FINAL REMEDIAL
INVESTIGATION/FEASIBILITY STUDY
FOR THE HILLYARD DROSS SITE
EAST 3412 WELLESLEY AVENUE, SPOKANE, WA

for

The Burlington Northern and Santa Fe Railway Company

BNSF File No. WASPO-05-005
Agreed Order No. DE 98TC-E105
EMR Project 338

August 1999

EMR
INCORPORATED

ENVIRONMENTAL MANAGEMENT RESOURCES

Lawrence, KS ▼ Redmond, WA ▼ Duluth, MN ▼ Lincoln, NE ▼ Ft. Worth, TX ▼ Denver, CO

DRAFT FINAL REMEDIAL INVESTIGATION/FEASIBILITY STUDY FOR THE HILLYARD DROSS SITE EAST 3412 WELLESLEY AVENUE, SPOKANE, WA

for

The Burlington Northern and Santa Fe Railway Company

BNSF File No. WASPO-05-005
Agreed Order No. DE 98TC-E105
EMR Project 338

August 1999

EMR
INCORPORATED

ENVIRONMENTAL MANAGEMENT RESOURCES

Lawrence, KS ▼ Redmond, WA ▼ Duluth, MN ▼ Lincoln, NE ▼ Ft. Worth, TX ▼ Denver, CO

TABLE OF CONTENTS

TABLE OF CONTENTS

TABLE OF CONTENTS

TABLE OF CONTENTS

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF FIGURES

LIST OF TABLES

LIST OF TABLES

LIST OF ACRONYMS

Acronym	**Definition**
Ag	Silver
ARAR	Applicable or relevant and appropriate requirement
amsl	above mean sea level
As	Arsenic
BNRR	Burlington Northern Railroad
BNSF	The Burlington Northern and Santa Fe Railway Company
Ba	Barium
bgs	Below ground surface
COPC	Contaminent of potential concern
Chempro	Chemical Processors, Inc.
Cd	Cadmium
Cr	Chromium
Cu	Copper
EMR	Environmental Management Resources
EPA	Environmental Protection Agency
FS	Feasibility Study
gpd/ft^2	gallons per day per square foot
HDPE	High tensile strength, high density polythylene
Hg	Mercury
MKE	Morrison Knudsen Engineers
mg/kg	milligrams per kilogram
mg/l	milligrams per liter
µg/l	micrograms per liter
MTCA	Model Toxics Control Act
NFA	No Further Action
NGVD	National Geodetic Vertical Datum
O&M	Operation and maintenance
PA	preliminary assessment
PA/SI	Preliminary Assessment/Site Inspection
PID	photoionization detector
Pb	Lead
POTW	Publicly owned treatment works
PRG	Project remediation goal
RAO	Remedial action objective
RCRA 8 metals	As, Ba, Cd, Cr, Pb, Hg, Se, and Ag
RI	Remedial Investigation
RI/FS	Remedial Investigation/Feasibility Study
Se	Selenium
TBC	To-be-considered

LIST OF ACRONYMS

Acronym	**Definition**
TCLP	Toxicity Characteristic Leaching Potential
TPH	Total petroleum hydrocarbons
USEPA	United States Environmental Protection Agency
WDOE	Washington Department of Ecology
WDOT	Washington Department of Transportation

SECTION 1.0

EXECUTIVE SUMMARY

This Remedial Investigation (RI)/Feasibility Study (FS) has been prepared by Environmental Management Resources, Inc. (EMR) on behalf of The Burlington Northern and Santa Fe Railway Co. (BNSF) to address environmental concerns at the Aluminum Recycling Corporation-Wellesley Site in Spokane, Washington.

The Site is located in the Hillyard area of north Spokane along Wellesley Avenue. The property is owned by BNSF and was leased and operated by Hillyard Processing Co. and later by Aluminum Recycling Corp. as an aluminum dross recycling and secondary recovery facility. During operation of the Site aluminum dross was transported to the Site, stockpiled and processed. Operations at the Site ended in the mid-1980s. Approximately 65,000 cubic yards of dross remain.

The aluminum dross piles are known to contain concentrations of fluoride, nitrates, chloride and ammonia that are of potential concern for human health and ecological receptors. An RI has been completed at the Site, and the data is used to prepare a FS that evaluates remedial alternatives.

The overall objectives of the RI/FS are as follows:

- Provide information on the extent and magnitude of soil and ground-water contamination at the Site so that a FS can be completed.
- Complete an FS to evaluate alternative remedial actions at the Site.

To accomplish these objectives, the following tasks were completed:

- 34 samples of aluminum dross were collected;
- 19 subsurface soil samples were collected;
- 5 ground-water monitoring wells were installed and sampled;
- 8 surface soil samples were collected; and,
- A survey of wells in the area was completed;

Samples were analyzed for fluoride, nitrates, chloride, ammonia and other anions, salts and RCRA metals (arsenic, barium, cadmium, chromium, lead, mercury, selenium and silver, plus copper). Selected samples were analyzed for leaching potential. Sample results were compared with Model Toxics Control Act (MTCA) cleanup up goals. Fate and transport evaluations were completed to identify potential fate of the identified contaminants, and to focus the evaluation of transport pathways on persistent contaminants. A baseline risk assessment was completed to determine whether the presence and concentration of contaminants posed a significant risk to human health or the environment. An FS was completed so that remedial alternatives were evaluated to determine the ability to achieve closure goals, the length of time required for closure, and cost-effectiveness in accordance with the Model Toxics Control Act (Washington Administrative Code 173-340). The alternatives that were considered in the FS were: no action; institutional controls with long-term ground-water monitoring; excavation with off-site disposal; and, on-site containment beneath a multi-media cap.

1.1 Hydrogeology

The unconsolidated deposits at the surface, to a total depth of 200 feet below ground surface, consist of interbedded layers of sand and gravel. Ground water is present at about 170 feet below ground surface. The uppermost aquifer is the Spokane-Rathdrum Aquifer, which has been designated as a sole-source aquifer. General ground-water flow direction in the Spokane-Rathdrum Aquifer is to the northwest.

1.2 Contaminated Soil and Ground Water

Approximately 65,000 cubic yards of aluminum dross are present at the Site. In addition, soil beneath the largest pile of dross at the Site has been contaminated to a depth exceeding five feet. The total volume of contaminated soil is estimated to be 7,400 cubic yards. Contaminants of concern include arsenic, barium, cadmium, chloride, fluoride and selenium.

Access to the Site is restricted by a chain link fence. Surface soil and the dross surface were treated with a foaming agent that reduced airborne transport of contaminants while the Site is being studied.

Infiltrating leachate from the dross materials has impacted ground-water at the Site. As a result, chloride concentrations are locally elevated. The dilution along the ground-water flow path decreases chloride levels to acceptable concentrations within a few hundred feet of the Site.

1.3 Baseline Risk Assessment

A baseline risk assessment was conducted to evaluate the potential risk to human health. The following exposure routes were considered: direct contact with dross and contaminated soil resulting in incidental ingestion; inhalation of fugitive dust from contaminated soil or dross material; and, ingestion of ground-water by hypothetical residents with on-site water wells. Results are summarized in Table 1-1. The hazard quotient, which is a measure of non-carcinogenic risks, for drinking ground water by a hypothetical resident is 63, which exceeds regulatory cleanup levels and project remedial action goals. Potential carcinogenic risk for incidental ingestion and inhalation also exceeds project remedial action goals for these routes (see Table 1-1).

1.4 Feasibility Study

A focused FS was completed to evaluate remedial alternatives for the Site. This FS evaluates each remedial alternative's ability to achieve MTCA cleanup standards in a timely and cost effective manner. The alternatives considered were no action, institutional controls with long-term ground-water monitoring, excavation with off-site disposal, and on-site containment beneath a cap. Based on the FS evaluation, the preferred remedial alternative for the Site was the On-site Containment.

TABLE 1-1

Summary of Hazard Quotient and Potential Risks
BNSF Hillyard Dross Site, Spokane, Washington

Media	Exposure Route	Hazard Quotient	Potential Risk
Dross	Inhalation		1.11E+01
Dross	Incidental ingestion	3.37E+00	3.32E-01
Soil	Inhalation		1.30E+01
Soil	Incidental ingestion	6.61E-01	3.90E-01
Ground Water	Residential use (ingestion)	6.29E+01	2.54E-05

SECTION 2.0

INTRODUCTION

Environmental Management Resources, Inc. (EMR) has prepared this report for the Remedial Investigation/Feasibility Study (RI/FS) conducted at the Aluminum Recycling Corporation- Wellesley (Hillyard Dross) Site in Spokane, Washington. The RI/FS was performed under Agreed Order No. DE 98TC-E105 between The Burlington Northern and Santa Fe Railway Co. (BNSF) and Washington Department of Ecology (WDOE).

The RI/FS follows applicable regulations and guidance of the WDOE. A description of activities performed during this RI is included in EMR's RI Workplan (EMR, 1997). Field activities for the RI were performed in December, 1998.

The objectives of this RI/FS report are to:

1) Present the results of soil and ground-water investigations conducted at the Site;

2) Determine the nature and extent of contamination at the Site;

3) Evaluate contaminant fate and transport processes and finalize a conceptual Site model;

4) Develop MTCA cleanup levels for soil and ground-water;

5) Complete a baseline risk assessment;

6) Evaluate remedial alternatives in an FS; and,

7) Recommend a preferred remedial alternative.

This introduction includes the following subsections:

- Report Organization; and,

- Site Background Information.

2.1 Report Organization

This RI/FS Report provides a summary of the activities for the RI and presents the FS evaluation. The report is organized into 12 sections and 8 appendices. The contents of the sections are as follows:

- Section 1.0 provides an executive summary for this report;
- Section 2.0 provides general introductory information for the Hillyard Dross Site;
- Section 3.0 summarizes environmental setting data for the vicinity of the Site;
- Section 4.0 describes the field investigation program;
- Section 5.0 presents the investigation findings;
- Section 6.0 discusses contaminant fate and transport;
- Section 7.0 discusses risk assessment;
- Section 8.0 presents the general remedial action objectives (RAOs) and MTCA cleanup levels to be considered.
- Section 9.0 presents the potential remediation technologies applicable and compares remedial alternatives developed for the Hillyard Dross Site against MTCA threshold requirements for remedy selection.
- Section 10.0 describes the evaluation of each remedial alternative by the MTCA remedy selection (WAC 173-340-360) criteria considered during the detailed analysis phase of the FS.
- Section 11.0 presents the conclusions of the RI/FS and recommends a preferred remedial alternative.
- Section 12.0 lists references.

Appendices to this report include the following:

- APPENDIX A - EPA GIS DATABASE QUERY
- APPENDIX B - WATER WELL SURVEY
- APPENDIX C - BORING LOGS FOR BORING AND MONITORING WELL LOCATIONS
- APPENDIX D - LOCATION AND ELEVATION SURVEY DATA

- APPENDIX E - GEOTECHNICAL ANALYSES REPORTS
- APPENDIX F - ANALYTICAL RESULTS FOR SOIL AND GROUNDWATER SAMPLES
- APPENDIX G - HELP MODEL OUTPUT
- APPENDIX H - PERTINENT FEDERAL AND STATE LAWS AND REGULATIONS

2.2 Site Background Information

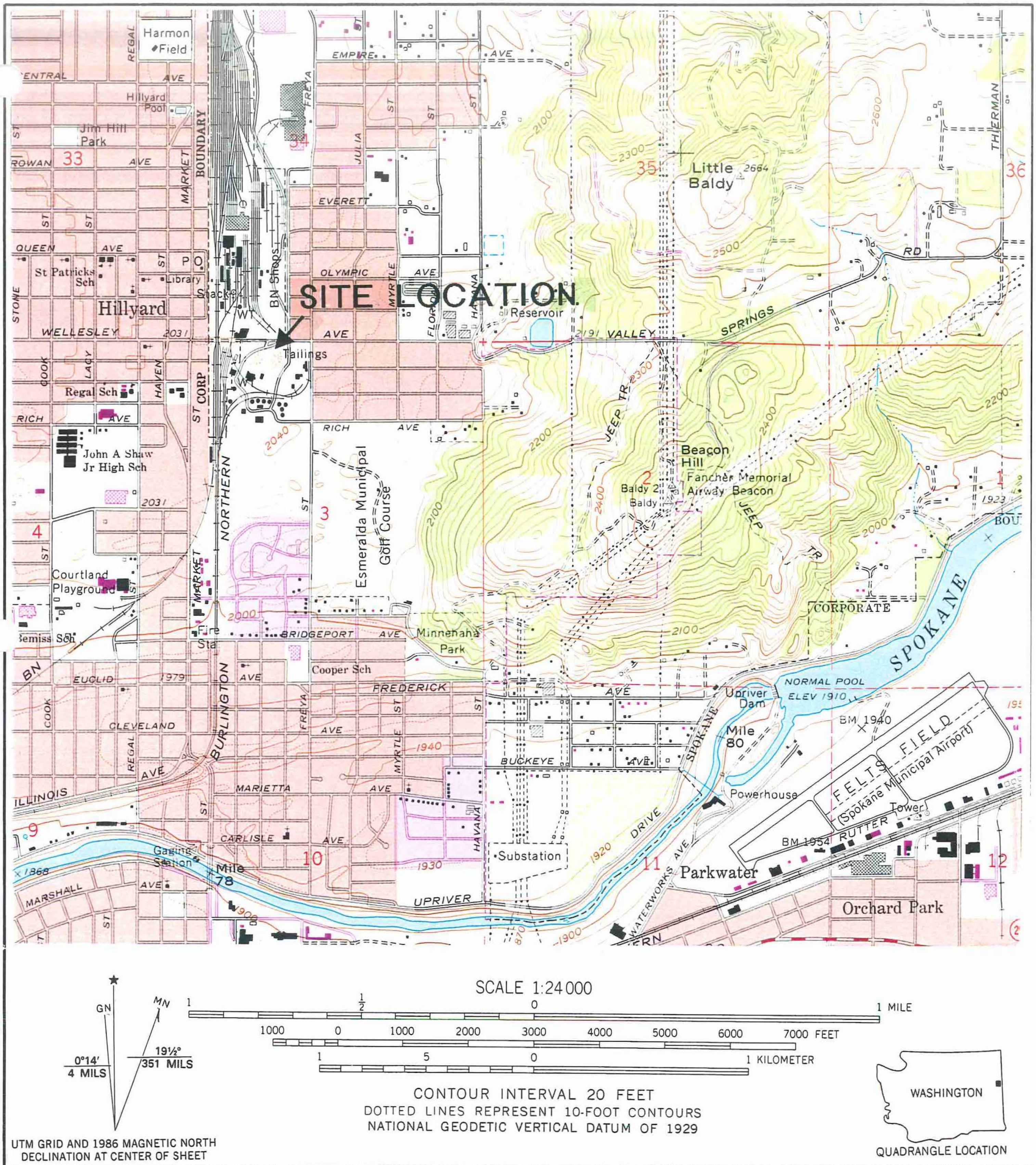
The Hillyard Dross Site is located in the City of Spokane (near the northern city limits) at East 3412 Wellesley Avenue. The Site is bounded by Wellesley Avenue on the north, Freya Street on the east and Market Street on the west (Figure 2-1). The site encompasses approximately eight acres in an industrial-zoned portion of the city. The elevation is approximately 2,040 feet above mean sea level (amsl). The latitude is 47°42'12" and longitude 117°21'35". The location is in the NW1/4 of the NW1/4 of Section 3, Township 25 North, Range 43 East. Aerial photographs were reviewed as part of the RI/FS Workplan effort and are shown in Appendix B of that document (EMR, 1997).

2.2.1 Historical Site Improvements

The facility consisted of two buildings, dross processing equipment and five underground storage tanks containing gasoline or diesel fuel. The buildings were demolished and the underground storage tanks were reportedly removed in March 1987. The concrete building foundations still remain on the Site. There are no other paved areas on the Site. A pretreatment wastewater operation on Site consisted of numerous aboveground settling and detention tanks described below. All of these tanks have been removed.

2.2.2 Historical Waste Management Operations

During its early operation beginning in November 1954, the aluminum dross processing plant discharged waste water to the gravel pit. Washington Department of Health documents from 1955 describe sampling of nearby wells and chloride concentrations of 2.1 to 35.7 milligrams per liter (mg/l). The Department of Health recommended redirecting the effluent to an industrial sewer. Subsequently, the discharge was diverted, following pretreatment, to the former nearby industrial sewer, south to the Spokane River at Greene Street. The date



EMR INCORPORATED

The Burlington Northern Santa Fe Railway Co.
Hillyard Dross Site, Spokane, WA

Remedial Investigation/Feasibility Study (RI/FS)
Site Location Map

Drawn By:	DLW
Checked By:	DC
Project #:	338
File Name:	338fg2-1.GCD
Date:	2/8/99
Scale:	As shown

FIGURE 2-1

the discharge was connected to the sewer is not known; however, exact permit information in Pollution Control Commission files indicate that discharge to the sewer occurred sometime after January 24, 1955 and was authorized at least until May, 1972.

Based on information contained in the permit documents in the Pollution Control Commission files, the pretreatment process consisted of washing the aluminum dross with clean water. The water then was sent through a series of five steel settling and detention tanks (5000 cubic feet each), then through two rectangular tanks (600 cubic feet each), followed by two round tanks (2500 cubic feet each). Following treatment, the discharge of wash water from the dross processing operation went to a storm sewer southward to the Spokane River. The facility operated this discharge under permits from the State of Washington.

2.2.3 Site Usage History

The Site was initially used as a gravel pit for a nearby asphalt plant. In 1955, the Site was leased by Hillyard Processing Co. and converted to an aluminum recycling operation using scrap aluminum and dross primarily from Kaiser-Trentwood. In 1979, a new lessee (Lyon, Halpin and Buescher) renamed it Hillyard Aluminum Recovery Corp. and later to Aluminum Recycling Corporation. In 1987, the property was abandoned by the lessee who left a large volume of aluminum dross in a number of piles spread around a two acre portion of the Site. In addition, a large volume of semi-processed "white dross" material was left in the old gravel pit.

Several complaints were made to the City between 1979 and 1983 regarding wind blown particulates and ammonia odors, caused when the dross became wet and copper ammonium nitrides were generated. In 1979, heat caused by a metal oxide reaction reportedly started a fire and created smoke and ammonia fumes.

2.3 Previous Investigations and Documentation

Several investigations and interim actions have been completed at the Site as described below.

2.3.1 Previous Investigations

A preliminary assessment (PA) was conducted by WDOE on July 17, 1985. As a result of the PA, WDOE recommended that wells in the vicinity of the Site be sampled due to the potential for impacts from the Site. Additionally, WDOE recommended that air quality in the vicinity of the Site be addressed to prevent dust and ammonia vapors from the Site from creating a public nuisance. WDOE also recommended that the dross materials be appropriately disposed. A subsequent inspection, carried out by WDOE under the Superfund multi-site cooperative agreement Preliminary Assessment/Site Inspection (PA/SI) program, was conducted. The PA/SI Phase I Site Inspection (SI) was conducted at the facility during the afternoon of October 13, 1987. The PA/SI was conducted by Fred Gardner, WDOE Hazardous Waste Cleanup Program, and Sherman Spencer, WDOE Eastern Regional Office.

Previous studies by Morrison Knudsen Engineers (MKE) and WDOE in 1987 were limited to surficial examination and sampling of the piles. At that time, no determination was made as to the designation of the piles under Washington State Dangerous Waste Regulations; however, the Site was identified by WDOE as potentially contaminated with hazardous substances in the December 1987 PA/SI Phase I Site Inspection Report. The City of Spokane requested improvements in dust suppression and site security.

Chemical Processors, Inc. (Chempro) conducted a stabilization and characterization study on the Site in 1989. Chempro's characterization indicated that approximately 95 percent of the dross material located on the Site possibly could be considered a dangerous waste under Washington State regulations due to high concentrations of chloride, fluoride and nitrate. Chempro additionally noted that ground-water beneath the dross piles contained levels of chloride, fluoride and nitrates, which exceeded state drinking water standards.

A summary of existing data at the Site was completed by EMR in 1996 (EMR, 1996). In June 1997, ground-water sampling was conducted at the Site (EMR, 1997).

2.3.2 Past Interim Actions

In June 1988, Burlington Northern Railroad (BNRR) initiated a dust suppression and site characterization program on the aluminum dross piles. The principal objective of the program was to cover and contain the dross piles to eliminate dust emissions. The piles were surveyed and subsurface samples collected to characterize the dross composition and volume to determine if the material could be recycled. Finally, the ground-water at the Site was sampled and analyzed to determine levels of chlorides, fluorides and nitrates within the aquifer.

A number of dust suppression products were considered for application to the dross piles. A polyvinyl acetate solution mixed with wood fiber (Marloc) was determined to be the most appropriate solution, and was applied to the piles. This product forms a thin film on the surface of the piles and has been used successfully in the desert southwest to control dust from mine tailings. Although it ultimately breaks down under ultraviolet radiation, it is effective for a minimum of two years.

The Marloc was applied to the main dross piles on August 12th, 1988 by Nelson Landscaping of Spokane.

Site security was addressed by the installation an eight foot high chain link fence around the dross piles and pit area in October of 1988. The fence is approximately 2,300 feet in length and is topped with three strands of barbed wire. A gate is located on the east side of the Site.

ENVIRONMENTAL SETTING

The environmental setting at the Hillyard Dross Site is presented here to establish a reference for discussion of the RI. Some of this information is from a query of the United States Environmental Protection Agency (EPA) geographic information system. A copy of the results of that query is attached as Appendix A.

3.1 Topography

The Hillyard Dross Site is on the northern edge of the Columbia Plateau Province, which covers central to eastern Washington, northern to west central Idaho, and northeast Oregon. Topography on the Columbia Plateau consists of generally flat terrain with deep canyons. The Site is on a relatively flat area in the Spokane River Valley at an elevation of about 2,040 feet amsl. Several mounds of aluminum dross and one large quarry pit exist on-site. Much of the surface water runoff either percolates through the surface soils or runs into the pit.

3.2 Meteorology

In the Spokane area, temperatures vary from 20°F to 46°F in the winter to 53°F to 84°F in the summer. The average annual precipitation is less than 20 inches, including over 50 inches of snow. The greatest precipitation occurs between the months of November and January, during the winter season. The average monthly precipitation ranges from 0.50 inches in July to 2.49 inches in December. The heaviest 1-day rainfall of 2.07 inches was recorded in June 1964. Rainfall intensity, based on a 2-year, 24-hour duration, is 1.38 inches. Free water surface evaporation in the Spokane area is approximately 35 inches per year, resulting in a net precipitation of -18.29 inches per year. The prevailing wind is from the southwest, and the highest average wind speed of 10 miles per hour is experienced during the month of April.

3.3 Geology

The geologic section of the Columbia Plateau in the Spokane area is divided into three major categories: Quaternary deposits, Pliocene and Miocene sedimentary and volcanic rocks (predominantly the Columbia River Basalt Group), and Precambrian metasedimentary rocks of the Belt Supergroup, which are intruded by Eocene and Cretaceous plutons (Alt, 1984). A geologic map of the area is shown on Figure 3-1.

The Belt Supergroup consists of a mixture of metasedimentary rocks (i.e., quartzite, schist, gneiss, and phyllite) which were intruded by granitic magma during the Cretaceous and Tertiary Periods. The surface of the Belt Supergroup is highly irregular and relief of 1,100 feet has been measured in a distance of one-half mile (Griggs, 1976).

The predominant rock within the Columbia Plateau Province is basalt, which extends over an area of approximately 50,000 square kilometers. The basalt was extruded in numerous flows during the Miocene and early Pliocene Ages between 6 and 16 million years ago. Within the area of Spokane, the primary basalts are the Priest Rapids Formation of the Yakima Basalt Subgroup and the Grande Ronde Basalt (Swanson, et al., 1979). Typically, these basalts are flat-lying, have a fine-grained texture, and exhibit columnar jointing. The basalts are bracketed and interbedded by sediments of the Latah formation, which includes siltstone, claystone, and minor sandstone (Joseph, 1990).

Continental glaciers have periodically moved across the northern portion of Washington during the Pleistocene Age. Very little geological evidence of glaciation is present in the Spokane area. This is the result of massive flooding which occurred during the Pleistocene when glacial ice dams to the east burst repeatedly, releasing floodwaters from glacial Lake Missoula. The Spokane Valley was one of the main channels of the floods, which are estimated to have occurred at least 40 times. Volumes of water in excess of 20,000 cubic kilometers poured across what is now eastern Washington State, leaving deep canyons and water-scoured channels referred to as the channeled scablands. Results of the flooding may be seen in large deposits of poorly sorted boulders, cobbles, gravel, and sand throughout the Spokane Valley (Livingston, 1978).

The Quaternary deposits present in the Spokane area include loess, flood deposits, and recent alluvium. Area highlands, which were untouched by the Pleistocene floods, are covered with loess of the Palouse formation. The loess is a mixture of wind-deposited silt, sand, and clay (montmorillonite and illite) deposited as the Pleistocene glaciers retreated from northern Washington (Livingston, 1978). Flood deposits and alluvium are present in the plains and valley areas around

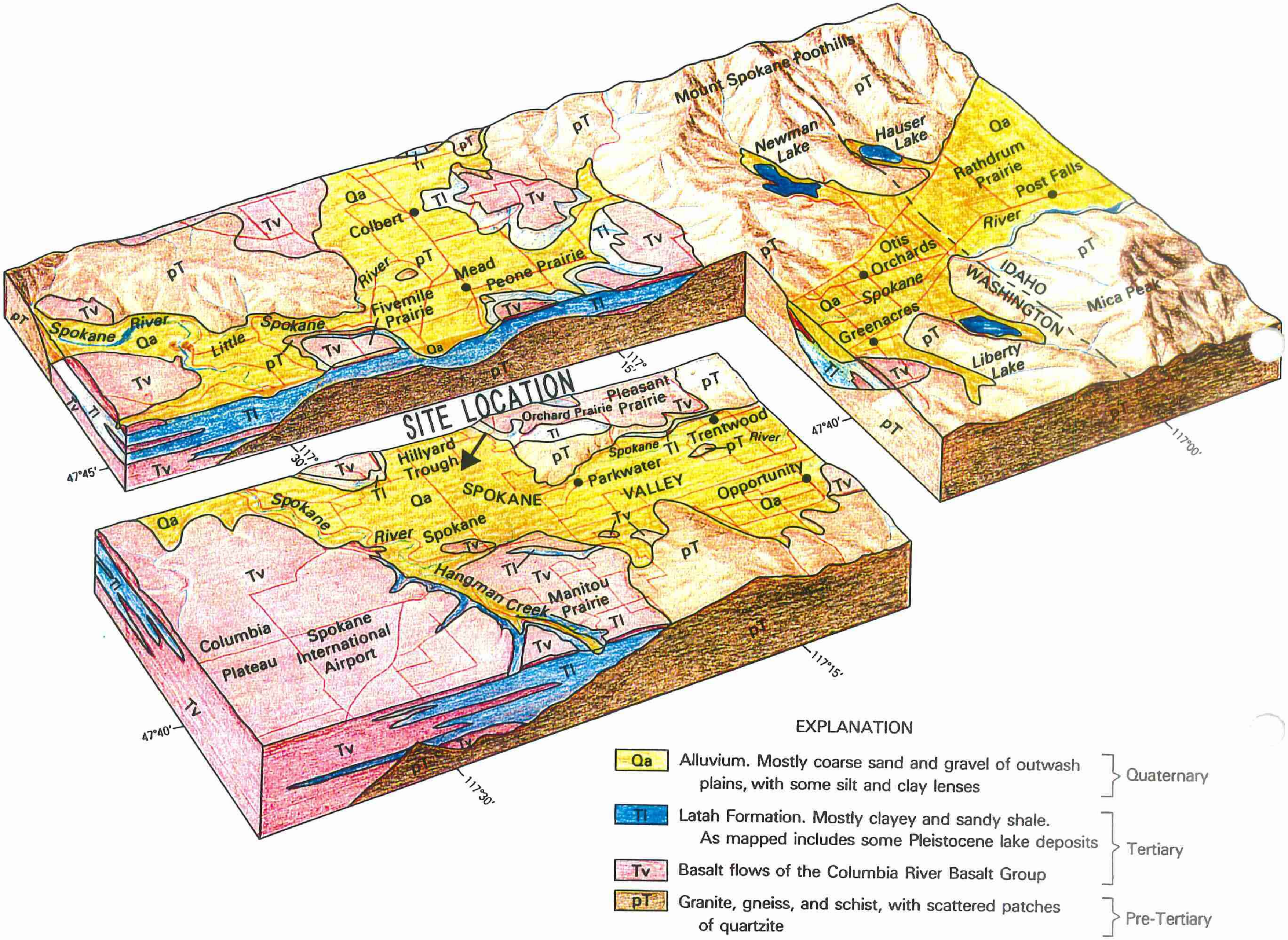


FIGURE 3-1 Geologic map of the Spokane, Washington Area (taken from Molenaar, 1988)

Spokane. Flood deposits typically consist of poorly sorted mixture of boulders, cobbles, gravel, and sand, while alluvium deposits generally consist of well-sorted deposits of silt, sand, and gravel (Joseph, 1990).

The Site is directly underlain by Pleistocene flood deposits, which overlie basalts of the Priest Rapids Member of the Yakima Basalt (Schuster, 1992; Joseph, 1990).

3.4 Surface Water Hydrology

Surface water in the immediate area is limited to intermittent runoff from rainwater. The Spokane River is approximately 1.5 miles south of the Site.

Regionally, Spokane is located within the Spokane River Basin, which is a subbasin of the larger Columbia River Basin. The Spokane River originates in the panhandle of Idaho at Lake Coeur d'Alene, drains an area of approximately 5,022 square miles, and then joins the Columbia River northwest of Spokane. The Columbia, in turn, flows southward and then west, emptying into the Pacific Ocean at Astoria, Oregon. The Columbia River forms the border between the states of Washington and Oregon and is a major source for hydroelectric power and irrigation water for the states of Washington, Idaho, and Oregon.

3.5 Hydrogeology

The following subsections describe the regional and local hydrogeology in the vicinity of the Hillyard Dross Site.

3.5.1 Regional Hydrogeology

Regional ground-water in the Columbia Basin area is dominated by the Columbia River Plateau Aquifer System, which covers nearly 70,000 square miles in eastern Washington, and which is the major source for industrial, municipal, irrigation, and domestic water usage. Four distinct hydrogeological units comprise the Aquifer System and are, in descending order, the Overburden Unit, the Saddle Mountain Unit, the Wanapum Unit, and the Grande Ronde Unit (Drost and Whitemand, 1986). In addition, portions of Spokane obtain their water from fractured intrusive and metasedimentary water bearing zones. Hydrogeological units in the area are not continuously connected; ground-water flow is governed primarily by the fractures and joints in the basalts and the permeability of interlayered sediments.

3.5.2 Local Hydrogeology

The ground-water aquifer underlying the Site is the Spokane-Rathdrum Aquifer, which is used as a drinking water source by almost 400,000 people in the State of Washington. There are 21 public wells and over 150 private wells within three miles of the Site.

The Spokane-Rathdrum sole source aquifer underlies eastern Washington and northern Idaho, extending from Lake Pend Oreille through the Spokane Valley under the city of Spokane, and exists as springs near the Little Spokane River (Figure 3-2). The aquifer underlies approximately 350 square miles and is contained in glacio-fluvial deposits. The deposits consist mostly of poorly to moderately sorted sands and gravels, with some beds of cobbles and boulders, and a few scattered clay lenses. The sands and gravels are relatively free of fine sand and silt, except in the uppermost 3-5 feet. of the aquifer.

The Spokane-Rathdrum Aquifer is several hundred feet thick. The water surface of the aquifer is about 178 feet below the ground surface (bgs) at the Site, and only about 50 feet bgs near the eastern boundary of the City of Spokane. The saturated thickness under the Site is 51-100 feet. The aquifer is exposed in some areas of the valley in deep pits that are used for gravel quarries and concrete operations.

In general, the permeability of the Spokane-Rathdrum Aquifer is high because of its relatively clean sand and gravel composition. This high permeability, coupled with its hydraulic gradient, results in velocities as high as 60-90 feet per day. At these rates, the volume of flow could reach 1,000 cubic feet per second. Lower velocities of approximately 10 to 50 feet/day (ft/day) occur toward the middle and western edge of the aquifer. These rates are high compared with more typical aquifer velocities, which range between five feet per day to five feet per year.

The generalized ground-water flow in the Spokane-Rathdrum Aquifer is from east to west down the Spokane Valley. North of the Spokane River the flow direction turns north to northwest near the Spokane city limits. The flow bifurcates around the Fivemile Prarie, which is located northwest of the Site (Figure 3-3). Ground water flows at a rate of approximately 46 ft/day through the Hillyard Trough from south to north where the Site is located. Under the Site, the transmissivity of the aquifer is expected to be approximately 6 ft^2/s with a specific yield of 10 to 15% (Molenaar, 1988).

3.6 Land Use

The Site has been used as a gravel quarry and for aluminum dross recycling. The property to the south of the Site is occupied by Koch Materials operating as an asphalt plant. The property to the north of the Site, across Wellesley Avenue, has

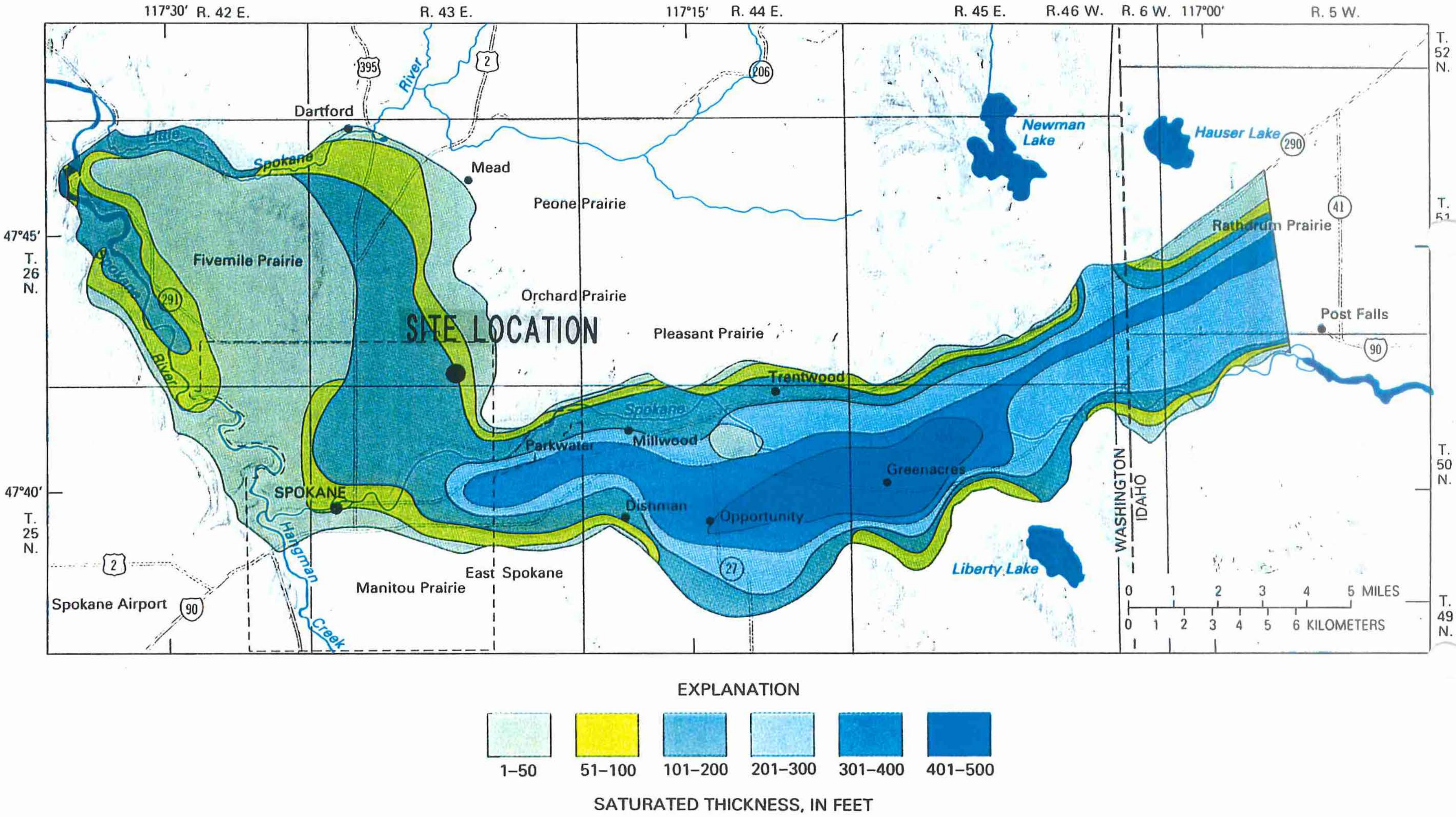


FIGURE 3-2 Saturated Thickness of the Spokane-Rathdrum Aquifer (taken from Molenaar, 1988)

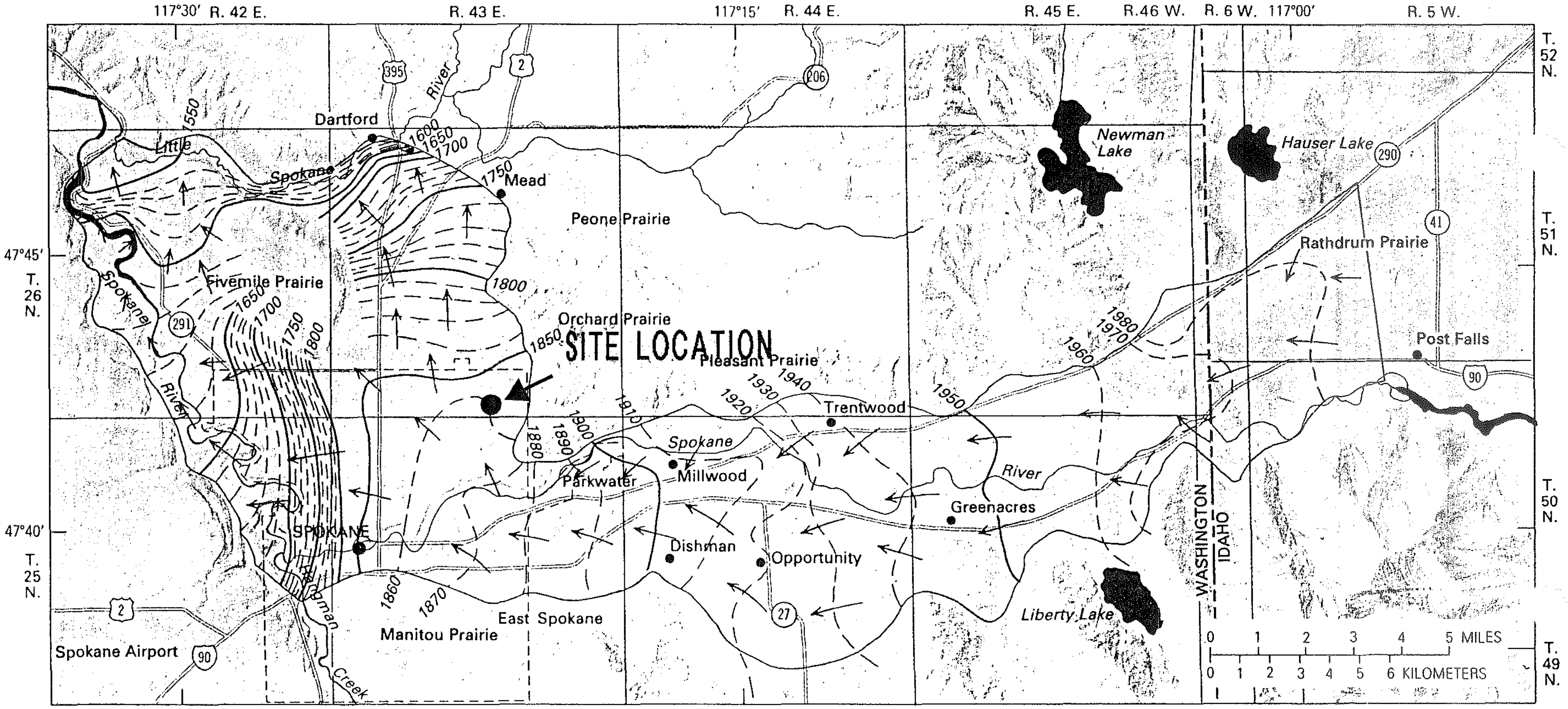


FIGURE 3-3 Water Table Contours and the Direction of Ground-Water Flow in the Spokane-Rathdrum Aquifer, May 1978 (taken from Molenaar, 1988)

historically been a railroad yard known as the Great Northern Hillyard Shops. The west side of the Site is bordered by BNSF railroad tracks, followed to the west by a commercial and residential area. The property to the east of the Site is occupied by a commercial business, followed to the east by a residential area. The Site and surrounding area are zoned M1-1L, which is mixed use – light industrial. BNSF had begun developing a plan to redevelop its property in Hillyard (including this Site) for industrial and commercial activity, but these plans have been delayed pending a decision by the Washington Department of Transportation (WDOT) on a route for the north-south freeway.

3.6.1 Ground-Water Supply

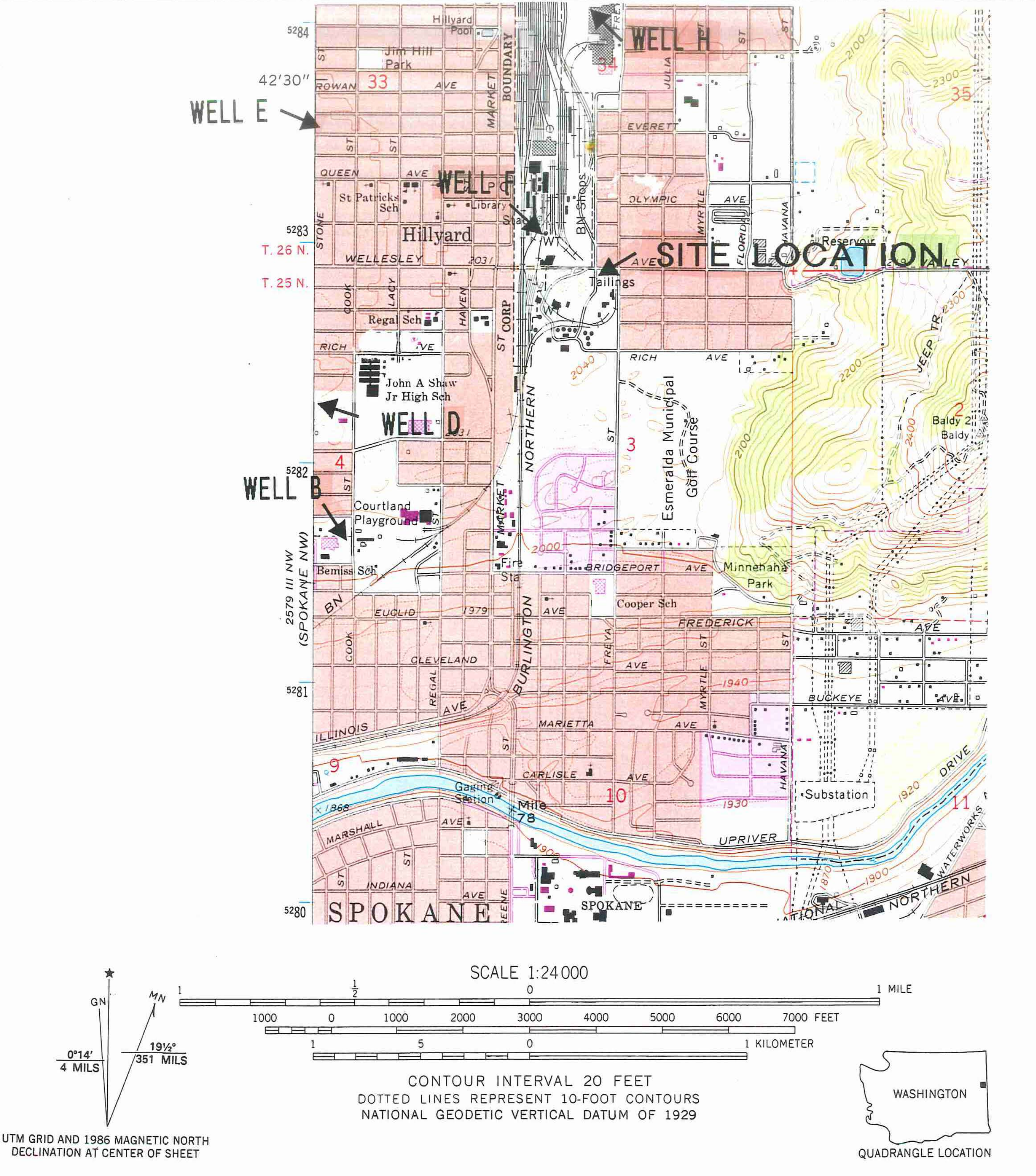
Research was conducted to identify the existence and location of water wells in the Hillyard area of Spokane. Various agencies were contacted including the Eastern Section of the WDOE, the City of Spokane, Department of Water Resources, the US Geological Survey, and Region 10 of the US Environmental Protection Agency. Numerous wells were identified in the Hillyard area (Appendix B) within a two mile radius of the Site.

The nearest up gradient wells are Well B and Well D on Figure 3-4. Well B is a 168-foot deep well approximately 0.9 miles southwest of the Site. The existence of this well could not be confirmed. Well D is a 380 foot deep well located approximately 0.9 miles southwest of the Site. None of the other wells were located up gradient of the Site.

Down gradient wells also are shown on Figure 3-4. There were two down gradient monitoring wells (MW-3 and BN-5). Of these, only monitoring well MW-3 remains: it is located just north of the dross area and south of Wellesley Avenue. Monitoring well BN-5 was located approximately 1,517 feet northwest of the aluminum dross Site. Well F was located approximately 450 feet northwest of the Site and was a hand-dug well that serviced the former railroad facilities. Well E was a 220 foot deep domestic water well located approximately one mile northwest of the Site.

3.6.2 Population

There are approximately 3,438 households within one mile of the Site with a total population of approximately 8,000 people. Average population per square mile is 2,500. Within a five mile radius there are over 176,000 people in almost 80,000 households (Appendix A).



EMR INCORPORATED

The Burlington Northern Santa Fe Railway Co.
Hillyard Dross Site, Spokane, WA

Remedial Investigation/Feasibility Study (RI/FS)
Well Survey Map

Drawn By:	DLW
Checked By:	DC
Project #:	338
File Name:	338fg3-5.GCD
Date:	2/8/99
Scale:	As shown

FIGURE 3-4

SECTION 4.0

FIELD PROGRAM

This section describes the field program activities conducted during the RI at the Hillyard Dross Site. Methods and procedures are presented in the Workplan (EMR, 1998). Deviations from the workplan are also presented herein. The results of the field program are presented and discussed in Section 5.0. Table 4-1 contains a summary of the field activities. Figure 4-1 shows sampling locations.

4.1 Summary of Field Activities

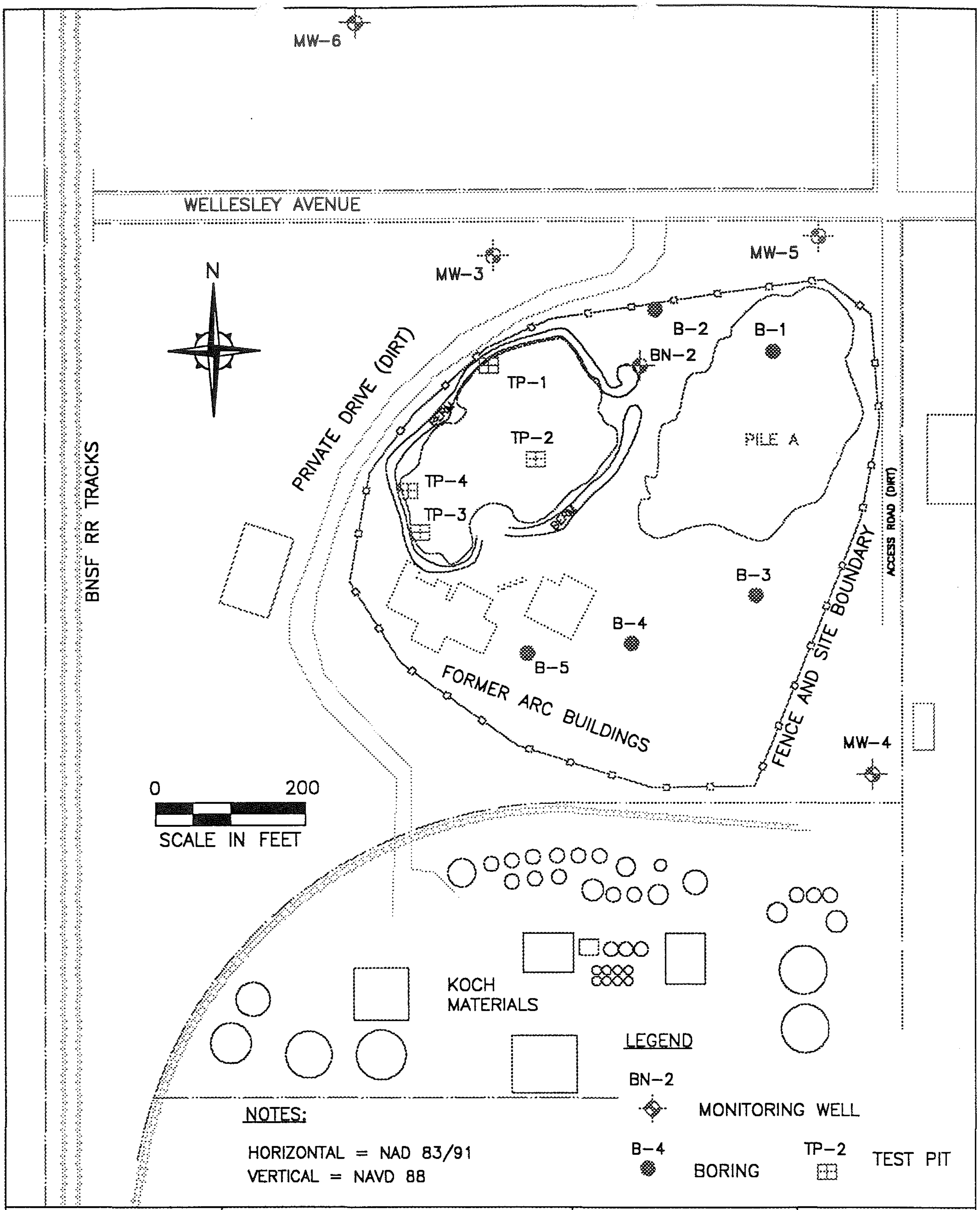
EMR commenced field activities in December of 1998. The field program as conducted is summarized in this section. Deviations from the Ecology-approved RI/FS workplan are presented in Section 4-2. The field program consisted of the following:

- Excavate four (4) test pits TP-1 through TP-4 inside two main aluminum dross pits on the north side of the Site. Collect soil samples from dross and soil for geotechnical and chemical analyses at selected depth intervals.
- Drill five (5) soil borings B1 through B5 inside the aluminum dross Site fenced area with one of the soil borings completed through Dross Pile A. Collect soil samples from dross and soil for geotechnical and chemical analyses at selected depth intervals.
- Drill and install three (3) ground-water monitoring wells MW-4, MW-5 and MW-6. Collect soil samples during drilling for purposes of logging soils and geotechnical analyses at selected depth intervals.
- Locate wells BN-5 and west well on the former railyard to the north of the Site. Survey horizontal and vertical control of all monitoring wells and current sampling locations.
- Measure depth to ground-water on all ground-water monitoring wells from surveyed top of casing elevations to construct potentiometric surface map of uppermost aquifer.
- Develop and purge ground-water monitoring wells.
- Collect ground-water samples for chemical analyses.

TABLE 4-1

Summary of Remedial Investigation Activities
Hillyard Dross Site, Spokane, WA

Explorations/Samples	Number
Number of Shallow Soil Borings	4
Number of Deep Soil Borings	1
Number of Test Pits	4
Number of Groundwater Monitoring Wells (Previous)	2
Number of Groundwater Monitoring Wells (New)	3
Number of Aluminum Dross Samples (Geotechnical Testing)	5
Number of Aluminum Dross Samples (Chemical Testing)	8
Number of Soil Samples (Geotechnical Testing)	10
Number of Soil Samples (Chemical Testing)	19
Number of Groundwater Samples	5
Number of Groundwater Samples (QA/QC)	1



EMR
INCORPORATED

Burlington Northern Santa Fe
Spokane, Washington

Monitoring Well and Sampling Locations

Drawn by:	I.D.S.
Checked By:	TJP
Project Number:	338
File Name:	FIG_4-1.DWG
Revision No.:	2
Date:	2/24/99
Scale:	as shown

FIGURE 4-1

A summary of soil and dross samples collected for laboratory analysis is shown in Table 4-2. A summary of ground-water samples collected for laboratory analysis is shown in Table 4-3. A summary of samples collected for geotechnical analysis is shown in Table 4-4. A summary of ground-water monitoring well construction is shown in Table 4-5. Boring logs and monitoring well construction information are attached as Appendix C.

4.1.1 Test Pit Exploration

Four (4) test pits were excavated with a rubber-tired backhoe by Environmental West Exploration, Inc. on December 3, 1998. Locations are shown on Figure 4-1. EMR, represented by Gregory McCormick, logged the aluminum dross and underlying soils during excavation activities.

The objectives of the test pits were to:

- Log the aluminum dross based on color and texture;
- Determine the depth of the aluminum dross (i.e., elevation of natural soil or other fill material beneath the dross);
- Evaluate whether a shallow perched water zone exists; and,
- Obtain samples of the dross and underlying soil for geotechnical and chemical analysis.

Laboratory analyses are summarized in Table 4-2. Three (3) samples from each test pit were collected and submitted for chemical analyses. An additional fourth sample was collected from TP-1. The sample location and laboratory analyses for samples are described below:

- Analyze selected dross samples for RCRA 8 metals (arsenic [As], barium [Ba], cadmium [Cd], chromium [Cr], lead [Pb], mercury [Hg], selenium [Se], and silver [Ag]) plus copper [Cu], and Toxicity Characteristic Leaching Potential (TCLP) sodium, TCLP potassium, and TCLP chloride of the dross.
- Analyze selected soil samples at 1 foot below the dross/soil interface for RCRA 8 metals plus Cu, sodium, potassium and chloride.
- Analyze selected soil samples at 5 feet below the dross/soil interface for RCRA 8 metals, chloride and nitrate.

TABLE 4-2

Chemical Laboratory Testing Summary -Soils and Dross
Hillyard Dross Site, Spokane, WA

Laboratory Number	Sample Number	Date Sampled	Matrix	Sample Type	Lab Parameters/USEPA Method			
					RCRA 8 Metals + Cu /EPA 6010A/7471A (Mercury)	TCLP Sodium, Potassium, & Chloride/EPA 1311/6010/7000/300 (Chloride)	Sodium, Potassium and Chloride/6010A/300 (Chloride)	Nitrate-Nitrogen/EPS 300
S812016-04	TP- 1 (Dross Interface)	03-Dec-98	Dross	Grab	X	X	X	X
S812016-02	TP-1 (Soil Interface)	03-Dec-98	Soil	Grab	X	X	X	X
S812016-01	TP-1 (Soil 1')	03-Dec-98	Soil	Grab	X	X	X	X
S812016-03	TP-1 (Soil 5')	03-Dec-98	Soil	Grab	X	X	X	X
S812016-06	TP- 2 (Dross Interface)	03-Dec-98	Dross	Grab	X	X	X	X
S812016-05	TP-2 (Soil 1')	03-Dec-98	Soil	Grab	X	X	X	X
S812016-07	TP-2 (Soil 5')	03-Dec-98	Soil	Grab	X	X	X	X
S812016-10	TP- 3 (Dross 20")	03-Dec-98	Dross	Grab	X	X	X	X
S812016-09	TP-3 (Soil 2')	03-Dec-98	Soil	Grab	X	X	X	X
S812016-11	TP-3 (Soil 7')	03-Dec-98	Soil	Grab	X	X	X	X
S812016-12	TP- 4 (Dross 18")	03-Dec-98	Dross	Grab	X	X	X	X
S812016-13	TP-4 (Soil 1')	03-Dec-98	Soil	Grab	X	X	X	X
S812016-14	TP-4 (Soil 5')	03-Dec-98	Soil	Grab	X	X	X	X
S812054-01	B1-9	14-Dec-98	Dross	SS	X	X	X	
S812054-02	B1-23	14-Dec-98	Soil	SS	X		X	
S812054-03	B1-27	14-Dec-98	Soil	SS	X		X	
S812054-04	B2-1	15-Dec-98	Soil	SS	X		X	
S812054-05	B2-5	15-Dec-98	Soil	SS	X		X	
S812054-06	B3-1	15-Dec-98	Dross	SS	X	X	X	
S812054-07	B3-3	15-Dec-98	Soil	SS	X		X	
S812054-08	B3-7	15-Dec-98	Soil	SS	X		X	
S812054-09	B4-S	15-Dec-98	Dross	SS	X	X	X	
S812054-10	B4-2	15-Dec-98	Soil	SS	X		X	
S812054-11	B4-5	15-Dec-98	Soil	SS	X		X	
S812054-12	B5-S	15-Dec-98	Dross	SS	X	X	X	
S812054-13	B5-2	15-Dec-98	Soil	SS	X		X	
S812054-14	B5-5	15-Dec-98	Soil	SS	X		X	

Grab - Grab Sample
SS= Split Spoon

TCLP = Toxicity characteristic leaching procedure
USEPA = United States Environmental Protection Agency
RCRA = Resource Conservation & Recovery Act

B1-23= Soil Boring ID & Depth
TP-4 (Soil 1')= Test Pit I.D. (Material & Depth)

31-7

TABLE 4-3

Chemical Laboratory Testing Summary - Ground Water

Hillyard Dross Site, Spokane, WA

Laboratory Number	Sample Number	Date Sampled	Matrix	Sample Type	Lab Parameters/USEPA Method									
					Sodium, Potassium and Chloride	Nitrate-Nitrogen	Calcium & Magnesium	Alkalinity (methyl-orange endpoint)/EPA 3010 A	Iron & Manganese	Ammonia/ Nitrogen/ EPA 350.3	Nitrite/ Nitrogen/ EPA 300	Full Anion Scan (Br, Cl, F, NO2, NO3, & SO4)/ EPA 300	Flouride/ EPA 300	Orthophosphate-Phosphorus/ EPA 300
S812053-01	BN-2 (12-15-98)	15-Dec-98	Water	SP	X	X	X	X	X	X	X	X	X	X
S812053-02	BN-2 (12-15-98D)	15-Dec-98	Water	SP/D	X	X	X	X	X	X	X	X	X	X
S812053-03	MW-3 (12-16-98)	16-Dec-98	Water	DB	X	X	X	X	X	X	X	X	X	X
S812053-04	MW-4 (12-16-98)	16-Dec-98	Water	SP	X	X	X	X	X	X	X	X	X	X
S812053-05	MW-5 (12-15-98)	15-Dec-98	Water	SP	X	X	X	X	X	X	X	X	X	X
S812053-06	MW-6 (12-16-98)	16-Dec-98	Water	SP	X	X	X	X	X	X	X	X	X	X

D = Duplicate
DB = Disposable Bailer
SP = Submersible Pump

MW-3 (12-16-98) = Monitoring Well I.D. & Date of Collection
USEPA = United States Environmental Protection Agency

TABLE 4-4

Geotechnical Laboratory Testing Summary
Hillyard Dross Site, Spokane, WA

Laboratory Number	Sample Number	Date Sampled	Matrix	Sample Type	Geotechnical Parameter/ASTM Method			
					Modified Proctor (Maximum Density & Optimum Moisture)/ASTM D-1557	Sample Moisture/ASTM D-2216	Particle Size Analysis of Soils (Sieve Test)/ASTM D-422	Atterberg Limits/Non-Plastic Determination (Plasticity Index)/ASTM D-4318
98-1293	MW-5, 170'	02-Dec-98	Dross	Grab		X	X	
98-1294	TP-1, Grey Dross	03-Dec-98	Soil	Grab	X	X	X	X
98-1295	MW-4, 175'	07-Dec-98	Soil	Grab		X	X	
98-1296	MW-4, 180'	07-Dec-98	Soil	Grab		X	X	
98-1297	MW-4, 90'	07-Dec-98	Dross	Grab		X	X	
98-1298	MW-4, 40'	04-Dec-98	Soil	Grab		X	X	
98-1299	B1-29, Soil	14-Dec-98	Soil	Grab		X	X	
98-1300	B1-7, Dross	14-Dec-98	Dross	Grab		X	X	
98-1301	B2-S, Soil	15-Dec-98	Soil	Grab		X	X	
98-1302	B3-1, Dross	15-Dec-98	Soil	Grab		X	X	
98-1303	B3-3, Soil	15-Dec-98	Dross	Grab		X	X	
98-1304	B4-S, Dross	15-Dec-98	Soil	Grab		X	X	
98-1305	B4-4, Soil	15-Dec-98	Soil	Grab		X	X	
98-1306	B5-S, Dross	15-Dec-98	Dross	Grab		X	X	
98-1307	B5-4, Soil	15-Dec-98	Soil	Grab		X	X	

Grab - Grab Sample
SS= Split Spoon

QA/QC = Quality assurance / Quality control
TCLP = Toxicity characteristic leaching procedure
USEPA = United States Environmental Protection Agency
RCRA = Resource Conservation & Recovery Act

B1-23= Soil Boring ID & Depth
MW-3 (12-16-98) = Monitoring Well I.D. & Date of Collection
TP-4 (Soil 1')= Test Pit I.D. (Material & Depth)

TABLE 4-5

Monitoring Well Construction Summary
Hillyard Dross Site, Spokane, Washington

Well / Measuring Point Name	Screened Zone	Grade Elevation (feet amsl)	Top of Casing / Measuring Point Elevation (feet amsl)	Bottom of Screen Elevations (feet amsl)	Screen Length (feet)	Top of Screen Elevations (feet amsl)
MW-3	Deep	2036.01	2039.01	1860.01	10.00	1870.01
MW-4	Deep	2036.42	2039.42	1841.42	20.00	1861.42
MW-5	Deep	2038.80	2041.80	1843.80	20.00	1863.80
MW-6	Deep	2039.73	2042.73	1844.73	20.00	1864.73
BN-2	Deep	2036.06	2039.06	1849.56	15.00	1864.56

amsl = Above mean sea level

- Analyze selected dross samples from test pit TP-1 for grain size (sieve) analysis, moisture content, maximum density and optimum moisture.

4.1.2 Soil Boring Exploration

Five (5) soil borings were advanced with a truck-mounted drill rig by Environmental West Exploration, Inc. on December 14 and 15, 1998. Locations are shown on Figure 4-1. EMR, represented by David L. Welch, logged the aluminum dross and underlying soils during drilling activities.

The objectives of the soil borings were to:

- Log the aluminum dross based on color and texture;
- Determine the depth of the aluminum dross (i.e., elevation of natural soil or other fill material beneath the dross);
- Evaluate whether a shallow perched water zone exists; and,
- Obtain samples of the dross and underlying soil for geotechnical and chemical analysis.
- Laboratory analyses are summarized in Table 4-2.

4.1.3 Ground-Water Monitoring Wells

Three (3) ground-water monitoring wells were installed by under-reaming casing advance down-the-hole-hammer system. Locations are shown on Figure 4-1. The well borings were logged by David L. Welch or Greg McCormick. Each boring was completed with a 20-foot length of two-inch diameter ten-slot (0.01 inch) PVC screen. Silica sand pack (number 2/12 Lonestar) was emplaced from the bottom of the screened interval to three feet above the top of the screen. The boring for the wells was logged by collecting wire-line split spoon sample at selected intervals. The well borings were advanced to 200 feet, and then the casing cleaned out and a water level measurement taken.

Within 24 to 48 hours after completion, the monitoring wells were developed by the drilling subcontractor using a properly decontaminated submersible pump or a bailer. The water level in the well was measured before development began. Temperature, conductivity, specific conductivity and pH were monitored and recorded while a minimum of 10 well volumes were purged from the well. In addition, observations of turbidity were made. Well development continued until temperature, pH, turbidity, and conductivity had stabilized and the water was clear and free of sand.

Immediately following well development, and with the sample pump or bailer, ground-water samples were collected. Samples were submitted for laboratory analyses listed in Table 4-3. The ground-water samples were collected into laboratory-prepared sample containers; ground-water samples collected for RCRA metals analyses were collected in a container, filtered immediately following collection by pumping through a peristaltic pump and filter, and pumped into the sample bottle with acid. Samples were labeled, placed in individual sealed plastic bags, and stored on ice.

4.2 Deviations from the Workplan

The following is a comprehensive description of differences between the RI/FS workplan and the actual field work completed.

4.2.1 Sampling Deviations

A photoionization detector (PID) was not used to screen for petroleum hydrocarbons, as there were no visual or olfactory indications of any hydrocarbon contamination

4.2.1.1 Test Pits

The workplan specified three (3) soil samples be collected from each test pit for chemical analyses to include: one of dross, one at soil/dross interface, and one at base of the test pit. The actual field program added a fourth sample to TP-1 at one foot below the soil/dross interface and specified the bottom soil sample to be collected 5 feet below the soil/dross interface.

4.2.1.2 Soil Borings

All soil borings were advanced using a truck-mounted drill rig. No samples were collected using a stainless steel hand auger. The workplan specified four soil borings drilled to 15 feet and a fifth soil boring drilled through dross pile A to at least 15 feet. The actual field program consisted of soil borings advanced to a maximum depth of 5 feet below the dross/soil interface at each soil boring location. Soil boring B1, through Pile A was advanced to 27 feet while borings B-2 through B-5 were advanced to depths ranging from 5 feet to 7 feet. The workplan specified three (3) soil samples collected from each soil boring at 5-foot intervals for laboratory analyses and at the dross/soil interface. The actual field program consisted of collecting three soil samples at each boring: one collected of the dross; one collected 1 foot below the soil/dross interface; and one collected 5 feet below the soil/dross interface.

4.2.1.3 Well Borings/Ground-water Samples

Location of monitoring wells MW-4 and MW-6 are reversed from the workplan. Well MW-4 was located in the southeast corner of the Site and well MW-6 was located north of Wellesley Avenue. Monitoring wells were installed to a depth of 195 feet instead of 180 feet as stated in the workplan. This additional depth was necessary to allow for seasonal fluctuations in ground-water elevations. All wells were completed with 20 feet of machine-slotted PVC well screen rather than 10 feet.

Only ground-water samples collected from well MW-3 were collected using a new disposable plastic bailer. All other wells were sampled with a Grundfos Redi-Flo submersible pump. Well MW-3 did not contain enough ground-water to fully submerge the pump.

All monitoring wells were sampled immediately following development. The workplan stated that the wells would not be sampled until at least one week after development.

Well BN-5 and the hand dug wells north of the Site were not located. A thorough search revealed a well monument and several feet of four-inch diameter PVC near the former location of BN-5. The well is presumed to have been destroyed.

4.2.2 Analytical Deviations

4.2.2.1 Ground-water Sample Analysis Deviations

One ground-water sample was analyzed for RCRA 8 metals plus copper.

4.2.2.2 Waste Handling Deviations

All water and soil cuttings from field activities were scarified on Site. No 55-gallon drums were used for containerization of investigation-derived waste. Likewise, purge ground water was not containerized.

4.3 Location and Elevation Survey

Location and elevation surveys at the Hillyard Dross site were performed by David Evans & Associates, Inc. of Spokane, Washington. The locations and elevations of the wells, borings and test pits were tied into control points designated during the RI. Appendix D contains coordinates and elevations of wells, soil borings, test pits and control points surveyed during the RI.

SECTION 5.0

REMEDIAL INVESTIGATION FINDINGS

This section describes and discusses the overall geology and hydrogeology of the Hillyard Dross Site, presents and discusses the results of soil and ground-water sampling, presents the results of the RI, and discusses the cumulative results of all site characterization findings.

5.1 Geologic and Hydrogeologic Investigation Results

The geology and hydrogeology discussion for the Hillyard Dross Site is based on boring logs; water levels; geotechnical, soil, and water analytical data. The results of these data, obtained during the RI, are presented below. Results are consistent with published regional geologic and hydrogeologic information of the area as discussed in Section 3.5.

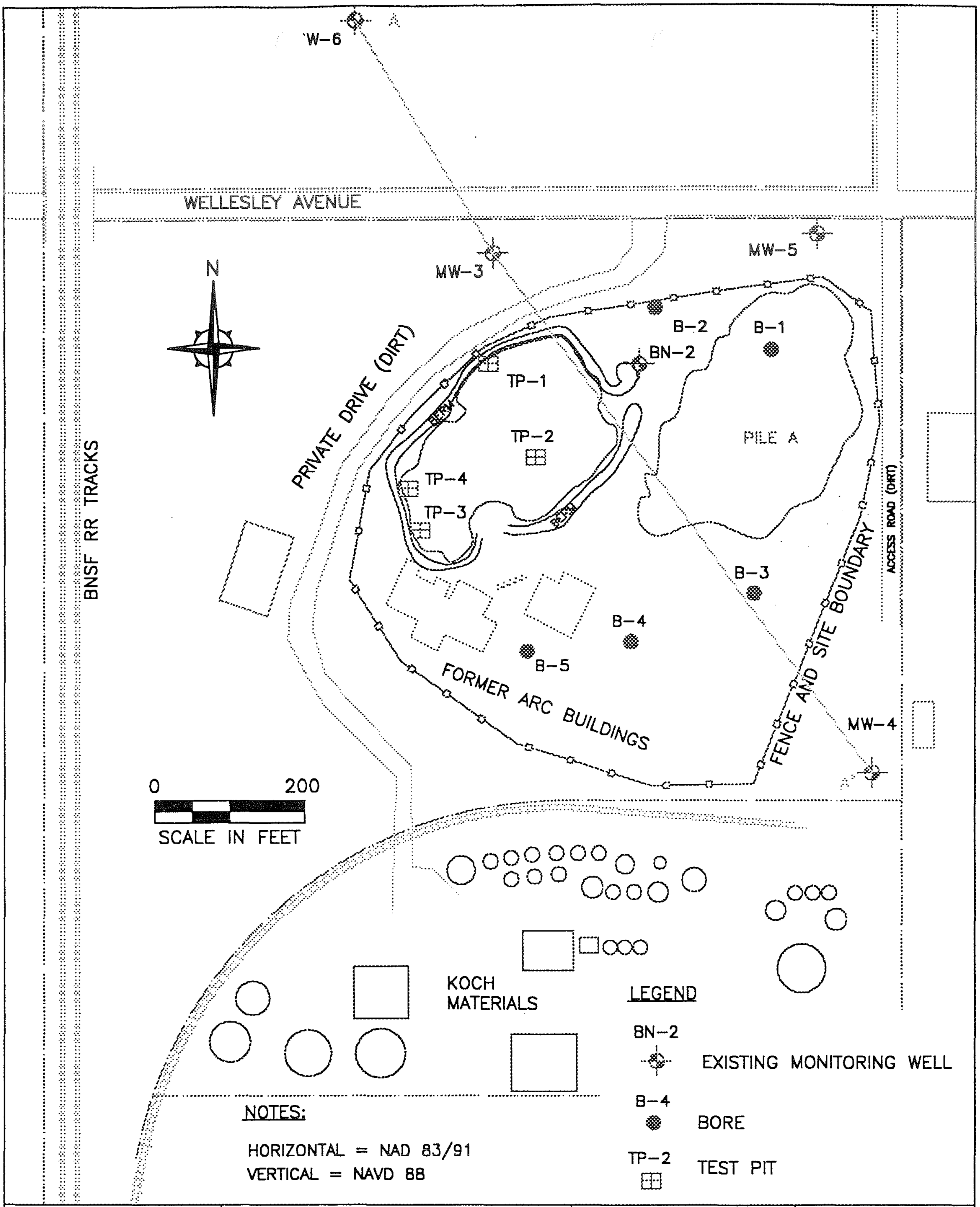
5.1.1 Stratigraphy

A cross section traverse is shown in Figure 5-1. The cross section A-A' is shown in Figure 5-2. The subsurface materials encountered during activities on the Site are consistent with published information. Poorly sorted mixtures of gravel, sand, silt and clay were encountered during well installation to depths of approximately 200 feet. At shallow depths (less than 50 feet bgs) fine to coarse sand with some gravel and cobbles is present. Between 50 and 85 feet bgs grain size coarsens to an equal proportion of gravel and sand or predominantly gravel, with lesser amounts of silt and clay. At moderate depths (approximately 50 to approximately 170 feet bgs) soils generally consisted of sand, with some silt/clay and minor amounts of gravel. Below a depth of between 140 and 170 feet, a gradual increase in sand and decrease in gravel and cobbles occurs.

Grain size distribution curves, shown in Appendix E, are skewed to the sand range because of the inability of split spoon samplers to retain the gravel and cobble range grains.

5.1.2 Hydrogeologic Setting

The Hillyard Dross site lies over the Spokane-Rathdrum sole source aquifer. The regional setting is described in Section 3.5.



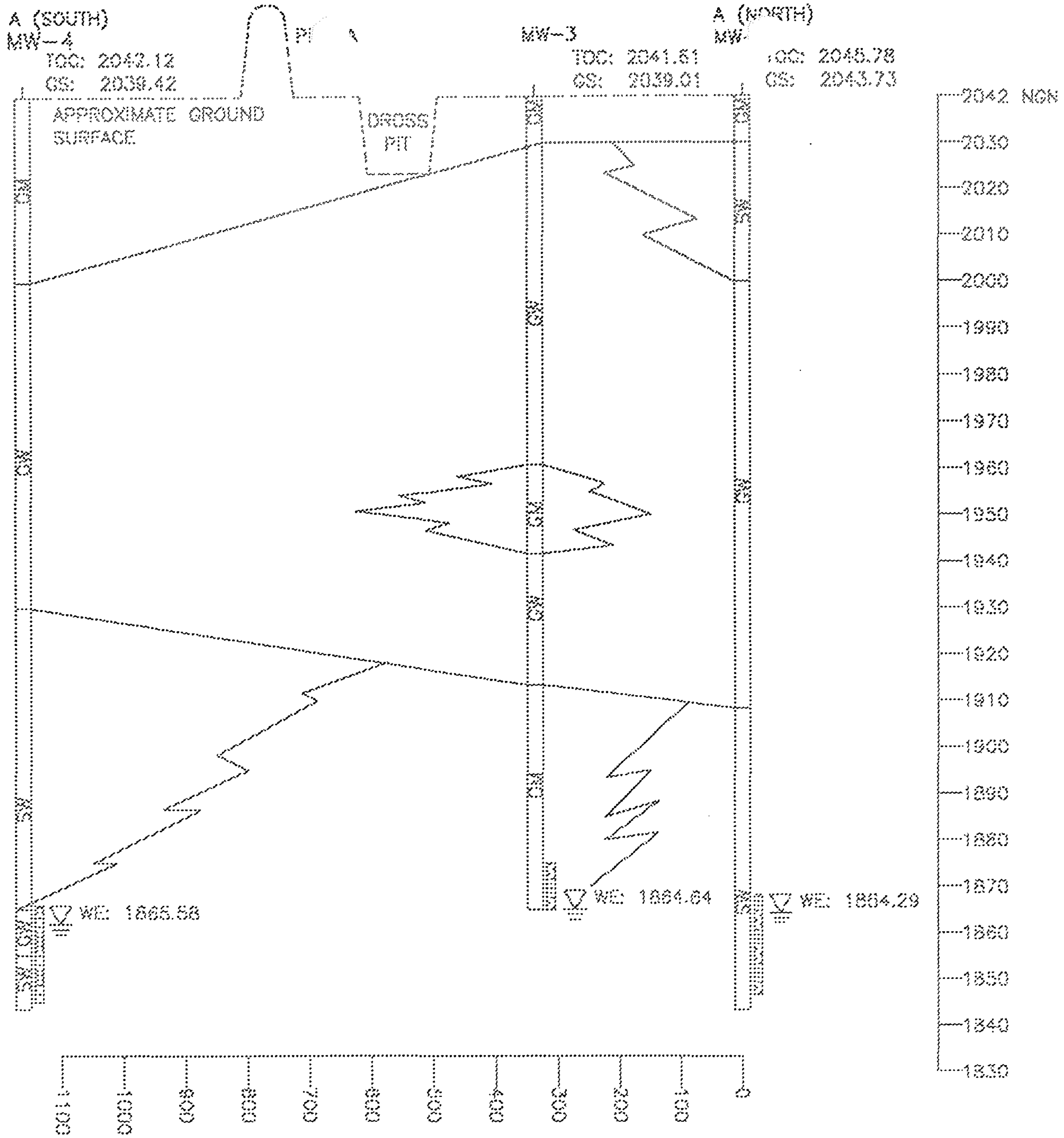
EMR
INCORPORATED

Burlington Northern Santa Fe
Spokane, Washington

Cross-Section Location Map

Drawn by: I.D.S.
Checked By:
Project No.: 338
File Name: FIG_5-1.DWG
Revision No.: 2
Date: 2/16/99
Scale: as shown

FIGURE 5-1



VERTICAL 1" = 30'
HORIZONTAL 1" = 200'

LEGEND

TOC – TOP OF CASING ELEVATION
GS – GROUND SURFACE ELEVATION
WE – GROUND-WATER ELEVATION
▽ – LOCATION OF STATIC WATER LEVEL

▯ – MONITORING WELL SCREENED INTERVAL
GM – GRAVEL-SAND-SILT MIXTURE
GW – GRAVEL-SAND MIXTURE
SW – GRAVELLY SAND

EMR INCORPORATED	*Burlington Northern Santa Fe* *Spokane, Washington*	Drawn by: I.D.S. Checked By: Project No.: 338 File Name: FIG_5-2.DWG Revision No.: 2 Date: 2/17/99 Scale: as shown	FIGURE 5-2
	Geologic Cross Section A-A'		

5.1.2.1 Hydraulic Conductivity from Grain Size

Samples from the aluminum dross material, shallow soil, unsaturated zone and aquifer were collected. Grain size analysis tests (ASTM D422 and C136/D1140) were performed on selected soil and dross samples collected from borings and monitoring wells. Geotechnical results for these tests are provided in Appendix E and grain size distribution curves typical for the stratigraphic zones are shown on Figure 5-3.

Hazen developed an empirical method for estimating hydraulic conductivity from grain size analysis (Walton, 1984). The method is based on the "effective grain size" of the sediments, which is the particle size that 10 percent of the sample is finer and 90 percent is coarser:

$$K = (D_{10})^2$$

where:
$K =$ Hydraulic conductivity in meters per second (cm/s); and
$D_{10} =$ Effective grain size in millimeters.

Hydraulic conductivities estimated using Hazen's approximation for the various zones at the Site are listed in Table 5-1. The degree of error in Hazen's approximation increases with decreasing grain size. Estimates are considered best for medium sand. In general, Hazen found that hydraulic conductivity varies in proportion to the square of the effective grain size, but as the uniformity coefficient increases the effect of a greater effective grain size decreases. The Hazen approximation works best when less than five percent of the sediment is made up of silt plus clay, and when the hydraulic conductivity is more than 0.001 cm/sec.

At the Hillyard Site the estimate is best for the unsaturated zone, but averages appear reasonable for all hydraulic zones. Average hydraulic conductivity for the dross is 30 gallons per day per square foot (gpd/ft^2), and the soil is 50 gpd/ft^2. The hydraulic conductivity estimated from unsaturated zone samples is 10,000 gpd/ft^2, and the estimate from saturated zone samples is 28,000 gpd/ft^2. A more realistic estimate of the aquifer hydraulic conductivity is 5,000 gpd/ft2, which is the average of the unsaturated and saturated zones samples except for the unreasonably large sample result from MW-4 at 180 feet.

5.1.2.2 Potentiometric Surface of the Aquifer

Ground-water level information indicates the water table is approximately 177 feet bgs at an approximate elevation of 1,863 feet above the National Geodetic Vertical Datum (NGVD). Ground-water flow directions from activities conducted in 1985 and 1988 indicate flow in a northerly to northwesterly direction in the vicinity of the Site. The 1988 investigation indicated a ground-water gradient of

FIGURE 5-3

Typical Grain-Size Distribution Curves
BNSF Hillyard Dross Site, Spokane, Washington

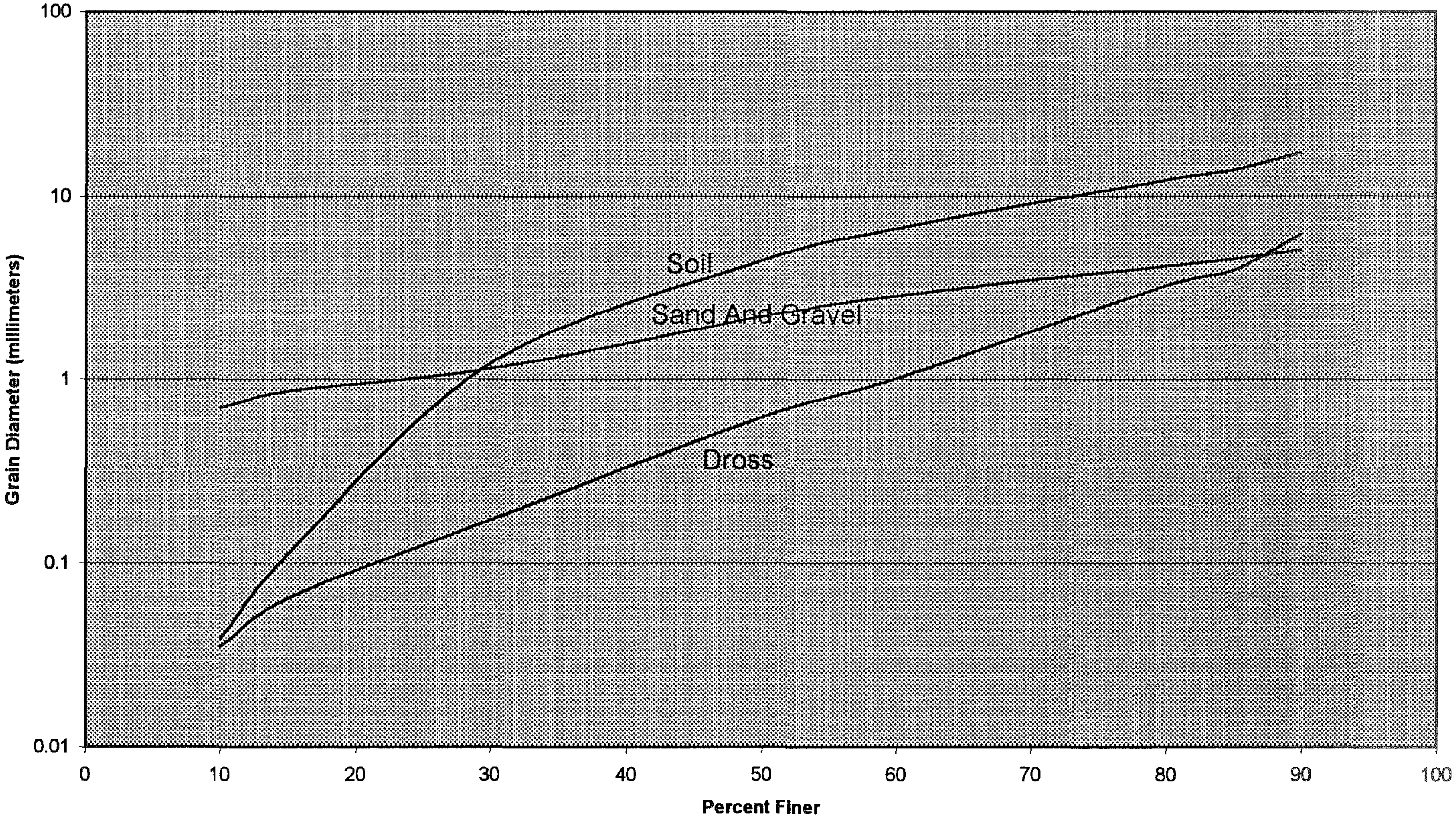


TABLE 5-1

Estimated Hydraulic Conductivities Based on Grain Size Analysis
BNSF Hillyard Dross Site, Spokane, WA

Sample ID	Material	D(10) mm	Hazen's Approximation cm/sec	ft/day	gpd/ft^2
B1-7 Dross	Dross	0.04	1.94E-03	5	40
B3-1 Dross	Dross	0.05	2.50E-03	7	50
B4-5 Dross	Dross	0.01	1.96E-04	1	0
B5-5 Dross	Dross	0.01	1.00E-04	0	0
TP-1 Grey Dross	Dross	0.06	3.25E-03	9	70
B1-29 Soil	Soil	0.05	2.30E-03	7	50
B2-5 Soil	Soil	0.02	3.24E-04	1	10
B3-3 Soil	Soil	0.02	3.24E-04	1	10
B4-4 Soil	Soil	0.09	8.10E-03	23	170
B5-4 Soil	Soil	0.02	3.24E-04	1	10
MW-4 @ 40'	Unsaturated	#REF!	5.78E-01	1637	12230
MW-4 @ 90'	Unsaturated	0.6	3.60E-01	1021	7620
MW-4 @ 175'	Aquifer	0.03	9.00E-04	3	20
MW-4 @ 180'	Aquifer	2.0	4.00E+00	11340	84720
MW-5 @ 170'	Aquifer	0.11	1.21E-02	34	260

mm=millimeters
cm/sec=centimeters per second
ft/day=feet per day
gpd/ft^2=gallons per day per square foot

approximately 7 feet per mile, while the 1985 investigation indicated a gradient of approximately 10 feet per mile in the southern Hillyard area increasing to approximately 20 feet per mile at the northern end.

Ground water levels from the February 1999 results are shown in Table 5-2. A potentiometric surface map based on water levels measured in February of 1999 is presented as Figure 5-4. The ground-water flow direction for the February 1999 event is towards the northwest.

5.1.2.3 Changes in Ground-water Elevations

In the Spokane-Rathdrum aquifer, typical changes in ground-water elevations occur on a seasonal basis and generally are fluctuations of less than 5 feet from the highest levels in spring to the lowest levels in late summer and fall. Generally, the aquifer responds rapidly and in proportion with changes in the Spokane River. Year to year changes in aquifer elevations have been typically less than 5 feet.

In the vicinity of the Site, within the Hillyard Trough, seasonal ground-water fluctuations are generally 2 to 3 feet. Water levels in the Hillyard Trough generally are not as dependent on the Spokane River stage and respond less quickly to precipitation and river discharge.

A comparison of water level information from 1987 through 1998 indicates the water levels varied between depths of 179.9 feet to 176.11 feet below ground surface, for a maximum variation of 3.79 feet over approximately 10 years. This difference is likely due to seasonal or annual variations in the static water level.

5.1.3 Aquifer Chemistry

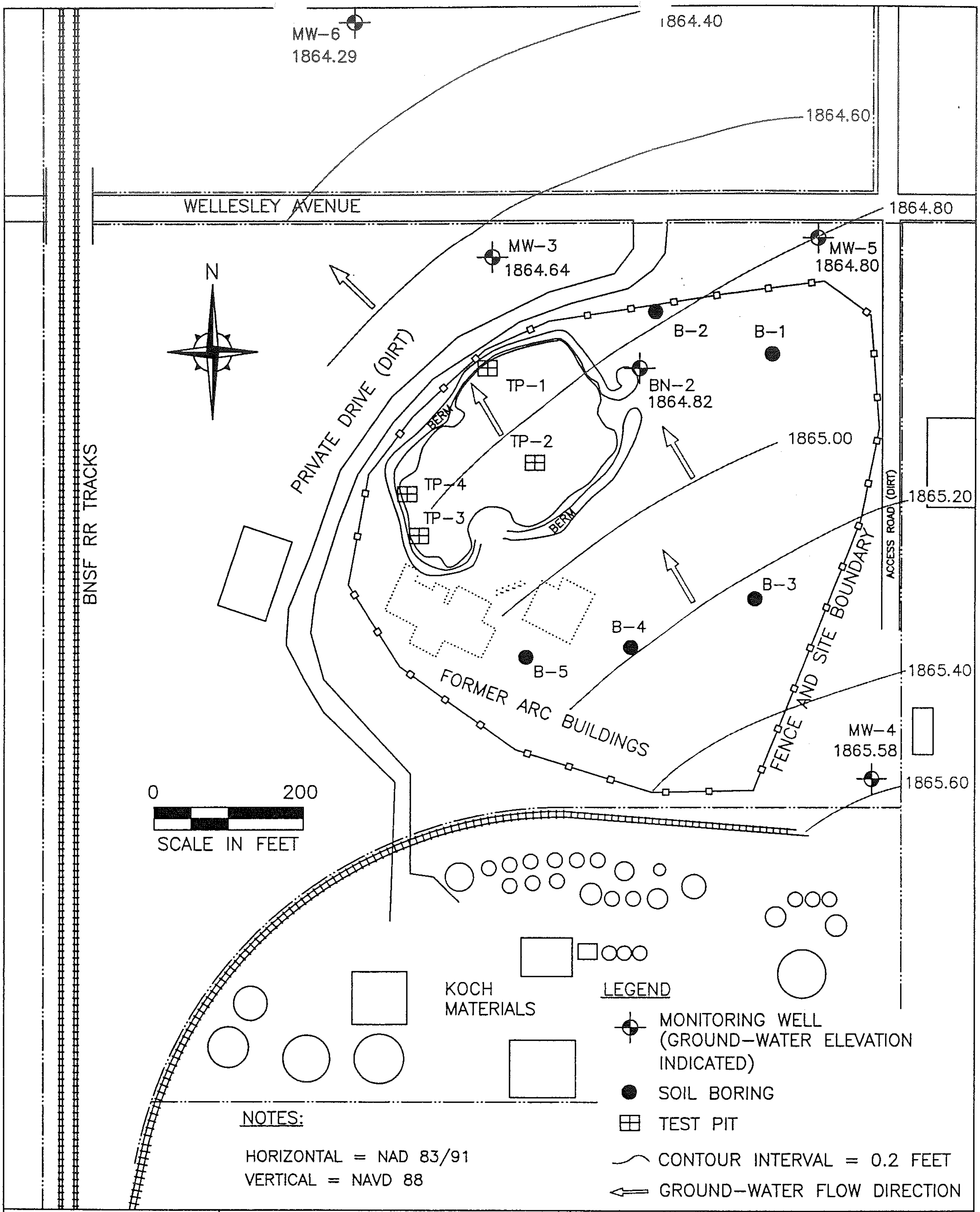
An evaluation of ground-water quality in the Spokane-Rathdrum Aquifer was conducted by Vaccaro and Bolke (1983) by collection of water samples from 142 wells. Of the 142 wells sampled, 100 existing wells were sampled a minimum of three times during the study. Generally, the study found the aquifer water to be of good quality, low in chlorides and nitrate-nitrogen. Localized areas of higher concentrations of chlorides and nitrate-nitrogen were attributed directly with land usage loading contaminants into the aquifer.

Precipitation in the area is dilute, with dissolved solids less than 7 mg/l, and slightly acidic (Peters and Bonelli, 1982). Infiltrating water moves through the unsaturated zone where oxidation of organic matter and iron sulfide in the soil increase bicarbonate and sulfate ionic concentrations. Oxidation of organic matter produces hydrogen ions, thereby increasing acidity and promoting reaction with carbonate minerals. Carbonate minerals are dissolved, increasing ionic concentrations of bicarbonate, calcium and magnesium. Other dissolved ions,

TABLE 5-2

Ground Water Levels Measured in February, 1999
Hillyard Dross Site, Spokane, Washington

Well / Measuring Point Name	Top of Casing / Measuring Point Elevation (feet amsl)	Depth to Water (feet)	Ground-Water Elevation (feet amsl)
MW-3	2039.01	174.37	1864.64
MW-4	2039.42	173.84	1865.58
MW-5	2041.80	177.00	1864.80
MW-6	2042.73	178.44	1864.29
BN-2	2039.06	174.24	1864.82



LEGEND

- MONITORING WELL (GROUND-WATER ELEVATION INDICATED)
- ● SOIL BORING
- ⊞ TEST PIT
- CONTOUR INTERVAL = 0.2 FEET
- ⇐ GROUND-WATER FLOW DIRECTION

NOTES:

HORIZONTAL = NAD 83/91
VERTICAL = NAVD 88

EMR
INCORPORATED

Burlington Northern Santa Fe
Spokane, Washington

Potentiometric Surface Map
for February 1999

Drawn by:	I.D.S.
Checked By:	
Project No.:	338
File Name:	FIG_5-4.DWG
Revision No.:	1
Date:	2/24/99
Scale:	as shown

FIGURE 5-4

including sodium, potassium, and trace elements present as impurities in carbonate and igneous minerals in the unsaturated zone, are released as the minerals dissolve. Ionic concentrations of these elements are controlled by concentrations in the source minerals and tendency to adsorb to clay minerals or form complexes (Drever, 1982).

5.2 Ground-Water Sampling Results

In 1987, Morrison Knudsen installed two ground-water monitoring wells at the Site in order to begin defining the degree and extent of ground-water impact at the Site due to leaching from the dross piles. The MKE wells are BN-2 (located immediately west of dross pile A) and BN-5 (reportedly located approximately 1,517 feet north-northwest of the Site). MKE conducted ground-water sampling of BN-2 and BN-5 in 1987. Additionally, BN-2 and BN-5 were purged and sampled again in August of 1988 by Ponderosa Drilling. EMR redeveloped monitoring well BN-2 prior to collecting ground-water samples from the well in October of 1995.

EMR installed an additional well (MW-3) in June of 1997 in the northwest portion of the Site. EMR purged and sampled monitoring wells BN-2 and MW-3 on June 30, 1997.

As part of the Remedial Investigation/Feasibility Study, EMR installed three additional ground-water monitoring wells. EMR purged and sampled monitoring wells MW-4, MW-5 and MW-6 in December 1998. Monitoring well BN-5 was noted as destroyed in December of 1998. When and how BN-5 was destroyed has not been determined.

A summary of analytical results by constituent is provided below. Results are shown in Tables 5-3 and 5-4. Laboratory reports are enclosed in Appendix F.

5.2.1 Major-Ion Chemistry

Alkalinity: Ground-water samples collected prior to 1998 were not analyzed for alkalinity. Ground-water samples collected from all wells in 1998 indicate ground-water alkalinity at the Site ranges from 122 mg/l in MW-6 to 240 mg/l in MW-3. There have been 6 ground-water samples collected for analysis of alkalinity with 6 detections for a detection percentage of 100 percent. The average concentration was 157 mg/l.

Calcium: Ground-water samples collected prior to 1998 were not analyzed for calcium. Ground-water samples collected from all wells in 1998 indicate ground-water concentrations at the Site range from 21.3 mg/l in MW-6 to 120 mg/l in

TABLE 5-3

Results of Metals Analyses in Groundwater
Hillyard Dross Site, Spokane, Washington

			Concentrations in milligrams per liter														
Location Identifier	Date Sampled	Laboratory Number	Calcium	Iron	Magnesium	Manganese	Potassium	Sodium	Arsenic	Barium	Cadmium	Chromium	Copper	Lead	Mercury	Selenium	Silver
			EPA 6010A	EPA 6010A	EPA 6010A	EPA 6010A	EPA 6010A	EPA 6010A									
BN2/12/15/98	12/15/1998	S812053-01	66.6	ND	33.0	0.205	175	414	NA	NA	NA	NA	NA	NA	NA	NA	NA
BN2/12/15/98D	12/15/1998	S812053-02	66.5	ND	33.9	0.191	173	420	NA	NA	NA	NA	NA	NA	NA	NA	NA
MW-3/12/16/98	12/16/1998	S812053-05	120	80.1	72.3	1.86	72.4	184	NA	NA	NA	NA	NA	NA	NA	NA	NA
MW-4/12/16/98	12/16/1998	S812053-04	29.2	1.38	9.86	0.0213	0.886	2.30	NA	NA	NA	NA	NA	NA	NA	NA	NA
MW-5/12/15/98	12/15/1998	S812053-03	69.4	0.139	28.6	0.0113	255	401	.00148	.134	ND	.00154	ND	ND	ND	.00150	ND
MW-6/12/16/98	12/16/1998	S812053-06	21.3	0.210	8.36	0.0125	34.8	15.4	NA	NA	NA	NA	NA	NA	NA	NA	NA
		Detection Levels	0.413	0.108	0.105	0.00757	0.440	0.0781	0.001	0.01	0.001	0.001	0.001	0.001	0.001	0.001	0.001

ND = Not detected above detection level

TABLE 5-4

Results of Anion Analyses in Groundwater
Hillyard Dross Site, Spokane, Washington

			Concentrations in milligrams per liter								
Location Identifier	Date Sampled	Laboratory Number	Total Alkalinity	Ammonia-Nitrogen	Fluoride	Choride	Nitrite-Nitrogen	Bromide	Nitrate-Nitrogen	Orthophosphate-Phosphorous	Sulfate
			EPA 310.1	EPA 350.3	EPA 300.0	EPA 300.0	EPA 300.0	EPA 300.0	EPA 300.0	EPA 300.0	EPA 300.0
BN2/12/15/98	12/15/1998	S812053-01	164	1.23	ND	657	ND	0.724	13.5	ND	24.8
BN2/12/15/98D	12/15/1998	S812053-02	165	0.998	ND	651	ND	0.697	28.6	ND	32.8
MW-3/12/16/98	12/16/1998	S812053-05	240	0.407	0.375	181	ND	0.226	42.4	ND	70.0
MW-4/12/16/98	12/16/1998	S812053-04	102	0.743	0.123	2.46	ND	ND	1.22	ND	22.3
MW-5/12/15/98	12/15/1998	S812053-03	151	7.34	ND	690	ND	0.696	19.4	ND	27.5
MW-6/12/16/98	12/16/1998	S812053-06	122	0.206	0.164	14.2	ND	0.262	7.85	ND	17.5
		Detection Levels	5	0.1	0.1	2.5	0.1	0.2	5	0.2	10

MW-3. The average concentration was 62 mg/l and the median concentration of 66.6 mg/l.

Chloride: Ground-water samples collected from BN-2 and BN-5 in 1988 had concentrations of 1,150 and 3.4 mg/l, respectively. A ground-water sample collected from BN-2 in 1995 contained 1,400 mg/l chloride. Ground-water samples collected in 1997 had significantly lower concentrations of chloride in well BN-2 (46.6 mg/l). Monitoring well MW-3 contained 397 mg/l chloride in 1997. Analysis of ground-water samples collected in December 1998 indicate chloride concentrations range from 2.46 mg/l in MW-4 (the upgradient monitoring well) to 690 mg/l in MW-5. An isoconcentration contour map of chloride concentration in ground-water is shown in Figure 5-5. Elevated concentrations extend to the northwest in the direction of ground-water flow. The plume is centered just down gradient from Pile A, which is apparently the predominant source of chloride on the Site.

Since ground-water monitoring commenced in 1987, there have been 11 ground-water samples collected for analysis of chloride. The highest concentration of chloride was 1,400 mg/l (BN-2 in 1995), and the average concentration was 472 mg/l.

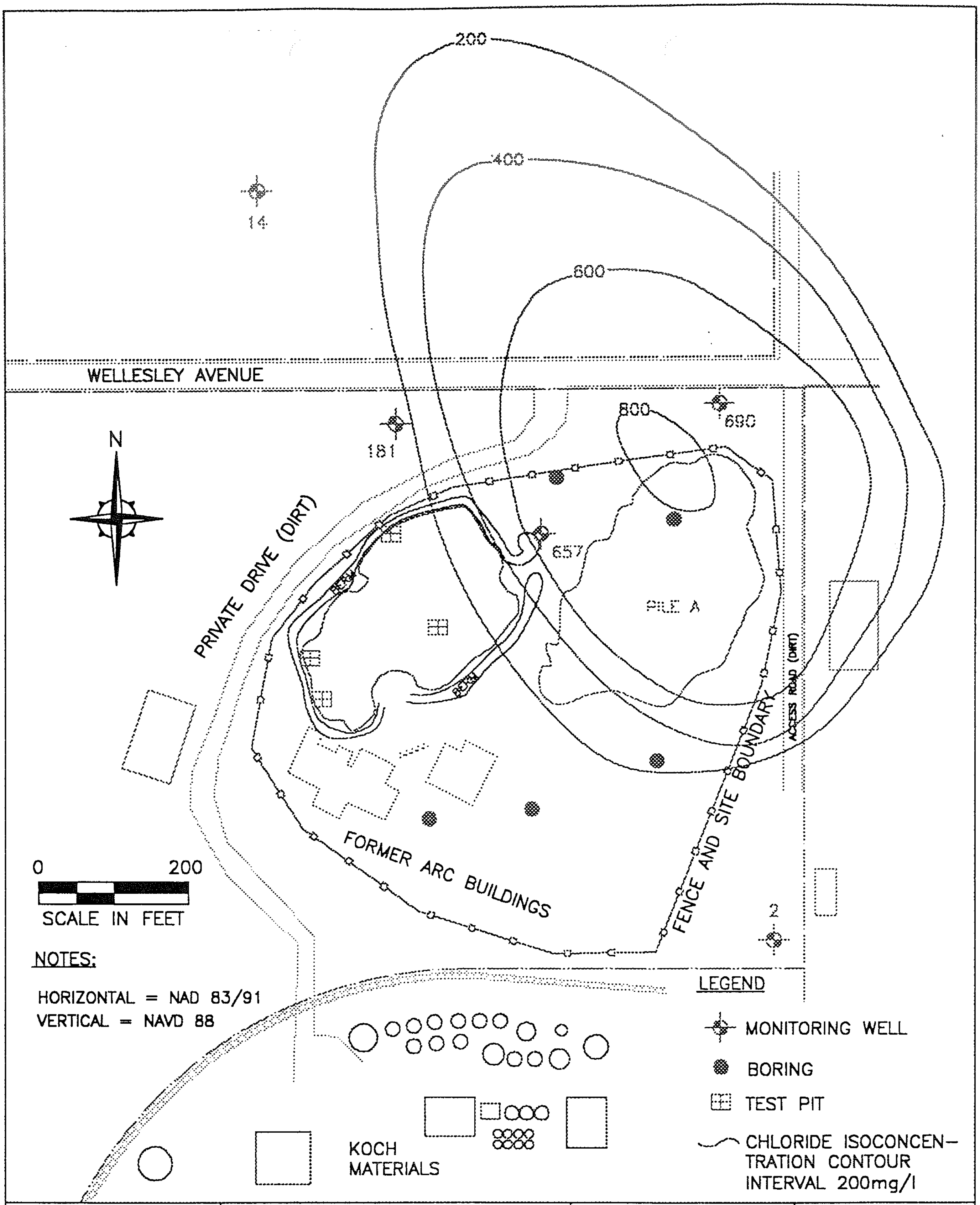
Magnesium: Ground-water samples collected prior to 1998 were not analyzed for magnesium. Ground-water samples collected from all wells in 1998 indicate ground-water concentrations at the Site range from 8.36 mg/l in MW-6 to 72.3 mg/l in MW-3. There have been 6 ground-water samples collected for analysis of magnesium with 6 detections for a detection percentage of 100 percent. The average concentration was 31 mg/l and the median concentration was 30.8 mg/l for a standard deviation of 23.

Potassium: Ground-water samples collected prior to the 1997 event were not analyzed for potassium. Ground-water samples collected from BN-2 and MW-3 in July 1997 contained concentrations of potassium of 58.6 mg/l and 9.56 mg/l, respectively.

Ground-water samples collected in December of 1998 indicate potassium concentrations ranging from 0.886 mg/l in MW-4 to 255 mg/l in MW-5. The distribution of potassium in ground-water is similar to the chloride distribution shown in Figure 5-5.

Since ground-water monitoring commenced in 1987 there have been 8 ground-water samples collected for analysis of potassium. The average concentration was 97 mg/l and the median concentration was 65.5 mg/l.

Sodium: Ground-water samples collected prior to the 1997 event were not analyzed for sodium. Ground-water samples collected from BN-2 and MW-3 in



EMR INCORPORATED

Burlington Northern Santa Fe
Spokane, Washington

Chloride Isoconcentration
Contour Map

Drawn by:	I.D.S.
Checked By:	TJP
Project Number:	338
File Name:	FIG_5-5.DWG
Revision No.:	2
Date:	2/24/99
Scale:	as shown

FIGURE 5-5

1997 had sodium concentrations of 85.4 and 238 mg/l, respectively. Ground-water samples collected in December of 1998 indicate concentrations of sodium ranging from 414 mg/l in BN-2 to 15.4 mg/l in MW-6. The distribution of sodium in ground-water is similar to the chloride distribution shown in Figure 5-5.

Since ground-water monitoring commenced in 1987, there have been 8 ground-water samples collected for analysis of sodium. The highest concentration of sodium was 414 mg/l (BN-2 in 1998) with an average concentration of 220 mg/l and a median concentration of 211 mg/l.

Sulfate: Ground-water samples collected in 1988 from BN-2 and BN-5 indicate sulfate concentrations of 17 and 11 mg/l, respectively. The ground-water sample collected from BN-2 in 1995 contained a sulfate concentration of 26 mg/l. Ground-water samples collected from BN-2 and MW-3 in 1997 had sulfate concentrations of 20.1 and 74.8 mg/l, respectively. Ground-water samples collected in December of 1998 indicate concentrations of sulfate ranging from 70 mg/l in MW-3 to 17.5 mg/l in MW-6.

Since ground-water monitoring commenced in 1987, there have been 11 ground-water samples collected for analysis of sulfate. The highest concentration of sulfate was 74.8 mg/l (MW-3 in 1997) with an average concentration of 31 mg/l and a median concentration of 24.8 mg/l.

5.2.2 Trilinear Diagram

Ground-water characteristic is displayed on a Trilinear diagram in Figure 5-6. In natural ground-water, represented by the upgradient monitoring well MW-4, major dissolved anions include bicarbonate and sulfate; major cations are calcium and magnesium. The resulting plot is in the left-middle quadrant of the trilinear diagram.

In source wells (BN-2 and MW-5) and downgradient wells (MW-3 and MW-6) the effect of leachate from the aluminum dross is apparent. In source wells, the major cation is chloride, the major anion is sodium, and the resulting plot is in the right-middle quadrant of the trilinear diagram. Downgradient wells plot between the upgradient well MW-4 and the source wells.

5.2.3 Inorganic Compounds

RCRA 8 Metals and Copper: During the 1998 sample event a sample from MW-5 was analyzed for RCRA 8 metals plus copper. Results, shown in Table 5-3, are typical of natural ground-water concentrations for these compounds.

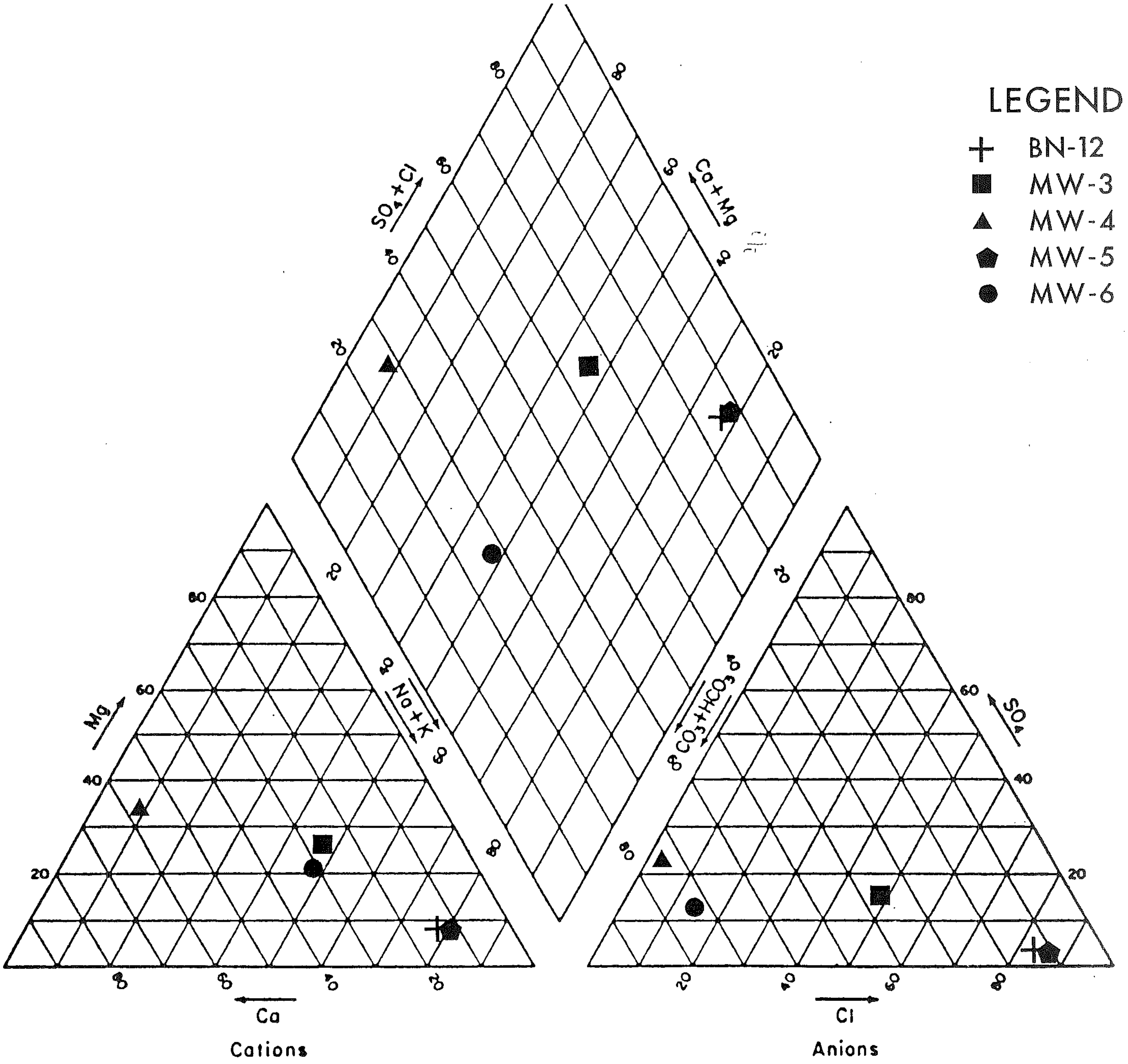


FIGURE 5-6 Tri-linear Diagram for Ground-water Samples.

Bromide: Ground-water samples collected prior to the December 1998 event were not analyzed for bromide. Ground-water samples collected in December 1998 had concentrations of bromide ranging from below the detection limit in MW-4 to 0.724 mg/l in BN-2. There were 6 ground-water samples collected for analysis of bromide with 5 detections for a detection percentage of 83 percent. The average concentration was 0.77 mg/l.

Nitrate-Nitrogen: Ground-water samples collected in 1988 from BN-2 and BN-5 contained nitrate-nitrogen concentrations of 0.9 mg/l in BN-5 and 33 mg/l in BN-2. Ground-water samples collected from BN-2 in 1995 contained nitrate-nitrogen concentrations of 23 mg/l. Ground-water samples collected in 1997 from monitoring wells BN-2 and MW-3 contained nitrate-nitrogen concentrations of 4.83 mg/l in BN-2 and 83.8 mg/l in MW-3. Ground-water samples collected in December of 1998 indicate nitrate-nitrogen concentrations ranging from 1.22 mg/l in MW-4 to 42.4 mg/l in MW-3.

Since ground-water monitoring commenced in 1987, there have been 11 ground-water samples collected for analysis of nitrate-nitrogen. Nitrate-nitrogen has been detected in all samples. The highest concentration of nitrate-nitrogen was 83.8 mg/l (MW-3 in 1997), and the average concentration is 24 mg/l.

Nitrite-Nitrogen: Ground-water samples collected in 1988 from BN-2 and BN-5 contained nitrite-nitrogen concentrations of 1.5 mg/l and below the detection limit in BN-5, respectively. Ground-water samples collected from BN-2 in 1995, 1997 and 1998 contained no detectable concentrations of nitrite-nitrogen.

Since ground-water monitoring commenced in 1987, there have been 11 ground-water samples collected for analysis of nitrite-nitrogen with 1 detection for a detection percentage of 9 percent. The highest concentration (and only detection) of nitrite-nitrogen was 1.5 mg/l (BN-2 in 1988).

Ammonia: Ground-water samples collected prior to 1998 were not analyzed for ammonia. Ground-water samples collected from all wells in 1998 indicate ground-water concentrations at the Site range from 0.21 mg/l in MW-6 to 7.34 mg/l in MW-5. The average concentration of ammonia was 1.8 mg/l, and the median concentration was 0.9 mg/l.

Fluoride: Ground-water samples collected from BN-2 and BN-5 in 1987 indicated concentrations of fluoride of 1.2 mg/l in monitoring well BN-2 and below the detection limit in BN-5. In 1988, fluoride concentrations were 14.0 mg/l in well BN-2 and non-detect in BN-5. A ground-water sample collected from BN-2 in 1995 had a fluoride concentration below the detection limit (1.0 mg/l). The 1988 result, therefore, is suspect based on previous and subsequent sample results. A ground-water sample collected from BN-2 in 1997 had a concentration of 0.177

mg/l. Fluoride was not detected in the sample collected from MW-3 in 1997 with a method detection limit of 0.1 mg/l.

Analysis of ground-water samples collected in December 1998 indicate no detectable amounts of fluoride in monitoring wells BN-2 and MW-5. Fluoride concentrations in the remaining wells were 0.375 mg/l in MW-3, 0.123 mg/l in MW-4 and 0.164 mg/l in MW-6.

Orthophosphate-Phosphorus: Since ground-water monitoring commenced in 1987, there have been 11 ground-water samples collected for analysis of orthophosphate-phosphorus with no detections.

Iron: Ground-water samples collected prior to 1998 were not analyzed for iron. Ground-water samples collected from all wells in 1998 indicate ground-water concentrations at the Site range from below the detection limit to 80.1 mg/l in MW-3. There have been 6 ground-water samples collected for analysis of iron with 4 detections for a detection percentage of 67 percent. The highest concentration of iron was 80.1 mg/l in MW-3, and the average concentration was 20 mg/l. The elevated concentration in MW-3 is likely from iron bacteria in the well, which was observed during well sampling.

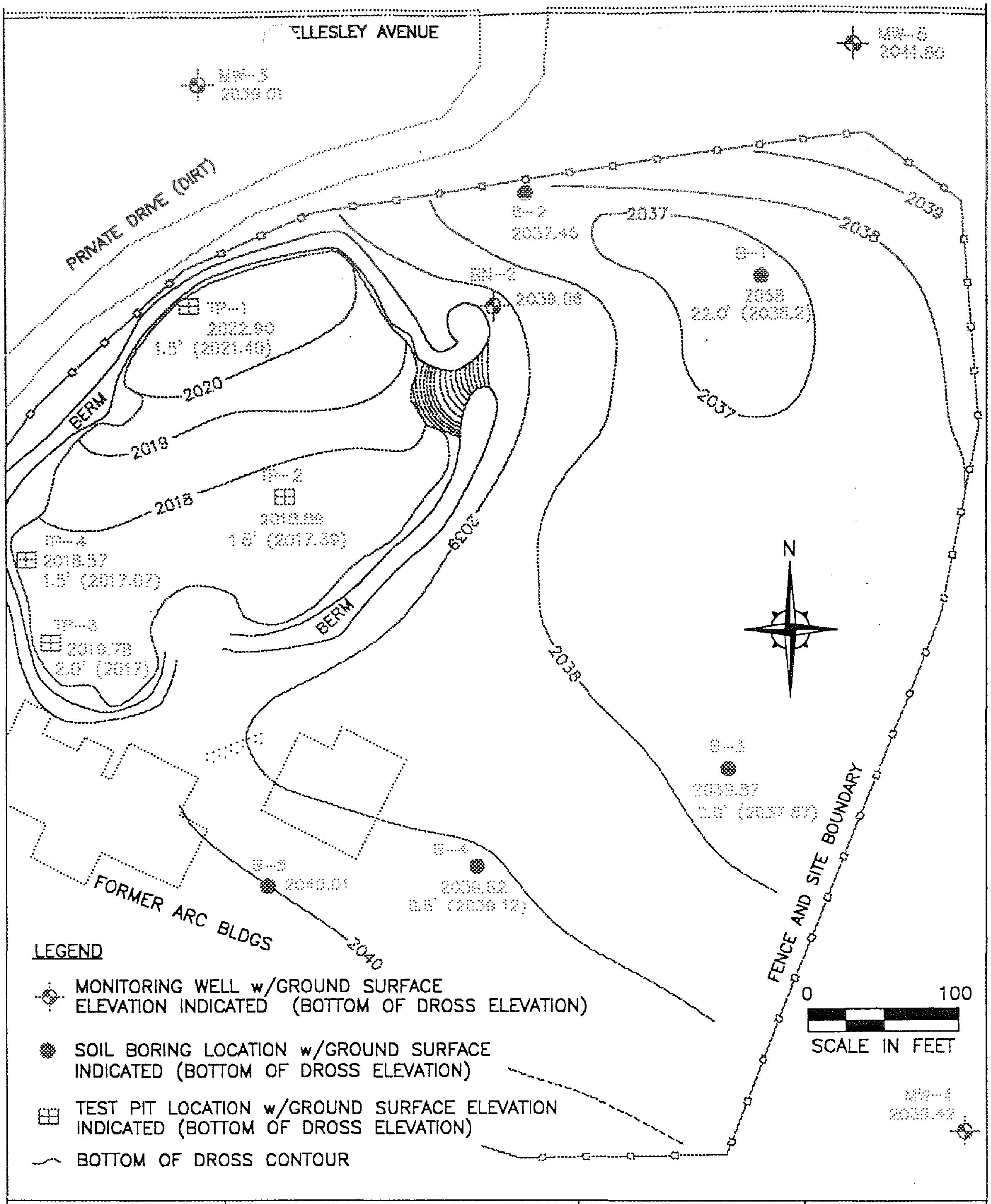
Manganese: Ground-water samples collected prior to 1998 were not analyzed for manganese. Ground-water samples collected from all wells in 1998 indicate ground-water concentrations at the Site range from 0.0113 mg/l in MW-5 to 1.86 mg/l in MW-3. The highest concentration of manganese was 1.86 mg/l in MW-3, with an average concentration of 0.38 mg/l and a median concentration of 0.1 mg/l.

5.3 Dross Investigation Results

The aluminum dross has been tested by numerous parties for various reasons. Additional testing was conducted to determine if the dross material was suitable for recycling.

5.3.1 Chempro Investigation

The investigation of aluminum dross conducted by Chempro is detailed in their report (Chempro, 1989) and summarized in the Data Summary Report (EMR, 1996). Chempro conducted dross testing beginning in August of 1988 with the collection of samples from test pits, borings and excavations. A comprehensive survey resulted in naming and volume estimates for each pile of dross. The bottom of the dross is contoured on Figure 5-7. Pile identification is shown in Figure 5-8.



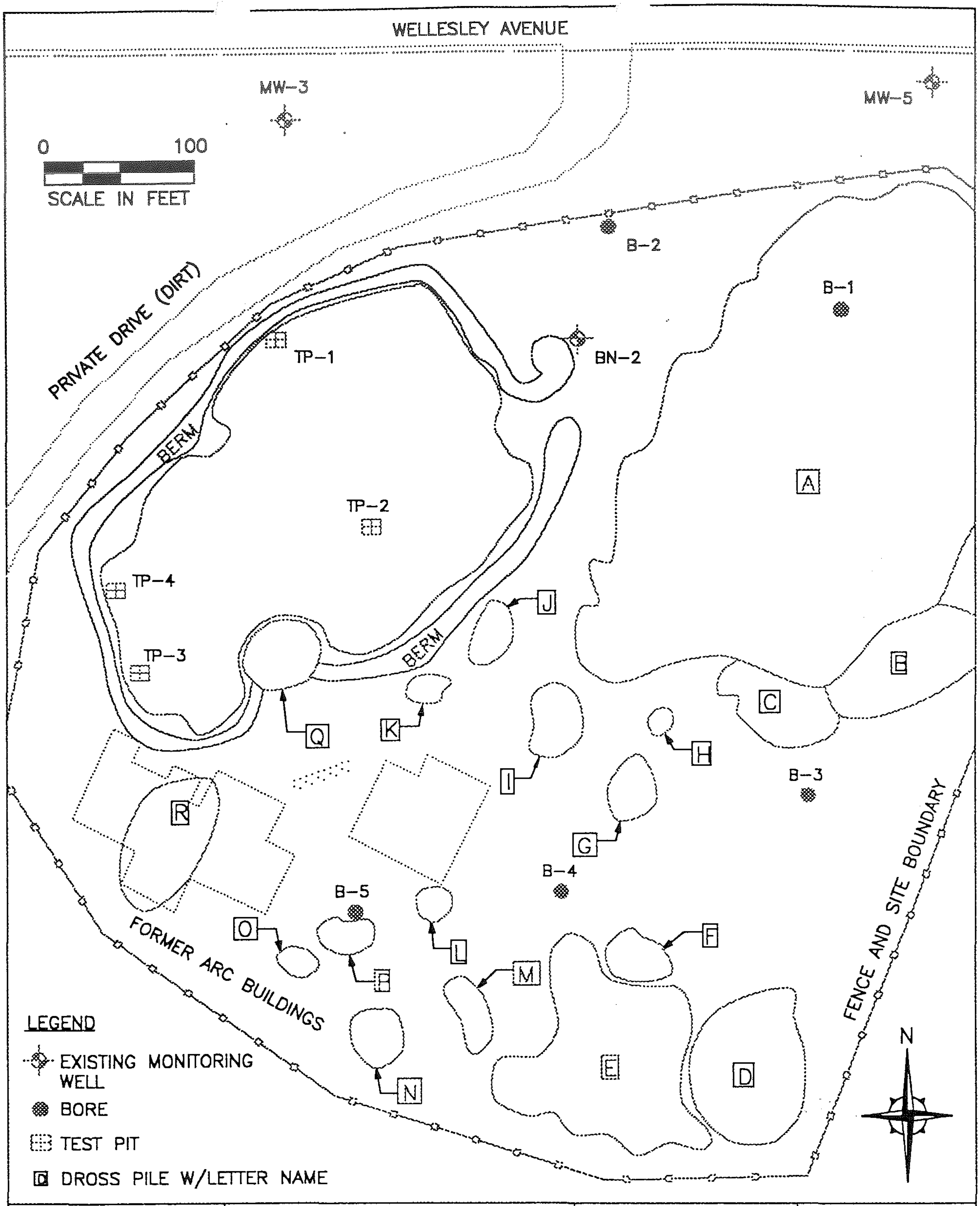
EMR INCORPORATED

Burlington Northern Santa Fe
Spokane, Washington

Contour Map of Bottom
of the Dross

Drawn by: I.D.S.
Checked By:
Project No.: 338
File Name: FIG_5-7.DWG
Revision No.: 1
Date: 2/16/99
Scale: as shown

FIGURE 5-7



EMR
INCORPORATED

Burlington Northern Santa Fe
Spokane, Washington

Dross Pile Identification Map

Drawn by: I.D.S.
Checked By:
Project No.: 338
File Name: FIG_5-8.DWG
Revision No.: 1
Date: 2/16/99
Scale: as shown

FIGURE 5-8

Samples were collected utilizing various techniques and submitted to Chempro's Tacoma plant where the samples were composited prior to analysis. The end results were 25 dross samples, eight of which were from dross pile A. The remainder was composed of one sample each from dross piles B through Q and the dross pit. Additionally, field samples collected from Pile A by borings, test pits and excavations were composited into another sample (number 26). The composited samples were analyzed by EPA method 300 for fluoride, chloride, nitrite, nitrate, phosphate and sulfate. The dross samples analyzed by Chempro (EPA method 300) contained chloride concentrations ranging from 56 to 57,000 mg/l, with an average of 13,634 mg/l.

Nineteen of the dross samples collected by Chempro were analyzed by TrecLen Laboratory by pulverizing each sample. Association of Analytical Chemists (AOAC) Method 18.030 was utilized by TrecLen in the analysis for chloride and EPA method 340.2 was utilized in the analysis for fluoride. Flame emissions were used in the analysis of sodium and potassium. Dross samples analyzed by TrecLan contained chloride concentrations ranging from 275 to 104,000 mg/l, with an average of 28,193 mg/l. These samples contained fluoride concentrations ranging from1.85 to 375 mg/l, with an average of 184 mg/l.

By pulverizing the dross samples, TrecLan broke any encapsulation of the salts from smelting along with dramatically increasing the surface area of the samples and therefore the solubility of the salts. Additionally, the use of deionized water in sample preparation further increased the analytical results, as the deionized water has a stronger affinity for chloride and fluoride ions. Generally, the analytical results obtained by TrecLan were maximized, and are not representative of the leachability of the salts from the dross under normal conditions. One dross sample was collected as a continuous dross sample for the low salt dross over a vertical extent of approximately 16 feet.

5.3.2 RI Investigation

As part of this RI, EMR collected dross samples for geotechnical and analytical testing during the soil boring and test pit field activities in December of 1998. Results are shown in Tables 5-5 and 5-6.

Five soil borings and four test pits were completed on the Hillyard Dross Site to determine the extent of chloride, nitrite, ammonia and metals impact at the Site. Locations are shown in Figure 4-1. Twenty seven soil samples were collected from soil borings and test pits at various depths at the dross-soil interface and within the soil below the dross for analysis of selected anions and metals. Additionally, fifteen geotechnical samples were collected for grain-size analysis.

TABLE 5-5

Results of Analyses in Test Pit Soil Samples
Hillyard Dross Site, Spokane, Washington

				Concentrations in milligrams per kilogram														
Location Identifier	Date Sampled	Depth (feet)	Material	Ammonia	Arsenic	Barium	Cadmium	Chloride	Chromium	Copper	Fluoride	Lead	Mercury	Nitrate-Nitrogen	Potassium	Selenium	Silver	Sodium
					EPA 6010A	EPA 6010A	EPA 6010A	EPA 300	EPA 6010A	EPA 6010A	EPA 300.0	EPA 6010A	EPA 7471A	EPS 300	EPA 6010A	EPA 6010A	EPA 6010A	EPA 6010A
TP1 Dross Interface	12/3/1998	1	Dross	ND	1.34	480	2.06	4.85	477	2840	74.5	80.8	0.00697	7.85	33800	ND	ND	3290
TP 1 Soil Interface	12/3/1998	2	Soil	ND	10.1	46.7	ND	ND	11.3	26.4	2.79	ND	0.005298	ND	3530	ND	ND	308
TP1 Soil 1 foot	12/3/1998	3	Soil	ND	2.46	42.1	ND	ND	7.98	30.3	4.36	12.6	ND	1.59	3130	ND	ND	351
TP1 Soil 5 foot	12/3/1998	5	Soil	ND	12.9	44.4	ND	ND	9.41	17.5	ND	4.46	ND	3.72	3410.0	ND	ND	328.0
TP2 Dross Interface	12/3/1998	1	Dross	ND	ND	107	ND	22.4	295	2370	223	ND	0.0163	6.03	8220	ND	ND	19100
TP2 Soil 1 foot	12/3/1998	3	Soil	ND	10.3	60.6	0.229	ND	49.3	231	71.6	15.8	ND	ND	5150	ND	ND	1230
TP2 Soil 5 foot	12/3/1998	5	Soil	ND	ND	37.8	ND	3.64	9.33	18.9	13.6	ND	0.00729	ND	2530	ND	ND	ND
TP3 Dross 20 inches	12/3/1998	1.5	Dross	ND	19.9	33.6	ND	56.5	499	4520	423	6.59	ND	32	1770	ND	ND	3970
TP3 Soil 1 foot	12/3/1998	2	Soil	ND	ND	31.4	0.388	9.53	8.83	32.3	24.5	12.2	0.00416	5.29	2530	0.514	ND	321
TP3 Soil 5 foot	12/3/1998	7	Soil	ND	ND	6.36	ND	112	4.71	15.9	88.2	2.63	0.00564	4.94	2340	6.36	ND	220
TP4 Dross 18 inches	12/3/1998	1.5	Dross	ND	6.45	65.4	ND	2.90	432	3720	370	6.28	0.014	1.05	4750	ND	ND	8680
TP4 Soil 1 foot	12/3/1998	2.5	Soil	ND	22.2	64.3	ND	ND	11.5	19.3	45	4.95	ND	2.09	5120	ND	ND	668
TP4 Soil 5 foot	12/3/1998	6.5	Soil	ND	7.23	58.2	ND	3.08	7.07	14.5	25.1	2.83	0.012	3.39	3250	ND	ND	332
DETECTION LEVEL				2.00	2.07	0.313	0.214	1	0.195	0.354	2.00	1.59	0.004	1.00	22.3	0.5	2.26	1.95
AVERAGE DROSS				NA	6.92	172	0.515	21.7	425.75	3363	273	23.4	0.00932	11.7	12135	0.00	0.00	8760
AVERAGE SOIL 1 foot				NA	8.74	49.6	0.154	2.383	19.4025	78.2	36.4	11.4	0.00104	2.24	3983	0.129	0.00	643
AVERAGE SOIL 5 foot				NA	5.03	36.7	ND	29.7	7.63	16.7	31.7	2.48	0.00623	3.01	2883	1.59	0.00	220
MAXIMUM DROSS				NA	19.9	480	2.06	56.5	499.00	4520	423	80.8	0.016	32.0	33800	0.00	0.00	19100
MAXIMUM SOIL 1 foot				NA	22.2	64.3	0.39	9.53	49.3	231	71.6	15.8	0.004	5.29	5150	0.51	0.00	1230
MAXIMUM SOIL 5 foot				NA	12.9	58.2	ND	112	9.41	18.90	88.2	4.46	0.012	4.94	3410	6.36	0.00	332

ND = Not detected above detection level

TABLE 5-6

Results of Analyses in Boring Soil Samples
Hillyard Dross Site, Spokane, Washington

				Concentrations in milligrams per kilogram											
Location Identifier	Date Sampled	Depth (feet)	Material	Arsenic	Barium	Cadmium	Chloride	Chromium	Copper	Lead	Potassium	Selenium	Silver	Sodium	Mercury
				EPA 6010A	EPA 6010A	EPA 6010A	EPA 300	EPA 6010A	EPA 6010A	EPA 6010A	EPA 6010A	EPA 6010A	EPA 6010A	EPA 6010A	EPA 7471A
B1-9	12/14/1998	9	DROSS	1.51	25.1	.356	21.9	112	629	38.3	NA	5.3	ND	19100	0.00971
B1-23	12/14/1998	23	SOIL	8.3	108	0.388	17500	12	441	23.4	24300	ND	ND	25900	ND
B1-27	12/14/1998	27	SOIL	7.31	52.4	ND	13700	11.9	194	12.8	15900	ND	ND	14800	0.0344
B2-1	12/15/1998	1	SOIL	17.1	81.9	1.46	34.4	10.4	18.6	30.0	1110	ND	ND	374	.02
B2-5	12/15/1998	5	SOIL	7.24	149	ND	49	10	16.6	13	1720	8.79	ND	287	0.00643
B3-1	12/15/1998	1	DROSS	1.01	45.8	ND	43.4	138	1220	38.6	NA	3.13	ND	NA	0.0122
B3-3	12/15/1998	3	SOIL	10.2	68.3	ND	14.7	8.34	29.9	14.3	3040	18.2	ND	1160	ND
B3-7	12/15/1998	7	SOIL	6	43.3	ND	12.5	6.25	16.2	16.6	2110	ND	ND	800	0.00487
B4-S	12/15/1998	0.5	DROSS	5.75	24.2	ND	37.6	173	2420	25.8	NA	25.3	ND	NA	0.00939
B4-2	12/15/1998	2	SOIL	22.2	110	ND	51.7	17.8	80.6	17.8	8900	ND	ND	3320	0.0235
B4-5	12/15/1998	5	SOIL	7	54.2	ND	43.1	14	42.9	16	4270	ND	ND	933	0.0295
B5-S	12/15/1998	0.5	DROSS	1.34	35.4	0.231	35.6	149	1460	7.51	NA	8.74	ND	NA	0.00914
B5-2	12/15/1998	2	SOIL	4.83	128	0.339	37.5	12.9	34.7	485	8910	ND	ND	892	0.0192
B5-5	12/15/1998	5	SOIL	4.71	71.5	0.254	39.1	13.2	18.4	147.8	5650	ND	5.27	606	ND
DETECTION LEVEL				2.07	0.313	0.214	1.0	0.195	0.354	1.59	22.3	2.32	2.26	1.95	0.5

ND = Not detected above detection level
NA = Not Analyzed

Soil boring B-1 was completed on top of Dross Pile A. Twenty two feet of aluminum dross was encountered during drilling of this soil boring. Soil boring B-1 was drilled to a depth of 30 feet with two geotechnical samples collected and three analytical samples collected. The geotechnical samples were collected from depths of 7 feet (within the dross) and 29 feet (approximately 8 feet below the dross-soil interface). The analytical samples were collected from depths of 9 feet (within the dross), 23 feet (immediately below the dross-soil interface) and 29 feet (at the bottom of the boring).

Soil boring B-2 was completed northeast of monitoring well BN-2, near the west boundary of Dross Pile A. No aluminum dross was encountered during drilling of this soil boring. Soil boring B-2 was drilled to a depth of 5 feet with one geotechnical sample and two analytical samples collected. The geotechnical sample was collected from the surface. The analytical samples were collected at depths of 1 foot (within soil) and 5 feet (at the bottom of the boring).

Soil boring B-3 was completed south of Dross Pile A and northeast of Dross Pile D. Two feet of aluminum dross was encountered during drilling of this soil boring. Soil boring B-3 was drilled to a depth of 7.5 feet with two geotechnical samples and three analytical samples collected. The geotechnical samples were collected from depths of 1 foot (within the dross) and 3 feet (immediately below the dross-soil interface). The analytical samples were collected from depths of 1 foot (within the dross), 3 feet (immediately below the dross-soil interface) and 7 feet (from the bottom of the soil boring).

Soil boring B-4 was completed in the central portion of the dross area, east of Dross Pile L. Approximately 0.5 feet of aluminum dross was encountered during drilling of this soil boring. Soil boring B-4 was drilled to a depth of 7.5 feet with two geotechnical samples and three analytical samples collected. The geotechnical samples were collected from the surface (of the dross) and from a depth of 4 feet (within the soil). The analytical samples were collected from the surface (of the dross) and at depths of 2 feet (below the dross) and 5 feet (in the soil).

Soil boring B-5 was completed in the southwest portion of the Site south of the building slab, between Dross Piles R and O. Approximately 0.5 feet of aluminum dross was encountered during drilling of this soil boring. Soil boring B-5 was drilled to a depth of 7 feet with two geotechnical samples and three analytical samples collected. The geotechnical samples were collected from the surface (of the dross) and at a depth of 4 feet (in the soil). The analytical samples were collected from the surface (of the dross) and depths of 2 feet (below the dross) and 5 feet (within the soil).

Four test pits were excavated by use of a backhoe to depths of 7 feet in order to expose the dross-soil interface and the soil below the dross. All four test pits were located within the Dross Pit area of the Site.

Test pit TP-1 was completed in the north end of the east Dross Pit to a depth of 7 feet. Approximately 1.5 feet of aluminum dross was encountered in this test pit. One geotechnical sample and four analytical samples were collected. The geotechnical sample was collected from a depth of 0.5 feet (within the dross). The analytical samples were collected from depths of 1.5 feet (at the dross interface), 1.5 feet (at the soil interface), 3 feet (one foot below the dross) and 6.5 feet (five feet below the dross).

Test pit TP-2 was completed in the south end of the east Dross Pit and was completed to a depth of 7 feet. Approximately 1.5 feet of aluminum dross was encountered in this test pit. Four analytical samples were collected from this test pit, at depths of 1.5 feet (at the dross interface), 1.5 (at the soil interface), 3 feet (one foot below the dross), and at 6.5 feet (five feet below the dross).

Test pit TP-3 was completed in the south end of the west Dross Pit and was completed to a depth of 7 feet. Approximately two feet of aluminum dross was encountered in this test pit. Four analytical samples were collected from this test pit at depths of 2 feet (at the dross interface), 2 feet (at the soil interface), 3 feet (one foot below the dross) and 6 feet (five feet below the dross).

Test pit TP-4 was completed in the west end of the west Dross Pit and was completed to a depth of 7 feet. Approximately 1.5 feet of aluminum dross was encountered in this test pit. Four analytical samples were collected from this test pit at depths of 1.5 feet (at the dross interface), 1.5 feet (at the soil interface),2.5 feet (one foot below the dross) and 6.5 feet (five feet below the dross).

5.3.2.1 Geotechnical Results

Geotechnical results indicate the dross generally has a similar grain-size distribution as the native sands and gravels; however, the gray dross sample collected from test pit TP-1 contained a small amount of fines. Ten percent of the sample passed the 0.05 mm sieve into the silt range of particle size, and 2 percent passing the 0.001 mm sieve into the clay range of particle size. The only other sample with material passing the 0.05 mm sieve was the sample from monitoring well MW-4 (175 feet), which had 14 percent passing. The MW-4 sample also had 1 percent passing the 0.001 mm sieve. All other samples had 100 percent of the sample caught by the 0.5 mm sieve, making all other soil samples varying gradations of sand with little or no fines.

Geotechnical analysis indicated the dross samples contained an average of 31 percent moisture. The soil samples averaged 5.8 percent moisture with the exception of MW-4 (175 feet) which contained 27.4 percent moisture, which is likely due to the greater percent of fines within the sample than in the other soil samples.

5.3.2.2 Chemical Results

Chemical analyses confirm that elevated concentrations of ammonia, chloride, fluoride, and nitrate are present in aluminum dross. In addition, results show that elevated concentrations of some RCRA 8 metals (barium, chromium) and copper are present in the aluminum dross. Of these metals and the other metals in the dross, leachable concentrations of concern were not detected in TCLP analyses or a 60-year leachability simulation test (EMR, 1996).

Additional TCLP analyses for chloride, potassium, sodium and ammonia were completed for the RI. Results are shown in Table 5-7 and Figure 5-12. The average leachable concentration of chloride from eight samples was 5.28 mg/l. Average concentrations for potassium and sodium were 288 and 184 mg/l, respectively.

5.4 Soil Investigation Results

A soil sample was collected one foot beneath the aluminum dross and five feet below the dross at the five boring and four test pit locations installed during the RI. The average concentrations from these samples are shown on the bottom of Tables 5-5 through 5-7. Results are shown graphically in Figures 5-9 through 5-11.

In general, concentrations decrease significantly in the soil column from the concentrations contained in aluminum dross. The only exception is chloride, which is present on average at higher concentrations in soil five feet below the dross. This, along with the relatively low TCLP result for chloride in dross, suggests that most of the chloride in the dross has previously been leached.

TABLE 5-7

Results of TCLP Analyses of Test Pit Soil Samples
Hillyard Dross Site, Spokane, Washington

				Concentrations in milligrams per liter			
Location Identifier	Date Sampled	Depth (feet)	Material	Potassium	Sodium	Chloride	Ammonia
				1311/6010/7000	1311/6010/7000	EPA 300.0	EPA 350.3
TP1 Dross	12/3/1998	1	Dross	465	31.4	ND	ND
TP 1 Soil Interface	12/3/1998	2	Soil	27.1	15.8	ND	1.27
TP1 Soil 1 foot	12/3/1998	3	Soil	29.4	18.4	ND	1.39
TP1 Soil 5 foot	12/3/1998	5	Soil	26.1	14.3	ND	1.46
TP2 Dross	12/3/1998	1	Dross	131	150	7.58	ND
TP2 Soil 1 foot	12/3/1998	3	Soil	33.3	38.3	ND	ND
TP2 Soil 5 foot	12/3/1998	5	Soil	24.9	16.4	ND	ND
TP3 Dross	12/3/1998	1.5	Dross	249	99.1	6.76	ND
TP3 Soil 1 foot	12/3/1998	2	Soil	23.9	17	ND	ND
TP3 Soil 5 foot	12/3/1998	7	Soil	30	18.3	8.26	ND
TP4 Dross	12/3/1998	1.5	Dross	656	99.7	ND	ND
TP4 Soil 1 foot	12/3/1998	2.5	Soil	52.4	26.7	5.2	ND
TP4 Soil 5 foot	12/3/1998	6.5	Soil	32.7	20.9	6.08	0.156
B1-9	12/3/1998	9	Dross	327	535	7.16	NA
B3-1	12/3/1998	1	Dross	114	147	7.10	NA
B4-S	12/3/1998	0.5	Dross	277	334	6.64	NA
B5-S	12/3/1998	0.5	Dross	86.2	78.7	6.96	NA
DETECTION LEVEL				0.466	0.0781	2.00	0.1
AVERAGE DROSS				288	184	5.28	ND
AVERAGE SOIL 1 foot				34.8	25.1	1.30	0.35
AVERAGE SOIL 5 foot				28.4	17.5	7.17	0.404

FIGURE 5-9

Average Concentration of Selected Parameters with Depth
BNSF Hillyard Dross Site, Spokane, Washington

g

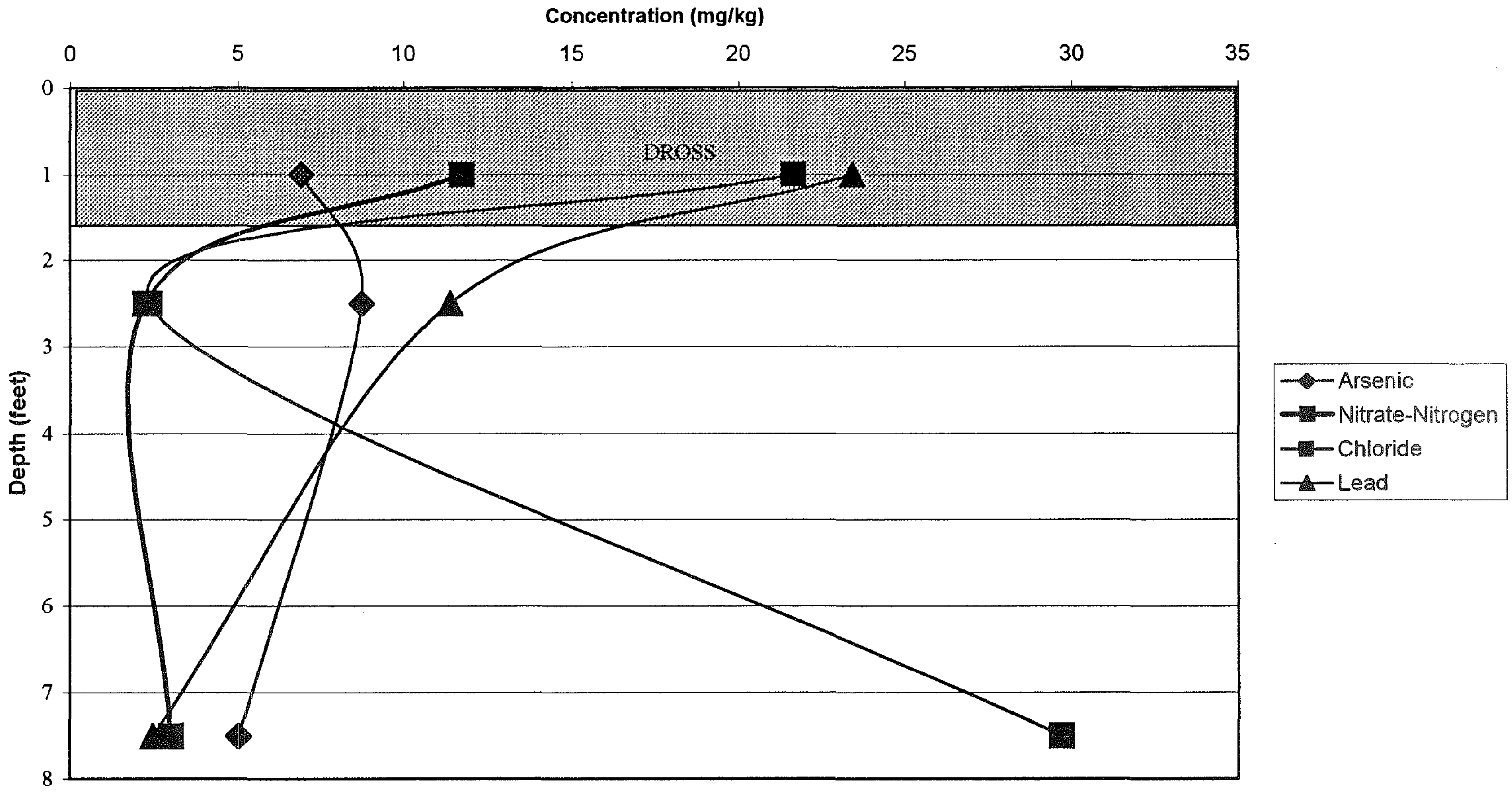


FIGURE 5-10

Average Concentration of Selected Parameters with Depth
BNSF Hillyard Dross Site, Spokane, Washington

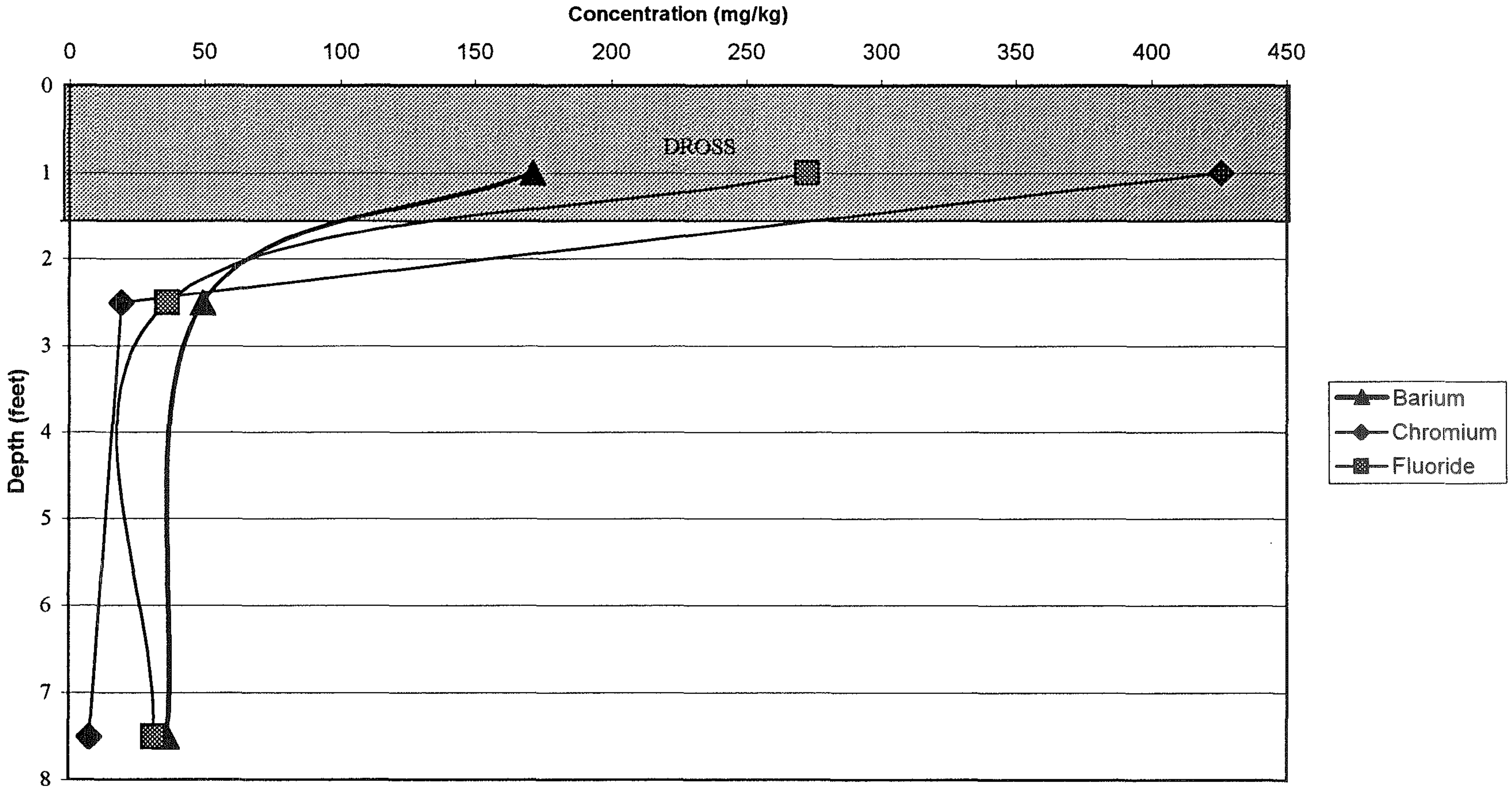


FIGURE 5-11

Average Concentration of Selected Parameters with Depth
BNSF Hillyard Dross Site, Spokane, Washington

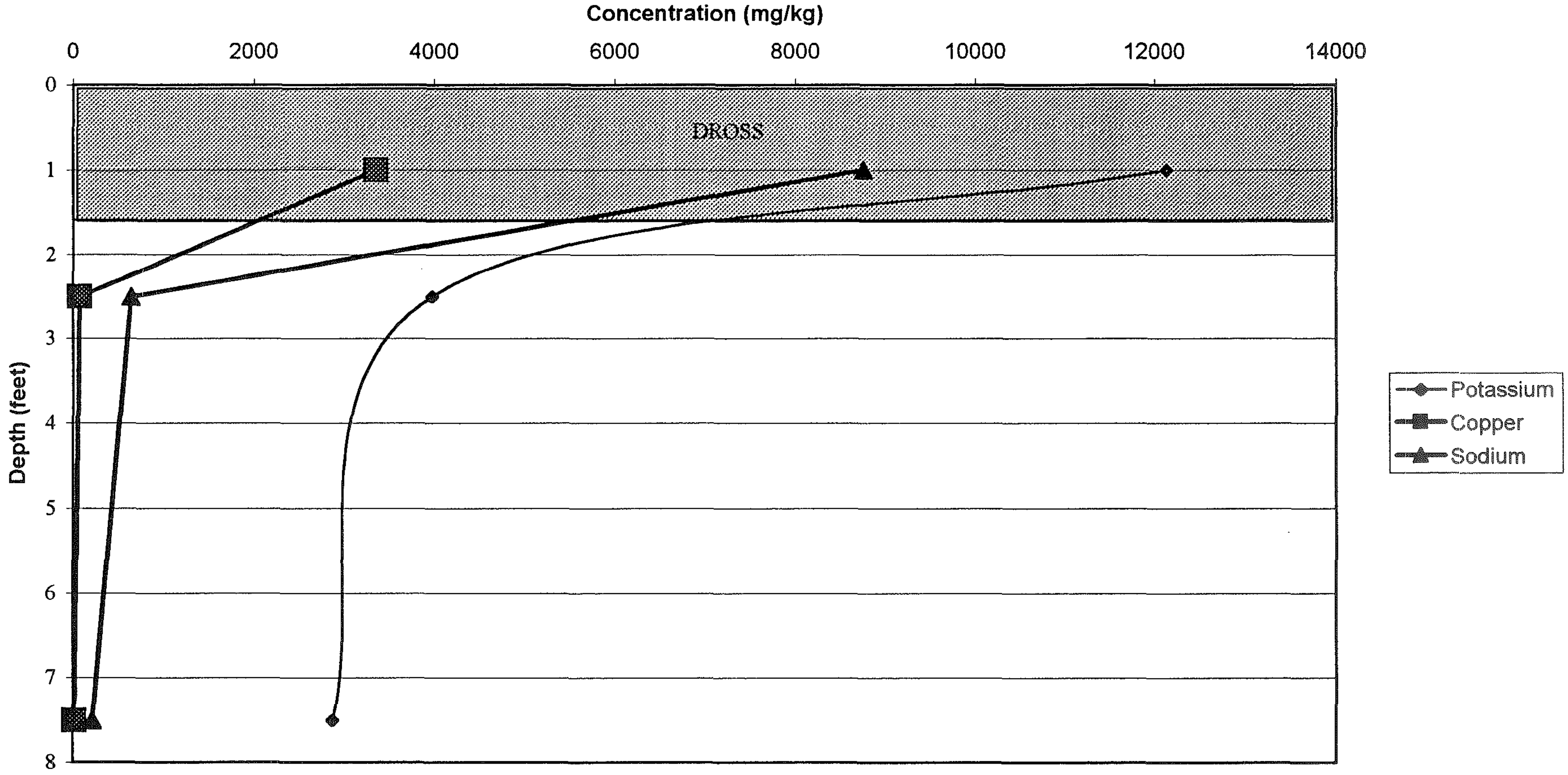
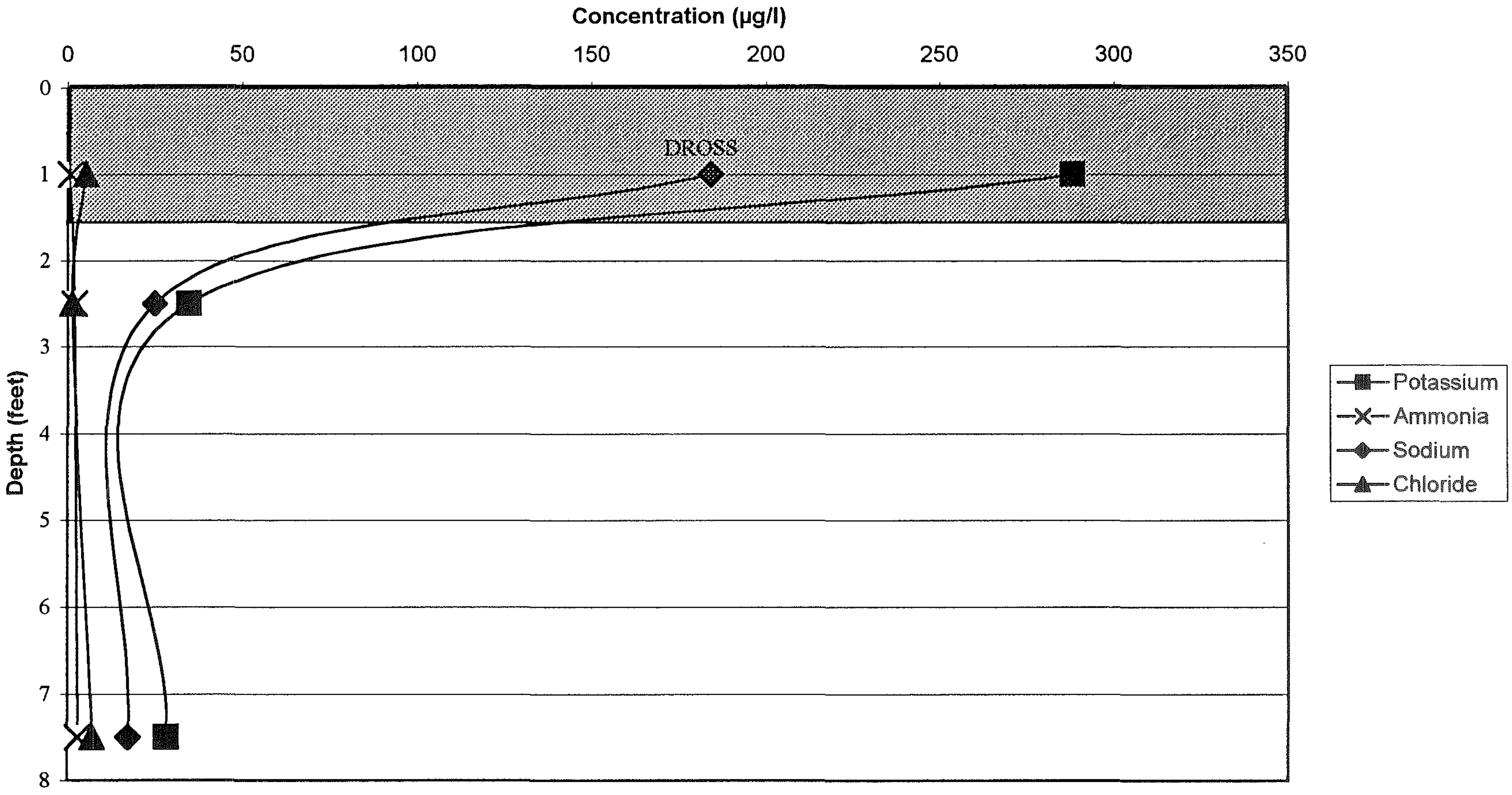


FIGURE 5-12

Average Concentration of TCLP Analyses with Depth
BNSF Hillyard Dross Site, Spokane, Washington



SECTION 6.0

CONTAMINANT FATE AND TRANSPORT

This section summarizes the environmental fate and transport for those compounds identified in Hillyard Dross Site soils or ground-water. Potential routes of migration at the Hillyard Dross Site include:

- infiltration of rainwater through contaminated soil;
- ground-water transport;
- surface water transport; and,
- air transport.

Current potential receptors include on-site workers or visitors and ecological receptors. Future or hypothetical potential receptors include users of ground-water as drinking water and on-site residences.

The geochemical and physical relationships that control the distribution of contaminants in soil and ground-water are evaluated by considering the following:

- Properties of the contaminants of concern;
- Properties of the soil and aquifer materials;
- Physical processes of infiltration and ground-water flow; and,
- Oxidation-reduction (redox) controls on chemical contaminant persistence.

The characteristics of the contaminants of concern are discussed in Section 6.1. Physical processes that influence the fate and transport of contaminants of concern along the important pathways at the Hillyard Dross Site are described in Section 6.2. Routes of migration are discussed in Section 6.3.

6.1 Properties of Contaminants of Concern

Metals, saline compounds and nitrogen compounds have been detected in soil or ground-water at the Site. Properties of these chemicals are discussed below.

6.1.1 Metals

Arsenic. Arsenic is an inorganic chemical subject to complex oxidation/reduction, precipitation, dissolution and sorption reactions. A common concentration range from 1 to 50 milligrams per kilogram (mg/kg) has been reported for arsenic in soils (Lindsay, 1979); a regional study detected concentrations from 1 to 10 mg/kg with a 90th percentile ranking value of 9 mg/kg (San Juan, 1994).

Arsenic oxides in soil are moderately soluble and readily transported in natural waters in dissolved form (Hem, 1970). Upon dissolution, anionic complexes of arsenate (AsO_4^{-3}) are formed. In oxidizing environments, arsenic is present in natural waters in its pentavalent form as anion complexes $H_2AsO_4^-$ and $HAsO_4^{-2}$. For pH ranges below 7.2, $H_2AsO_4^-$ is the predominant species, whereas $HAsO_4^{-2}$ predominates for more alkaline waters (i.e. pH > 7.2) (Hem, 1970). In reducing aqueous environments, $HAsO_2$ may be present.

The solubility of arsenic in subsurface waters is controlled primarily by the precipitation of arsenate solids, sorption onto immobile solids, and by coprecipitation with other metals (Hem, 1970). The latter process could be significant at inhibiting arsenic mobility in natural waters at the Hillyard Dross Site, as pentavalent arsenic forms insoluble salts with heavy metals including cadmium, copper, lead, and zinc (USEPA, 1985). For example, arsenic solubility in the presence of major cations such as calcium and magnesium is on the order of 30 mg/l, whereas a copper concentration of only 0.065 mg/l limits the equilibrium solubility of arsenic by several orders of magnitude to less than 0.5 mg/l. Arsenate sorption by iron hydroxides or other inorganic or organic surfaces also limits arsenic solubility (Hem, 1970).

In general, arsenic is bound in soil minerals and compounds by insoluble complexes and sorption onto clays, hydroxides and organic matter. Arsenate, which is predominant in aerobic soils, is bound as slightly soluble salts of iron and aluminum and more soluble salts of calcium, sodium and magnesium. The availability of arsenic for leaching depends on the amount of arsenic, the amount of precipitation, and the type of soil.

Arsenic can be mobile under other conditions such as anaerobic conditions, and high or low pH. These conditions are not present at the site, however, nor are they likely to become present in the future.

Barium. Barium is abundant in natural soil and ground-water. The chief sources of barium are the minerals barite (barium sulfate) and witherite (barium carbonate). Barium metal is produced in limited quantities by aluminum reduction of barium oxide in a retort and is little used by industry. Barium occurs naturally in most water at concentrations ranging from 2 to 340 μg/l.

Cadmium. Cadmium is a relatively mobile heavy metal that is transported in the aqueous environment in solution as a hydrated cation or as an inorganic or organic compound. A typical cadmium concentration range reported for soils is 0.01 to 0.7 mg/kg (Lindsay,1979); Dragun (1988) reports an extreme range from 0.01 to 45 mg/kg.

Cadmium is often present in soils and waters as the divalent cation (Lindsay, f79). Compared to other heavy metals, cadmium is relatively mobile in natural waters. In solution, cadmium is primarily the divalent cation or an oxide. $CdOH^+$ and $Cd(OH)^2$ are important secondary species at pH values greater than 7.5 (Lindsay, 1979). Cadmium solubility is largely affected by pH and not affected by redox potential. Cadmium is generally more soluble and therefore is more mobile as pH decrease. The range of aqueous solubility for cadmium is approximately 0.1 to 1.0 mg/l.

The limits on cadmium solubility depend on the presence of inorganic or organic ligands present. In most cases, organic substances (i.e. humic substances) can account for the majority of cadmium complexes. The second most important complexing ligand is probably carbonate followed by hydroxide. Cadmium sulphate minerals are generally highly soluble and are unlikely to form in soils. However, under reducing conditions, in the presence of sulfide, insoluble sulfide precipitates could form (USEPA, 1979). Sorption of cadmium by clays and organic matter, coprecipitation with hydrous iron, aluminum and manganese oxides, and isomorphous substitution in carbonate minerals are all mechanisms for the removal of cadmium from natural waters.

Chromium. Chromium exists in two possible oxidation states in soil: the trivalent chromium present in reducing environments is relatively immobile; the hexavalent ion is present in oxidizing environments and is mobile. Trivalent chromium is relatively more prevalent and less toxic than hexavalent chromium.

A typical chromium concentration in western United States soils is 3 to 2,000 mg/kg (Shacklette and Boerngen, 1984); the mean concentration is 41 mg/kg.

Under normal soil and redox conditions hexavalent chromium is reduced to trivalent chromium by soil organic matter. Trivalent chromium is readily adsorbed by soils. Sorption by clays and organic matter, and nonspecific adsorption by iron and aluminum oxides, effectively removes chromium from most natural waters (Lindsay, 1979).

Copper. Copper is a common metallic element that is primarily associated with various sulfide minerals. Typical copper concentrations in soils range from 2 to 100 mg/kg (Lindsay, 1979); extreme copper concentration ranges for soils are from 0.1 to 14,000 mg/kg (Dragun, 1988). Copper is generally present in oxidizing soils and waters as a divalent cation (Cu^{+2}) (U.S. EPA,1985). Under reducing conditions, the monovalent cation (Cu^{+1}) is present. Copper is strongly bound to inorganic and organic materials in soils and water and is nearly insoluble (Lindsay, 1979). The solubility of dissolved copper species is largely dependent on pH and redox conditions. Hem (1970) reports that in oxidizing environments copper solubility ranges from approximately 0.01 to 0.1 mg/l between a pH of 7 and 8. In general, copper solubility increases as pH decreases. Copper solubility decreases in reducing environments, especially when reduced sulfur species are present (Hem, 1970).

In natural waters, the cupric ion is highly reactive and forms strong complexes and precipitates with organic and inorganic constituents. As with cadmium, copper forms strong complexes with organic ligands. Copper-organic ligand complexes increase the solubility of copper. In the absence of abundant organic material, a majority of copper exists as a carbonate complex. Copper solubility is also controlled coprecipitation/-sorption by hydrous iron and manganese oxides, ion exchange with carbonate minerals, and adsorption to clays and other minerals. However, the sorption efficiency of clays and other mineral solids decreases with an increasing organic content (US EPA, 1985).

Lead. Lead is a relatively immobile element. Typical lead concentrations in soils range from 2 to 200 mg/kg (Lindsay, 1979); extreme lead concentration ranges for soils are from 0.1 to 3,000 mg/kg (Dragun, 1988).

Natural lead minerals (i.e. carbonates, sulfates, and sulfides) have low solubilities in water and are generally not very mobile in natural waters because of the tendency to be adsorbed or to precipitate from solution (USEPA, 1979). In an aqueous environment, Pb_2^+ is expected to be the primary species at a pH less than about 7. At a pH from 7 to 9, $PbCO_3$ is the primary species. Under oxidizing conditions, lead carbonates and sulfates (i.e. cerrusite [$PbCO_3$] and anglesite [$PbSO_4$]) will to a large extent limit lead solubility. In the presence of reduced sulfur, galena (PbS) will greatly limit the solubility of lead due to its extremely low solubility.

Hem (1970) suggests that in most natural waters at equilibrium, lead solubility (as Pb_2^+) is limited to about 0.02 mg/l. As with the other metals, lead solubility is pH dependent and rapidly increases with an increase or decrease in pH. Also, as with cadmium, lead readily forms complexes with organic ligands, which can increase lead solubility (USEPA, 1985).

Potassium. Potassium is an abundant element found most commonly in silicate rocks. The alkali metal usually forms potassium salts that are generally highly soluble, but the ion is integral to clay and mineral structures and is not typically found at high concentrations in water. Concentration is typically less than 10 mg/l.

Selenium. Selenium is usually found as a sulfide ore of the heavy metals. Natural weathering of rocks and soils provide the major source of selenium to soil and ground-water. Selenium solubility varies from greater than forty percent by weight for the sodium selenates to between 16,000 and 33,000 µg/l for the silver selenates.

Sodium. Sodium is an abundant alkali metal found in evaporite sediments. Sodium dissolves readily in water and does not participate in redox or hydration processes. Adsorption to clay or mineral surface is the only important process limiting sodium concentrations in water.

Zinc. Zinc is one of the more mobile metallic elements in water. Typical zinc concentrations in soils range from 10 to 300 mg/kg (Lindsay,1979); extreme zinc concentration ranges for soils are from 3 to 10,000 mg/kg (Dragun, 1988).

The solubility of zinc is similar to cadmium; however, zinc is generally more abundant than cadmium in soils. Zinc is slightly soluble under neutral to alkaline pH conditions (Lindsay, 1979). However, zinc is more soluble and therefore more mobile than copper. Under oxidizing conditions, zinc is present as the divalent cation.

6.1.2 Other Inorganic Compounds

Chloride. Chloride is abundant in soil and ground-water. Sources of chloride ion probably include release of evaporite minerals from fluid inclusions in carbonates, and concentration by evaporation of recharging water in the unsaturated zone (Feth, 1981). An anthropogenic source of chloride at the Site may include de-icing road salts. In dilute natural waters, chloride does not participate in oxidation-reduction reactions and does not complex with other ions or form low solubility salts. Chloride transport is mainly from physical processes.

Fluoride Concentrations of fluoride in natural waters are typically low; usually less than 1 mg/l. Sources of fluoride include igneous and sedimentary rock minerals. The free fluoride ion is predominant in neutral pH. Strong fluoride complexes with aluminum, beryllium and ferric iron are possible (Hem, 1970).

Nitrate and Ammonia Nitrogen occurs in water in cationic form as ammonia, and in anionic form as nitrate or nitrite. Nitrogen concentrations attributable to natural sources are typically less than 1 mg/l as nitrate and less than 0.05 mg/l as ammonia (Hallberg, 1989). Ammonia is strongly adsorbed onto clay and mineral surfaces. Nitrate and nitrite, however, are stable under natural conditions and are transported by physical processes in ground-water and surface water. Sources of nitrogen are fertilizers and septic tanks (Hem, 1970).

6.2 Physical Processes

The contaminants of concern are subjected to several physical processes including advection, dispersion, and molecular diffusion. Advection is the migration of a substance due to the bulk movement of water. Advection tends to move chemicals in the direction of flow. Hydrodynamic dispersion, which consists of both mechanical dispersion and molecular diffusion, dilutes concentrations primarily in the direction of flow. Mechanical dispersion of ground-water plumes is caused primarily by the movement of ground water around the soil particles that are in the flow path. These particles divert the forward motion of ground water and tend to disperse substances. Molecular diffusion, caused by intermolecular collisions, also causes chemicals to dilute in ground water. As contaminants of concern migrate, therefore, these physical processes, in combination with the chemical and biological processes, retard and dilute contaminants of concern concentrations in water along the infiltration and ground-water pathways.

Infiltrating rainwater comes into contact with contaminated soil at the Site. For pathways activated by contact of water with contaminated soil (e.g., overland runoff and infiltration), the migration rate is controlled by the availability of water, the time of contact between the water and contaminants, the rate of evaporation, the permeability and wetting characteristics of soil and the Vadose Zone, and the solubility of the contaminants of concern. The relative partitioning of contaminants of concern between the dissolved and particulate phases is controlled by a complex combination of precipitation, dissolution and sorption reactions.

Sorption is an important process affecting metals migration for infiltrating rainwater and ground water. Sorption can be thought of as an equilibrium-partitioning process between the soil and water. For relatively greater sorbed or residual concentrations in soil, correspondingly greater concentrations in water are related by the K_{oc} factor.

The soil-water partition coefficient (K_d) is the ratio of contaminant concentration in soil to concentration in water at equilibrium. Partitioning between soil and water strongly influences the fate and transport of contaminants, and K_d is a key parameter for predicting mobility in such systems. K_ds may be derived experimentally or estimated from K_{oc} by the following relationship, where K_{oc} is either measured or calculated.

$$K_d = f_{OC} \times K_{oc}$$

K_ds for metals are dependent on several parameters (e.g., pH and redox potential [Eh]) and for a given metal may vary over several orders of magnitude depending on site-specific conditions.

Metals exist within various forms including: primary and secondary minerals, chemical compounds, adsorbed ions, colloid-bound ions, ion complexes, and freely dissolved ions. Properties of the soil that affect the fate of the substances of concern include pH, redox potential, particle size, mineralogy, cation exchange capacity, concentration of various cations and anions, organic carbon concentration, alkalinity, and moisture content.

One of the controlling factors that determine the partitioning of metals is pH. Metals can be fixed by chemical reaction within the structure or on the surface of a mineral or compound. Adsorption is the removal of an ion or compound from water by accumulation on the surface of a solid. Most ions exist in liquid in more than one molecular or ionic form, and the fate and migration rate varies depending on the form for each of the metals of concern.

The pH of a soil is the negative logarithm of the hydrogen (H^+) ion concentration in the soil moisture. The hydrogen ion is in dynamic equilibrium with the predominantly negatively charged surfaces of the soil particles. Hydrogen ions are strongly attracted to the surface negative charges, and they have the ability to replace other ions. Cationic metals, such as copper, lead, and zinc compete with the hydrogen ion for adsorption sites on solids. At low pH values the hydrogen ion preferentially gains the Site. As pH increases, reflecting the decrease in hydrogen ion in solution, additional adsorption sites are available for cationic metals and a corresponding decrease in metals concentrations in solution occurs. In general, the opposite is the case for anionic metals such as arsenic which are commonly present as anions of weak acids. Their solubility generally decreases with decreasing pH.

6.3 Contaminant Migration

The migration pathways discussed in the previous sections have either been documented or are suspected to be contributing to the transport of contaminants of concern. The primary release mechanism includes infiltration of rainwater. The principle routes of migration include the following:

- Transport of contaminant compounds in solution or via sediment transport from surface soils via surface water runoff;
- Vertical transport of contaminant compounds from the Vadose Zone to ground water via leaching; and,
- Horizontal and vertical transport of contaminant compounds in ground water via ground-water flow.

The primary potential migration pathways for contaminant movement at the Hillyard Dross Site are leaching of soil contaminants to ground water and transport of contaminants downgradient of the source area by ground-water flow. Other pathways are important to consider further in assessing risk to human health and are discussed further in Section 8.0.

6.3.1 Estimate of Percolation

The vadose zone at the Site is approximately 182 feet thick. Moisture content is low; laboratory values of shallow soil samples ranged 6 to 11 percent. The field capacity of the shallow soil is probably around 10 percent, and the wilting point is probably less than 6 percent. The upper few feet of soil contains silt and a trace of clay minerals that are available for adsorption of metals and other inorganics. The lithology of soil and aquifer materials is described in Section 5.1.

Below the upper few feet of soil, lithology is primarily sand and gravel made up predominantly of silica and feldspathic minerals. Organic content is very low. Percolation of water through the dross and contaminated soil to ground water can be inferred from chloride and nitrate in ground water, but has not been observed for metals at the Site. Based on the profiles of metals concentrations with depth within the soil profile, the extent of metals contamination is constrained to dross itself and the upper ten feet of soil (see Section 5.4).

Hydraulic parameters essential to estimating moisture movement through the vadose zone include precipitation, pan evaporation, barometric pressure, soil profile moisture characteristic curves, initial soil moisture conditions, and the spatial variation of soil type and continuity. The EPA HELP model is used to estimate the rate of recharge to the aquifer at the Hillyard Dross Site (Schroeder et al., 1994). The HELP model integrates all of these factors and uses synthetic data generated from climatological information for Spokane.

Rainfall for the HELP model simulation averages 16.7 inches per year. Results are shown in Table 6-1. The average simulated percolation to the aquifer was 0.011 inches per year assuming a two percent slope, which is the minimum allowed by the HELP model. A conservative interpretation of model results would combine the percolation plus runoff amounts for an estimate of amount of percolation to the aquifer. This interpretation is justified at the Site because approximately half of the site is a pit, and runoff does not occur over that area. The amount of runoff plus percolation simulated by the model is 3.65 inches per year, or for the two-acre Site approximately 200,000 gallons (26,533 cubic feet). HELP model output is attached as Appendix G.

6.3.2 Metals Solubility in Pore Water

Infiltration of metals through the unsaturated zone only occurs within the upper few feet of soil. Based on the processes discussed in Section 6.2, the partitioning of metals from waste and contaminated soil to the aqueous phase is related to solubility of the pH-dependent compounds and the pH. The amount of pore water is controlled by the amount of precipitation after evapotranspiration, and the concentration of metals in pre water is limited by the metals concentration in the solid phase and the chemical processes discussed in Section 6.1.1.

TABLE 6-1

Results of HELP Model Simulation of Percolation to the Aquifer
BNSF Hillyard Dross Site, Spokane, Washington

AVERAGE MONTHLY VALUES IN INCHES FOR YEARS 1974 THROUGH 1978

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
PRECIPITATION	2.85	1.34	0.55	0.64	1.4	2.55	0.75	1.14	0.07	0.26	3.19	1.39
RUNOFF	2.173	0.721	0.021	0	0.000	0.004	0.000	0	0	0	0	0
EVAPOTRANSPIRATION	0.467	0.823	1.716	0.743	1.399	2.441	2.201	1.072	0.241	0.23	0.554	0.615
PERCOLATION/LEAKAGE	0.0009	0.0008	0.0007	0.0005	0.0006	0.0007	0.0007	0.0008	0.0009	0.0009	0.0008	0.0003

AVERAGE ANNUAL TOTALS & (STD. DEVIATIONS) FOR YEARS 1974 THROUGH 1978

	INCHES	STDDEV	CUBIC FEET	PERCENT
PRECIPITATION	16.68	(0.919)	121111	100
RUNOFF	3.64	(0.8790)	26452	21.8
EVAPOTRANSPIRATION	11.82	(1.28)	85789	70.83
PERCOLATION/LEAKAGE	1.21	(0.6975)	8789	7.28

The vertical profile of metals concentrations displayed graphically in Figures 5.8 through 5-11 illustrate that metals dissolved in pore water are adsorbed by the sediments in the upper few feet of soil. As long as pH values remain neutral for the percolating water, metals are not persistent in pore water.

6.3.3 Other Inorganic Compounds Solubility in Pore Water

Chloride and nitrate have been detected in ground water at elevated concentrations. Results of TCLP analyses suggest that the amount of chloride and ammonia available for dissolution in the dross has already been depleted substantially by infiltration. The concentration of these compounds in ground water should continue to decrease over time. The same is probably true for other anions. The concentration of cations, which are more tightly adsorbed to the clay particles in the dross material, remains elevated in dross. These compounds, including sodium, potassium and manganese, remain available to percolating vadose zone pore waters.

6.3.4 Ground-Water Transport

Ground-water flow through the aquifer is relatively fast. Saturated hydraulic conductivity is estimated to be 5,000 gpd/ft^2, or 670 ft/day. Assuming an effective porosity of 30 percent, average linear velocity (hydraulic conductivity divided by effective porosity) through pore spaces is 2,200 ft/day.

Over the course of a year, an estimated 200,000 gallons of percolating water with elevated concentrations of chloride, nitrogen compounds, sodium, potassium and manganese enters the aquifer. Over the course of a few hundred feet concentrations are diluted. Concentrations of the cations chloride and manganese are at background levels in downgradient monitoring well MW-6. Anionic compounds, however, remain elevated further downgradient. The downgradient monitoring well MW-6 displays elevated concentrations of sodium, potassium, and nitrate-nitrogen relative to the upgradient well MW-4.

6.3.5 Surface Water Runoff

Surface water runoff is augmented by a shallow slope. Drainage pathways are limited, however, and surface soils are relatively permeable. As a result, no streams or channels are present in the immediate vicinity of the Site. The surface water runoff pathway, therefore, is limited in length before surface water infiltrates into the unsaturated zone.

SECTION 7.0

RISK ASSESSMENT

WDOE and BNSF have determined that cleanup standards for the Hillyard Dross Site are obvious and undisputed, and allow an adequate margin of safety for protection of human health and the environment. Cleanup standards are derived in Section 8.0. A toxicity assessment, therefore, is not completed for the Site. The other elements of the risk assessment, including data evaluation, exposure assessment and risk calculation, are summarized below.

7.1 Human Health Risk Assessment

Consistent with the MTCA, the human health risk assessment prepared for the Hillyard Dross Site followed the risk assessment process defined by WAC 173-340-708. This process entails the following steps:

- <u>Selection of Indicator Hazardous Substances</u> – Since there is a limited number of hazardous substances, all of the detected hazardous substances will be considered for defining site cleanup requirements.

- <u>Reasonable Maximum Exposure</u> – Cleanup levels are based on estimates of current and future resource uses and reasonable maximum exposures. In the exposure assessment, populations that may be potentially exposed to site contaminants are identified, and potential exposure pathways are defined. Once complete exposure pathways are identified, exposure scenarios are developed, exposure point concentrations are calculated, and chemical intakes are estimated for each contaminant, consistent with the defined conditions of exposure. A complete exposure pathway requires a contaminant source, an exposure point (such as on-site soils), and an exposure route (such as inhalation, dermal contact, or ingestion).

- <u>Cleanup Levels for Individual Substances</u> – Cleanup levels for individual hazardous substances established under Method B are compared with reasonable maximum exposure concentrations. Cleanup levels are adjusted downward to take into account exposure to multiple hazardous substances. Cancer risks are assumed to be additive. Exposure to hazardous substances from more than one exposure pathway is assumed to be additive. Cleanup levels are established using the established reference doses from current WDOE (Clarc Tables) databases.

The human health risk assessment prepared for the Site utilized current risk assessment guidance developed by the WDOE. The basic approaches used to develop each step of the human health risk assessment and the results of each step are outlined in the following subsections.

7.1.1 Selection of Indicator Hazardous Substances

In the first step of the human health risk assessment for the Hillyard Dross Site, available analytical data were reviewed and contaminants of concern were selected for evaluation. Identification of these contaminants was performed separately for soil and ground water as discussed below.

Ground Water. All contaminants detected in current and historic ground-water samples were selected for evaluation in the risk assessment.

Soils. All inorganic constituents positively detected at concentrations above potentially applicable cleanup levels in soils were selected for evaluation in the human health risk assessment. For this evaluation of metals and other inorganic contaminants, it should be emphasized that some of these contaminants occur naturally in soils at concentrations that are generally similar to those reported for site soils. However, to ensure that potential risks would not be underestimated, all inorganic contaminants were conservatively carried through the analysis.

Table 7-1 lists potentially applicable Federal and State concentration-based screening or cleanup up goals for all metal and inorganic parameters analyzed for this project. Background concentrations of selected metals are listed from a study of naturally occurring background soil metals concentrations in the area (San Juan, 1994). Ranges of detected contaminants, and frequency of detection, are shown in Tables 7-2, 7-3 and 7-4.

Based on the limited number of contaminants of concern, selection of indicator parameters is not necessary at the Hillyard Dross Site. All detected parameters will be carried through the risk assessment.

7.1.2 Reasonable Maximum Exposure Assessment

In the next step of the human health risk assessment for the Hillyard Dross Site, an exposure assessment was developed. As discussed below, the exposure assessment consisted of three principal components:

- Identification of potentially exposed populations;
- Exposure pathway analysis; and,

TABLE 7-1

Potentially Applicable Screening-Level or Cleanup Goals
BNSF Hillyard Dross Site, Spokane, Washington

	GROUND WATER Concentration in µg/l						SOILS Concentration in mg/kg					
	Primary MCL	Secondary MCL	MTCA - Method A	MTCA - Method B Cancer	MTCA - Method B Non-Cancer	Minimum	MTCA - Method A Industrial	MTCA - Method B Cancer	MTCA - Method B Non-Cancer	100 x Ground Water Non-Cancer	Background (San Juan, 1994)	Minimum
Alkalinity	--	--	--	--	--	--	--	--	--	--	--	--
Ammonia	--	--	--	--	272,000	272,000	--	--	2,720,000	27,200	--	27,200
Arsenic	50	--	--	0.0583	4.8	0.0583	200	1.67	60	0.0058	9	9
Barium	2,000	--	--	--	1,120	1,120	--	--	5,600	112	--	112.00
Bromide	--	--	--	--	--	--	--	--	--	--	--	--
Cadmium	5	--	5	--	8	5	10	--	80	0.5	1	1
Calcium	--	--	--	--	--	--	--	--	--	--	--	--
Chloride	--	250,000	--	--	--	250,000	--	--	--	25,000	--	25,000
Chromium	100	--	50	80	--	50	500	--	400	--	18	400
Copper	--	--	--	--	592	592	--	--	2,660	59.2	22	59.2
Fluoride	4,000	2,000	--	--	960	960	--	--	4,800	96.0	--	96
Iron	--	--	--	--	--	--	--	--	--	--	25,000	--
Lead	--	--	5	--	--	5	1,000	--	--	--	15	1,000
Magnesium	--	--	--	--	--	--	--	--	--	--	--	--
Mercury (inorganic)	2	--	2	--	4.8	2	1	--	24	0.20	--	0.20
Nitrate-Nitrogen	10,000	--	--	--	25,600	10,000	--	--	128,000	1,000	--	1,000
Nitrite-Nitrogen	1,000	--	--	--	1,600	1,000	--	--	8,000	100	--	100
Orthophosphate-Phosphorous	--	--	--	--	--	--	--	--	--	--	--	--
Potassium	--	--	--	--	--	--	--	--	--	--	--	--
Selenium	50	--	--	--	80	50	--	--	400	5	--	5
Silver	--	100	--	--	80	80	--	--	400	8	--	8
Sodium	--	--	--	--	--	--	--	--	--	--	--	--
Sulfate	--	250,000	--	--	--	250,000	--	--	--	25,000	--	25,000

µg/l = micrograms per liter
mg/kg = milligrams per kilogram
-- = Not available
MCL = Federal Maximum Contaminant Level (40 CFR 141)
MTCA Method A/B = Model Toxics Control Act

TABLE 7-2

Screening of Compounds Positively Detected in Dross Samples
BNSF Hillyard Dross Site, Spokane, Washington

	Number of Analyses	Number of Detections	Percent Detections	Maximum Conentration	Average Concentration	Median Concentration	Standard Deviation	Coeff. Variation	Minimum Potential ARAR	Number of Exceedences	Percent > Min ARAR
Ammonia	4	0	0	NA	NA	NA	NA	NA	27200	0	0%
Arsenic	8	7	88%	19.9	5	1.51	7	4.51	9	1	13%
Barium	8	8	100%	480	102	40.6	155	3.82	112	1	13%
Cadmium	8	3	38%	2.06	0.88	0.356	1.02	2.87	1	1	13%
Chloride	34	34	100%	57000	10441	610	18592	30	25000	7	21%
Chromium	9	9	100%	499	286	295	153	0.52	400	3	33%
Copper	9	9	100%	4520	2453	2420	1228	0.51	59.2	0	0%
Fluoride	30	30	100%	6400	1143	595	1599	2.69	96	24	90%
Lead	8	7	88%	80.8	29.1	25.8	27	1.04	1000	0	0%
Mercury	4	3	75%	0.0163	0	0.014	0	0.35	0.2	0	0%
Nitrate-Nitrogen	29	29	100%	420	81.9	32	116	3.62	1000	0	0%
Nitrite-Nitrogen	21	1	5%	20	20.0	20	NA	NA	100	0	0%
Orthphosphate-Phospohorous	24	0	0%	0	NA	NA	NA	NA	--	0	0%
Potassium	21	21	100%	46000	12705	5600	14090	2.52	--	0	0%
Selenium	8	4	50%	25.3	10.6	7.02	10.1	1.43	5	3	38%
Silver	8	0	0%	0	NA	NA	NA	NA	8	0	0%
Sodium	22	22	100%	47000	14202	7100	13924	1.96	--	0	0%
Sulfate	25	25	100%	700	281	300	201	0.67	25000	0	0%

TABLE 7-3

Screening of Compounds Positively Detected in Soil Samples
BNSF Hillyard Dross Site, Spokane, Washington

	Number of Analyses	Number of Detections	Percent Detections	Maximum Conentration	Average Concentration	Median Concentration	Standard Deviation	Coeff. Variation	Minimum Potential ARAR	Number of Exceedences	Percent > Min ARAR
Ammonia	9	0	0%	NA	NA	NA	NA	NA	27200	0	0%
Arsenic	19	16	84%	23.4	10	7.805	6.05	0.78	9	7	37%
Barium	19	19	100%	149	66	58.2	35.4	0.61	112	2	11%
Cadmium	19	6	32%	1.46	0.51	0.364	0.47	1.29	1	1	5%
Chloride	19	14	74%	17500	2258	38.3	5701	149	25000	0	0%
Chromium	19	19	100%	49.3	12	10.4	9.42	0.91	400	0	0%
Copper	19	19	100%	441	68	26.4	109	4.12	59.2	4	21%
Fluoride	9	8	89%	88.2	34.4	24.8	31.4	1.27	96	0	0%
Lead	19	17	89%	485	49.0	14.3	117	8.20	1000	0	0%
Mercury	19	12	63%	0.0344	0.0141	0.009645	0.010	1.088	0.2	0	0%
Nitrate-Nitrogen	9	6	67%	5.29	3.50	3.56	1.48	0.417	1000	0	0%
Nitrite-Nitrogen	0	NA	NA	NA	NA	NA	NA	NA	100	0	0%
Orthphosphate-Phospohorous	0	NA	NA	NA	NA	NA	NA	NA	--	0	0%
Potassium	19	19	100%	24300	5626	3410	5696	1.67	--	0	0%
Selenium	19	4	21%	18.2	8.47	7.575	7.36	0.972	5	3	16%
Silver	19	1	5%	5.27	5.27	5.27	NA	NA	8	0	0%
Sodium	19	18	95%	25900	2935	637	6654	10.45	--	0	0%
Sulfate	0	NA	NA	NA	NA	NA	NA	NA	25000	0	0%

TABLE 7-4

Screening of Compounds Positively Detected in Ground Water Samples
BNSF Hillyard Dross Site, Spokane, Washington

	Number of Analyses	Number of Detections	Percent Detections	Maximum Conentration	Average Concentration	Median Concentration	Standard Deviation	Coeff. Variation	Minimum Potential ARAR	Number of Exceedences	Percent > Min ARAR
Alkalinity	6	6	100%	240	157	158	47.5	0.3	--	0	0%
Ammonia	6	6	100%	7.34	1.82	0.9	2.7	3.1	272	0	0%
Arsenic	1	1	100%	0.00148	NA	NA	NA	NA	0.0583	0	0%
Barium	1	1	100%	0.134	NA	NA	NA	NA	1.12	0	0%
Bromide	6	5	83%	0.724	0.52	0.7	0.3	0.4	--	0	0%
Cadmium	1	0	0%	NA	NA	NA	NA	NA	0.005	0	0%
Calcium	6	6	100%	120	62	66.6	35.2	0.5	--	0	0%
Chloride	11	11	100%	1400	472	397	485	1.2	250	6	55%
Chromium	1	1	100%	0.00154	NA	NA	NA	NA	0.05	0	0%
Copper	1	0	0%	NA	NA	NA	NA	NA	0.592	0	0%
Fluoride	11	5	45%	14	2.97	0.2	6.2	34.8	0.96	1	9%
Iron	6	4	67%	80.1	20	0.8	39.8	50.0	--	0	0%
Lead	1	0	0%	NA	NA	NA	NA	NA	0.005	0	0%
Magnesium	6	6	100%	72.3	31	30.8	23.2	0.8	--	0	0%
Mercury	1	0	0%	NA	NA	NA	NA	NA	0.002	0	0%
Nitrate-Nitrogen	11	11	100%	83.8	24	19.4	24.1	1.2	10	7	64%
Nitrite-Nitrogen	11	1	9%	1.5	1.50	1.5	NA	NA	1	1	9%
Orthophosphate-Phosphorous	11	0	0%	0	NA	NA	NA	NA	--	0	0%
Potassium	8	8	100%	255	97	65.5	92.3	1.4	--	0	0%
Selenium	1	1	100%	0.0015	NA	NA	NA	NA	0.05	0	0%
Silver	1	0	0%	NA	NA	NA	NA	NA	0.08	0	0%
Sodium	8	8	100%	420	220	211	177.0	0.8	--	0	0%
Sulfate	11	11	100%	74.8	31	24.8	21.2	0.9	250	0	0%

- Calculation of chemical intakes.

The following sections describe the potentially exposed populations and the exposure pathways that were identified, followed by a discussion of the exposure scenarios developed for the Site. The final sections describe the estimation of chemical intakes for the defined exposures.

7.1.2.1 Identification of Potentially Exposed Populations and Potential Exposure Pathways

The Hillyard Dross Site is in an area of mixed residential, commercial and industrialized land use. The immediate area consists of paved areas and buildings with some vegetative cover. The Site is completely fenced and access is restricted. The Site is bordered on the west and north by vacant BNSF property, and to the south by industry. The area to the east of the Hillyard Dross Site is a salvage yard, and the to east of the salvage yard is residential property. Thus, under current conditions, potential receptors include:

- On-site workers;
- Trespassers; and,
- Various off-site populations (e.g., workers, residents, passers-by).

The Site is highly industrialized and is expected to remain under industrial use in the foreseeable future. However, a conservative approach was taken and a low-density residential scenario has been included in this Human Health Risk Assessment. Thus, under future conditions, potential receptors include:

- Construction workers;
- Trespassers;
- Various off-site populations (e.g., workers, residents, passers-by); and,
- Hypothetical on-site residents.

As shown on Table 7-5, the following exposure pathways were determined to represent potentially complete pathways and were selected for evaluation in this human health risk assessment.

Potential exposure pathways associated with soil include:

- Direct contact with soil (i.e., incidental ingestion and dermal contact); and,
- Inhalation of fugitive dust released from disturbed soils.

TABLE 7-5

Summary of Potential Exposure Scenarios
BNSF Hillyard Dross Site, Spokane, Washington

Exposure Medium	Release Mechanism	Exposure Point	Potentially Exposed Population	Exposure Route
Air	Fugitive dust	On-site	Construction workers	Inhalation
	(Surface/subsurface soil)		Tresspassers	Inhalation
			Residents (hypothetical)	Inhalation
	Fugitive dust	Off-site	Workers	Inhalation
	(Surface/subsurface soil)		Residents	Inhalation
Soils	(None)	On-site	Construction workers	Incidental ingestion
			Trespassers	Incidental ingestion
			Residents (hypothetical)	Incidental ingestion
Ground water	Leaching	On-site	Residents (hypothetical)	Residential use (ingestion)
		Off-site	Residents	Residential use (ingestion)

Notes:
Currently there is no on-site use of groundwater.

Potential exposure pathways associated with ground water include:

- Use of ground water as a residential water supply (ingestion and direct contact).

With regard to populations potentially exposed to ground water, it should be noted that the Site and most of the surrounding area is served by municipal water; there are no known supplemental ground-water supply wells on site.

7.1.2.2 Potential Exposure Scenarios

Potential exposure scenarios were developed based on an analysis of current and future use conditions and the exposure pathways identified at the Site. Table 7-5 summarizes the exposure pathways selected for analysis in this risk assessment.

- Direct contact with contaminated surface soils resulting in incidental ingestion or dermal contact is currently prohibited by a site-boundary fence. The Site is unpaved, except for a slab foundation of a former building. Exposure to contaminated surface soils for construction workers, trespassers and hypothetical residents, therefore, is possible. This is the reasonable maximum exposure scenario for soil.

- Inhalation of fugitive dust by off-site workers and residents is currently not an active exposure pathway because of a crust that has formed on the dross surface. The crust is easily disturbed and will not be effective in the future. Exposure to contaminated fugitive dust by inhalation for on-site construction workers, trespassers and hypothetical residents, and off-site construction workers and residents, therefore, is possible. This is the reasonable maximum exposure scenario for air.

- Residential use of the Site currently is prohibited by zoning and ownership of the property by BNSF. The extent of off-site ground water impact is limited to the BNSF Hillyard Yard area; therefore, there are no current exposure pathways. Hypothetical residents consuming and coming into direct contact with ground water would, however, by exposed to site contaminants in ground water. This is the reasonable maximum exposure scenario for ground water.

7.1.2.3 Calculation of Intakes

The last step of the exposure assessment involves the selection of appropriate exposure parameters and the calculation of chemical intakes. Exposure parameters and chemical intakes are as specified in MTCA guidance (WDOE, 1996).

7.1.3 Cleanup Levels for Individual Hazardous Substances

MTCA Method B levels for individual chemicals in soil and ground water are developed from formula values based on human health. The Method B input parameters are listed on Tables 7-6, 7-7 and 7-8.

7.1.4 Multiple Hazardous Substances Risk Characterization

In the last step of this risk assessment, exposure and toxicity information were integrated to derive quantitative estimates of potential risks, following the standard procedures defined in the WDOE's MTCA regulation (WAC 173-340; WDOE, 1996). Intake and risk calculations for each medium and scenario are presented in Tables 7-6, 7-7 and 7-8.

In reviewing the results of this risk characterization, it should be emphasized that the potential risks estimated in this analysis are based on a series of conservative assumptions regarding exposure and toxicity. As discussed at the conclusion of this section, these assumptions have been used to ensure that potential risks are not underestimated; however, any actual risks associated with the Site are expected to be much less than those estimated in this analysis.

The following subsections discuss the specific results of the risk characterization at the Site. Following the discussion of the risk assessment results, a brief discussion of the uncertainties is presented.

- The cumulative Hazard Quotient associated with exposure routes from dross for the construction worker, trespasser, off-site resident and hypothetical on-site resident was 3. Potential cancer risk was 0.3 for ingestion and 11 for inhalation.
- The cumulative Hazard Quotient associated with exposure routes from contaminated soil for the construction worker, trespasser, off-site resident and hypothetical on-site resident was 0.6. Potential cancer risk was 0.4 for ingestion and 13 for inhalation.
- The cumulative Hazard Quotient associated with exposure routes from ground water for the hypothetical on-site resident was 63. Potential cancer risk was 0.0000254.

7.1.5 Multiple Pathways of Exposure

Multiple pathways exist for the hypothetical on-site resident. Adding the cumulative Hazard Quotient for soil, dross and groundwater results in a total of 67. Total potential respiratory risk is 24, and total potential oral risk is 0.72.

TABLE 7-6

Calculation of Potential Risks/Dross/Hypothetical Residential Scenario
BNSF Hillyard Dross Site, Spokane, Washington

Constituent	Maximum Concentration mg/kg	Oral CPF kg-day/mg	Respiratory CPF kg-day/mg	RFD mg/kg-day	LIFE years	ABW kg	DUR years	UCF mg/kg	SIR mg/day	AB1	FOC	Hazard Quotient	Potential Oral Risk	Potential Respiratory Risk
Ammonia	NA	NA	NA	3.40E+01	7.50E+01	1.6E+01	6.0E+00	1.0E+06	2.0E+02	1.0E+00	1.00E+00	0.00E+00	0.00E+00	0.00E+00
Arsenic	19.9	1.5	50	3.00E-04	7.50E+01	1.6E+01	6.0E+00	1.0E+06	2.0E+02	4.0E-01	1.00E+00	3.32E-01	3.32E-01	1.11E+01
Barium	480	NA	NA	7.00E-02	7.50E+01	1.6E+01	6.0E+00	1.0E+06	2.0E+02	1.0E+00	1.00E+00	8.57E-02	0.00E+00	0.00E+00
Cadmium	2.06	NA	NA	1.00E-03	7.50E+01	1.6E+01	6.0E+00	1.0E+06	2.0E+02	1.0E+00	1.00E+00	2.58E-02	0.00E+00	0.00E+00
Chloride	57000	NA	NA	NA	7.50E+01	1.6E+01	6.0E+00	1.0E+06	2.0E+02	1.0E+00	1.00E+00	0.00E+00	0.00E+00	0.00E+00
Chromium	499	NA	NA	NA	7.50E+01	1.6E+01	6.0E+00	1.0E+06	2.0E+02	1.0E+00	1.00E+00	0.00E+00	0.00E+00	0.00E+00
Copper	4520	NA	NA	3.70E-02	7.50E+01	1.6E+01	6.0E+00	1.0E+06	2.0E+02	1.0E+00	1.00E+00	1.53E+00	0.00E+00	0.00E+00
Fluoride	6400	NA	NA	6.00E-02	7.50E+01	1.6E+01	6.0E+00	1.0E+06	2.0E+02	1.0E+00	1.00E+00	1.33E+00	0.00E+00	0.00E+00
Lead	80.8	NA	NA	NA	7.50E+01	1.6E+01	6.0E+00	1.0E+06	2.0E+02	1.0E+00	1.00E+00	0.00E+00	0.00E+00	0.00E+00
Mercury	0.0163	NA	NA	3.00E-04	7.50E+01	1.6E+01	6.0E+00	1.0E+06	2.0E+02	1.0E+00	1.00E+00	6.79E-04	0.00E+00	0.00E+00
Nitrate-Nitrogen	420	NA	NA	1.60E+00	7.50E+01	1.6E+01	6.0E+00	1.0E+06	2.0E+02	1.0E+00	1.00E+00	3.28E-03	0.00E+00	0.00E+00
Nitrite-Nitrogen	20	NA	NA	0.1	7.50E+01	1.6E+01	6.0E+00	1.0E+06	2.0E+02	1.0E+00	1.00E+00	2.50E-03	0.00E+00	0.00E+00
Orthphosphate-Phospohorous	0	NA	NA	NA	7.50E+01	1.6E+01	6.0E+00	1.0E+06	2.0E+02	1.0E+00	1.00E+00	0.00E+00	0.00E+00	0.00E+00
Potassium	46000	NA	NA	NA	7.50E+01	1.6E+01	6.0E+00	1.0E+06	2.0E+02	1.0E+00	1.00E+00	0.00E+00	0.00E+00	0.00E+00
Selenium	25.3	NA	NA	0.005	7.50E+01	1.6E+01	6.0E+00	1.0E+06	2.0E+02	1.0E+00	1.00E+00	6.33E-02	0.00E+00	0.00E+00
Silver	0	NA	NA	0.005	7.50E+01	1.6E+01	6.0E+00	1.0E+06	2.0E+02	1.0E+00	1.00E+00	0.00E+00	0.00E+00	0.00E+00
Sodium	47000	NA	NA	NA	7.50E+01	1.6E+01	6.0E+00	1.0E+06	2.0E+02	1.0E+00	1.00E+00	0.00E+00	0.00E+00	0.00E+00
Sulfate	700	NA	NA	NA	7.50E+01	1.6E+01	6.0E+00	1.0E+06	2.0E+02	1.0E+00	1.00E+00	0.00E+00	0.00E+00	0.00E+00
											TOTALS	**3.37E+00**	**3.32E-01**	**1.11E+01**

Potential Risk = (Maximum Concentration x CPF x SIR x AB1 X DUR x FOC) / ABW x LIFE x UCF)
Hazard Quotient = (Maximum Concentration x SIR x AB1 x FOC) / (RFD x ABW X UCF)
CPF = Oral Carcinogenic Potency Factor

RFD = Reference Dose (Method B Formula Value for Non-Carcinogen)
SIR = Soil Ingestion Rate
AB1 = Gastrointesitnal Absorption Rate
FOC = Frequency of Contact
ABW = Average Body Weight
UCF = Unit Conversion Factor
DUR = Duration of Exposure
LIFE = Lifetime

TABLE 7-7

Calculation of Potential Risks/Soil/Hypothetical Residential Scenario

BNSF Hillyard Dross Site, Spokane, Washington

Constituent	Maximum Concentration mg/kg	Oral CPF kg-day/mg	Respiratory CPF kg-day/mg	RFD mg/kg-day	LIFE years	ABW kg	DUR years	UCF mg/kg	SIR mg/day	AB1	FOC	Hazard Quotient	Potential Oral Risk	Potential Respiratory Risk
Ammonia	NA	NA	NA	3.40E+01	7.50E+01	1.6E+01	6.0E+00	1.0E+06	2.0E+02	1.0E+00	1.00E+00	0.00E+00	0.00E+00	0.00E+00
Arsenic	23.4	1.50E+00	50	3.00E-04	7.50E+01	1.6E+01	6.0E+00	1.0E+06	2.0E+02	4.0E-01	1.00E+00	3.90E-01	3.90E-01	1.30E+01
Barium	149	NA	NA	7.00E-02	7.50E+01	1.6E+01	6.0E+00	1.0E+06	2.0E+02	1.0E+00	1.00E+00	2.66E-02	0.00E+00	0.00E+00
Cadmium	1.46	NA	NA	1.00E-03	7.50E+01	1.6E+01	6.0E+00	1.0E+06	2.0E+02	1.0E+00	1.00E+00	1.83E-02	0.00E+00	0.00E+00
Chloride	17500	NA	NA	NA	7.50E+01	1.6E+01	6.0E+00	1.0E+06	2.0E+02	1.0E+00	1.00E+00	0.00E+00	0.00E+00	0.00E+00
Chromium	49.3	NA	NA	NA	7.50E+01	1.6E+01	6.0E+00	1.0E+06	2.0E+02	1.0E+00	1.00E+00	0.00E+00	0.00E+00	0.00E+00
Copper	441	NA	NA	3.70E-02	7.50E+01	1.6E+01	6.0E+00	1.0E+06	2.0E+02	1.0E+00	1.00E+00	1.49E-01	0.00E+00	0.00E+00
Fluoride	88.2	NA	NA	6.00E-02	7.50E+01	1.6E+01	6.0E+00	1.0E+06	2.0E+02	1.0E+00	1.00E+00	1.84E-02	0.00E+00	0.00E+00
Lead	485	NA	NA	NA	7.50E+01	1.6E+01	6.0E+00	1.0E+06	2.0E+02	1.0E+00	1.00E+00	0.00E+00	0.00E+00	0.00E+00
Mercury	0.012	NA	NA	3.00E-04	7.50E+01	1.6E+01	6.0E+00	1.0E+06	2.0E+02	1.0E+00	1.00E+00	5.00E-04	0.00E+00	0.00E+00
Nitrate-Nitrogen	5.29	NA	NA	1.60E+00	7.50E+01	1.6E+01	6.0E+00	1.0E+06	2.0E+02	1.0E+00	1.00E+00	4.13E-05	0.00E+00	0.00E+00
Nitrite-Nitrogen	NA	NA	NA	0.1	7.50E+01	1.6E+01	6.0E+00	1.0E+06	2.0E+02	1.0E+00	1.00E+00	0.00E+00	0.00E+00	0.00E+00
rthphosphate-Phospohorous	NA	NA	NA	NA	7.50E+01	1.6E+01	6.0E+00	1.0E+06	2.0E+02	1.0E+00	1.00E+00	0.00E+00	0.00E+00	0.00E+00
Potassium	24300	NA	NA	NA	7.50E+01	1.6E+01	6.0E+00	1.0E+06	2.0E+02	1.0E+00	1.00E+00	0.00E+00	0.00E+00	0.00E+00
Selenium	18.2	NA	NA	0.005	7.50E+01	1.6E+01	6.0E+00	1.0E+06	2.0E+02	1.0E+00	1.00E+00	4.55E-02	0.00E+00	0.00E+00
Silver	5.27	NA	NA	0.005	7.50E+01	1.6E+01	6.0E+00	1.0E+06	2.0E+02	1.0E+00	1.00E+00	1.32E-02	0.00E+00	0.00E+00
Sodium	25900	NA	NA	NA	7.50E+01	1.6E+01	6.0E+00	1.0E+06	2.0E+02	1.0E+00	1.00E+00	0.00E+00	0.00E+00	0.00E+00
Sulfate	NA	NA	NA	NA	7.50E+01	1.6E+01	6.0E+00	1.0E+06	2.0E+02	1.0E+00	1.00E+00	0.00E+00	0.00E+00	0.00E+00
											TOTALS	**6.61E-01**	**3.90E-01**	**1.30E+01**

Potential Risk = (Maximum Concentration x CPF x SIR x AB1 X DUR x FOC) / ABW x LIFE x UCF)
Hazard Quotient = (Maximum Concentration x SIR x AB1 x FOC) / (RFD x ABW X UCF)
CPF = Oral Carcinogenic Potency Factor
RFD = Reference Dose (Method B Formula Value for Non-Carcinogen)
SIR = Soil Ingestion Rate
AB1 = Gastrointesitnal Absorption Rate
FOC = Frequency of Contact
ABW = Average Body Weight
UCF = Unit Conversion Factor
DUR = Duration of Exposure
LIFE = Lifetime

TABLE 7-8

Calculation of Potential Risks/Ground Water/Hypothetical Residential Scenario
BNSF Hillyard Dross Site, Spokane, Washington

Constituent	Maximum Concentration µg/l	Oral CPF kg-day/mg	RFD mg/kg-day	LIFE years	ABWHQ kg	ABWRSK kg	UCF µg/mg	DUR years	INH	DWIRHQ l/day	DWIRRSK l/day	Hazard Quotient	Potential Risk
Alkalinity	240000	NA	NA	7.50E+01	1.6E+01	7.0E+01	1.0E+03	3.0E+01	1.0E+00	1.0E+00	2.0E+00	0.00E+00	0.00E+00
Ammonia	7340	NA	3.40E+01	7.50E+01	1.6E+01	7.0E+01	1.0E+03	3.0E+01	1.0E+00	1.0E+00	2.0E+00	1.35E-02	0.00E+00
Arsenic	1.48	1.50E+00	3.00E-04	7.50E+01	1.6E+01	7.0E+01	1.0E+03	3.0E+01	1.0E+00	1.0E+00	2.0E+00	3.08E-01	2.54E-05
Barium	134	NA	7.00E-02	7.50E+01	1.6E+01	7.0E+01	1.0E+03	3.0E+01	1.0E+00	1.0E+00	2.0E+00	1.20E-01	0.00E+00
Bromide	724	NA	1.00E-03	7.50E+01	1.6E+01	7.0E+01	1.0E+03	3.0E+01	1.0E+00	1.0E+00	2.0E+00	4.53E+01	0.00E+00
Cadmium	NA	NA	NA	7.50E+01	1.6E+01	7.0E+01	1.0E+03	3.0E+01	1.0E+00	1.0E+00	2.0E+00	0.00E+00	0.00E+00
Calcium	120000	NA	NA	7.50E+01	1.6E+01	7.0E+01	1.0E+03	3.0E+01	1.0E+00	1.0E+00	2.0E+00	0.00E+00	0.00E+00
Choride	1400000	NA	NA	7.50E+01	1.6E+01	7.0E+01	1.0E+03	3.0E+01	1.0E+00	1.0E+00	2.0E+00	0.00E+00	0.00E+00
Chromium	1.54	NA	3.70E-02	7.50E+01	1.6E+01	7.0E+01	1.0E+03	3.0E+01	1.0E+00	1.0E+00	2.0E+00	2.60E-03	0.00E+00
Copper	NA	NA	NA	7.50E+01	1.6E+01	7.0E+01	1.0E+03	3.0E+01	1.0E+00	1.0E+00	2.0E+00	0.00E+00	0.00E+00
Fluoride	14000	NA	6.00E-02	7.50E+01	1.6E+01	7.0E+01	1.0E+03	3.0E+01	1.0E+00	1.0E+00	2.0E+00	1.46E+01	0.00E+00
Iron	80000	NA	NA	7.50E+01	1.6E+01	7.0E+01	1.0E+03	3.0E+01	1.0E+00	1.0E+00	2.0E+00	0.00E+00	0.00E+00
Lead	NA	NA	NA	7.50E+01	1.6E+01	7.0E+01	1.0E+03	3.0E+01	1.0E+00	1.0E+00	2.0E+00	0.00E+00	0.00E+00
Magnesium	72300	NA	NA	7.50E+01	1.6E+01	7.0E+01	1.0E+03	3.0E+01	1.0E+00	1.0E+00	2.0E+00	0.00E+00	0.00E+00
Mercury	NA	NA	3.00E-04	7.50E+01	1.6E+01	7.0E+01	1.0E+03	3.0E+01	1.0E+00	1.0E+00	2.0E+00	0.00E+00	0.00E+00
Nitrate-Nitrogen	42400	NA	1.60E+00	7.50E+01	1.6E+01	7.0E+01	1.0E+03	3.0E+01	1.0E+00	1.0E+00	2.0E+00	1.66E+00	0.00E+00
Nitrite-Nitrogen	1500	NA	0.1	7.50E+01	1.6E+01	7.0E+01	1.0E+03	3.0E+01	1.0E+00	1.0E+00	2.0E+00	9.38E-01	0.00E+00
Orthophosphate-Phosphorous	0	NA	NA	7.50E+01	1.6E+01	7.0E+01	1.0E+03	3.0E+01	1.0E+00	1.0E+00	2.0E+00	0.00E+00	0.00E+00
Potassium	255000	NA	NA	7.50E+01	1.6E+01	7.0E+01	1.0E+03	3.0E+01	1.0E+00	1.0E+00	2.0E+00	0.00E+00	0.00E+00
Selenium	1.5	NA	0.005	7.50E+01	1.6E+01	7.0E+01	1.0E+03	3.0E+01	1.0E+00	1.0E+00	2.0E+00	1.88E-02	0.00E+00
Silver	NA	NA	0.005	7.50E+01	1.6E+01	7.0E+01	1.0E+03	3.0E+01	1.0E+00	1.0E+00	2.0E+00	0.00E+00	0.00E+00
Sodium	420000	NA	NA	7.50E+01	1.6E+01	7.0E+01	1.0E+03	3.0E+01	1.0E+00	1.0E+00	2.0E+00	0.00E+00	0.00E+00
Sulfate	74800	NA	NA	7.50E+01	1.6E+01	7.0E+01	1.0E+03	3.0E+01	1.0E+00	1.0E+00	2.0E+00	0.0E+00	0.00E+00
											TOTAL	**6.29E+01**	**2.54E-05**

Hazard Quotient = (Maximum Concentration x DWIRHQ x INH) / (RFD x ABWHQ X UCF)

Potential Risk = (Maximum Concentration x CPF x DWIR x DUR x INH x DWF)/(ABWRSK x LIFE x UCF)

CPF = Oral Carcinogenic Potency Factor
RFD = Reference Dose (Method B Formula Value for Non-Carcinogen)
ABWHQ = Average Body Weight for Hazard Quotient Calculation
ABWRSK = Average Body Weight for Carcinogenic Risk Calculation
UCF = Unit Conversion Factor
DUR = Duration of Exposure
INH = Inhalation Correction Fraction
DWIRHQ = Drinking Water Ingestion Rate for Hazard Quotient Calculation
DWIRRSK = Drinking Water Ingestion Rate for Risk Calculation

7.1.6 Uncertainty Analysis

This section includes a discussion of the uncertainties associated with each step of the human health risk assessment, as well as an evaluation of the significance of those uncertainties. This discussion includes identification of some of the uncertainties associated with the risk assessment process itself, as well as with the specific assumptions used in developing this human health risk assessment. Information regarding uncertainty is an integral part of any risk assessment because it provides important insight into the significance of the results, thus supporting risk management decisions.

Data Evaluation. Data used in this human health risk assessment were based on site investigation efforts, which generally focused on areas of known impact, in order that the presence and extent of any detected contaminants could be determined.

Exposure Assessment. The exposure assessment utilized a number of exposure assumptions that are also anticipated to result in an overestimation of any potential risks. These assumptions include:

- The use of maximum contaminant concentrations;
- The inclusion of a low-density residential scenario, even though there are no plans to develop any portion of the Hillyard Dross Site for residential housing; and,
- The use of conservative, default factors to characterize exposure by future on-site receptors.

Risk Characterization. Methods used for the characterization of potential risk were developed by WDOE to streamline and simplify the risk assessment process, while ensuring that potential risks are not underestimated. Furthermore, the risk estimates presented in this human health risk assessment incorporated the various uncertainties associated with each step of the risk assessment process, as described above. Thus, the potential risks calculated in this assessment are anticipated to overestimate potential risks associated with the defined exposure scenarios. Actual risks are expected to be less than estimated in this report.

7.2 Ecological Evaluation

The Hillyard Dross Site represents a potential threat to ecological receptors. Tier 2 soil screening values are exceeded for arsenic, lead, and copper. The Site does not qualify for a site-specific Tier III ecological risk assessment. There are no management or land use objectives for habitat on, or directly adjacent to, the Site. In addition, no known occurrence of wildlife species designated as "Priority Species" or "Species of Special Concern" are on, or directly adjacent to, the Site.

The Site qualifies for the Tier 2 "habitat off-ramp" because of the low habitat quality of the land, the industrial nature of the land, and the lack of persistent dioxins, PCBs and organochlorine pesticides. The Table 3 worksheet for the Tier 2 "habitat off-ramp" is on Table 7-9.

TABLE 7-9

Tier 2 Habitat Off-Ramp Worksheet

BNSF Hillyard Dross Site, Spokane, Washington

	Score
Area of Undeveloped Land	8
Industrial or Commercial Property (Yes=3, No=1)	3
Habitat Quality (High=1, Intermediate=2, Low=3)	3
Is the undeveloped land likely to attract wildlife" (Yes=1, No=2)	2
Are there any of the follow soil contaminants present: dioxins, PCBs and organochlorine pesticides, dibensofurans? (Yes=1, No = 4)	4
Add the numbers from lines 2 through. If result is larger than points under "Area of Undeveloped Land" then site qualifies for the "habitat off-ramp"	12

SECTION 8.0

REMEDIAL ACTION OBJECTIVES

This section identifies Remedial Action Objectives (RAOs) developed for medium-specific and/or area-specific protection of human health and the environment at the Site. Chemical-, action-, and location-specific Applicable or Relevant and Appropriate Requirements (ARARs) and To-Be-Considered (TBC) criteria for the Site are also addressed. MTCA cleanup levels are included in the discussion of ARARs.

8.1 Identification of Objectives

RAOs developed for protecting human health typically address both chemical concentrations and potential exposure routes. Protection can be achieved by either reducing concentrations or reducing or eliminating potential exposure pathways. The Risk Assessment identified the following exposure routes that require RAOs for protecting human health at the Site:

- Direct contact with dross and contaminated soil resulting in incidental ingestion.
- Inhalation of fugitive dust from contaminated soil or dross material.
- Ingestion of ground water by hypothetical residents with on-site water wells.

The recommended RAOs for human health are to prevent human exposure to contaminants of concern, to minimize exposure to contaminants of concern in airborne particulates, and to minimize exposure to contaminants of concern via ground-water migration. Specifically, RAO-1 is to reduce the Hazard Quotient for the Site to less than one, and to reduce the potential cancer risk for the Site to less than one in one million.

RAOs for protecting the environment typically seek to minimize impacts on resources by addressing the media of concern and the target cleanup levels. The risk assessment identified no exposure routes for ecological receptors that require RAOs.

Current conditions at the Site are satisfying RAO-1 to a significant degree. The fence has effectively prevented human exposure by ingestion, and an application of a foam to the surface of the dross has minimized airborne particulates.

RAOs for protecting the probable and beneficial use of the land also are considered. This land has been, and will continue to be, zoned industrial and used for that purpose. RAO-2, therefore, seeks to restore the land to a condition that would allow its use by industry (RAO2).

While a current exposure to contaminated ground-water migration is not occurring at this time, the Site overlies the Spokane-Rathdrum Aquifer, which is the sole source of drinking water for almost 400,000 people in the State of Washington. There are 21 public wells and over 150 private wells within three miles of the Site. The sole source aquifer designation requires that the threat of ground-water contamination be effectively mitigated. RAO3, therefore, is for ground-water protection.

8.2 ARARs

Appendix H provides a preliminary summary of key ARARs that may be relevant to RI and cleanup activities at the Hillyard Dross Site. This information provides a framework for determining remediation goals based on the fate and transport evaluations and risk assessment.

8.2.1 Soil Project Remediation Goals

Soil ARARs are listed in Table 7-1. These ARARs apply to the aluminum dross and contaminated soil. They are exceeded by arsenic, barium, cadmium, chloride, chromium, fluoride and selenium in dross or soil. Of these parameters, however, only arsenic, barium, cadmium, copper and selenium contribute significantly to the risk to human health at the Site. PRGs for these compounds are listed in Table 8-1. The PRGs are based on the minimum ARAR, which is generally the Method B formula values. The cumulative Hazard Quotient using either the PRGs or the maximum detected concentration at the site, whichever is less, is less than 1. Arsenic, which is the only parameter contributing to the potential carcinogenic risk formula, has a background concentration of 9 mg/kg. For metals with background concentrations (90th percentile) greater than other minimum ARARs, the background concentration is used (San Juan, 1994).

Dross sample analytical data compare to these PRGs as follows:

- The PRGs for arsenic, barium and cadmium, at 9, 112 and 1 mg/kg, respectively, each are exceeded by one sample concentration; a total of 8 samples were analyzed.
- Seven samples exceed the PRG for chloride of 25,000 mg/kg out of a total of 34 sample analyses.

- Three samples exceed the PRG for chromium of 400 mg/kg. A total of nine samples were analyzed for chromium.

- The PRG for copper, 59 mg/kg, is exceeded in all nine dross samples analyzed for copper; the maximum detected copper value was 4,520 mg/kg.

- Of the thirty dross samples analyzed for fluoride three samples were less than the PRG of 96 mg/kg. The PRG for selenium, 5 mg/kg, is exceeded by three samples (out of a total of 8 samples analyzed for selenium).

Soil sample analytical data compare to PRGs as follows:

- The PRG for arsenic is exceeded in seven samples out of a total of 19 sample analyses.

- Two soil sample concentrations exceed the PRG for barium out of a total of 19 samples analyzed.

- One soil sample exceeded the PRG for cadmium out of a total of 19 samples.

- The PRG for selenium, 5 mg/kg, is exceeded by three samples (out of a total of 19 samples analyzed for selenium).

8.2.2 Ground-water Project Remediation Goals

Ground-water ARARs are listed in Table 7-1. They are exceeded in on-site wells by chloride, fluoride, nitrate, and nitrite. Both nitrate and fluoride are considered a health risk to children for brain development. PRGs for these compounds are listed in Table 8-1. The PRGs are based on Method B formula values corresponding to the lesser concentration for a Hazard Quotient of 1 or a potential carcinogen risk of one in one million. PRGs are adjusted to maintain a cumulative Hazard Quotient of 1; fluoride and nitrite PRG concentrations are less than the Method B formula values.

Ground-water PRGs are exceeded for chloride in six out of the 11 samples that have been collected during this RI. The PRG for chloride is 250 mg/l; during the December 1998 sampling event the PRG is exceeded in samples BN-2 and MW-5, which had concentrations of 657 and 690 mg/l, respectively.

The PRG for fluoride was exceeded in only one sample out of 11 samples collected. The sample was from BN-2 in 1988. Fluoride was reported at 14 mg/l. Since that detection fluoride has not been detected above the PRG. That same sample also had the only detection of nitrite at a concentration of 1.5 mg/l, which is above the PRG for nitrate of 0.7 mg/l. The PRG for nitrate has been exceeded seven times out of the 11 samples that have been collected during this RI. The PRG for nitrate is 1 mg/l.

8.3 Other Factors To Be Considered at the Site

8.3.1 Land Use

The Hillyard Dross Site was developed within an industrial corridor and surrounding properties consist of ongoing industrial concerns and the old railyard, which is unlikely to be used for any land use besides industrial in the future. The Site is zoned industrial, and land use will be presumed to remain industrial in the future.

8.3.2 Obnoxious Odors

When recently disturbed aluminum dross is wetted, the resulting chemical reaction results in the release of ammonia. Prior to applying the foaming agent to the surface of the dross, neighboring residents complained of such odors between 1979 and 1983.

During any remedial actions, odor control must be practiced. Of particular concern is the fact that normal dust suppression by water application is not appropriate for the aluminum dross. The Spokane County Air Pollution Control Authority odor regulations will be complied with during remedial actions.

TABLE 8-1

Potentially Applicable Screening-Level or Cleanup Goals
BNSF Hillyard Dross Site, Spokane, Washington

	GROUND WATER Concentration in µg/l						
	Primary MCL	Secondary MCL	MTCA - Method A	MTCA - Method B Cancer	MTCA - Method B Non-Cancer	Required to Achieve HQ < 1	PRG
Arsenic	50	–	5	0.0583	4.8	0.0583	0.0583
Barium	2,000	–	–	–	1,120	2,000	1,120
Bromide	–	–	–	–	–	–	–
Cadmium	5	–	5	–	8	5	5
Chloride	–	250,000	–	–	–	250,000	250,000
Chromium	100	–	50	80	–	50	50
Copper	–	–	–	–	592	592	592
Fluoride	4,000	2,000	–	–	960	200	200
Nitrate-Nitrogen	10,000	–	–	–	25,600	10,000	10,000
Nitrite-Nitrogen	1,000	–	–	–	1,600	700	700
Selenium	50	–	–	–	80	50	50

	SOILS Concentration in mg/kg					
	MTCA - Method A Industrial	MTCA - Method B Cancer	MTCA - Method B Non-Cancer	100 x Ground Water Non-Cancer	Background (San Juan, 1994)	PRG
Arsenic	200	1.67	60	0.48	9	9
Barium	–	–	5,600	112	–	112
Bromide	–	–	–	–	–	–
Cadmium	10	–	80	0.5	1	1
Chloride	–	–	–	25,000	–	25,000
Chromium	500	–	400	–	18	400
Copper	–	–	2,660	59.2	22	59
Fluoride	–	–	4,800	96	–	96
Nitrate-Nitrogen	–	–	128,000	1,000	–	1,000
Nitrite-Nitrogen	–	–	8,000	100	–	100
Selenium	–	–	400	5	–	5.00

µg/l = micrograms per liter
mg/kg = milligrams per kilogram
– = Not available
MCL = Federal Maximum Contaminant Level (40 CFR 141)
MTCA Method A/B = Model Toxics Control Act

SECTION 9.0

DEVELOPMENT AND SCREENING OF ALTERNATIVES

In this section, remediation technologies and process options are combined to form potential remedial alternatives. These alternatives are designed to address the affected soil and dross at the Hillyard Dross Site and the significant pathways of potential contaminant migration. The objective of this step is to develop remedial alternatives that protect human health and the environment and encompass a variety of response options, including:

- Control of potential exposure pathways;
- Prevention of further contact of contaminants with percolating water infiltrating to ground water; and,
- Reduction of risk to an acceptable level and prevention of potential off-site migration.

In accordance with MTCA regulations, potential remedial alternatives are first developed, and then further considered if they:

1. Effectively protect human health and the environment (effectiveness criterion);
2. Comply with state and federal cleanup standards (effectiveness criterion);
3. Comply with ARARs (effectiveness criterion);
4. Provide for compliance monitoring (effectiveness criterion);
5. Provide permanent solutions to the maximum extent practicable (implementability criterion);
6. Provide for a reasonable restoration time frame (implementability criterion);
7. Consider public concerns raised during public comment on the draft cleanup action plan (implementability criterion);

Screening of potential alternatives using the above criteria results in a smaller, more manageable set of the most appropriate alternatives which are then further evaluated during the detailed analysis phase of the FS (Section 10.0).

9.1 Development of Alternatives

Several potential alternatives for remediation are outlined below. This section describes the site parameters used to develop conceptual designs and evaluate each remedial alternative. These site parameters include the following:

- Site Surface Area: The Site is currently enclosed by a chain-link fence approximately 600 feet by 600 feet in dimension. This area is slightly larger than the extent of the dross piles. Total site surface area used for comparison purposes is 250,000 square feet, which conservatively covers the known extent of dross.

- Volume of Dross: The volume of dross at the Site was surveyed in detail with over 1020 shots. Total volume in piles is 43,310 cubic yards. An additional 21,900 cubic yards of dross remains in the old gravel pit. Total volume of dross at the Site is 65,210 cubic yards. Over 43,000 cubic yards of "high salt" dross are present, and the remainder is "low salt" dross.

- Depth to the Water Table: The water table varies between 170 and 180 feet bgs.

- Soil Characteristics: Soil in the vicinity of the site consists predominately of a silty sand and gravel.

9.2 Screening Criteria

This section describes the potential remedial alternatives outlined above and evaluates each alternative with respect to criteria of effectiveness, and implementability.

The factors considered for each of these screening criteria include:

- Effectiveness
    1. Protection of human health and the environment
    2. Compliance with state and federal cleanup standards
    3. Compliance with the ARARs
    4. Provide for compliance monitoring
- Implementability

1. Provide for a reasonable restoration time frame;
2. Consider public concerns raised during public comment on the draft cleanup action plan;
3. Are problematic with respect to technical or administrative feasibility.

9.3 Screening of Alternatives

The three remedial alternatives developed for evaluation of their ability to meet site RAOs are described in this section. These include:

• Remedial Alternative 1:	Limited Action/Institutional Controls;
• Remedial Alternative 2:	Removal and Off-Site Disposal; and,
• Remedial Alternative 3:	On-Site Containment.

Initial subsections present the conceptual designs for each remedial alternative. The evaluation of the three remedial alternatives based on applicable screening criteria is discussed in the following subsections. A comparative analysis of remedial alternatives and the recommended remedial alternative for addressing site RAOs are presented in Section 10.

9.4 Alternative 1 - Limited Action/Institutional Controls

The remedial action components that constitute Alternative 1 are described below.

Remedial Action Component 1a - Ground-water Monitoring: The ground-water monitoring program would consist of semi-annual sampling events conducted at downgradient monitoring wells MW-3, MW-5 and MW-6, upgradient well MW-5. Samples collected from these monitoring wells would be subject to laboratory analysis for contaminants of concern. The ground-water monitoring program would be conducted during late summer and late winter.

Ground-water quality data collected as part of Remedial Action Component 1 would be used to evaluate potential off-site migration of contaminants of concern in ground water. Under the no action alternative, however, no remedial actions would be taken to address potential migration of contaminants of concern in ground water.

Remedial Action Component 1b - Maintenance of the Existing Fence: An approximately 8-foot high chain-link fence currently surrounds the Site. An 8-foot wide, locked gate is located at the eastern side of the Site. This fence would remain in-place if Alternative 1 was implemented. The fence would be subject to maintenance events concurrent with ground-water monitoring at the Site. Warning signs are posted at the fence gate and at each of the four sides of the Site. These signs would also be maintained.

Remedial Action Component 1c – Deed Restriction: Because implementation of Alternative 1 would leave contaminants above PRGs, a restriction to the land deed is required with mandated restrictions and notifications to WDOE.

Remedial Action Component 1d - Five-Year Reviews: Because implementation of Alternative 1 would leave contaminants above PRGs, a periodic review by WDOE will be necessary. The purpose of the review is to evaluate whether the chosen remedial action remains protective of public health and the environment. Because Alternative 1 ensures protectiveness through exposure protection (e.g., deed restrictions and fence) the review will focus on whether the controls remain in place.

For Alternative 1, five-year review activities will include the following:

- Evaluation of annual ground-water monitoring data; and
- Preparation of a five-year report summarizing site conditions and implementation of the selected remedial action, identifying the scope and nature of the five-year review, describing activities performed during the five-year review period, and presenting results and recommendations pursuant to the five-year review.

9.5 Alternative 2 - Removal and Off-Site Disposal

Alternative 2, removal and off-site disposal would involve removal of the existing dross and surface soils. The material would then be removed from the Site and transported to a disposal facility.

The remedial action components, which constitute Alternative 2, are described below.

Remedial Action Component 2a - Site Preparation: Site preparation would consist of removing the existing fence in preparation for excavation activities. Initially, an exclusion zone would be established. The exclusion zone would encompass the area of the dross and necessary maneuvering space for construction equipment such as the excavator. The exclusion zone would also include an area for loading the dross and soil. Site preparation would also include the installation of temporary roads to enable excavation within the old gravel pit and provide access to the rail lines to northwest of the Site. Dust and odor suppression would be supplied by trucks standing by with foaming agent. The nitrogen reaction with water that forms ammonia would be minimized or eliminated by using a non-water based foaming agent.

Remedial Action Component 2b - Removal of Dross and Soil: Excavators would be used to excavate dross and contaminated soil onto dump trucks. Dump trucks would then carry the load to the rail lines. Characterization samples would be collected and analyzed for approval at the disposal facility.

Remedial Action Component 2c – Transport and Disposal: Contaminated soil and dross would be loaded onto rail cars and transported to a landfill for disposal.

Remedial Action Component 2d - Site Restoration: The excavation area would be filled and graded to original grade.

Remedial Action Component 2e - Ground-water Monitoring: The ground-water monitoring program described for Alternative 1 would be implemented at the Site as part of Alternative 2 for a period of 5 years to confirm restoration of ground water beneath the Site.

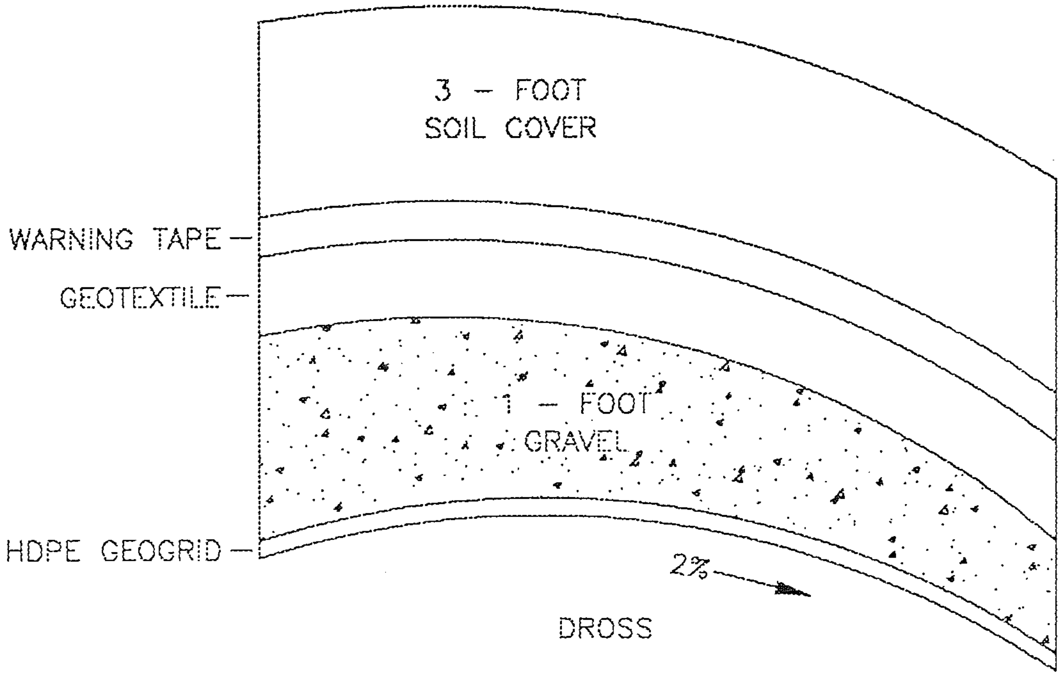
9.6 Alternative 3 – On-Site Containment

Alternative 3 involves grading the dross to a mounded surface and installation of a multi-media cap at the Site to address RAOs. The multi-media cap would be installed over the entire surface of the Site. It is designed to prevent human exposure to the dross beyond the protection offered by the fence, and to allow limited reuse of the Site for industrial purposes.

9.6.1 Description of Multi-media Cap

The following is a discussion of the material layers of the multi-media cap for Alternative 2. The material layers of the cap are schematically represented in Figure 9-1. It will be noted that this is a generalized conceptual design for multi-media cap installation, and not an absolute specification. A complete design document, which includes technical design basis, technical specifications, and construction plans for the recommended remedial action would be prepared.

HDPE Geogrid/Liner: A high tensile strength, high density polyethylene (HDPE) geogrid/liner would be placed directly over the regraded dross surface, as shown in Figure 9-1. The geogrid/liner would serve as a low permeability barrier to infiltrating rain water. The HDPE geogrid/liner also would act to distribute loading over the Site surface, and therefore limit long-term multi-media cap deflection caused by localized subsidences at the Site surface. Furthermore, the HDPE geogrid/liner would reduce short-term subsidence at the Site surface during surface cap construction.



SCHEMATIC NOT TO SCALE

EMR
INCORPORATED

Burlington Northern Santa Fe
Spokane, Washington

Multi-Media Cap
Schematic

Drawn by: I.D.S.
Checked By:
Project No.: 338
File Name: FIG_10-1.DWG
Revision No.: 1
Date: 2/16/99
Scale: as shown

FIGURE
9-1

<u>Angular Gravel Layer:</u> A 1-foot thick layer of angular gravel would be placed above the HDPE geogrid/liner. The angular gravel will be lightly compacted with a vibratory plate compacter such that the gravel particles would interlock into place, thus providing further protection against short-term subsidence during placement of the overlying soil layer, as well as assist in preventing differential settlements of the multi-media cap as a result of potential long-term subsidence. The gravel layer would further function as a drainage layer for surface water which may percolate through the overlying soil cover, thus increasing multi-media cap life by providing protection against erosion of the soil cover. During site preparation activities for Alternative 3, site grading would be conducted to establish drainage patterns for gravity drainage of water from the components of the multi-media cap. Site preparation activities are described in subsequent discussions. Because the angular gravel layer is more permeable than dross, it is expected that the bulk of any surface water percolating into the gravel layer would migrate horizontally through the gravel layer to the edge of the multi-media cap and drain to the surrounding area, outside the Site.

<u>Geotextile:</u> A woven geotextile fabric would be placed over the angular gravel layer. The geotextile would prevent clogging of the angular gravel layer by preventing migration of soil from the overlying soil cover into the gravel layer.

<u>Warning Tape:</u> Plastic warning tape would be placed on a 2-foot grid pattern over the Site surface to indicate the presence of buried hazardous materials at the Site.

<u>Soil Cover:</u> A 3-foot thick soil cover would be placed over the geofabric and vegetated with native plant species. The purpose of the soil cover is to provide an additional surface barrier to prevent exposure to the buried aluminum dross. Clean fill material would be used for soil cover.

9.6.2 Remedial Action Components for Alternative 3

The remedial action components that constitute Alternative 3 are described in the following subsections.

<u>Remedial Action Component 3a - Site Preparation:</u> The existing fence would be dismantled. The Site would then be graded to establish a surface water runoff pattern for the installed cap. The runoff pattern would optimize surface water drainage from the soil cover, as well as drainage of water from the angular gravel layer. During grading, a truck with foaming agent would be on stand-by to apply emulsified foam to the ground surface for dust and odor suppression, if necessary. The nitrogen reaction with water that forms ammonia would be minimized or eliminated by using a non-water based foaming agent.

<u>Remedial Action Component 3b - Multi-media Cap Installation:</u> Following site grading, the multi-media cap would be installed. Each material component of the

multi-media cap would be installed sequentially, beginning with the HDPE geotextile and ending with native plant species to prevent soil cover erosion.

Remedial Action Component 3c - Deed Restrictions: A deed restriction would be instituted at the Site to prohibit any future site construction that could breach the multi-media cap and expose the dross.

Remedial Action Component 3d - Reinstallation of Existing Site Fence: The existing site fence would be removed prior to beginning remedial activities for Alternative 3. Following installation of the multi-media cap, this fence would be reinstalled around the site perimeter.

Remedial Action Component 3e - Ground-water Monitoring: The ground-water monitoring program described under Alternative 1 would be implemented following completion of this remedial action. The focus of the monitoring program, which would be performed every five years, is as described for Alternative 1. Reports describing the results of monitoring would be prepared upon completion of each event, and would be incorporated with five-year review reports described below.

Remedial Action Component 3f - Surface Cap Maintenance: Long-term cap monitoring would be performed concurrently with ground-water monitoring events. As necessary, cap maintenance would be conducted. It is anticipated that cap maintenance would consist of the periodic addition of soil to the soil cover to account for natural erosion and possible site ground surface subsidence.

The surface cap maintenance component would include conducting periodic surveys to monitor possible future subsidence. These surveys would be conducted every five years, and the results would be incorporated into the five-year review reports addressed below.

Remedial Action Component 3g - Five-Year Reviews: Implementation of Alternative 3 ensures protection of public health and the environment through exposure protection and institutional controls. As described for Alternative 1, a five-year review by WDOE, focusing on whether the multi-media cap remains effective and the controls remain in place, will be required. Five-year review activities for Alternative 3 are identical to those described for Alternative 1.

SECTION 10.0

DETAILED ANALYSIS OF ALTERNATIVES

In this section, the three alternatives for addressing RAOs for the Site are evaluated.

10.1 Remedial Alternatives Evaluation Criteria

The criteria used to evaluate remedial alternatives for the Site are:

- The effectiveness of the alternative in meeting RAOs; and,
- The implementability of the alternative.

These evaluation criteria, which are described in detail below, are derived from MTCA (WAC 173-340-360) regulation for selection of cleanup actions. In addition, capital cost and the operation and maintenance cost associated with implementing the alternative are considered consistent with WAC 173-340-360 (5) (iv).

10.1.1 Effectiveness

The effectiveness of a remedial alternative is a measure of the ability of the alternative to satisfy the RAOs established for a remedial action. The effectiveness of each alternative was assessed by evaluating:

- The degree to which the alternative protects persons from exposures to the contaminants of concern during construction of the alternative (short-term effectiveness) and following completion of the alternative (long-term effectiveness); and
- The degree to which the alternative protects the existing and potential beneficial uses of the Site during construction of the alternative (short-term effectiveness) and following completion of the alternative (long-term effectiveness).

Since it is not practicable to reuse, destroy or detoxify the aluminum dross, a cleanup action that relies on on-site containment can be considered under WAC 173-340-360 (8).

10.1.2 Implementability

The implementability of an alternative is assessed by evaluating the technical feasibility and the administrative feasibility of constructing the alternative. Technical feasibility has been evaluated against the following factors:

- The degree to which an alternative can be constructed and reliably operated and maintained following construction; and
- The ability of the alternative to meet technology-specific regulations pertaining to the alternative until a remedial action is complete.

Administrative feasibility has been evaluated against the following factors:

- The likelihood of obtaining necessary permits and approvals from regulatory agencies and offices;
- The availability of required treatment, storage, and disposal services and the capacity of available services;
- The availability of equipment required to construct the alternative; and
- The time required to complete remediation.

10.1.3 Cost

The costs for implementing each alternative have been estimated to perform cost comparisons. Costs include both capital and operation and maintenance costs. The total estimated costs developed herein include the present worth cost for 30 years of operation and maintenance (O&M) following construction of the alternative. Indirect capital costs such as engineering design, legal and financial costs, construction management, and contingencies are also included. A 3% inflation rate was used to develop present worth costs. Cost estimates for each alternative are included in Table 10-1.

The costs developed for each alternative include the following qualifications and assumptions:

- Sufficient qualified labor would be available to support construction needs and schedule requirements;
- Access to work areas would be available;
- Taxes, environmental permitting costs, and deed restrictions were excluded (but are expected to influence costs by less than ten percent);

TABLE 10-1

Approximate Cost of Remedial Alternatives
BNSF Hillyard Dross Site, Spokane, Washington

ITEM	Capital	Annual O&M	Life of O&M	Total	Present Worth
No Action	$ -	$ -	-	$ -	$ -
Limited Action/Institutional Controls					
2a - Ground Water Monitoring (1)	$ 24,000	$ 16,000	30	$ 504,000	$ 269,960
2b - Maintenance of the Existing Fence	$ -	$ 500	30	$ 15,000	$ 7,686
2c – Deed Restriction	$ 5,000	$ -	-	$ 5,000	$ 5,000
2d - Five-Year Reviews	$ -	$ 2,000	30	$ 60,000	$ 30,745
Subtotal Alternative 2	$ 29,000	$ 18,500		$ 584,000	$ 313,391
Removal and Off-Site Disposal					
3a - Site Preparation (2)	$ 9,762	$ -	-	$ 9,762	$ 9,762
3b - Removal of Dross and Soil (3)	$ 325,000	$ -	-	$ 325,000	$ 325,000
3c – Transport and Disposal (4)	$ 2,730,000	$ -	-	$ 2,730,000	$ 2,730,000
3d - Site Restoration (5)	$ 700,000	$ -	-	$ 700,000	$ 700,000
3e - Ground Water Monitoring (1)	$ 24,000	$ 16,000	5	$ 104,000	$ 93,272
Subtotal Alternative 3	$ 3,788,762	$ 16,000		$ 3,868,762	$ 3,858,034
Multimedia Cap					
4a - Site Preparation (2)	$ 9,762	$ -	-	$ 9,762	$ 9,762
4b - Multimedia Cap Installation (6)	$ 455,000	$ -	-	$ 455,000	$ 455,000
4c - Deed Restrictions	$ 5,000	$ -	-	$ 5,000	$ 5,000
4d - Reinstallation of Existing Site Fence	$ 3,762	$ -	-	$ 3,762	$ 3,762
4e - Ground Water Monitoring (1)	$ 24,000	$ 16,000	10	$ 184,000	$ 147,547
4f - Surface Cap Maintenance	$ -	$ 500	10	$ 5,000	$ 3,861
4g - Five-Year Reviews	$ -	$ 2,000	10	$ 20,000	$ 15,443
Subtotal Alternative 4	$ 497,524	$ 18,500		$ 682,524	$ 640,375

Life of ground-water monitoring is 30 years.
Interest for present worth calculations is 5 percent.
Capital cost for ground-water monitoring is installation of dedicated pumps.
Notes on construction estimates:
(1) Capital cost is for installation of four dedicated sample pumps. O&M costs is based on sampling four wells each quarter.
(2) Mobilization ($6,000) plus create 600 ft access road ($6.27/ft).
(3) Assumes excavation rate of $5/cy
(4) Assumes transportation plus tipping fee of 35/cy
(5) Assumes 35,000 tons of backfill transported and placed at $20/ton
(6) Assumes surface area of cap of 45,000 sf plus oversight costs of $5,000.

- O&M costs were calculated for a maximum 30-year period;
- Published unit cost data were used where appropriate;
- Quantities applied to unit costs were approximate and would be accurately established at the time of implementation;
- Vendor quotes were used where available and appropriate.

10.2 Remedial Alternatives Evaluation

In the following sections, each alternative is evaluated according to the effectiveness, implementability, and cost criteria.

10.2.1 Alternative 1 – Limited Action/Institutional Controls

Implementability of Alternative 1. The existing fence at the Site would be maintained, and long-term ground-water monitoring would be conducted. Ground-water monitoring and maintenance of the existing fence could easily be implemented, although the long-term integrity and long-term maintenance requirements of the existing cap cannot be quantified with certainty.

Cost of Alternative 1. The estimated present worth cost to implement Alternative 1 is $313K. This includes fence maintenance and ground-water monitoring for a period of 30 years following implementation of remedial actions for Alternative 1.

10.2.2 Alternative 2 - Removal and Off-Site Disposal

The evaluation of Alternative 2 for addressing RAOs is presented in the following subsections.

Effectiveness of Alternative 2 in Meeting RAOs: Alternative 2 would provide long-term effectiveness and reduction in toxicity, mobility, or volume since the contaminants of concern would be completely removed from the Site. Alternative 2 would provide short-term and long-term effectiveness for meeting RAO-1 and RAO-2.

Implementability of Alternative 2. Alternative 2 is technically feasible. Routine excavation and transport methods would be used.

Cost of Alternative 2: The estimated present worth cost to implement Alternative 2 is $3,858K. This includes ground-water monitoring according to the ground-water monitoring program described under Alternative 2 on a semiannual basis for five years following implementation of remedial actions for Alternative 2.

10.2.3 Alternative 3 – On-Site Containment

The evaluation of Alternative 3 for addressing RAOs is presented in the following subsections.

Effectiveness of Alternative 3 in Meeting RAOs: Installing the multi-media cap for Alternative 3 would be effective in prohibiting human exposure to contaminants of concern whether by direct contact or by airborne particulates. Therefore, Alternative 3 would be effective in reducing the mobility of contaminants of concern. The cap contains flexible material components so that even if large-scale subsidence did occur in the long-term at the Site, the cap would flex with the subsidence such that a barrier to contaminants of concern would be maintained. The presence of three feet of soil cover would prohibit exposure due to vandalism or weathering, and deed restrictions in combination with warning tape would provide notification in the event of future site construction actions in the area. Alternative 3 is viewed as effective in satisfying RAO-1 except for on-site ground water use as a source of drinking water.

Alternative 3 also addresses RAO-2 and RAO-3. The Site could be redeveloped for industrial uses. The geogrid/liner would reduce the amount of leachate that infiltrates to ground water.

Implementability of Alternative 3. Alternative 3 presents no implementation difficulties. The multi-media cap design shown in Figure 9-1 can be constructed with standard construction equipment and methods. An air monitoring program would be in-place during site grading, therefore regulatory agency permission to perform site grading can be obtained.

Cost of Alternative 3. The estimated present worth cost to implement Alternative 3 is $640K. This includes fence and cap maintenance and ground-water monitoring for a period of 30 years following implementation of remedial actions for Alternative 3.

10.3 Comparative Analysis

The following discussion summarizes the degree to which the various remedial alternatives meet the evaluation criteria of effectiveness in meeting RAOs, implementability and cost, and presents a recommendation for the preferred alternative.

This analysis is based on the understanding that current conditions partially satisfy short- and long-term effectiveness criteria for meeting RAO1 established for the Site.

Alternative 1 would be effective in the long-term in meeting RAO1. However, this alternative would not adequately satisfy short-term effectiveness criteria for RAOs.

The two other alternatives, Alternative 2 and Alternative 3, are both viewed as satisfying RAO-1 and RAO-2. However, Alternate 3 is cost prohibitive. Additionally, removal of the dross and contaminated soil is not viewed as necessary to satisfy RAO-2, based on the results of historic ground-water monitoring, soil characteristics, site hydrogeologic conditions, and the chemical properties of contaminants of concern in the subsurface environment. Since it is not practicable to reuse, destroy or detoxify the aluminum dross, Alternative 3, which relies on on-site containment can be considered under WAC 173-340-360 (8).

Remedial Alternative 2, off-site disposal, is over six times the cost as Alternative 3, on-site containment. The degree of protection from both alternatives is equivalent.

- Metals are currently immobile and would be permanently contained under both alternatives.
- Chloride is present in higher concentrations in soil compared with dross; Alternative 3, therefore, does not provide additional protection of ground water compared with Alternative 2 for minimizing chloride migration.
- Other contaminants of concern would be contained under both alternatives.

10.4 Recommended Alternative

Alternative 3 - On-Site Containment is therefore the recommended remedial alternative for the Site. This approach satisfies RAOs, is cost effective relative to the benefits of the remedial action, and provides environmental protection from contaminants of concern. This alternative will satisfy all RAOs for the Site by protecting persons from direct exposure to the contaminants of concern, and by protecting the existing and potential and probable beneficial uses of land. It is easily implementable and is cost-effective relative to the other two remedial alternatives evaluated for the Site.

One potential land use for the Site has been suggested by the Washington Department of Transportation. The Site could be used as a park-and-ride parking lot or as part of a highway project. That land use is consistent with the recommended alternative.

SECTION 11.0

CONCLUSIONS

11.1 Remedial Investigation

RI analytical results confirm previous investigations results showing that elevated concentrations of ammonia, chloride, fluoride, and nitrate are present in aluminum dross. In addition, results show that elevated concentrations of some RCRA 8 metals barium, chromium and copper are present in the aluminum dross. Of these metals and the other metals in the dross, leachable concentrations of concern were not detected in TCLP analyses or a 60-year leachability simulation test (EMR, 1996).

Additional TCLP analyses for chloride, potassium, sodium and ammonia were completed for the RI. The average leachable concentration of chloride from eight samples was 5.28 mg/l, which suggests that most of the leachable chloride has been removed from the dross. Results for potassium and sodium are higher suggesting that significant leachable quantities remain for these compounds.

During boring and well installation, the subsurface materials encountered consisted of poorly sorted mixtures of gravel and sand. The uppermost aquifer is approximately 175 feet below the ground surface. The unconfined aquifer is the Spokane-Rathdrum sole source aquifer, which underlies eastern Washington and northern Idaho. The aquifer underlies approximately 350 square miles and is used by over 400,000 people. The Site is located within the Hillyard trough, where ground-water velocity has been calculated at 46 feet per day (Molenaar, 1988). Based on grain size distribution results, the hydraulic conductivity of the sand and gravel is approximately 5,000 gpd/ft^2. The regional ground-water flow direction in the vicinity of the Hillyard Dross Site is west.

Ground-water quality in the Spokane-Rathdrum aquifer is relatively good, with total dissolved solids typically below 250 mg/l. Recharge is from precipitation and rivers. Leachate formed by rain water infiltrating through the aluminum dross at the Site contains elevated concentrations of ammonia, chloride, fluoride, potassium, sodium, nitrate. These compounds flow through the unsaturated zone to ground water. Chloride concentrations beneath the aluminum dross are as high as 700 mg/l. The concentrations have diminished, however, from historical levels. Metals are not present above naturally occurring concentrations in ground water.

11.2 Fate and Transport Evaluations

Inorganic contaminants from the aluminum dross are transported along the following routes of migration:

- Transport of contaminant compounds in solution or via sediment transport from surface soils via surface water runoff;

- Vertical transport of contaminant compounds from the Vadose Zone to ground water via leaching;

- Horizontal and vertical transport of contaminant compounds in ground water via ground-water flow; and,

- Air transport of contaminants in particulate matter.

The primary potential migration pathways for contaminant movement at the Hillyard Dross Site are leaching of soil contaminants to ground water and transport of contaminants downgradient of the source area by ground-water flow. Average percolation to the aquifer is estimated at 0.004 inches per year. Over the two-acre area of aluminum dross, average annual percolation is approximately 220 gallons.

11.3 Risk Assessment

The risk assessment evaluated the following current potential receptors:

- On-site workers;

- Trespassers; and,

- Various off-site populations (e.g., workers, residents, passers-by).

Under future conditions, the following potential receptors were evaluated:

- Construction workers; and,

- Hypothetical on-site residents.

Consistent with the fate and transport evaluation, the following exposure pathways were evaluated for the human health risk assessment. Potential exposure pathways associated with soil include:

- Direct contact with soil (i.e., incidental ingestion and dermal contact); and,

- Inhalation of fugitive dust released from disturbed soils.

Potential exposure pathways associated with ground water include:

- Use of ground water as a residential water supply (ingestion and direct contact).

The cumulative Hazard Quotient associated with exposure routes from dross for the construction worker, trespasser, off-site resident and hypothetical on-site resident was 3. Potential cancer risk was 0.3 for ingestion and 11 for inhalation. The cumulative Hazard Quotient associated with exposure routes from contaminated soil for the construction worker, trespasser, off-site resident and hypothetical on-site resident was 0.6. Potential cancer risk was 0.4 for ingestion and 13 for inhalation. The cumulative Hazard Quotient associated with exposure routes from ground water for the hypothetical on-site resident was 63. Potential cancer risk was 2.54×10^{-5}.

11.4 Project Remediation Goals

ARARs are exceeded by arsenic, barium, cadmium, chloride, chromium, fluoride and selenium in dross or soil. Of these parameters, however, only arsenic, barium, cadmium, copper and selenium contribute significantly to the risk to human health at the Site. PRGs for these compounds are listed in Table 8-1. Dross sample concentrations exceed PRGs for chloride, chromium, fluoride and selenium. Soil sample concentrations exceed PRGs for chloride and selenium. Ground-water PRGs are exceeded for chloride and fluoride.

11.5 Feasability Study

The three remedial alternatives developed for evaluation include:

- Remedial Alternative 1:	Limited Action/Institutional Controls;
- Remedial Alternative 2:	Removal and Off-Site Disposal; and,
- Remedial Alternative 3:	On-Site Containment.

Each alternative is evaluated according to the effectiveness, implementability, and cost criteria.

Under the Limited Action/Institutional Controls alternative, the existing fence at the Site would be maintained, and long-term ground-water monitoring would be conducted. Ground-water monitoring and maintenance of the existing fence could easily be implemented, although the long-term integrity and long-term maintenance requirements of the existing cap cannot be quantified with certainty. The estimated present worth cost to implement Alternative 1 is $313K. This includes fence maintenance and ground-water monitoring for a period of 30 years following implementation of remedial actions for Alternative 1.

The effectiveness of the Removal and Off-Site Disposal alternative for the aluminum dross and contaminated soil is obvious, and it is technically feasible. Routine excavation and transport methods would be used. The cost, however, is substantial and disproportionate to the benefits of Alternate 2 versus Alternate 3. The estimated present worth cost $3,858K.

Installation of a multi-media cap would be effective in prohibiting human exposure to contaminants of concern whether by direct contact or by airborne particulates. In addition, the amount of water infiltrating through the cap and dross material to ground water would be negligible. Therefore, the alternative is viewed as effective in satisfying remedial action objectives. Construction presents no implementation difficulties, and can be constructed with standard construction equipment and methods. The estimated present worth cost to implement Alternative 3 is $640K. This includes fence and cap maintenance and ground-water monitoring for a period of 30 years following implementation of remedial actions for Alternative 3.

11.6 Preferred Remedial Alternative

Installation of the multi-media cap is the recommended remedial alternative for the Site. The alternative satisfies remedial action objectives, is cost effective relative to the benefits of the remedial action, and provides environmental protection from contaminants of concern. It is easily implementable and is cost-effective relative to the other remedial alternatives evaluated for the Site. Remedial Alternative 2, off-site disposal, is over six times the cost as Alternative 3, on-site containment. The degree of protection from both alternatives is equivalent.

REFERENCES

Alt, David D, 1984. *Roadside Geology of Washington*, Mountain Press Publishing Company, Missoula, Montana.

Battelle Corporation, 1995, *Contaminants and Remedial Options at Selected Metal-Contaminated Sites*, Battelle Columbus Division, National Risk Management Research Laboratory, Office of Research and Development, EPA/540/R-95/512, July 1995.

Chempro, 1989, Hillyard Aluminum Dross Stabilization and Characterization Study: Prepared for Burlington Northern Railroad and Glacier Park Company, 26 p.

Drever, J. I., 1982, The Geochemistry of Natural Waters: Prentice-Hall, Inc., Englewood Cliffs, New Jersey, 388 p.

Drost, B. W., and Whitemand, K. J., 1986. *Surficial Geology, Structure, and Thickness of Selected Geohydrological Units in the Columbia Plateau*, United States Geological Survey Water Resources Investigations Report 84-4326.

EMR, 1998, *Draft Focused RI/FS Workplan - The Burlington Northern and Santa Fe Railway Company, Focused Remedial Investigation/Feasibility Study, Aluminum Recycling - Wellesley Site, Spokane, Washington.* August 1998.

EMR, 1997, *Ground water Sampling Report, Hillyard Aluminum Dross Site, Spokane, Washington.* September 1997.

EMR, 1996, *Summary Report – BNRR Hillyard Aluminum Dross Site, Spokane, Washington.* June 1996.

Feth, J. H., 1981, Chloride in natural continental water - a review: U.S. Geological Survey Water-Supply Paper 2176, p. 9-16.

Griggs, A.B., 1976. *The Columbia River Basalts in the Spokane Quadrangle, Washington.* United States Geological Survey Bulletin 1413.

Hallberg, G.R., 1989, Nitrate in Ground Water in the United States, in Follett, R.F., ed., Nitrogem management and ground water protection: Ney York, Elsevier Development in Agricultural and Managed-Forest Ecology 21, p. 35-74.

Hem, J. D., 1985, Study and Interpretation of the chemical characteristics of natural water: U.S. Geological Survey Water-Supply Paper 2254, p. 164.

Joseph, Nancy L., 1990. *Geological Map of the Spokane 1:100000 Quadrangle, Washington and Idaho*, Washington Division of Geology and Earth Resources Open File Report 90-17.

Lindsay, W. L., 1979, Chemical Equilibria in Soils. John Wiley & Sons, New York, N. Y.

Livingston, V. E., 1978. *Geology of Washington*, Washington Department of Conservation, Division of Mines and Geology, Reprint 12.

Molenaar, Dee, 1988. The Spokane Aquifer, Washington: Its Geologic Origin and Water-Beariung and Water-Quality Characteristics: United States Geological Survey Water-Supply Paper 2265, 74 p.

Petters, N. E., and Bonelli, J. E., 1982, Chemical composition of bulk precipitation in the north-central and northeastern United States, December 1980 through February 1981: U.S. Geological Survey Circular 874, p. 48-57.

San Juan, Charles, 1994, Natural Background Concentrations in Washington State: WDOE Publication 94-114.

Schroeder, Paul R., et al, 1994, The Hydrologic Evaluation of Landfill Performance (HELP) Model Version 3: U.S. EPA/600/R-94/168a.

Schuster, J. Eric, 1992. *Geologic Map of Washington*, Washington Division of Geology and Earth Resources, Department of Natural Resources.

Shacklette, T., and Boerngen, J. G., 1984, *Element Concentrations in Soils and Other Surficial Materials of the Conterminous United States.* U. S. Geological Survey Professional Paper No. 1270.

Swanson, D. A., Wright, T. L., Hooper, P. R., and Bentley, R. D., 1979. *Revisions in Stratigraphic Nomenclature in the Columbia River Basalt Group*, United States Geological Survey Bulletin 1457-G.

U.S. EPA, 1979 Water-related Environmental Fate of 129 Priority Pollutants: EPA-440/4-79-0299

U.S. EPA, 1985, Water Quality Assessment: EPA/600/6-85/0029

U.S. Environmental Protection Agency (EPA), 1986, *Test Methods for Evaluating Solid Waste*, SW-846, Third Edition.

United States Environmental Protection Agency, 1988, *Guidance for Conducting Remedial Investigation and Feasibility Studies Under CERCLA*. Office of Emergency and Remedial Response.

Vaccaro, J.J., and Bolke, E.L., 1983, Evaluation of Water-Quality Characteristics of Part of the Spokane Aquifer, Washington and Idaho: U.S. Geological Survey Water-Resources Investigations Open-File Report 82-0769, 69 p.

Walton, William C., 1984, *Practical Aspects of Ground Water Modeling*: National Ground Water Association, 566 p.

Washington State Department of Ecology (WDOE), 1992, *Statistical Guidance for Ecology Site Managers*, Publication No. 94-54.

WDOE, 1996, *Model Toxics Control Act Cleanup Levels and Risk Calculations (CLARC II) Update*.

WDOE, 1996, *The Model Toxics Control Act Cleanup Regulation*, Publication No. 94-06, Amended January 1996.

Welch, A.H., M.S. Lico, and J.L. Hughes, 1988, *Arsenic in Ground Water of the Western United States*, Ground water, Vol. 26, No. 3, May-June 1988.