Final
Remedial Investigation/
Feasibility Study

Remediation Area 2 • Salmon Bay Steel • North Section

The Port of Seattle Southwest Harbor Cleanup and Redevelopment Project

Volume I
Remedial Investigation

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3.0 Sources of Potential Contamination

3.1 Historical Information

Current and past uses identified at RA2 were related to steel mill support operations, and included slag and scrap metal processing and stockpiling, rail lines, and fueling areas. Aspects of past site use relating to sources of chemical contamination are briefly summarized in the following discussion. Table 2-1 provides a summary of the past owners of the steel mill and the RA2 site, the duration of ownership, and the property boundary during ownership.

The steelmaking processes used at the steel mill have changed as new technologies and equipment were developed. Two steelmaking processes have been used: open-hearth furnace and electric arc furnace. Open-hearth furnaces were used initially, but electric arc furnaces were added in 1929. In 1957, the remaining open-hearth furnaces were replaced with electric arc furnaces. Additional information on the different steelmaking processes is presented in Section 3.3.1.

Pig iron and iron or scrap metal (usually in a 50-50 ratio) are the sources of iron for open-hearth furnaces. Electric furnaces also use iron or steel scrap but, unlike open-hearth furnaces, the electric furnaces can melt a charge of 100 percent scrap (Cannon 1974). Since at least 1929, the primary feedstock for the steel mill has been scrap metal. Scrap consists of the byproducts of steel fabrication and broken or discarded articles containing iron or steel. This scrap metal consists of outdated consumer goods; beams, girders, railings, pipe from building demolition; farm or industrial machinery; railroad rails and automobiles. Scrap often contains unknown and unwanted elements such as copper, lead, tin, and nickel that may be difficult to identify. These elements, which alloy readily with steel, are referred to as "tramp alloys" and may be removed during the steelmaking process or in many cases, render the steel unfit for use (Kirk-Othmer 1983).

Historically, byproducts from steelmaking and fabrication processes included slag, pickle liquor, mill scale, and dust. However, pickle liquor use was terminated prior to Salmon Bay Steel's purchase of the facility. Slag, pickle liquor, and mill scale are the primary byproducts that have been stored or disposed at RA2. Slag is a rock-like residue composed of lime and metal impurities that remain after steelmaking. Slag has been the primary material used as fill throughout RA2 since the early 1920s. The slag/soil fill consists primarily of slag but also includes refractory brick, soil, and other debris. Slag/soil fill depths range from 1 to 25 feet over the site, but average 15 feet

thick over most of the area. Slag is currently stockpiled on the site. Additional information on slag characteristics is presented in Section 3.3.

Pickle liquor consists primarily of sulfuric acid and metals and was used to clean the steel before applying the final finish to the steel product. Historically, pickle liquor was disposed of near the Rebar Shop and on RA3. Additional information on pickle liquor is presented in Section 3.4.

Mill scale is the oxidized "skin" that forms on the outside of the steel product. It is formed when the hot metal exits the furnace and is exposed to air and cooling water. Mill scale has also been used as fill at RA2, but is currently only stockpiled on the site. The mill scale appears to be relatively inert and ranges in size from a fine powder to scales approximately 1/2 inch in size. Slag and mill scale may contain metallic iron, zinc, lead, and manganese, as well as the metal oxides of iron, zinc, calcium, silica, and aluminum (Tetra Tech 1989).

Dust created during the primary production of steel is captured in the baghouse and is comprised mainly or iron (34 percent) and zinc (20 percent) with lesser amounts of lead, manganese and other constituents (Tetra Tech 1989). Trace amounts of cadmium and chromium are also present in the baghouse dust (Tetra Tech 1989). Baghouse dust is a RCRA-listed waste (K061). Additionally, historical EP Toxicity test data from the Seattle Steel facility indicates that the baghouse dust contained leachable cadmium and lead (Hart Crowser 1987).

PGG (1990) reported that it was not a common historic practice to dispose of baghouse dust at RA2. Seattle Steel sold baghouse dust for a profit until 1982, therefore, the dust was conserved rather than disposed. One reported exception was when Bethlehem Steel mixed approximately 50 cubic yards of dust with spent pickle liquor to neutralize it before disposal at RA2 (Bob Dutton, in Personal Communication to Janet Knox 1990). Collected baghouse dust from Salmon Bay Steel is recycled for its zinc.

Historically, the primary petroleum products used in the steelmaking process included diesel, gasoline, turbine oils, fuel oils, hydraulic oils, lubricating and cutting oils, and greases. Prior to Salmon Bay Steel's ownership of the steel facility, some of the petroleum products used for mill operation have been stored and disposed of at RA2. Fuel oil was one source of energy for operating the steel furnaces. Four ASTs for storing fuel oil were located on the east side of the site from the early 1940s to the 1960s (Figure 2-6 through 2-9). Two above-ground fuel tanks were installed adjacent to the southwest corner of RA2 between 1960 and 1980 (Figure 2-9 through 2-12). These tanks were removed in 1988 (Parametrix 1993). In 1969, Bethlehem

Steel records indicate that 300 gallons of heavy tars, greases, and used oils were disposed of in the area east of these tanks (R. Mytty, Bethlehem Steel files 1969).

An underground 8-inch fuel oil pipeline was reported to cross the site (Parametrix 1993). PGG (1990) reported that the line which ran from the West Waterway of the Duwamish River and across RA2 was removed before 1980, although no records were found documenting this. The 8-inch diameter fuel oil pipeline was not encountered by METRO while excavating to install the RETS Line on the eastern side of the RA2 (PGG 1990). Test pits TP14 through TP18 were excavated in the west central portion of RA2 during the Phase I investigation and the fuel line was not located.. An 8-inch diameter fuel line was observed beneath the SW Spokane Street viaduct (Appendix A). The pipeline observed beneath SW Spokane Street is reported to have serviced fuel tanks on the steel mill property.

Prior to the banning of PCBs from general industrial use, materials containing PCBs were used at many points in the Bethlehem and Seattle Steel manufacturing process. Due to the high temperature manufacturing process, PCBs were used for their heat transfer abilities in soaking pits and hydraulic systems. Cooling water containing PCBs was discharged to an unlined holding pond where a portion of the water was discharged to the LOL (Ecology 1990). Since acquiring the operation, Salmon Bay Steel has prohibited use of any PCB containing materials in the process and has stopped using the holding pond in its cooling water system. Currently there are low levels of PCBs found in LOL Water that can be traced to historical operations.

Prior to Salmon Bay Steel ownership, some amount of chemical wastes were reportedly disposed of north of the Rebar Shop at RA2. PGG (1990) references Bethlehem Steel file records presented by R. Mytty as listing fill material including chemical wastes. The constituents of this chemical waste were not documented in steel mill records, but could have included a range of non-hazardous and hazardous wastes. Drums, reportedly containing soil contaminated with 1,1,1-trichloroethane, were uncovered in this area and a site cleanup was performed by METRO (Kulzer 1988).

Prior to Salmon Bay Steel ownership, a boat construction contractor leased the northern part of the rebar building in 1991. No solvents or paints were noted in the boat construction area; however, fiberglass resins, marine paint, solvents, thinners, and several drums of waste oil were noted in the former Eastern Products Warehouse during a 1991 Seattle Steel environmental assessment (Confidential 1991).

3.2 Buildings and Surface Debris

Environmental Health Services, Inc. (Black and Veatch 1994a), conducted onsite inspections of all buildings at RA2 as part of the Phase I Field investigation. These assessments found asbestos, lead-based paint, and fluorescent light ballasts containing PCBs. Asbestos was present in building siding, vinyl asbestos tile, acoustic ceiling material, and heater duct paper. These materials will require special handling and disposal methods during building demolition, but are not sources of contaminants to soils or water at RA2 in their existing state. Removal of these structures and debris will be conducted under a separate demolition contract and is not included as part of this RI/FS report.

Stockpiles of slag, mill scale, and scrap metal cover the surface of a large portion of the southern half of RA2 (Figure 2-13). Slag is discussed extensively in the following sections. Mill scale has been used as fill material at RA2 and is a source of metals in the slag/soil fill. Scrap metal is processed and stored on RA2 before being used for steel production. Although the scrap metal has not been used as fill, pieces of metal are present in the fill material. Therefore, scrap metal is also a source of metals in RA2 soil. In addition, the scrap metal stored on the site contains automotive and industrial equipment parts that required oil and grease during use. Therefore, the scrap metal piles are a likely source of TPH contamination on the site.

Concrete and construction debris containing some rebar and soil have been disposed of on the northern portion of RA2 (Figure 2-13). The construction debris are relatively inert and do not appear to be a potential source of contamination.

3.3 Slag and Slag/Soil Mixtures

3.3.1 Production of Steel Slag

The manufacture of steel involves the removal from iron (i.e., pig iron, iron, or scrap metal) by oxidation, of excess quantities of carbon and silicon, and the addition of small quantities of other constituents that are necessary for imparting special properties to the steel. Steelmaking is basically a refining process in which the unwanted constituents in the iron are transferred to slag. Although the steelmaking process may vary with different processes, the same fundamental slag-metal reactions apply to them all (Cannon 1974).

Oxidation is the primary chemical process that converts a molten bath of scrap into steel. The oxygen combines with the unwanted elements (with the exception of sulfur) and, unavoidably, some of the iron, to form oxides which leave the bath as gases or enter the slag. The mechanism by which sulfur is removed does not involve

direct reaction with oxygen but depends instead on whether the slag is sufficiently alkaline and temperatures are high enough. When the carbon, phosphorus, and sulfur concentrations are decreased and the temperature has been raised to the desired level, the steel is tapped from the furnace into a ladle at the same time that ferromanganese, ferrosilicon, and other additional agents are added to deoxidize the steel and obtain the desired composition. For alloy steel, copper, nickel, and molybdenum can be added at any time without loss by oxidation. Alloy elements such at aluminum, titanium, zirconium, vanadium, and boron are added in the ladle because they are easily oxidized (Kirk-Othmer 1983). The current Salmon Bay Steel process may vary from this description.

For a number of years, much of the steel made in the United States, including Bethlehem Steel, was produced by the open-hearth process. The open-hearth furnace is a large structure constructed primarily of refractory bricks. The iron or scrap metals are placed on the bottom of an elongated tunnel-like reverberatory furnace. A fuel, such as fuel oil or tar, is heated and injected into the furnace. Preheated air burns the fuel, heating the scrap until it melts. Excess carbon and silicon in the hot metal are removed by oxidation. The oxygen comes from air above the bath, oxygen gas blown into the liquid, or iron ore added to the scrap.

The electric arc furnace is currently the principal electric steelmaking furnace. These furnaces provide the higher temperatures and flexibility of operation required for the production of alloy steels. In this type of furnace, an electric arc passes between electrodes, either above the metal or through the metal bath, heating the scrap metal placed in the furnace's "charge bucket." Ores or additives may be added to form different alloys. Ores and additives can include columbium, ferro-vanadium, graphite, high carbon chrome, manganese, and nickel (Tetra Tech 1989).

Modern steelmaking processes are either acidic or alkaline processes. Historically and presently, an alkaline process is used at the steel manufacturing facility operated by Salmon Bay Steel. Lime is added before or during the melting stage to force impurities in the metal to float to the top of the charge bucket in a frothy material. The frothy substance is poured off the top of the molten steel and allowed to cool until it solidifies as slag. Carbon, manganese, and silicon are removed with relative ease during this process and are components in slag (Kirk-Othmer 1983). Phosphorus and sulfur are also removed by the alkaline process. The addition of lime produces an alkaline slag that forms compounds with phosphorus and sulfur during the refining operations, removing these chemicals from the metal.

Slag is a byproduct of both open-hearth and electric arc steelmaking. The solidified slag is removed in irregular, brittle sheets. It is still extremely hot and must be cooled before handling. The cooled slag is crushed and piled, and may be reused. Slag was used as fill at RA2. Currently, the slag is reused as offsite fill, railroad ballast, or roadbed material.

3.3.2 Slag Studies

Information concerning slag and slag/soil at RA2 was compiled from general steel slag data reported in scientific publications and from site-specific results obtained in two field investigations. Parametrix conducted a site investigation for the Port of Seattle in 1993 at the former Seattle Steel Inc. property (RA3) directly north of RA2 and collected data on slag and slag/soil chemistry and characteristics. Parametrix collected 54 samples for chemical analysis from the slag/soil used as landfill cover and the stockpiled slag at the former Seattle Steel Inc. property. Selected samples were also analyzed for pH and acute fish toxicity tests. In addition, data collected by Woodward Clyde (1994) at RA3 provided additional information on slag chemistry. Data from these investigations were used because selected samples were identified as slag, and were not slag/soil mixtures. Finally, relevant information collected by Hart Crowser (1987) and M-K Environmental (1990) was summarized by Black and Veatch (1994a).

Each of these investigations included data used to characterize and quantify surface material and debris piles that were composed primarily of slag from the steel processing facilities adjacent to RA2 prior to Salmon Bay Steel's operation of the facility. This information is summarized in the following sections.

3.3.3 Physical Characteristics

Steel slag is relatively non-porous, and consequently makes a high density stone of high crushing strength (Lee 1974). It is denser and stronger than blast furnace slag, and has a high resistance to polishing. Typical physical properties of steel slag are as follows:

Specific gravity	3.1 to 3.5
Bulk density	1600 to 1760 kg/m^3

Water absorption   0.2 to 2 percent by mass

The mixed slag/soil fill at RA2 ranges in color from gray to brown depending on the relative proportions of slag, mill scale, refractory bricks, and sandy soil. The slag typically resembles a gray crushed rock; the mill scale appears dark brown and the sandy soil tan to light brown. Grain size distribution of the slag/soil fill is typical of crushed rock, ranging from boulders to fine sand, with predominant sand and gravel fractions. Surface slag/soil fill permeability at RA2 is relatively high, as evidenced by the quick infiltration rate following storm events observed during the Phase I investigation. Little or no surface runoff from unpaved portions of the site was observed during an intense rainstorm.

Bulk density values of the slag/soil fill ranged from 128 to 166 pounds per cubic foot (pcf), indicating that the material is extremely dense (e.g., concrete = 165 pcf). This characteristic accounts for the high compaction and resistance that was observed during test pit excavation. However, the slag/soil fill is also fairly permeable. Hydraulic conductivity ranges for the slag/soil mixtures encountered at a location adjacent to RA3 were measured by Hart Crowser (1987) and reported by Black and Veatch (1994a). The granular slag/soil fill has an estimated hydraulic conductivity of $<1 \times 10^{-3}$ to 1×10^{-2} cm/s. Results of the slug tests conducted in the present investigation corroborate these data. Black & Veatch performed slug tests during Phase II of the RA2 investigation. Hydraulic conductivities measured in the slag/soil fill (upper fill/alluvial aquifer) ranged from 1.4×1^{-4} to 3.7×10^{-1} cm/s with an average of 7.1×10^{-2} cm/s. Porosity values ranged from 29 to 38 percent.

3.3.4 Chemical Characteristics

The general composition of steel slag is approximately half lime, with silica (10 to 20 percent) and iron oxide (12 to 20 percent) as the two other main constituents (Lee 1974). Aluminum (3 to 4 percent), magnesium (2 to 9 percent), sulfur (0.2 to 0.9 percent) and other trace metal impurities may also be present. Slag may vary between amorphous and crystalline states depending on the temperature at which the slag was quenched. If the slag is allowed to cool naturally, various silicate minerals will form. The majority of slags contain the mineral larnite ($2CaO.SiO_3$) and lime (CaO) as main components (Cooke 1994). Specifically, electric arc slag is composed of calcium silicates containing slaked lime (i.e., lime that has absorbed water and carbon dioxide from the air) and metal impurities (Cooke 1994). The high pH

(greater than 10) measured in groundwater at RA2 indicates that free lime (CaO and Ca(OH)$_2$) is present in equilibrium between the source slag and groundwater. At a lower pH of 9 to 10, calcium would be available as Ca(OH)2 and calcite (CaCO3). Gypsum (CaSO$_4$) may also be present due to the presence of sulfur in the scrap metal (Cooke 1994). The specific nature of slag from Salmon Bay Steel may vary from this general description.

There is also a metal component in slag, although this may vary depending on the source material. For example, lead is never intentionally added to steel and so is present in slag only as a fugitive component (Cooke 1994). Fugitive metals are common when the source material is scrap metal that may contain steel alloys or other metal components.

Analyses of a slag sample conducted by Bethlehem Steel in 1975 indicate that the slag produced at that time was 21 percent calcium, 12 percent iron, and 12 percent silica. Manganese (8.6 percent), aluminum (4.72 percent), and magnesium (3 percent) were also found at concentrations greater than 1 percent. Other metal impurities included chromium (0.46 percent), copper (0.038 percent), and nickel (0.0026 percent). Lead was reported as less than 0.02 percent (Hart Crowser 1987).

Specific information on the characteristics of slag that has been produced at the steel manufacturing facility prior to Salmon Bay Steel's ownership was derived from the sampling and analysis conducted by Parametrix (1993) and Woodward-Clyde (1994) at the former Seattle Steel Inc. property (RA3). Samples of slag collected by Parametrix from storage piles and landfill fill cover material were analyzed for six metals, TPH, and PCBs. Eleven of these samples were identified by Parametrix, based on field observations, to consist of slag, rather than slag/soil fill or other debris. Results from analyses of these eleven samples are presented in Table 3-1. The same approach was used for samples of slag cover material collected by Woodward Clyde as part of the RA3 RI. These samples were analyzed for four metals, TPH, and PCBs and the results are also presented in Table 3-1.

Arsenic and chromium were reported at concentrations greater than the detection limit in all slag samples. Cadmium, copper, lead, and zinc were found in all but one of the samples analyzed by Parametrix. Cadmium and lead were also reported in at least half of the samples analyzed by Woodward Clyde. Although PCBs and petroleum are not chemicals resulting from the steel making process, these compounds are consistently present in the slag samples. PCBs were detected in all but one sample; TPH or oil was reported in over half of the samples.

Table 3-1
Chemical Concentrations Reported in Steel Slag
From Storage Piles and Landfill Cover

	Parametrix (1993)				
	No. of Samples	No. of Detects	Minimum mg/kg, dry wt.	Maximum mg/kg, dry wt.	Average mg/kg, dry wt.
Metals					
Arsenic	11	11.	2	29	15
Cadmium	11	10	0.5 U	9.4	3.0
Chromium	11	11	26	1,900	781
Copper	11	10	5 U	1,800	575
Lead	11	10	5 U	340	127
Zinc	11	10	5 U	2,400	654
TPH/Oil[1]	11	8	10 U	48,000	4,510
Aroclor 1248	11	10	.050 U	5.8	1.3
	Woodward Clyde (1994)				
	No. of Samples	No. of Detects	Minimum mg/kg, dry wt.	Maximum mg/kg, dry wt.	Average mg/kg, dry wt.
Metals					
Arsenic	73	73	1.9	190	31
Cadmium	73	57	0.26	100	5.6
Chromium	73	73	25	2,500	841
Lead	73	73	3.1	6,400	381
TPH/Oil[1]	51	46	32	3,900	494
Aroclor 1248	60	39	0.005	200	5.6

[1] - Parametrix analyzed total petroleum hydrocarbons using Method 418.1;
  Woodward Clyde analyzed oil using Method WTPH-HCID.
J - Estimated value.
U - Not detected at or above the concentration indicated.
UJ - The analyte PQL is an estimate.

Woodward Clyde (1994) analyzed six samples from a variety of slag cover matrices at RA3 for hexavalent chromium. Hexavalent chromium was undetected at 0.20 mg/kg in all samples.

3.3.5 Leaching Potential

Although steel mill slag typically contains metals, there is substantial data indicating that these metals do not readily leach from the slag. In most slags, iron, manganese, aluminum, and zinc are present as spinels (i.e., natural oxides of magnesium and aluminum) and are unavailable for leaching. These metals could only be released from the slag through a vigorous digestion or fusion; typical natural leaching processes would not be sufficient to remove these metals from the spinel

form. Chromium is usually present in spinels or insoluble iron chromates, and therefore is also not readily leached from the slag (Cooke 1994).

Results from both previous studies and the current investigation indicate that even when metals are present in slag, they are not readily leached. The majority of these leaching studies were either EP Toxicity or Toxicity Characteristics Leaching Procedure (TCLP) tests conducted primarily to determine if the material would designate as dangerous waste according to state and federal dangerous waste regulations. However, during Phase II of the present investigation, column leaching tests were conducted to simulate in situ leaching characteristics. The results of the various leaching tests are summarized in the following sections.

3.3.5.1 EP Toxicity. Hart Crowser (1987) reported EP Toxicity values for slag from Seattle Steel. These results are summarized in Table 3-2. These results indicated that electric arc slag was not dangerous waste based on EP Toxicity concentrations.

Table 3-2
EP Toxicity Concentrations (mg/L) reported for
Seattle Steel Slag (Hart Crowser 1987)

Analyte	Slag Stockpile 12/17/86	Electric Arc Furnace Slag 07/03/80
Arsenic	<0.2	<0.01
Barium	1.5	8.4
Cadmium	<0.01	0.31
Chromium	<0.1	0.16
Lead	<0.1	0.26
Mercury	<0.005	<0.002
Selenium	<0.6	<0.01
Silver	<0.1	<0.02
Copper	<0.1	NR
Nickel	0.3	NR
Zinc	1.2	NR
NR - Not Reported.		

3.3.5.2 TCLP: Previous Investigations. Salmon Bay Steel reported that slag produced at their mill typically does not contain any TCLP extractable metals at detectable concentrations. Parametrix (1993) sampled 22 locations at the former Seattle Steel property that contained primarily soil and steel mill slag deposited prior to 1991. Only one location (Station G-8A) contained TCLP metals at concentrations greater than the Washington State Dangerous Waste criteria. Of the three samples collected at this location, two samples exceeded the criterion for lead and one sample exceeded the criteria for both lead and cadmium.

3.3.5.3 TCLP: Current Investigation. Black and Veatch (1994a) conducted TCLP metals analyses on 25 slag/soil samples. These analyses were conducted on slag/soil samples generally collected from 0 to 2 feet below ground surface (bgs) for waste characterization purposes, should future excavation and disposal be required. Detected concentrations are summarized in Table 3-3.

Barium was detected in 23 of the 25 samples at concentrations ranging from 0.5 to 1.6 mg/L. These concentrations are substantially lower than the Dangerous Waste criterion of 100 mg/L.

Cadmium was detected in two samples and lead in six samples. However, only one sample contained cadmium and two samples contained lead at concentrations above the Dangerous Waste criteria. Hart Crowser (1992) also conducted TCLP analysis of four soil samples collected in the vicinity of the ringwalls. Results were similar to those reported by Black and Veatch: cadmium exceeded the Dangerous Waste TCLP criteria in one sample and lead exceeded the TCLP criteria in two samples.

3.3.5.4 Column Leaching Tests. During the current investigation, column leaching studies were performed on six slag/soil samples collected from three test pit locations at RA2 (Appendix C). The objective of these tests was to simulate leaching under in situ conditions in the soil. The result of the column leaching studies indicate that little to no iron, lead, or zinc leached from the soil. Low concentrations of arsenic and copper leached primarily from the unsaturated soil columns. Elevated chromium concentrations were detected in the initial leachate samples from the unsaturated soil. However, chromium did not leach under groundwater conditions and rapidly precipitates under alkaline conditions such as those found at RA2.

It was hypothesized, based on Phase I TCLP analyses results, that "older" slag (i.e., produced from the open-hearth process) allowed contaminants to leach more

Table 3-3
Detected Concentrations of TCLP Metals in Slag/Soil Collected from RA2[1]

Compound Class	Compound	Location						
		TP03 2.0 ft bgs	TP06 1.5 ft bgs	TP07 2.0 ft bgs	TP08 2.0 ft bgs	TP20 2.0 ft bgs	TP21 2.0 ft bgs	TP22 2.0 ft bgs
		Result/Qual	Result/Qual	Result/Qual	Result/Qual	Result/Qual	Result/Qual	Result/Qual
TCLP Metals (mg/L)	Barium	0.9	1.2	0.5 U	0.5 U	1.1	1.2	0.6
	Cadmium	5.2	0.1 U	0.1	0.1 U	0.1 U	0.1 U	0.1 U
	Lead	72	0.5 U	0.7	7.0	1.5	0.5 U	0.5 U

[1] - The samples were collected from near surface slag/soil material during Phase I and Phase II of the remedial investigation of RA2.
U - Not detected at or above the concentration indicated.
ft bgs - Feet Below Ground Surface.

Compound Class	Compound	Location						
		TP25 2.0 ft bgs	TP26 2.0 ft bgs	TP27 2.0 ft bgs	TP28 2.0 ft bgs	TP29 2.0 ft bgs	TP30 2.0 ft bgs	TP31 2.0 ft bgs
		Result/Qual	Result/Qual	Result/Qual	Result/Qual	Result/Qual	Result/Qual	Result/Qual
TCLP Metals (mg/L)	Barium	0.8	0.6	1.0	0.6	0.9	0.6	0.5
	Cadmium	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U
	Lead	0.5 U	1.3	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U

[1] - The samples were collected from near surface slag/soil material during Phase I and Phase II of the remedial investigation of RA2.
U - Not detected at or above the concentration indicated.
ft bgs - Feet Below Ground Surface.

Table 3-3 (Continued)
Detected Concentrations of TCLP Metals in Slag/Soil Collected from RA2[1]

		Location					
		TP32 2.0 ft bgs	TP33 2.0 ft bgs	TP34 2.0 ft bgs	GTP201 0-2.0 ft bgs	GTP202 1.0-2.0 ft bgs	GTP203 0-1.0 ft bgs
Compound Class	Compound	Result/Qual	Result/Qual	Result/Qual	Result/Qual	Result/Qual	Result/Qual
TCLP Metals (mg/L)	Barium	1.3	0.9	0.7	0.7	0.6	0.8
	Cadmium	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U
	Lead	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U

[1] - The samples were collected from near surface slag/soil material during Phase I and Phase II of the remedial investigation of RA2.
U - Not detected at or above the concentration indicated.
ft bgs - Feet Below Ground Surface.

		Location				
		GTP204 0-1.0 ft bgs	MW-203 5.0-6.5 ft bgs	MW-208 1.5-2.0 ft bgs	MW-210 0-2.0 ft bgs	MW-211 2.5-4.0 ft bgs
Compound Class	Compound	Result/Qual	Result/Qual	Result/Qual	Result/Qual	Result/Qual
TCLP Metals (mg/L)	Barium	0.9	1.4	1.6	1.1	0.5
	Cadmium	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U
	Lead	0.5 U	0.5 U	1.1	0.5 U	0.5 U

[1] - The samples were collected from near surface slag/soil material during Phase I and Phase II of the remedial investigation of RA2.
U - Not detected at or above the concentration indicated.
ft bgs - Feet Below Ground Surface.

readily than slag from electric arc furnaces. Results of the column leaching tests did not support this hypothesis. Although physical properties of the different samples varied, there were not substantial differences in the chemical leaching behavior of samples from different areas of the site.

Finally, despite the presence of metals in the slag/soil cover at RA2, relatively few dissolved metals were detected in groundwater. Barium and arsenic were the most frequently detected dissolved metals in groundwater. The only other dissolved metals that were detected in Phase II samples were lead (2 of 37 samples) and zinc (9 of 37 samples).

The column leaching study is considerably more representative of environmental conditions than TCLP analysis for steel slag containing residual lime. As shown in the studies with both rainwater and groundwater leached columns, the residual lime in the slag rapidly raises the pH of the leaching media, unless it is heavily buffered to an acidic pH as in the TCLP extraction. The strong acid buffer in the TCLP extraction (based on acetic acid) was designed to mimic the acidic leachate produced during the first phase of a municipal landfill when oxidative degradation of fresh, putrescible waste is occurring. For landfills, this first phase is when metal leaching is the highest. The conditions at RA2 are not similar to the TCLP conditions. The alkaline leachate produced when rainwater and upgradient groundwater passes through the slag leaches metal very differently than the acidic leachate in TCLP extraction. Consequently, the TCLP extraction is a poor predictor of slag leaching behavior at RA2.

3.3.6 Evaluation of Dangerous Waste Criteria

Slag that is currently produced at the mill is crushed and marketed for resale and used as fill, roadbed material, and railroad ballast. The slag has been, and continues to be, tested to ensure that it is safe for reuse. Data provided by Salmon Bay Steel indicates that electric arc furnace slag produced at their facility is nonhazardous based on TCLP criteria. Previous investigations also indicate that, with the exception of a few locations, the slag/soil fill at RA2 is below state dangerous waste levels based on TCLP characteristic criteria. The near surface slag/soil samples collected during the present investigation tends to confirm this assessment.

Of the four dangerous waste characteristics (WAC 173-303-090), corrosivity and toxicity are the two characteristics most applicable to slag. A waste is dangerous based on corrosivity if, when mixed with an equal amount of water, the liquid portion of the resulting mixture has a pH greater than 12.5. Slag samples from current and

historical processes and from the slag/soil fill contain significant amounts residual lime and are highly alkaline. The pH measurements have ranged from 7.2 to 12.6 using EPA Method 150.1. However, waste designation of calcareous soils specifically requires the use of Method 9045, with calcium chloride used as the liquid in place of water (USEPA SW-846 1992). When slag/soil samples were reanalyzed with this method, pH values for the more alkaline samples decreased by approximately 0.6 pH units (Section 8.2.2.6). Based on these results, the slag/soil does not designate as a dangerous waste based on corrosivity.

Toxicity characteristics, as indicated by TCLP, may also designate a waste material as a Dangerous Waste. Existing data indicate that slag/soil would exceed the TCLP criteria only for a limited number of specific samples. The Phase I investigation collected only one slag/soil sample with TCLP results for cadmium and two slag/soil samples containing lead at concentrations above the dangerous waste criteria. Similarly, Parametrix (1993) reported samples from only one slag/soil fill test pit location at the former Seattle Steel property that exceeded the TCLP criteria for lead and/or cadmium. These results indicate that the majority of the slag/soil fill material would not designate as dangerous waste on the basis of toxicity characteristics and that only random samples would exceed the criteria.

Washington State has established three additional criteria for dangerous waste designation (WAC 173-303-100): persistence, carcinogenicity, and toxicity. Parametrix reported that a few slag/soil samples (6 of 54 samples collected in this investigation) failed the persistence and carcinogenicity criteria. This was due primarily to the presence of PCBs in these samples. The state toxicity dangerous waste criteria can be evaluated either by "book designation" procedures or laboratory toxicity testing. Parametrix (1993) evaluated slag and slag/soil fill toxicity using both methods. None of the samples they collected were dangerous waste based on the book designation method. Parametrix also conducted acute fish toxicity tests. The fish toxicity tests confirmed that none of the slag/soil samples were toxic dangerous wastes.

3.4 Potential Liquid Waste Sources

3.4.1 Historical Pickling Liquor Disposal

Dirt, grease, and the iron-oxide scale which accumulates on the steel during fabrication are removed before applying the final finish to steel products. Prior to Salmon Bay Steel's ownership of the facility, this cleaning may have been accomplished at the steel mill or related fabrication operations by immersing the steel in dilute sulfuric acid (15 percent to 25 percent by weight). This process, known as

"pickling", produced a waste called "pickling liquor". Pickling liquor is a RCRA-listed waste (K062) based on corrosivity and potential metal (primarily lead and chromium) content. The liquor was composed mainly of unused acid and the iron salts of the acid (such as $FeSO_4$). As the acid was used, it would become weaker and would have to be renewed. Eventually, the concentration of $FeSO_4$ increased to such a degree that the pickling liquor would be replaced with a fresh batch of sulfuric acid and the spent pickling liquor discarded (Nemerow 1978). The steel products would then be rinsed in water after they left the pickling tank to remove all traces of acid. The rinse or wash water eventually became acidic and was also discarded. The amount of waste pickling liquor per ton of steel product depended on the size and type of plant (Nemerow 1978).

Prior to 1974, pickling liquor was disposed of by Bethlehem Steel at RA2 by pouring the liquid over the alkaline slag piles near the Rebar Shop, in an attempt to neutralize the acidic pH of the pickling liquor. After 1974 but before purchase by Salmon Bay Steel, spent pickling liquor was disposed of offsite by Seattle Steel at a permitted disposal facility. Pickling liquor was never used in Salmon Bay Steel operations due to changes in the milling operation.

3.4.2. Water

3.4.2.1 Stormwater. Stormwater from Salmon Bay Steel drains to a stormwater collection system and is ultimately discharged through the LOL to Elliott Bay. The stormwater released by Salmon Bay Steel to the LOL is regulated by an NPDES permit. Stormwater from the steel mill also discharged to the LOL prior to Salmon Bay ownership.

3.4.2.2 Non-contact Cooling Water. Water has been used to cool machinery at the steel manufacturing facility now operated by Salmon Bay Steel. The steel mill has two cooling water systems. The first system is for the rolling mills. When Seattle Steel operated the facility, this system circulated water from a cooling pond to the mill, then to settling basins with oil skimmers, and then returned the water back to the cooling pond. The second cooling water system cools the electric arc furnaces and molds. The water in this system circulated in three closed circulating loops (PGG 1990).

In 1991, Hart Crowser (1992) collected water samples from Seattle Steel during dry weather which were assumed to represent non-contact cooling water. A composite sample was reported to contain PCBs (Aroclor 1248, 0.029 μg/L). Arsenic