL DRAINAGE COLLECTED FROM LAYER 2	2.36968	(0.00249)	215048.625	6.13907
PERCOLATION/LEAKAGE THROUGH LAYER 3	28.38611	(0.06550)	2576039.750	73.53913
AVERAGE HEAD ON TOP OF LAYER 3	0.004	(0.000)		
PERCOLATION/LEAKAGE THROUGH LAYER 4	27.72512	(1.48570)	2516054.750	71.82672
CHANGE IN WATER STORAGE	0.661	(1.4733)	59985.13	1.712

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PEAK DAILY VALUES FOR YEARS 1999 THROUGH 1995

	(INCHES)	(CU. FT.)
PRECIPITATION	0.75	68062.500
RUNOFF	0.089	8110.1738
DRAINAGE COLLECTED FROM LAYER 2	1.28695	116791.07800
PERCOLATION/LEAKAGE THROUGH LAYER 3	1.604179	145579.25000
AVERAGE HEAD ON TOP OF LAYER 3	0.156	
MAXIMUM HEAD ON TOP OF LAYER 3	0.073	
LOCATION OF MAXIMUM HEAD IN LAYER 2 (DISTANCE FROM DRAIN)	0.0 FEET	
PERCOLATION/LEAKAGE THROUGH LAYER 4	0.988737	89727.85940
SNOW WATER	24.15	2191189.0000

MAXIMUM VEG. SOIL WATER (VOL/VOL)	0.3362
MINIMUM VEG. SOIL WATER (VOL/VOL)	0.0130

*** Maximum heads are computed using McEnroe's equations. ***

Reference: Maximum Saturated Depth over Landfill Liner
by Bruce M. McEnroe, University of Kansas
ASCE Journal of Environmental Engineering
Vol. 119, No. 2, March 1993, pp. 262-270.

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FINAL WATER STORAGE AT END OF YEAR 1995

LAYER	(INCHES)	(VOL/VOL)
1	0.1778	0.0593
2	0.1678	0.0559
3	1.3110	0.4370
4	45.0684	0.1902
SNOW WATER	12.815	

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**              HYDROLOGIC EVALUATION OF LANDFILL PERFORMANCE               **
**                HELP MODEL VERSION 3.07  (1 NOVEMBER 1997)                **
**                  DEVELOPED BY ENVIRONMENTAL LABORATORY                   **
**                    USAE WATERWAYS EXPERIMENT STATION                     **
**             FOR USEPA RISK REDUCTION ENGINEERING LABORATORY              **
**                                                                          **
**                                                                          **
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PRECIPITATION DATA FILE:     G:\CRAIG\HELP3\HOLDEN4.D4
TEMPERATURE DATA FILE:       g:\craig\help3\HOLDEN7.D7
SOLAR RADIATION DATA FILE:   g:\craig\help3\HOLDEN13.D13
EVAPOTRANSPIRATION DATA:     g:\craig\help3\HOLDEN11.D11
SOIL AND DESIGN DATA FILE:   g:\craig\help3\SCEN2P1.D10
OUTPUT DATA FILE:            G:\CRAIG\HELP3\scen2p1.OUT


TIME:  15:19     DATE:  10/ 7/1999


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     TITLE:  Holden Mine Tailings Pile 1 - Scenario 1

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     NOTE:  INITIAL MOISTURE CONTENT OF THE LAYERS AND SNOW WATER WERE
              COMPUTED AS NEARLY STEADY-STATE VALUES BY THE PROGRAM.


                                 LAYER  1
                                 --------

                    TYPE 1 - VERTICAL PERCOLATION LAYER
                        MATERIAL TEXTURE NUMBER  21
          THICKNESS                  =       3.00    INCHES
          POROSITY                   =       0.3970 VOL/VOL
          FIELD CAPACITY             =       0.0320 VOL/VOL
          WILTING POINT              =       0.0130 VOL/VOL
          INITIAL SOIL WATER CONTENT =       0.0593 VOL/VOL
          EFFECTIVE SAT. HYD. COND.  =  0.300000012000     CM/SEC
        NOTE:  SATURATED HYDRAULIC CONDUCTIVITY IS MULTIPLIED BY  3.00
                 FOR ROOT CHANNELS IN TOP HALF OF EVAPORATIVE ZONE.
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LAYER 2

TYPE 2 - LATERAL DRAINAGE LAYER
MATERIAL TEXTURE NUMBER 21

THICKNESS	=	3.00	INCHES
POROSITY	=	0.3970	VOL/VOL
FIELD CAPACITY	=	0.0320	VOL/VOL
WILTING POINT	=	0.0130	VOL/VOL
INITIAL SOIL WATER CONTENT	=	0.0559	VOL/VOL
EFFECTIVE SAT. HYD. COND.	=	0.300000012000	CM/SEC
SLOPE	=	58.00	PERCENT
DRAINAGE LENGTH	=	20.5	FEET

LAYER 3

TYPE 3 - BARRIER SOIL LINER
MATERIAL TEXTURE NUMBER 4

THICKNESS	=	3.00	INCHES
POROSITY	=	0.4370	VOL/VOL
FIELD CAPACITY	=	0.1050	VOL/VOL
WILTING POINT	=	0.0470	VOL/VOL
INITIAL SOIL WATER CONTENT	=	0.4370	VOL/VOL
EFFECTIVE SAT. HYD. COND.	=	0.170000002000E-02	CM/SEC

LAYER 4

TYPE 1 - VERTICAL PERCOLATION LAYER
MATERIAL TEXTURE NUMBER 4

THICKNESS	=	237.00	INCHES
POROSITY	=	0.4370	VOL/VOL
FIELD CAPACITY	=	0.1050	VOL/VOL
WILTING POINT	=	0.0470	VOL/VOL
INITIAL SOIL WATER CONTENT	=	0.1762	VOL/VOL
EFFECTIVE SAT. HYD. COND.	=	0.170000002000E-02	CM/SEC

GENERAL DESIGN AND EVAPORATIVE ZONE DATA

NOTE: SCS RUNOFF CURVE NUMBER WAS COMPUTED FROM DEFAULT SOIL DATA BASE USING SOIL TEXTURE #21 WITH BARE GROUND CONDITIONS, A SURFACE SLOPE OF 58.% AND

A SLOPE LENGTH OF 75. FEET.

SCS RUNOFF CURVE NUMBER	=	75.00	
FRACTION OF AREA ALLOWING RUNOFF	=	5.0	PERCENT
AREA PROJECTED ON HORIZONTAL PLANE	=	25.000	ACRES
EVAPORATIVE ZONE DEPTH	=	6.0	INCHES
INITIAL WATER IN EVAPORATIVE ZONE	=	0.346	INCHES
UPPER LIMIT OF EVAPORATIVE STORAGE	=	2.382	INCHES
LOWER LIMIT OF EVAPORATIVE STORAGE	=	0.078	INCHES
INITIAL SNOW WATER	=	12.815	INCHES
INITIAL WATER IN LAYER MATERIALS	=	43.420	INCHES
TOTAL INITIAL WATER	=	56.235	INCHES
TOTAL SUBSURFACE INFLOW	=	0.00	INCHES/YEAR

EVAPOTRANSPIRATION AND WEATHER DATA

NOTE: EVAPOTRANSPIRATION DATA WAS OBTAINED FROM
Holden WASHINGTON

STATION LATITUDE	=	48.12	DEGREES
MAXIMUM LEAF AREA INDEX	=	2.00	
START OF GROWING SEASON (JULIAN DATE)	=	183	
END OF GROWING SEASON (JULIAN DATE)	=	245	
EVAPORATIVE ZONE DEPTH	=	6.0	INCHES
AVERAGE ANNUAL WIND SPEED	=	9.10	MPH
AVERAGE 1ST QUARTER RELATIVE HUMIDITY	=	89.00	%
AVERAGE 2ND QUARTER RELATIVE HUMIDITY	=	78.00	%
AVERAGE 3RD QUARTER RELATIVE HUMIDITY	=	71.00	%
AVERAGE 4TH QUARTER RELATIVE HUMIDITY	=	88.00	%

NOTE: PRECIPITATION DATA FOR Holden Washington
WAS ENTERED BY THE USER.

NOTE: TEMPERATURE DATA FOR Holden Washington
WAS ENTERED BY THE USER.

NOTE: SOLAR RADIATION DATA WAS SYNTHETICALLY GENERATED USING
COEFFICIENTS FOR STAMPEDE PASS WASHINGTON
AND STATION LATITUDE = 47.17 DEGREES

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ANNUAL TOTALS FOR YEAR 1999

	INCHES	CU. FEET	PERCENT
PRECIPITATION	38.60	3502951.000	100.00
RUNOFF	1.245	112959.312	3.22
EVAPOTRANSPIRATION	6.619	600640.000	17.15
DRAINAGE COLLECTED FROM LAYER 2	2.3730	215353.594	6.15
PERC./LEAKAGE THROUGH LAYER 3	28.363609	2573997.500	73.48
AVG. HEAD ON TOP OF LAYER 3	0.0039		
PERC./LEAKAGE THROUGH LAYER 4	25.067959	2274917.250	64.94
CHANGE IN WATER STORAGE	3.296	299080.969	8.54
SOIL WATER AT START OF YEAR	43.420	3940359.000	
SOIL WATER AT END OF YEAR	46.716	4239440.000	
SNOW WATER AT START OF YEAR	12.815	1162944.120	33.20
SNOW WATER AT END OF YEAR	12.815	1162944.120	33.20
ANNUAL WATER BUDGET BALANCE	0.0000	-0.346	0.00

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ANNUAL TOTALS FOR YEAR 1998

	INCHES	CU. FEET	PERCENT
PRECIPITATION	38.60	3502951.000	100.00
RUNOFF	1.245	112959.320	3.22
EVAPOTRANSPIRATION	6.602	599125.000	17.10
DRAINAGE COLLECTED FROM LAYER 2	2.3660	214714.187	6.13
PERC./LEAKAGE THROUGH LAYER 3	28.387342	2576151.250	73.54
AVG. HEAD ON TOP OF LAYER 3	0.0039		
PERC./LEAKAGE THROUGH LAYER 4	28.379025	2575396.500	73.52
CHANGE IN WATER STORAGE	0.008	754.681	0.02
SOIL WATER AT START OF YEAR	46.716	4239440.000	

SOIL WATER AT END OF YEAR	46.724	4240194.500	
SNOW WATER AT START OF YEAR	12.815	1162944.120	33.20
SNOW WATER AT END OF YEAR	12.815	1162944.120	33.20
ANNUAL WATER BUDGET BALANCE	0.0000	1.212	0.00

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ANNUAL TOTALS FOR YEAR 1997

	INCHES	CU. FEET	PERCENT
PRECIPITATION	38.60	3502951.000	100.00
RUNOFF	1.245	112959.336	3.22
EVAPOTRANSPIRATION	6.631	601738.000	17.18
DRAINAGE COLLECTED FROM LAYER 2	2.3705	215118.359	6.14
PERC./LEAKAGE THROUGH LAYER 3	28.354101	2573134.750	73.46
AVG. HEAD ON TOP OF LAYER 3	0.0039		
PERC./LEAKAGE THROUGH LAYER 4	28.380142	2575498.000	73.52
CHANGE IN WATER STORAGE	-0.026	-2362.358	-0.07
SOIL WATER AT START OF YEAR	46.724	4240194.500	
SOIL WATER AT END OF YEAR	46.698	4237832.000	
SNOW WATER AT START OF YEAR	12.815	1162944.120	33.20
SNOW WATER AT END OF YEAR	12.815	1162944.120	33.20
ANNUAL WATER BUDGET BALANCE	0.0000	-0.346	0.00

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ANNUAL TOTALS FOR YEAR 1996

	INCHES	CU. FEET	PERCENT
PRECIPITATION	38.60	3502951.000	100.00

RUNOFF	1.245	112959.898	3.22
EVAPOTRANSPIRATION	6.662	604563.625	17.26
DRAINAGE COLLECTED FROM LAYER 2	2.3697	215046.031	6.14
PERC./LEAKAGE THROUGH LAYER 3	28.328079	2570773.250	73.39
AVG. HEAD ON TOP OF LAYER 3	0.0039		
PERC./LEAKAGE THROUGH LAYER 4	28.358572	2573540.500	73.47
CHANGE IN WATER STORAGE	-0.035	-3161.177	-0.09
SOIL WATER AT START OF YEAR	46.698	4237832.000	
SOIL WATER AT END OF YEAR	46.667	4235064.500	
SNOW WATER AT START OF YEAR	12.815	1162944.120	33.20
SNOW WATER AT END OF YEAR	12.810	1162550.620	33.19
ANNUAL WATER BUDGET BALANCE	0.0000	2.077	0.00

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ANNUAL TOTALS FOR YEAR 1995

	INCHES	CU. FEET	PERCENT
PRECIPITATION	38.60	3502951.000	100.00
RUNOFF	1.249	113371.094	3.24
EVAPOTRANSPIRATION	6.480	588032.875	16.79
DRAINAGE COLLECTED FROM LAYER 2	2.3693	215010.875	6.14
PERC./LEAKAGE THROUGH LAYER 3	28.497425	2586141.250	73.83
AVG. HEAD ON TOP OF LAYER 3	0.0039		
PERC./LEAKAGE THROUGH LAYER 4	28.439911	2580922.000	73.68
CHANGE IN WATER STORAGE	0.062	5613.543	0.16
SOIL WATER AT START OF YEAR	46.667	4235064.500	
SOIL WATER AT END OF YEAR	46.725	4240284.500	
SNOW WATER AT START OF YEAR	12.810	1162550.620	33.19

SNOW WATER AT END OF YEAR	12.815	1162944.120	33.20
ANNUAL WATER BUDGET BALANCE	0.0000	0.692	0.00

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AVERAGE MONTHLY VALUES IN INCHES FOR YEARS 1999 THROUGH 1995

	JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
PRECIPITATION						
TOTALS	6.62	4.74	2.81	1.60	0.93	1.11
	0.76	1.11	1.62	3.41	6.50	7.39
STD. DEVIATIONS	0.00	0.00	0.00	0.00	0.00	0.00
	0.00	0.00	0.00	0.00	0.00	0.00
RUNOFF						
TOTALS	0.000	0.000	0.158	1.087	0.000	0.000
	0.000	0.000	0.000	0.000	0.000	0.000
STD. DEVIATIONS	0.000	0.000	0.010	0.010	0.000	0.000
	0.000	0.000	0.000	0.000	0.000	0.000
EVAPOTRANSPIRATION						
TOTALS	0.248	0.173	0.048	0.058	0.681	0.846
	0.915	0.952	0.999	1.008	0.375	0.295
STD. DEVIATIONS	0.042	0.000	0.002	0.013	0.048	0.049
	0.044	0.028	0.035	0.045	0.005	0.002
LATERAL DRAINAGE COLLECTED FROM LAYER 2						
TOTALS	0.0000	0.0000	0.0418	2.2721	0.0001	0.0002
	0.0001	0.0000	0.0085	0.0466	0.0003	0.0000
STD. DEVIATIONS	0.0000	0.0000	0.0049	0.0066	0.0001	0.0002
	0.0001	0.0000	0.0005	0.0039	0.0000	0.0000
PERCOLATION/LEAKAGE THROUGH LAYER 3						
TOTALS	0.0000	0.0000	3.1894	21.5762	0.0903	0.1633
	0.0988	0.0428	0.6547	2.2800	0.2907	0.0000
STD. DEVIATIONS	0.0000	0.0000	0.2004	0.2162	0.0230	0.0462

	0.0438	0.0240	0.0256	0.0284	0.0066	0.0000

PERCOLATION/LEAKAGE THROUGH LAYER 4

TOTALS	0.8988	0.7167	0.6790	3.6728	11.7084	3.3528
	1.9739	1.4125	0.9742	0.5988	0.7014	1.0357
STD. DEVIATIONS	0.3065	0.1810	0.1283	0.8816	0.3474	0.0417
	0.0407	0.0218	0.0165	0.0098	0.0060	0.0040

AVERAGES OF MONTHLY AVERAGED DAILY HEADS (INCHES)

DAILY AVERAGE HEAD ON TOP OF LAYER 3

AVERAGES	0.0000	0.0000	0.0045	0.0365	0.0001	0.0002
	0.0001	0.0001	0.0011	0.0037	0.0004	0.0000
STD. DEVIATIONS	0.0000	0.0000	0.0003	0.0003	0.0000	0.0001
	0.0001	0.0000	0.0001	0.0002	0.0000	0.0000

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AVERAGE ANNUAL TOTALS & (STD. DEVIATIONS) FOR YEARS 1999 THROUGH 1995

	INCHES	CU. FEET	PERCENT
PRECIPITATION	38.60 (0.013)	3502951.0	100.00
RUNOFF	1.246 (0.0020)	113041.79	3.227
EVAPOTRANSPIRATION	6.599 (0.0700)	598819.94	17.095
LATERAL DRAINAGE COLLECTED FROM LAYER 2	2.36968 (0.00249)	215048.625	6.13907
PERCOLATION/LEAKAGE THROUGH LAYER 3	28.38611 (0.06550)	2576039.750	73.53913
AVERAGE HEAD ON TOP OF LAYER 3	0.004 (0.000)		
PERCOLATION/LEAKAGE THROUGH LAYER 4	27.72512 (1.48570)	2516054.750	71.82672
CHANGE IN WATER STORAGE	0.661 (1.4733)	59985.13	1.712

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PEAK DAILY VALUES FOR YEARS 1999 THROUGH 1995

	(INCHES)	(CU. FT.)
PRECIPITATION	0.75	68062.500
RUNOFF	0.089	8110.1738
DRAINAGE COLLECTED FROM LAYER 2	1.28695	116791.07800
PERCOLATION/LEAKAGE THROUGH LAYER 3	1.604179	145579.25000
AVERAGE HEAD ON TOP OF LAYER 3	0.156	
MAXIMUM HEAD ON TOP OF LAYER 3	0.073	
LOCATION OF MAXIMUM HEAD IN LAYER 2 (DISTANCE FROM DRAIN)	0.0 FEET	
PERCOLATION/LEAKAGE THROUGH LAYER 4	0.988737	89727.85940
SNOW WATER	24.15	2191189.0000
MAXIMUM VEG. SOIL WATER (VOL/VOL)		0.3362
MINIMUM VEG. SOIL WATER (VOL/VOL)		0.0130

*** Maximum heads are computed using McEnroe's equations. ***

Reference: Maximum Saturated Depth over Landfill Liner
by Bruce M. McEnroe, University of Kansas
ASCE Journal of Environmental Engineering
Vol. 119, No. 2, March 1993, pp. 262-270.

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FINAL WATER STORAGE AT END OF YEAR 1995

LAYER	(INCHES)	(VOL/VOL)
1	0.1778	0.0593
2	0.1678	0.0559
3	1.3110	0.4370
4	45.0684	0.1902
SNOW WATER	12.815	

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**              HYDROLOGIC EVALUATION OF LANDFILL PERFORMANCE               **
**                HELP MODEL VERSION 3.07  (1 NOVEMBER 1997)                **
**                  DEVELOPED BY ENVIRONMENTAL LABORATORY                   **
**                    USAE WATERWAYS EXPERIMENT STATION                     **
**             FOR USEPA RISK REDUCTION ENGINEERING LABORATORY              **
**                                                                          **
**                                                                          **
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PRECIPITATION DATA FILE:     G:\CRAIG\HELP3\HOLDEN4.D4
TEMPERATURE DATA FILE:       g:\craig\help3\HOLDEN7.D7
SOLAR RADIATION DATA FILE:   g:\craig\help3\HOLDEN13.D13
EVAPOTRANSPIRATION DATA:     g:\craig\help3\HOLDEN11.D11
SOIL AND DESIGN DATA FILE:   g:\craig\help3\SCEN2P2.D10
OUTPUT DATA FILE:            G:\CRAIG\HELP3\scen2p2.OUT


TIME:  15:20     DATE:  10/ 7/1999


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     TITLE:  Holden Mine Tailings Pile 2 - Scenario 1

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     NOTE:  INITIAL MOISTURE CONTENT OF THE LAYERS AND SNOW WATER WERE
              COMPUTED AS NEARLY STEADY-STATE VALUES BY THE PROGRAM.


                                   LAYER  1
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                       TYPE 1 - VERTICAL PERCOLATION LAYER
                           MATERIAL TEXTURE NUMBER  21
           THICKNESS                  =       3.00   INCHES
           POROSITY                   =       0.3970 VOL/VOL
           FIELD CAPACITY             =       0.0320 VOL/VOL
           WILTING POINT              =       0.0130 VOL/VOL
           INITIAL SOIL WATER CONTENT =       0.0593 VOL/VOL
           EFFECTIVE SAT. HYD. COND.  =  0.300000012000     CM/SEC
         NOTE:  SATURATED HYDRAULIC CONDUCTIVITY IS MULTIPLIED BY  3.00
                  FOR ROOT CHANNELS IN TOP HALF OF EVAPORATIVE ZONE.
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LAYER 2

TYPE 2 - LATERAL DRAINAGE LAYER
MATERIAL TEXTURE NUMBER 21

THICKNESS	=	3.00	INCHES
POROSITY	=	0.3970	VOL/VOL
FIELD CAPACITY	=	0.0320	VOL/VOL
WILTING POINT	=	0.0130	VOL/VOL
INITIAL SOIL WATER CONTENT	=	0.0559	VOL/VOL
EFFECTIVE SAT. HYD. COND.	=	0.300000012000	CM/SEC
SLOPE	=	58.00	PERCENT
DRAINAGE LENGTH	=	20.5	FEET

LAYER 3

TYPE 3 - BARRIER SOIL LINER
MATERIAL TEXTURE NUMBER 4

THICKNESS	=	3.00	INCHES
POROSITY	=	0.4370	VOL/VOL
FIELD CAPACITY	=	0.1050	VOL/VOL
WILTING POINT	=	0.0470	VOL/VOL
INITIAL SOIL WATER CONTENT	=	0.4370	VOL/VOL
EFFECTIVE SAT. HYD. COND.	=	0.170000002000E-02	CM/SEC

LAYER 4

TYPE 1 - VERTICAL PERCOLATION LAYER
MATERIAL TEXTURE NUMBER 4

THICKNESS	=	237.00	INCHES
POROSITY	=	0.4370	VOL/VOL
FIELD CAPACITY	=	0.1050	VOL/VOL
WILTING POINT	=	0.0470	VOL/VOL
INITIAL SOIL WATER CONTENT	=	0.1762	VOL/VOL
EFFECTIVE SAT. HYD. COND.	=	0.170000002000E-02	CM/SEC

GENERAL DESIGN AND EVAPORATIVE ZONE DATA

NOTE: SCS RUNOFF CURVE NUMBER WAS COMPUTED FROM DEFAULT SOIL DATA BASE USING SOIL TEXTURE #21 WITH BARE GROUND CONDITIONS, A SURFACE SLOPE OF 58.% AND

A SLOPE LENGTH OF 125. FEET.

SCS RUNOFF CURVE NUMBER	=	74.20	
FRACTION OF AREA ALLOWING RUNOFF	=	5.0	PERCENT
AREA PROJECTED ON HORIZONTAL PLANE	=	45.000	ACRES
EVAPORATIVE ZONE DEPTH	=	6.0	INCHES
INITIAL WATER IN EVAPORATIVE ZONE	=	0.346	INCHES
UPPER LIMIT OF EVAPORATIVE STORAGE	=	2.382	INCHES
LOWER LIMIT OF EVAPORATIVE STORAGE	=	0.078	INCHES
INITIAL SNOW WATER	=	12.815	INCHES
INITIAL WATER IN LAYER MATERIALS	=	43.420	INCHES
TOTAL INITIAL WATER	=	56.235	INCHES
TOTAL SUBSURFACE INFLOW	=	0.00	INCHES/YEAR

EVAPOTRANSPIRATION AND WEATHER DATA

NOTE: EVAPOTRANSPIRATION DATA WAS OBTAINED FROM
Holden WASHINGTON

STATION LATITUDE	=	48.12	DEGREES
MAXIMUM LEAF AREA INDEX	=	2.00	
START OF GROWING SEASON (JULIAN DATE)	=	183	
END OF GROWING SEASON (JULIAN DATE)	=	245	
EVAPORATIVE ZONE DEPTH	=	6.0	INCHES
AVERAGE ANNUAL WIND SPEED	=	9.10	MPH
AVERAGE 1ST QUARTER RELATIVE HUMIDITY	=	89.00	%
AVERAGE 2ND QUARTER RELATIVE HUMIDITY	=	78.00	%
AVERAGE 3RD QUARTER RELATIVE HUMIDITY	=	71.00	%
AVERAGE 4TH QUARTER RELATIVE HUMIDITY	=	88.00	%

NOTE: PRECIPITATION DATA FOR Holden Washington
WAS ENTERED BY THE USER.

NOTE: TEMPERATURE DATA FOR Holden Washington
WAS ENTERED BY THE USER.

NOTE: SOLAR RADIATION DATA WAS SYNTHETICALLY GENERATED USING
COEFFICIENTS FOR STAMPEDE PASS WASHINGTON
AND STATION LATITUDE = 47.17 DEGREES

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ANNUAL TOTALS FOR YEAR 1999

	INCHES	CU. FEET	PERCENT
PRECIPITATION	38.60	6305311.500	100.00
RUNOFF	1.245	203326.766	3.22
EVAPOTRANSPIRATION	6.619	1081152.000	17.15
DRAINAGE COLLECTED FROM LAYER 2	2.3730	387636.469	6.15
PERC./LEAKAGE THROUGH LAYER 3	28.363609	4633195.500	73.48
AVG. HEAD ON TOP OF LAYER 3	0.0039		
PERC./LEAKAGE THROUGH LAYER 4	25.067959	4094851.000	64.94
CHANGE IN WATER STORAGE	3.296	538345.750	8.54
SOIL WATER AT START OF YEAR	43.420	7092646.000	
SOIL WATER AT END OF YEAR	46.716	7630992.000	
SNOW WATER AT START OF YEAR	12.815	2093299.370	33.20
SNOW WATER AT END OF YEAR	12.815	2093299.370	33.20
ANNUAL WATER BUDGET BALANCE	0.0000	-0.623	0.00

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ANNUAL TOTALS FOR YEAR 1998

	INCHES	CU. FEET	PERCENT
PRECIPITATION	38.60	6305311.500	100.00
RUNOFF	1.245	203326.781	3.22
EVAPOTRANSPIRATION	6.602	1078425.000	17.10
DRAINAGE COLLECTED FROM LAYER 2	2.3660	386485.531	6.13
PERC./LEAKAGE THROUGH LAYER 3	28.387342	4637072.500	73.54
AVG. HEAD ON TOP OF LAYER 3	0.0039		
PERC./LEAKAGE THROUGH LAYER 4	28.379025	4635713.500	73.52
CHANGE IN WATER STORAGE	0.008	1358.425	0.02
SOIL WATER AT START OF YEAR	46.716	7630992.000	

SOIL WATER AT END OF YEAR	46.724	7632350.500	
SNOW WATER AT START OF YEAR	12.815	2093299.370	33.20
SNOW WATER AT END OF YEAR	12.815	2093299.370	33.20
ANNUAL WATER BUDGET BALANCE	0.0000	2.181	0.00

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ANNUAL TOTALS FOR YEAR 1997

	INCHES	CU. FEET	PERCENT
PRECIPITATION	38.60	6305311.500	100.00
RUNOFF	1.245	203326.797	3.22
EVAPOTRANSPIRATION	6.631	1083128.500	17.18
DRAINAGE COLLECTED FROM LAYER 2	2.3705	387213.062	6.14
PERC./LEAKAGE THROUGH LAYER 3	28.354101	4631642.500	73.46
AVG. HEAD ON TOP OF LAYER 3	0.0039		
PERC./LEAKAGE THROUGH LAYER 4	28.380142	4635896.000	73.52
CHANGE IN WATER STORAGE	-0.026	-4252.245	-0.07
SOIL WATER AT START OF YEAR	46.724	7632350.500	
SOIL WATER AT END OF YEAR	46.698	7628098.000	
SNOW WATER AT START OF YEAR	12.815	2093299.370	33.20
SNOW WATER AT END OF YEAR	12.815	2093299.370	33.20
ANNUAL WATER BUDGET BALANCE	0.0000	-0.623	0.00

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ANNUAL TOTALS FOR YEAR 1996

	INCHES	CU. FEET	PERCENT
PRECIPITATION	38.60	6305311.500	100.00

RUNOFF	1.245	203327.812	3.22
EVAPOTRANSPIRATION	6.662	1088214.500	17.26
DRAINAGE COLLECTED FROM LAYER 2	2.3697	387082.844	6.14
PERC./LEAKAGE THROUGH LAYER 3	28.328079	4627391.500	73.39
AVG. HEAD ON TOP OF LAYER 3	0.0039		
PERC./LEAKAGE THROUGH LAYER 4	28.358572	4632372.500	73.47
CHANGE IN WATER STORAGE	-0.035	-5690.119	-0.09
SOIL WATER AT START OF YEAR	46.698	7628098.000	
SOIL WATER AT END OF YEAR	46.667	7623116.000	
SNOW WATER AT START OF YEAR	12.815	2093299.370	33.20
SNOW WATER AT END OF YEAR	12.810	2092591.120	33.19
ANNUAL WATER BUDGET BALANCE	0.0000	3.739	0.00

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ANNUAL TOTALS FOR YEAR 1995

	INCHES	CU. FEET	PERCENT
PRECIPITATION	38.60	6305311.500	100.00
RUNOFF	1.249	204067.969	3.24
EVAPOTRANSPIRATION	6.480	1058459.120	16.79
DRAINAGE COLLECTED FROM LAYER 2	2.3693	387019.562	6.14
PERC./LEAKAGE THROUGH LAYER 3	28.497425	4655054.500	73.83
AVG. HEAD ON TOP OF LAYER 3	0.0039		
PERC./LEAKAGE THROUGH LAYER 4	28.439911	4645659.500	73.68
CHANGE IN WATER STORAGE	0.062	10104.378	0.16
SOIL WATER AT START OF YEAR	46.667	7623116.000	
SOIL WATER AT END OF YEAR	46.725	7632512.500	
SNOW WATER AT START OF YEAR	12.810	2092591.120	33.19

SNOW WATER AT END OF YEAR	12.815	2093299.370	33.20
ANNUAL WATER BUDGET BALANCE	0.0000	1.246	0.00

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AVERAGE MONTHLY VALUES IN INCHES FOR YEARS 1999 THROUGH 1995

	JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
PRECIPITATION						
TOTALS	6.62	4.74	2.81	1.60	0.93	1.11
	0.76	1.11	1.62	3.41	6.50	7.39
STD. DEVIATIONS	0.00	0.00	0.00	0.00	0.00	0.00
	0.00	0.00	0.00	0.00	0.00	0.00
RUNOFF						
TOTALS	0.000	0.000	0.158	1.087	0.000	0.000
	0.000	0.000	0.000	0.000	0.000	0.000
STD. DEVIATIONS	0.000	0.000	0.010	0.010	0.000	0.000
	0.000	0.000	0.000	0.000	0.000	0.000
EVAPOTRANSPIRATION						
TOTALS	0.248	0.173	0.048	0.058	0.681	0.846
	0.915	0.952	0.999	1.008	0.375	0.295
STD. DEVIATIONS	0.042	0.000	0.002	0.013	0.048	0.049
	0.044	0.028	0.035	0.045	0.005	0.002
LATERAL DRAINAGE COLLECTED FROM LAYER 2						
TOTALS	0.0000	0.0000	0.0418	2.2721	0.0001	0.0002
	0.0001	0.0000	0.0085	0.0466	0.0003	0.0000
STD. DEVIATIONS	0.0000	0.0000	0.0049	0.0066	0.0001	0.0002
	0.0001	0.0000	0.0005	0.0039	0.0000	0.0000
PERCOLATION/LEAKAGE THROUGH LAYER 3						
TOTALS	0.0000	0.0000	3.1894	21.5762	0.0903	0.1633
	0.0988	0.0428	0.6547	2.2800	0.2907	0.0000
STD. DEVIATIONS	0.0000	0.0000	0.2004	0.2162	0.0230	0.0462

	0.0438	0.0240	0.0256	0.0284	0.0066	0.0000

PERCOLATION/LEAKAGE THROUGH LAYER 4

TOTALS	0.8988	0.7167	0.6790	3.6728	11.7084	3.3528
	1.9739	1.4125	0.9742	0.5988	0.7014	1.0357
STD. DEVIATIONS	0.3065	0.1810	0.1283	0.8816	0.3474	0.0417
	0.0407	0.0218	0.0165	0.0098	0.0060	0.0040

AVERAGES OF MONTHLY AVERAGED DAILY HEADS (INCHES)

DAILY AVERAGE HEAD ON TOP OF LAYER 3

AVERAGES	0.0000	0.0000	0.0045	0.0365	0.0001	0.0002
	0.0001	0.0001	0.0011	0.0037	0.0004	0.0000
STD. DEVIATIONS	0.0000	0.0000	0.0003	0.0003	0.0000	0.0001
	0.0001	0.0000	0.0001	0.0002	0.0000	0.0000

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AVERAGE ANNUAL TOTALS & (STD. DEVIATIONS) FOR YEARS 1999 THROUGH 1995

	INCHES	CU. FEET	PERCENT
PRECIPITATION	38.60 (0.013)	6305311.5	100.00
RUNOFF	1.246 (0.0020)	203475.22	3.227
EVAPOTRANSPIRATION	6.599 (0.0700)	1077875.87	17.095
LATERAL DRAINAGE COLLECTED FROM LAYER 2	2.36968 (0.00249)	387087.531	6.13907
PERCOLATION/LEAKAGE THROUGH LAYER 3	28.38611 (0.06550)	4636871.500	73.53913
AVERAGE HEAD ON TOP OF LAYER 3	0.004 (0.000)		
PERCOLATION/LEAKAGE THROUGH LAYER 4	27.72512 (1.48570)	4528899.000	71.82672
CHANGE IN WATER STORAGE	0.661 (1.4733)	107973.24	1.712

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PEAK DAILY VALUES FOR YEARS 1999 THROUGH 1995

	(INCHES)	(CU. FT.)
PRECIPITATION	0.75	122512.500
RUNOFF	0.089	14598.3125
DRAINAGE COLLECTED FROM LAYER 2	1.28695	210223.93700
PERCOLATION/LEAKAGE THROUGH LAYER 3	1.604179	262042.65600
AVERAGE HEAD ON TOP OF LAYER 3	0.156	
MAXIMUM HEAD ON TOP OF LAYER 3	0.073	
LOCATION OF MAXIMUM HEAD IN LAYER 2 (DISTANCE FROM DRAIN)	0.0 FEET	
PERCOLATION/LEAKAGE THROUGH LAYER 4	0.988737	161510.14100
SNOW WATER	24.15	3944140.2500

MAXIMUM VEG. SOIL WATER (VOL/VOL)	0.3362
MINIMUM VEG. SOIL WATER (VOL/VOL)	0.0130

*** Maximum heads are computed using McEnroe's equations. ***

Reference: Maximum Saturated Depth over Landfill Liner
by Bruce M. McEnroe, University of Kansas
ASCE Journal of Environmental Engineering
Vol. 119, No. 2, March 1993, pp. 262-270.

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FINAL WATER STORAGE AT END OF YEAR 1995

LAYER	(INCHES)	(VOL/VOL)
1	0.1778	0.0593
2	0.1678	0.0559
3	1.3110	0.4370
4	45.0684	0.1902
SNOW WATER	12.815	

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**              HYDROLOGIC EVALUATION OF LANDFILL PERFORMANCE               **
**                HELP MODEL VERSION 3.07  (1 NOVEMBER 1997)                **
**                  DEVELOPED BY ENVIRONMENTAL LABORATORY                   **
**                    USAE WATERWAYS EXPERIMENT STATION                     **
**              FOR USEPA RISK REDUCTION ENGINEERING LABORATORY             **
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PRECIPITATION DATA FILE:     G:\CRAIG\HELP3\HOLDEN4.D4
TEMPERATURE DATA FILE:       g:\craig\help3\HOLDEN7.D7
SOLAR RADIATION DATA FILE:   g:\craig\help3\HOLDEN13.D13
EVAPOTRANSPIRATION DATA:     g:\craig\help3\HOLDEN11.D11
SOIL AND DESIGN DATA FILE:   g:\craig\help3\SCEN2P3.D10
OUTPUT DATA FILE:            G:\CRAIG\HELP3\scen2p3.OUT


TIME:  15:20     DATE:  10/ 7/1999


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     TITLE:  Holden Mine Tailings Pile 3 - Scenario 1

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     NOTE:  INITIAL MOISTURE CONTENT OF THE LAYERS AND SNOW WATER WERE
              COMPUTED AS NEARLY STEADY-STATE VALUES BY THE PROGRAM.


                                   LAYER  1
                                   --------

                     TYPE 1 - VERTICAL PERCOLATION LAYER
                         MATERIAL TEXTURE NUMBER  21
          THICKNESS                  =      3.00   INCHES
          POROSITY                   =      0.3970 VOL/VOL
          FIELD CAPACITY             =      0.0320 VOL/VOL
          WILTING POINT              =      0.0130 VOL/VOL
          INITIAL SOIL WATER CONTENT =      0.0593 VOL/VOL
          EFFECTIVE SAT. HYD. COND.  =  0.300000012000     CM/SEC
        NOTE:  SATURATED HYDRAULIC CONDUCTIVITY IS MULTIPLIED BY  3.00
                FOR ROOT CHANNELS IN TOP HALF OF EVAPORATIVE ZONE.
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LAYER 2

TYPE 2 - LATERAL DRAINAGE LAYER
MATERIAL TEXTURE NUMBER 21

THICKNESS	=	3.00	INCHES
POROSITY	=	0.3970	VOL/VOL
FIELD CAPACITY	=	0.0320	VOL/VOL
WILTING POINT	=	0.0130	VOL/VOL
INITIAL SOIL WATER CONTENT	=	0.0559	VOL/VOL
EFFECTIVE SAT. HYD. COND.	=	0.300000012000	CM/SEC
SLOPE	=	58.00	PERCENT
DRAINAGE LENGTH	=	20.5	FEET

LAYER 3

TYPE 3 - BARRIER SOIL LINER
MATERIAL TEXTURE NUMBER 4

THICKNESS	=	3.00	INCHES
POROSITY	=	0.4370	VOL/VOL
FIELD CAPACITY	=	0.1050	VOL/VOL
WILTING POINT	=	0.0470	VOL/VOL
INITIAL SOIL WATER CONTENT	=	0.4370	VOL/VOL
EFFECTIVE SAT. HYD. COND.	=	0.170000002000E-02	CM/SEC

LAYER 4

TYPE 1 - VERTICAL PERCOLATION LAYER
MATERIAL TEXTURE NUMBER 4

THICKNESS	=	237.00	INCHES
POROSITY	=	0.4370	VOL/VOL
FIELD CAPACITY	=	0.1050	VOL/VOL
WILTING POINT	=	0.0470	VOL/VOL
INITIAL SOIL WATER CONTENT	=	0.1762	VOL/VOL
EFFECTIVE SAT. HYD. COND.	=	0.170000002000E-02	CM/SEC

GENERAL DESIGN AND EVAPORATIVE ZONE DATA

NOTE: SCS RUNOFF CURVE NUMBER WAS COMPUTED FROM DEFAULT SOIL DATA BASE USING SOIL TEXTURE #21 WITH BARE GROUND CONDITIONS, A SURFACE SLOPE OF 58.% AND

A SLOPE LENGTH OF 100. FEET.

SCS RUNOFF CURVE NUMBER	=	74.60	
FRACTION OF AREA ALLOWING RUNOFF	=	5.0	PERCENT
AREA PROJECTED ON HORIZONTAL PLANE	=	22.000	ACRES
EVAPORATIVE ZONE DEPTH	=	6.0	INCHES
INITIAL WATER IN EVAPORATIVE ZONE	=	0.346	INCHES
UPPER LIMIT OF EVAPORATIVE STORAGE	=	2.382	INCHES
LOWER LIMIT OF EVAPORATIVE STORAGE	=	0.078	INCHES
INITIAL SNOW WATER	=	12.815	INCHES
INITIAL WATER IN LAYER MATERIALS	=	43.420	INCHES
TOTAL INITIAL WATER	=	56.235	INCHES
TOTAL SUBSURFACE INFLOW	=	0.00	INCHES/YEAR

EVAPOTRANSPIRATION AND WEATHER DATA

NOTE: EVAPOTRANSPIRATION DATA WAS OBTAINED FROM
Holden WASHINGTON

STATION LATITUDE	=	48.12	DEGREES
MAXIMUM LEAF AREA INDEX	=	2.00	
START OF GROWING SEASON (JULIAN DATE)	=	183	
END OF GROWING SEASON (JULIAN DATE)	=	245	
EVAPORATIVE ZONE DEPTH	=	6.0	INCHES
AVERAGE ANNUAL WIND SPEED	=	9.10	MPH
AVERAGE 1ST QUARTER RELATIVE HUMIDITY	=	89.00	%
AVERAGE 2ND QUARTER RELATIVE HUMIDITY	=	78.00	%
AVERAGE 3RD QUARTER RELATIVE HUMIDITY	=	71.00	%
AVERAGE 4TH QUARTER RELATIVE HUMIDITY	=	88.00	%

NOTE: PRECIPITATION DATA FOR Holden Washington
WAS ENTERED BY THE USER.

NOTE: TEMPERATURE DATA FOR Holden Washington
WAS ENTERED BY THE USER.

NOTE: SOLAR RADIATION DATA WAS SYNTHETICALLY GENERATED USING
COEFFICIENTS FOR STAMPEDE PASS WASHINGTON
AND STATION LATITUDE = 47.17 DEGREES

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ANNUAL TOTALS FOR YEAR 1999

	INCHES	CU. FEET	PERCENT
PRECIPITATION	38.60	3082596.750	100.00
RUNOFF	1.245	99404.195	3.22
EVAPOTRANSPIRATION	6.619	528563.187	17.15
DRAINAGE COLLECTED FROM LAYER 2	2.3730	189511.156	6.15
PERC./LEAKAGE THROUGH LAYER 3	28.363609	2265117.750	73.48
AVG. HEAD ON TOP OF LAYER 3	0.0039		
PERC./LEAKAGE THROUGH LAYER 4	25.067959	2001927.250	64.94
CHANGE IN WATER STORAGE	3.296	263191.250	8.54
SOIL WATER AT START OF YEAR	43.420	3467515.750	
SOIL WATER AT END OF YEAR	46.716	3730707.250	
SNOW WATER AT START OF YEAR	12.815	1023390.810	33.20
SNOW WATER AT END OF YEAR	12.815	1023390.810	33.20
ANNUAL WATER BUDGET BALANCE	0.0000	-0.305	0.00

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ANNUAL TOTALS FOR YEAR 1998

	INCHES	CU. FEET	PERCENT
PRECIPITATION	38.60	3082596.750	100.00
RUNOFF	1.245	99404.203	3.22
EVAPOTRANSPIRATION	6.602	527230.000	17.10
DRAINAGE COLLECTED FROM LAYER 2	2.3660	188948.484	6.13
PERC./LEAKAGE THROUGH LAYER 3	28.387342	2267013.250	73.54
AVG. HEAD ON TOP OF LAYER 3	0.0039		
PERC./LEAKAGE THROUGH LAYER 4	28.379025	2266349.000	73.52
CHANGE IN WATER STORAGE	0.008	664.119	0.02
SOIL WATER AT START OF YEAR	46.716	3730707.250	

SOIL WATER AT END OF YEAR	46.724	3731371.250	
SNOW WATER AT START OF YEAR	12.815	1023390.810	33.20
SNOW WATER AT END OF YEAR	12.815	1023390.810	33.20
ANNUAL WATER BUDGET BALANCE	0.0000	1.066	0.00

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ANNUAL TOTALS FOR YEAR 1997

	INCHES	CU. FEET	PERCENT
PRECIPITATION	38.60	3082596.750	100.00
RUNOFF	1.245	99404.211	3.22
EVAPOTRANSPIRATION	6.631	529529.437	17.18
DRAINAGE COLLECTED FROM LAYER 2	2.3705	189304.156	6.14
PERC./LEAKAGE THROUGH LAYER 3	28.354101	2264358.500	73.46
AVG. HEAD ON TOP OF LAYER 3	0.0039		
PERC./LEAKAGE THROUGH LAYER 4	28.380142	2266438.250	73.52
CHANGE IN WATER STORAGE	-0.026	-2078.875	-0.07
SOIL WATER AT START OF YEAR	46.724	3731371.250	
SOIL WATER AT END OF YEAR	46.698	3729292.500	
SNOW WATER AT START OF YEAR	12.815	1023390.810	33.20
SNOW WATER AT END OF YEAR	12.815	1023390.810	33.20
ANNUAL WATER BUDGET BALANCE	0.0000	-0.305	0.00

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ANNUAL TOTALS FOR YEAR 1996

	INCHES	CU. FEET	PERCENT
PRECIPITATION	38.60	3082596.750	100.00

RUNOFF	1.245	99404.711	3.22
EVAPOTRANSPIRATION	6.662	532016.000	17.26
DRAINAGE COLLECTED FROM LAYER 2	2.3697	189240.500	6.14
PERC./LEAKAGE THROUGH LAYER 3	28.328079	2262280.500	73.39
AVG. HEAD ON TOP OF LAYER 3	0.0039		
PERC./LEAKAGE THROUGH LAYER 4	28.358572	2264715.500	73.47
CHANGE IN WATER STORAGE	-0.035	-2781.836	-0.09
SOIL WATER AT START OF YEAR	46.698	3729292.500	
SOIL WATER AT END OF YEAR	46.667	3726856.750	
SNOW WATER AT START OF YEAR	12.815	1023390.810	33.20
SNOW WATER AT END OF YEAR	12.810	1023044.560	33.19
ANNUAL WATER BUDGET BALANCE	0.0000	1.828	0.00

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ANNUAL TOTALS FOR YEAR 1995

	INCHES	CU. FEET	PERCENT
PRECIPITATION	38.60	3082596.750	100.00
RUNOFF	1.249	99766.562	3.24
EVAPOTRANSPIRATION	6.480	517468.937	16.79
DRAINAGE COLLECTED FROM LAYER 2	2.3693	189209.562	6.14
PERC./LEAKAGE THROUGH LAYER 3	28.497425	2275804.250	73.83
AVG. HEAD ON TOP OF LAYER 3	0.0039		
PERC./LEAKAGE THROUGH LAYER 4	28.439911	2271211.250	73.68
CHANGE IN WATER STORAGE	0.062	4939.918	0.16
SOIL WATER AT START OF YEAR	46.667	3726856.750	
SOIL WATER AT END OF YEAR	46.725	3731450.500	
SNOW WATER AT START OF YEAR	12.810	1023044.560	33.19

SNOW WATER AT END OF YEAR	12.815	1023390.810	33.20
ANNUAL WATER BUDGET BALANCE	0.0000	0.609	0.00

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AVERAGE MONTHLY VALUES IN INCHES FOR YEARS 1999 THROUGH 1995

	JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
PRECIPITATION						
TOTALS	6.62	4.74	2.81	1.60	0.93	1.11
	0.76	1.11	1.62	3.41	6.50	7.39
STD. DEVIATIONS	0.00	0.00	0.00	0.00	0.00	0.00
	0.00	0.00	0.00	0.00	0.00	0.00
RUNOFF						
TOTALS	0.000	0.000	0.158	1.087	0.000	0.000
	0.000	0.000	0.000	0.000	0.000	0.000
STD. DEVIATIONS	0.000	0.000	0.010	0.010	0.000	0.000
	0.000	0.000	0.000	0.000	0.000	0.000
EVAPOTRANSPIRATION						
TOTALS	0.248	0.173	0.048	0.058	0.681	0.846
	0.915	0.952	0.999	1.008	0.375	0.295
STD. DEVIATIONS	0.042	0.000	0.002	0.013	0.048	0.049
	0.044	0.028	0.035	0.045	0.005	0.002
LATERAL DRAINAGE COLLECTED FROM LAYER 2						
TOTALS	0.0000	0.0000	0.0418	2.2721	0.0001	0.0002
	0.0001	0.0000	0.0085	0.0466	0.0003	0.0000
STD. DEVIATIONS	0.0000	0.0000	0.0049	0.0066	0.0001	0.0002
	0.0001	0.0000	0.0005	0.0039	0.0000	0.0000
PERCOLATION/LEAKAGE THROUGH LAYER 3						
TOTALS	0.0000	0.0000	3.1894	21.5762	0.0903	0.1633
	0.0988	0.0428	0.6547	2.2800	0.2907	0.0000
STD. DEVIATIONS	0.0000	0.0000	0.2004	0.2162	0.0230	0.0462

	0.0438	0.0240	0.0256	0.0284	0.0066	0.0000

PERCOLATION/LEAKAGE THROUGH LAYER 4

TOTALS	0.8988	0.7167	0.6790	3.6728	11.7084	3.3528
	1.9739	1.4125	0.9742	0.5988	0.7014	1.0357
STD. DEVIATIONS	0.3065	0.1810	0.1283	0.8816	0.3474	0.0417
	0.0407	0.0218	0.0165	0.0098	0.0060	0.0040

AVERAGES OF MONTHLY AVERAGED DAILY HEADS (INCHES)

DAILY AVERAGE HEAD ON TOP OF LAYER 3

AVERAGES	0.0000	0.0000	0.0045	0.0365	0.0001	0.0002
	0.0001	0.0001	0.0011	0.0037	0.0004	0.0000
STD. DEVIATIONS	0.0000	0.0000	0.0003	0.0003	0.0000	0.0001
	0.0001	0.0000	0.0001	0.0002	0.0000	0.0000

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AVERAGE ANNUAL TOTALS & (STD. DEVIATIONS) FOR YEARS 1999 THROUGH 1995

	INCHES	CU. FEET	PERCENT
PRECIPITATION	38.60 (0.013)	3082596.7	100.00
RUNOFF	1.246 (0.0020)	99476.77	3.227
EVAPOTRANSPIRATION	6.599 (0.0700)	526961.50	17.095
LATERAL DRAINAGE COLLECTED FROM LAYER 2	2.36968 (0.00249)	189242.797	6.13907
PERCOLATION/LEAKAGE THROUGH LAYER 3	28.38611 (0.06550)	2266915.000	73.53913
AVERAGE HEAD ON TOP OF LAYER 3	0.004 (0.000)		
PERCOLATION/LEAKAGE THROUGH LAYER 4	27.72512 (1.48570)	2214128.250	71.82672
CHANGE IN WATER STORAGE	0.661 (1.4733)	52786.92	1.712

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PEAK DAILY VALUES FOR YEARS 1999 THROUGH 1995

	(INCHES)	(CU. FT.)
PRECIPITATION	0.75	59895.000
RUNOFF	0.089	7136.9531
DRAINAGE COLLECTED FROM LAYER 2	1.28695	102776.14800
PERCOLATION/LEAKAGE THROUGH LAYER 3	1.604179	128109.75000
AVERAGE HEAD ON TOP OF LAYER 3	0.156	
MAXIMUM HEAD ON TOP OF LAYER 3	0.073	
LOCATION OF MAXIMUM HEAD IN LAYER 2 (DISTANCE FROM DRAIN)	0.0 FEET	
PERCOLATION/LEAKAGE THROUGH LAYER 4	0.988737	78960.51560
SNOW WATER	24.15	1928246.3700

MAXIMUM VEG. SOIL WATER (VOL/VOL)	0.3362
MINIMUM VEG. SOIL WATER (VOL/VOL)	0.0130

*** Maximum heads are computed using McEnroe's equations. ***

Reference: Maximum Saturated Depth over Landfill Liner
by Bruce M. McEnroe, University of Kansas
ASCE Journal of Environmental Engineering
Vol. 119, No. 2, March 1993, pp. 262-270.

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FINAL WATER STORAGE AT END OF YEAR 1995

LAYER	(INCHES)	(VOL/VOL)
1	0.1778	0.0593
2	0.1678	0.0559
3	1.3110	0.4370
4	45.0684	0.1902
SNOW WATER	12.815	

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**              HYDROLOGIC EVALUATION OF LANDFILL PERFORMANCE               **
**                HELP MODEL VERSION 3.07  (1 NOVEMBER 1997)                **
**                  DEVELOPED BY ENVIRONMENTAL LABORATORY                   **
**                     USAE WATERWAYS EXPERIMENT STATION                    **
**             FOR USEPA RISK REDUCTION ENGINEERING LABORATORY              **
**                                                                          **
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PRECIPITATION DATA FILE:      G:\CRAIG\HELP3\HOLDEN4.D4
TEMPERATURE DATA FILE:        g:\craig\help3\HOLDEN7.D7
SOLAR RADIATION DATA FILE:    g:\craig\help3\HOLDEN13.D13
EVAPOTRANSPIRATION DATA:      g:\craig\help3\HOLDEN11.D11
SOIL AND DESIGN DATA FILE:    g:\craig\help3\SCEN9P1.D10
OUTPUT DATA FILE:             G:\CRAIG\HELP3\scen9p1.OUT


TIME:  15:28      DATE:  10/ 7/1999


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    TITLE:  Holden Mine Tailings Pile 1 -  Scenario 2

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    NOTE:  INITIAL MOISTURE CONTENT OF THE LAYERS AND SNOW WATER WERE
              COMPUTED AS NEARLY STEADY-STATE VALUES BY THE PROGRAM.


                                   LAYER  1
                                   --------

                    TYPE 1 - VERTICAL PERCOLATION LAYER
                        MATERIAL TEXTURE NUMBER  21
         THICKNESS                   =       3.00   INCHES
         POROSITY                    =       0.3970 VOL/VOL
         FIELD CAPACITY              =       0.0320 VOL/VOL
         WILTING POINT               =       0.0130 VOL/VOL
         INITIAL SOIL WATER CONTENT  =       0.0584 VOL/VOL
         EFFECTIVE SAT. HYD. COND.   =  0.300000012000     CM/SEC
      NOTE:  SATURATED HYDRAULIC CONDUCTIVITY IS MULTIPLIED BY  3.00
               FOR ROOT CHANNELS IN TOP HALF OF EVAPORATIVE ZONE.
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LAYER 2

TYPE 2 - LATERAL DRAINAGE LAYER
MATERIAL TEXTURE NUMBER 21

THICKNESS	=	3.00	INCHES
POROSITY	=	0.3970	VOL/VOL
FIELD CAPACITY	=	0.0320	VOL/VOL
WILTING POINT	=	0.0130	VOL/VOL
INITIAL SOIL WATER CONTENT	=	0.0554	VOL/VOL
EFFECTIVE SAT. HYD. COND.	=	0.300000012000	CM/SEC
SLOPE	=	3.00	PERCENT
DRAINAGE LENGTH	=	20.5	FEET

LAYER 3

TYPE 3 - BARRIER SOIL LINER
MATERIAL TEXTURE NUMBER 4

THICKNESS	=	3.00	INCHES
POROSITY	=	0.4370	VOL/VOL
FIELD CAPACITY	=	0.1050	VOL/VOL
WILTING POINT	=	0.0470	VOL/VOL
INITIAL SOIL WATER CONTENT	=	0.4370	VOL/VOL
EFFECTIVE SAT. HYD. COND.	=	0.170000002000E-02	CM/SEC

LAYER 4

TYPE 1 - VERTICAL PERCOLATION LAYER
MATERIAL TEXTURE NUMBER 4

THICKNESS	=	237.00	INCHES
POROSITY	=	0.4370	VOL/VOL
FIELD CAPACITY	=	0.1050	VOL/VOL
WILTING POINT	=	0.0470	VOL/VOL
INITIAL SOIL WATER CONTENT	=	0.1326	VOL/VOL
EFFECTIVE SAT. HYD. COND.	=	0.170000002000E-02	CM/SEC

GENERAL DESIGN AND EVAPORATIVE ZONE DATA

NOTE: SCS RUNOFF CURVE NUMBER WAS COMPUTED FROM DEFAULT SOIL DATA BASE USING SOIL TEXTURE #21 WITH BARE GROUND CONDITIONS, A SURFACE SLOPE OF 3.% AND

A SLOPE LENGTH OF 600. FEET.

SCS RUNOFF CURVE NUMBER	=	68.90	
FRACTION OF AREA ALLOWING RUNOFF	=	100.0	PERCENT
AREA PROJECTED ON HORIZONTAL PLANE	=	25.000	ACRES
EVAPORATIVE ZONE DEPTH	=	6.0	INCHES
INITIAL WATER IN EVAPORATIVE ZONE	=	0.341	INCHES
UPPER LIMIT OF EVAPORATIVE STORAGE	=	2.382	INCHES
LOWER LIMIT OF EVAPORATIVE STORAGE	=	0.078	INCHES
INITIAL SNOW WATER	=	12.815	INCHES
INITIAL WATER IN LAYER MATERIALS	=	33.084	INCHES
TOTAL INITIAL WATER	=	45.899	INCHES
TOTAL SUBSURFACE INFLOW	=	0.00	INCHES/YEAR

EVAPOTRANSPIRATION AND WEATHER DATA

NOTE: EVAPOTRANSPIRATION DATA WAS OBTAINED FROM
Holden WASHINGTON

STATION LATITUDE	=	48.12	DEGREES
MAXIMUM LEAF AREA INDEX	=	2.00	
START OF GROWING SEASON (JULIAN DATE)	=	183	
END OF GROWING SEASON (JULIAN DATE)	=	245	
EVAPORATIVE ZONE DEPTH	=	6.0	INCHES
AVERAGE ANNUAL WIND SPEED	=	9.10	MPH
AVERAGE 1ST QUARTER RELATIVE HUMIDITY	=	89.00	%
AVERAGE 2ND QUARTER RELATIVE HUMIDITY	=	78.00	%
AVERAGE 3RD QUARTER RELATIVE HUMIDITY	=	71.00	%
AVERAGE 4TH QUARTER RELATIVE HUMIDITY	=	88.00	%

NOTE: PRECIPITATION DATA FOR Holden Washington
WAS ENTERED BY THE USER.

NOTE: TEMPERATURE DATA FOR Holden Washington
WAS ENTERED BY THE USER.

NOTE: SOLAR RADIATION DATA WAS SYNTHETICALLY GENERATED USING
COEFFICIENTS FOR STAMPEDE PASS WASHINGTON
AND STATION LATITUDE = 47.17 DEGREES

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ANNUAL TOTALS FOR YEAR 1999

	INCHES	CU. FEET	PERCENT
PRECIPITATION	38.60	3502951.000	100.00
RUNOFF	24.598	2232225.000	63.72
EVAPOTRANSPIRATION	6.618	600614.187	17.15
DRAINAGE COLLECTED FROM LAYER 2	0.0142	1286.411	0.04
PERC./LEAKAGE THROUGH LAYER 3	7.369965	668824.312	19.09
AVG. HEAD ON TOP OF LAYER 3	0.0018		
PERC./LEAKAGE THROUGH LAYER 4	0.023789	2158.846	0.06
CHANGE IN WATER STORAGE	7.346	666665.500	19.03
SOIL WATER AT START OF YEAR	33.084	3002382.000	
SOIL WATER AT END OF YEAR	40.430	3669047.500	
SNOW WATER AT START OF YEAR	12.815	1162944.120	33.20
SNOW WATER AT END OF YEAR	12.815	1162944.120	33.20
ANNUAL WATER BUDGET BALANCE	0.0000	0.958	0.00

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ANNUAL TOTALS FOR YEAR 1998

	INCHES	CU. FEET	PERCENT
PRECIPITATION	38.60	3502951.000	100.00
RUNOFF	24.598	2232225.000	63.72
EVAPOTRANSPIRATION	6.727	610484.937	17.43
DRAINAGE COLLECTED FROM LAYER 2	0.0139	1265.691	0.04
PERC./LEAKAGE THROUGH LAYER 3	7.261427	658974.500	18.81
AVG. HEAD ON TOP OF LAYER 3	0.0018		
PERC./LEAKAGE THROUGH LAYER 4	2.707059	245665.594	7.01
CHANGE IN WATER STORAGE	4.554	413308.469	11.80
SOIL WATER AT START OF YEAR	40.430	3669047.500	

SOIL WATER AT END OF YEAR	44.985	4082356.000	
SNOW WATER AT START OF YEAR	12.815	1162944.120	33.20
SNOW WATER AT END OF YEAR	12.815	1162944.120	33.20
ANNUAL WATER BUDGET BALANCE	0.0000	1.168	0.00

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ANNUAL TOTALS FOR YEAR 1997

	INCHES	CU. FEET	PERCENT
PRECIPITATION	38.60	3502951.000	100.00
RUNOFF	24.598	2232225.000	63.72
EVAPOTRANSPIRATION	6.653	603762.625	17.24
DRAINAGE COLLECTED FROM LAYER 2	0.0142	1291.429	0.04
PERC./LEAKAGE THROUGH LAYER 3	7.335214	665670.687	19.00
AVG. HEAD ON TOP OF LAYER 3	0.0019		
PERC./LEAKAGE THROUGH LAYER 4	6.585552	597638.812	17.06
CHANGE IN WATER STORAGE	0.750	68031.687	1.94
SOIL WATER AT START OF YEAR	44.985	4082356.000	
SOIL WATER AT END OF YEAR	45.734	4150387.500	
SNOW WATER AT START OF YEAR	12.815	1162944.120	33.20
SNOW WATER AT END OF YEAR	12.815	1162944.120	33.20
ANNUAL WATER BUDGET BALANCE	0.0000	1.298	0.00

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ANNUAL TOTALS FOR YEAR 1996

	INCHES	CU. FEET	PERCENT
PRECIPITATION	38.60	3502951.000	100.00

RUNOFF	24.598	2232254.500	63.72
EVAPOTRANSPIRATION	6.768	614212.375	17.53
DRAINAGE COLLECTED FROM LAYER 2	0.0136	1231.030	0.04
PERC./LEAKAGE THROUGH LAYER 3	7.224741	655645.187	18.72
AVG. HEAD ON TOP OF LAYER 3	0.0018		
PERC./LEAKAGE THROUGH LAYER 4	7.251146	658041.500	18.79
CHANGE IN WATER STORAGE	-0.031	-2790.068	-0.08
SOIL WATER AT START OF YEAR	45.734	4150387.500	
SOIL WATER AT END OF YEAR	45.708	4147991.000	
SNOW WATER AT START OF YEAR	12.815	1162944.120	33.20
SNOW WATER AT END OF YEAR	12.810	1162550.620	33.19
ANNUAL WATER BUDGET BALANCE	0.0000	1.471	0.00

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ANNUAL TOTALS FOR YEAR 1995

	INCHES	CU. FEET	PERCENT
PRECIPITATION	38.60	3502951.000	100.00
RUNOFF	24.688	2240449.750	63.96
EVAPOTRANSPIRATION	6.529	592527.875	16.92
DRAINAGE COLLECTED FROM LAYER 2	0.0143	1301.158	0.04
PERC./LEAKAGE THROUGH LAYER 3	7.363940	668277.562	19.08
AVG. HEAD ON TOP OF LAYER 3	0.0018		
PERC./LEAKAGE THROUGH LAYER 4	7.263532	659165.562	18.82
CHANGE IN WATER STORAGE	0.105	9504.995	0.27
SOIL WATER AT START OF YEAR	45.708	4147991.000	
SOIL WATER AT END OF YEAR	45.808	4157102.500	
SNOW WATER AT START OF YEAR	12.810	1162550.620	33.19

SNOW WATER AT END OF YEAR	12.815	1162944.120	33.20
ANNUAL WATER BUDGET BALANCE	0.0000	1.644	0.00

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AVERAGE MONTHLY VALUES IN INCHES FOR YEARS 1999 THROUGH 1995

	JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
PRECIPITATION						
TOTALS	6.62	4.74	2.81	1.60	0.93	1.11
	0.76	1.11	1.62	3.41	6.50	7.39
STD. DEVIATIONS	0.00	0.00	0.00	0.00	0.00	0.00
	0.00	0.00	0.00	0.00	0.00	0.00
RUNOFF						
TOTALS	0.000	0.000	2.913	21.703	0.000	0.000
	0.000	0.000	0.000	0.000	0.000	0.000
STD. DEVIATIONS	0.000	0.000	0.193	0.207	0.000	0.000
	0.000	0.000	0.000	0.000	0.000	0.000
EVAPOTRANSPIRATION						
TOTALS	0.248	0.173	0.048	0.058	0.703	0.898
	0.920	0.998	0.954	0.991	0.374	0.295
STD. DEVIATIONS	0.042	0.000	0.002	0.012	0.067	0.047
	0.040	0.067	0.042	0.045	0.005	0.002
LATERAL DRAINAGE COLLECTED FROM LAYER 2						
TOTALS	0.0000	0.0000	0.0000	0.0000	0.0000	0.0001
	0.0001	0.0000	0.0018	0.0119	0.0001	0.0000
STD. DEVIATIONS	0.0000	0.0000	0.0000	0.0000	0.0000	0.0001
	0.0000	0.0000	0.0002	0.0002	0.0000	0.0000
PERCOLATION/LEAKAGE THROUGH LAYER 3						
TOTALS	0.0000	0.0000	0.4721	3.2336	0.0726	0.1204
	0.0696	0.0247	0.6953	2.3481	0.2745	0.0000
STD. DEVIATIONS	0.0000	0.0000	0.0221	0.0275	0.0409	0.0537

0.0246	0.0344	0.0245	0.0121	0.0070	0.0000

PERCOLATION/LEAKAGE THROUGH LAYER 4

TOTALS	0.4590	0.3801	0.3764	0.3129	0.1569	0.5809
	0.5525	0.5029	0.4375	0.2536	0.2584	0.4952
STD. DEVIATIONS	0.4235	0.3497	0.3290	0.1999	0.1233	0.4274
	0.3490	0.3053	0.2528	0.1446	0.1573	0.2967

AVERAGES OF MONTHLY AVERAGED DAILY HEADS (INCHES)

DAILY AVERAGE HEAD ON TOP OF LAYER 3

AVERAGES	0.0000	0.0000	0.0001	0.0000	0.0004	0.0008
	0.0005	0.0001	0.0037	0.0133	0.0030	0.0000
STD. DEVIATIONS	0.0000	0.0000	0.0000	0.0000	0.0002	0.0004
	0.0001	0.0002	0.0003	0.0003	0.0001	0.0000

AVERAGE ANNUAL TOTALS & (STD. DEVIATIONS) FOR YEARS 1999 THROUGH 1995

	INCHES	CU. FEET	PERCENT
PRECIPITATION	38.60 (0.013)	3502951.0	100.00
RUNOFF	24.616 (0.0410)	2233875.75	63.771
EVAPOTRANSPIRATION	6.659 (0.0936)	604320.44	17.252
LATERAL DRAINAGE COLLECTED FROM LAYER 2	0.01405 (0.00031)	1275.144	0.03640
PERCOLATION/LEAKAGE THROUGH LAYER 3	7.31106 (0.06470)	663478.437	18.94056
AVERAGE HEAD ON TOP OF LAYER 3	0.002 (0.000)		
PERCOLATION/LEAKAGE THROUGH LAYER 4	4.76622 (3.25777)	432534.031	12.34770
CHANGE IN WATER STORAGE	2.545 (3.2750)	230944.11	6.593

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PEAK DAILY VALUES FOR YEARS 1999 THROUGH 1995

	(INCHES)	(CU. FT.)
PRECIPITATION	0.75	68062.500
RUNOFF	1.786	162067.3910
DRAINAGE COLLECTED FROM LAYER 2	0.00147	133.61839
PERCOLATION/LEAKAGE THROUGH LAYER 3	1.902861	172684.64100
AVERAGE HEAD ON TOP OF LAYER 3	0.051	
MAXIMUM HEAD ON TOP OF LAYER 3	0.001	
LOCATION OF MAXIMUM HEAD IN LAYER 2 (DISTANCE FROM DRAIN)	1.1 FEET	
PERCOLATION/LEAKAGE THROUGH LAYER 4	0.041321	3749.85889
SNOW WATER	24.15	2191189.0000
MAXIMUM VEG. SOIL WATER (VOL/VOL)		0.3362
MINIMUM VEG. SOIL WATER (VOL/VOL)		0.0130

*** Maximum heads are computed using McEnroe's equations. ***

Reference: Maximum Saturated Depth over Landfill Liner
by Bruce M. McEnroe, University of Kansas
ASCE Journal of Environmental Engineering
Vol. 119, No. 2, March 1993, pp. 262-270.

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FINAL WATER STORAGE AT END OF YEAR 1995

LAYER	(INCHES)	(VOL/VOL)
1	0.1752	0.0584
2	0.1661	0.0554
3	1.3110	0.4370
4	44.1561	0.1863
SNOW WATER	12.815	

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**              HYDROLOGIC EVALUATION OF LANDFILL PERFORMANCE               **
**                HELP MODEL VERSION 3.07  (1 NOVEMBER 1997)                **
**                  DEVELOPED BY ENVIRONMENTAL LABORATORY                   **
**                    USAE WATERWAYS EXPERIMENT STATION                     **
**             FOR USEPA RISK REDUCTION ENGINEERING LABORATORY              **
**                                                                          **
**                                                                          **
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PRECIPITATION DATA FILE:    G:\CRAIG\HELP3\HOLDEN4.D4
TEMPERATURE DATA FILE:      g:\craig\help3\HOLDEN7.D7
SOLAR RADIATION DATA FILE:  g:\craig\help3\HOLDEN13.D13
EVAPOTRANSPIRATION DATA:    g:\craig\help3\HOLDEN11.D11
SOIL AND DESIGN DATA FILE:  g:\craig\help3\SCEN9P2.D10
OUTPUT DATA FILE:           G:\CRAIG\HELP3\scen9p2.OUT


TIME:  15:29     DATE:  10/ 7/1999


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     TITLE:  Holden Mine Tailings Pile 2 -   Scenario 2

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     NOTE:  INITIAL MOISTURE CONTENT OF THE LAYERS AND SNOW WATER WERE
              COMPUTED AS NEARLY STEADY-STATE VALUES BY THE PROGRAM.


                                   LAYER  1
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                        TYPE 1 - VERTICAL PERCOLATION LAYER
                           MATERIAL TEXTURE NUMBER  21
           THICKNESS                     =      3.00   INCHES
           POROSITY                      =      0.3970 VOL/VOL
           FIELD CAPACITY                =      0.0320 VOL/VOL
           WILTING POINT                 =      0.0130 VOL/VOL
           INITIAL SOIL WATER CONTENT    =      0.0584 VOL/VOL
           EFFECTIVE SAT. HYD. COND.     =   0.300000012000     CM/SEC
         NOTE:  SATURATED HYDRAULIC CONDUCTIVITY IS MULTIPLIED BY  3.00
                  FOR ROOT CHANNELS IN TOP HALF OF EVAPORATIVE ZONE.
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LAYER 2

TYPE 2 - LATERAL DRAINAGE LAYER
MATERIAL TEXTURE NUMBER 21

THICKNESS	=	3.00	INCHES
POROSITY	=	0.3970	VOL/VOL
FIELD CAPACITY	=	0.0320	VOL/VOL
WILTING POINT	=	0.0130	VOL/VOL
INITIAL SOIL WATER CONTENT	=	0.0554	VOL/VOL
EFFECTIVE SAT. HYD. COND.	=	0.300000012000	CM/SEC
SLOPE	=	3.00	PERCENT
DRAINAGE LENGTH	=	20.5	FEET

LAYER 3

TYPE 3 - BARRIER SOIL LINER
MATERIAL TEXTURE NUMBER 4

THICKNESS	=	3.00	INCHES
POROSITY	=	0.4370	VOL/VOL
FIELD CAPACITY	=	0.1050	VOL/VOL
WILTING POINT	=	0.0470	VOL/VOL
INITIAL SOIL WATER CONTENT	=	0.4370	VOL/VOL
EFFECTIVE SAT. HYD. COND.	=	0.170000002000E-02	CM/SEC

LAYER 4

TYPE 1 - VERTICAL PERCOLATION LAYER
MATERIAL TEXTURE NUMBER 4

THICKNESS	=	237.00	INCHES
POROSITY	=	0.4370	VOL/VOL
FIELD CAPACITY	=	0.1050	VOL/VOL
WILTING POINT	=	0.0470	VOL/VOL
INITIAL SOIL WATER CONTENT	=	0.1326	VOL/VOL
EFFECTIVE SAT. HYD. COND.	=	0.170000002000E-02	CM/SEC

GENERAL DESIGN AND EVAPORATIVE ZONE DATA

NOTE: SCS RUNOFF CURVE NUMBER WAS COMPUTED FROM DEFAULT SOIL DATA BASE USING SOIL TEXTURE #21 WITH BARE GROUND CONDITIONS, A SURFACE SLOPE OF 3.% AND

A SLOPE LENGTH OF 900. FEET.

SCS RUNOFF CURVE NUMBER	=	68.10	
FRACTION OF AREA ALLOWING RUNOFF	=	100.0	PERCENT
AREA PROJECTED ON HORIZONTAL PLANE	=	45.000	ACRES
EVAPORATIVE ZONE DEPTH	=	6.0	INCHES
INITIAL WATER IN EVAPORATIVE ZONE	=	0.341	INCHES
UPPER LIMIT OF EVAPORATIVE STORAGE	=	2.382	INCHES
LOWER LIMIT OF EVAPORATIVE STORAGE	=	0.078	INCHES
INITIAL SNOW WATER	=	12.815	INCHES
INITIAL WATER IN LAYER MATERIALS	=	33.084	INCHES
TOTAL INITIAL WATER	=	45.899	INCHES
TOTAL SUBSURFACE INFLOW	=	0.00	INCHES/YEAR

EVAPOTRANSPIRATION AND WEATHER DATA

NOTE: EVAPOTRANSPIRATION DATA WAS OBTAINED FROM
Holden WASHINGTON

STATION LATITUDE	=	48.12	DEGREES
MAXIMUM LEAF AREA INDEX	=	2.00	
START OF GROWING SEASON (JULIAN DATE)	=	183	
END OF GROWING SEASON (JULIAN DATE)	=	245	
EVAPORATIVE ZONE DEPTH	=	6.0	INCHES
AVERAGE ANNUAL WIND SPEED	=	9.10	MPH
AVERAGE 1ST QUARTER RELATIVE HUMIDITY	=	89.00	%
AVERAGE 2ND QUARTER RELATIVE HUMIDITY	=	78.00	%
AVERAGE 3RD QUARTER RELATIVE HUMIDITY	=	71.00	%
AVERAGE 4TH QUARTER RELATIVE HUMIDITY	=	88.00	%

NOTE: PRECIPITATION DATA FOR Holden Washington
WAS ENTERED BY THE USER.

NOTE: TEMPERATURE DATA FOR Holden Washington
WAS ENTERED BY THE USER.

NOTE: SOLAR RADIATION DATA WAS SYNTHETICALLY GENERATED USING
COEFFICIENTS FOR STAMPEDE PASS WASHINGTON
AND STATION LATITUDE = 47.17 DEGREES

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ANNUAL TOTALS FOR YEAR 1999

	INCHES	CU. FEET	PERCENT
PRECIPITATION	38.60	6305311.500	100.00
RUNOFF	24.598	4018005.000	63.72
EVAPOTRANSPIRATION	6.618	1081105.500	17.15
DRAINAGE COLLECTED FROM LAYER 2	0.0142	2315.541	0.04
PERC./LEAKAGE THROUGH LAYER 3	7.369965	1203883.750	19.09
AVG. HEAD ON TOP OF LAYER 3	0.0018		
PERC./LEAKAGE THROUGH LAYER 4	0.023789	3885.924	0.06
CHANGE IN WATER STORAGE	7.346	1199997.870	19.03
SOIL WATER AT START OF YEAR	33.084	5404287.500	
SOIL WATER AT END OF YEAR	40.430	6604285.500	
SNOW WATER AT START OF YEAR	12.815	2093299.370	33.20
SNOW WATER AT END OF YEAR	12.815	2093299.370	33.20
ANNUAL WATER BUDGET BALANCE	0.0000	1.725	0.00

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ANNUAL TOTALS FOR YEAR 1998

	INCHES	CU. FEET	PERCENT
PRECIPITATION	38.60	6305311.500	100.00
RUNOFF	24.598	4018005.000	63.72
EVAPOTRANSPIRATION	6.727	1098872.870	17.43
DRAINAGE COLLECTED FROM LAYER 2	0.0139	2278.244	0.04
PERC./LEAKAGE THROUGH LAYER 3	7.261427	1186154.120	18.81
AVG. HEAD ON TOP OF LAYER 3	0.0018		
PERC./LEAKAGE THROUGH LAYER 4	2.707059	442198.062	7.01
CHANGE IN WATER STORAGE	4.554	743955.250	11.80
SOIL WATER AT START OF YEAR	40.430	6604285.500	

SOIL WATER AT END OF YEAR	44.985	7348240.500	
SNOW WATER AT START OF YEAR	12.815	2093299.370	33.20
SNOW WATER AT END OF YEAR	12.815	2093299.370	33.20
ANNUAL WATER BUDGET BALANCE	0.0000	2.103	0.00

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ANNUAL TOTALS FOR YEAR 1997

	INCHES	CU. FEET	PERCENT
PRECIPITATION	38.60	6305311.500	100.00
RUNOFF	24.598	4018005.000	63.72
EVAPOTRANSPIRATION	6.653	1086772.750	17.24
DRAINAGE COLLECTED FROM LAYER 2	0.0142	2324.573	0.04
PERC./LEAKAGE THROUGH LAYER 3	7.335214	1198207.250	19.00
AVG. HEAD ON TOP OF LAYER 3	0.0019		
PERC./LEAKAGE THROUGH LAYER 4	6.585552	1075749.870	17.06
CHANGE IN WATER STORAGE	0.750	122457.039	1.94
SOIL WATER AT START OF YEAR	44.985	7348240.500	
SOIL WATER AT END OF YEAR	45.734	7470697.500	
SNOW WATER AT START OF YEAR	12.815	2093299.370	33.20
SNOW WATER AT END OF YEAR	12.815	2093299.370	33.20
ANNUAL WATER BUDGET BALANCE	0.0000	2.337	0.00

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ANNUAL TOTALS FOR YEAR 1996

	INCHES	CU. FEET	PERCENT
PRECIPITATION	38.60	6305311.500	100.00

RUNOFF	24.598	4018058.250	63.72
EVAPOTRANSPIRATION	6.768	1105582.250	17.53
DRAINAGE COLLECTED FROM LAYER 2	0.0136	2215.853	0.04
PERC./LEAKAGE THROUGH LAYER 3	7.224741	1180161.370	18.72
AVG. HEAD ON TOP OF LAYER 3	0.0018		
PERC./LEAKAGE THROUGH LAYER 4	7.251146	1184474.620	18.79
CHANGE IN WATER STORAGE	-0.031	-5022.123	-0.08
SOIL WATER AT START OF YEAR	45.734	7470697.500	
SOIL WATER AT END OF YEAR	45.708	7466384.000	
SNOW WATER AT START OF YEAR	12.815	2093299.370	33.20
SNOW WATER AT END OF YEAR	12.810	2092591.120	33.19
ANNUAL WATER BUDGET BALANCE	0.0000	2.648	0.00

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ANNUAL TOTALS FOR YEAR 1995

	INCHES	CU. FEET	PERCENT
PRECIPITATION	38.60	6305311.500	100.00
RUNOFF	24.688	4032809.250	63.96
EVAPOTRANSPIRATION	6.529	1066550.250	16.92
DRAINAGE COLLECTED FROM LAYER 2	0.0143	2342.084	0.04
PERC./LEAKAGE THROUGH LAYER 3	7.363940	1202899.500	19.08
AVG. HEAD ON TOP OF LAYER 3	0.0018		
PERC./LEAKAGE THROUGH LAYER 4	7.263532	1186498.000	18.82
CHANGE IN WATER STORAGE	0.105	17108.990	0.27
SOIL WATER AT START OF YEAR	45.708	7466384.000	
SOIL WATER AT END OF YEAR	45.808	7482784.500	
SNOW WATER AT START OF YEAR	12.810	2092591.120	33.19

SNOW WATER AT END OF YEAR	12.815	2093299.370	33.20
ANNUAL WATER BUDGET BALANCE	0.0000	2.960	0.00

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AVERAGE MONTHLY VALUES IN INCHES FOR YEARS 1999 THROUGH 1995

	JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
PRECIPITATION						
TOTALS	6.62	4.74	2.81	1.60	0.93	1.11
	0.76	1.11	1.62	3.41	6.50	7.39
STD. DEVIATIONS	0.00	0.00	0.00	0.00	0.00	0.00
	0.00	0.00	0.00	0.00	0.00	0.00
RUNOFF						
TOTALS	0.000	0.000	2.913	21.703	0.000	0.000
	0.000	0.000	0.000	0.000	0.000	0.000
STD. DEVIATIONS	0.000	0.000	0.193	0.207	0.000	0.000
	0.000	0.000	0.000	0.000	0.000	0.000
EVAPOTRANSPIRATION						
TOTALS	0.248	0.173	0.048	0.058	0.703	0.898
	0.920	0.998	0.954	0.991	0.374	0.295
STD. DEVIATIONS	0.042	0.000	0.002	0.012	0.067	0.047
	0.040	0.067	0.042	0.045	0.005	0.002
LATERAL DRAINAGE COLLECTED FROM LAYER 2						
TOTALS	0.0000	0.0000	0.0000	0.0000	0.0000	0.0001
	0.0001	0.0000	0.0018	0.0119	0.0001	0.0000
STD. DEVIATIONS	0.0000	0.0000	0.0000	0.0000	0.0000	0.0001
	0.0000	0.0000	0.0002	0.0002	0.0000	0.0000
PERCOLATION/LEAKAGE THROUGH LAYER 3						
TOTALS	0.0000	0.0000	0.4721	3.2336	0.0726	0.1204
	0.0696	0.0247	0.6953	2.3481	0.2745	0.0000
STD. DEVIATIONS	0.0000	0.0000	0.0221	0.0275	0.0409	0.0537

	0.0246	0.0344	0.0245	0.0121	0.0070	0.0000

PERCOLATION/LEAKAGE THROUGH LAYER 4

TOTALS	0.4590	0.3801	0.3764	0.3129	0.1569	0.5809
	0.5525	0.5029	0.4375	0.2536	0.2584	0.4952
STD. DEVIATIONS	0.4235	0.3497	0.3290	0.1999	0.1233	0.4274
	0.3490	0.3053	0.2528	0.1446	0.1573	0.2967

AVERAGES OF MONTHLY AVERAGED DAILY HEADS (INCHES)

DAILY AVERAGE HEAD ON TOP OF LAYER 3

AVERAGES	0.0000	0.0000	0.0001	0.0000	0.0004	0.0008
	0.0005	0.0001	0.0037	0.0133	0.0030	0.0000
STD. DEVIATIONS	0.0000	0.0000	0.0000	0.0000	0.0002	0.0004
	0.0001	0.0002	0.0003	0.0003	0.0001	0.0000

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AVERAGE ANNUAL TOTALS & (STD. DEVIATIONS) FOR YEARS 1999 THROUGH 1995

	INCHES	CU. FEET	PERCENT
PRECIPITATION	38.60 (0.013)	6305311.5	100.00
RUNOFF	24.616 (0.0410)	4020976.50	63.771
EVAPOTRANSPIRATION	6.659 (0.0936)	1087776.75	17.252
LATERAL DRAINAGE COLLECTED FROM LAYER 2	0.01405 (0.00031)	2295.259	0.03640
PERCOLATION/LEAKAGE THROUGH LAYER 3	7.31106 (0.06470)	1194261.120	18.94056
AVERAGE HEAD ON TOP OF LAYER 3	0.002 (0.000)		
PERCOLATION/LEAKAGE THROUGH LAYER 4	4.76622 (3.25777)	778561.250	12.34770
CHANGE IN WATER STORAGE	2.545 (3.2750)	415699.41	6.593

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PEAK DAILY VALUES FOR YEARS 1999 THROUGH 1995

	(INCHES)	(CU. FT.)
PRECIPITATION	0.75	122512.500
RUNOFF	1.786	291721.3120
DRAINAGE COLLECTED FROM LAYER 2	0.00147	240.51311
PERCOLATION/LEAKAGE THROUGH LAYER 3	1.902861	310832.37500
AVERAGE HEAD ON TOP OF LAYER 3	0.051	
MAXIMUM HEAD ON TOP OF LAYER 3	0.001	
LOCATION OF MAXIMUM HEAD IN LAYER 2 (DISTANCE FROM DRAIN)	1.1 FEET	
PERCOLATION/LEAKAGE THROUGH LAYER 4	0.041321	6749.74609
SNOW WATER	24.15	3944140.2500

MAXIMUM VEG. SOIL WATER (VOL/VOL)	0.3362
MINIMUM VEG. SOIL WATER (VOL/VOL)	0.0130

*** Maximum heads are computed using McEnroe's equations. ***

Reference: Maximum Saturated Depth over Landfill Liner
by Bruce M. McEnroe, University of Kansas
ASCE Journal of Environmental Engineering
Vol. 119, No. 2, March 1993, pp. 262-270.

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FINAL WATER STORAGE AT END OF YEAR 1995

LAYER	(INCHES)	(VOL/VOL)
1	0.1752	0.0584
2	0.1661	0.0554
3	1.3110	0.4370
4	44.1561	0.1863
SNOW WATER	12.815	

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**              HYDROLOGIC EVALUATION OF LANDFILL PERFORMANCE               **
**                HELP MODEL VERSION 3.07  (1 NOVEMBER 1997)                **
**                 DEVELOPED BY ENVIRONMENTAL LABORATORY                    **
**                   USAE WATERWAYS EXPERIMENT STATION                      **
**            FOR USEPA RISK REDUCTION ENGINEERING LABORATORY               **
**                                                                          **
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PRECIPITATION DATA FILE:     G:\CRAIG\HELP3\HOLDEN4.D4
TEMPERATURE DATA FILE:       g:\craig\help3\HOLDEN7.D7
SOLAR RADIATION DATA FILE:   g:\craig\help3\HOLDEN13.D13
EVAPOTRANSPIRATION DATA:     g:\craig\help3\HOLDEN11.D11
SOIL AND DESIGN DATA FILE:   g:\craig\help3\SCEN9P3.D10
OUTPUT DATA FILE:            G:\CRAIG\HELP3\scen9p3.OUT


TIME:  15:29      DATE:  10/ 7/1999


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    TITLE:  Holden Mine Tailings Pile 3 - Scenario 2

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    NOTE:  INITIAL MOISTURE CONTENT OF THE LAYERS AND SNOW WATER WERE
             COMPUTED AS NEARLY STEADY-STATE VALUES BY THE PROGRAM.


                                   LAYER  1
                                   --------

                       TYPE 1 - VERTICAL PERCOLATION LAYER
                          MATERIAL TEXTURE NUMBER  21
           THICKNESS                    =        3.00    INCHES
           POROSITY                     =        0.3970 VOL/VOL
           FIELD CAPACITY               =        0.0320 VOL/VOL
           WILTING POINT                =        0.0130 VOL/VOL
           INITIAL SOIL WATER CONTENT   =        0.0584 VOL/VOL
           EFFECTIVE SAT. HYD. COND.    =   0.300000012000     CM/SEC
         NOTE:  SATURATED HYDRAULIC CONDUCTIVITY IS MULTIPLIED BY  3.00
                  FOR ROOT CHANNELS IN TOP HALF OF EVAPORATIVE ZONE.
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LAYER 2

TYPE 2 - LATERAL DRAINAGE LAYER
MATERIAL TEXTURE NUMBER 21

THICKNESS	=	3.00	INCHES
POROSITY	=	0.3970	VOL/VOL
FIELD CAPACITY	=	0.0320	VOL/VOL
WILTING POINT	=	0.0130	VOL/VOL
INITIAL SOIL WATER CONTENT	=	0.0554	VOL/VOL
EFFECTIVE SAT. HYD. COND.	=	0.300000012000	CM/SEC
SLOPE	=	3.00	PERCENT
DRAINAGE LENGTH	=	20.5	FEET

LAYER 3

TYPE 3 - BARRIER SOIL LINER
MATERIAL TEXTURE NUMBER 4

THICKNESS	=	3.00	INCHES
POROSITY	=	0.4370	VOL/VOL
FIELD CAPACITY	=	0.1050	VOL/VOL
WILTING POINT	=	0.0470	VOL/VOL
INITIAL SOIL WATER CONTENT	=	0.4370	VOL/VOL
EFFECTIVE SAT. HYD. COND.	=	0.170000002000E-02	CM/SEC

LAYER 4

TYPE 1 - VERTICAL PERCOLATION LAYER
MATERIAL TEXTURE NUMBER 4

THICKNESS	=	237.00	INCHES
POROSITY	=	0.4370	VOL/VOL
FIELD CAPACITY	=	0.1050	VOL/VOL
WILTING POINT	=	0.0470	VOL/VOL
INITIAL SOIL WATER CONTENT	=	0.1326	VOL/VOL
EFFECTIVE SAT. HYD. COND.	=	0.170000002000E-02	CM/SEC

GENERAL DESIGN AND EVAPORATIVE ZONE DATA

NOTE: SCS RUNOFF CURVE NUMBER WAS COMPUTED FROM DEFAULT SOIL DATA BASE USING SOIL TEXTURE #21 WITH BARE GROUND CONDITIONS, A SURFACE SLOPE OF 3.% AND

A SLOPE LENGTH OF 650. FEET.

SCS RUNOFF CURVE NUMBER	=	68.70	
FRACTION OF AREA ALLOWING RUNOFF	=	100.0	PERCENT
AREA PROJECTED ON HORIZONTAL PLANE	=	22.000	ACRES
EVAPORATIVE ZONE DEPTH	=	6.0	INCHES
INITIAL WATER IN EVAPORATIVE ZONE	=	0.341	INCHES
UPPER LIMIT OF EVAPORATIVE STORAGE	=	2.382	INCHES
LOWER LIMIT OF EVAPORATIVE STORAGE	=	0.078	INCHES
INITIAL SNOW WATER	=	12.815	INCHES
INITIAL WATER IN LAYER MATERIALS	=	33.084	INCHES
TOTAL INITIAL WATER	=	45.899	INCHES
TOTAL SUBSURFACE INFLOW	=	0.00	INCHES/YEAR

EVAPOTRANSPIRATION AND WEATHER DATA

NOTE: EVAPOTRANSPIRATION DATA WAS OBTAINED FROM
Holden WASHINGTON

STATION LATITUDE	=	48.12	DEGREES
MAXIMUM LEAF AREA INDEX	=	2.00	
START OF GROWING SEASON (JULIAN DATE)	=	183	
END OF GROWING SEASON (JULIAN DATE)	=	245	
EVAPORATIVE ZONE DEPTH	=	6.0	INCHES
AVERAGE ANNUAL WIND SPEED	=	9.10	MPH
AVERAGE 1ST QUARTER RELATIVE HUMIDITY	=	89.00	%
AVERAGE 2ND QUARTER RELATIVE HUMIDITY	=	78.00	%
AVERAGE 3RD QUARTER RELATIVE HUMIDITY	=	71.00	%
AVERAGE 4TH QUARTER RELATIVE HUMIDITY	=	88.00	%

NOTE: PRECIPITATION DATA FOR Holden Washington
WAS ENTERED BY THE USER.

NOTE: TEMPERATURE DATA FOR Holden Washington
WAS ENTERED BY THE USER.

NOTE: SOLAR RADIATION DATA WAS SYNTHETICALLY GENERATED USING
COEFFICIENTS FOR STAMPEDE PASS WASHINGTON
AND STATION LATITUDE = 47.17 DEGREES

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ANNUAL TOTALS FOR YEAR 1999

	INCHES	CU. FEET	PERCENT
PRECIPITATION	38.60	3082596.750	100.00
RUNOFF	24.598	1964358.000	63.72
EVAPOTRANSPIRATION	6.618	528540.500	17.15
DRAINAGE COLLECTED FROM LAYER 2	0.0142	1132.042	0.04
PERC./LEAKAGE THROUGH LAYER 3	7.369965	588565.375	19.09
AVG. HEAD ON TOP OF LAYER 3	0.0018		
PERC./LEAKAGE THROUGH LAYER 4	0.023789	1899.785	0.06
CHANGE IN WATER STORAGE	7.346	586665.625	19.03
SOIL WATER AT START OF YEAR	33.084	2642096.250	
SOIL WATER AT END OF YEAR	40.430	3228761.750	
SNOW WATER AT START OF YEAR	12.815	1023390.810	33.20
SNOW WATER AT END OF YEAR	12.815	1023390.810	33.20
ANNUAL WATER BUDGET BALANCE	0.0000	0.843	0.00

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ANNUAL TOTALS FOR YEAR 1998

	INCHES	CU. FEET	PERCENT
PRECIPITATION	38.60	3082596.750	100.00
RUNOFF	24.598	1964358.000	63.72
EVAPOTRANSPIRATION	6.727	537226.750	17.43
DRAINAGE COLLECTED FROM LAYER 2	0.0139	1113.808	0.04
PERC./LEAKAGE THROUGH LAYER 3	7.261427	579897.562	18.81
AVG. HEAD ON TOP OF LAYER 3	0.0018		
PERC./LEAKAGE THROUGH LAYER 4	2.707059	216185.719	7.01
CHANGE IN WATER STORAGE	4.554	363711.437	11.80
SOIL WATER AT START OF YEAR	40.430	3228761.750	

SOIL WATER AT END OF YEAR	44.985	3592473.250	
SNOW WATER AT START OF YEAR	12.815	1023390.810	33.20
SNOW WATER AT END OF YEAR	12.815	1023390.810	33.20
ANNUAL WATER BUDGET BALANCE	0.0000	1.028	0.00

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ANNUAL TOTALS FOR YEAR 1997

	INCHES	CU. FEET	PERCENT
PRECIPITATION	38.60	3082596.750	100.00
RUNOFF	24.598	1964358.000	63.72
EVAPOTRANSPIRATION	6.653	531311.125	17.24
DRAINAGE COLLECTED FROM LAYER 2	0.0142	1136.458	0.04
PERC./LEAKAGE THROUGH LAYER 3	7.335214	585790.187	19.00
AVG. HEAD ON TOP OF LAYER 3	0.0019		
PERC./LEAKAGE THROUGH LAYER 4	6.585552	525922.187	17.06
CHANGE IN WATER STORAGE	0.750	59867.887	1.94
SOIL WATER AT START OF YEAR	44.985	3592473.250	
SOIL WATER AT END OF YEAR	45.734	3652341.000	
SNOW WATER AT START OF YEAR	12.815	1023390.810	33.20
SNOW WATER AT END OF YEAR	12.815	1023390.810	33.20
ANNUAL WATER BUDGET BALANCE	0.0000	1.142	0.00

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ANNUAL TOTALS FOR YEAR 1996

	INCHES	CU. FEET	PERCENT
PRECIPITATION	38.60	3082596.750	100.00

RUNOFF	24.598	1964384.000	63.72
EVAPOTRANSPIRATION	6.768	540506.875	17.53
DRAINAGE COLLECTED FROM LAYER 2	0.0136	1083.306	0.04
PERC./LEAKAGE THROUGH LAYER 3	7.224741	576967.750	18.72
AVG. HEAD ON TOP OF LAYER 3	0.0018		
PERC./LEAKAGE THROUGH LAYER 4	7.251146	579076.500	18.79
CHANGE IN WATER STORAGE	-0.031	-2455.260	-0.08
SOIL WATER AT START OF YEAR	45.734	3652341.000	
SOIL WATER AT END OF YEAR	45.708	3650232.000	
SNOW WATER AT START OF YEAR	12.815	1023390.810	33.20
SNOW WATER AT END OF YEAR	12.810	1023044.560	33.19
ANNUAL WATER BUDGET BALANCE	0.0000	1.295	0.00

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ANNUAL TOTALS FOR YEAR 1995

	INCHES	CU. FEET	PERCENT
PRECIPITATION	38.60	3082596.750	100.00
RUNOFF	24.688	1971595.750	63.96
EVAPOTRANSPIRATION	6.529	521424.531	16.92
DRAINAGE COLLECTED FROM LAYER 2	0.0143	1145.019	0.04
PERC./LEAKAGE THROUGH LAYER 3	7.363940	588084.250	19.08
AVG. HEAD ON TOP OF LAYER 3	0.0018		
PERC./LEAKAGE THROUGH LAYER 4	7.263532	580065.687	18.82
CHANGE IN WATER STORAGE	0.105	8364.396	0.27
SOIL WATER AT START OF YEAR	45.708	3650232.000	
SOIL WATER AT END OF YEAR	45.808	3658250.250	
SNOW WATER AT START OF YEAR	12.810	1023044.560	33.19

SNOW WATER AT END OF YEAR	12.815	1023390.810	33.20
ANNUAL WATER BUDGET BALANCE	0.0000	1.447	0.00

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AVERAGE MONTHLY VALUES IN INCHES FOR YEARS 1999 THROUGH 1995

	JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
PRECIPITATION						
TOTALS	6.62	4.74	2.81	1.60	0.93	1.11
	0.76	1.11	1.62	3.41	6.50	7.39
STD. DEVIATIONS	0.00	0.00	0.00	0.00	0.00	0.00
	0.00	0.00	0.00	0.00	0.00	0.00
RUNOFF						
TOTALS	0.000	0.000	2.913	21.703	0.000	0.000
	0.000	0.000	0.000	0.000	0.000	0.000
STD. DEVIATIONS	0.000	0.000	0.193	0.207	0.000	0.000
	0.000	0.000	0.000	0.000	0.000	0.000
EVAPOTRANSPIRATION						
TOTALS	0.248	0.173	0.048	0.058	0.703	0.898
	0.920	0.998	0.954	0.991	0.374	0.295
STD. DEVIATIONS	0.042	0.000	0.002	0.012	0.067	0.047
	0.040	0.067	0.042	0.045	0.005	0.002
LATERAL DRAINAGE COLLECTED FROM LAYER 2						
TOTALS	0.0000	0.0000	0.0000	0.0000	0.0000	0.0001
	0.0001	0.0000	0.0018	0.0119	0.0001	0.0000
STD. DEVIATIONS	0.0000	0.0000	0.0000	0.0000	0.0000	0.0001
	0.0000	0.0000	0.0002	0.0002	0.0000	0.0000
PERCOLATION/LEAKAGE THROUGH LAYER 3						
TOTALS	0.0000	0.0000	0.4721	3.2336	0.0726	0.1204
	0.0696	0.0247	0.6953	2.3481	0.2745	0.0000
STD. DEVIATIONS	0.0000	0.0000	0.0221	0.0275	0.0409	0.0537

0.0246	0.0344	0.0245	0.0121	0.0070	0.0000

PERCOLATION/LEAKAGE THROUGH LAYER 4

TOTALS	0.4590	0.3801	0.3764	0.3129	0.1569	0.5809
	0.5525	0.5029	0.4375	0.2536	0.2584	0.4952
STD. DEVIATIONS	0.4235	0.3497	0.3290	0.1999	0.1233	0.4274
	0.3490	0.3053	0.2528	0.1446	0.1573	0.2967

AVERAGES OF MONTHLY AVERAGED DAILY HEADS (INCHES)

DAILY AVERAGE HEAD ON TOP OF LAYER 3

AVERAGES	0.0000	0.0000	0.0001	0.0000	0.0004	0.0008
	0.0005	0.0001	0.0037	0.0133	0.0030	0.0000
STD. DEVIATIONS	0.0000	0.0000	0.0000	0.0000	0.0002	0.0004
	0.0001	0.0002	0.0003	0.0003	0.0001	0.0000

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AVERAGE ANNUAL TOTALS & (STD. DEVIATIONS) FOR YEARS 1999 THROUGH 1995

	INCHES	CU. FEET	PERCENT
PRECIPITATION	38.60 (0.013)	3082596.7	100.00
RUNOFF	24.616 (0.0410)	1965810.75	63.771
EVAPOTRANSPIRATION	6.659 (0.0936)	531802.00	17.252
LATERAL DRAINAGE COLLECTED FROM LAYER 2	0.01405 (0.00031)	1122.126	0.03640
PERCOLATION/LEAKAGE THROUGH LAYER 3	7.31106 (0.06470)	583861.000	18.94056
AVERAGE HEAD ON TOP OF LAYER 3	0.002 (0.000)		
PERCOLATION/LEAKAGE THROUGH LAYER 4	4.76622 (3.25777)	380629.969	12.34770
CHANGE IN WATER STORAGE	2.545 (3.2750)	203230.81	6.593

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PEAK DAILY VALUES FOR YEARS 1999 THROUGH 1995

	(INCHES)	(CU. FT.)
PRECIPITATION	0.75	59895.000
RUNOFF	1.786	142619.3120
DRAINAGE COLLECTED FROM LAYER 2	0.00147	117.58418
PERCOLATION/LEAKAGE THROUGH LAYER 3	1.902861	151962.48400
AVERAGE HEAD ON TOP OF LAYER 3	0.051	
MAXIMUM HEAD ON TOP OF LAYER 3	0.001	
LOCATION OF MAXIMUM HEAD IN LAYER 2 (DISTANCE FROM DRAIN)	1.1 FEET	
PERCOLATION/LEAKAGE THROUGH LAYER 4	0.041321	3299.87598
SNOW WATER	24.15	1928246.3700

MAXIMUM VEG. SOIL WATER (VOL/VOL) 0.3362

MINIMUM VEG. SOIL WATER (VOL/VOL) 0.0130

*** Maximum heads are computed using McEnroe's equations. ***

Reference: Maximum Saturated Depth over Landfill Liner
by Bruce M. McEnroe, University of Kansas
ASCE Journal of Environmental Engineering
Vol. 119, No. 2, March 1993, pp. 262-270.

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FINAL WATER STORAGE AT END OF YEAR 1995

LAYER	(INCHES)	(VOL/VOL)
1	0.1752	0.0584
2	0.1661	0.0554
3	1.3110	0.4370
4	44.1561	0.1863
SNOW WATER	12.815	

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**              HYDROLOGIC EVALUATION OF LANDFILL PERFORMANCE               **
**                HELP MODEL VERSION 3.07   (1 NOVEMBER 1997)               **
**                  DEVELOPED BY ENVIRONMENTAL LABORATORY                   **
**                    USAE WATERWAYS EXPERIMENT STATION                     **
**             FOR USEPA RISK REDUCTION ENGINEERING LABORATORY              **
**                                                                          **
**                                                                          **
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PRECIPITATION DATA FILE:     G:\CRAIG\HELP3\HOLDEN4.D4
TEMPERATURE DATA FILE:       g:\craig\help3\HOLDEN7.D7
SOLAR RADIATION DATA FILE:   g:\craig\help3\HOLDEN13.D13
EVAPOTRANSPIRATION DATA:     g:\craig\help3\HOLDEN11.D11
SOIL AND DESIGN DATA FILE:   g:\craig\help3\SCEN11P1.D10
OUTPUT DATA FILE:            G:\CRAIG\HELP3\scen11p1.OUT


TIME:  15:31      DATE:  10/ 7/1999


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     TITLE:  Holden Mine Tailings Pile 1 -  Scenario 3

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     NOTE:  INITIAL MOISTURE CONTENT OF THE LAYERS AND SNOW WATER WERE
              COMPUTED AS NEARLY STEADY-STATE VALUES BY THE PROGRAM.


                                  LAYER  1
                                  --------

                     TYPE 1 - VERTICAL PERCOLATION LAYER
                         MATERIAL TEXTURE NUMBER   4
           THICKNESS                   =      6.00   INCHES
           POROSITY                    =      0.4370 VOL/VOL
           FIELD CAPACITY              =      0.1050 VOL/VOL
           WILTING POINT               =      0.0470 VOL/VOL
           INITIAL SOIL WATER CONTENT  =      0.1760 VOL/VOL
           EFFECTIVE SAT. HYD. COND.   =  0.170000002000E-02 CM/SEC
         NOTE:  SATURATED HYDRAULIC CONDUCTIVITY IS MULTIPLIED BY  3.00
                  FOR ROOT CHANNELS IN TOP HALF OF EVAPORATIVE ZONE.
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LAYER 2

TYPE 2 - LATERAL DRAINAGE LAYER
MATERIAL TEXTURE NUMBER 4

THICKNESS	=	6.00	INCHES
POROSITY	=	0.4370	VOL/VOL
FIELD CAPACITY	=	0.1050	VOL/VOL
WILTING POINT	=	0.0470	VOL/VOL
INITIAL SOIL WATER CONTENT	=	0.1333	VOL/VOL
EFFECTIVE SAT. HYD. COND.	=	0.170000002000E-02	CM/SEC
SLOPE	=	3.00	PERCENT
DRAINAGE LENGTH	=	20.0	FEET

LAYER 3

TYPE 3 - BARRIER SOIL LINER
MATERIAL TEXTURE NUMBER 4

THICKNESS	=	3.00	INCHES
POROSITY	=	0.4370	VOL/VOL
FIELD CAPACITY	=	0.1050	VOL/VOL
WILTING POINT	=	0.0470	VOL/VOL
INITIAL SOIL WATER CONTENT	=	0.4370	VOL/VOL
EFFECTIVE SAT. HYD. COND.	=	0.170000002000E-02	CM/SEC

LAYER 4

TYPE 1 - VERTICAL PERCOLATION LAYER
MATERIAL TEXTURE NUMBER 4

THICKNESS	=	225.00	INCHES
POROSITY	=	0.4370	VOL/VOL
FIELD CAPACITY	=	0.1050	VOL/VOL
WILTING POINT	=	0.0470	VOL/VOL
INITIAL SOIL WATER CONTENT	=	0.1256	VOL/VOL
EFFECTIVE SAT. HYD. COND.	=	0.170000002000E-02	CM/SEC

GENERAL DESIGN AND EVAPORATIVE ZONE DATA

NOTE: SCS RUNOFF CURVE NUMBER WAS COMPUTED FROM DEFAULT SOIL DATA BASE USING SOIL TEXTURE # 4 WITH A GOOD STAND OF GRASS, A SURFACE SLOPE OF 3.%

AND A SLOPE LENGTH OF 600. FEET.

SCS RUNOFF CURVE NUMBER	=	47.00	
FRACTION OF AREA ALLOWING RUNOFF	=	100.0	PERCENT
AREA PROJECTED ON HORIZONTAL PLANE	=	25.000	ACRES
EVAPORATIVE ZONE DEPTH	=	8.0	INCHES
INITIAL WATER IN EVAPORATIVE ZONE	=	1.436	INCHES
UPPER LIMIT OF EVAPORATIVE STORAGE	=	3.496	INCHES
LOWER LIMIT OF EVAPORATIVE STORAGE	=	0.376	INCHES
INITIAL SNOW WATER	=	12.815	INCHES
INITIAL WATER IN LAYER MATERIALS	=	31.417	INCHES
TOTAL INITIAL WATER	=	44.232	INCHES
TOTAL SUBSURFACE INFLOW	=	0.00	INCHES/YEAR

EVAPOTRANSPIRATION AND WEATHER DATA

NOTE: EVAPOTRANSPIRATION DATA WAS OBTAINED FROM
Holden WASHINGTON

STATION LATITUDE	=	48.12	DEGREES
MAXIMUM LEAF AREA INDEX	=	2.00	
START OF GROWING SEASON (JULIAN DATE)	=	183	
END OF GROWING SEASON (JULIAN DATE)	=	245	
EVAPORATIVE ZONE DEPTH	=	8.0	INCHES
AVERAGE ANNUAL WIND SPEED	=	9.10	MPH
AVERAGE 1ST QUARTER RELATIVE HUMIDITY	=	89.00	%
AVERAGE 2ND QUARTER RELATIVE HUMIDITY	=	78.00	%
AVERAGE 3RD QUARTER RELATIVE HUMIDITY	=	71.00	%
AVERAGE 4TH QUARTER RELATIVE HUMIDITY	=	88.00	%

NOTE: PRECIPITATION DATA FOR Holden Washington
WAS ENTERED BY THE USER.

NOTE: TEMPERATURE DATA FOR Holden Washington
WAS ENTERED BY THE USER.

NOTE: SOLAR RADIATION DATA WAS SYNTHETICALLY GENERATED USING
COEFFICIENTS FOR STAMPEDE PASS WASHINGTON
AND STATION LATITUDE = 47.17 DEGREES

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ANNUAL TOTALS FOR YEAR 1999

	INCHES	CU. FEET	PERCENT
PRECIPITATION	38.60	3502951.000	100.00
RUNOFF	26.023	2361560.750	67.42
EVAPOTRANSPIRATION	7.892	716208.000	20.45
DRAINAGE COLLECTED FROM LAYER 2	0.0011	101.348	0.00
PERC./LEAKAGE THROUGH LAYER 3	4.684089	425081.094	12.13
AVG. HEAD ON TOP OF LAYER 3	0.0053		
PERC./LEAKAGE THROUGH LAYER 4	0.010172	923.125	0.03
CHANGE IN WATER STORAGE	4.674	424156.469	12.11
SOIL WATER AT START OF YEAR	31.417	2851128.500	
SOIL WATER AT END OF YEAR	36.091	3275284.750	
SNOW WATER AT START OF YEAR	12.815	1162944.120	33.20
SNOW WATER AT END OF YEAR	12.815	1162944.120	33.20
ANNUAL WATER BUDGET BALANCE	0.0000	1.097	0.00

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ANNUAL TOTALS FOR YEAR 1998

	INCHES	CU. FEET	PERCENT
PRECIPITATION	38.60	3502951.000	100.00
RUNOFF	26.008	2360257.500	67.38
EVAPOTRANSPIRATION	7.963	722627.437	20.63
DRAINAGE COLLECTED FROM LAYER 2	0.0011	102.851	0.00
PERC./LEAKAGE THROUGH LAYER 3	4.627700	419963.750	11.99
AVG. HEAD ON TOP OF LAYER 3	0.0052		
PERC./LEAKAGE THROUGH LAYER 4	0.213152	19343.535	0.55
CHANGE IN WATER STORAGE	4.415	400618.406	11.44
SOIL WATER AT START OF YEAR	36.091	3275284.750	

SOIL WATER AT END OF YEAR	40.506	3675903.250	
SNOW WATER AT START OF YEAR	12.815	1162944.120	33.20
SNOW WATER AT END OF YEAR	12.815	1162944.120	33.20
ANNUAL WATER BUDGET BALANCE	0.0000	1.222	0.00

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ANNUAL TOTALS FOR YEAR 1997

	INCHES	CU. FEET	PERCENT
PRECIPITATION	38.60	3502951.000	100.00
RUNOFF	26.031	2362301.250	67.44
EVAPOTRANSPIRATION	8.036	729264.250	20.82
DRAINAGE COLLECTED FROM LAYER 2	0.0011	99.992	0.00
PERC./LEAKAGE THROUGH LAYER 3	4.532089	411287.062	11.74
AVG. HEAD ON TOP OF LAYER 3	0.0049		
PERC./LEAKAGE THROUGH LAYER 4	2.588862	234939.250	6.71
CHANGE IN WATER STORAGE	1.943	176344.984	5.03
SOIL WATER AT START OF YEAR	40.506	3675903.250	
SOIL WATER AT END OF YEAR	42.449	3852248.250	
SNOW WATER AT START OF YEAR	12.815	1162944.120	33.20
SNOW WATER AT END OF YEAR	12.815	1162944.120	33.20
ANNUAL WATER BUDGET BALANCE	0.0000	1.125	0.00

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ANNUAL TOTALS FOR YEAR 1996

	INCHES	CU. FEET	PERCENT
PRECIPITATION	38.60	3502951.000	100.00

RUNOFF	26.021	2361390.250	67.41
EVAPOTRANSPIRATION	7.873	714454.187	20.40
DRAINAGE COLLECTED FROM LAYER 2	0.0011	101.821	0.00
PERC./LEAKAGE THROUGH LAYER 3	4.709552	427391.812	12.20
AVG. HEAD ON TOP OF LAYER 3	0.0055		
PERC./LEAKAGE THROUGH LAYER 4	4.056828	368157.156	10.51
CHANGE IN WATER STORAGE	0.648	58846.570	1.68
SOIL WATER AT START OF YEAR	42.449	3852248.250	
SOIL WATER AT END OF YEAR	43.102	3911488.250	
SNOW WATER AT START OF YEAR	12.815	1162944.120	33.20
SNOW WATER AT END OF YEAR	12.810	1162550.620	33.19
ANNUAL WATER BUDGET BALANCE	0.0000	0.995	0.00

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ANNUAL TOTALS FOR YEAR 1995

	INCHES	CU. FEET	PERCENT
PRECIPITATION	38.60	3502951.000	100.00
RUNOFF	26.132	2371486.750	67.70
EVAPOTRANSPIRATION	7.817	709375.437	20.25
DRAINAGE COLLECTED FROM LAYER 2	0.0011	102.931	0.00
PERC./LEAKAGE THROUGH LAYER 3	4.645619	421589.906	12.04
AVG. HEAD ON TOP OF LAYER 3	0.0053		
PERC./LEAKAGE THROUGH LAYER 4	4.558258	413661.875	11.81
CHANGE IN WATER STORAGE	0.092	8322.085	0.24
SOIL WATER AT START OF YEAR	43.102	3911488.250	
SOIL WATER AT END OF YEAR	43.189	3919417.000	
SNOW WATER AT START OF YEAR	12.810	1162550.620	33.19

SNOW WATER AT END OF YEAR	12.815	1162944.120	33.20
ANNUAL WATER BUDGET BALANCE	0.0000	1.774	0.00

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AVERAGE MONTHLY VALUES IN INCHES FOR YEARS 1999 THROUGH 1995

	JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
PRECIPITATION						
TOTALS	6.62	4.74	2.81	1.60	0.93	1.11
	0.76	1.11	1.62	3.41	6.50	7.39
STD. DEVIATIONS	0.00	0.00	0.00	0.00	0.00	0.00
	0.00	0.00	0.00	0.00	0.00	0.00
RUNOFF						
TOTALS	0.000	0.000	3.139	22.904	0.000	0.000
	0.000	0.000	0.000	0.000	0.000	0.000
STD. DEVIATIONS	0.000	0.000	0.207	0.225	0.000	0.000
	0.000	0.000	0.000	0.000	0.000	0.000
EVAPOTRANSPIRATION						
TOTALS	0.248	0.173	0.048	0.267	0.989	0.873
	1.129	1.020	1.439	1.064	0.373	0.295
STD. DEVIATIONS	0.042	0.000	0.002	0.073	0.058	0.063
	0.109	0.051	0.026	0.042	0.004	0.002
LATERAL DRAINAGE COLLECTED FROM LAYER 2						
TOTALS	0.0000	0.0000	0.0000	0.0010	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0001	0.0000	0.0000
STD. DEVIATIONS	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
PERCOLATION/LEAKAGE THROUGH LAYER 3						
TOTALS	0.0000	0.0000	0.0000	2.3714	0.1082	0.0180
	0.0201	0.0224	0.0154	1.8121	0.2724	0.0000
STD. DEVIATIONS	0.0000	0.0000	0.0000	0.0074	0.0177	0.0062

0.0057	0.0109	0.0058	0.0626	0.0124	0.0000

PERCOLATION/LEAKAGE THROUGH LAYER 4

TOTALS	0.1698	0.1909	0.2086	0.1990	0.1128	0.1869
	0.2644	0.2642	0.2256	0.2479	0.1217	0.0938
STD. DEVIATIONS	0.2164	0.1996	0.2053	0.1919	0.1011	0.1971
	0.2511	0.2455	0.2084	0.1976	0.0722	0.0843

AVERAGES OF MONTHLY AVERAGED DAILY HEADS (INCHES)

DAILY AVERAGE HEAD ON TOP OF LAYER 3

AVERAGES	0.0000	0.0000	0.0000	0.0353	0.0014	0.0003
	0.0003	0.0003	0.0003	0.0216	0.0035	0.0000
STD. DEVIATIONS	0.0000	0.0000	0.0000	0.0019	0.0003	0.0001
	0.0001	0.0002	0.0001	0.0017	0.0002	0.0000

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AVERAGE ANNUAL TOTALS & (STD. DEVIATIONS) FOR YEARS 1999 THROUGH 1995

	INCHES		CU. FEET	PERCENT
PRECIPITATION	38.60	(0.013)	3502951.0	100.00
RUNOFF	26.043	(0.0521)	2363399.00	67.469
EVAPOTRANSPIRATION	7.916	(0.0849)	718385.87	20.508
LATERAL DRAINAGE COLLECTED FROM LAYER 2	0.00112	(0.00001)	101.789	0.00291
PERCOLATION/LEAKAGE THROUGH LAYER 3	4.63981	(0.06823)	421062.719	12.02023
AVERAGE HEAD ON TOP OF LAYER 3	0.005	(0.000)		
PERCOLATION/LEAKAGE THROUGH LAYER 4	2.28545	(2.11346)	207404.969	5.92086
CHANGE IN WATER STORAGE	2.354	(2.1109)	213657.70	6.099

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PEAK DAILY VALUES FOR YEARS 1999 THROUGH 1995

	(INCHES)	(CU. FT.)
PRECIPITATION	0.75	68062.500
RUNOFF	1.834	166461.7500
DRAINAGE COLLECTED FROM LAYER 2	0.00106	96.23346
PERCOLATION/LEAKAGE THROUGH LAYER 3	2.330393	211483.12500
AVERAGE HEAD ON TOP OF LAYER 3	1.082	
MAXIMUM HEAD ON TOP OF LAYER 3	0.138	
LOCATION OF MAXIMUM HEAD IN LAYER 2 (DISTANCE FROM DRAIN)	1.2 FEET	
PERCOLATION/LEAKAGE THROUGH LAYER 4	0.024047	2182.26001
SNOW WATER	24.15	2191189.0000

MAXIMUM VEG. SOIL WATER (VOL/VOL) 0.4363

MINIMUM VEG. SOIL WATER (VOL/VOL) 0.0470

*** Maximum heads are computed using McEnroe's equations. ***

Reference: Maximum Saturated Depth over Landfill Liner
by Bruce M. McEnroe, University of Kansas
ASCE Journal of Environmental Engineering
Vol. 119, No. 2, March 1993, pp. 262-270.

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FINAL WATER STORAGE AT END OF YEAR 1995

LAYER	(INCHES)	(VOL/VOL)
1	1.0561	0.1760
2	0.7999	0.1333
3	1.3110	0.4370
4	40.0222	0.1779
SNOW WATER	12.815	

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**              HYDROLOGIC EVALUATION OF LANDFILL PERFORMANCE               **
**                HELP MODEL VERSION 3.07  (1 NOVEMBER 1997)                **
**                  DEVELOPED BY ENVIRONMENTAL LABORATORY                   **
**                    USAE WATERWAYS EXPERIMENT STATION                     **
**              FOR USEPA RISK REDUCTION ENGINEERING LABORATORY             **
**                                                                          **
**                                                                          **
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PRECIPITATION DATA FILE:     G:\CRAIG\HELP3\HOLDEN4.D4
TEMPERATURE DATA FILE:       g:\craig\help3\HOLDEN7.D7
SOLAR RADIATION DATA FILE:   g:\craig\help3\HOLDEN13.D13
EVAPOTRANSPIRATION DATA:     g:\craig\help3\HOLDEN11.D11
SOIL AND DESIGN DATA FILE:   g:\craig\help3\SCEN11P2.D10
OUTPUT DATA FILE:            G:\CRAIG\HELP3\scen11p2.OUT


TIME:  15:31     DATE:  10/ 7/1999


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     TITLE:  Holden Mine Tailings Pile 2 -   Scenario 3

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     NOTE:  INITIAL MOISTURE CONTENT OF THE LAYERS AND SNOW WATER WERE
              COMPUTED AS NEARLY STEADY-STATE VALUES BY THE PROGRAM.


                                   LAYER  1
                                   --------

                       TYPE 1 - VERTICAL PERCOLATION LAYER
                           MATERIAL TEXTURE NUMBER   4
           THICKNESS                    =       6.00   INCHES
           POROSITY                     =       0.4370 VOL/VOL
           FIELD CAPACITY               =       0.1050 VOL/VOL
           WILTING POINT                =       0.0470 VOL/VOL
           INITIAL SOIL WATER CONTENT   =       0.1760 VOL/VOL
           EFFECTIVE SAT. HYD. COND.    =   0.170000002000E-02 CM/SEC
         NOTE:  SATURATED HYDRAULIC CONDUCTIVITY IS MULTIPLIED BY  3.00
                  FOR ROOT CHANNELS IN TOP HALF OF EVAPORATIVE ZONE.
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LAYER 2

TYPE 2 - LATERAL DRAINAGE LAYER
MATERIAL TEXTURE NUMBER 4

THICKNESS	=	6.00	INCHES
POROSITY	=	0.4370	VOL/VOL
FIELD CAPACITY	=	0.1050	VOL/VOL
WILTING POINT	=	0.0470	VOL/VOL
INITIAL SOIL WATER CONTENT	=	0.1333	VOL/VOL
EFFECTIVE SAT. HYD. COND.	=	0.170000002000E-02	CM/SEC
SLOPE	=	3.00	PERCENT
DRAINAGE LENGTH	=	20.0	FEET

LAYER 3

TYPE 3 - BARRIER SOIL LINER
MATERIAL TEXTURE NUMBER 4

THICKNESS	=	3.00	INCHES
POROSITY	=	0.4370	VOL/VOL
FIELD CAPACITY	=	0.1050	VOL/VOL
WILTING POINT	=	0.0470	VOL/VOL
INITIAL SOIL WATER CONTENT	=	0.4370	VOL/VOL
EFFECTIVE SAT. HYD. COND.	=	0.170000002000E-02	CM/SEC

LAYER 4

TYPE 1 - VERTICAL PERCOLATION LAYER
MATERIAL TEXTURE NUMBER 4

THICKNESS	=	225.00	INCHES
POROSITY	=	0.4370	VOL/VOL
FIELD CAPACITY	=	0.1050	VOL/VOL
WILTING POINT	=	0.0470	VOL/VOL
INITIAL SOIL WATER CONTENT	=	0.1256	VOL/VOL
EFFECTIVE SAT. HYD. COND.	=	0.170000002000E-02	CM/SEC

GENERAL DESIGN AND EVAPORATIVE ZONE DATA

NOTE: SCS RUNOFF CURVE NUMBER WAS COMPUTED FROM DEFAULT
SOIL DATA BASE USING SOIL TEXTURE # 4 WITH A
GOOD STAND OF GRASS, A SURFACE SLOPE OF 3.%

AND A SLOPE LENGTH OF 900. FEET.

SCS RUNOFF CURVE NUMBER	=	45.20	
FRACTION OF AREA ALLOWING RUNOFF	=	100.0	PERCENT
AREA PROJECTED ON HORIZONTAL PLANE	=	45.000	ACRES
EVAPORATIVE ZONE DEPTH	=	8.0	INCHES
INITIAL WATER IN EVAPORATIVE ZONE	=	1.436	INCHES
UPPER LIMIT OF EVAPORATIVE STORAGE	=	3.496	INCHES
LOWER LIMIT OF EVAPORATIVE STORAGE	=	0.376	INCHES
INITIAL SNOW WATER	=	12.815	INCHES
INITIAL WATER IN LAYER MATERIALS	=	31.417	INCHES
TOTAL INITIAL WATER	=	44.232	INCHES
TOTAL SUBSURFACE INFLOW	=	0.00	INCHES/YEAR

EVAPOTRANSPIRATION AND WEATHER DATA

NOTE: EVAPOTRANSPIRATION DATA WAS OBTAINED FROM
Holden WASHINGTON

STATION LATITUDE	=	48.12	DEGREES
MAXIMUM LEAF AREA INDEX	=	2.00	
START OF GROWING SEASON (JULIAN DATE)	=	183	
END OF GROWING SEASON (JULIAN DATE)	=	245	
EVAPORATIVE ZONE DEPTH	=	8.0	INCHES
AVERAGE ANNUAL WIND SPEED	=	9.10	MPH
AVERAGE 1ST QUARTER RELATIVE HUMIDITY	=	89.00	%
AVERAGE 2ND QUARTER RELATIVE HUMIDITY	=	78.00	%
AVERAGE 3RD QUARTER RELATIVE HUMIDITY	=	71.00	%
AVERAGE 4TH QUARTER RELATIVE HUMIDITY	=	88.00	%

NOTE: PRECIPITATION DATA FOR Holden Washington
WAS ENTERED BY THE USER.

NOTE: TEMPERATURE DATA FOR Holden Washington
WAS ENTERED BY THE USER.

NOTE: SOLAR RADIATION DATA WAS SYNTHETICALLY GENERATED USING
COEFFICIENTS FOR STAMPEDE PASS WASHINGTON
AND STATION LATITUDE = 47.17 DEGREES

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ANNUAL TOTALS FOR YEAR 1999

	INCHES	CU. FEET	PERCENT
PRECIPITATION	38.60	6305311.500	100.00
RUNOFF	26.023	4250809.500	67.42
EVAPOTRANSPIRATION	7.892	1289174.370	20.45
DRAINAGE COLLECTED FROM LAYER 2	0.0011	182.426	0.00
PERC./LEAKAGE THROUGH LAYER 3	4.684089	765145.937	12.13
AVG. HEAD ON TOP OF LAYER 3	0.0053		
PERC./LEAKAGE THROUGH LAYER 4	0.010172	1661.624	0.03
CHANGE IN WATER STORAGE	4.674	763481.687	12.11
SOIL WATER AT START OF YEAR	31.417	5132031.000	
SOIL WATER AT END OF YEAR	36.091	5895513.000	
SNOW WATER AT START OF YEAR	12.815	2093299.370	33.20
SNOW WATER AT END OF YEAR	12.815	2093299.370	33.20
ANNUAL WATER BUDGET BALANCE	0.0000	1.975	0.00

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ANNUAL TOTALS FOR YEAR 1998

	INCHES	CU. FEET	PERCENT
PRECIPITATION	38.60	6305311.500	100.00
RUNOFF	26.008	4248463.500	67.38
EVAPOTRANSPIRATION	7.963	1300729.370	20.63
DRAINAGE COLLECTED FROM LAYER 2	0.0011	185.132	0.00
PERC./LEAKAGE THROUGH LAYER 3	4.627700	755934.750	11.99
AVG. HEAD ON TOP OF LAYER 3	0.0052		
PERC./LEAKAGE THROUGH LAYER 4	0.213152	34818.363	0.55
CHANGE IN WATER STORAGE	4.415	721113.125	11.44
SOIL WATER AT START OF YEAR	36.091	5895513.000	

SOIL WATER AT END OF YEAR	40.506	6616626.000	
SNOW WATER AT START OF YEAR	12.815	2093299.370	33.20
SNOW WATER AT END OF YEAR	12.815	2093299.370	33.20
ANNUAL WATER BUDGET BALANCE	0.0000	2.200	0.00

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ANNUAL TOTALS FOR YEAR 1997

	INCHES	CU. FEET	PERCENT
PRECIPITATION	38.60	6305311.500	100.00
RUNOFF	26.031	4252142.500	67.44
EVAPOTRANSPIRATION	8.036	1312675.620	20.82
DRAINAGE COLLECTED FROM LAYER 2	0.0011	179.986	0.00
PERC./LEAKAGE THROUGH LAYER 3	4.532089	740316.687	11.74
AVG. HEAD ON TOP OF LAYER 3	0.0049		
PERC./LEAKAGE THROUGH LAYER 4	2.588862	422890.625	6.71
CHANGE IN WATER STORAGE	1.943	317420.969	5.03
SOIL WATER AT START OF YEAR	40.506	6616626.000	
SOIL WATER AT END OF YEAR	42.449	6934047.000	
SNOW WATER AT START OF YEAR	12.815	2093299.370	33.20
SNOW WATER AT END OF YEAR	12.815	2093299.370	33.20
ANNUAL WATER BUDGET BALANCE	0.0000	2.025	0.00

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ANNUAL TOTALS FOR YEAR 1996

	INCHES	CU. FEET	PERCENT
PRECIPITATION	38.60	6305311.500	100.00

RUNOFF	26.021	4250502.500	67.41
EVAPOTRANSPIRATION	7.873	1286017.620	20.40
DRAINAGE COLLECTED FROM LAYER 2	0.0011	183.278	0.00
PERC./LEAKAGE THROUGH LAYER 3	4.709552	769305.312	12.20
AVG. HEAD ON TOP OF LAYER 3	0.0055		
PERC./LEAKAGE THROUGH LAYER 4	4.056828	662682.875	10.51
CHANGE IN WATER STORAGE	0.648	105923.820	1.68
SOIL WATER AT START OF YEAR	42.449	6934047.000	
SOIL WATER AT END OF YEAR	43.102	7040679.000	
SNOW WATER AT START OF YEAR	12.815	2093299.370	33.20
SNOW WATER AT END OF YEAR	12.810	2092591.120	33.19
ANNUAL WATER BUDGET BALANCE	0.0000	1.792	0.00

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ANNUAL TOTALS FOR YEAR 1995

	INCHES	CU. FEET	PERCENT
PRECIPITATION	38.60	6305311.500	100.00
RUNOFF	26.132	4268676.000	67.70
EVAPOTRANSPIRATION	7.817	1276875.750	20.25
DRAINAGE COLLECTED FROM LAYER 2	0.0011	185.276	0.00
PERC./LEAKAGE THROUGH LAYER 3	4.645619	758861.875	12.04
AVG. HEAD ON TOP OF LAYER 3	0.0053		
PERC./LEAKAGE THROUGH LAYER 4	4.558258	744591.375	11.81
CHANGE IN WATER STORAGE	0.092	14979.753	0.24
SOIL WATER AT START OF YEAR	43.102	7040679.000	
SOIL WATER AT END OF YEAR	43.189	7054950.500	
SNOW WATER AT START OF YEAR	12.810	2092591.120	33.19

SNOW WATER AT END OF YEAR	12.815	2093299.370	33.20
ANNUAL WATER BUDGET BALANCE	0.0000	3.194	0.00

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AVERAGE MONTHLY VALUES IN INCHES FOR YEARS 1999 THROUGH 1995

	JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
PRECIPITATION						
TOTALS	6.62	4.74	2.81	1.60	0.93	1.11
	0.76	1.11	1.62	3.41	6.50	7.39
STD. DEVIATIONS	0.00	0.00	0.00	0.00	0.00	0.00
	0.00	0.00	0.00	0.00	0.00	0.00
RUNOFF						
TOTALS	0.000	0.000	3.139	22.904	0.000	0.000
	0.000	0.000	0.000	0.000	0.000	0.000
STD. DEVIATIONS	0.000	0.000	0.207	0.225	0.000	0.000
	0.000	0.000	0.000	0.000	0.000	0.000
EVAPOTRANSPIRATION						
TOTALS	0.248	0.173	0.048	0.267	0.989	0.873
	1.129	1.020	1.439	1.064	0.373	0.295
STD. DEVIATIONS	0.042	0.000	0.002	0.073	0.058	0.063
	0.109	0.051	0.026	0.042	0.004	0.002
LATERAL DRAINAGE COLLECTED FROM LAYER 2						
TOTALS	0.0000	0.0000	0.0000	0.0010	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0001	0.0000	0.0000
STD. DEVIATIONS	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
PERCOLATION/LEAKAGE THROUGH LAYER 3						
TOTALS	0.0000	0.0000	0.0000	2.3714	0.1082	0.0180
	0.0201	0.0224	0.0154	1.8121	0.2724	0.0000
STD. DEVIATIONS	0.0000	0.0000	0.0000	0.0074	0.0177	0.0062

	0.0057	0.0109	0.0058	0.0626	0.0124	0.0000

PERCOLATION/LEAKAGE THROUGH LAYER 4

TOTALS	0.1698	0.1909	0.2086	0.1990	0.1128	0.1869
	0.2644	0.2642	0.2256	0.2479	0.1217	0.0938
STD. DEVIATIONS	0.2164	0.1996	0.2053	0.1919	0.1011	0.1971
	0.2511	0.2455	0.2084	0.1976	0.0722	0.0843

AVERAGES OF MONTHLY AVERAGED DAILY HEADS (INCHES)

DAILY AVERAGE HEAD ON TOP OF LAYER 3

AVERAGES	0.0000	0.0000	0.0000	0.0353	0.0014	0.0003
	0.0003	0.0003	0.0003	0.0216	0.0035	0.0000
STD. DEVIATIONS	0.0000	0.0000	0.0000	0.0019	0.0003	0.0001
	0.0001	0.0002	0.0001	0.0017	0.0002	0.0000

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AVERAGE ANNUAL TOTALS & (STD. DEVIATIONS) FOR YEARS 1999 THROUGH 1995

	INCHES	CU. FEET	PERCENT
PRECIPITATION	38.60 (0.013)	6305311.5	100.00
RUNOFF	26.043 (0.0521)	4254118.50	67.469
EVAPOTRANSPIRATION	7.916 (0.0849)	1293094.62	20.508
LATERAL DRAINAGE COLLECTED FROM LAYER 2	0.00112 (0.00001)	183.220	0.00291
PERCOLATION/LEAKAGE THROUGH LAYER 3	4.63981 (0.06823)	757912.875	12.02023
AVERAGE HEAD ON TOP OF LAYER 3	0.005 (0.000)		
PERCOLATION/LEAKAGE THROUGH LAYER 4	2.28545 (2.11346)	373328.969	5.92086
CHANGE IN WATER STORAGE	2.354 (2.1109)	384583.87	6.099

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PEAK DAILY VALUES FOR YEARS 1999 THROUGH 1995

	(INCHES)	(CU. FT.)
PRECIPITATION	0.75	122512.500
RUNOFF	1.834	299631.1560
DRAINAGE COLLECTED FROM LAYER 2	0.00106	173.22023
PERCOLATION/LEAKAGE THROUGH LAYER 3	2.330393	380669.62500
AVERAGE HEAD ON TOP OF LAYER 3	1.082	
MAXIMUM HEAD ON TOP OF LAYER 3	0.138	
LOCATION OF MAXIMUM HEAD IN LAYER 2 (DISTANCE FROM DRAIN)	1.2 FEET	
PERCOLATION/LEAKAGE THROUGH LAYER 4	0.024047	3928.06812
SNOW WATER	24.15	3944140.2500
MAXIMUM VEG. SOIL WATER (VOL/VOL)		0.4363
MINIMUM VEG. SOIL WATER (VOL/VOL)		0.0470

*** Maximum heads are computed using McEnroe's equations. ***

Reference: Maximum Saturated Depth over Landfill Liner
by Bruce M. McEnroe, University of Kansas
ASCE Journal of Environmental Engineering
Vol. 119, No. 2, March 1993, pp. 262-270.

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FINAL WATER STORAGE AT END OF YEAR 1995

LAYER	(INCHES)	(VOL/VOL)
1	1.0561	0.1760
2	0.7999	0.1333
3	1.3110	0.4370
4	40.0222	0.1779
SNOW WATER	12.815	

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**              HYDROLOGIC EVALUATION OF LANDFILL PERFORMANCE               **
**                HELP MODEL VERSION 3.07  (1 NOVEMBER 1997)                **
**                 DEVELOPED BY ENVIRONMENTAL LABORATORY                    **
**                   USAE WATERWAYS EXPERIMENT STATION                      **
**             FOR USEPA RISK REDUCTION ENGINEERING LABORATORY              **
**                                                                          **
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PRECIPITATION DATA FILE:      G:\CRAIG\HELP3\HOLDEN4.D4
TEMPERATURE DATA FILE:        g:\craig\help3\HOLDEN7.D7
SOLAR RADIATION DATA FILE:    g:\craig\help3\HOLDEN13.D13
EVAPOTRANSPIRATION DATA:      g:\craig\help3\HOLDEN11.D11
SOIL AND DESIGN DATA FILE:    g:\craig\help3\SCEN11P3.D10
OUTPUT DATA FILE:             G:\CRAIG\HELP3\scen11p3.OUT


TIME:  15:31     DATE:  10/ 7/1999


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     TITLE:  Holden Mine Tailings Pile 3 -   Scenario 3

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     NOTE:  INITIAL MOISTURE CONTENT OF THE LAYERS AND SNOW WATER WERE
              COMPUTED AS NEARLY STEADY-STATE VALUES BY THE PROGRAM.


                                  LAYER  1
                                  --------

                      TYPE 1 - VERTICAL PERCOLATION LAYER
                          MATERIAL TEXTURE NUMBER   4
           THICKNESS                    =       6.00    INCHES
           POROSITY                     =       0.4370 VOL/VOL
           FIELD CAPACITY               =       0.1050 VOL/VOL
           WILTING POINT                =       0.0470 VOL/VOL
           INITIAL SOIL WATER CONTENT   =       0.1760 VOL/VOL
           EFFECTIVE SAT. HYD. COND.    =   0.170000002000E-02 CM/SEC
         NOTE:  SATURATED HYDRAULIC CONDUCTIVITY IS MULTIPLIED BY  3.00
                  FOR ROOT CHANNELS IN TOP HALF OF EVAPORATIVE ZONE.
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LAYER 2

TYPE 2 - LATERAL DRAINAGE LAYER
MATERIAL TEXTURE NUMBER 4

THICKNESS	=	6.00 INCHES
POROSITY	=	0.4370 VOL/VOL
FIELD CAPACITY	=	0.1050 VOL/VOL
WILTING POINT	=	0.0470 VOL/VOL
INITIAL SOIL WATER CONTENT	=	0.1333 VOL/VOL
EFFECTIVE SAT. HYD. COND.	=	0.170000002000E-02 CM/SEC
SLOPE	=	3.00 PERCENT
DRAINAGE LENGTH	=	20.0 FEET

LAYER 3

TYPE 3 - BARRIER SOIL LINER
MATERIAL TEXTURE NUMBER 4

THICKNESS	=	3.00 INCHES
POROSITY	=	0.4370 VOL/VOL
FIELD CAPACITY	=	0.1050 VOL/VOL
WILTING POINT	=	0.0470 VOL/VOL
INITIAL SOIL WATER CONTENT	=	0.4370 VOL/VOL
EFFECTIVE SAT. HYD. COND.	=	0.170000002000E-02 CM/SEC

LAYER 4

TYPE 1 - VERTICAL PERCOLATION LAYER
MATERIAL TEXTURE NUMBER 4

THICKNESS	=	225.00 INCHES
POROSITY	=	0.4370 VOL/VOL
FIELD CAPACITY	=	0.1050 VOL/VOL
WILTING POINT	=	0.0470 VOL/VOL
INITIAL SOIL WATER CONTENT	=	0.1256 VOL/VOL
EFFECTIVE SAT. HYD. COND.	=	0.170000002000E-02 CM/SEC

GENERAL DESIGN AND EVAPORATIVE ZONE DATA

NOTE: SCS RUNOFF CURVE NUMBER WAS COMPUTED FROM DEFAULT SOIL DATA BASE USING SOIL TEXTURE # 4 WITH A GOOD STAND OF GRASS, A SURFACE SLOPE OF 3.%

AND A SLOPE LENGTH OF 650. FEET.

SCS RUNOFF CURVE NUMBER	=	46.60	
FRACTION OF AREA ALLOWING RUNOFF	=	100.0	PERCENT
AREA PROJECTED ON HORIZONTAL PLANE	=	22.000	ACRES
EVAPORATIVE ZONE DEPTH	=	8.0	INCHES
INITIAL WATER IN EVAPORATIVE ZONE	=	1.436	INCHES
UPPER LIMIT OF EVAPORATIVE STORAGE	=	3.496	INCHES
LOWER LIMIT OF EVAPORATIVE STORAGE	=	0.376	INCHES
INITIAL SNOW WATER	=	12.815	INCHES
INITIAL WATER IN LAYER MATERIALS	=	31.417	INCHES
TOTAL INITIAL WATER	=	44.232	INCHES
TOTAL SUBSURFACE INFLOW	=	0.00	INCHES/YEAR

EVAPOTRANSPIRATION AND WEATHER DATA

NOTE: EVAPOTRANSPIRATION DATA WAS OBTAINED FROM
Holden WASHINGTON

STATION LATITUDE	=	48.12	DEGREES
MAXIMUM LEAF AREA INDEX	=	2.00	
START OF GROWING SEASON (JULIAN DATE)	=	183	
END OF GROWING SEASON (JULIAN DATE)	=	245	
EVAPORATIVE ZONE DEPTH	=	8.0	INCHES
AVERAGE ANNUAL WIND SPEED	=	9.10	MPH
AVERAGE 1ST QUARTER RELATIVE HUMIDITY	=	89.00	%
AVERAGE 2ND QUARTER RELATIVE HUMIDITY	=	78.00	%
AVERAGE 3RD QUARTER RELATIVE HUMIDITY	=	71.00	%
AVERAGE 4TH QUARTER RELATIVE HUMIDITY	=	88.00	%

NOTE: PRECIPITATION DATA FOR Holden Washington
WAS ENTERED BY THE USER.

NOTE: TEMPERATURE DATA FOR Holden Washington
WAS ENTERED BY THE USER.

NOTE: SOLAR RADIATION DATA WAS SYNTHETICALLY GENERATED USING
COEFFICIENTS FOR STAMPEDE PASS WASHINGTON
AND STATION LATITUDE = 47.17 DEGREES

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ANNUAL TOTALS FOR YEAR 1999

	INCHES	CU. FEET	PERCENT
PRECIPITATION	38.60	3082596.750	100.00
RUNOFF	26.023	2078173.500	67.42
EVAPOTRANSPIRATION	7.892	630263.062	20.45
DRAINAGE COLLECTED FROM LAYER 2	0.0011	89.186	0.00
PERC./LEAKAGE THROUGH LAYER 3	4.684089	374071.375	12.13
AVG. HEAD ON TOP OF LAYER 3	0.0053		
PERC./LEAKAGE THROUGH LAYER 4	0.010172	812.350	0.03
CHANGE IN WATER STORAGE	4.674	373257.687	12.11
SOIL WATER AT START OF YEAR	31.417	2508993.000	
SOIL WATER AT END OF YEAR	36.091	2882250.750	
SNOW WATER AT START OF YEAR	12.815	1023390.810	33.20
SNOW WATER AT END OF YEAR	12.815	1023390.810	33.20
ANNUAL WATER BUDGET BALANCE	0.0000	0.966	0.00

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ANNUAL TOTALS FOR YEAR 1998

	INCHES	CU. FEET	PERCENT
PRECIPITATION	38.60	3082596.750	100.00
RUNOFF	26.008	2077026.500	67.38
EVAPOTRANSPIRATION	7.963	635912.125	20.63
DRAINAGE COLLECTED FROM LAYER 2	0.0011	90.509	0.00
PERC./LEAKAGE THROUGH LAYER 3	4.627700	369568.125	11.99
AVG. HEAD ON TOP OF LAYER 3	0.0052		
PERC./LEAKAGE THROUGH LAYER 4	0.213152	17022.311	0.55
CHANGE IN WATER STORAGE	4.415	352544.187	11.44
SOIL WATER AT START OF YEAR	36.091	2882250.750	

SOIL WATER AT END OF YEAR	40.506	3234795.000	
SNOW WATER AT START OF YEAR	12.815	1023390.810	33.20
SNOW WATER AT END OF YEAR	12.815	1023390.810	33.20
ANNUAL WATER BUDGET BALANCE	0.0000	1.076	0.00

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ANNUAL TOTALS FOR YEAR 1997

	INCHES	CU. FEET	PERCENT
PRECIPITATION	38.60	3082596.750	100.00
RUNOFF	26.031	2078825.120	67.44
EVAPOTRANSPIRATION	8.036	641752.562	20.82
DRAINAGE COLLECTED FROM LAYER 2	0.0011	87.993	0.00
PERC./LEAKAGE THROUGH LAYER 3	4.532089	361932.594	11.74
AVG. HEAD ON TOP OF LAYER 3	0.0049		
PERC./LEAKAGE THROUGH LAYER 4	2.588862	206746.531	6.71
CHANGE IN WATER STORAGE	1.943	155183.578	5.03
SOIL WATER AT START OF YEAR	40.506	3234795.000	
SOIL WATER AT END OF YEAR	42.449	3389978.500	
SNOW WATER AT START OF YEAR	12.815	1023390.810	33.20
SNOW WATER AT END OF YEAR	12.815	1023390.810	33.20
ANNUAL WATER BUDGET BALANCE	0.0000	0.990	0.00

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ANNUAL TOTALS FOR YEAR 1996

	INCHES	CU. FEET	PERCENT
PRECIPITATION	38.60	3082596.750	100.00

RUNOFF	26.021	2078023.370	67.41
EVAPOTRANSPIRATION	7.873	628719.687	20.40
DRAINAGE COLLECTED FROM LAYER 2	0.0011	89.602	0.00
PERC./LEAKAGE THROUGH LAYER 3	4.709552	376104.812	12.20
AVG. HEAD ON TOP OF LAYER 3	0.0055		
PERC./LEAKAGE THROUGH LAYER 4	4.056828	323978.281	10.51
CHANGE IN WATER STORAGE	0.648	51784.980	1.68
SOIL WATER AT START OF YEAR	42.449	3389978.500	
SOIL WATER AT END OF YEAR	43.102	3442109.750	
SNOW WATER AT START OF YEAR	12.815	1023390.810	33.20
SNOW WATER AT END OF YEAR	12.810	1023044.560	33.19
ANNUAL WATER BUDGET BALANCE	0.0000	0.876	0.00

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ANNUAL TOTALS FOR YEAR 1995

	INCHES	CU. FEET	PERCENT
PRECIPITATION	38.60	3082596.750	100.00
RUNOFF	26.132	2086908.370	67.70
EVAPOTRANSPIRATION	7.817	624250.375	20.25
DRAINAGE COLLECTED FROM LAYER 2	0.0011	90.580	0.00
PERC./LEAKAGE THROUGH LAYER 3	4.645619	370999.125	12.04
AVG. HEAD ON TOP OF LAYER 3	0.0053		
PERC./LEAKAGE THROUGH LAYER 4	4.558258	364022.437	11.81
CHANGE IN WATER STORAGE	0.092	7323.435	0.24
SOIL WATER AT START OF YEAR	43.102	3442109.750	
SOIL WATER AT END OF YEAR	43.189	3449087.000	
SNOW WATER AT START OF YEAR	12.810	1023044.560	33.19

SNOW WATER AT END OF YEAR	12.815	1023390.810	33.20
ANNUAL WATER BUDGET BALANCE	0.0000	1.561	0.00

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AVERAGE MONTHLY VALUES IN INCHES FOR YEARS 1999 THROUGH 1995

	JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
PRECIPITATION						
TOTALS	6.62	4.74	2.81	1.60	0.93	1.11
	0.76	1.11	1.62	3.41	6.50	7.39
STD. DEVIATIONS	0.00	0.00	0.00	0.00	0.00	0.00
	0.00	0.00	0.00	0.00	0.00	0.00
RUNOFF						
TOTALS	0.000	0.000	3.139	22.904	0.000	0.000
	0.000	0.000	0.000	0.000	0.000	0.000
STD. DEVIATIONS	0.000	0.000	0.207	0.225	0.000	0.000
	0.000	0.000	0.000	0.000	0.000	0.000
EVAPOTRANSPIRATION						
TOTALS	0.248	0.173	0.048	0.267	0.989	0.873
	1.129	1.020	1.439	1.064	0.373	0.295
STD. DEVIATIONS	0.042	0.000	0.002	0.073	0.058	0.063
	0.109	0.051	0.026	0.042	0.004	0.002
LATERAL DRAINAGE COLLECTED FROM LAYER 2						
TOTALS	0.0000	0.0000	0.0000	0.0010	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0001	0.0000	0.0000
STD. DEVIATIONS	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
PERCOLATION/LEAKAGE THROUGH LAYER 3						
TOTALS	0.0000	0.0000	0.0000	2.3714	0.1082	0.0180
	0.0201	0.0224	0.0154	1.8121	0.2724	0.0000
STD. DEVIATIONS	0.0000	0.0000	0.0000	0.0074	0.0177	0.0062

	0.0057	0.0109	0.0058	0.0626	0.0124	0.0000

PERCOLATION/LEAKAGE THROUGH LAYER 4

TOTALS	0.1698	0.1909	0.2086	0.1990	0.1128	0.1869
	0.2644	0.2642	0.2256	0.2479	0.1217	0.0938
STD. DEVIATIONS	0.2164	0.1996	0.2053	0.1919	0.1011	0.1971
	0.2511	0.2455	0.2084	0.1976	0.0722	0.0843

AVERAGES OF MONTHLY AVERAGED DAILY HEADS (INCHES)

DAILY AVERAGE HEAD ON TOP OF LAYER 3

AVERAGES	0.0000	0.0000	0.0000	0.0353	0.0014	0.0003
	0.0003	0.0003	0.0003	0.0216	0.0035	0.0000
STD. DEVIATIONS	0.0000	0.0000	0.0000	0.0019	0.0003	0.0001
	0.0001	0.0002	0.0001	0.0017	0.0002	0.0000

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AVERAGE ANNUAL TOTALS & (STD. DEVIATIONS) FOR YEARS 1999 THROUGH 1995

	INCHES	CU. FEET	PERCENT
PRECIPITATION	38.60 (0.013)	3082596.7	100.00
RUNOFF	26.043 (0.0521)	2079791.12	67.469
EVAPOTRANSPIRATION	7.916 (0.0849)	632179.62	20.508
LATERAL DRAINAGE COLLECTED FROM LAYER 2	0.00112 (0.00001)	89.574	0.00291
PERCOLATION/LEAKAGE THROUGH LAYER 3	4.63981 (0.06823)	370535.187	12.02023
AVERAGE HEAD ON TOP OF LAYER 3	0.005 (0.000)		
PERCOLATION/LEAKAGE THROUGH LAYER 4	2.28545 (2.11346)	182516.375	5.92086
CHANGE IN WATER STORAGE	2.354 (2.1109)	188018.78	6.099

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PEAK DAILY VALUES FOR YEARS 1999 THROUGH 1995

	(INCHES)	(CU. FT.)
PRECIPITATION	0.75	59895.000
RUNOFF	1.834	146486.3440
DRAINAGE COLLECTED FROM LAYER 2	0.00106	84.68545
PERCOLATION/LEAKAGE THROUGH LAYER 3	2.330393	186105.15600
AVERAGE HEAD ON TOP OF LAYER 3	1.082	
MAXIMUM HEAD ON TOP OF LAYER 3	0.138	
LOCATION OF MAXIMUM HEAD IN LAYER 2 (DISTANCE FROM DRAIN)	1.2 FEET	
PERCOLATION/LEAKAGE THROUGH LAYER 4	0.024047	1920.38879
SNOW WATER	24.15	1928246.3700

MAXIMUM VEG. SOIL WATER (VOL/VOL) 0.4363

MINIMUM VEG. SOIL WATER (VOL/VOL) 0.0470

*** Maximum heads are computed using McEnroe's equations. ***

Reference: Maximum Saturated Depth over Landfill Liner
by Bruce M. McEnroe, University of Kansas
ASCE Journal of Environmental Engineering
Vol. 119, No. 2, March 1993, pp. 262-270.

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FINAL WATER STORAGE AT END OF YEAR 1995

LAYER	(INCHES)	(VOL/VOL)
1	1.0561	0.1760
2	0.7999	0.1333
3	1.3110	0.4370
4	40.0222	0.1779
SNOW WATER	12.815	

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**              HYDROLOGIC EVALUATION OF LANDFILL PERFORMANCE               **
**                HELP MODEL VERSION 3.07  (1 NOVEMBER 1997)                **
**                  DEVELOPED BY ENVIRONMENTAL LABORATORY                   **
**                    USAE WATERWAYS EXPERIMENT STATION                     **
**             FOR USEPA RISK REDUCTION ENGINEERING LABORATORY              **
**                                                                          **
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PRECIPITATION DATA FILE:     G:\CRAIG\HELP3\HOLDEN4.D4
TEMPERATURE DATA FILE:       g:\craig\help3\HOLDEN7.D7
SOLAR RADIATION DATA FILE:   g:\craig\help3\HOLDEN13.D13
EVAPOTRANSPIRATION DATA:     g:\craig\help3\HOLDEN11.D11
SOIL AND DESIGN DATA FILE:   g:\craig\help3\SCEN12P1.D10
OUTPUT DATA FILE:            G:\CRAIG\HELP3\scen12p1.OUT


TIME:  10:12     DATE:  10/ 6/1999


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     TITLE:  Holden Mine Tailings Pile 1 -    Scenario 4

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     NOTE:  INITIAL MOISTURE CONTENT OF THE LAYERS AND SNOW WATER WERE
              COMPUTED AS NEARLY STEADY-STATE VALUES BY THE PROGRAM.


                                 LAYER  1
                                 --------

                      TYPE 1 - VERTICAL PERCOLATION LAYER
                          MATERIAL TEXTURE NUMBER  21
           THICKNESS                   =       6.00   INCHES
           POROSITY                    =       0.3970 VOL/VOL
           FIELD CAPACITY              =       0.0320 VOL/VOL
           WILTING POINT               =       0.0130 VOL/VOL
           INITIAL SOIL WATER CONTENT  =       0.0635 VOL/VOL
           EFFECTIVE SAT. HYD. COND.   =  0.300000012000      CM/SEC
         NOTE:  SATURATED HYDRAULIC CONDUCTIVITY IS MULTIPLIED BY  3.00
                  FOR ROOT CHANNELS IN TOP HALF OF EVAPORATIVE ZONE.
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LAYER 2

TYPE 2 - LATERAL DRAINAGE LAYER
MATERIAL TEXTURE NUMBER 4

THICKNESS	=	24.00 INCHES
POROSITY	=	0.4370 VOL/VOL
FIELD CAPACITY	=	0.1050 VOL/VOL
WILTING POINT	=	0.0470 VOL/VOL
INITIAL SOIL WATER CONTENT	=	0.1434 VOL/VOL
EFFECTIVE SAT. HYD. COND.	=	0.170000002000E-02 CM/SEC
SLOPE	=	3.00 PERCENT
DRAINAGE LENGTH	=	22.5 FEET

LAYER 3

TYPE 4 - FLEXIBLE MEMBRANE LINER
MATERIAL TEXTURE NUMBER 17

THICKNESS	=	0.50 INCHES
POROSITY	=	0.0000 VOL/VOL
FIELD CAPACITY	=	0.0000 VOL/VOL
WILTING POINT	=	0.0000 VOL/VOL
INITIAL SOIL WATER CONTENT	=	0.0000 VOL/VOL
EFFECTIVE SAT. HYD. COND.	=	0.300000003000E-08 CM/SEC
FML PINHOLE DENSITY	=	1.00 HOLES/ACRE
FML INSTALLATION DEFECTS	=	4.00 HOLES/ACRE
FML PLACEMENT QUALITY	=	3 - GOOD

LAYER 4

TYPE 1 - VERTICAL PERCOLATION LAYER
MATERIAL TEXTURE NUMBER 4

THICKNESS	=	240.00 INCHES
POROSITY	=	0.4370 VOL/VOL
FIELD CAPACITY	=	0.1050 VOL/VOL
WILTING POINT	=	0.0470 VOL/VOL
INITIAL SOIL WATER CONTENT	=	0.1080 VOL/VOL
EFFECTIVE SAT. HYD. COND.	=	0.170000002000E-02 CM/SEC

GENERAL DESIGN AND EVAPORATIVE ZONE DATA

NOTE: SCS RUNOFF CURVE NUMBER WAS COMPUTED FROM DEFAULT SOIL DATA BASE USING SOIL TEXTURE #21 WITH BARE GROUND CONDITIONS, A SURFACE SLOPE OF 3.% AND A SLOPE LENGTH OF 600. FEET.

SCS RUNOFF CURVE NUMBER	=	68.90	
FRACTION OF AREA ALLOWING RUNOFF	=	100.0	PERCENT
AREA PROJECTED ON HORIZONTAL PLANE	=	25.000	ACRES
EVAPORATIVE ZONE DEPTH	=	8.0	INCHES
INITIAL WATER IN EVAPORATIVE ZONE	=	0.698	INCHES
UPPER LIMIT OF EVAPORATIVE STORAGE	=	3.256	INCHES
LOWER LIMIT OF EVAPORATIVE STORAGE	=	0.172	INCHES
INITIAL SNOW WATER	=	12.815	INCHES
INITIAL WATER IN LAYER MATERIALS	=	29.751	INCHES
TOTAL INITIAL WATER	=	42.565	INCHES
TOTAL SUBSURFACE INFLOW	=	0.00	INCHES/YEAR

EVAPOTRANSPIRATION AND WEATHER DATA

NOTE: EVAPOTRANSPIRATION DATA WAS OBTAINED FROM Holden WASHINGTON

STATION LATITUDE	=	48.12	DEGREES
MAXIMUM LEAF AREA INDEX	=	2.00	
START OF GROWING SEASON (JULIAN DATE)	=	183	
END OF GROWING SEASON (JULIAN DATE)	=	245	
EVAPORATIVE ZONE DEPTH	=	8.0	INCHES
AVERAGE ANNUAL WIND SPEED	=	9.10	MPH
AVERAGE 1ST QUARTER RELATIVE HUMIDITY	=	89.00	%
AVERAGE 2ND QUARTER RELATIVE HUMIDITY	=	78.00	%
AVERAGE 3RD QUARTER RELATIVE HUMIDITY	=	71.00	%
AVERAGE 4TH QUARTER RELATIVE HUMIDITY	=	88.00	%

NOTE: PRECIPITATION DATA FOR Holden Washington WAS ENTERED BY THE USER.

NOTE: TEMPERATURE DATA FOR Holden Washington WAS ENTERED BY THE USER.

NOTE: SOLAR RADIATION DATA WAS SYNTHETICALLY GENERATED USING COEFFICIENTS FOR STAMPEDE PASS WASHINGTON AND STATION LATITUDE = 47.17 DEGREES

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ANNUAL TOTALS FOR YEAR 1999

	INCHES	CU. FEET	PERCENT
PRECIPITATION	38.60	3502951.000	100.00
RUNOFF	25.527	2316582.250	66.13
EVAPOTRANSPIRATION	7.206	653935.437	18.67
DRAINAGE COLLECTED FROM LAYER 2	5.0095	454609.094	12.98
PERC./LEAKAGE THROUGH LAYER 3	0.858892	77944.492	2.23
AVG. HEAD ON TOP OF LAYER 3	1.0017		
PERC./LEAKAGE THROUGH LAYER 4	0.004939	448.194	0.01
CHANGE IN WATER STORAGE	0.853	77375.359	2.21
SOIL WATER AT START OF YEAR	30.801	2795148.000	
SOIL WATER AT END OF YEAR	31.653	2872523.250	
SNOW WATER AT START OF YEAR	12.815	1162944.120	33.20
SNOW WATER AT END OF YEAR	12.815	1162944.120	33.20
ANNUAL WATER BUDGET BALANCE	0.0000	0.590	0.00

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ANNUAL TOTALS FOR YEAR 1998

	INCHES	CU. FEET	PERCENT
PRECIPITATION	38.60	3502951.000	100.00
RUNOFF	25.513	2315279.750	66.10
EVAPOTRANSPIRATION	7.338	665948.437	19.01
DRAINAGE COLLECTED FROM LAYER 2	4.9082	445422.062	12.72
PERC./LEAKAGE THROUGH LAYER 3	0.845082	76691.219	2.19
AVG. HEAD ON TOP OF LAYER 3	0.9822		
PERC./LEAKAGE THROUGH LAYER 4	0.005706	517.788	0.01
CHANGE IN WATER STORAGE	0.835	75781.359	2.16

SOIL WATER AT START OF YEAR	31.653	2872523.250	
SOIL WATER AT END OF YEAR	32.488	2948304.500	
SNOW WATER AT START OF YEAR	12.815	1162944.120	33.20
SNOW WATER AT END OF YEAR	12.815	1162944.120	33.20
ANNUAL WATER BUDGET BALANCE	0.0000	1.531	0.00

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ANNUAL TOTALS FOR YEAR 1997

	INCHES	CU. FEET	PERCENT
PRECIPITATION	38.60	3502951.000	100.00
RUNOFF	25.535	2317326.000	66.15
EVAPOTRANSPIRATION	7.196	653056.875	18.64
DRAINAGE COLLECTED FROM LAYER 2	5.0121	454844.062	12.98
PERC./LEAKAGE THROUGH LAYER 3	0.859946	78040.141	2.23
AVG. HEAD ON TOP OF LAYER 3	1.0025		
PERC./LEAKAGE THROUGH LAYER 4	0.008307	753.836	0.02
CHANGE IN WATER STORAGE	0.848	76968.773	2.20
SOIL WATER AT START OF YEAR	32.488	2948304.500	
SOIL WATER AT END OF YEAR	33.336	3025273.250	
SNOW WATER AT START OF YEAR	12.815	1162944.120	33.20
SNOW WATER AT END OF YEAR	12.815	1162944.120	33.20
ANNUAL WATER BUDGET BALANCE	0.0000	1.364	0.00

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ANNUAL TOTALS FOR YEAR 1996

	INCHES	CU. FEET	PERCENT
PRECIPITATION	38.60	3502951.000	100.00
RUNOFF	25.525	2316417.500	66.13

EVAPOTRANSPIRATION	7.324	664622.625	18.97
DRAINAGE COLLECTED FROM LAYER 2	4.9137	445914.375	12.73
PERC./LEAKAGE THROUGH LAYER 3	0.845587	76736.992	2.19
AVG. HEAD ON TOP OF LAYER 3	0.9832		
PERC./LEAKAGE THROUGH LAYER 4	0.011904	1080.250	0.03
CHANGE IN WATER STORAGE	0.826	74915.031	2.14
SOIL WATER AT START OF YEAR	33.336	3025273.250	
SOIL WATER AT END OF YEAR	34.166	3100581.750	
SNOW WATER AT START OF YEAR	12.815	1162944.120	33.20
SNOW WATER AT END OF YEAR	12.810	1162550.620	33.19
ANNUAL WATER BUDGET BALANCE	0.0000	1.185	0.00

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ANNUAL TOTALS FOR YEAR 1995

	INCHES	CU. FEET	PERCENT
PRECIPITATION	38.60	3502951.000	100.00
RUNOFF	25.636	2326485.250	66.42
EVAPOTRANSPIRATION	7.056	640370.437	18.28
DRAINAGE COLLECTED FROM LAYER 2	5.0253	456046.062	13.02
PERC./LEAKAGE THROUGH LAYER 3	0.860998	78135.602	2.23
AVG. HEAD ON TOP OF LAYER 3	1.0046		
PERC./LEAKAGE THROUGH LAYER 4	0.017896	1624.029	0.05
CHANGE IN WATER STORAGE	0.864	78424.297	2.24
SOIL WATER AT START OF YEAR	34.166	3100581.750	
SOIL WATER AT END OF YEAR	35.026	3178612.750	
SNOW WATER AT START OF YEAR	12.810	1162550.620	33.19
SNOW WATER AT END OF YEAR	12.815	1162944.120	33.20
ANNUAL WATER BUDGET BALANCE	0.0000	0.741	0.00

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AVERAGE MONTHLY VALUES IN INCHES FOR YEARS 1999 THROUGH 1995

	JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
PRECIPITATION						
TOTALS	6.62	4.74	2.81	1.60	0.93	1.11
	0.76	1.11	1.62	3.41	6.50	7.39
STD. DEVIATIONS	0.00	0.00	0.00	0.00	0.00	0.00
	0.00	0.00	0.00	0.00	0.00	0.00
RUNOFF						
TOTALS	0.000	0.000	2.695	22.852	0.000	0.000
	0.000	0.000	0.000	0.000	0.000	0.000
STD. DEVIATIONS	0.000	0.000	0.205	0.223	0.000	0.000
	0.000	0.000	0.000	0.000	0.000	0.000
EVAPOTRANSPIRATION						
TOTALS	0.248	0.173	0.048	0.143	0.685	0.918
	1.078	1.019	1.207	1.036	0.374	0.295
STD. DEVIATIONS	0.042	0.000	0.002	0.012	0.059	0.057
	0.073	0.060	0.036	0.046	0.005	0.002
LATERAL DRAINAGE COLLECTED FROM LAYER 2						
TOTALS	0.1825	0.0774	0.0475	0.1580	1.6486	0.4660
	0.1657	0.0824	0.0568	0.5625	1.0801	0.4463
STD. DEVIATIONS	0.0026	0.0010	0.0006	0.0391	0.0297	0.0068
	0.0041	0.0061	0.0049	0.0315	0.0265	0.0084
PERCOLATION/LEAKAGE THROUGH LAYER 3						
TOTALS	0.0429	0.0230	0.0173	0.0279	0.2226	0.0880
	0.0399	0.0247	0.0192	0.0957	0.1670	0.0858
STD. DEVIATIONS	0.0005	0.0003	0.0001	0.0043	0.0027	0.0010
	0.0007	0.0012	0.0011	0.0045	0.0029	0.0013
PERCOLATION/LEAKAGE THROUGH LAYER 4						
TOTALS	0.0011	0.0005	0.0004	0.0001	0.0006	0.0018
	0.0012	0.0007	0.0004	0.0001	0.0011	0.0019
STD. DEVIATIONS	0.0009	0.0008	0.0009	0.0001	0.0000	0.0003
	0.0010	0.0010	0.0008	0.0001	0.0000	0.0002

AVERAGES OF MONTHLY AVERAGED DAILY HEADS (INCHES)

DAILY AVERAGE HEAD ON TOP OF LAYER 3

AVERAGES	0.4585	0.2138	0.1194	0.3521	3.6544	1.2093
	0.4163	0.2071	0.1474	1.3665	2.6720	1.1214
STD. DEVIATIONS	0.0066	0.0029	0.0016	0.0808	0.0538	0.0176
	0.0103	0.0152	0.0128	0.0736	0.0572	0.0211

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AVERAGE ANNUAL TOTALS & (STD. DEVIATIONS) FOR YEARS 1999 THROUGH 1995

	INCHES	CU. FEET	PERCENT
PRECIPITATION	38.60 (0.013)	3502951.0	100.00
RUNOFF	25.547 (0.0507)	2318418.00	66.185
EVAPOTRANSPIRATION	7.224 (0.1142)	655586.81	18.715
LATERAL DRAINAGE COLLECTED FROM LAYER 2	4.97374 (0.05769)	451367.125	12.88534
PERCOLATION/LEAKAGE THROUGH LAYER 3	0.85410 (0.00805)	77509.680	2.21270
AVERAGE HEAD ON TOP OF LAYER 3	0.995 (0.011)		
PERCOLATION/LEAKAGE THROUGH LAYER 4	0.00975 (0.00531)	884.820	0.02526
CHANGE IN WATER STORAGE	0.845 (0.0151)	76692.96	2.189

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PEAK DAILY VALUES FOR YEARS 1999 THROUGH 1995

	(INCHES)	(CU. FT.)
PRECIPITATION	0.75	68062.500
RUNOFF	1.834	166406.4060
DRAINAGE COLLECTED FROM LAYER 2	0.08997	8164.85059
PERCOLATION/LEAKAGE THROUGH LAYER 3	0.010281	933.03247
AVERAGE HEAD ON TOP OF LAYER 3	5.585	

MAXIMUM HEAD ON TOP OF LAYER 3	6.564	
LOCATION OF MAXIMUM HEAD IN LAYER 2 (DISTANCE FROM DRAIN)	12.0 FEET	
PERCOLATION/LEAKAGE THROUGH LAYER 4	0.000069	6.28914
SNOW WATER	24.15	2191189.0000
MAXIMUM VEG. SOIL WATER (VOL/VOL)	0.4060	
MINIMUM VEG. SOIL WATER (VOL/VOL)	0.0215	

*** Maximum heads are computed using McEnroe's equations. ***

Reference: Maximum Saturated Depth over Landfill Liner
by Bruce M. McEnroe, University of Kansas
ASCE Journal of Environmental Engineering
Vol. 119, No. 2, March 1993, pp. 262-270.

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FINAL WATER STORAGE AT END OF YEAR 1995

LAYER	(INCHES)	(VOL/VOL)
1	0.3812	0.0635
2	3.4445	0.1435
3	0.0000	0.0000
4	30.1504	0.1256
SNOW WATER	12.815	

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**              HYDROLOGIC EVALUATION OF LANDFILL PERFORMANCE               **
**                HELP MODEL VERSION 3.07  (1 NOVEMBER 1997)                **
**                  DEVELOPED BY ENVIRONMENTAL LABORATORY                   **
**                    USAE WATERWAYS EXPERIMENT STATION                     **
**              FOR USEPA RISK REDUCTION ENGINEERING LABORATORY             **
**                                                                          **
**                                                                          **
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PRECIPITATION DATA FILE:     G:\CRAIG\HELP3\HOLDEN4.D4
TEMPERATURE DATA FILE:       g:\craig\help3\HOLDEN7.D7
SOLAR RADIATION DATA FILE:   g:\craig\help3\HOLDEN13.D13
EVAPOTRANSPIRATION DATA:     g:\craig\help3\HOLDEN11.D11
SOIL AND DESIGN DATA FILE:   g:\craig\help3\SCEN12P2.D10
OUTPUT DATA FILE:            G:\CRAIG\HELP3\scen12p2.OUT


TIME:  10:12      DATE:  10/ 6/1999


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    TITLE:  Holden Mine Tailings Pile 2 -    Scenario 4

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    NOTE:  INITIAL MOISTURE CONTENT OF THE LAYERS AND SNOW WATER WERE
             COMPUTED AS NEARLY STEADY-STATE VALUES BY THE PROGRAM.


                                  LAYER  1
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                      TYPE 1 - VERTICAL PERCOLATION LAYER
                          MATERIAL TEXTURE NUMBER  21
           THICKNESS                  =      6.00   INCHES
           POROSITY                   =      0.3970 VOL/VOL
           FIELD CAPACITY             =      0.0320 VOL/VOL
           WILTING POINT              =      0.0130 VOL/VOL
           INITIAL SOIL WATER CONTENT =      0.0635 VOL/VOL
           EFFECTIVE SAT. HYD. COND.  =  0.300000012000     CM/SEC
        NOTE:  SATURATED HYDRAULIC CONDUCTIVITY IS MULTIPLIED BY  3.00
                 FOR ROOT CHANNELS IN TOP HALF OF EVAPORATIVE ZONE.
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LAYER 2

TYPE 2 - LATERAL DRAINAGE LAYER
MATERIAL TEXTURE NUMBER 4

THICKNESS	=	24.00	INCHES
POROSITY	=	0.4370	VOL/VOL
FIELD CAPACITY	=	0.1050	VOL/VOL
WILTING POINT	=	0.0470	VOL/VOL
INITIAL SOIL WATER CONTENT	=	0.1434	VOL/VOL
EFFECTIVE SAT. HYD. COND.	=	0.170000002000E-02	CM/SEC
SLOPE	=	3.00	PERCENT
DRAINAGE LENGTH	=	22.5	FEET

LAYER 3

TYPE 4 - FLEXIBLE MEMBRANE LINER
MATERIAL TEXTURE NUMBER 17

THICKNESS	=	0.50	INCHES
POROSITY	=	0.0000	VOL/VOL
FIELD CAPACITY	=	0.0000	VOL/VOL
WILTING POINT	=	0.0000	VOL/VOL
INITIAL SOIL WATER CONTENT	=	0.0000	VOL/VOL
EFFECTIVE SAT. HYD. COND.	=	0.300000003000E-08	CM/SEC
FML PINHOLE DENSITY	=	1.00	HOLES/ACRE
FML INSTALLATION DEFECTS	=	4.00	HOLES/ACRE
FML PLACEMENT QUALITY	=	3 - GOOD	

LAYER 4

TYPE 1 - VERTICAL PERCOLATION LAYER
MATERIAL TEXTURE NUMBER 4

THICKNESS	=	240.00	INCHES
POROSITY	=	0.4370	VOL/VOL
FIELD CAPACITY	=	0.1050	VOL/VOL
WILTING POINT	=	0.0470	VOL/VOL
INITIAL SOIL WATER CONTENT	=	0.1080	VOL/VOL
EFFECTIVE SAT. HYD. COND.	=	0.170000002000E-02	CM/SEC

GENERAL DESIGN AND EVAPORATIVE ZONE DATA

NOTE: SCS RUNOFF CURVE NUMBER WAS COMPUTED FROM DEFAULT SOIL DATA BASE USING SOIL TEXTURE #21 WITH BARE GROUND CONDITIONS, A SURFACE SLOPE OF 3.% AND A SLOPE LENGTH OF 900. FEET.

SCS RUNOFF CURVE NUMBER	=	68.10	
FRACTION OF AREA ALLOWING RUNOFF	=	100.0	PERCENT
AREA PROJECTED ON HORIZONTAL PLANE	=	45.000	ACRES
EVAPORATIVE ZONE DEPTH	=	8.0	INCHES
INITIAL WATER IN EVAPORATIVE ZONE	=	0.698	INCHES
UPPER LIMIT OF EVAPORATIVE STORAGE	=	3.256	INCHES
LOWER LIMIT OF EVAPORATIVE STORAGE	=	0.172	INCHES
INITIAL SNOW WATER	=	12.815	INCHES
INITIAL WATER IN LAYER MATERIALS	=	29.751	INCHES
TOTAL INITIAL WATER	=	42.565	INCHES
TOTAL SUBSURFACE INFLOW	=	0.00	INCHES/YEAR

EVAPOTRANSPIRATION AND WEATHER DATA

NOTE: EVAPOTRANSPIRATION DATA WAS OBTAINED FROM Holden WASHINGTON

STATION LATITUDE	=	48.12	DEGREES
MAXIMUM LEAF AREA INDEX	=	2.00	
START OF GROWING SEASON (JULIAN DATE)	=	183	
END OF GROWING SEASON (JULIAN DATE)	=	245	
EVAPORATIVE ZONE DEPTH	=	8.0	INCHES
AVERAGE ANNUAL WIND SPEED	=	9.10	MPH
AVERAGE 1ST QUARTER RELATIVE HUMIDITY	=	89.00	%
AVERAGE 2ND QUARTER RELATIVE HUMIDITY	=	78.00	%
AVERAGE 3RD QUARTER RELATIVE HUMIDITY	=	71.00	%
AVERAGE 4TH QUARTER RELATIVE HUMIDITY	=	88.00	%

NOTE: PRECIPITATION DATA FOR Holden Washington WAS ENTERED BY THE USER.

NOTE: TEMPERATURE DATA FOR Holden Washington WAS ENTERED BY THE USER.

NOTE: SOLAR RADIATION DATA WAS SYNTHETICALLY GENERATED USING COEFFICIENTS FOR STAMPEDE PASS WASHINGTON AND STATION LATITUDE = 47.17 DEGREES

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ANNUAL TOTALS FOR YEAR 1999

	INCHES	CU. FEET	PERCENT
PRECIPITATION	38.60	6305311.500	100.00
RUNOFF	25.527	4169848.000	66.13
EVAPOTRANSPIRATION	7.206	1177083.750	18.67
DRAINAGE COLLECTED FROM LAYER 2	5.0095	818296.375	12.98
PERC./LEAKAGE THROUGH LAYER 3	0.858892	140300.078	2.23
AVG. HEAD ON TOP OF LAYER 3	1.0017		
PERC./LEAKAGE THROUGH LAYER 4	0.004939	806.750	0.01
CHANGE IN WATER STORAGE	0.853	139275.656	2.21
SOIL WATER AT START OF YEAR	30.801	5031266.000	
SOIL WATER AT END OF YEAR	31.653	5170542.000	
SNOW WATER AT START OF YEAR	12.815	2093299.370	33.20
SNOW WATER AT END OF YEAR	12.815	2093299.370	33.20
ANNUAL WATER BUDGET BALANCE	0.0000	1.061	0.00

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ANNUAL TOTALS FOR YEAR 1998

	INCHES	CU. FEET	PERCENT
PRECIPITATION	38.60	6305311.500	100.00
RUNOFF	25.513	4167503.500	66.10
EVAPOTRANSPIRATION	7.338	1198707.250	19.01
DRAINAGE COLLECTED FROM LAYER 2	4.9082	801759.750	12.72
PERC./LEAKAGE THROUGH LAYER 3	0.845082	138044.187	2.19
AVG. HEAD ON TOP OF LAYER 3	0.9822		
PERC./LEAKAGE THROUGH LAYER 4	0.005706	932.018	0.01
CHANGE IN WATER STORAGE	0.835	136406.453	2.16
SOIL WATER AT START OF YEAR	31.653	5170542.000	

SOIL WATER AT END OF YEAR	32.488	5306948.500	
SNOW WATER AT START OF YEAR	12.815	2093299.370	33.20
SNOW WATER AT END OF YEAR	12.815	2093299.370	33.20
ANNUAL WATER BUDGET BALANCE	0.0000	2.756	0.00

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ANNUAL TOTALS FOR YEAR 1997

	INCHES	CU. FEET	PERCENT
PRECIPITATION	38.60	6305311.500	100.00
RUNOFF	25.535	4171186.750	66.15
EVAPOTRANSPIRATION	7.196	1175502.370	18.64
DRAINAGE COLLECTED FROM LAYER 2	5.0121	818719.312	12.98
PERC./LEAKAGE THROUGH LAYER 3	0.859946	140472.250	2.23
AVG. HEAD ON TOP OF LAYER 3	1.0025		
PERC./LEAKAGE THROUGH LAYER 4	0.008307	1356.905	0.02
CHANGE IN WATER STORAGE	0.848	138543.781	2.20
SOIL WATER AT START OF YEAR	32.488	5306948.500	
SOIL WATER AT END OF YEAR	33.336	5445492.000	
SNOW WATER AT START OF YEAR	12.815	2093299.370	33.20
SNOW WATER AT END OF YEAR	12.815	2093299.370	33.20
ANNUAL WATER BUDGET BALANCE	0.0000	2.455	0.00

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ANNUAL TOTALS FOR YEAR 1996

	INCHES	CU. FEET	PERCENT
PRECIPITATION	38.60	6305311.500	100.00
RUNOFF	25.525	4169551.250	66.13
EVAPOTRANSPIRATION	7.324	1196320.750	18.97
DRAINAGE COLLECTED FROM LAYER 2	4.9137	802645.875	12.73

PERC./LEAKAGE THROUGH LAYER 3	0.845587	138126.578	2.19
AVG. HEAD ON TOP OF LAYER 3	0.9832		
PERC./LEAKAGE THROUGH LAYER 4	0.011904	1944.450	0.03
CHANGE IN WATER STORAGE	0.826	134847.062	2.14
SOIL WATER AT START OF YEAR	33.336	5445492.000	
SOIL WATER AT END OF YEAR	34.166	5581047.500	
SNOW WATER AT START OF YEAR	12.815	2093299.370	33.20
SNOW WATER AT END OF YEAR	12.810	2092591.120	33.19
ANNUAL WATER BUDGET BALANCE	0.0000	2.132	0.00

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ANNUAL TOTALS FOR YEAR 1995

	INCHES	CU. FEET	PERCENT
PRECIPITATION	38.60	6305311.500	100.00
RUNOFF	25.636	4187673.500	66.42
EVAPOTRANSPIRATION	7.056	1152666.750	18.28
DRAINAGE COLLECTED FROM LAYER 2	5.0253	820882.937	13.02
PERC./LEAKAGE THROUGH LAYER 3	0.860998	140644.078	2.23
AVG. HEAD ON TOP OF LAYER 3	1.0046		
PERC./LEAKAGE THROUGH LAYER 4	0.017896	2923.252	0.05
CHANGE IN WATER STORAGE	0.864	141163.734	2.24
SOIL WATER AT START OF YEAR	34.166	5581047.500	
SOIL WATER AT END OF YEAR	35.026	5721503.000	
SNOW WATER AT START OF YEAR	12.810	2092591.120	33.19
SNOW WATER AT END OF YEAR	12.815	2093299.370	33.20
ANNUAL WATER BUDGET BALANCE	0.0000	1.334	0.00

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AVERAGE MONTHLY VALUES IN INCHES FOR YEARS 1999 THROUGH 1995

	JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
PRECIPITATION						
TOTALS	6.62	4.74	2.81	1.60	0.93	1.11
	0.76	1.11	1.62	3.41	6.50	7.39
STD. DEVIATIONS	0.00	0.00	0.00	0.00	0.00	0.00
	0.00	0.00	0.00	0.00	0.00	0.00
RUNOFF						
TOTALS	0.000	0.000	2.695	22.852	0.000	0.000
	0.000	0.000	0.000	0.000	0.000	0.000
STD. DEVIATIONS	0.000	0.000	0.205	0.223	0.000	0.000
	0.000	0.000	0.000	0.000	0.000	0.000
EVAPOTRANSPIRATION						
TOTALS	0.248	0.173	0.048	0.143	0.685	0.918
	1.078	1.019	1.207	1.036	0.374	0.295
STD. DEVIATIONS	0.042	0.000	0.002	0.012	0.059	0.057
	0.073	0.060	0.036	0.046	0.005	0.002
LATERAL DRAINAGE COLLECTED FROM LAYER 2						
TOTALS	0.1825	0.0774	0.0475	0.1580	1.6486	0.4660
	0.1657	0.0824	0.0568	0.5625	1.0801	0.4463
STD. DEVIATIONS	0.0026	0.0010	0.0006	0.0391	0.0297	0.0068
	0.0041	0.0061	0.0049	0.0315	0.0265	0.0084
PERCOLATION/LEAKAGE THROUGH LAYER 3						
TOTALS	0.0429	0.0230	0.0173	0.0279	0.2226	0.0880
	0.0399	0.0247	0.0192	0.0957	0.1670	0.0858
STD. DEVIATIONS	0.0005	0.0003	0.0001	0.0043	0.0027	0.0010
	0.0007	0.0012	0.0011	0.0045	0.0029	0.0013
PERCOLATION/LEAKAGE THROUGH LAYER 4						
TOTALS	0.0011	0.0005	0.0004	0.0001	0.0006	0.0018
	0.0012	0.0007	0.0004	0.0001	0.0011	0.0019
STD. DEVIATIONS	0.0009	0.0008	0.0009	0.0001	0.0000	0.0003
	0.0010	0.0010	0.0008	0.0001	0.0000	0.0002

AVERAGES OF MONTHLY AVERAGED DAILY HEADS (INCHES)

DAILY AVERAGE HEAD ON TOP OF LAYER 3

AVERAGES	0.4585	0.2138	0.1194	0.3521	3.6544	1.2093
	0.4163	0.2071	0.1474	1.3665	2.6720	1.1214
STD. DEVIATIONS	0.0066	0.0029	0.0016	0.0808	0.0538	0.0176
	0.0103	0.0152	0.0128	0.0736	0.0572	0.0211

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AVERAGE ANNUAL TOTALS & (STD. DEVIATIONS) FOR YEARS 1999 THROUGH 1995

	INCHES	CU. FEET	PERCENT
PRECIPITATION	38.60 (0.013)	6305311.5	100.00
RUNOFF	25.547 (0.0507)	4173152.50	66.185
EVAPOTRANSPIRATION	7.224 (0.1142)	1180056.25	18.715
LATERAL DRAINAGE COLLECTED FROM LAYER 2	4.97374 (0.05769)	812460.812	12.88534
PERCOLATION/LEAKAGE THROUGH LAYER 3	0.85410 (0.00805)	139517.422	2.21270
AVERAGE HEAD ON TOP OF LAYER 3	0.995 (0.011)		
PERCOLATION/LEAKAGE THROUGH LAYER 4	0.00975 (0.00531)	1592.675	0.02526
CHANGE IN WATER STORAGE	0.845 (0.0151)	138047.33	2.189

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PEAK DAILY VALUES FOR YEARS 1999 THROUGH 1995

	(INCHES)	(CU. FT.)
PRECIPITATION	0.75	122512.500
RUNOFF	1.834	299531.5310
DRAINAGE COLLECTED FROM LAYER 2	0.08997	14696.73050
PERCOLATION/LEAKAGE THROUGH LAYER 3	0.010281	1679.45850
AVERAGE HEAD ON TOP OF LAYER 3	5.585	
MAXIMUM HEAD ON TOP OF LAYER 3	6.564	

LOCATION OF MAXIMUM HEAD IN LAYER 2 (DISTANCE FROM DRAIN)	12.0 FEET	
PERCOLATION/LEAKAGE THROUGH LAYER 4	0.000069	11.32045
SNOW WATER	24.15	3944140.2500

MAXIMUM VEG. SOIL WATER (VOL/VOL)	0.4060
MINIMUM VEG. SOIL WATER (VOL/VOL)	0.0215

*** Maximum heads are computed using McEnroe's equations. ***

Reference: Maximum Saturated Depth over Landfill Liner
by Bruce M. McEnroe, University of Kansas
ASCE Journal of Environmental Engineering
Vol. 119, No. 2, March 1993, pp. 262-270.

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FINAL WATER STORAGE AT END OF YEAR 1995

LAYER	(INCHES)	(VOL/VOL)
1	0.3812	0.0635
2	3.4445	0.1435
3	0.0000	0.0000
4	30.1504	0.1256
SNOW WATER	12.815	

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**                                                                          **
**                                                                          **
**              HYDROLOGIC EVALUATION OF LANDFILL PERFORMANCE               **
**                 HELP MODEL VERSION 3.07  (1 NOVEMBER 1997)               **
**                   DEVELOPED BY ENVIRONMENTAL LABORATORY                  **
**                     USAE WATERWAYS EXPERIMENT STATION                    **
**              FOR USEPA RISK REDUCTION ENGINEERING LABORATORY             **
**                                                                          **
**                                                                          **
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PRECIPITATION DATA FILE:     G:\CRAIG\HELP3\HOLDEN4.D4
TEMPERATURE DATA FILE:       g:\craig\help3\HOLDEN7.D7
SOLAR RADIATION DATA FILE:   g:\craig\help3\HOLDEN13.D13
EVAPOTRANSPIRATION DATA:     g:\craig\help3\HOLDEN11.D11
SOIL AND DESIGN DATA FILE:   g:\craig\help3\SCEN12P3.D10
OUTPUT DATA FILE:            G:\CRAIG\HELP3\scen12p3.OUT


TIME:  10:12     DATE:  10/ 6/1999


******************************************************************************

     TITLE:  Holden Mine Tailings Pile 3 -   Scenario 4

******************************************************************************


     NOTE:  INITIAL MOISTURE CONTENT OF THE LAYERS AND SNOW WATER WERE
              COMPUTED AS NEARLY STEADY-STATE VALUES BY THE PROGRAM.


                                  LAYER  1
                                  --------

                       TYPE 1 - VERTICAL PERCOLATION LAYER
                          MATERIAL TEXTURE NUMBER  21
         THICKNESS                  =        6.00   INCHES
         POROSITY                   =        0.3970 VOL/VOL
         FIELD CAPACITY             =        0.0320 VOL/VOL
         WILTING POINT              =        0.0130 VOL/VOL
         INITIAL SOIL WATER CONTENT =        0.0635 VOL/VOL
         EFFECTIVE SAT. HYD. COND.  =   0.300000012000      CM/SEC
     NOTE:  SATURATED HYDRAULIC CONDUCTIVITY IS MULTIPLIED BY  3.00
              FOR ROOT CHANNELS IN TOP HALF OF EVAPORATIVE ZONE.
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LAYER 2

TYPE 2 - LATERAL DRAINAGE LAYER
MATERIAL TEXTURE NUMBER 4

THICKNESS	=	24.00 INCHES
POROSITY	=	0.4370 VOL/VOL
FIELD CAPACITY	=	0.1050 VOL/VOL
WILTING POINT	=	0.0470 VOL/VOL
INITIAL SOIL WATER CONTENT	=	0.1434 VOL/VOL
EFFECTIVE SAT. HYD. COND.	=	0.170000002000E-02 CM/SEC
SLOPE	=	3.00 PERCENT
DRAINAGE LENGTH	=	22.5 FEET

LAYER 3

TYPE 4 - FLEXIBLE MEMBRANE LINER
MATERIAL TEXTURE NUMBER 17

THICKNESS	=	0.50 INCHES
POROSITY	=	0.0000 VOL/VOL
FIELD CAPACITY	=	0.0000 VOL/VOL
WILTING POINT	=	0.0000 VOL/VOL
INITIAL SOIL WATER CONTENT	=	0.0000 VOL/VOL
EFFECTIVE SAT. HYD. COND.	=	0.300000003000E-08 CM/SEC
FML PINHOLE DENSITY	=	1.00 HOLES/ACRE
FML INSTALLATION DEFECTS	=	4.00 HOLES/ACRE
FML PLACEMENT QUALITY	=	3 - GOOD

LAYER 4

TYPE 1 - VERTICAL PERCOLATION LAYER
MATERIAL TEXTURE NUMBER 4

THICKNESS	=	240.00 INCHES
POROSITY	=	0.4370 VOL/VOL
FIELD CAPACITY	=	0.1050 VOL/VOL
WILTING POINT	=	0.0470 VOL/VOL
INITIAL SOIL WATER CONTENT	=	0.1080 VOL/VOL
EFFECTIVE SAT. HYD. COND.	=	0.170000002000E-02 CM/SEC

GENERAL DESIGN AND EVAPORATIVE ZONE DATA

NOTE: SCS RUNOFF CURVE NUMBER WAS COMPUTED FROM DEFAULT SOIL DATA BASE USING SOIL TEXTURE #21 WITH BARE GROUND CONDITIONS, A SURFACE SLOPE OF 3.% AND A SLOPE LENGTH OF 650. FEET.

SCS RUNOFF CURVE NUMBER	=	68.70	
FRACTION OF AREA ALLOWING RUNOFF	=	100.0	PERCENT
AREA PROJECTED ON HORIZONTAL PLANE	=	22.000	ACRES
EVAPORATIVE ZONE DEPTH	=	8.0	INCHES
INITIAL WATER IN EVAPORATIVE ZONE	=	0.698	INCHES
UPPER LIMIT OF EVAPORATIVE STORAGE	=	3.256	INCHES
LOWER LIMIT OF EVAPORATIVE STORAGE	=	0.172	INCHES
INITIAL SNOW WATER	=	12.815	INCHES
INITIAL WATER IN LAYER MATERIALS	=	29.751	INCHES
TOTAL INITIAL WATER	=	42.565	INCHES
TOTAL SUBSURFACE INFLOW	=	0.00	INCHES/YEAR

EVAPOTRANSPIRATION AND WEATHER DATA

NOTE: EVAPOTRANSPIRATION DATA WAS OBTAINED FROM Holden WASHINGTON

STATION LATITUDE	=	48.12	DEGREES
MAXIMUM LEAF AREA INDEX	=	2.00	
START OF GROWING SEASON (JULIAN DATE)	=	183	
END OF GROWING SEASON (JULIAN DATE)	=	245	
EVAPORATIVE ZONE DEPTH	=	8.0	INCHES
AVERAGE ANNUAL WIND SPEED	=	9.10	MPH
AVERAGE 1ST QUARTER RELATIVE HUMIDITY	=	89.00	%
AVERAGE 2ND QUARTER RELATIVE HUMIDITY	=	78.00	%
AVERAGE 3RD QUARTER RELATIVE HUMIDITY	=	71.00	%
AVERAGE 4TH QUARTER RELATIVE HUMIDITY	=	88.00	%

NOTE: PRECIPITATION DATA FOR Holden Washington WAS ENTERED BY THE USER.

NOTE: TEMPERATURE DATA FOR Holden Washington WAS ENTERED BY THE USER.

NOTE: SOLAR RADIATION DATA WAS SYNTHETICALLY GENERATED USING COEFFICIENTS FOR STAMPEDE PASS WASHINGTON AND STATION LATITUDE = 47.17 DEGREES

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ANNUAL TOTALS FOR YEAR 1999

	INCHES	CU. FEET	PERCENT
PRECIPITATION	38.60	3082596.750	100.00
RUNOFF	25.527	2038592.370	66.13
EVAPOTRANSPIRATION	7.206	575463.187	18.67
DRAINAGE COLLECTED FROM LAYER 2	5.0095	400056.000	12.98
PERC./LEAKAGE THROUGH LAYER 3	0.858892	68591.148	2.23
AVG. HEAD ON TOP OF LAYER 3	1.0017		
PERC./LEAKAGE THROUGH LAYER 4	0.004939	394.411	0.01
CHANGE IN WATER STORAGE	0.853	68090.320	2.21
SOIL WATER AT START OF YEAR	30.801	2459730.250	
SOIL WATER AT END OF YEAR	31.653	2527820.500	
SNOW WATER AT START OF YEAR	12.815	1023390.810	33.20
SNOW WATER AT END OF YEAR	12.815	1023390.810	33.20
ANNUAL WATER BUDGET BALANCE	0.0000	0.519	0.00

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ANNUAL TOTALS FOR YEAR 1998

	INCHES	CU. FEET	PERCENT
PRECIPITATION	38.60	3082596.750	100.00
RUNOFF	25.513	2037446.120	66.10
EVAPOTRANSPIRATION	7.338	586034.625	19.01
DRAINAGE COLLECTED FROM LAYER 2	4.9082	391971.437	12.72
PERC./LEAKAGE THROUGH LAYER 3	0.845082	67488.273	2.19
AVG. HEAD ON TOP OF LAYER 3	0.9822		
PERC./LEAKAGE THROUGH LAYER 4	0.005706	455.653	0.01
CHANGE IN WATER STORAGE	0.835	66687.594	2.16
SOIL WATER AT START OF YEAR	31.653	2527820.500	

SOIL WATER AT END OF YEAR	32.488	2594508.000	
SNOW WATER AT START OF YEAR	12.815	1023390.810	33.20
SNOW WATER AT END OF YEAR	12.815	1023390.810	33.20
ANNUAL WATER BUDGET BALANCE	0.0000	1.347	0.00

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ANNUAL TOTALS FOR YEAR 1997

	INCHES	CU. FEET	PERCENT
PRECIPITATION	38.60	3082596.750	100.00
RUNOFF	25.535	2039246.870	66.15
EVAPOTRANSPIRATION	7.196	574690.062	18.64
DRAINAGE COLLECTED FROM LAYER 2	5.0121	400262.781	12.98
PERC./LEAKAGE THROUGH LAYER 3	0.859946	68675.320	2.23
AVG. HEAD ON TOP OF LAYER 3	1.0025		
PERC./LEAKAGE THROUGH LAYER 4	0.008307	663.376	0.02
CHANGE IN WATER STORAGE	0.848	67732.516	2.20
SOIL WATER AT START OF YEAR	32.488	2594508.000	
SOIL WATER AT END OF YEAR	33.336	2662240.500	
SNOW WATER AT START OF YEAR	12.815	1023390.810	33.20
SNOW WATER AT END OF YEAR	12.815	1023390.810	33.20
ANNUAL WATER BUDGET BALANCE	0.0000	1.200	0.00

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ANNUAL TOTALS FOR YEAR 1996

	INCHES	CU. FEET	PERCENT
PRECIPITATION	38.60	3082596.750	100.00
RUNOFF	25.525	2038447.370	66.13
EVAPOTRANSPIRATION	7.324	584867.875	18.97

DRAINAGE COLLECTED FROM LAYER 2	4.9137	392404.656	12.73
PERC./LEAKAGE THROUGH LAYER 3	0.845587	67528.547	2.19
AVG. HEAD ON TOP OF LAYER 3	0.9832		
PERC./LEAKAGE THROUGH LAYER 4	0.011904	950.620	0.03
CHANGE IN WATER STORAGE	0.826	65925.234	2.14
SOIL WATER AT START OF YEAR	33.336	2662240.500	
SOIL WATER AT END OF YEAR	34.166	2728512.000	
SNOW WATER AT START OF YEAR	12.815	1023390.810	33.20
SNOW WATER AT END OF YEAR	12.810	1023044.560	33.19
ANNUAL WATER BUDGET BALANCE	0.0000	1.043	0.00

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ANNUAL TOTALS FOR YEAR 1995

	INCHES	CU. FEET	PERCENT
PRECIPITATION	38.60	3082596.750	100.00
RUNOFF	25.636	2047307.120	66.42
EVAPOTRANSPIRATION	7.056	563526.000	18.28
DRAINAGE COLLECTED FROM LAYER 2	5.0253	401320.531	13.02
PERC./LEAKAGE THROUGH LAYER 3	0.860998	68759.328	2.23
AVG. HEAD ON TOP OF LAYER 3	1.0046		
PERC./LEAKAGE THROUGH LAYER 4	0.017896	1429.145	0.05
CHANGE IN WATER STORAGE	0.864	69013.383	2.24
SOIL WATER AT START OF YEAR	34.166	2728512.000	
SOIL WATER AT END OF YEAR	35.026	2797179.250	
SNOW WATER AT START OF YEAR	12.810	1023044.560	33.19
SNOW WATER AT END OF YEAR	12.815	1023390.810	33.20
ANNUAL WATER BUDGET BALANCE	0.0000	0.652	0.00

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AVERAGE MONTHLY VALUES IN INCHES FOR YEARS 1999 THROUGH 1995

	JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
PRECIPITATION						
TOTALS	6.62	4.74	2.81	1.60	0.93	1.11
	0.76	1.11	1.62	3.41	6.50	7.39
STD. DEVIATIONS	0.00	0.00	0.00	0.00	0.00	0.00
	0.00	0.00	0.00	0.00	0.00	0.00
RUNOFF						
TOTALS	0.000	0.000	2.695	22.852	0.000	0.000
	0.000	0.000	0.000	0.000	0.000	0.000
STD. DEVIATIONS	0.000	0.000	0.205	0.223	0.000	0.000
	0.000	0.000	0.000	0.000	0.000	0.000
EVAPOTRANSPIRATION						
TOTALS	0.248	0.173	0.048	0.143	0.685	0.918
	1.078	1.019	1.207	1.036	0.374	0.295
STD. DEVIATIONS	0.042	0.000	0.002	0.012	0.059	0.057
	0.073	0.060	0.036	0.046	0.005	0.002
LATERAL DRAINAGE COLLECTED FROM LAYER 2						
TOTALS	0.1825	0.0774	0.0475	0.1580	1.6486	0.4660
	0.1657	0.0824	0.0568	0.5625	1.0801	0.4463
STD. DEVIATIONS	0.0026	0.0010	0.0006	0.0391	0.0297	0.0068
	0.0041	0.0061	0.0049	0.0315	0.0265	0.0084
PERCOLATION/LEAKAGE THROUGH LAYER 3						
TOTALS	0.0429	0.0230	0.0173	0.0279	0.2226	0.0880
	0.0399	0.0247	0.0192	0.0957	0.1670	0.0858
STD. DEVIATIONS	0.0005	0.0003	0.0001	0.0043	0.0027	0.0010
	0.0007	0.0012	0.0011	0.0045	0.0029	0.0013
PERCOLATION/LEAKAGE THROUGH LAYER 4						
TOTALS	0.0011	0.0005	0.0004	0.0001	0.0006	0.0018
	0.0012	0.0007	0.0004	0.0001	0.0011	0.0019
STD. DEVIATIONS	0.0009	0.0008	0.0009	0.0001	0.0000	0.0003
	0.0010	0.0010	0.0008	0.0001	0.0000	0.0002

AVERAGES OF MONTHLY AVERAGED DAILY HEADS (INCHES)

DAILY AVERAGE HEAD ON TOP OF LAYER 3

AVERAGES	0.4585	0.2138	0.1194	0.3521	3.6544	1.2093
	0.4163	0.2071	0.1474	1.3665	2.6720	1.1214
STD. DEVIATIONS	0.0066	0.0029	0.0016	0.0808	0.0538	0.0176
	0.0103	0.0152	0.0128	0.0736	0.0572	0.0211

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AVERAGE ANNUAL TOTALS & (STD. DEVIATIONS) FOR YEARS 1999 THROUGH 1995

	INCHES	CU. FEET	PERCENT
PRECIPITATION	38.60 (0.013)	3082596.7	100.00
RUNOFF	25.547 (0.0507)	2040207.87	66.185
EVAPOTRANSPIRATION	7.224 (0.1142)	576916.37	18.715
LATERAL DRAINAGE COLLECTED FROM LAYER 2	4.97374 (0.05769)	397203.062	12.88534
PERCOLATION/LEAKAGE THROUGH LAYER 3	0.85410 (0.00805)	68208.523	2.21270
AVERAGE HEAD ON TOP OF LAYER 3	0.995 (0.011)		
PERCOLATION/LEAKAGE THROUGH LAYER 4	0.00975 (0.00531)	778.641	0.02526
CHANGE IN WATER STORAGE	0.845 (0.0151)	67489.81	2.189

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PEAK DAILY VALUES FOR YEARS 1999 THROUGH 1995

	(INCHES)	(CU. FT.)
PRECIPITATION	0.75	59895.000
RUNOFF	1.834	146437.6410
DRAINAGE COLLECTED FROM LAYER 2	0.08997	7185.06836
PERCOLATION/LEAKAGE THROUGH LAYER 3	0.010281	821.06860
AVERAGE HEAD ON TOP OF LAYER 3	5.585	

MAXIMUM HEAD ON TOP OF LAYER 3	6.564	
LOCATION OF MAXIMUM HEAD IN LAYER 2 (DISTANCE FROM DRAIN)	12.0 FEET	
PERCOLATION/LEAKAGE THROUGH LAYER 4	0.000069	5.53444
SNOW WATER	24.15	1928246.3700

MAXIMUM VEG. SOIL WATER (VOL/VOL)	0.4060
MINIMUM VEG. SOIL WATER (VOL/VOL)	0.0215

*** Maximum heads are computed using McEnroe's equations. ***

Reference: Maximum Saturated Depth over Landfill Liner
by Bruce M. McEnroe, University of Kansas
ASCE Journal of Environmental Engineering
Vol. 119, No. 2, March 1993, pp. 262-270.

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FINAL WATER STORAGE AT END OF YEAR 1995

LAYER	(INCHES)	(VOL/VOL)
1	0.3812	0.0635
2	3.4445	0.1435
3	0.0000	0.0000
4	30.1504	0.1256
SNOW WATER	12.815	

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APPENDIX H
TOXICOLOGICAL EVALUATION BY S.R. HANSEN & ASSOCIATES

Hansen, Stephen R. 2004a. *Evaluation of Potential Impacts to Aquatic Life in Railroad Creek after Remediation due to Residual Metals Concentrations.* February 2004.

ATTACHMENT H-1

Probability of Sensitive Species being Present in Railroad Creek

ATTACHMENT H-2

Expected Form of Aluminum in Railroad Creek Surface Water

Evaluation of Potential Impacts to Aquatic Life in Railroad Creek after Remediation Due to Residual Metal Concentrations

Prepared for

URS Corporation
1501 Fourth Avenue
Suite 1400
Seattle, Washington 98101

Prepared by

S.R. Hansen & Associates
P.O. Box 539
Occidental, CA 95465

February 11, 2004

TABLE OF CONTENTS

LIST OF TABLES

1. INTRODUCTION AND SUMMARY

All of the alternatives being considered for remediation at the Holden Mine site are projected to reduce concentrations of cadmium, copper, zinc, iron, and aluminum in Railroad Creek. However, for all of the remediation alternatives being considered, the concentrations of these metals may still, on occasion, exceed potential water quality criteria on a short-term basis. The highest post-remediation metal concentrations in Railroad Creek are predicted to occur under Alternatives 2 and 4, which do not include the collection and treatment of the portal drainage, groundwater, or seeps in the West Area. Under these alternatives, ambient metal concentrations are predicted to seasonally exceed potential criteria by up to an order of magnitude in the short-term. All other alternatives (i.e., 3, 5, 6, 7, and 8) include West Area water treatment and are predicted to result in post-remediation metal concentrations in the creek that meet or only slightly exceed potential criteria. In this document, for each of the five potential metals of concern, an assessment is made concerning the level of impact to aquatic life that is expected to occur in Railroad Creek due to the predicted occasional exceedences of potential water quality criteria under the alternatives that include a West Area treatment component. In addition, for some metals, Alternatives 2 and 4 (i.e., those without a West Area treatment component) are predicted to cause relatively small exceedences of the potential water quality criteria and, therefore, an assessment of impact for these alternatives is also provided.

Based on available monitoring data from Railroad Creek and results from post-remediation loading analyses performed by URS, it appears that potential water quality criteria for cadmium, copper, zinc, iron, and aluminum might be occasionally exceeded, in the short-term after remediation, in portions of Railroad Creek downstream of the portal and tailings piles for many of the remediation alternatives under consideration. The magnitude of these exceedences is expected to be low and their ecological significance is expected to be minor. The findings for each metal are as follows:

- **Dissolved Zinc –** Implementation of alternatives which include West Area water treatment (Alternatives 3, 5, 6, 7, and 8) are predicted to significantly reduce dissolved zinc concentrations at stations adjacent to and downstream of the portal and tailings piles. Slight exceedences of the potential National Recommended Water Quality Criterion (NRWQC) of approximately 24 ug/l (depending upon hardness) may occur in the short-term during the spring flush under Alternatives 3a and 3b (predicted concentrations of 27 ug/l and 26 ug/l, respectively), but not under the other alternatives. Exceedences are not anticipated during the fall low-flow period under any of the alternatives. Based on available toxicological data, the spring flush exceedences associated with Alternative 3 are not expected to adversely impact the aquatic community, including salmonids or their food supply.

  Implementation of Alternatives 2 and 4, which do not include any West Area water treatment, are predicted to result in dissolved zinc concentrations that exceed the potential NRWQC for zinc (24 ug/l) in the short-term by up to 3-fold in the spring flush (predicted concentrations for alternatives range from 42 to 76 ug/l) and up to 2-fold in the fall low-flow period (predicted concentrations for alternatives range from 32 to 41ug/l). However, based on available toxicological data, the spring and fall exceedences under these alternatives are not expected to adversely impact the aquatic community in Railroad Creek.

- **Dissolved Copper –** Implementation of alternatives which include West Area water treatment (Alternatives 3, 5, 6, 7, and 8) are predicted to significantly reduce dissolved copper concentrations at stations adjacent to and downstream of the portal and tailings piles. Under all of these alternatives, slight exceedences of the potential NRWQC of approximately 1.8 ug/l (depending upon hardness) may occur during the spring flush (predicted concentrations for these alternatives range from 2.2 to 3.6 ug/l) and no exceedences are anticipated during the fall low-flow period. Based on available toxicological data, the spring flush exceedences are not expected to adversely impact the aquatic community in Railroad Creek, including salmonids or their food supply. If any impacts were to occur, it is expected that very few species would be affected, the effects would be sub-lethal (i.e., causing reduced growth or reproduction, but not causing death), and the affected area would be localized adjacent to the site.

- **Dissolved Cadmium –** Implementation of alternatives which include West Area water treatment (Alternatives 3, 5, 6, 7, and 8) are predicted to significantly reduce dissolved cadmium concentrations at stations adjacent to and downstream of the portal and tailings piles. Slight exceedences of the potential NRWQC of approximately 0.07 ug/l (depending upon hardness) may occur in the short-term during both the spring flush (predicted concentrations for alternatives range from 0.09 to 0.17 ug/l) and the fall low-flow period (predicted concentrations for alternatives range from 0.05 to 0.16 ug/l). Based on available toxicological data, the spring and fall exceedences are not expected to adversely impact the aquatic community, including salmonids or their food supply.

  Implementation of Alternatives 2 and 4, which do not include any West Area water treatment, are predicted to result in dissolved cadmium concentrations that exceed the potential NRWQC for cadmium (0.07 ug/l) by up to 7-fold in the spring flush (predicted concentrations for these alternatives range from 0.24 to 0.47 ug/l) and up to 3-fold in the fall low-flow period (predicted concentrations for these alternatives range from 0.09 to 0.24 ug/l). However, based on available toxicological data, the spring and fall exceedences are not expected to adversely impact the aquatic community in Railroad Creek.

- **Total Iron –** Since the post-remediation loading analysis was not established for evaluating total metals, there is no quantitative prediction as to whether the potential NWRQC for total iron of 1,000 ug/l would be exceeded during either the spring flush or the fall low-flow period. All of the alternatives would be expected to reduce iron concentrations below current levels. However, based on pre-remediation concentrations (which are over-estimates of post-remediation conditions), it is possible that exceedences of the iron criterion could occur during low-flow periods (observed concentrations as high as 2,250 ug/l) under some alternatives. Based on available toxicological data, these exceedences are not expected to adversely impact the aquatic community, including salmonids or their food supply. This conclusion applies to all remediation alternatives.

- **Total Aluminum -** Since the post-remediation loading analysis was not established for the evaluation of total metals, there is no quantitative prediction as to whether the potential NRWQC for total aluminum of 87 ug/l would be exceeded in the short-term during either the spring flush or the fall low-flow period. However, based on pre-remediation concentrations, it is possible that exceedences of the aluminum criterion could occur during both the spring flush period (observed concentrations as high as 250 ug/l) and the fall low-flow period (observed concentrations as high as 160 ug/l). Based on available toxicological data, these exceedences are not expected to adversely impact the aquatic community, including salmonids or their food supply. This conclusion applies to all remediation alternatives.

2. APPROACH

The general approach taken in this assessment is to evaluate each metal separately. Due to the unknown manner in which these metals interact, this metal-by-metal approach is the one taken by USEPA in the development of national ambient water quality criteria. In this document, for each metal, the assessment of potential impact to aquatic life in Railroad Creek is accomplished using the following five step procedure:

1. For each remediation alternative, estimates are made of pre-remediation and post-remediation concentrations at two locations in Railroad Creek (i.e., RC-4 and downstream of RC-2). Station RC-4 is downstream of the portal releases but immediately upstream of the tailings piles. Station RC-2 is immediately downstream of the tailings piles. The estimates associated with the location immediately downstream of RC-2 should be the highest concentrations in Railroad Creek because this station is immediately downstream of both the portal releases and the tailings piles and dilution from tributaries can be expected to reduce metal concentrations at stations further downstream. The estimated pre-remediation concentrations are based on actual measurements made at the stations in May and September of 1997. Historical Railroad Creek data are provided in Section 2 of the Draft Final Feasibility Study (DFFS) report. For copper, zinc, and cadmium, post-remediation concentrations are based on computer assisted mathematical loading analyses performed by URS. The post-remediation loading analysis is summarized in Section 7 of the DFFS. No such analyses are available for iron and aluminum and, therefore, it is conservatively assumed in this evaluation that post-remediation concentrations for these metals will be the same as pre-remediation concentrations.

2. For each remediation alternative, predicted post-remediation concentrations are compared to potential water quality criteria to determine if concentrations in Railroad Creek are expected to exceed the objectives and, if so, during which time of year and by how much. For the purposes of this evaluation, the estimated short-term post-remediation concentrations are compared to the NRWQC. The NRWQC[1] established for cadmium and copper are more stringent than other potential requirements evaluated for site surface

[1] This memorandum does not address the question whether the NRWQC are relevant and appropriate, which is discussed elsewhere by Intalco.

water and there are no other potential requirements established for aluminum and iron. The NRWQC for zinc is slightly higher than the Washington State water quality criteria (SWQC). However, the difference in the two values does not alter any of the conclusions reached in this document. All evaluations considered both the NRWQC and the SWQC and, merely for convenience, only the NRWQC is discussed throughout this document. It should be pointed out, that for copper, cadmium, and zinc, the NRWQC is hardness-dependent, with the criterion decreasing with decreasing hardness. However, at low hardnesses like those observed in Railroad Creek (i.e., 12 – 15 mg/l), these hardness corrections tend to produce overly-conservative criteria that over-estimate the toxicity of the metals.

3. The available toxicological literature is reviewed to determine the range of sensitivities that species in a natural aquatic community would be expected to exhibit when exposed to the metal under consideration. The primary sources of these sensitivity values are the USEPA ambient water quality criteria documents. The use of these datasets is particularly relevant because they are the basis of the potential criteria.

4. For each remediation alternative, the predicted post-remediation metal concentrations are compared against the toxicological database to estimate which species, if any, will potentially be impacted by the predicted exceedences. In order to be conservative, all of the toxicity data included in Tables 2, 3, 5, 6, 8, and 12 were adjusted based on EPA's hardness adjustment equations for each of the criteria. These adjustments were made so that the toxicity values presented in the tables are theoretically appropriate for the hardnesses observed in Railroad Creek . However, as indicated above, these hardness corrections tend to over-estimate the toxicity at low hardness values. The durations of the predicted exceedences are not precisely known, but are expected to last for at least several days. Therefore, estimates of the chronic sensitivity of aquatic species are used in this evaluation. When available, two sets of estimates of chronic sensitivities are presented. The first set is based on the results of chronic bioassay tests as reported in each of the appropriate national ambient water quality criteria documents (generally Table 2 of these documents). The second set is based on the results of acute bioassay tests as reported in the water quality criteria documents (generally Tables 1 and 3 of these documents). These acute values are converted to estimated chronic values by use of the final acute-to-chronic ratio (i.e., ACR) that is also reported in each of the criteria documents. The first set of estimates is the most pertinent because it is based on the results of actual chronic tests. The second set of estimates is somewhat less accurate because it presents estimates of chronic sensitivities based on the results of acute tests. It is included because it significantly increases the number of species that can be considered in the assessment and, therefore, permits a more wide-ranging evaluation of potential community-level impacts.

5. Conclusions as to the ecological significance of the predicted exceedences are made based on the number and type of species that have reported chronic sensitivities less than the predicted exposure concentrations. It should be pointed out that these conclusions are expected to be conservative because they do not take into consideration acclimation of resident organisms to the metals of concern. It is well established that, in nature, aquatic

organisms physiologically adapt to ambient metal concentrations and, consequently, are less sensitive to these metals than would be expected based on the laboratory-derived values presented in the water quality criteria documents. The sensitivities reported in the criteria documents are based on experiments using naïve animals which have not had the opportunity to develop any physiological protection.

3. ASSESSMENT OF ZINC IMPACTS

Estimated Pre-Remediation Concentrations - Based on historical data, the pre-remediation concentrations of dissolved zinc in Railroad Creek have been shown to significantly exceed the potential water quality criterion for zinc during the spring flush and come close to, but not exceed this criterion at other times of the year. This is illustrated in Table 1, in which the potential NRWQC for zinc (adjusted for hardness) is compared against dissolved concentrations of zinc that were measured in Railroad Creek in May 1997 (spring flush) and in September 1997 (low flow). These comparisons show that:

- During the spring flush (May 1997), the measured concentration of dissolved zinc was 73 ug/l at RC-4 and 84 ug/l at RC-2. These pre-remediation concentrations are more than three times greater than the NRWQC for these two locations – i.e., 21 and 23.7 ug/l, respectively. The difference in the criterion for stations RC-4 and RC-2 is due to slight differences in water hardness at the two sites.

- During the fall low-flow period (September 1997), the measured concentration of dissolved zinc was 11 ug/l at RC-4 and 23 ug/l at RC-2. These pre-remediation concentrations are less than the NRWQC for the two sites of 19.6 ug/l and 23.7 ug/l, respectively.

Predicted Post-Remediation Concentrations - Based on the output of the URS post-remediation loading analysis, concentrations of dissolved zinc are expected to vary depending upon the selected remediation alternative. The predicted concentrations, by alternative, are summarized in Table 1 and further described below:

- Implementation of Alternatives 2 and 4 are predicted to have, in the short-term, moderate impact on dissolved zinc concentrations in the spring and would potentially result in increased concentrations in the fall. During the spring flush, dissolved zinc concentrations are predicted to exceed the zinc criterion by 2 to 3 fold, with the highest concentration predicted to be 76 ug/l at RC-2 under Alternative 2a. During the fall low-flow period, the exceedences would potentially approach 1.5 times the criterion, with the highest concentration predicted to be 41 ug/l at RC-2 under Alternative 2b.

- Implementation of Alternatives 3, 5, 6, 7, and 8 (all of which include some West Area water treatment) would result, in the short-term, in significant reductions in dissolved zinc concentrations in both the spring and fall at both RC-4 and RC-2. Slight exceedences of the potential zinc criterion are predicted to occur in the short term only during the spring and only under Alternative 3 (i.e., no exceedences under Alternatives 5, 6, 7 or 8). Under Alternative 3a, the highest dissolved concentration of zinc at RC-2 is predicted to be 27 ug/l. During the fall, the model results indicate that the potential zinc criteria would be met under all of these alternatives.

Ecological Significance of Implementing Alternatives 3, 5, 6, 7, and 8 - A comparison of the predicted dissolved zinc concentrations in Railroad Creek (Table 1) and the expected sensitivities of aquatic organisms to zinc (Tables 2 and 3) indicates that the slight exceedences of the potential zinc criterion predicted for the spring flush under Alternative 3 would cause no impact on aquatic life in Railroad Creek. The toxicological data presented in Tables 2 and 3 come from the 1987 zinc criteria document (USEPA 1987) and the 1995 criteria updates (USEPA 1996). During the spring flush, the highest concentration of dissolved zinc in the creek, under Alternative 3, would occur immediately downstream of RC-2 and would be approximately 27 ug/l. The toxicological data presented in Tables 2 and 3 indicate that most, if not all, species resident in Railroad Creek, including salmonids, would not be adversely impacted if exposed to 27 ug/l of dissolved zinc at a hardness value of 15 ppm. Specifically:

- Based on the available chronic bioassay data (as presented in Table 2), only two of the nine species tested (i.e., the cladoceran, *Dapnia magna*, and the flagfish, *Jordanella floridae*) would be sufficiently sensitive to be potentially impacted by chronic exposure to 27 ug/l of dissolved zinc. However, based on a review of the probability of sensitive species being present in Railroad Creek (Attachment H-1), neither of these species, or closely related species, are part of the Railroad Creek aquatic community. All of the other species tested, including 4 species of salmonid, are less sensitive to zinc and, consequently would not be expected to suffer adverse impacts.

- Based on the available acute bioassay data divided by the final ACR (as presented in Table 3), only 2 species of the 44 species tested would be sufficiently sensitive to zinc to be potentially impacted by the predicted exposure. These two species are a cladoceran, *Ceriodaphnia reticulate*, and the striped bass, *Morone saxatilis*. As indicated in Attachment H-1, neither of these species, or closely related species, are part of the Railroad Creek aquatic community and, consequently, their sensitivity to zinc has little relevance to this assessment. This data set indicates that not only are most species tolerant of the predicted exposure concentrations, but that these tolerant species represent a large range of taxomonic diversity, including 6 salmonid species, 15 other fish species, and 20 invertebrate species.

In summary, the available toxicological data (Tables 2 and 3) coupled with species distribution patterns (Attachment H-1) indicate no impacts to aquatic life in Railroad Creek due to the predicted exceedences of the potential zinc criterion under Alternatives 3, 5, 6, 7, and 8. None of the 45 species tested would be expected to suffer acute toxicity effects and only 4 species would have the potential to suffer chronic effects. However, none of these 4 species, or their close relatives, is naturally present in Railroad Creek. Therefore, there is no evidence that aquatic species in Railroad Creek, including salmonids and their prey, are at risk from the predicted post-remediation zinc concentrations under any of the alternatives that include West Area water treatment. In addition, the criteria are conservative because they do not consider acclimation, which would tend to increase the tolerance of the resident species.

Ecological Significance of Implementing Alternatives 2 and 4 - A comparison of the predicted mean dissolved zinc concentrations in Railroad Creek (Table 1) and the expected sensitivities of aquatic organisms to zinc (Tables 2 and 3) indicates that the exceedences of the potential zinc criteria predicted under Alternatives 2 and 4 would also cause no significant impact to the aquatic community in Railroad Creek. During the spring flush, the highest concentration of dissolved zinc in the creek at RC-2 is predicted to be 76 ug/l under Alternative 2a. During the fall low-flow period, the highest concentration of dissolved zinc in the creek at RC-2 is predicted to be 41 ug/l under Alternative 2b. The toxicological data presented in Tables 2 and 3 indicate that most, if not all, species resident in Railroad Creek, including salmonids, would not be adversely impacted if exposed to either 41 ug/l or 76 ug/l of dissolved zinc. Specifically:

- Based on the available chronic bioassay data (as presented in Table 2), three of the nine species tested (i.e., the cladoceran, *Dapnia magna*, the flagfish, *Jordanella floridae*, and the minnow, *Pimephales promelas*) would be sufficiently sensitive to be potentially impacted by chronic exposure to either 41 ug/l or 76 ug/l of dissolved zinc. However, as indicated in Attachment H-1, none of these species, or closely related species, is part of the Railroad Creek aquatic community. All of the other species tested, including 4 species of salmonid, are less sensitive to zinc and, consequently would not be expected to suffer adverse impacts.

- Based on the available acute bioassay data divided by the final ACR (as presented in Table 3), 6 species of the 44 species tested would be sufficiently sensitive to zinc to be potentially impacted by exposure to 76 ug/l. These six species include four cladocerans (*Ceriodaphnia reticulate*, *Ceriodaphnia dubia*, *Dapnia pulex, and Daphnia magna*), the striped bass, *Morone saxatilis*, and the longfin dace, *Agosia chrysogaster*. This number reduces to 4 (i.e., *D. magna* and D. pulex are eliminated), if the exposure does not exceed 41 ug/l. As indicated in Attachment H-1, none of these species is part of the Railroad Creek aquatic community and only the longfin dace, with an estimated chronic value of 40.6 ug/l, has closely related species that might be present in Railroad Creek. Consequently, the sensitivities of five of the six species have little relevance to this assessment. The available data set indicates that not only are most species tolerant of the predicted exposure concentrations, but that these tolerant species represent a large range of taxomonic diversity, including 6 salmonid species, 14 other fish species, and 17 invertebrate species.

In summary, the available toxicological data (Tables 2 and 3) coupled with species distribution patterns (Attachment H-1) indicate that any impacts to aquatic life in Railroad Creek due to the predicted exceedences of the potential zinc criterion under Alternatives 2 and 4 would not significantly impact the aquatic community. None of the 45 species tested would be expected to suffer acute toxicity effects and only 8 species would have the potential to suffer chronic effects. However, none of these 8 species is naturally present in Railroad Creek and only one species (i.e., the longfin dace) has close relatives which might occur in the creek. Therefore, only 1 of the 45 tested taxa (i.e., 2.2%) might have a species present in Railroad Creek that is sensitive enough to dissolved zinc to potentially suffer an impact. In addition, as stated previously, the criteria are conservative because they do not consider acclimation, which would tend to increase the tolerance of the resident species. If any minor impact were to occur (i.e., to the one taxa discussed above), it would be expected to be localized near RC-2, with dilution from tributaries reducing the exposure concentrations at sites further downstream in Railroad Creek. This potential level of impact is within the range considered acceptable by USEPA in the national ambient water quality criteria documents (USEPA 1985b), where it is stated that the criteria are designed to provide less than full protection to the most sensitive species and, consequently, set the criteria at a value that should protect 95% of the resident species.

4. ASSESSMENT OF POTENTIAL COPPER IMPACTS

Estimated Pre-Remediation Concentrations - Based on historical data, the pre-remediation concentrations of dissolved copper in Railroad Creek have been shown to exceed the potential water quality criterion for copper during the spring flush and only slightly exceed this criterion at other times of the year. This is illustrated in Table 4, in which the potential water quality criterion for copper (adjusted for hardness) is compared against dissolved concentrations of copper that were measured in Railroad Creek in May 1997 (spring flush) and in September 1997 (low flow). These comparisons show that:

- During the spring flush (May 1997), the measured concentration of dissolved copper was 26.4 ug/l at RC-4 and 23.6 ug/l at RC-2. These pre-remediation concentrations are more than an order of magnitude greater than the chronic NRWQC for these two locations – i.e., 1.6 and 1.8 ug/l, respectively. The difference in the criterion at stations RC-4 and RC-2 is due to slight differences in water hardness at the two sites.

- During the fall low-flow period (September 1997), the measured concentration of dissolved copper was 1.8 ug/l at RC-4 and 1.2 ug/l at RC-2. These pre-remediation concentrations are very close to or less than the chronic NRWQC for the two sites of 1.5 ug/l and 1.8 ug/l, respectively.

Predicted Post-Remediation Concentrations - Based on the output of the URS post-remediation loading analysis, concentrations of dissolved copper are expected to vary depending upon the selected remediation alternative. The predicted concentrations, by alternative, are summarized in Table 4 and further described below:

- Implementation of Alternatives 2 and 4 are predicted to have little impact, in the short-term, on dissolved copper concentrations in the spring and would potentially result in increased concentrations in the fall. Based on the URS loading analysis, during both of these periods, the potential NRWQC for copper would be significantly exceeded at both RC-4 and RC-2. At RC-2, the highest concentration of dissolved copper is predicted to be 21.5 ug/l under Alternative 2a.

- Implementation of Alternatives 3, 5, 6, 7, and 8 (all of which include some West Area water treatment) would, in the short-term, result in significant reductions in dissolved copper concentrations in both the spring and fall. Results of the loading analysis indicate a potential for slight exceedences of the NRWQC only during the spring at both RC-4 and RC-2. These exceedences would occur under all alternatives, with the highest concentration of dissolved copper at RC-2 predicted to be 3.6 ug/l under Alternative 3a. During the fall, the model results indicate that the potential criterion for copper would be met under all of the alternatives.

Ecological Significance of Implementing Alternatives 3, 5, 6, 7, and 8 - A comparison of the predicted dissolved copper concentrations in Railroad Creek (Table 4) and the expected sensitivities of aquatic organisms to copper (Tables 5 and 6) indicates that the slight exceedences of the potential copper water quality criterion predicted for the spring flush under Alternatives 3, 5, 6, 7, and 8 would cause little, if any, impact on aquatic life in Railroad Creek. The toxicological data presented in Tables 5 and 6 come from the 1984 copper criteria document (USEPA 1985a) and the 1995 criteria updates (USEPA 1996). During the spring flush, the highest short-term concentration of dissolved copper in the creek is predicted to be 3.6 ug/l (under Alternative 3a) and would occur immediately downstream of RC-2. For the other alternatives, the concentrations were predicted to be lower, ranging from 2.2 to 3.4 ug/l. The toxicological data presented in Tables 5 and 6 indicate that most, if not all, species resident in Railroad Creek, including the salmonids, would not be adversely impacted if exposed to this highest predicted concentration. Specifically:

- Based on the available chronic bioassay data (as presented in Table 5), only three of the fourteen species tested (i.e., the amphipod *Gammarus pseudolimnaeus*, the snail, *Physa integra*, and the snail *Campeloma decisum*) would be sufficiently sensitive to be potentially impacted by chronic exposure to 3.6 ug/l of dissolved copper at a hardness value of 15 ppm as measured at RC-2. The other species, including 5 species of salmonid, have sufficiently high tolerances to copper so that adverse impacts would not be expected. The predicted impact to the two snail species would only occur under Alternative 3a. For *Gammarus*, all alternatives which include West Area treatment are predicted to produce dissolved copper concentrations at RC-2 that could be slightly chronically toxic. However, based on the information provided in Attachment H-1, none of the three sensitive species would be expected to be found in Railroad Creek. In addition, only for *Physa integra* is it probable that a closely related species could be present in the creek.

- Based on the available acute bioassay data divided by the final ACR (as presented in Table 6), only 6 species of the 56 species tested would be sufficiently sensitive to copper to be potentially impacted by the predicted exposure. These six include 4 daphnid species, a northern pikeminnow (*Ptychocheilus oregonensis*), and the amphipod (*Gammarus pseudolimnaeus*). Daphnids do not live in fast-flowing streams and, consequently, their high sensitivity to copper is not relevant to Railroad Creek. In addition, neither the amphipod nor any closely related species are expected to be members of the Railroad Creek aquatic community (see Attachment H-1). However, there is some evidence that the northern pikeminnow may periodically be present in Railroad Creek downstream of the waterfall located near the mouth at Lake Chelan. Post-remediation copper concentrations at this location (Station RC-3) are expected to be significantly lower than at RC-2 based on historical monitoring data. This data set indicates that not only are most species tolerant of the predicted exposure concentrations, but that these tolerant species represent a large range of taxomonic diversity, including 7 salmonid species, 22 other fish species, and 21 invertebrate species.

In summary, the available toxicological data (Tables 5 and 6) coupled with species distribution patterns (Attachment H-1) indicate that any impacts to aquatic life in Railroad Creek due to the predicted exceedences of the potential copper criterion would not significantly impact the aquatic community. None of the 62 species tested would be expected to suffer acute toxicity effects and only 8 species would have the potential to suffer chronic effects. However, only one of these 8 species (*Ptychocheilus oregonensis*) may be naturally present in Railroad Creek and only one species (*Physa integra*) has close relatives which might occur in the creek. Therefore, only 2 of the 62 taxa tested (i.e., 3.2%) might either be present or related to a species which may be present in Railroad Creek that are sensitive enough to dissolved copper to potentially suffer an impact. Neither of these two species is expected to be a major prey item of salmonids in Railroad Creek. Any young northern pikeminnows would be limited to a very small area near the mouth of Railroad Creek and even if present, would not likely be consumed by salmonids of the size observed in Railroad Creek. Physa sp., if consumed by salmonids, would be a minor component of the available invertebrate fauna. In addition, as stated previously, the criteria are conservative because they do not consider acclimation, which would tend to increase the tolerance of the resident species. If any minor impact were to occur (i.e., to the two taxa discussed above), it would be expected to be localized adjacent to the site, with dilution from tributaries reducing the exposure concentrations at sites further downstream in Railroad Creek. The vast majority of species, including salmonids and their prey are not at risk from the predicted post-remediation copper concentrations. Consequently, the potential level of impact associated with the predicted copper exceedences is within the range considered acceptable by USEPA in the national ambient water quality criteria documents (USEPA 1985b), where it is stated that the criteria are designed to provide less than full protection to the most sensitive species and, consequently, set the criteria at a value that should protect 95% of the resident species.

5. ASSESSMENT OF CADMIUM IMPACTS

Estimated Pre-Remediation Concentrations - Based on historical data, the pre-remediation concentrations of dissolved cadmium in Railroad Creek have been shown to significantly exceed the potential water quality criterion for cadmium during the spring flush and only slightly exceed the potential criterion at other times of the year. This is illustrated in Table 7, in which the potential criterion for cadmium (adjusted for hardness) is compared against dissolved concentrations of cadmium that were measured in Railroad Creek in May 1997 (spring flush) and in September 1997 (low flow). These comparisons show that:

- During the spring flush (May 1997), the measured concentration of dissolved cadmium was 0.44 ug/l at RC-4 and 0.53 ug/l at RC-2. These pre-remediation concentrations are more than seven times greater than the chronic NRWQC for these two locations – i.e., 0.06 and 0.07 ug/l, respectively. The difference in the criterion at stations RC-4 and RC-2 is due to slight differences in water hardness at the two sites.

- During the fall low-flow period (September 1997), the measured concentration of dissolved cadmium was 0.06 ug/l at RC-4 and 0.10 ug/l at RC-2. These pre-remediation concentrations are very close to the chronic NRWQC for the two sites of 0.06 ug/l and 0.07 ug/l, respectively.

Predicted Post-Remediation Concentrations - Based on the output of the URS post-remediation loading analysis, concentrations of dissolved cadmium are expected to vary depending upon the selected remediation alternative. The predicted concentrations, by alternative, are summarized in Table 7 and further described below:

- Implementation of Alternatives 2 and 4 are predicted, in the short-term, to moderately reduce dissolved cadmium concentrations in the spring and potentially result in slightly increased concentrations in the fall. Based on the URS loading analysis, the potential cadmium criterion would be exceeded in the spring flush by up to 6-fold, with the highest concentration of dissolved cadmium predicted to be 0.47 ug/l at RC-2 under Alternative 2a. During the fall low-flow period, the potential criterion is predicted to be exceeded by up to 3 times, with the highest concentration predicted to be 0.24 ug/l at RC-2 under Alternative 4c.

- Implementation of Alternatives 3, 5, 6, 7, and 8 (all of which include some West Area treatment) would result, in the short-term, in reductions in dissolved cadmium concentrations in the spring and potentially result in slightly increased concentrations in the fall. Slight exceedences of the potential cadmium criterion are predicted to occur under all these alternatives during one or both periods. The magnitude of the exceedences would be up to 2-fold during both spring and fall. The highest short-term concentration of dissolved cadmium is predicted, in the spring flush, to be 0.17 ug/l at RC-2 under Alternative 3a and, in the fall low-flow period, to be 0.16 ug/l at RC-2 under Alternative 6.

Ecological Significance of Implementing Alternatives 3, 5, 6, 7, and 8 - A comparison of the predicted dissolved cadmium concentrations in Railroad Creek (Table 7) and the expected sensitivities of aquatic organisms to cadmium (Table 8) suggests that the exceedences of the potential NRWQC for cadmium (predicted for the spring flush under Alternatives 3, 5, 6, 7, and 8 and for the fall under Alternatives 3, 5, 6, and 7) would cause no impact on aquatic life in Railroad Creek. The toxicological data presented in Table 8 come from the 1984 cadmium criteria document (USEPA 1985c), the 1995 criteria updates (USEPA 1996), and the 2001 update of the cadmium criteria document (USEPA 2001). During the spring and fall periods, the highest short-term concentrations of dissolved cadmium in the creek would be expected to occur immediately downstream of RC-2 and are predicted to be 0.17 ug/l and 0.16 ug/l, respectively. The toxicological data presented in Table 8 indicate that most, if not all, species resident in Railroad Creek, including salmonids, would not be adversely impacted if exposed to 0.17 ug/l of dissolved cadmium. Specifically:

- Based on the available chronic bioassay data (as presented in Table 8), only 2 of the 21 species tested (i.e., the amphipod, *Hyalella azteca*, and the cladoceran, *Daphnia magna*) would be sufficiently sensitive to be potentially impacted by chronic exposure to 0.16

ug/l or 0.17 ug/l of dissolved cadmium. However, as indicated in Attachment H-1, neither of these species, or closely related species, are part of the Railroad Creek aquatic community and, consequently, their high sensitivity is not relevant to Railroad Creek. The data set indicates that not only are most species tolerant of the predicted exposure concentrations, but that these tolerant species represent a large range of taxomonic diversity, including 7 species of salmonid, 7 other fish species, and 5 invertebrate species.

- Acute bioassay data were not considered in this evaluation of cadmium impacts because of the lack of a suitable final ACR. The 2001 cadmium criteria document supports this approach and states "These ratios (i.e., ACRs) do not seem to follow any of the patterns recommended in the Guidelines, and so it does not seem reasonable to use a freshwater Final Acute-to-Chronic Ratio to calculate a Final Chronic Value".

In summary, the available toxicological data (Table 8) coupled with species distribution patterns (Attachment H-1) indicate no impacts to aquatic life in Railroad Creek due to the predicted exceedences of the potential cadmium water quality criterion in both the spring and the fall . None of the 21 species tested would be expected to suffer acute toxicity effects and only 2 species would have the potential to suffer chronic effects. However, neither of these species, or their close relatives, is naturally present in Railroad Creek. Therefore, there is no evidence that aquatic species in Railroad Creek, including salmonids and their prey, are at risk from predicted post-remediation cadmium concentrations under any of the alternatives that include West Area water treatment. In addition, as stated previously, the criteria are conservative because they do not consider acclimation, which would tend to increase the tolerance of the resident species

Ecological Significance of Implementing Alternatives 2 and 4 - A comparison of the predicted dissolved cadmium concentrations in Railroad Creek (Table 7) and the expected sensitivities of aquatic organisms to cadmium (Table 8) suggests that the exceedences of the potential NRWQC for cadmium predicted under Alternatives 2 and 4 would also cause no impact on aquatic life in Railroad Creek. During the spring flush, the highest concentration of dissolved cadmium in the creek at RC-2 is predicted to be 0.47 ug/l under Alternative 2a. During the fall low-flow period, the highest concentration is the creek at RC-2 is predicted to be 0.24 under Alternative 4c. The toxicological data presented in Table 8 indicate that most, if not all, species resident in Railroad Creek, including salmonids, would not be adversely impacted if exposed to either 0.24 ug/l or 0.47 ug/l of dissolved cadmium. Specifically:

- Based on the available chronic bioassay data (as presented in Table 8), only 2 of the 21 species tested (i.e., the amphipod, *Hyalella azteca*, and the cladoceran, *Daphnia magna*) would be sufficiently sensitive to be potentially impacted by chronic exposure to 0.24 ug/l or 0.47 ug/l of dissolved cadmium. However, as indicated in Attachment H-1, neither of these species, or closely related species, are part of the Railroad Creek aquatic community and, consequently, their high sensitivity is not relevant to Railroad Creek. The data set indicates that not only are most species tolerant of the predicted exposure concentrations, but that these tolerant species represent a large range of taxomonic diversity, including 7 species of salmonid, 7 other fish species, and 5 invertebrate species.

In summary, the available toxicological data (Table 8) coupled with species distribution patterns (Attachment H-1) indicate no impacts to aquatic life in Railroad Creek due to the predicted exceedences of the potential cadmium water quality criterion under Alternatives 2 and 4 in both the spring and the fall . None of the 21 species tested would be expected to suffer acute toxicity effects and only 2 species would have the potential to suffer chronic effects. However, neither of these species, or their close relatives, is naturally present in Railroad Creek. Therefore, there is no evidence that aquatic species in Railroad Creek, including salmonids and their prey, are at risk from predicted post-remediation cadmium concentrations under any of the alternatives that include West Area water treatment. In addition, as stated previously, the criteria are conservative because they do not consider acclimation, which would tend to increase the tolerance of the resident species.

6. ASSESSMENT OF IRON IMPACTS

Estimated Pre-Remediation Concentrations - Based on historical data, the pre-remediation concentrations of total iron in Railroad Creek have been shown to meet the potential water quality criterion for iron during the spring flush and to exceed this criterion during the fall low-flow period. This is illustrated in Table 9, in which the water quality objective for iron (which does not have a hardness adjustment) is compared against total and dissolved concentrations of iron that were measured in Railroad Creek during the spring flush and low-flow conditions between 1997 and 2003. These comparisons show that:

- During the spring flush, the measured concentrations of total iron ranged from 60 to 170 ug/l at RC-4 and from 300 to 960 ug/l at RC-2. For both stations, all of the measured concentrations are less than the iron criterion.

- During the low-flow period, the measured concentration of total iron ranged from 50 to 90 ug/l at RC-4 and from 1,280 to 2,250 at RC-2. The highest of the measured concentrations at RC-4 are less than the iron criterion. The entire range of values measured at RC-2 exceed the potential water quality criterion of 1,000 ug/l by up to more than 2-fold.

Predicted Post-Remediation Concentrations – Since the URS loading analysis was not established for evaluating total metals, there are no quantitative predictions as to the post-remediation concentrations of total iron associated with each of the remediation alternatives. For all of the remediation alternatives, it is anticipated that the resulting concentrations of total iron at RC-2 and further downstream would be lower than those observed during the pre-remediation period. This assumption is supported by predictions made in the post-remediation loading analysis which indicates that dissolved concentrations of iron at RC-2 are expected to decrease in most of the remediation alternatives. As illustrated in Table 10, implementation of Alternatives 4, 5, 6, 7, and 8 is predicted to reduce dissolved iron concentrations RC-2 during both the spring flush and the fall low-flow period. However, without quantitative modeling results, the magnitude of the reductions in total iron concentrations in Railroad Creek cannot be determined. Therefore, it is assumed in this evaluation that the concentration of total iron remains unchanged for each of the alternatives.

Ecological Significance of Implementing Any of the Alternatives - Based on the conservative assumption that post-remediation concentrations of total iron are the same as pre-remediation concentrations, it is probable that the NRWQC for iron of 1,000 ug/l (as total iron) would be exceeded during the low-flow period. In order to understand the potential significance of the anticipated exceedences, it is necessary to understand the basis of the criterion and its limitations. There is no national ambient water quality criteria document for iron from which to obtain data related to the chronic sensitivity of aquatic species to iron. The iron criterion was developed by USEPA in 1976 (EPA 1976) and was based primarily on field data, which are not relevant to Railroad Creek. A review of the toxicological literature indicates that the toxicity of iron to aquatic organisms is governed by the effects of iron floc rather than by dissolved iron. In addition, after the initial formation of the iron floc, it rapidly becomes less toxic to fish and invertebrates because of changes in the floc's physical structure. Taking these factors into consideration, the scientific literature indicates that in Railroad Creek, a water quality criterion for iron of between 3 and 6 ppm would be protective of salmonids and their invertebrate food supply. The significant toxicological data supporting this safe concentration range can be summarized as follows:

- For salmonids in Railroad Creek, the scientific literature suggests that a protective concentration of iron from prolonged exposure (i.e., 30 days to 2 years) is between 3 and 6 ppm. In 35-week and 2-year studies on brook trout exposed to iron floc (Sykora et al. 1972 and Sykora et al. 1975, respectively), it was demonstrated that brook trout do not suffer reduced survival, growth, or egg hatchability at concentrations less than 12 ppm. Rainbow trout appear to have a similar level of sensitivity. In fish farms in Germany, it was reported that rainbow trout exhibited good survival and growth when the total iron content in the water was between 5 and 10 ppm as long as the pH was circumneutral or slightly alkaline and the dissolved oxygen remained higher than 5 mg/l (Steffins et al. 1993). Fertilized eggs of coho salmon and brook trout, exposed for approximately 45 days, exhibited no reduction in hatchability at 12 ppm iron floc, which was the highest concentration tested (Smith & Sykora 1976). In the same study, when exposed for 30, 60 and 90 days, coho salmon juveniles suffered reduced survival and growth in 6 ppm iron floc, but were not adversely affected in a 3 ppm solution (Smith & Sykora 1976). Smith et al. (1973) suggest that fish species that "live in cool, fast-flowing, spring-fed streams, where iron is more common and remains in suspension for longer periods" are more resistant to the toxicological effects of iron floc than are other species of fish.

- For invertebrates likely to be found in Railroad Creek, the scientific literature suggests a wide range of sensitivities to iron, with a protective level of approximately 5 ppm for the most sensitive species and a much higher level for the majority of species. Daphnids, which are not residents of fast-flowing streams such as Railroad Creek, are apparently the most sensitive aquatic invertebrates to iron. However, even for daphnids, under conditions found in Railroad Creek, a 3-week exposure resulted in a LOEC (i.e., lowest observed effect concentration) for reproduction of 4.38 ppm and a LC50 for survival of 5.9 ppm (Biesinger and Christensen 1972, Dave 1984). Other stream invertebrate species have been shown to be considerably less sensitive, with the mayfly, *Leptophlebia marginata*, exhibiting no reduction in survival when exposed for 30 days at 40 ppm

(Gerhardt 1995). Warnick & Bell (1969) reported 7-day and 9-day LC50s of 16 ppm for a caddisfly, *Hydropsyche betteni*, and a stonefly, *Acroneuria lycorias*, respectively.

In summary, the exceedences of the potential iron water quality criterion predicted for the low-flow period are not expected to cause any impact on aquatic life in Railroad Creek. During this period, the maximum concentration of total iron in the creek would be expected to occur at RC-2 and has been observed to be as high as 2,250 ug/l. As described above, no species resident in Railroad Creek would be expected to be adversely impacted if exposed to these maximum predicted concentrations. All species tested chronically, under physical and chemical conditions similar to those expected in Railroad Creek, had toxicity thresholds greatly in excess of the predicted exposure concentrations.

7. ASSESSMENT OF ALUMINUM IMPACTS

Estimated Pre-Remediation Concentrations - Based on historical data, the pre-remediation concentrations of total aluminum in Railroad Creek have been shown to exceed the potential water quality criteria for aluminum during the spring flush and fall low-flow period. This is illustrated in Table 11, in which the NRWQC for aluminum (which does not have a hardness adjustment) is compared against total and dissolved concentrations of aluminum that were measured in Railroad Creek during the spring flush and low-flow conditions between 1997 and 2003. These comparisons show that:

- During the spring flush, the concentration of total aluminum ranged from 100 to 200 ug/l at RC-4 and from 140 to 250 ug/l at RC-2. For both stations, all measured spring-flush values exceed the potential aluminum criterion of 87ug/l.

- During the fall low-flow period, the concentration of total aluminum ranged from 40 to 50 ug/l at RC-4 and from 90 to 160 ug/l at RC-2. For RC-4, all measured low-flow values met the aluminum criterion of 87 ug/l. At RC-2, all measured total aluminum concentrations exceeded the aluminum criterion.

Predicted Post-Remediation Concentrations - Since the URS loading analysis was not established for evaluating total metals, there are no quantitative predictions as to the post-remediation concentrations of total aluminum associated with each of the remediation alternatives. For all of the remediation alternatives, it is anticipated that the resulting concentrations of total aluminum would be lower than those observed during the pre-remediation period. However, without quantitative modeling results, the magnitude of these reductions cannot be determined. Therefore, it is assumed in this evaluation that the concentration of aluminum remains unchanged for each of the alternatives.

Ecological Significance of Implementing Any of the Alternatives - Based on the conservative assumption that post-remediation concentrations of total aluminum are the same as pre-remediation concentrations, it is probable that the NRWQC for aluminum of 87 ug/l would be routinely exceeded during the spring flush by 2 to 3 times and during the fall low-flow period by up to 2 times. In order to understand the potential significance of the anticipated exceedences, it is necessary to understand the basis of the criterion and its limitations. The ambient water quality criterion for aluminum for chronic exposure is set at 87 ug/l total aluminum (USEPA 1988). This criterion was not established following the normal EPA procedure, but rather was based on the results of two studies using brook trout and striped bass. The application of the normal EPA procedure, which consisted of applying an ACR to the Final Acute Value, came up with a chronic criterion of 748 ug/l. However, this chronic criterion was lowered to 87 ug/l in order to provide additional protection for brook trout and striped bass. This was deemed necessary by USEPA because a 60-day brook trout test indicated that the NOEC was 88 ug/l and the 7-day striped bass test indicated that the NOEC was 87.2 ug/l. Each of these tests was performed under slightly acidic conditions with a pH of 6.5 to 6.6. In a more recent revision of the ambient water quality criteria (USEPA 1999), EPA states that the aluminum chronic criterion may not be appropriate for all ambient waters for the following three major reasons:

- "The value of 87 ug/l is based on a toxicity test with the striped bass in water with pH=6.5-6.6 and hardness <10mg/l. Data in "Aluminum Water Effect Ratio for the 3M Plant Effluent Discharge, Middleway, West Virginia" (May 1994) indicate that aluminum is substantially less toxic at higher pH and hardness, but effects of pH and hardness are not well quantified at this time."

- "In tests with the brook trout at low pH and hardness, effects increased with increasing concentrations of total aluminum even though the concentrations of dissolved aluminum were constant, indicating that total recoverable is a more appropriate measurement than dissolved, at least when particulate aluminum is primarily aluminum hydroxide particles. In surface waters, however, that total recoverable procedure might measure aluminum associated with clay particles, which might be less toxic than aluminum associated with aluminum hydroxide."

- "EPA is aware of field data indicating that many high quality waters in the U.S. contain more than 87 ug aluminum/L, when either total recoverable or dissolved is measured."

The second of the aforementioned exceptions appears relevant to the Railroad Creek situation. Available data, as summarized in Attachment H-2 to this report, indicate that a portion of the aluminum in Railroad Creek downstream of the portals and the tailings piles is associated with particulate matter, and so is not biologically available. Therefore, comparison of measured total concentrations of aluminum against the criterion will tend to over-estimate risk to aquatic organisms in the creek. The aluminum which is found in Railroad Creek downstream of the portal drainage and tailings piles consists of aluminum that emanates from the portal and tailings piles and background aluminum which comes from sources upstream of the site. The aluminum emanating from the portals and tailings piles is expected to be mostly biologically available, consisting of dissolved aluminum and aluminum hydroxide type floc. However, as shown in Table 11, available monitoring data indicate a relatively high background concentration of aluminum and approximately 66% of this background aluminum is associated with rock and clay particles, which is not very biologically available. The mean background concentration of aluminum is predicted to be 86 ug/l total of which 29 ug/l is dissolved. The dissolved fraction of the background aluminum is expected to be a mixture of aluminum hydroxides and the undissolved aluminum fraction is expected to be attached to rock particles (feldspars and micas) and clays (i.e., aluminum silicates). Therefore, 57 ug/l of the background load of aluminum should have low biological availability and, consequently, low toxicity. Considering the form of aluminum in Railroad Creek, the concentration of aluminum which would be safe to the most sensitive species (i.e., brook trout and striped bass), if they were present in Railroad Creek, would be no lower than 144 ug/l (i.e., 87 ug/l, as per the criterion, + 57 ug/l for unavailable background).

Neither brook trout nor striped bass are resident in Railroad Creek and the available data suggest that other species which are resident are less sensitive to aluminum. Data on the sensitivity of aquatic species to aluminum are presented in the 1988 ambient water quality document (see Table 12). Based on these data, rainbow trout are the next most sensitive of the resident species tested. Daphnids are not considered because they do not reside in fast-moving streams. According to these data, rainbow trout are approximately 3 times less sensitive than brook trout. Consequently, a concentration of aluminum which is safe for resident species in Railroad Creek, including rainbow trout and other salmonids, can be set at 3 times the ambient criterion or approximately 260 ug/l. It should be noted that this estimated safe concentration of aluminum is overly conservative because it is primarily based on the sensitivity of the early life-stages of salmonids. Since resident rainbow trout and cutthroat trout do not spawn in Railroad Creek until mid-summer, the sensitive early-life stages are not present in the creek until September or October. At other times of the year, including the spring flush, early life-stage salmonids would not be present and, consequently, the concentration of aluminum which would be safe to the resident biological community would be substantially higher.

In summary, the pre-remediation range of concentrations of total aluminum occurring in Railroad Creek during both the spring flush and fall low-flow period is not expected to be causing adverse impacts to the resident biological community. Since all post-remediation alternatives are expected to decrease aluminum concentrations in Railroad Creek, no impacts to aquatic life in the creek are anticipated under any of the proposed alternatives.

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Table 1. Comparison of Pre-Remediation and Post-Remediation Dissolved Zinc Concentrations with Potential Water Quality Criteria

Location	Time of Year	Expected Hardness (mg/l)	Chronic NRWQC (ug/l)	Pre-Remedy (ug/l)	Predicted Post-Remedy Concentration of Dissolved Zinc (ug/l)														
					Alternative 2		Alternative 3		Alternative 4			Alternative 5				Alternative 6		Altern 7	Altern 8
					2a	2b	3a	3b	4a	4b	4c	5a	5b	5c	5d	6a	6b	7	8
RC-4	Spring	13	**21.0**	73	66	38	15	14	38	38	38	14	14	14	14	15	14	14	13
	Fall	12	**19.6**	11	9	31	5	5	31	31	31	5	5	5	4	4	4	5	4
RC-2*	Spring	15	**23.7**	84	76	50	27	26	47	42	44	23	19	20	20	21	21	20	17
	Fall	15	**23.7**	23	22	41	18	18	38	32	36	15	9	13	12	13	13	11	6

Source: Draft Final Feasibility Study Report (URS 2004) - Section 7

* Note: The estimated post-remediation concentrations are predicted for a point downstream of RC-2 to account for additional groundwater loading contributions from the tailings piles

Table 2. Estimated Minimum Safe Chronic Concentrations of Dissolved Zinc for Freshwater Aquatic Species (based on chronic test results and sorted by species)

Spp Rank	Genus	Species	Spp Chr Value (as Total) Hard = 50 ppm	Est. Species Chronic Values (as Dissolved) Hard = 50 ppm	Hard = 12 ppm	Hard = 13 ppm	Hard = 15 ppm
9	Caddisfly (Clistoronia)	C. magnifica	7,865	7,755	2,319	2,482	2,792
8	Salmonid (Salvelinus)	Brook Trout	915	902	270	289	325
7	Salmonid (Oncorhynchus)	Rainbow Trout	723	713	213	228	257
6	Salmonid (Oncorhynchus)	Chinook Salmon	668	659	197	211	237
5	Salmonid (Oncorhynchus)	Sockeye Salmon	327	322	96	103	116
4	Guppy (Poecilia)	P. reticulata	266	262	78	84	94
3	Minnow (Pimephales)	P. promelas	113	111	33	36	40
2	Cladoceran (Daphnid)	D. magna	51.5	51	15	16	18
1	Flagfish (Jordanella)	J. floridae	40	39	12	13	14

Table 3. Estimated Minimum Safe Chronic Concentrations of Dissolved Zinc for Freshwater Aquatic Species (based on acute LC50s divided by ACR and sorted by species)

Spp Rank	Genus	Species	Spp Acute LC50 (as Total) Hard = 50 ppm	Est. Species Chronic NOEC (LC50÷ACR) (as Dissolved)			
				Hard = 50 ppm	Hard = 12 ppm	Hard = 13 ppm	Hard = 15 ppm
44	Damselfly (Argia)	Argia sp.	88960	43857	13131	14057	15833
43	Amphipod (Crangonyx)	C. pseudogracilis	19800	9761	2923	3129	3524
42	Frog (Xenopus)	X. laevis	19176	9454	2830	3030	3413
41	Fish (Lepomis)	Pumpkinseed	18790	9263	2773	2969	3344
40	Worm (Nais)	Nais sp.	18400	9071	2716	2907	3275
39	Killifish (Fundulus)	F. diaphanus	17940	8844	2648	2835	3193
38	Snail (Amnicola)	Amnicola sp.	16820	8292	2483	2658	2994
37	Eel (Anguilla)	A. rostrata	13630	6720	2012	2154	2426
36	Isopod (Asellus)	A. communis	11610	5724	1714	1835	2066
35	Goldfish (Carassius)	C. auratus	10250	5053	1513	1620	1824
34	Worm (Lumbriculus)	L. variegatus	9712	4788	1434	1535	1729
33	Amphipod (Gammarus)	Gammarus sp.	8100	3993	1196	1280	1442
32	Carp (Cyprinus)	C. carpio	7233	3566	1068	1143	1287
31	Squawfish (Ptychocheilus)	P. oregonensis	6580	3244	971	1040	1171
30	Guppy (Poecilia)	P. reticulata	6053	2984	893	956	1077
29	Shiner (Notemigonus)	N. crysoleucas	6000	2958	886	948	1068
28	Fish (Lepomis)	Bluegill	5937	2927	876	938	1057
27	Isopod (Asellus)	A. bicrenata	5731	2825	846	906	1020
26	Sucker (Catostomus)	C. commersoni	5228	2577	772	826	930
25	Clam (Corbicula)	C. fluminea	4900	2416	723	774	872
24	Platyfish (Xiphophorus)	X. maculatus	4341	2140	641	686	773
23	Minnow (Pimephales)	P. promelas	3830	1888	565	605	682
22	Isopod (Lirceus)	L. alabamae	3265	1610	482	516	581
21	Salmonid (Salvo)	Atlantic Salmon	2176	1073	321	344	387
20	Salmonid (Salvelinus)	Brook Trout	2100	1035	310	332	374
19	Bryozoan (Lophopodella)	L. cateri	1707	842	252	270	304
18	Snail (Physa)	P. gyrina	1683	830	248	266	300
17	Flagfish (Jordanella)	J. floridae	1672	824	247	264	298
16	Salmonid (Oncorhynchus)	Coho Salmon	1628	803	240	257	290
15	Bryozoan (Plumatella)	P. emarginata	1607	792	237	254	286
14	Snail (Helisoma)	H. campanulatum	1578	778	233	249	281
13	Salmonid (Oncorhynchus)	Sockeye Salmon	1502	740	222	237	267
12	Bryozoan (Pectinatella)	P. magnifica	1307	644	193	207	233
11	Tubificid Worm (Limnodrilus)	L. hoffmeisteri	1264	623	187	200	225
10	Snail (Physa)	P. heterostropha	1088	536	161	172	194
9	Tilapia (Tilapia)	T. mossambica	790	389	117	125	141
8	Salmonid (Oncorhynchus)	Rainbow Trout	689	340	102	109	123
7	Salmonid (Oncorhynchus)	Chinook Salmon	446	220	65.8	70.5	79.4
6	Cladoceran (Daphnid)	D. magna	356	176	52.5	56.3	63.4
5	Cladoceran (Daphnid)	D. pulex	253	125	37.3	40.0	45.0
4	Dace (Agosia)	A. chrysogaster	228	112	33.7	36.0	40.6
3	Cladoceran (Ceriodaphnid)	C. dubia	174	85.8	25.7	27.5	31.0
2	Striped Bass (Morone)	M. saxatilis	119	58.7	17.6	18.8	21.2
1	Cladoceran (Ceriodaphnid)	C. reticulata	51	25.0	7.48	8.01	9.02

Table 4. Comparison of Pre-Remediation and Post-Remediation Dissolved Copper Concentrations with Potential Water Quality Criteria

Location	Time of Year	Expected Hardness (mg/l)	Chronic NRWQC (ug/l)	Pre-Remedy (ug/l)	Predicted Post-Remedy Concentration of Dissolved Copper (ug/l)														
					Alternative 2		Alternative 3		Alternative 4			Alternative 5				Alternative 6		Altern 7	Altern 8
					2a	2b	3a	3b	4a	4b	4c	5a	5b	5c	5d	6a	6b	7	8
RC-4	Spring	13	**1.6**	26.4	23.7	22.3	2.3	2.2	22.3	22.3	22.3	2.2	2.2	2.2	1.8	1.8	1.7	2.2	2.0
	Fall	12	**1.5**	1.8	1.5	15.4	0.9	0.9	15.4	15.4	15.4	0.9	0.9	0.9	0.6	0.6	0.6	0.9	0.7
RC-2*	Spring	15	**1.8**	23.6	21.5	20.4	3.6	3.4	20.3	19.4	19.5	3.3	2.5	2.6	2.3	2.3	2.2	3.2	2.3
	Fall	15	**1.8**	1.2	1.2	6.7	1.0	1.0	6.7	6.4	6.8	1.0	0.6	1.0	0.9	1.0	1.0	0.6	0.4

Source: Draft Final Feasibility Study Report (URS 2004) - Section 7

* Note: The estimated post-remediation concentrations are predicted for a point downstream of RC-2 to account for additional groundwater loading contributions from the tailings piles

Table 5. Estimated Minimum Safe Chronic Concentrations of Dissolved Copper for Freshwater Aquatic Species (based on chronic tests and sorted by species)

Spp Rank	Genus	Species	Spp Chr Value (as Total) Hard = 50 ppm	Est. Species Chronic Values (as Dissolved) Hard = 50 ppm	Hard = 12 ppm	Hard = 13 ppm	Hard = 15 ppm
14	Northern Pike (Esox)	E. lucius	65.6	54.4	16.8	17.2	19.4
13	Salmonid (Salmo)	Brown Trout	33.9	28.1	8.7	8.9	10.0
12	Salmonid (Salvelinus)	Lake Trout	33.1	27.5	8.5	8.7	9.8
11	Bluegill (Lepomis)	L. macochirus	31.7	26.3	8.1	8.3	9.4
10	Sucker (Catostomus)	C. commersoni	23.0	19.1	5.9	6.0	6.8
9	Salmonid (Oncorhynchus)	Rainbow Trout	20.6	17.1	5.3	5.4	6.1
8	Caddisfly (Clistoronia)	C. magnifica	18.2	15.1	4.7	4.8	5.4
7	Salmonid (Oncorhynchus)	Chinook Salmon	14.4	12.0	3.7	3.8	4.3
6	Salmonid (Salvelinus)	Brook Trout	13.4	11.1	3.4	3.5	4.0
5	Cladoceran (Daphnid)	D. magna	13.4	11.1	3.4	3.5	4.0
4	Minnow (Pimephales)	P. promelas	12.6	10.5	3.2	3.3	3.7
3	Snail (Campeloma)	C. decisum	11.9	9.9	3.0	3.1	3.5
2	Snail (Physa)	P. integra	11.9	9.9	3.0	3.1	3.5
1	Amphipod (Gammarus)	G. pseudolimnaeus	6.67	5.5	1.7	1.7	2.0

Table 6. Estimated Minimum Safe Chronic Concentrations of Dissolved Copper for Freshwater Aquatic Species (based on acute LC50s divided by ACR and sorted by species)

Spp Rank	Genus	Species	Spp Acute LC50 (as Total) Hard = 50 ppm	Est. Species Chronic NOEC (LC50÷ACR) (as Dissolved) Hard = 50 ppm	Hard = 12 ppm	Hard = 13 ppm	Hard = 15 ppm
56	Stonefly (Acroneuria)	A. lycorias	10240.00	3473.64	1023.16	1097.17	1238.82
55	Clam (Corbicula)	C. manilensis	7184.00	2436.98	717.81	769.73	869.11
54	Caddisfly	Caddisfly spp	6200.00	2103.18	619.49	664.30	750.06
53	Bass & Perch (Morone)	White Perch	5860.00	1987.84	585.52	627.87	708.93
52	Damselfly	Damselfly spp	4600.00	1560.42	459.62	492.87	556.50
51	Eel (Anguilla)	A. rostrata	4305.00	1460.35	430.15	461.26	520.81
50	Crayfish (Procambarus)	P. clarkii	1990.00	675.05	198.84	213.22	240.75
49	Snail (Campleloma)	C. decisum	1877.00	636.72	187.55	201.11	227.08
48	Fish (Lepomis)	Bluegill	1742.00	590.93	174.06	186.65	210.74
47	Crayfish (Orconectes)	O. rusticus	1397.00	473.89	139.59	149.68	169.01
46	Amphipod (Crangonyx)	C. psuedogracilis)	1290.00	437.60	128.89	138.22	156.06
45	Snail (Amnicola)	Amnicola spp	900.00	305.30	89.93	96.43	108.88
44	Midge (Chironomus)	C. decorus	834.00	282.91	83.33	89.36	100.90
43	Killifish (Fundulus)	F. diaphanus	790.60	268.19	79.00	84.71	95.65
42	Tilapia (Tilapia)	T. mossambica)	684.30	232.13	68.37	73.32	82.79
41	Fish (Lepomis)	Pumpkinseed	640.90	217.41	64.04	68.67	77.53
40	Shiner (Notropis)	N. chrysocephalus	331.80	112.55	33.15	35.55	40.14
39	Goldfish (Carassius)	C. auratus	289.00	98.04	28.88	30.97	34.96
38	Worm (Lumbriculus)	L. variegatus	242.70	82.33	24.25	26.00	29.36
37	Salmonid (Oncorhynchus)	Sockeye Salmon	233.80	79.31	23.36	25.05	28.28
36	Darter (Etheostoma)	Orangethroat Darter	230.20	78.09	23.00	24.66	27.85
35	Midge (Chironomus)	C. tentans	197.00	66.83	19.68	21.11	23.83
34	Mosquitofish (Gambusia)	G. affinis	196.10	66.52	19.59	21.01	23.72
33	Snail (Goniobasis)	G. livescens	166.20	56.38	16.61	17.81	20.11
32	Carp (Cyrinus)	C. carpio	156.80	53.19	15.67	16.80	18.97
31	Bryozoan (Pectinatella)	P. magnifica	135.00	45.80	13.49	14.46	16.33
30	Chiselmouth (Acrocheilus)	A. alutaceus	133.00	45.12	13.29	14.25	16.09
29	Minnow (Pimephales)	Bluntnose Minnow	132.90	45.08	13.28	14.24	16.08
28	Salmonid (Salvelinus)	Brook Trout	110.40	37.45	11.03	11.83	13.36
27	Salmonid (Salmo)	Atlantic Salmon	109.90	37.28	10.98	11.78	13.30
26	Worm (Nais)	Nais sp.	90.00	30.53	8.99	9.64	10.89
25	Minnow (Pimephales)	Fathead Minnow	90.00	30.53	8.99	9.64	10.89
24	Salmonid (Oncorhynchus)	Coho Salmon	87.10	29.55	8.70	9.33	10.54
23	Dace (Rhinichtys)	R. atratulus	86.67	29.40	8.66	9.29	10.49
22	Darter (Etheostoma)	Rainbow Darter	86.67	29.40	8.66	9.29	10.49
21	Chub (Semotilus)	S. atromaculatus	83.97	28.48	8.39	9.00	10.16
20	Guppy (Poecilia)	P. reticulata	83.00	28.16	8.29	8.89	10.04
19	Stoneroller (Campostoma)	C. anomalum	78.55	26.65	7.85	8.42	9.50
18	Bullhead (Ictalurus)	I. nebulosus	69.81	23.68	6.98	7.48	8.45
17	Salmonid (Oncorhynchus)	Cutthroat Trout	66.26	22.48	6.62	7.10	8.02
16	Snail (Gyraulus)	G. circumstriatus	56.21	19.07	5.62	6.02	6.80
15	Worm (Limnodrilus)	L. hoffmeisteri	53.08	18.01	5.30	5.69	6.42
14	Bass & Perch (Morone)	Striped Bass	52.00	17.64	5.20	5.57	6.29
13	Snail (Physa)	P. integra	43.07	14.61	4.30	4.61	5.21
12	Salmonid (Oncorhynchus)	Chinook Salmon	42.26	14.34	4.22	4.53	5.11
11	Salmonid (Oncorhynchus)	Rainbow Trout	38.89	13.19	3.89	4.17	4.70
10	Bryozoan (Plumatella)	P. emarginata	37.05	12.57	3.70	3.97	4.48
9	Bryozoan (Lophopodella)	L. carteri	37.05	12.57	3.70	3.97	4.48
8	Snail (Physa)	P. heterostropha	35.91	12.18	3.59	3.85	4.34
7	Midge (Chironomus)	C. spp.	30.00	10.18	3.00	3.21	3.63
6	Amphipod (Gammarus)	G. pseudolmnaeus	22.09	7.49	2.21	2.37	2.67
5	Cladoceran (Daphnid)	D. magna	19.88	6.74	1.99	2.13	2.41
4	Squawfish (Ptychocheilus)	P. oregonensis	16.74	5.68	1.67	1.79	2.03
3	Cladoceran (Daphnid)	D. Pulex	16.50	5.60	1.65	1.77	2.00
2	Cladoceran (Ceriodaphnia)	C. reticulata	9.92	3.37	0.99	1.06	1.20
1	Cladoceran (Daphnid)	D. pulicaria	9.26	3.14	0.93	0.99	1.12

Table 7. Comparison of Pre-Remediation and Post-Remediation Dissolved Cadmium Concentrations with Potential Water Quality Criteria

Location	Time of Year	Expected Hardness (mg/l)	Chronic NRWQC (ug/l)	Pre-Remedy (ug/l)	Predicted Post-Remedy Concentration of Dissolved Cadmium (ug/l)														
					Alternative 2		Alternative 3		Alternative 4			Alternative 5				Alternative 6		Altern 7	Altern 8
					2a	2b	3a	3b	4a	4b	4c	5a	5b	5c	5d	6a	6b	7	8
RC-4	Spring	13	**0.06**	0.44	0.39	0.18	0.08	0.05	0.18	0.18	0.18	0.05	0.05	0.05	0.05	0.07	0.05	0.05	0.04
	Fall	12	**0.06**	0.06	0.05	0.16	0.06	0.06	0.16	0.16	0.16	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.04
RC-2*	Spring	15	**0.07**	0.53	0.47	0.27	0.17	0.14	0.28	0.24	0.26	0.16	0.11	0.13	0.13	0.15	0.14	0.12	0.09
	Fall	15	**0.07**	0.10	0.09	0.19	0.10	0.11	0.21	0.18	0.24	0.12	0.09	0.15	0.14	0.16	0.16	0.09	0.05

Source: Draft Final Feasibility Study Report (URS 2004) - Section 7

* Note: The estimated post-remediation concentrations are predicted for a point downstream of RC-2 to account for additional groundwater loading contributions from the tailings piles

Table 8. Estimated Minimum Safe Chronic Concentrations of Dissolved Cadmium for Freshwater Aquatic Species (based on chronic test results and sorted by species)

Spp Rank	Genus	Species	Spp Chr Value (as Total) Hard = 50 ppm	Est. Species Chronic Values (as Dissolved) Hard = 50 ppm	Hard = 12 ppm	Hard = 13 ppm	Hard = 15 ppm
21	Cladoceran (Ceriodaphnia)	C. dubia	27.17	26.98	9.38	9.95	11.07
20	Talapia (Oreochromis)	O. aurea	23.63	23.46	8.16	8.65	9.62
19	Oligochaete (Aeolosoma)	A. headleyi	20.74	20.59	7.16	7.59	8.45
18	Bluegill (Lepomis)	L. macrochirus	17.38	17.26	6.00	6.36	7.08
17	Minnow (Pimephales)	Fathead Minnow	16.38	16.27	5.66	6.00	6.67
16	Bass (Micropterus)	M. dolomieui	8.12	8.06	2.80	2.97	3.31
15	Salmonid (Salvelinus)	Lake Trout	8.09	8.03	2.79	2.96	3.30
14	Pike (Esox)	E. lucius	8.09	8.03	2.79	2.96	3.30
13	Salmonid (Salmo)	Altlantic Salmon	7.92	7.86	2.73	2.90	3.23
12	Sucker (Catostomus)	C. commersoni	7.80	7.75	2.69	2.86	3.18
11	Cladoceran (Daphnid)	D. Pulex	6.17	6.13	2.13	2.26	2.51
10	Flagfish (Jordenella)	J. floridae	5.32	5.28	1.84	1.95	2.17
9	Salmonid (Salmo)	Brown Trout	5.00	4.97	1.73	1.83	2.04
8	Snail (Aplexa)	A. hypnorum	4.82	4.79	1.66	1.76	1.96
7	Salmonid (Oncorhynchus)	Coho Salmon	4.27	4.24	1.47	1.56	1.74
6	Midge (Chironomus)	C. tentans	2.80	2.78	0.97	1.03	1.14
5	Salmonid (Salvelinus)	Brook Trout	2.64	2.62	0.91	0.97	1.08
4	Salmonid (Oncorhynchus)	Chinook Salmon	2.61	2.59	0.90	0.96	1.06
3	Salmonid (Oncorhynchus)	Rainbow Trout	1.31	1.30	0.45	0.48	0.53
2	Cladoceran (Daphnid)	D. magna	0.38	0.38	0.13	0.14	0.15
1	Amphipod (Hyalella)	H. azteca	0.27	0.27	0.09	0.10	0.11

Table 9. Comparison of Pre-Remediation Total Iron Concentrations with Potential Water Quality Criteria

Location	Flow Conditions	Expected Hardness	Chronic NRWQC (ug/l)	Tot Fe (ug/l) at Site			Diss Fe (ug/l) at Site		
				Pre-Remedy Range (1997-2003)	Background Mean	Background 90th UCL	Pre-Remedy Range (1997-2003)	Background Mean	Background 90th UCL
RC-4	Spring Flush	13	**1000**	60 - 170			20 - 25*		
	Low-Flow	12	**1000**	50 - 90			30 - 40		
RC-2	Spring Flush	15	**1000**	300 - 960			25* - 480		
	Low-Flow	15	**1000**	1280 - 2250			100 - 1430		
Upstream	All Year				110	177		38	40

Source: Draft Final Feasibility Study Report (URS 2004) - Section 2

* Measurement is a non-detect and is assigned a value of one half the detection limit

Table 10. Comparison of Measured Pre-Remediation and Predicted Post-Remediation Dissolved Iron Concentrations

				Predicted Post-Remedy Concentration of Dissolved Iron (ug/l)															
				Alternative 2		Alternative 3		Alternative 4			Alternative 5				Alternative 6		Altern	Altern
Location	Time of Year	Expected Hardness	Pre-Remedy	2a	2b	3a	3b	4a	4b	4c	5a	5b	5c	5d	6a	6b	7	8
RC-4	Spring	13	20	20	20	21	20	20	20	20	20	20	20	20	21	20	20	20
	Fall	12	40	40	42	41	41	42	42	42	41	41	41	41	41	41	41	40
RC-2*	Spring	15	303	301	301	301	301	180	71	72	180	71	72	72	72	72	127	54
	Fall	15	1201	1231	1232	1232	1232	445	246	249	444	246	248	248	249	249	404	156

Source: Draft Final Feasibility Study Report (URS 2004) - Section 7

* Note: The estimated post-remediation concentrations are predicted for a point downstream of RC-2 to account for additional groundwater loading contributions from the tailings piles

Table 11. Comparison of Pre-Remediation Total Aluminum Concentrations with Potential Water Quality Criteria

Location	Flow Conditions	Expected Hardness	Chronic NRWQC	Tot Al (ug/l) at Site Pre-Remedy Range (1997-2003)	Tot Al (ug/l) at Site Background Mean	Tot Al (ug/l) at Site Background 90th UCL	Diss Al (ug/l) at Site Pre-Remedy Range (1997-2003)	Diss Al (ug/l) at Site Background Mean	Diss Al (ug/l) at Site Background 90th UCL	pH at Site Pre-Remedy	pH at Site Back-Ground
RC-4	Spring Flush	13	**87**	100 - 200	86	144	<30 - 80	29	37	5.5 - 7.8	5.0 - 8.3
	Low-Flow	12	**87**	40 - 50	86	144	<20 - 30	29	37	6.7 - 6.8	5.0 - 8.3
RC-2	Spring Flush	15	**87**	140 - 250	86	144	<50 - 100	29	37	6.0 - 8.2	5.0 - 8.3
	Low-Flow	15	**87**	90 - 160	86	144	<20 - 40	29	37	5.7	5.0 - 8.3

Source: Draft Final Feasibility Study Report (URS 2004) - Section 2

Table 12. Estimated Minimum Safe Chronic Concentrations of Total Aluminum for Freshwater Aquatic Species

Genus Rank	Genus	Species	Spp Acute LC50 (as Total) Hard = 50 ppm	Est Spp Chr Value (as Total) (Acute LC50/ACR)
14	Midge (Tanytarsus)	T. dissimilis	79,900	39,950
13	Sunfish (Lepomis)	L. cyanellus	50,000	25,000
12	Perch (Perce)	P. flavescens	49,800	24,900
11	Catfish (Ictalurus)	I. punctalus	47,900	23,950
10	Salmonid (Oncorhynchus)	Chinook Salmon	40,000	20,000
9	Cladoceran (Daphnid)	D. magna	38,200	19,100
8	Minnow (Pimephales)	P. promelas	35,000	17,500
7	Snail (Physa)	Physa spp	30,600	15,300
6	Planarian (Dugesia)	D. tigrina	23,000	11,500
5	Stonefly (Acroneuria)	Acroneuria spp	22,600	11,300
4	Amphipod (Gammarus)	G. pseudolimnaeus	22,000	11,000
3	Salmonid (Oncorhynchus)	Rainbow Trout	10,390	5,195
1	Cladoceran (Ceriodaphnid)	C. spp	3,690	1,845
2	Salmonid (Salvelinus)	Brook Trout	3,600	1,800
1	Cladoceran (Ceriodaphnid)	C. dubia	1,900	950

Attachment H-1
Probability of Sensitive Species Being Present In Railroad Creek

A report by S.R. Hansen & Associates (SRHA), dated February 11, 2004, evaluates potential impacts to aquatic life in Railroad Creek in the short-term following remedy implementation due to residual metal concentrations exceeding potential water quality criteria. In the SRHA document, several taxa (taxonomic groups of organisms) are identified which, due to their high sensitivity, have the potential to be adversely impacted by the concentrations of dissolved copper, zinc, and cadmium that are predicted to occur in Railroad Creek post-remediation. These taxa, which are referred to in this document as indicator species, are summarized in Table 1. Available monitoring data and scientific literature were reviewed to determine whether any of the indicator species, or closely related species, have either been observed in Railroad Creek or, based on their documented range of distribution, might be expected to be present in Railroad Creek. The results of the review (as summarized in Table 1) indicate the following:

1. None of the indicator species have been documented to be present in Railroad Creek during monitoring surveys.

2. Based on distributional information in the literature, only one of the indicator species (i.e., northern pikeminnow, *Ptychocheilus oregonensis)* may be present in Railroad Creek.

3. Based on distributional information in the literature, two of the indicator species (i.e., longfin dace, *Agosia chrysogaster*, and southern pond snail, *Physa integra*) that are not expected to be present in Railroad Creek have close relatives that might be.

The bases for these conclusions are presented below.

Of the 5 fish indicator species listed on Table 1, the study area is not within the range of distribution for the fathead minnow (*Pimephales promelas*), longfin dace (*Agosia chrysogaster*), American flag fish (*Jordanella floridae*), or striped bass (*Morone saxatilis*) (Wydoski and Whitney 2003, ADFD 2002, Huntley 1995, Brown 1984, CCPUD 2000abc, Dames & Moore 1999, PNL 1992). Although not observed during monitoring surveys, two native species of dace, longnose dace (*Rhinichthys cataractae*) and speckled dace (*R. osculus*), may be present in Railroad Creek below the barrier fall located near the mouth at Lake Chelan (Wydoski and Whitney 2003). These two species, along with northern pikeminnow are native to the watershed and may be present in Railroad Creek. Northern pikeminnows are primarily lacustrine (living in lake habitat) in the Lake Chelan basin and would only utilize stream habitat similar to that of lower Railroad Creek for spawning and early rearing of juveniles. They prefer slow moving streams with water temperatures of 57 to 65ºF for spawning in May through July. It is unlikely that these conditions are met in Railroad Creek and it is probable that northern pikeminnows rarely, if at all, occur in Railroad Creek. Based on the size of the adult salmonids observed in Railroad Creek, juvenile northern pikeminnows, if present, would not likely be consumed by salmonids present in Railroad Creek. Northern pikeminnows are predators of juvenile salmonids and smaller fishes, such as dace (Wydoski and Whitney 2003). Longnose dace (riffle habitat) and speckled dace (pool habitat) commonly occur in cold, small to medium sized streams and may be found in lower Railroad Creek below the barrier falls, although not observed during the RI. These fish are closely related to longfin dace. The food of both species of dace is primarily aquatic insect larvae and some algae (Wydoski and Whitney 2003).

Of the two indicator snail species listed in Table 1, the study area is not within the range of distribution for either the pond snail, *Physa integra*, or the brown mystery snail, *Campeloma decisum* (Clench 1995). No snails or other mollusks were detected during stream surveys for benthic macroinvertebrates (Dames & Moore 1999). Snails of the genus *Campeloma* are not distributed in Washington, but *Physa spp*. do occur in the Columbia River basin of Washington and is possible that representative species may occur in Railroad Creek.

All of the indicator crustacean taxa (5 species of water fleas and 2 species of amphipods) are lentic habitat (still-water or lake) species and would be unlikely to occur in a stream environment (Chace et al. 1995, Mattox 1995). Water fleas are a component of the zooplankton community of lakes and pond and would not have been sampled for in any surveys of Railroad Creek. Freshwater amphipods were not detected during surveys of benthic macroinvertebrates in Railroad Creek (Dames & Moore 1999).

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Table 1. Potential for Sensitive Aquatic Species to be Present in Railroad Creek

Indicator Species		Indicator Species				Similar Taxa					
		Railroad Creek Above Falls		Railroad Creek Below Falls		Railroad Creek Above Falls		Railroad Creek Below Falls			
Common Name	Scientific Name	Documented Present	May be Present	Documented Present	May be Present	Documented Present	May be Present	Documented Present	May be Present	Common Name	Scientific Name
Fish Species											
fathead minnow	*Pimephales promelas*										
longfin dace	*Agosia chrysogaster*								X	speckled dace	*Rhinichthys osculus*
northern pikeminnow	*Ptychocheilus oregonensis*				X						
American flag fish	*Jordanella floridae*										
striped bass	*Morone saxatilis*										
Invertebrate Species											
southern pond snail	*Physa integra*						X		X	pond snail	*Physa spp.*
brown mystery snail	*Campeloma decisum*										
water flea	*Ceriodaphnia reticulata*										
water flea	*Ceriodaphnia dubia*										
water flea	*Daphnia pulicaria*										
water flea	*Daphnia magna*										
water flea	*Daphnia pulex*										
amphipod	*Gammarus pseudolmnaeus*										
amphipod	*Hyalella azteca*										

Attachment H-2
Expected Form of Aluminum in Railroad Creek Surface Water

Introduction

Data collected to date from Railroad Creek indicate that total recoverable (total) aluminum concentrations during high spring flow conditions exceed the chronic National Recommended Water Quality Criterion (NRWQC) of 87 ug/l. The data also indicate that total aluminum concentrations during low-flow conditions (fall) may periodically exceed the chronic criteria. Information provided in the 1999 revision of the ambient water quality criteria (USEPA 1999) indicate that the toxicity of aluminum is correlated with pH and the concentration of total recoverable aluminum when "particulate aluminum is primarily aluminum hydroxide particles". The USEPA also acknowledges that measured total recoverable aluminum in surface water may be associated with "clay particles, which might be less toxic than aluminum associated with aluminum hydroxide". The inference is that total recoverable aluminum concentrations may include aluminum that is not bioavailable. A description of the most likely species of aluminum present in Railroad Creek and discharge waters from the portal drainage and the tailings piles at Holden Mine site (Site) is provided below. A brief summary of how the types of aluminum in Railroad Creek relate to the measured total recoverable concentrations in Railroad Creek is also provided.

Forms of Aluminum in Railroad Creek Upstream of the Site, Portal Drainage, and Tailings Pile Seepage

The most likely forms of filterable (dissolved) aluminum in Railroad Creek upstream of the site are $AlOH^{2+}$, $Al(OH)_2^{+}$, $Al(OH)_4^{-}$, and $Al(OH)_3^{0}$ when evaluated at a pH of 7 using MINTEQA2 (Allison et al. 1991). The $Al(OH)_4^{-}$ species accounts for the largest percentage of dissolved aluminum present, approximately 75%, followed by diminishing concentrations of $Al(OH)_2^{+}$, $Al(OH)_3$, and $AlOH^{2+}$. These forms of aluminum will pass through a 0.45-micron filter used to collect samples for dissolved metals analysis. The unfilterable form (constituents that will not pass through a 0.45-micron filter) is associated with rock particles (feldpars and micas) and clays (aluminum silicates) formed by the breakdown of aluminosilicates in native rocks. The upstream dissolved aluminum fraction results from equilibration with suspended solids, and is a natural product of weathering. The range of pH in Railroad Creek is typically between 5 and 8.3 SU.

A majority of the aluminum measured in the portal drainage during the early spring flush is dissolved. During the early spring flush, the portal drainage exhibits an acidic pH near 4.8. Based on the results of MINTEQA2, the most dominant dissolved aluminum form present in the portal drainage water is Al^{3+} (approximately 50%), followed by aluminum sulfate ($AlSO_4^{+}$, approximately 30%), and diminishing percentages of AlF^{2+}, $AlOH^{2+}$, and $Al(SO_4)^{2-}$. The formation of aluminum sulfate complexes is due to the elevated concentrations of sulfate also present in the portal drainage. Aluminum sulfate compounds typically precipitate at pH 4.5 or higher. During the summer and fall, as the portal drainage flows decrease and the pH is observed to increase, the dominant aluminum species becomes $Al(OH)_4^{-}$, similar to the species present in Railroad Creek.

Seepage from the tailings piles also has an acidic pH, generally between 3 and 4, and high sulfate concentrations. Similar to the portal drainage during high flow, the aluminum species in the seepage is predominantly Al^{3+}, followed by $AlSO_4^{+}$ with concentrations of each greater than the levels likely present in the portal drainage.

Forms of Aluminum in Railroad Creek Adjacent to the Site

As the portal drainage and tailings pile seeps enter the higher-pH water within Railroad Creek, the aluminum species shift to dissolved aluminum hydroxide complexes ($AlOH^{2+}$, $Al(OH)_2^{+}$, $Al(OH)_4^{-}$, and $Al(OH)_3$). Due to the concentration of sulfate in both the portal drainage and the tailings seeps, aluminum sulfate complexes will be the dominant dissolved forms until dilution lowers overall sulfate concentrations. Aluminum hydroxide complexes become dominant as sulfate decreases. As the drainage and seeps mix with Railroad Creek, basic aluminum sulfates (eg., $AlOHSO_4$) are most likely to precipitate.

Based on field measurements for pH from Railroad Creek, the pH of the creek is not affected by the portal and tailings discharges to the creek. In this case, the dominant form of dissolved aluminum in Railroad Creek is likely aluminum hydroxide complexes ($AlOH^{2+}$, $Al(OH)_2^{+}$, $Al(OH)_4^{-}$, and $Al(OH)_3^{0}$). The non-filterable component of aluminum in Railroad Creek adjacent to the site would be similar to the upstream components described earlier (minerals and aluminum silicates) with the potential addition of $AlOHSO_4$ and AlOH floc.

Summary

Based on an evaluation of dissolved aluminum in Railroad Creek using MINTEQA2, the dissolved aluminum species most likely present in Railroad Creek are dissolved AlOH forms ($AlOH^{2+}$, $Al(OH)_2^{+}$, $Al(OH)_4^{-}$, and $Al(OH)_3^{0}$). The non-filterable (does not pass through a 0.45-micron filter) aluminum component most likely consists of rock (mineral) particulate or clays (aluminum silicates). Because the pH in Railroad Creek remains relatively constant from upstream to downstream, the predominant forms of dissolved aluminum in Railroad Creek are likely aluminum hydroxide complexes.

References

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APPENDIX I
CANDIDATE ALTERNATIVE COST DETAIL SHEETS

Table I-1
Alternative 1 - No Action/Institutional Controls
Cost Estimate Detail Sheet

ITEM	UNIT	UNIT COST	QTY	TOTAL
CAPITAL COSTS				
Mob/Demob	ls	$25,000	1	$25,000
Limited Mine Actions	ls	$375,000	1	$375,000
Physical Access Restrictions	ls	$50,000	1	$50,000
SubTotal				**$450,000**
Engineering Design/Planning		15%		$67,500
Construction Management		10%		$45,000
Project Management		4%		$18,000
Total Capital Costs				**$580,500**
ANNUAL O&M COSTS				
Surface Water Monitoring	ls	$40,000	1	$40,000
Groundwater Monitoring	ls	$10,000	1	$10,000
Slope Inspection (Spring)	ls	$5,000	1	$5,000
Limited Mine Actions (Spring)	ls	$25,000	1	$25,000
Reporting (Annual)	ls	$20,000	1	$20,000
Subtotal Annual O&M				**$100,000**
Total O&M Costs (present worth @ 7%)				**$1,240,000**
Subtotal Cost				**$1,820,500**
Contingency Cost		50%		$910,250
TOTAL PROJECT COST				**$2,730,750**

Notes:
1- Costs are in 2004 dollars.

Table I-2
Cost Estimate Detail Sheet
Alternative 2 - Water Management

ITEM	UNIT	UNIT COST	ALTERNATIVE 2a QTY	ALTERNATIVE 2a TOTAL	ALTERNATIVE 2b QTY	ALTERNATIVE 2b TOTAL
CAPITAL COSTS						
Mob/Demob	ls	15%	1	$1,012,950	1	$1,012,950
Physical Access Restrictions	ls	$50,000	1	$50,000	1	$50,000
Mine Actions						
Access/Air-flow Restrictions in Adits	ea	$7,500	6	$45,000	6	$45,000
Access/Air Flow Restriction 1,500 Level	ea	$50,000	2	$100,000	0	$0
Mine Rehabilitation	ls	$750,000	0.5	$375,000	1	$750,000
Hydrostatic Bulkheads	ea	$250,000	0	$0	2	$500,000
West Area Actions						
Upgradient/Near Surf Water Controls	lf	$100	3,600	$360,000	3,600	$360,000
Mill Building/Maintenance Yard Actions						
Excavation/Relocation of Impacted Soils	cy	$80	2,500	$200,000	2,500	$200,000
Cover for Impacted Soils	sf	$3	45,000	$135,000	45,000	$135,000
Lagoon Area / Former Retention Pond Actions						
Excavations/Relocation of Impacted Soils	cy	$10	9,000	$90,000	9,000	$90,000
Impacted Soil Disposal Cell	sf	$4	62,000	$248,000	62,000	$248,000
Former Retention Pond Containment	sy	$50	400	$20,000	400	$20,000
East Area Actions						
Revegetation (Includes Regrading)	ac	$10,000	92	$920,000	92	$920,000
Upgradient/Near Surf Water Controls	lf	$140	4,000	$560,000	4,000	$560,000
Side Slope Regrading	cy	$10	250,000	$2,500,000	250,000	$2,500,000
Develop Riprap Source	lf	$300,000	1	$300,000	1	$300,000
Enhance Rip-rap at Toe of Tailings	cy	$100	8,500	$850,000	8,500	$850,000
SubTotal				**$7,766,000**		**$8,541,000**
Engineering Investigations/Design/Planning		15%		$1,164,900		$1,281,150
Construction Management		10%		$776,600		$854,100
Project Management		4%		$310,640		$341,640
Total Capital Costs				**$10,018,200**		**$11,017,900**
LONG TERM O&M COSTS						
Surface Water Monitoring	ls	$40,000	1	$40,000	1	$40,000
Groundwater Monitoring	ls	$10,000	1	$10,000	1	$10,000
Slope Inspection (Spring)	ls	$5,000	1	$5,000	1	$5,000
Download Transducers (Fall)	ls	$5,000	1	$5,000	1	$5,000
Civil Maintenance (Annual)	ls	$25,000	1	$25,000	1	$25,000
Revegetation (First 5 Years Only)	ls	$45,000	1	$45,000	1	$45,000
Reporting (Annual)	ls	$20,000	1	$20,000	1	$20,000
Subtotal Annual O&M				**$150,000**		**$150,000**
Total O&M Costs (present worth @ 7%)				**$1,486,500**		**$1,486,500**
Subtotal Cost				**$11,504,700**		**$12,504,400**
Contingency		50%		$5,752,350		$6,252,200
TOTAL PROJECT COST				**$17,257,050**		**$18,756,600**

Notes:
1- Costs are in 2004 dollars.

Table I-3
Cost Estimate Detail Sheet
Alternative 3 - Water Management and Low-Energy West Area Treatment

ITEM	UNIT	UNIT COST	ALTERNATIVE 3A QTY	ALTERNATIVE 3A TOTAL	ALTERNATIVE 3B QTY	ALTERNATIVE 3B TOTAL
CAPITAL COSTS						
Mob/Demob	ls	17%	1	$1,718,445	1	$1,799,195
Physical Access Restrictions	ls	$50,000	1	$50,000	1	$50,000
Mine Actions						
Access/Air-flow Restrictions in Adits	ea	$7,500	6	$45,000	6	$45,000
Access/Air Flow Restrictions 1,500 Level	ea	$50,000	2	$100,000	0	$0
Mine Rehabilitation	ls	$750,000	1	$375,000	1	$750,000
Hydrostatic Bulkheads	ea	$250,000	0	$0	2	$500,000
West Area Actions						
Upgradient/Near Surf Water Controls	lf	$100	3,000	$300,000	3,000	$300,000
Work Platform (Steep Area)	lf	$50	2,500	$125,000	2,500	$125,000
Seep/Groundwater Collection (5 ft Deep Closed Trench)	lf	$50	2,500	$125,000	2,500	$125,000
Barrier Wall (Soil/Bentonite)	sf	$15	62,500	$937,500	62,500	$937,500
Seep 12 & 23 Collection/Treatment (pipe)	lf	$22	2,000	$44,000	2,000	$44,000
Detention Pond on TP-1 (5 Acre)	ls	$500,000	1	$500,000	0	$0
Water Treatment System - Open Portal	ls	$1,800,000	1	$1,800,000	0	$0
Water Treatment System - Bulkhead	ls	$2,000,000	0	$0	1	$2,000,000
Mill Building/Maintenance Yard Actions						
Excavation/Relocation of Impacted Soils	cy	$80	2,500	$200,000	2,500	$200,000
Cover for Impacted Soils	sf	$3	45,000	$135,000	45,000	$135,000
Lagoon Area / Former Retention Pond Actions						
Excavations/Relocation of Impacted Soils	cy	$10	9,000	$90,000	9,000	$90,000
Impacted Soil/sludge Disposal Cell	sy	$40	7,300	$292,000	7,300	$292,000
Former Retention Pond Containment	sy	$50	400	$20,000	400	$20,000
East Area Actions						
Revegetation (Includes Regrading)	ac	$10,000	92	$920,000	92	$920,000
Upgradient/Near Surf Water Controls	lf	$100	4,000	$400,000	4,000	$400,000
Work Platform (Flat Area)	lf	$20	0	$0	0	$0
Work Platform (Steep Area)	lf	$50	0	$0	0	$0
Seep/Groundwater Collection (5' Open Ditch)	lf	$25	0	$0	0	$0
Seep/Groundwater Collection (8' Open Ditch)	lf	$50	0	$0	0	$0
Seep/Groundwater Collection (5 ft Deep Closed Trench)	lf	$50	0	$0	0	$0
Seep/Groundwater Collection (8 ft Deep Closed Trench)	lf	$80	0	$0	0	$0
Seep/Groundwater Collection (12 ft Deep Closed Trench)	lf	$135	0	$0	0	$0
Barrier Wall (Soil/Bentonite)	sf	$15	0	$0	0	$0
Barrier Wall (Cement/Bentonite)	sf	$35	0	$0	0	$0
Slope Regrading	cy	$10	250,000	$2,500,000	250,000	$2,500,000
Develop Riprap Source	ls	$300,000	1	$300,000	1	$300,000
Enhance Rip-rap at Toe of Tailings	cy	$100	8,500	$850,000	8,500	$850,000
SubTotal				**$11,827,000**		**$12,382,700**
Engineering Investigations/Design/Planning		15%		$1,774,050		$1,857,405
Construction Management		10%		$1,182,700		$1,238,270
Project Management		4%		$473,080		$495,308
Total Capital Costs				**$15,256,900**		**$15,973,700**
LONG TERM O&M COSTS						
Surface Water Monitoring	ls	$40,000	1	$40,000	1	$40,000
Groundwater Monitoring	ls	$10,000	1	$10,000	1	$10,000
Slope Inspection (Spring)	ls	$5,000	1	$5,000	1	$5,000
Download Transducers (Fall)	ls	$5,000	1	$5,000	1	$5,000
Diversion Channel Maintenance (Annual)	hr	$80	100	$8,000	100	$8,000
Collect/Treatment System O&M (1/2 FTE)	yr	$70,000	0.5	$35,000	0.5	$35,000
Lime (Delivered to system)	ton	$300	30	$9,000	30	$9,000
Civil Maintenance, Equipment Maintenance, and Fuel	yr	$75,000	1	$75,000	1	$75,000
Revegetation (First 5 Years Only)	yr	$45,000	1	$45,000	1	$45,000
Reporting (Annual)	ls	$24,000	1	$24,000	1	$24,000
Subtotal Annual O&M				**$256,000**		**$256,000**
Total O&M Costs (present worth @ 7%)				**$2,801,000**		**$2,801,000**
Subtotal Cost				**$18,057,900**		**$18,774,700**
Contingency		50%		$9,028,950		$9,387,350
TOTAL PROJECT COST				**$27,086,900**		**$28,162,100**

Notes:
1- Costs are in 2004 dollars.

Table I-4
Cost Estimate Detail Sheet
Alternative 4 - Water Management and East Area Collection and Treatment

ITEM	UNIT	UNIT COST	ALTERNATIVE 4A QTY	ALTERNATIVE 4A TOTAL	ALTERNATIVE 4B QTY	ALTERNATIVE 4B TOTAL	ALTERNATIVE 4C QTY	ALTERNATIVE 4C TOTAL
CAPITAL COSTS								
Mob/Demob	ls	15%	1	$2,076,060	1	$4,465,230	1	$1,861,500
Physical Access Restrictions	ls	$50,000	1	$50,000	1	$50,000	1	$50,000
Mine Actions								
Access/Air-flow Restrictions in Adits	ea	$7,500	6	$45,000	6	$45,000	6	$45,000
Mine Rehabilitation	ls	$750,000	1	$750,000	1	$750,000	1	$750,000
Hydrostatic Bulkheads	ea	$250,000	2	$500,000	2	$500,000	2	$500,000
West Area Actions								
Upgradient/Near Surf Water Controls	lf	$100	3,600	$360,000	3,600	$360,000	3,600	$360,000
Mill Building/Maintenance Yard Actions								
Excavation/Relocation of Impacted Soils	cy	$80	2,500	$200,000	2,500	$200,000	2,500	$200,000
Cover for Impacted Soils	sf	$3	45,000	$135,000	45,000	$135,000	45,000	$135,000
Lagoon Area / Former Retention Pond Actions								
Excavations/Relocation of Impacted Soils	cy	$10	9,000	$90,000	9,000	$90,000	9,000	$90,000
Impacted Soil/Sludge Disposal Cell	sy	$40	7,300	$292,000	7,300	$292,000	7,300	$292,000
Former Retention Pond Containment	sy	$50	400	$20,000	400	$20,000	400	$20,000
East Area Actions								
Revegetation (Includes Regrading)	ac	$10,000	92	$920,000	92	$920,000	92	$920,000
Upgradient/Near Surf Water Controls	lf	$100	4,000	$400,000	4,000	$400,000	4,000	$400,000
Copper Creek Culvert	lf	$200	1,200	$240,000	1,200	$240,000	1,200	$240,000
Slope Regrading	cy	$10	250,000	$2,500,000	1,000,000	$10,000,000	150,000	$1,500,000
Develop Riprap Source	ls	$300,000	1	$300,000	1	$300,000	1	$300,000
Enhance Rip-rap at Toe of Tailings	cy	$100	7,500	$750,000	7,500	$750,000	0	$0
Work Platform (Flat Area)	lf	$20	980	$19,600	2,220	$44,400	4,900	$98,000
Work Platform (Steep Area)	lf	$50	1,220	$61,000	3,600	$180,000	0	$0
Seep/Groundwater Collection (5' Open Ditch)	lf	$25		$0	0	$0	4,900	$122,500
Seep/Groundwater Collection (8' Open Ditch)	lf	$50	2,200	$110,000	0	$0	0	$0
Seep/Groundwater Collection (5 ft Deep Closed Trench)	lf	$50	0	$0	0	$0	0	$0
Seep/Groundwater Collection (8 ft Deep Closed Trench)	lf	$80	0	$0	920	$73,600	0	$0
Seep/Groundwater Collection (12 ft Deep Closed Trench)	lf	$135	0	$0	4,900	$661,500	0	$0
Barrier Wall (Soil/Bentonite)	sf	$15	67,260	$1,008,900	145,380	$2,180,700	82,500	$1,237,500
Barrier Wall (Cement/Bentonite)	sf	$35	84,540	$2,958,900	255,600	$8,946,000	0	$0
East Area Treatment (Partial Collection)	ls	$1,500,000	1	$1,500,000	0	$0	0	$0
East Area Treatment (Extended Collect)	ls	$2,000,000	0	$0	1	$2,000,000	1	$2,000,000
Railroad Creek Actions								
Relocation of Railroad Creek	lf	$630	1,000	$630,000	1,000	$630,000	5,000	$3,150,000
Slope Stabilization	lf	$320	0	$0	0	$0	1,600	$512,000
SubTotal				**$15,916,500**		**$34,233,500**		**$14,271,500**
Engineering Investigations/Design/Planning 4A, 4C		13%	1	$2,069,145	0	$0	1	$1,855,295
Engineering Investigations/Design/Planning 4B		8%	0	$0	1	$2,738,680	0	$0
Construction Management		7%		$1,114,155		$2,396,345		$999,005
Project Management		3%		$477,495		$1,027,005		$428,145
Total Capital Costs				**$19,577,300**		**$40,395,600**		**$17,554,000**
ANNUAL O&M COSTS								
Surface Water Monitoring	ls	$40,000	1	$40,000	1	$40,000	1	$40,000
Groundwater Monitoring	ls	$10,000	1	$10,000	1	$10,000	1	$10,000
Slope Inspection (Spring)	ls	$5,000	1	$5,000	1	$5,000	1	$5,000
Download Transducers (Fall)	ls	$5,000	1	$5,000	1	$5,000	1	$5,000
Diversion Channel Maintenance	hr	$80	100	$8,000	100	$8,000	100	$8,000
Collection/Treatment System O&M	yr	$70,000	0.5	$35,000	0.75	$52,500	0.75	$52,500
Lime (Delivered to system)	ton	$300	100	$30,000	200	$60,000	200	$60,000
Civil Maintenance, Equipment Maintenance, and Fuel	yr	$100,000	1	$100,000	1.5	$150,000	1	$100,000
Maintain Riparian Habitat (5 years only)	ls	$28,000	0	$0	0	$0	1	$28,000
Revegetation (5 years only)	ls	$45,000	1	$45,000	1	$45,000	1	$45,000
Reporting (Annual)	ls	$24,000	1	$24,000	1	$24,000	1	$24,000
Subtotal Annual O&M				**$302,000**		**$399,500**		**$377,500**
Total O&M Costs (present worth @ 7%)				**$3,372,000**		**$4,581,000**		**$4,076,000**
Subtotal Cost				**$22,949,300**		**$44,976,600**		**$21,630,000**
Contingency		50%		$11,474,650		$22,488,300		$10,815,000
TOTAL PROJECT COST				**$34,423,950**		**$67,464,900**		**$32,445,000**

Notes:
1- Costs are in 2004 dollars.

Table I-5
Cost Estimate Detail Sheet
Alternative 5 - Water Management and Low-Energy East/West Area Treatment

			ALTERNATIVE 5A		ALTERNATIVE 5B		ALTERNATIVE 5C		ALTERNATIVE 5D	
ITEM	**UNIT**	**UNIT COST**	**QTY**	**TOTAL**	**QTY**	**TOTAL**	**QTY**	**TOTAL**	**QTY**	**TOTAL**
CAPITAL COSTS										
Mob/Demob	ls	15%	1	$2,551,785	1	$4,940,955	1	$2,414,025	1	$2,760,900
Physical Access Restrictions	ls	$50,000	1	$50,000	1	$50,000	1	$50,000	1	$50,000
Mine Actions										
Access/Air-flow Restrictions in Adits	ea	$7,500	6	$45,000	6	$45,000	6	$45,000	6	$45,000
Mine Rehabilitation	ls	$750,000	1	$750,000	1	$750,000	1	$750,000	1	$750,000
Hydrostatic Bulkheads	ea	$250,000	2	$500,000	2	$500,000	2	$500,000	2	$500,000
West Area Actions										
Upgradient/Near Surf Water Controls	lf	$100	3,000	$300,000	3,000	$300,000	3,000	$300,000	3,000	$300,000
Work Platform (Flat Area)	lf	$20	0	$0	0	$0	0	$0	2,500	$50,000
Work Platform (Steep Area)	lf	$50	2,500	$125,000	2,500	$125,000	2,500	$125,000	2,500	$125,000
Seep/Groundwater Collection (5' Open Ditch)	lf	$25	0	$0	0	$0	0	$0	0	$0
Seep/Groundwater Collection (8' Open Ditch)	lf	$50	0	$0	0	$0	0	$0	0	$0
Seep/Groundwater Collection (5 ft Deep Closed Trench)	lf	$50	2,500	$125,000	2,500	$125,000	2,500	$125,000	2,500	$125,000
Seep/Groundwater Collection (8 ft Deep Closed Trench)	lf	$80	0	$0	0	$0	0	$0	2,500	$200,000
Seep/Groundwater Collection (12 ft Deep Closed Trench)	lf	$135	0	$0	0	$0	0	$0	0	$0
Barrier Wall (Soil/Bentonite)	sf	$15	62,500	$937,500	62,500	$937,500	62,500	$937,500	200,000	$3,000,000
Seep 12 & 23 Collection/Treatment (pipe)	lf	$22	2,000	$44,000	2,000	$44,000	2,000	$44,000	2,000	$44,000
West Area Treatment System - Bulkhead	ls	$2,000,000	1	$2,000,000	1	$2,000,000	1	$2,000,000	1	$2,000,000
Mill Building/Maintenance Yard Actions										
Excavation/Relocation of Impacted Soils	cy	$80	2,500	$200,000	2,500	$200,000	2,500	$200,000	2,500	$200,000
Cover for Impacted Soils	sf	$3	45,000	$135,000	45,000	$135,000	45,000	$135,000	45,000	$135,000
Lagoon Area / Former Retention Pond Actions										
Excavations/Relocation of Impacted Soils	cy	$10	9,000	$90,000	9,000	$90,000	9,000	$90,000	9,000	$90,000
Impacted Soil/Sludge Disposal Cell	sy	$40	7,300	$292,000	7,300	$292,000	7,300	$292,000	7,300	$292,000
Former Retention Pond	sy	$50	400	$20,000	400	$20,000	400	$20,000	400	$20,000
East Area Actions										
Revegetation (Includes Regrading)	ac	$10,000	92	$920,000	92	$920,000	92	$920,000	92	$920,000
Upgradient/Near Surf Water Controls	lf	$100	4,000	$400,000	4,000	$400,000	4,000	$400,000	4,000	$400,000
Copper Creek Culvert	lf	$200	1,200	$240,000	1,200	$240,000	1,200	$240,000	1,200	$240,000
Slope Regrading	cy	$10	250,000	$2,500,000	1,000,000	$10,000,000	150,000	$1,500,000	150,000	$1,500,000
Develop Riprap Source	ls	$300,000	1	$300,000	1	$300,000	1	$300,000	1	$300,000
Enhance Rip-rap at Toe of Tailings	cy	$100	7,500	$750,000	7,500	$750,000	0	$0	0	$0
Work Platform (Flat Area)	lf	$20	980	$19,600	2,220	$44,400	4,900	$98,000	4,900	$98,000
Work Platform (Steep Area)	lf	$50	1,220	$61,000	3,600	$180,000	0	$0	0	$0
Seep/Groundwater Collection (5' Open Ditch)	lf	$25	0	$0	0	$0	4,900	$122,500	4,900	$122,500
Seep/Groundwater Collection (8' Open Ditch)	lf	$50	2,200	$110,000	0	$0	0	$0	0	$0
Seep/Groundwater Collection (5 ft Deep Closed Trench)	lf	$50	0	$0	0	$0	0	$0	0	$0
Seep/Groundwater Collection (8 ft Deep Closed Trench)	lf	$80	0	$0	920	$73,600	0	$0	0	$0
Seep/Groundwater Collection (12 ft Deep Closed Trench)	lf	$135	0	$0	4,900	$661,500	0	$0	0	$0
Barrier Wall (Soil/Bentonite)	sf	$15	67,260	$1,008,900	145,380	$2,180,700	82,500	$1,237,500	82,500	$1,237,500
Barrier Wall (Cement/Bentonite)	sf	$35	84,540	$2,958,900	255,600	$8,946,000	0	$0	0	$0
East Area Treatment (Partial Collection)	ls	$1,500,000	1	$1,500,000	0	$0	0	$0	0	$0
East Area Treatment (Extended Collect)	ls	$2,000,000	0	$0	1	$2,000,000	1	$2,000,000	1	$2,000,000
Railroad Creek Actions										
Relocation of Railroad Creek	lf	$630	1,000	$630,000	1,000	$630,000	5,000	$3,150,000	5,000	$3,150,000
Slope Stabilization	lf	$320	0	$0	0	$0	1,600	$512,000	1,600	$512,000
SubTotal				**$19,563,700**		**$37,880,700**		**$18,507,600**		**$21,166,900**
Engineering Investigations/Design/Planning 5A, 5C, 5D		12%	1	$2,347,644	0	$0	1	$2,220,912	1	$2,540,028
Engineering Investigations/Design/Planning 5B		8%	0	$0	1	$3,030,456	0	$0	0	$0
Construction Management 5A, 5C, 5D		7%	1	$1,369,459	0	$0	1	$1,295,532	1	$1,481,683
Construction Management 5B		7%	0	$0	1	$2,651,649	0	$0	0	$0
Project Management 5A, 5C, 5D		3%	1	$586,911	0	$0	1	$555,228	1	$635,007
Project Management 5B		3%	0	$0	1	$1,136,421	0	$0	0	$0
Total Capital Costs				**$23,867,800**		**$44,699,300**		**$22,579,300**		**$25,823,700**
ANNUAL O&M COSTS										
Surface Water Monitoring	ls	$40,000	1	$40,000	1	$40,000	1	$40,000	1	$40,000
Groundwater Monitoring	ls	$10,000	1	$10,000	1	$10,000	1	$10,000	1	$10,000
Slope Inspection (Spring)	ls	$5,000	1	$5,000	1	$5,000	1	$5,000	1	$5,000
Download Transducers (Fall)	ls	$5,000	1	$5,000	1	$5,000	1	$5,000	1	$5,000
Diversion Channel Maintenance	hr	$80	100	$8,000	100	$8,000	100	$8,000	100	$8,000
Collection/Treatment System O&M	yr	$70,000	0.75	$52,500	1	$70,000	1	$70,000	1.4	$98,000
Lime (Delivered to Systems)	ton	$300	100	$30,000	200	$60,000	200	$60,000	200	$60,000
Civil Maintenance, Equipment Maintenance, and Fuel	yr	$100,000	1	$100,000	1.5	$150,000	1	$100,000	1	$100,000
Maintain Riparian Habitat (5 yrs only)	ls	$28,000	0	$0	0	$0	1	$28,000	1	$28,000
Revegetation (5 years only)	ls	$45,000	1	$45,000	1	$45,000	1	$45,000	1	$45,000
Reporting (Annual)	ls	$28,000	1	$28,000	1	$28,000	1	$28,000	1	$28,000
Subtotal Annual O&M				**$323,500**		**$421,000**		**$399,000**		**$427,000**
Total O&M Costs (present worth @ 7%)				**$3,638,000**		**$4,847,000**		**$4,342,000**		**$4,689,000**
Subtotal Cost				**$27,505,800**		**$49,546,300**		**$26,921,300**		**$30,512,700**
Contingency		50%		$13,752,900		$24,773,150		$13,460,650		$15,256,350
TOTAL PROJECT COST				**$41,258,700**		**$74,319,450**		**$40,381,950**		**$45,769,050**

Notes:
1- Costs are in 2004 dollars.

Table I-6
Cost Estimate Detail Sheet
Alternative 6 - Water Management, Extended Secondary West Area Collection, Extended Railroad Creek Relocation, and East/West Area Treatment (Mechanical West Area WTP)

ITEM	UNIT	UNIT COST	ALTERNATIVE 6A QTY	ALTERNATIVE 6A TOTAL	ALTERNATIVE 6B QTY	ALTERNATIVE 6B TOTAL
CAPITAL COSTS						
Mob/Demob	ls	15%	1	$4,442,400	1	$4,228,650
Physical Access Restrictions	ls	$50,000	1	$50,000	1	$50,000
Mine Actions						
Access/Air-flow Restrictions in Adits	ea	$7,500	6	$45,000	6	$45,000
Access/Air-flow Restrictions in 1,500 Level	ea	$50,000	2	$100,000	6	$300,000
Mine Rehabilitation	ls	$750,000	1	$375,000	1	$750,000
Hydrostatic Bulkheads	ea	$250,000	0	$0	2	$500,000
West Area Actions						
Upgradient/Near Surf Water Controls	lf	$100	3,000	$300,000	3,000	$300,000
Seep 12 & 23 Collection/Treatment (pipe)	lf	$22	2,000	$44,000	2,000	$44,000
Work Platform (Flat Area)	lf	$20	2,100	$42,000	2,100	$42,000
Work Platform (Steep Area)	lf	$50	4,300	$215,000	4,300	$215,000
Seep/Groundwater Collection (5' Open Ditch)	lf	$25	0	$0	0	$0
Seep/Groundwater Collection (8' Open Ditch)	lf	$50	0	$0	0	$0
Seep/Groundwater Collection (5 ft Deep Closed Trench)	lf	$50	4,300	$215,000	4,300	$215,000
Seep/Groundwater Collection (8 ft Deep Closed Trench)	lf	$80	2,100	$168,000	2,100	$168,000
Seep/Groundwater Collection (12 ft Deep Closed Trench)	lf	$135	0	$0	0	$0
Barrier Wall (Soil/Bentonite)	sf	$15	223,000	$3,345,000	223,000	$3,345,000
Barrier Wall (Cement/Bentonite)	sf	$35	0	$0	0	$0
Detention Pond on TP-1 (5 Acre)	ls	$500,000	1	$500,000	0	$0
West Area Treatment System - Open Portal	ls	$13,000,000	1	$13,000,000	0	$0
West Area Treatment System - Bulkhead	ls	$11,000,000	0	$0	1	$11,000,000
Mill Building/Maintenance Yard Actions						
Excavation/Relocation of Impacted Soils	cy	$80	2,500	$200,000	2,500	$200,000
Cover for Impacted Soils	sf	$3	45,000	$135,000	45,000	$135,000
Lagoon Area / Former Retention Pond Actions						
Excavations/Relocation of Impacted Soils	cy	$10	9,000	$90,000	9,000	$90,000
Impacted Soil/Sludge Disposal Cell	sy	$40	7,300	$292,000	7,300	$292,000
Former Retention Pond	sy	$50	400	$20,000	400	$20,000
East Area Actions						
Revegetation (Includes Regrading)	ac	$10,000	92	$920,000	92	$920,000
Upgradient/Near Surf Water Controls	lf	$100	4,000	$400,000	4,000	$400,000
Copper Creek Culvert	lf	$200	1,200	$240,000	1,200	$240,000
Slope Regrading	cy	$10	150,000	$1,500,000	150,000	$1,500,000
Develop Riprap Source	ls	$300,000	1	$300,000	1	$300,000
Work Platform (Flat Area)	lf	$20	4,900	$98,000	4,900	$98,000
Work Platform (Steep Area)	lf	$50	0	$0	0	$0
Seep/Groundwater Collection (5' Open Ditch)	lf	$25	4,900	$122,500	4,900	$122,500
Seep/Groundwater Collection (8' Open Ditch)	lf	$50	0	$0	0	$0
Seep/Groundwater Collection (5 ft Deep Closed Trench)	lf	$50	0	$0	0	$0
Seep/Groundwater Collection (8 ft Deep Closed Trench)	lf	$80	0	$0	0	$0
Seep/Groundwater Collection (12 ft Deep Closed Trench)	lf	$135	0	$0	0	$0
Barrier Wall (Soil/Bentonite)	sf	$15	82,500	$1,237,500	82,500	$1,237,500
Barrier Wall (Cement/Bentonite)	sf	$35	0	$0	0	$0
East Area Treatment (Extended Collect)	ls	$2,000,000	1	$2,000,000	1	$2,000,000
Railroad Creek Actions						
Relocation of Railroad Creek	lf	$630	5,000	$3,150,000	5,000	$3,150,000
Slope Stabilization	lf	$320	1,600	$512,000	1,600	$512,000
SubTotal				**$34,058,400**		**$32,419,700**
Engineering Investigations/Design/Planning		8%	1	$2,724,672	1	$2,593,576
Construction Management		7%	1	$2,384,088	1	$2,269,379
Project Management		3%	1	$1,021,752	1	$972,591
Total Capital Costs				**$40,189,000**		**$38,255,300**
ANNUAL O&M COSTS						
Surface Water Monitoring	ls	$40,000	1	$40,000	1	$40,000
Groundwater Monitoring	ls	$10,000	1	$10,000	1	$10,000
Slope Inspection (Spring)	ls	$5,000	1	$5,000	1	$5,000
Download Transducers (Fall)	ls	$5,000	1	$5,000	1	$5,000
Diversion Channel Maintenance	hr	$80	100	$8,000	100	$8,000
Collection/Treatment System O&M	yr	$70,000	2	$140,000	2	$140,000
Lime (Delivered to Systems)	ton	$300	200	$60,000	200	$60,000
Civil Maintenance, Equipment Maintenance, and Fuel	yr	$100,000	1	$100,000	1	$100,000
Fuel/Energy Generation	yr	$500,000	1	$500,000	1	$500,000
Maintain Riparian Habitat (5 yrs only)	ls	$28,000	1	$28,000	1	$28,000
Revegetation (5 years only)	ls	$45,000	1	$45,000	1	$45,000
Reporting (Annual)	ls	$28,000	1	$28,000	1	$28,000
Subtotal Annual O&M				**$969,000**		**$969,000**
Total O&M Costs (present worth @ 7%)				**$11,410,000**		**$11,410,000**
Subtotal Cost				**$51,599,000**		**$49,665,300**
Contingency		50%		$25,799,500		$24,832,650
TOTAL PROJECT COST				**$77,398,500**		**$74,497,950**

Notes:
1- Costs are in 2004 dollars.

Table I-7
Cost Estimate Detail Sheet
Alternative 7 - Capping, Consolidation, Water Management and West Area Treatment (Low-Energy WTP)

ITEM	UNIT	UNIT COST	ALTERNATIVE 7 QTY	ALTERNATIVE 7 TOTAL
CAPITAL COSTS				
Mob/Demob	ls	12%	1	$5,884,020
Physical Access Restrictions	ls	$50,000	1	$50,000
Mine Actions				
Access/Air-flow Restrictions in Adits	ea	$7,500	6	$45,000
Mine Rehabilitation	ls	$750,000	1	$750,000
Hydrostatic Bulkheads	ea	$250,000	2	$500,000
West Area Actions				
Upgradient/Near Surf Water Controls	lf	$100	3,000	$300,000
Seep 12 & 23 Collection/Treatment (pipe)	lf	$22	2,000	$44,000
Work Platform (Flat Area)	lf	$20	0	$0
Work Platform (Steep Area)	lf	$50	2,500	$125,000
Seep/Groundwater Collection (5' Open Ditch)	lf	$25	0	$0
Seep/Groundwater Collection (8' Open Ditch)	lf	$50	0	$0
Seep/Groundwater Collection (5 ft Deep Closed Trench)	lf	$50	2,500	$125,000
Seep/Groundwater Collection (8 ft Deep Closed Trench)	lf	$80	0	$0
Seep/Groundwater Collection (12 ft Deep Closed Trench)	lf	$135	0	$0
Barrier Wall (Soil/Bentonite)	sf	$15	62,500	$937,500
West Area Treatment System - Bulkhead	ls	$2,000,000	1	$2,000,000
Mill Building/Maintenance Yard Actions				
Excavation/Relocation of Impacted Soils	cy	$80	2,500	$200,000
Cover for Impacted Soils	sf	$3	45,000	$135,000
Waste Rock Pile Actions				
Engineered Cover	sf	$3	400,000	$1,200,000
Lagoon Area / Former Retention Pond Actions				
Excavations/Relocation of Impacted Soils	cy	$10	9,000	$90,000
Impacted Soil/Sludge Disposal Cell	sy	$40	7,300	$292,000
Former Retention Pond	sy	$50	400	$20,000
East Area Actions				
Upgradient/Near Surf Water Controls	lf	$100	4,000	$400,000
Develop Riprap Source	ls	$300,000	1	$300,000
Enhance Rip-rap at Toe of Tailings	cy	$100	3,200	$320,000
Work Platform (Flat Area)	lf	$20	0	$0
Work Platform (Steep Area)	lf	$50	0	$0
Seep/Groundwater Collection (5' Open Ditch)	lf	$25	0	$0
Seep/Groundwater Collection (8' Open Ditch)	lf	$50	0	$0
Seep/Groundwater Collection (5 ft Deep Closed Trench)	lf	$50	0	$0
Seep/Groundwater Collection (8 ft Deep Closed Trench)	lf	$80	0	$0
Seep/Groundwater Collection (12 ft Deep Closed Trench)	lf	$135	0	$0
Barrier Wall (Soil/Bentonite)	sf	$15	0	$0
Barrier Wall (Cement/Bentonite)	sf	$35	0	$0
Consolidation of Tailings Piles	cy	$8	3,900,000	$31,200,000
Low-Permeability Cover	ac	$200,000	50	$10,000,000
SubTotal				**$54,917,600**
Engineering/Investigations/Design/Planning		6%		$3,295,056
Construction Management		7%		$3,844,232
Project Management		2%		$1,098,352
Total Capital Costs				**$63,155,300**
ANNUAL O&M COSTS				
Surface Water Monitoring	ls	$40,000	1	$40,000
Groundwater Monitoring	ls	$10,000	1	$10,000
Download Transducers (Fall)	hr	$5,000	1	$5,000
Diversion Channel Maintenance	hr	$80	100	$8,000
Collection/Treatment System O&M	1	$70,000	0.5	$35,000
Lime (Delivered to Systems)	ton	$300	30	$9,000
Civil Maintenance, Equipment Maintenance, and Fuel	yr	$100,000	1	$100,000
Cap Maintenance (Annual)	yr	$70,000	1	$70,000
Reporting (Annual)	yr	$28,000	1	$28,000
Subtotal Annual O&M				**$305,000**
Total O&M Costs (present worth @ 7%)				**$3,782,000**
Subtotal Cost				**$66,937,300**
Contingency		50%		$33,468,650
TOTAL PROJECT COST				**$100,405,950**

Notes:
1- Costs are in 2004 dollars.

Table I-8
Cost Estimate Detail Sheet
Alternative 8 - Source Control and East/West Area Treatment

ITEM	UNIT	UNIT COST	ALTERNATIVE 8 QTY	ALTERNATIVE 8 TOTAL
CAPITAL COSTS				
Mob/Demob	ls	12%	1	$6,564,420
Physical Access Restrictions	ls	$50,000	1	$50,000
Mine Actions				
Access/Air-flow Restrictions in Adits	ea	$7,500	6	$45,000
Mine Rehabilitation	ls	$750,000	1	$750,000
Hydrostatic Bulkheads	ea	$250,000	2	$500,000
West Area Actions				
Upgradient/Near Surf Water Controls	lf	$100	3,000	$300,000
Seep 12 & 23 Collection/Treatment (pipe)	lf	$22	2,000	$44,000
West Area Treatment System - Bulkhead	ls	$2,000,000	1	$2,000,000
Mill Building/Maintenance Yard Actions				
Excavation/Relocation of Impacted Soils	cy	$80	2,500	$200,000
Cover for Impacted Soils	sf	$3	45,000	$135,000
Waste Rock Pile Actions				
Relocate Rock to Consolidated Tailings Pile	cy	$10	250,000	$2,500,000
Lagoon Area / Former Retention Pond Actions				
Excavations/Relocation of Impacted Soils	cy	$10	9,000	$90,000
Impacted Soil/Sludge Disposal Cell	sy	$40	7,300	$292,000
Former Retention Pond	sy	$50	400	$20,000
Consolidated East Area Actions				
Upgradient/Near Surf Water Controls	lf	$100	4,000	$400,000
Develop Riprap Source	ls	$300,000	1	$300,000
Enhance Rip-rap at Toe of Tailings	cy	$100	3,200	$320,000
Work Platform (Flat Area)	lf	$20	3,500	$70,000
Work Platform (Steep Area)	lf	$50	0	$0
Seep/Groundwater Collection (5' Open Ditch)	lf	$25	2,000	$50,000
Seep/Groundwater Collection (8' Open Ditch)	lf	$50	0	$0
Seep/Groundwater Collection (5 ft Deep Closed Trench)	lf	$50	0	$0
Seep/Groundwater Collection (8 ft Deep Closed Trench)	lf	$80	0	$0
Seep/Groundwater Collection (12 ft Deep Closed Trench)	lf	$135	0	$0
Barrier Wall (Soil/Bentonite)	sf	$15	262,500	$3,937,500
Barrier Wall (Cement/Bentonite)	sf	$35	0	$0
East Area Treatment (Extended Collect)	ls	$1,500,000	1	$1,500,000
Consolidation of Tailings Piles	cy	$8	3,900,000	$31,200,000
Low-Permeability Cover	ac	$200,000	50	$10,000,000
SubTotal				**$61,268,000**
Engineering/Investigations/Design/Planning		6%		$3,676,080
Construction Management		7%		$4,288,760
Project Management		2%		$1,225,360
Total Capital Costs				**$70,458,200**
ANNUAL O&M COSTS				
Surface Water Monitoring	ls	$40,000	1	$40,000
Groundwater Monitoring	ls	$10,000	1	$10,000
Download Transducers (Fall)	hr	$5,000	1	$5,000
Diversion Channel Maintenance	hr	$80	100	$8,000
Collection/Treatment System O&M	1	$70,000	1	$70,000
Lime (Delivered to Systems)	ton	$300	200	$60,000
Civil Maintenance, Equipment Maintenance, and Fuel	yr	$100,000	1	$100,000
Cap Maintenance (Annual)	yr	$70,000	1	$70,000
Reporting (Annual)	yr	$28,000	1	$28,000
Subtotal Annual O&M				**$391,000**
Total O&M Costs (present worth @ 7%)				**$4,848,400**
Subtotal Cost				**$75,306,600**
Contingency		50%		$37,653,300
TOTAL PROJECT COST				**$112,959,900**

Notes:
1- Costs are in 2004 dollars.

APPENDIX J
NATURAL RESOURCE RESTORATION SUMMARY
CANDIDATE REMEDIAL ALTERNATIVES 1 THROUGH 8

Table J-1
Natural Resource Restoration Summary
Candidate Remedial Alternatives 1 through 8

Habitat/ Service Description and Location	Alternative 1 No Action/ Institutional Controls	Alternative 2a Water Management (Open Portal)	Alternative 2b Water Management (Hydrostatic Bulkheads)	Alternative 3a Water Management and Low-energy West Area Treatment (Open Portal)
Aquatic Habitat (Railroad Creek)				
Water Quality	No Active Measures	Slight reductions in short-term PCOC concentrations. Potential surface-water and groundwater ARARs would be met within approximately 250 years.	Slight reductions in short-term PCOC concentrations. Potential surface-water ARARs would be met within approximately 250 years.	Significant reductions in PCOC concentrations in Railroad Creek. Potential surface-water ARARs would be met within approximately 50 to 250 years, depending on the PCOC. Post-remediation PCOC concentrations in Railroad Creek are expected to be protective of resident aquatic species following remedy implementation in the short term.
Creek Substrate	No active measures. Reduction in iron loadings to Railroad Creek over time through natural attenuation.	No active measures. Reduction in iron loadings to Railroad Creek over time through natural attenuation.	No active measures. Reduction in iron loadings to Railroad Creek over time through natural attenuation.	No active measures. Reduction in iron loadings to Railroad Creek over time through natural attenuation.
Fish and Macroinvertebrates	Seasonal concentrations of cadmium, copper, and zinc would result in a continued potential for risks to aquatic life in Railroad Creek.	Short-term concentrations of cadmium, copper, and zinc would result in a continued potential for risks to aquatic life in Railroad Creek.	Short-term concentrations of cadmium, copper, and zinc would result in a continued potential for risks to aquatic life in Railroad Creek.	Post-remediation PCOC concentrations expected to be protective of resident species, including salmonids and their prey, following remedy implementation in the short term.
Terrestrial Habitat				
Riparian Habitat/Wetland Areas on South Side of Railroad Creek Adjacent to the Site	No Active Measures	Riparian habitat would be improved adjacent to the East Area through tailings pile slope regrading and revegetation.	Riparian habitat would be improved adjacent to the East Area through tailings pile slope regrading and revegetation.	Riparian habitat would be improved adjacent to the East Area through tailings pile slope regrading and revegetation.
Former Surface Water Retention Area	No Active Measures	Soils above potential risk-based cleanup levels would be removed or covered in place to mitigate exposure pathway.	Soils above potential risk-based cleanup levels would be removed or covered in place to mitigate exposure pathway.	Soils above potential risk-based cleanup levels would be removed or covered in place to mitigate exposure pathway.
Lagoon/West Area	No Active Measures	Soils above potential risk-based cleanup levels would be removed or covered in place to mitigate exposure pathway.	Soils above potential risk-based cleanup levels would be removed or covered in place to mitigate exposure pathway.	Soils above potential risk-based cleanup levels would be removed or covered in place to mitigate exposure pathway.
Tailings Piles	No Active Measures	Although not considered to be an injured resource, tailings pile revegetation activities would provide replacement upland habitat for other potentially injured areas on site.	Although not considered to be an injured resource, tailings pile revegetation activities would provide replacement upland habitat for other potentially injured areas on site.	Although not considered to be an injured resource, tailings pile revegetation activities would provide replacement upland habitat for other potentially injured areas on site.

Table J-1
Natural Resource Restoration Summary
Candidate Remedial Alternatives 1 through 8

Habitat/ Service Description and Location	Alternative 1 No Action/ Institutional Controls	Alternative 2a Water Management (Open Portal)	Alternative 2b Water Management (Hydrostatic Bulkheads)	Alternative 3a Water Management and Low-energy West Area Treatment (Open Portal)
Groundwater				
West Area Groundwater	Groundwater quality improved over time through natural attenuation.	PCOC loading to groundwater reduced over time through implementation of upgradient water diversion; source controls in the mill building, maintenance yard, and lagoon area; and natural attenuation.	PCOC loading to groundwater reduced over time through implementation of upgradient water diversion; source controls in the mill building, maintenance yard, and lagoon area; and natural attenuation.	PCOC loading to groundwater reduced over time through implementation of upgradient water diversion; source controls in the mill building, maintenance yard, and lagoon area; upper West Area groundwater collection and treatment; and natural attenuation.
East Area Groundwater	Groundwater quality improved over time through natural attenuation.	PCOC loading to groundwater reduced over time through implementation of upgradient water diversions, tailings pile revegetation, and natural attenuation.	PCOC loading to groundwater reduced over time through implementation of upgradient water diversions, tailings pile revegetation, and natural attenuation.	PCOC loading to groundwater reduced over time through implementation of upgradient water diversions, tailings pile revegetation, and natural attenuation.

Table J-1
Natural Resource Restoration Summary
Candidate Remedial Alternatives 1 through 8

Habitat/ Service Description and Location	Alternative 3b Water Management and Low-energy West Area Treatment (Hydrostatic Bulkheads)	Alternative 4a Water Management and Partial East Area Collection and Treatment	Alternative 4b Water Management and Extended East Area Collection and Treatment	Alternative 4c Water Management, Extended Railroad Creek Relocation, and East Area Collection and Treatment
Aquatic Habitat (Railroad Creek)				
Water Quality	Significant reductions in PCOC concentrations in Railroad Creek. Potential surface-water ARARs would be met within approximately 50 to 250 years, depending on the PCOC. Post-remediation PCOC concentrations in Railroad Creek are expected to be protective of resident aquatic species following remedy implementation in the short term.	Reductions in short-term PCOC concentrations. Potential surface-water ARARs would be met within approximately 50 to 250 years, depending on the PCOC.	Reductions in short-term PCOC concentrations. Potential surface-water ARARs would be met within approximately 50 to 250 years, depending on the PCOC.	Reductions in short-term PCOC concentrations. Potential surface-water ARARs would be met within approximately 50 to 250 years, depending on the PCOC.
Creek Substrate	No active measures. Reduction in iron loadings to Railroad Creek over time through natural attenuation.	Moderate reductions in iron loading to Railroad Creek. Extent of restoration unknown due to the potential for continued formation of iron flocculants and/or ferricrete adjacent to the site. Habitat enhancement measures (e.g., ferricrete removal and boulder placement) would be implemented adjacent to the Site.	Significant reductions in iron loading to Railroad Creek in the short term. Extent of restoration unknown due to the potential for continued formation of ferricrete adjacent to the site. Habitat enhancement measures (e.g., ferricrete removal and boulder placement) would be implemented adjacent to the Site.	Significant reductions in iron loading to Railroad Creek in the short term. Extent of restoration unknown due to the potential for continued formation of ferricrete adjacent to the site. Habitat enhancement measures (e.g., ferricrete removal and boulder placement) would be implemented adjacent to the Site.
Fish and Macroinvertebrates	Post-remediation PCOC concentrations expected to be protective of resident species, including salmonids and their prey, following remedy implementation in the short term.	Short-term concentrations of cadmium, copper, and zinc would result in a continued potential for risks to aquatic life in Railroad Creek.	Short-term concentrations of cadmium, copper, and zinc would result in a continued potential for risks to aquatic life in Railroad Creek.	Short-term concentrations of cadmium, copper, and zinc would result in a continued potential for risks to aquatic life in Railroad Creek.
Terrestrial Habitat				
Riparian Habitat/Wetland Areas on South Side of Railroad Creek Adjacent to the Site	Riparian habitat would be improved adjacent to the East Area through tailings pile slope regrading and revegetation.	Riparian habitat adjacent to the East Area would be improved through tailings pile slope regrading and revegetation.	Riparian habitat adjacent to the East Area would be improved through tailings pile slope regrading and revegetation.	Existing riparian habitat adjacent to the East Area would be improved through tailings pile slope regrading and revegetation. The relocated creek channel would include the establishment of riparian vegetation.
Former Surface Water Retention Area	Soils above potential risk-based cleanup levels would be removed or covered in place to mitigate exposure pathway.	Soils above potential risk-based cleanup levels would be removed or covered in place to mitigate exposure pathway.	Soils above potential risk-based cleanup levels would be removed or covered in place to mitigate exposure pathway.	Soils above potential risk-based cleanup levels would be removed or covered in place to mitigate exposure pathway.
Lagoon/West Area	Soils above potential risk-based cleanup levels would be removed or covered in place to mitigate exposure pathway.	Soils above potential risk-based cleanup levels would be removed or covered in place to mitigate exposure pathway.	Soils above potential risk-based cleanup levels would be removed or covered in place to mitigate exposure pathway.	Soils above potential risk-based cleanup levels would be removed or covered in place to mitigate exposure pathway.
Tailings Piles	Although not considered to be an injured resource, tailings pile revegetation activities would provide replacement upland habitat for other potentially injured areas on site.	Although not considered to be an injured resource, tailings pile revegetation activities would provide replacement upland habitat for other potentially injured areas on site.	Although not considered to be an injured resource, tailings pile revegetation activities would provide replacement upland habitat for other potentially injured areas on site.	Although not considered to be an injured resource, tailings pile revegetation activities would provide replacement upland habitat for other potentially injured areas on site.

Table J-1
Natural Resource Restoration Summary
Candidate Remedial Alternatives 1 through 8

Habitat/ Service Description and Location	Alternative 3b Water Management and Low-energy West Area Treatment (Hydrostatic Bulkheads)	Alternative 4a Water Management and Partial East Area Collection and Treatment	Alternative 4b Water Management and Extended East Area Collection and Treatment	Alternative 4c Water Management, Extended Railroad Creek Relocation, and East Area Collection and Treatment
Groundwater				
West Area Groundwater	PCOC loading to groundwater reduced over time through implementation of upgradient water diversion; source controls in the mill building, maintenance yard, and lagoon area; upper West Area groundwater collection and treatment; and natural attenuation.	PCOC loading to groundwater reduced over time through implementation of upgradient water diversion; source controls in the mill building, maintenance yard, and lagoon area; and natural attenuation.	PCOC loading to groundwater reduced over time through implementation of upgradient water diversion; source controls in the mill building, maintenance yard, and lagoon area; and natural attenuation.	PCOC loading to groundwater reduced over time through implementation of upgradient water diversion; source controls in the mill building, maintenance yard, and lagoon area; and natural attenuation.
East Area Groundwater	PCOC loading to groundwater reduced over time through implementation of upgradient water diversions, tailings pile revegetation, and natural attenuation.	PCOC loading to groundwater reduced over time through implementation of upgradient water diversions, tailings pile revegetation, and natural attenuation.	PCOC loading to groundwater reduced over time through implementation of upgradient water diversions, tailings pile revegetation, and natural attenuation.	PCOC loading to groundwater reduced over time through implementation of upgradient water diversions, tailings pile revegetation, and natural attenuation.

Table J-1
Natural Resource Restoration Summary
Candidate Remedial Alternatives 1 through 8

Habitat/ Service Description and Location	Alternative 5a Water Management, Partial East Area Collection, and East/West Area Treatment (Low-energy WTP)	Alternative 5b Water Management, Extended East Area Collection, and East/West Area Treatment (Low-energy WTP)	Alternative 5c Water Management, Extended Railroad Creek Relocation, and East/West Area Treatment (Low-energy WTP)	Alternative 5d Water Management, Secondary West Area Collection, Extended Railroad Creek Relocation, and East/West Area Treatment (Low-energy WTP)
Aquatic Habitat (Railroad Creek)				
Water Quality	Significant reductions in PCOC concentrations in Railroad Creek. Potential surface-water ARARs would be met within approximately 50 years, depending on the PCOC. Post-remediation PCOC concentrations in Railroad Creek are expected to be protective of resident aquatic species following remedy implementation in the short term.	Significant reductions in PCOC concentrations in Railroad Creek. Potential surface-water ARARs would be met within approximately 50 years, depending on the PCOC. Post-remediation PCOC concentrations in Railroad Creek are expected to be protective of resident aquatic species following remedy implementation in the short term.	Significant reductions in PCOC concentrations in Railroad Creek. Potential surface-water ARARs would be met within approximately 50 years, depending on the PCOC. Post-remediation PCOC concentrations in Railroad Creek are expected to be protective of resident aquatic species following remedy implementation in the short term.	Significant reductions in PCOC concentrations in Railroad Creek. Potential surface-water ARARs would be met within approximately 50 years, depending on the PCOC. Post-remediation PCOC concentrations in Railroad Creek are expected to be protective of resident aquatic species following remedy implementation in the short term.
Creek Substrate	Moderate reductions in iron loading to Railroad Creek in the short term. Extent of restoration unknown due to the potential for continued formation of iron flocculants and/or ferricrete adjacent to the site. Habitat enhancement measures (e.g., ferricrete removal and boulder placement) would be implemented adjacent to the Site.	Significant reductions in iron loading to Railroad Creek in the short term. Extent of restoration unknown due to the potential for continued formation of ferricrete adjacent to the site. Habitat enhancement measures (e.g., ferricrete removal and boulder placement) would be implemented adjacent to the Site.	Significant reductions in iron loading to Railroad Creek in the short term. Extent of restoration unknown due to the potential for continued formation of ferricrete adjacent to the site. Habitat enhancement measures (e.g., ferricrete removal and boulder placement) would be implemented adjacent to the Site.	Significant reductions in iron loading to Railroad Creek in the short term. Extent of restoration unknown due to the potential for continued formation of ferricrete adjacent to the site. Habitat enhancement measures (e.g., ferricrete removal and boulder placement) would be implemented adjacent to the Site.
Fish and Macroinvertebrates	Post-remediation PCOC concentrations expected to be protective of resident species, including salmonids and their prey, following remedy implementation in the short term.	Post-remediation PCOC concentrations expected to be protective of resident species, including salmonids and their prey, following remedy implementation in the short term.	Post-remediation PCOC concentrations expected to be protective of resident species, including salmonids and their prey, following remedy implementation in the short term.	Post-remediation PCOC concentrations expected to be protective of resident species, including salmonids and their prey, following remedy implementation in the short term.
Terrestrial Habitat				
Riparian Habitat/Wetland Areas on South Side of Railroad Creek Adjacent to the Site	Riparian habitat adjacent to the East Area would be improved through tailings pile slope regrading and revegetation.	Riparian habitat adjacent to the East Area would be improved through tailings pile slope regrading and revegetation.	Existing riparian habitat adjacent to the East Area would be improved through tailings pile slope regrading and revegetation. The relocated creek channel would include the establishment of riparian vegetation.	Existing riparian habitat adjacent to the East Area would be improved through tailings pile slope regrading and revegetation. The relocated creek channel would include the establishment of riparian vegetation.
Former Surface Water Retention Area	Soils above potential risk-based cleanup levels would be removed or covered in place to mitigate exposure pathway.	Soils above potential risk-based cleanup levels would be removed or covered in place to mitigate exposure pathway.	Soils above potential risk-based cleanup levels would be removed or covered in place to mitigate exposure pathway.	Soils above potential risk-based cleanup levels would be removed or covered in place to mitigate exposure pathway.
Lagoon/West Area	Soils above potential risk-based cleanup levels would be removed or covered in place to mitigate exposure pathway.	Soils above potential risk-based cleanup levels would be removed or covered in place to mitigate exposure pathway.	Soils above potential risk-based cleanup levels would be removed or covered in place to mitigate exposure pathway.	Soils above potential risk-based cleanup levels would be removed or covered in place to mitigate exposure pathway.
Tailings Piles	Although not considered to be an injured resource, tailings pile revegetation activities would provide replacement upland habitat for other potentially injured areas on site.	Although not considered to be an injured resource, tailings pile revegetation activities would provide replacement upland habitat for other potentially injured areas on site.	Although not considered to be an injured resource, tailings pile revegetation activities would provide replacement upland habitat for other potentially injured areas on site.	Although not considered to be an injured resource, tailings pile revegetation activities would provide replacement upland habitat for other potentially injured areas on site.

Table J-1
Natural Resource Restoration Summary
Candidate Remedial Alternatives 1 through 8

Habitat/ Service Description and Location	Alternative 5a Water Management, Partial East Area Collection, and East/West Area Treatment (Low-energy WTP)	Alternative 5b Water Management, Extended East Area Collection, and East/West Area Treatment (Low-energy WTP)	Alternative 5c Water Management, Extended Railroad Creek Relocation, and East/West Area Treatment (Low-energy WTP)	Alternative 5d Water Management, Secondary West Area Collection, Extended Railroad Creek Relocation, and East/West Area Treatment (Low-energy WTP)
Groundwater				
West Area Groundwater	PCOC loading to groundwater reduced over time through implementation of upgradient water diversion; source controls in the mill building, maintenance yard, and lagoon area; upper West Area groundwater collection and treatment; and natural attenuation.	PCOC loading to groundwater reduced over time through implementation of upgradient water diversion; source controls in the mill building, maintenance yard, and lagoon area; upper West Area groundwater collection and treatment; and natural attenuation.	PCOC loading to groundwater reduced over time through implementation of upgradient water diversion; source controls in the mill building, maintenance yard, and lagoon area; upper West Area groundwater collection and treatment; and natural attenuation.	PCOC loading to groundwater reduced over time through implementation of upgradient water diversion; source controls in the mill building, maintenance yard, and lagoon area; upper West Area groundwater collection and treatment; and natural attenuation.
East Area Groundwater	PCOC loading to groundwater reduced over time through implementation of upgradient water diversions, tailings pile revegetation, and natural attenuation.	PCOC loading to groundwater reduced over time through implementation of upgradient water diversions, tailings pile revegetation, and natural attenuation.	PCOC loading to groundwater reduced over time through implementation of upgradient water diversions, tailings pile revegetation, and natural attenuation.	PCOC loading to groundwater reduced over time through implementation of upgradient water diversions, tailings pile revegetation, and natural attenuation.

Table J-1
Natural Resource Restoration Summary
Candidate Remedial Alternatives 1 through 8

Habitat/ Service Description and Location	Alternative 6a Water Management, Extended Secondary West Area Collection, Extended Railroad Creek Relocation, and East/West Area Treatment (Mechanical WTP)	Alternative 6b Water Management, Extended Secondary West Area Collection, Extended Railroad Creek Relocation, and East/West Area Treatment (Mechanical WTP - Hydrostatic Bulkhead)	Alternative 7 Capping, Consolidation, Water Management, and West Area Treatment	Alternative 8 Source Control and East/West Area Treatment
Aquatic Habitat (Railroad Creek)				
Water Quality	Significant reductions in PCOC concentrations in Railroad Creek. Potential surface-water ARARs would be met within approximately 50 to 250 years, depending on the PCOC. Post-remediation PCOC concentrations in Railroad Creek are expected to be protective of resident aquatic species following remedy implementation in the short term.	Significant reductions in PCOC concentrations in Railroad Creek. Potential surface-water ARARs would be met within approximately 50 to 250 years, depending on the PCOC. Post-remediation PCOC concentrations in Railroad Creek are expected to be protective of resident aquatic species following remedy implementation in the short term.	Significant reductions in PCOC concentrations in Railroad Creek. Potential surface-water ARARs would be met within approximately 50 years, depending on the PCOC. Post-remediation PCOC concentrations in Railroad Creek are expected to be protective of resident aquatic species following remedy implementation in the short term.	Significant reductions in PCOC concentrations in Railroad Creek. Potential surface-water ARARs would be met within approximately 50 years, depending on the PCOC. Post-remediation PCOC concentrations in Railroad Creek are expected to be protective of resident aquatic species following remedy implementation in the short term.
Creek Substrate	Significant reductions in iron loading to Railroad Creek in the short term. Extent of restoration unknown due to the potential for continued formation of ferricrete adjacent to the site. Habitat enhancement measures (e.g., ferricrete removal and boulder placement) would be implemented adjacent to the Site.	Significant reductions in iron loading to Railroad Creek in the short term. Extent of restoration unknown due to the potential for continued formation of ferricrete adjacent to the site. Habitat enhancement measures (e.g., ferricrete removal and boulder placement) would be implemented adjacent to the Site.	Significant reductions in iron loading to Railroad Creek over time. Extent of restoration unknown due to the potential for continued formation of ferricrete adjacent to the site. Habitat enhancement measures (e.g., ferricrete removal and boulder placement) would be implemented adjacent to the Site.	Significant reductions in iron loading to Railroad Creek in the short term. Extent of restoration unknown due to the potential for continued formation of ferricrete adjacent to the site. Habitat enhancement measures (e.g., ferricrete removal and boulder placement) would be implemented adjacent to the Site.
Fish and Macroinvertebrates	Post-remediation PCOC concentrations expected to be protective of resident species, including salmonids and their prey, following remedy implementation in the short term.	Post-remediation PCOC concentrations expected to be protective of resident species, including salmonids and their prey, following remedy implementation in the short term.	Post-remediation PCOC concentrations expected to be protective of resident species, including salmonids and their prey, following remedy implementation in the short term.	Post-remediation PCOC concentrations expected to be protective of resident species, including salmonids and their prey, following remedy implementation in the short term.
Terrestrial Habitat				
Riparian Habitat/Wetland Areas on South Side of Railroad Creek Adjacent to the Site	Existing riparian habitat adjacent to the East Area would be improved through tailings pile slope regrading and revegetation. The relocated creek channel would include the establishment of riparian vegetation.	Existing riparian habitat adjacent to the East Area would be improved through tailings pile slope regrading and revegetation. The relocated creek channel would include the establishment of riparian vegetation.	Although not considered an injured resource, area within current footprint of tailings pile 1 would be revegetated following consolidation to provide replacement habitat for other potentially injured areas on site.	Although not considered an injured resource, area within current footprint of tailings pile 1 would be revegetated following consolidation to provide replacement habitat for other potentially injured areas on site.
Former Surface Water Retention Area	Soils above potential risk-based cleanup levels would be removed or covered in place to mitigate exposure pathway.	Soils above potential risk-based cleanup levels would be removed or covered in place to mitigate exposure pathway.	Soils above potential risk-based cleanup levels would be removed or covered in place to mitigate exposure pathway.	Soils above potential risk-based cleanup levels would be removed or covered in place to mitigate exposure pathway.
Lagoon/West Area	Soils above potential risk-based cleanup levels would be removed or covered in place to mitigate exposure pathway.	Soils above potential risk-based cleanup levels would be removed or covered in place to mitigate exposure pathway.	Soils above potential risk-based cleanup levels would be removed or covered in place to mitigate exposure pathway.	Soils above potential risk-based cleanup levels would be removed or covered in place to mitigate exposure pathway.
Tailings Piles	Although not considered to be an injured resource, tailings pile revegetation activities would provide replacement upland habitat for other potentially injured areas on site.	Although not considered to be an injured resource, tailings pile revegetation activities would provide replacement upland habitat for other potentially injured areas on site.	Following cover placement the consolidated tailings pile would be re-seeded. Maintenance would be conducted to prevent the growth of deep-rooted plants.	Following cover placement the consolidated tailings pile would be re-seeded. Maintenance would be conducted to prevent the growth of deep-rooted plants.

Table J-1
Natural Resource Restoration Summary
Candidate Remedial Alternatives 1 through 8

Habitat/ Service Description and Location	Alternative 6a Water Management, Extended Secondary West Area Collection, Extended Railroad Creek Relocation, and East/West Area Treatment (Mechanical WTP)	Alternative 6b Water Management, Extended Secondary West Area Collection, Extended Railroad Creek Relocation, and East/West Area Treatment (Mechanical WTP - Hydrostatic Bulkhead)	Alternative 7 Capping, Consolidation, Water Management, and West Area Treatment	Alternative 8 Source Control and East/West Area Treatment
Groundwater				
West Area Groundwater	PCOC loading to groundwater reduced over time through implementation of upgradient water diversion; source controls in the mill building, maintenance yard, and lagoon area; upper West Area groundwater collection and treatment; and natural attenuation.	PCOC loading to groundwater reduced over time through implementation of upgradient water diversion; source controls in the mill building, maintenance yard, and lagoon area; upper West Area groundwater collection and treatment; and natural attenuation.	PCOC loading to groundwater reduced over time through implementation of upgradient water diversion; source controls in the mill building, maintenance yard, and lagoon area; upper West Area groundwater collection and treatment; and natural attenuation.	PCOC loading to groundwater reduced over time through implementation of upgradient water diversion; source controls in the mill building, maintenance yard, and lagoon area; relocation of the east and west waste rock piles; upper West Area groundwater collection and treatment; and natural attenuation.
East Area Groundwater	PCOC loading to groundwater reduced over time through implementation of upgradient water diversions, tailings pile revegetation, and natural attenuation.	PCOC loading to groundwater reduced over time through implementation of upgradient water diversions, tailings pile revegetation, and natural attenuation.	PCOC loading to groundwater reduced over time through implementation of upgradient water diversions; tailings pile consolidation and capping; and natural attenuation.	PCOC loading to groundwater reduced over time through implementation of upgradient water diversions; tailings pile consolidation and capping; and natural attenuation.

APPENDIX K
EVALUATION OF PRELIMINARY RISK-BASED CLEANUP LEVELS FOR THE PROTECTION OF TERRESTRIAL ECOLOGICAL RECEPTORS AT THE HOLDEN MINE SITE

Evaluation of Preliminary Risk-based Soil Values for the Protection of Terrestrial Ecological Receptors at the Holden Mine Site

Prepared for

Intalco

Prepared by:

URS Corporation
February 16, 2004

Evaluation of Preliminary Risk-based Soil Values for the Protection of Terrestrial Ecological Receptors at the Holden Mine Site

INTRODUCTION

A site-specific ecological risk assessment (ERA) was performed for the Holden Mine site during the remedial investigation (RI) based on available federal and state guidance, and industry standards at the time. The ERA was accepted as final by the USDA Forest Service, US Environmental Protection Agency, and Washington State Department of Ecology (Agencies) in February 2002. The objectives of the ERA, as stated in the RI Report were to: (1) characterize the nature and extent of human activity-related conditions at the site; (2) provide limited characterization of ecological populations, communities, and ecosystems; (3) identify distribution of potential compounds of concern (PCOCs) and quantify, to the extent practicable, impacts of those PCOCs to Site ecology; and (4) support development and evaluation of risk management alternatives and provide a risk-based framework for identifying future data needs. The purpose and methods used for conducting the ERA were not intended for use in calculating numeric soil concentrations deemed protective of the various ecological receptors, including soil invertebrates and other wildlife.

This technical memorandum presents the evaluation of preliminary numeric soil values protective of terrestrial ecological receptors. The ERA and soil chemistry data collected during the RI from the Holden Village, Maintenance Yard, and Lagoon Area were used as a basis for this evaluation. Ecological receptors evaluated include terrestrial plants, soil invertebrates (worms), and the American robin, which was selected as a representative wildlife species previously identified in the ERA as potentially at risk from soil contaminants at the site. The PCOCs identified in the Agency-approved ERA include cadmium, copper, lead and zinc. Preliminary risk-based values for each of the four PCOCs are provided below.

METHODS AND RESULTS

Preliminary soil values identified during this assessment for the protection of terrestrial ecological receptors are summarized on Table 1. The first set of values provided on Table 1 was identified based upon a preliminary review of the ERA. Where ranges are provided, the low value represents a conservative screening value resulting in a hazard quotient equal to or less than 1. The upper value of the range represents the next lowest concentration, based on available sampling data, for which a potential for risk was indicated based on the results of the ERA. The second set of values on Table 1 includes potential risk-based values derived for soil invertebrates and the American robin. The basis for these potential risk-based values is described in this assessment. For comparison purposes, area background concentrations calculated for each soil PCOC are also presented in Table 1.

The shaded values in Table 1 are the preliminary soil values for cadmium (18 mg/kg), copper (440 mg/kg), lead (448 mg/kg) and zinc (514 mg/kg). Rationale for the selection of these values is presented below.

Plants

Results of the ERA indicate no risk to plants from metal PCOCs, except for copper in limited areas, when soil concentrations from the Site are compared with other mine sites where plants are successfully growing. Information presented in the ERA indicates that plants are revegetating at the Site, and that Site soils are not phytotoxic. Additionally, as described in the revised DRI (URS 1999), vegetation (trees and understory) is extensive and there is a wide variety of species present at the Site.

Based on data from other mine sites where plants are successfully revegetating, the ERA concluded that a copper concentration of 440 mg/kg would not present a risk to plants at the Holden Mine site.

Soil Invertebrates

For this assessment, preliminary values for soil invertebrates were calculated as the 20th percentile of the above site background rank-ordered adverse effect concentrations of metals in soil identified from a review of the literature. Potential concentrations were calculated for those PCOCs for which a potential for risk was indicated in the Agency-approved ERA. The 20th percentile was chosen based on a summary of information in Suter et al. (2000), which indicates that the lowest observed adverse effect levels (LOAELs) for both individual response parameters in terrestrial biota toxicity studies and the minimum detectable biological effect in field studies is approximately equal to a 20% change in the measured endpoint.

Percentiles of rank-ordered toxicity data are commonly used in ecological risk assessments as either screening values or cleanup levels. The United States Environmental Protection Agency (USEPA) uses percentiles of toxicity data in assessing ecological risk-based values for ambient water quality criteria, and the effects range-low (ER-L) and effects range-median (ER-M) sediment quality guidelines. This method is also consistent with the State of Washington Model Toxics Control Act (MTCA) requirements for terrestrial ecological evaluations and for developing potential soil cleanup levels as specified under WAC 173-340-7493(3). Under MTCA (WAC 173-340-700(6)(d)), area background levels must be considered in setting potential soil cleanup values. Therefore, cleanup values cannot be set below natural background concentrations. Area background data for the Holden Mine site was considered in this assessment.

Cadmium toxicity data for soil invertebrates (primarily earthworms) and the calculated potential risk-based values are provided in Table 2. The data in Table 2 were compiled from a review of the toxicological literature, and are presented in rank-ordered format, from the lowest to highest soil cadmium concentrations, sorted first by no adverse effect data, then by adverse effect data. Tables 3, 4, and 5 present copper, lead, and zinc toxicity data in the same format for soil invertebrates, respectively. Results of the assessment conducted for soil invertebrates are summarized on Table 1.

Data provided from other sites where plants are revegetating successfully and soils presumably contain functioning soil biota indicate that the preliminary value for copper, calculated based on the 20^{th} percentile of the above site background rank-ordered adverse effect concentrations, may be conservative for this site. A majority of the earthworm species tested are considered to be exotic species and are not native to the Pacific Northwest. As can be seen on Table 3, there are also a large number of studies indicating no observed effect to the earthworms tested at concentrations significantly higher than the value obtained using the 20^{th} percentile method. As a result, a value of 440 mg/kg for copper is proposed for both Site plants and soil invertebrates.

It should be noted that the results of the ERA found that due to the physical qualities of the substrate, portions of the site do not likely provide adequate habitat for earthworms. This would apply to areas of the site that have low organic matter content (e.g., maintenance yard, lagoon area, etc.). As a result, the exposure pathway would not be complete for soil invertebrates in these areas. Available studies also indicate that low soil pH, typical of high-elevation forests in the region, may be a limiting factor for the establishment of earthworms. Additionally, the risk-based evaluation conducted for the American Robin below did not indicate a potential risk due to exposure to Site constituents, including the consumption of earth worms.

American Robin

The results of the ERA indicated a potential risk to robins due to soil concentrations of cadmium, lead, and zinc at the Site. Preliminary risk-based values derived for these three PCOCs were based on a food web model that evaluated the LOAELs of ingested metal concentrations in the diet. The preliminary robin-based values are expected to correspond to small effects on individual robins that would have minimal impacts on populations or communities (Efroymson et al. 1997).

Preliminary risk-based values for the American robin were derived using an extension of the equations specified in Table 749-4 of MTCA (Ecology 2001) for calculating soil concentrations for wildlife protection. Specifically, the default exposure model specified for the robin in MTCA has been expanded to recognize the fact that robins are omnivorous, and not strictly vermivorous (i.e. feed only on earthworms). Based on information in USEPA (1993), we have assumed that the diet of the robin consists of 52% soil invertebrates and 48% plant material. The complete set of exposure factors for the robin used during calculation of soil values are presented in Table 6. The modification to the feeding habits of the robin in the food web model is consistent with MTCA requirements for terrestrial ecological evaluations presented at WAC 173-340-7493(3)(c).

The TRVs used in the calculation of preliminary soil values for the robin are based on sublethal LOAEL for robins presented in Sample et al. (1996). Use of LOAELs is permitted in site-specific ecological evaluations under MTCA at WAC 173-340-7493(4)(a). None of the ingested dose TRVs used in the calculations for robins has been allometrically scaled to adjust for differences in body weights between the laboratory test species and the American robin. Allometric scaling of the TRVs was not performed because Mineau et al. (1996), in a review of avian TRVs, found that scaling factors did not differ significantly from unity.

Calculated preliminary values for the American robin are presented in Table 7. The potential cleanup values were calculated using Equation 1.

Equation 1:

$$Soil\ CL\ (mg/kg) = \frac{TRV}{I_S + (BCF_{SP} \times I_P \times P_P) + (BCF_{SI} \times I_I \times P_I)}$$

Where: Soil CL = preliminary risk-based soil value for robins (mg contaminant / kg soil)
TRV = toxicity reference value (mg contaminant / kg body weight / day)
I_S = soil ingestion rate (kg soil / kg body weight / day)
BCF_{SP} = soil to plant bioconcentration factor (unitless)
I_P = plant ingestion rate (kg dry weight plants / kg body weight / day)
P_P = proportion of plants in diet
BCF_{SI} = soil to soil invertebrate bioconcentration factor (unitless)
I_I = soil invertebrate ingestion rate (kg dry weight inverts / kg body weight / day)
P_I = proportion of soil invertebrates in diet

The preliminary soil values based on the protection of robins are summarized on Table 1.

Summary

The proposed soil values for the protection of terrestrial ecological receptors at the Site include the following:

- Cadmium – 10 mg/kg based on the protection of soil invertebrates.
- Copper – 440 mg/kg based upon the protection of plants and soil invertebrates.
- Lead – 448 mg/kg based upon the protection of the American robin.
- Zinc – 514 mg/kg based upon the protection of soil invertebrates.

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Table 1. Preliminary Soil Values for Protection of Terrestrial Ecological Receptors.

Potential Constituent of Concern	Area Background[(1)] (mg/kg)	Preliminary Values Based on ERA[(2)] (mg/kg)			Preliminary Risk-based Soil Values (mg/kg)	
		Plants	Soil Invertebrates	American Robin	Soil Invertebrates	American Robin
Cadmium	5.4	No risk indicated	20 - 21.6	1.54 - 21.6	**18**	144
Copper	57.4	**440**	50 - 311	No risk indicated	**440**	No risk indicated
Lead	20.6	No risk indicated	500 - 620	61.4 - 620	1629	**448**
Zinc	253	No risk indicated	200 - 3240	246 - 3240	**514**	1436

(1) - Area background values based on statistical analyses per MTCA using data collected from the Railroad Creek drainage during the RI. Data presented in the revised DRI Report (URS 1999)

(2) - Values based on the findings of the ERA (URS 1999). Where ranges are provided, the low value represents a conservative screening value resulting in a hazard quotient equal to or less than 1. The upper value of the range represents the next lowest concentration, based on available sampling data, for which a potential for risk was indicated based on the results of the ERA.

[shaded box] - Highlighted values identify preliminary soil cleanup levels

Table 2. Literature Review of the Potential Toxicity of Cadmium in Soil to Soil Invertebrates

Chemical Form	Test species	Scientific name	Growth media	Exposure days	Soil concentration mg/kg	Endpoint	Response parameter	Percent decline at LOEC	Citation
		Intalco Reported Area Background =			**5.4**				
CdCl2	Earthworm	*Eisenia andrei*	OECD soil	21	10	NOEC	Cocoons/worm	23	van Gestel et al. 1992
$CdCl_2$	Earthworm	*Eisenia andrei*	OECD soil	21	10	NOEC	Juveniles/worm	22	van Gestel et al. 1992
$CdCl_2$	Earthworm	*Eisenia andrei*	OECD soil	84	10	NOEC	Growth	40	van Gestel et al. 1992
	Earthworm	*Dendrobaena rubida*	Soil & dung	120	10	NOEC	Cocoons/worm	62	Bengtsson et al. 1986
	Earthworm	*Dendrobaena rubida*	Soil & dung	120	10	NOEC	Cocoons/worm	78	Bengtsson et al. 1986
	Earthworm	*Dendrobaena rubida*	Soil & dung	120	10	NOEC	Hatchlings/cocoon	71	Bengtsson et al. 1986
	Earthworm	*Dendrobaena rubida*	Soil & dung	120	10	NOEC	% Cocoon hatching success	47	Bengtsson et al. 1986
$CdCl_2$	Earthworm	*Eisenia andrei*	Artificial soil	84	10	NOEC	Sexual development		van Gestel 1991
$CdCl_2$	Earthworm	*Eisenia andrei*	Artificial soil	42	10	NOEC	Progeny count		van Gestel 1992
$CdCl_2$	Earthworm	*Eisenia andrei*	Artificial soil	77	10	NOEC	Progeny count		van Gestel 1992
$CdCl_2$	Earthworm	*Eisenia andrei*	OECD soil	84	32	NOEC	Growth	44	van Gestel et al. 1992
$CdCl_2$	Earthworm	*Eisenia andrei*	Artificial soil	84	32	NOEC	Growth		van Gestel 1991
$CdCl_2$	Earthworm	*Eisenia andrei*	Artificial soil	42	100	NOEC	Weight		van Gestel 1992
$CdCl_2$	Earthworm	*Eisenia andrei*	Artificial soil	77	100	NOEC	Progeny count		van Gestel 1992
$CdCl_2$	Earthworm	*Eisenia andrei*	Artificial soil	77	100	NOEC	Fertile cocoons		van Gestel 1992
$CdCl_2$	Earthworm	*Lumbricus rubellus*	Sandy loam	84	150	NOEC	Survival	82	Ma 1982
Cd nitrate	Earthworm	*Eisenia fetida*	Artificial soil	21	207	NOEC	Weight		Spurgeon 1995
Cd nitrate	Earthworm	*Eisenia fetida*	Artificial soil	14	> 300	NOEC	Mortality		Spurgeon 1995
Cd nitrate	Earthworm	*Eisenia fetida*	Artificial soil	56	> 300	NOEC	Mortality		Spurgeon 1994
		Intalco Reported Area Background =			**5.4**				
CdSO4	Earthworm	*Aporrectodea caliginosa*	Egyptian	56	10	LOEC	Cocoon production	22	van Gestel et al. 1992
$CdCl_2$	Earthworm	*Eisenia andrei*	Artificial soil	84	10	LOEC	Sexual development		van Gestel 1991
$CdCl_2$	Earthworm	*Eisenia andrei*	Artificial soil	42	10	LOEC	Progeny count		van Gestel 1992
$CdCl_2$	Earthworm	*Eisenia andrei*	OECD soil	21	18	LOEC	Juveniles/worm	23	van Gestel et al. 1992
$CdCl_2$	Earthworm	*Eisenia andrei*	OECD soil	21	18	LOEC	Cocoons/worm	24	Malecki et al. 1982
$CdCl_2$	Earthworm	*Eisenia andrei*	Artificial soil	77	18	LOEC	Progeny count		van Gestel 1992
$C_4H_6CdO_4$	Earthworm	*Eisenia fetida*	Horse manure	56	25	LOEC	Cocoon production	25	Khalil et al. 1996
$CdCl_2$	Earthworm	*Eisenia andrei*	OECD soil	84	27	LOEC	Sexual development	25	Neuhauser et al. 1984
$CdCl_2$	Earthworm	*Eisenia andrei*	OECD soil	84	32	LOEC	Growth	30	Bengtsson et al. 1986
$Cd(NO_3)_2$	Earthworm	*Eisenia fetida*	OECD soil	56	46.3	LOEC	Cocoon production	38	Bengtsson et al. 1986
$C_4H_6CdO_4$	Earthworm	*Eisenia fetida*	Horse manure	140	50	LOEC	Cocoon production	40	van Gestel et al. 1992
Soluble forms	Earthworm	*Eisenia fetida*	Horse manure	42	100	LOEC	Growth	44	van Gestel et al. 1992
$CdCl_2$	Earthworm	*Eisenia andrei*	OECD soil	84	100	LOEC	Growth	47	Bengtsson et al. 1986
	Earthworm	*Dendrobaena rubida*	Soil & dung	120	100	LOEC	% Cocoon hatching success	50	van Gestel et al. 1992
	Earthworm	*Dendrobaena rubida*	Soil & dung	120	100	LOEC	Cocoons/worm	50	Spurgeon et al. 1994
	Earthworm	*Dendrobaena rubida*	Soil & dung	120	100	LOEC	Hatchlings/cocoon	50	van Gestel et al. 1992
	Earthworm	*Dendrobaena rubida*	Soil & dung	120	100	LOEC	Cocoons/worm	50	Spurgeon & Hopkin 1995

Table 2. Literature Review of the Potential Toxicity of Cadmium in Soil to Soil Invertebrates

Chemical Form	Test species	Scientific name	Growth media	Exposure days	Soil concentration mg/kg	Endpoint	Response parameter	Percent decline at LOEC	Citation
Soluble forms	Earthworm	*Eisenia fetida*	Horse manure	42	100	LOEC	Cocoon production	50	van Gestel & van Dis 1988
$CdCl_2$	Earthworm	*Eisenia andrei*	Artificial soil	84	100	LOEC	Growth		van Gestel 1991
$CdCl_2$	Earthworm	*Eisenia andrei*	OECD soil	84	108	LOEC	Sexual development	50	Neuhauser et al. 1985
$Cd(NO_3)_2$	Earthworm	*Eisenia fetida*	OECD soil	21	215	LOEC	Growth	52	Malecki et al. 1982
$CdCl_2$	Earthworm	*Eisenia fetida*	Sandy soil	14	440	LOEC	Survival	62	Bengtsson et al. 1986
$CdCl_2$	Earthworm	*Lumbricus rubellus*	Sandy loam	84	1000	LOEC	Survival	71	Bengtsson et al. 1986
CdNO3	Earthworm	*Eisenia fetida*	OECD soil	14	1843	LOEC	Survival	74	Bengtsson et al. 1986
	20th percentile of rank-ordered LOEC data (above bkgd) =				**18.0**				

Table 3. Literature Review of the Potential Toxicity of Copper in Soil to Soil Invertebrates

Chemical Form	Test species	Scientific name	Growth media	Exposure days	Soil concentration mg/kg	Endpoint	Response parameter	Percent decline at LOEC	Citation
$CuCl_2$	Earthworm	*Lumbricus rubellus*	Sandy loam	42	13	NOEC	Cocoon production	41	Ma 1984
$CuCl_2$	Earthworm	*Eisenia andrei*	OECD soil	84	32	NOEC	Growth	32	van Gestel et al. 1991a
Cu-sulfate	Earthworm	*Apporectodea caliginosa*	Egyptian	56	50	NOEC	Cocoon production	36	Khalil et al. 1996
CuCl2	Earthworm	*Lumbricus rubellus*	Loamy sand	42	54	NOEC	Cocoon production	42	Ma 1984
		Intalco Reported Area Background =			**57.4**				
$CuSO_4$	Earthworm	*Lumbricus rubellus*	Loamy sand	18	83	NOEC	Cocoon production	26	Ma 1984
	Earthworm	*Dendrobaena rubida*	Soil & dung	120	100	NOEC	Cocoons/worm	96	Bengtsson et al. 1986
	Earthworm	*Dendrobaena rubida*	Soil & dung	120	100	NOEC	Hatchlings/cocoon	100	Bengtsson et al. 1986
	Earthworm	*Dendrobaena rubida*	Soil & dung	120	100	NOEC	Cocoons/worm	90	Bengtsson et al. 1986
	Earthworm	*Dendrobaena rubida*	Soil & dung	120	100	NOEC	Hatchlings/cocoon	100	Bengtsson et al. 1986
$CuCl_2$	Earthworm	*Eisenia fetida*	OECD soil	21	120	NOEC	Cocoon production	36	van Gestel et al. 1991a
$CuSO_4$	Earthworm	*Lumbricus rubellus*	Loamy sand	18	148	NOEC	Cocoon production	33	Ma 1984
$CuCl_2$	Earthworm	*Lumbricus rubellus*	Sandy loam	84	150	NOEC	Survival	82	Ma 1984
$C_4H_6CuO_4$	Earthworm	*Eisenia fetida*	Horse manure	56	300	NOEC	Cocoon production	24	Malecki et al. 1982
$C_4H_6CuO_4$	Earthworm	*Eisenia fetida*	Horse manure	140	500	NOEC	Cocoon production	24	Malecki et al. 1982
CuSO4	Earthworm	*Eisenia fetida*	Natural soil	62	500	NOEC	Biomass		Aquaterra Environmental 2000
CuSO4	Earthworm	*Eisenia fetida*	Natural soil	62	800	NOEC	Cocoon hatch		Aquaterra Environmental 2000
CuSO4	Earthworm	*Eisenia fetida*	Natural soil	62	800	NOEC	Reproduction		Aquaterra Environmental 2000
Soluble forms	Earthworm	*Eisenia fetida*	Horse manure	42	1000	NOEC	Growth	27	Neuhauser et al. 1984
Soluble forms	Earthworm	*Eisenia fetida*	Horse manure	42	1000	NOEC	Cocoon production	85	Neuhauser et al. 1984
Cu	Earthworm	*Eisenia fetida*	Natural soil	56	22000	NOEC	Mortality		Hartenstein 1981
$CuCl_2$	Earthworm	*Allolobophora chlorotica*	Sandy loam		51	LOEC	Cocoon production	50	Ma 1988
$Cu(NO_3)_2$	Earthworm	*Eisenia fetida*	OECD soil	56	53.3	LOEC	Cocoon production	50	Spurgeon et al. 1994
		Intalco Reported Area Background =			**57.4**				
$CuCl_2$	Earthworm	*Lumbricus rubellus*	Sandy loam	42	63	LOEC	Cocoon production	41	Ma 1984
$CuCl_2$	Earthworm	*Apporectodea caliginosa*	Sandy loam		68	LOEC	Cocoon production	50	Ma 1988
$CuCl_2$	Earthworm	*Eisenia andrei*	OECD soil	84	100	LOEC	Growth	32	van Gestel et al. 1991a
Cu-sulfate	Earthworm	*Apporectodea caliginosa*	Egyptian	56	100	LOEC	Cocoon production	36	Khalil et al. 1996
	Earthworm	*Dendrobaena rubida*	Soil & dung	120	100	LOEC	Cocoons/worm	70	Bengtsson et al. 1986
	Earthworm	*Dendrobaena rubida*	Soil & dung	120	100	LOEC	Hatchlings/cocoon	64	Bengtsson et al. 1986
	Earthworm	*Allolobophora caliginosa*	Polder soil	60	110	LOEC	Cocoon production	27	van Rhee 1975
$CuCl_2$	Earthworm	*Lumbricus rubellus*	Sandy loam		122	LOEC	Cocoon production	50	Ma 1988
$CuCl_2$	Earthworm	*Lumbricus rubellus*	Loamy sand	42	131	LOEC	Cocoon production	42	Ma 1984
$CuSO_4$	Earthworm	*Lumbricus rubellus*	Loamy sand	18	148	LOEC	Cocoon production	26	Ma 1984
$CuCl_2$	Earthworm	*Eisenia fetida*	OECD soil	21	180	LOEC	Cocoon production	36	van Gestel et al. 1989
$CuSO_4$	Earthworm	*Octolasium cyaneum*	Brown soil	14	180	LOEC	Survival	50	Streit & Jaggy 1983
$CuSO_4$	Earthworm	*Lumbricus rubellus*	Loamy sand	18	278	LOEC	Cocoon production	33	Ma 1984
	Earthworm	*Dendrobaena rubida*	Soil & dung	120	500	LOEC	Cocoons/worm	96	Bengtsson et al. 1986

Table 3. Literature Review of the Potential Toxicity of Copper in Soil to Soil Invertebrates

Chemical Form	Test species	Scientific name	Growth media	Exposure days	Soil concentration mg/kg	Endpoint	Response parameter	Percent decline at LOEC	Citation
	Earthworm	*Dendrobaena rubida*	Soil & dung	120	500	LOEC	Hatchlings/cocoon	100	Bengtsson et al. 1986
	Earthworm	*Dendrobaena rubida*	Soil & dung	120	500	LOEC	Cocoons/worm	90	Bengtsson et al. 1986
	Earthworm	*Dendrobaena rubida*	Soil & dung	120	500	LOEC	Hatchlings/cocoon	100	Bengtsson et al. 1986
$C_4H_6CuO_4$	Earthworm	*Eisenia fetida*	Horse manure	56	500	LOEC	Cocoon production	24	Malecki et al. 1982
Cu-nitrate	Earthworm	*Eisenia fetida*	OECD soil	21	601	LOEC	Growth	50	Spurgeon & Hopkin 1995
$CuNO_3$	Earthworm	*Eisenia fetida*	OECD soil	14	643	LOEC	Survival	50	Neuhauser et al. 1985
CuSO4	Earthworm	*Eisenia fetida*	Natural soil	62	800	LOEC	Biomass		Aquaterra Environmental 2000
$CuSO_4$	Earthworm	*Octolasium cyaneum*	Rendzina soil	14	850	LOEC	Survival	50	Streit & Jaggy 1983
$CuCl_2$	Earthworm	*Lumbricus rubellus*	Sandy loam	84	1000	LOEC	Survival	82	Ma 1982
$C_4H_6CuO_4$	Earthworm	*Eisenia fetida*	Horse manure	140	1000	LOEC	Cocoon production	24	Malecki et al. 1982
CuSO4	Earthworm	*Eisenia fetida*	Natural soil	62	1000	LOEC	Cocoon hatch		Aquaterra Environmental 2000
CuSO4	Earthworm	*Eisenia fetida*	Natural soil	62	1000	LOEC	Reproduction		Aquaterra Environmental 2000
[Carbonato(2-)]dihydroxydicopper	Earthworm	*Eisenia fetida*	Media mixture	56	1000	LOEC	Weight		Malecki 1982
Soluble forms	Earthworm	*Eisenia fetida*	Horse manure	42	2000	LOEC	Growth	27	Neuhauser et al. 1984
Soluble forms	Earthworm	*Eisenia fetida*	Horse manure	42	2000	LOEC	Cocoon production	85	Neuhauser et al. 1984
[Carbonato(2-)]dihydroxydicopper	Earthworm	*Eisenia fetida*	Media mixture	56	2000	LOEC	Reproduction		Malecki 1982
CuSO4	Earthworm	*Octolasium cyaneum*	Peat soil	14	2500	LOEC	Survival	50	Streit & Jaggy 1983
Cu oxide	Earthworm	*Eisenia fetida*	Media mixture	56	40000	LOEC	Growth		Malecki 1982
Cu oxide	Earthworm	*Eisenia fetida*	Media mixture	56	20000	LOEC	Reproduction		Malecki 1982
	20th percentile of rank-ordered LOEC data (above bkgd) =				**114.8**				
	40th percentile of rank-ordered LOEC data (above bkgd) =				**455.6**				

Table 4. Literature Review of the Potential Toxicity of Lead in Soil to Soil Invertebrates

Chemical Form	Test species	Scientific name	Growth media	Exposure days	Soil concentration mg/kg	Endpoint	Response parameter	Percent decline at LOEC	Citation
		Intalco Reported Area Background =			**20.6**				
	Earthworm	*Dendrobaena rubida*	Soil and dung	120	100	NOEC	Cocoons/worm	75	Bengtsson et al. 1986
	Earthworm	*Dendrobaena rubida*	Soil and dung	120	100	NOEC	Hatchlings/cocoon	100	Bengtsson et al. 1986
$Pb(C_2H_3O_2)_2$	Earthworm	*Eisenia fetida*	Horse manure	140	1000	NOEC	Cocoon production	28	Malecki et al. 1982
Nitric acid, Pb(2+) salt	Earthworm	*Eisenia fetida*	Artificial soil	56	1940	NOEC	Reproduction		Spurgeon 1994
Nitric acid, Pb(2+) salt	Earthworm	*Eisenia fetida*	Artificial soil	21	1966	NOEC	Weight		Spurgeon 1995
Pb(C2H3O2)2	Earthworm	*Eisenia fetida*	Horse manure	56	2000	NOEC	Cocoon production	50	Malecki et al. 1982
Nitric acid, Pb(2+) salt	Earthworm	*Eisenia fetida*	Artificial soil	56	2190	NOEC	Mortality		Spurgeon 1994
Nitric acid, Pb(2+) salt	Earthworm	*Eisenia fetida*	Artificial soil	14	4793	NOEC	Mortality		Spurgeon 1995
Pb chloride	Earthworm	*Eisenia fetida*	Media mixture	56	14000	NOEC	Reproduction		Malecki 1982
Pb chloride	Earthworm	*Eisenia fetida*	Media mixture	56	40000	NOEC	Weight		Malecki 1982
		Intalco Reported Area Background =			**20.6**				
	Earthworm	*Dendrobaena rubida*	Soil and dung	120	500	LOEC	Cocoons/worm	75	Bengtsson et al. 1986
	Earthworm	*Dendrobaena rubida*	Soil and dung	120	500	LOEC	Hatchlings/cocoon	100	Bengtsson et al. 1986
$Pb(NO_3)_2$	Earthworm	*Eisenia fetida*	OECD soil	21	1629	LOEC	Growth	50	Spurgeon and Hopkin 1995
$Pb(NO_3)_2$	Earthworm	*Eisenia fetida*	OECD soil	56	1940	LOEC	Cocoon production	50	Spurgeon et al. 1994
$Pb(C_2H_3O_2)_2$	Earthworm	*Eisenia fetida*	Horse manure	56	4000	LOEC	Cocoon production	50	Malecki et al. 1982
Nitric acid, Pb(2+) salt	Earthworm	*Eisenia fetida*	Media mixture	56	4000	LOEC	Reproduction		Malecki 1982
$Pb(C_2H_3O_2)_2$	Earthworm	*Eisenia fetida*	Horse manure	140	5000	LOEC	Cocoon production	28	Malecki et al. 1982
Soluble forms	Earthworm	*Eisenia fetida*	Horse manure	42	5000	LOEC	Cocoon production	80	Neuhauser et al. 1984
Pb(NO3)2	Earthworm	*Eisenia fetida*	OECD soil	14	5941	LOEC	Survival	50	Neuhauser et al. 1985
Pb oxide	Earthworm	*Eisenia fetida*	Media mixture	56	10000	LOEC	Reproduction		Malecki 1982
Pb oxide	Earthworm	*Eisenia fetida*	Media mixture	56	20000	LOEC	Weight		Malecki 1982
Nitric acid, Pb(2+) salt	Earthworm	*Eisenia fetida*	Media mixture	56	20000	LOEC	Weight		Malecki 1982
	20th percentile of rank-ordered LOEC data (above bkgd) =				**1629.0**				

Table 5. Literature Review of the Potential Toxicity of Zinc in Soil to Soil Invertebrates

Chemical Form	Test species	Scientific name	Growth media	Exposure days	Soil concentration mg/kg	Endpoint	Response parameter	Percent decline at LOEC	Citation
$Zn(NO_3)_2$	Earthworm	*Eisenia fetida*	Artificial soil	21	7.2	NOEC	Mortality		Spurgeon 1996
$Zn(NO_3)_2$	Earthworm	*Eisenia fetida*	Artificial soil	21	7.2	NOEC	Reproduction		Spurgeon 1996
$Zn(NO_3)_2$	Earthworm	*Eisenia fetida*	Artificial soil	21	85	NOEC	Cocoon production	50	Spurgeon & Hopkin 1996b
$Zn(NO_3)_2$	Earthworm	*Eisenia fetida*	Artificial soil	21	97	NOEC	Cocoon production	50	Spurgeon & Hopkin 1996b
$Zn(NO_3)_2$	Earthworm	*Eisenia fetida*	Artificial soil	21	115	NOEC	Cocoon production	50	Spurgeon & Hopkin 1996b
$Zn(NO_3)_2$	Earthworm	*Eisenia fetida*	Artificial soil	21	161	NOEC	Cocoon production	50	Spurgeon & Hopkin 1996b
$Zn(NO_3)_2$	Earthworm	*Eisenia fetida*	Artificial soil	21	183	NOEC	Cocoon production	50	Spurgeon & Hopkin 1996b
$Zn(NO_3)_2$	Earthworm	*Eisenia fetida*	Artificial soil	56	199	NOEC	Reproduction		Spurgeon 1994
$Zn(NO_3)_2$	Earthworm	*Eisenia fetida*	Artificial soil	21	223	NOEC	Cocoon production	50	Spurgeon & Hopkin 1996b
		Intalco Reported Area Background =			**253**				
$Zn(NO_3)_2$	Earthworm	*Eisenia fetida*	Artificial soil	56	289	NOEC	Mortality		Spurgeon 1994
$ZnCl_2$	Earthworm	*Eisenia andrei*	OECD soil	21	320	NOEC	Cocoons/worm	31	van Gestel et al. 1993
$ZnCl_2$	Earthworm	*Eisenia andrei*	OECD soil	21	320	NOEC	Juveniles/worm	42	van Gestel et al. 1993
$Zn(NO_3)_2$	Earthworm	*Eisenia fetida*	Artificial soil	21	400	NOEC	Weight		Spurgeon 1995
$Zn(NO_3)_2$	Earthworm	*Eisenia fetida*	Artificial soil	21	414	NOEC	Cocoon production	50	Spurgeon & Hopkin 1996b
$Zn(NO_3)_2$	Earthworm	*Eisenia fetida*	Artificial soil	14	442	NOEC	Mortality		Spurgeon 1995
$Zn(NO_3)_2$	Earthworm	*Eisenia fetida*	Artificial soil	21	484	NOEC	Cocoon production	50	Spurgeon & Hopkin 1996b
Carbonic acid, Zinc salt (1:1)	Earthworm	*Eisenia fetida*	Media mixture	56	500	NOEC	Reproduction		Maecki 1982
$Zn(NO_3)_2$	Earthworm	*Eisenia fetida*	Artificial soil	21	553	NOEC	Reproduction		Spurgeon 1996
$Zn(C_2H_3O_2)_2$	Earthworm	*Eisenia fetida*	Horse manure	56	1000	NOEC	Cocoon production	36	Malecki et al. 1982
Soluble forms	Earthworm	*Eisenia fetida*	Horse manure	42	1000	NOEC	Cocoon production	50	Neuhauser et al. 1984
$Zn(NO_3)_2$	Earthworm	*Eisenia fetida*	Artificial soil	21	1048	NOEC	Mortality		Spurgeon 1996
Zn(C2H3O2)2	Earthworm	*Eisenia fetida*	Horse manure	140	2500	NOEC	Cocoon production	53	Malecki et al. 1982
Carbonic acid, Zinc salt (1:1)	Earthworm	*Eisenia fetida*	Media mixture	56	40000	NOEC	Weight		Maecki 1982
Zn	Earthworm	*Eisenia fetida*	Natural soil	56	56000	NOEC	Mortality		Hartenstein 1981
$Zn(NO_3)_2$	Earthworm	*Eisenia fetida*	Artificial soil	21	136	LOEC	Cocoon production	50	Spurgeon & Hopkin 1996b
$Zn(NO_3)_2$	Earthworm	*Eisenia fetida*	Artificial soil	21	142	LOEC	Cocoon production	50	Spurgeon & Hopkin 1996b
$Zn(NO_3)_2$	Earthworm	*Eisenia fetida*	Artificial soil	21	189	LOEC	Cocoon production	50	Spurgeon & Hopkin 1996b
$Zn(NO_3)_2$	Earthworm	*Eisenia fetida*	OECD soil	21	190	LOEC	Growth rate	69	Spurgeon & Hopkin 1996b
$Zn(NO_3)_2$	Earthworm	*Aporrectodea rosea*	OECD soil	21	190	LOEC	Growth rate	48	Spurgeon & Hopkin 1996b
$Zn(NO_3)_2$	Earthworm	*Lumbricus rubellus*	OECD soil	21	190	LOEC	Cocoon production	69	Spurgeon & Hopkin 1996b
$Zn(NO_3)_2$	Earthworm	*Eisenia fetida*	Artificial soil	21	199	LOEC	Cocoon production	50	Spurgeon & Hopkin 1996b
$Zn(NO_3)_2$	Earthworm	*Eisenia fetida*	Artificial soil	21	230	LOEC	Cocoon production	50	Spurgeon & Hopkin 1996b
		Intalco Reported Area Background =			**253**				
$Zn(NO_3)_2$	Earthworm	*Eisenia fetida*	OECD soil	56	276	LOEC	Cocoon production	50	Spurgeon et al. 1994
Zn-sulfate	Earthworm	*Aporrectodea caliginosa*	Egyptian	56	300	LOEC	Cocoon production	20	Khalil et al. 1996
$Zn(NO_3)_2$	Earthworm	*Eisenia fetida*	Artificial soil	21	343	LOEC	Cocoon production	50	Spurgeon & Hopkin 1996b
$Zn(NO_3)_2$	Earthworm	*Eisenia fetida*	Artificial soil	21	462	LOEC	Cocoon production	50	Spurgeon & Hopkin 1996b

Table 5. Literature Review of the Potential Toxicity of Zinc in Soil to Soil Invertebrates

Chemical Form	Test species	Scientific name	Growth media	Exposure days	Soil concentration mg/kg	Endpoint	Response parameter	Percent decline at LOEC	Citation
$Zn(NO_3)_2$	Earthworm	*Eisenia fetida*	Artificial soil	21	548	LOEC	Cocoon production	50	Spurgeon & Hopkin 1996b
$ZnCl_2$	Earthworm	*Eisenia andrei*	OECD soil	21	560	LOEC	Cocoons/worm	31	van Gestel et al. 1993
$ZnCl_2$	Earthworm	*Eisenia andrei*	OECD soil	21	560	LOEC	Juveniles/worm	42	van Gestel et al. 1993
$Zn(NO_3)_2$	Earthworm	*Eisenia fetida*	Artificial soil	21	592	LOEC	Cocoon production	50	Spurgeon & Hopkin 1996b
$ZnNO_3$	Earthworm	*Eisenia fetida*	OECD soil	14	662	LOEC	Survival	50	Neuhauser et al. 1985
$Zn(NO_3)_2$	Earthworm	*Eisenia fetida*	OECD soil	21	1078	LOEC	Growth	50	Spurgeon & Hopkin 1995a
	Earthworm	*Allolobophora caliginosa*	Polder soil		1100	LOEC	Body weight	53	van Rhee 1975
	Earthworm	*Allolobophora caliginosa*	Polder soil		1100	LOEC	Cocoon production	100	van Rhee 1975
	Earthworm	*Allolobophora caliginosa*	Polder soil		1100	LOEC	Mortality	22	van Rhee 1975
	Earthworm	*Allolobophora caliginosa*	Polder soil		1100	LOEC	Sexual development	100	van Rhee 1975
$Zn(C_2H_3O_2)_2$	Earthworm	*Eisenia fetida*	Horse manure	56	2000	LOEC	Cocoon production	36	Malecki et al. 1982
$ZnCl_2$	Earthworm	*Eisenia fetida*	Media mixture	56	2000	LOEC	Weight		Malecki 1982
$ZnCl_2$	Earthworm	*Eisenia fetida*	Media mixture	56	2000	LOEC	Reproduction		Malecki 1982
Soluble forms	Earthworm	*Eisenia fetida*	Horse manure	42	2500	LOEC	Cocoon production	50	Neuhauser et al. 1984
Zn(C2H3O2)2	Earthworm	*Eisenia fetida*	Horse manure	140	5000	LOEC	Cocoon production	53	Malecki et al. 1982
	20th percentile of rank-ordered LOEC data (above bkgd) =				**513.6**				

Table 6. Exposure Factors for the American Robin

Species	Scientific name	Body weight (BW) kg	Body weight source	Home range hectares[a]	Home range source	Abiotic media[b] ingestion rate kg/kg body wt/d	Abiotic media ingestion rate source	Water ingestion rate L/kg BW/d	Water ingestion rate source	Food ingestion rate kg food/kg BW/d	Food ingestion rate source	Dietary Composition Proportions: Terrestrial plant ingestion	Terrestrial invertebrate ingestion	Reptile and amphibian ingestion	Mammal and bird ingestion	Aquatic plant ingestion	Aquatic invertebrate ingestion	Fish ingestion	Dietary data sources
American robin	*Turdus migratorius*	0.077	USEPA 1993	0.48	USEPA 1993	0.0215	Beyer et al. 1994	0.14	USEPA 1993	0.207	Nagy 1987	0.48	0.52	0	0	0	0	0	USEPA 1993

ND - no data available
kg - kilogram
d - day
a - Home ranges given as linear measurements converted to area by assuming the linear distance is the diameter of a circle (USFS et al. 2000)
b - Abiotic media ingestion includes soil and sediment

Beyer, W.N., E. Conner and S. Gerould. 1994. Estimates of soil ingestion by wildlife. J. Wildl. Manage. 58:375-382.
Nagy, K.A. 1987. Field metabolic rate and food requirement scaling in mammals and birds. Ecol. Monogr. 57:111-128.
U.S. Environmental Protection Agency (USEPA). 1993. Wildlife Exposure Factors Handbook, Volumes 1 and 2. EPA/600/R-93/187a and b, Office of Research and Development, Washington, D.C.

Table 7. Potential Soil Cleanup Levels Based on Protection of American Robin.

Receptor	Chemical	Risk-based Soil Value mg/kg	Food ingestion rate (plant & invertebrate) kg food/kg wt/day	Proportion of small mammals or birds in diet	Proportion of soil biota in diet	Proportion of plant material in diet	Soil ingestion rate kg soil/kg wt/day	Gut absorption factor	Wildlife TRV mg/kg/day	Prey - predator BCF[a]	Earthworm - soil BCF[b]	Soil - plant BCF[c]	Wildlife body weight kg	Laboratory test species TRV mg/kg/day	Test species	Test species endpoint
American robin	Cd	144	0.207	0	0.52	0.48	0.0215	1	20	0.028	0.96	0.14	0.077	20	Mallard	Chronic LOAEL for egg production
	Pb	448	0.207	0	0.52	0.48	0.0215	1	11.3	0.015	0.03	0.0047	0.077	11.3	Japanese quail	Chronic LOAEL for reproduction
	Zn	1436	0.207	0	0.52	0.48	0.0215	1	131	5	0.56	0.095	0.077	131	White leghorn chicken	Chronic LOAEL for reproduction

Cleanup levels are based on LOAEL values from Sample et al. (1996)

a - Obtained from Savannah River Site, Environmental Restoration Division (1999)
b - Obtained from USEPA (1999)
c - Obtained from Ecology (2001)