**Kennedy/Jenks/Chilton**

Consulting Engineers and Scientists
530 South 336th Street
Federal Way, Washington 98003
206-874-0555 (Seattle)
206-927-8688 (Tacoma)
FAX 206-952-3435

28 August 1991

Ms. Susan Jackson
Champion International Corporation
One Champion Plaza
Stamford, Connecticut 06921

Subject: Supplemental Remedial Investigation/Risk Assessment/
Feasibility Study - Final Report
Champion International Corporation - Ballard Mill
K/J 916016.00

Dear Ms. Jackson:

Kennedy/Jenks/Chilton is pleased to submit this final report, which summarizes the results of the Supplemental Remedial Investigation (RI), Risk Assessment (RA), and Feasibility Study (FS) activities performed for Champion International Corporation at the former plywood mill located at 4025-13th Avenue West, Seattle, Washington. The Final RI/RA/FS Report has been prepared in accordance with Remedial Action Order No. DE89-N162 dated 28 August 1989, between the Washington Department of Ecology (Ecology) and Champion International Corporation.

The Final Report reflects comments provided by Ecology in their letter to Mr. Michael Thorp of Heller, Ehrman, White & McAuliffe dated 6 March 1991. All of Ecology's comments on the RI/RA/FS Report dated 28 September 1990 have been addressed in the Final Report, except Comment No. 5 regarding the location of the former maintenance shop. Identification of the former maintenance shop was briefly discussed in the <u>Champion Property Environmental Audit</u> report prepared by Parametrix, Inc., dated August 1985. However, the Parametrix report does not provide a discussion or a figure to accurately identify the location of the former maintenance shop.

Included with the Final RI/RA/FS Report is an amendment package to Volume 2 (Appendices) of the report. Please use the amendment package to revise Volume 2 of your report. This approach was taken to eliminate the need for unnecessary reproduction of this portion of the document.

If you have any questions or comments regarding the information presented herein, please call us at (206) 874-0555.

Very truly yours,

KENNEDY/JENKS/CHILTON INC.

Ty C. Schreiner

Ty C. Schreiner
Project Manager

Nathan A Graves

Nathan A. Graves, CHMM
Vice President

TCS:NAG/nd
8tcs3

Enclosure

cc: Mr. James Carraway - Champion International Corporation
Mr. Michael Thorp - Heller, Ehrman, White & McAuliffe
Mr. Ross MacFarlane - Preston, Thorgrimson, Shidler, Gates & Ellis
Mr. Peter Strong - Coastal Transportation
Mr. Brian Sato - Washington Department of Ecology

# SUPPLEMENTAL REMEDIAL INVESTIGATION/ RISK ASSESSMENT/ FEASIBILITY STUDY

REPORT

FORMER CHAMPION BALLARD MILL
SEATTLE, WASHINGTON

VOLUME 1
REVISION 1

Prepared for

CHAMPION INTERNATIONAL CORPORATION

Prepared by

KENNEDY/JENKS/CHILTON
Consulting Engineers and Scientists
530 South 336th Street
Federal Way, Washington 98003

K/J/C 916016.00

August 1991

# TABLE OF CONTENTS

Page

# TABLE OF CONTENTS

# TABLE OF CONTENTS

Page

## TABLE OF CONTENTS

## VOLUME II

## APPENDICES

# LIST OF TABLES

## LIST OF TABLES (Cont.)

## LIST OF FIGURES

## LIST OF FIGURES (Cont.)

# 1.0 INTRODUCTION

## 1.1 PURPOSE OF REPORT

This report presents the results of the Remedial Investigation (RI), Risk Assessment (RA), and Feasibility Study (FS) performed for Champion International Corporation (Champion) at a former plywood mill located at 4025 13th Avenue W, Seattle, Washington. RI/RA/FS activities were performed at the former Champion site in accordance with Remedial Action Order No. DE89-N162, dated 28 August 1989, between Champion and the Washington Department of Ecology (WDOE). This report addresses requirements set forth in the Remedial Action Order, Section 4.

Presented in the report are:

- A summary of investigative activities, investigation results, and remedial actions performed by Kennedy/Jenks/Chilton and others from August 1985 through October 1989, as part of the Preliminary RI at the site (Chapter 2.0).
- A description of activities and a summary of results of the Supplemental RI performed at the site by Kennedy/Jenks/Chilton from October 1989 through March 1990 (Chapter 3.0).
- A breakdown of areas of potential environmental concern (operable units) at the study site and a cumulative summary of the range of chemical concentrations detected at each operable unit. Also included is a summary of remedial actions performed by Champion (Chapter 4.0).
- An assessment of the public health and environmental risks of each operable unit (Chapter 5.0).
- An evaluation of the need for, and the feasibility of, remedial action for each operable unit (Chapter 6.0).

This report describes field investigations performed at the former Champion site and evaluates data from these investigations. Also outlined are specific mitigation actions taken by Champion to reduce possible adverse affects of chemicals occurring at the site. In addition, the report evaluates chemical data from each operable unit to assess the potential for adverse public health and environmental impacts. It identifies the need for and feasibility of remedial actions in areas of the site that pose unacceptable risks to human health and the environment.

RI/RA/FS activities were performed in general accordance with federal and state guidance documents. The RI and FS were based on procedures described in <u>Guidance for Conducting Remedial Investigations and Feasibility Studies under CERCLA</u>, published by the EPA in October 1988. The RA used a combination of methods specified in the Risk Assessment Guidance for Superfund Human Health Evaluation Manual, Volume 1, Part A, dated December 1989, and the cleanup standards (dated 28 February 1991) under the State of Washington Model Toxics Control Act [MTCA (WDOE, 1991)]. All investigations pursuant to the work plan dated 27 July 1989 were consistent with promulgated regulations under the MTCA, WAC 173-340.

## 1.2 OBJECTIVES OF INVESTIGATION

The objective of the RI was to identify areas of the site where chemicals might have been released into the environment, and to delineate the lateral and vertical extent of these chemicals. Using the information obtained during the RI, an assessment of potential human health and environmental risks was made during the RA. The RA was also intended to identify attainable cleanup goals based on specific regulatory criteria and existing site conditions.

In areas where human health and the environment might be threatened, the FS evaluated remedial actions mitigating contamination impacts. It also identified a range of remedial action alternatives, screened their effectiveness, and identified the feasibility of selected alternatives, based on chemical levels and existing site conditions. Investigations during the study screened several possible remedial technologies and identified those believed to be most suitable and effective to mitigate environmental concerns at the site. Finally, a remedial alternative most capable of meeting the screening objectives established in the FS was chosen.

# 2.0 BACKGROUND

## 2.1 SITE DESCRIPTION

The former Champion plywood mill is located on property sold by Champion to Salmon Bay Terminals, Inc. (SBT). SBT took possession of the site in 1989 and leased existing docks and warehouses to Coastal Transportation, Inc. (Coastal) as a distribution facility. Future SBT development plans are discussed in Section 2.3.

The location of the former Champion site is shown in Figure 2-1. As shown in Figure 2-2, the site is located at 4025 13th Avenue W, Seattle, Washington, on the southeast side of the Ballard Bridge. It is bordered on the north by Salmon Bay and the Lake Washington Ship Canal, and on the other three sides by light industry. The property covers 13.7 acres, an estimated half of which is water or marginal shoreline. The exact shoreline varies with seasonal water level fluctuations.

Several buildings onsite are supported by concrete foundations and pilings near or beyond the waterline. Since the SBT purchase of the property, many existing buildings have been either demolished or modified to meet current needs.

The property has been the site of plywood manufacturing for over 75 years. Until its closure in January 1985, the plywood mill employed 177 persons. It purchased veneer and finished the wood product. Manufacturing processes included debarking/peeling logs, cutting veneer, dryer heating to remove moisture, and gluing in the steam presses, using urea-formaldehyde resins or phenolic resins.

Leftover bark, sawdust, and trim pieces were burned in two small boiler units for generation of steam and electricity. Wastes generated at the facility included: wood product wastes; resin sludges and wastewater; fly ash and bottom slag from the burning of wood fuel; and residual paints, solvents, stains, and oils (Parametrix 1985).

## 2.2 SITE HISTORY

This section provides site history information based on a previous environmental audit by Parametrix, Inc. (Parametrix 1985).

### 2.2.1 Overview of Champion Facility Operations

Champion merged with the St. Regis Corporation in January 1985 and closed its plywood mill in Seattle. At the close of operations, this mill was relatively small, employing only 177 persons. The most recent mill operations (since June 1984) involved purchasing of veneer and drying, gluing, pressing, trimming, and sanding of the wood product.

Champion manufactured several products, including sanded cabinets, oak and birch plywoods, and marine wood products. At one time, logs were brought in by water and debarked and peeled at the northwest corner of the property. The water area in this vicinity provided the main storage for logs and other wood products that arrived at or left the facility via barges.

A hydraulic chipper produced chips from the larger leftover wood pieces. These chips were stored and then shipped offsite by barge. A railway located just south of the property was also available to transport raw material and finished products.

Steam-driven 8- and 10-foot lathes were used to cut logs at the facility. Veneer was cut and conveyed to four large steam coil-heated dryers located in the building on the west side of the property (Figure 2-2). Once moisture was removed from the wood, the pieces were laid out in layers and glued in the four steam presses located in the factory complex.

The glues most recently used at Champion are urea-formaldehyde resin for interior plywood production and phenolic resin for production of exterior plywood. Urea-formaldehyde resin is a common class of thermosetting amino resin used for plastic insulation, adhesives, and lamination. Phenolic resin is obtained by condensation of phenol with aldehydes, typically formaldehyde, acetaldehyde, and furfural. The phenol-formaldehyde resin, trademarked "Bakelite" in 1911, was the first synthetic thermosetting polymer resin ever used. Stored in drums or tank cars, this resin was used for laminating, plywood manufacturing, and glass fiber compositing.

At the Champion mill, resins were mixed with water and extenders, such as flour, corncobs, and walnut shells. Wastewater (56 percent glue) from the glue pressing operations was recirculated into resin mixing tanks. Alternatively, if the glue in the wastewater was determined to be no longer active, it was burned in the onsite boiler used to generate power for the facility.

Prior to 1978, two glue resin storage tanks were located adjacent to the boiler house and over the water (Figure 2-2). Due to environmental regulations concerning spills, two new fiberglass tanks were installed at the previous location of the water tower. These new tanks were contained by a concrete dike and were constructed in accordance with spill prevention, control, and countermeasure (SPCC) guidelines. They were removed and disposed of offsite when Champion closed the facility.

Another type of glue utilized at the Champion facility was a nontoxic white glue (aliphatic resin), e.g., Borden's glue. This glue was used at a specialized press where two wood pieces were glued together to produce 20- to 40-foot panels. It was reportedly stored in a large rail car-size steel tank located at the southwest corner of the site. The tank and pump were subsequently removed.

After the plywood was glued at the mill, the ends were trimmed in skinner saws. The product then went through a series of processes involving sanding, plugging of holes, and packaging. Until 1975, varnishing and staining operations were conducted in the north and east portions of the factory building (Figure 2-2).

Leftover bark, sawdust, and trim pieces were burned in two small boiler units, supplying steam for drying and pressing equipment and one-third of the electrical needs of the mill. The boiler units were located in the boiler house (Figure 2-2) and were capable of burning at least 500 pounds per hour of wood fuel, resin wastewater sludge, and pitch from the dryers.

Forklifts and hydraulic machinery were maintained at the former Champion site. The forklifts most recently used operated on propane distributed from an aboveground tank.

### 2.2.2 Historic Land Use and Property Development

A review of warranty deeds dating back to the first of the century shows that the site has been owned only by lumber companies. These companies have used the site, for the most part, as a sawmill or to manufacture plywood.

In 1905 and 1906, portions of the Seattle Tideland property were sold by the Smith Cove Land Company to Mr. James Mullen. In 1909, two lots were sold to Queens City Lumber Company. After a series of transactions, Queens City sold the lots to Gould-McMullen Lumber Company in 1910. In 1918, lots adjacent to 13th Avenue W were also sold to the Gould-McMullen Lumber Company by the Oregon and Washington Railroad Company.

In 1929, Gould-McMullen deeded all property to the Aircraft Plywood Corporation. U.S. Plywood of New York took over mortgages in 1937 and, in 1952, deeded the property to U.S. Plywood of Washington. In 1967, U.S. Plywood merged with Champion.

Assuming that the first industrial land use began with Queens City Lumber Company, the historical landowner sequence can be outlined as follows:

| Period | Landowner |
|---|---|
| 1909-1910 | Queens City Lumber Co. |
| 1910-1918 | Gould-McMullen Lumber Co. |
| 1929-1937 | Aircraft Plywood Corporation |
| 1937-1952 | U.S. Plywood of New York |
| 1952-1967 | U.S. Plywood of Washington |
| 1967-present | Champion (merged with U.S. Plywood) |

Note: The 1985 Parametrix, Inc. (Parametrix) report does not indicate site occupancy between 1918 and 1929.

In summary, for approximately 75 years the site has been used for manufacturing lumber products, mostly plywood and veneer products. Historical aerial photos indicate that land use has not changed significantly throughout the period of record.

### 2.2.3 Waste Generation

Known wastes generated at the facility through the years include normal wastes resulting from plywood operation, such as wood product wastes; resin sludges and wastewater; fly ash and bottom slag from the burning of wood fuel; and residual paints, solvents, stains, and oils. PCB capacitors and switch gears were also present onsite. This equipment was removed and either disposed of or salvaged.

Chemicals from a laboratory located in the sawmill building were packaged in lab packs. Additionally, asbestos used for insulation of the dryers and boilers was removed. Flammable solvents left over at the facility were transported offsite for disposal.

Fly ash waste was discharged into the log pond area located north of the boiler house. Boiler operations were discontinued in January 1985, when the site was shut down by Champion. A WDOE site inspection in February 1983 indicated that the settled fly ash material had been used to construct a dike directly north of the boiler house. WDOE recorded the fly ash as consisting generally of unburned carbon and sand.

The use of solvents, stains, and varnishes at the mill ended in 1975. These materials were used in the north and east ends of the factory building located at the center of the property. The solvents used are unknown. However, they might have included acetone, turpentine, and other hydrocarbon compounds.

According to WDOE, in May 1983 Champion stated that the quantities of solvent in use were either nonexistent or too small for the site to be regulated as a hazardous waste generator. At that time, Champion requested a formal withdrawal of the EPA ID number. This number was reactivated for removal of contaminated materials from the site in 1988.

## 2.3 POTENTIAL USES OF THE SITE

### 2.3.1 SBT

As mentioned previously, the former Champion site is currently owned by SBT, which leases it to Coastal as a distribution facility for marine transportation. Coastal has occupied the site since 1989 and has made modifications to several existing buildings. Future plans for development by SBT have not been fully defined and are dependent on the results of the RI/RA/FS. However, future development will include increasing onsite warehouse capacity and creating more docking space.

### 2.3.2 Other Potential Uses

SBT has not identified any plans for the site other than its present use. Potential uses of the site appear to depend on the needs of SBT or future property owners. Given the restrictive industrial zoning of the site, other potential uses are limited to industry and/or manufacturing.

### 2.3.3 Environmental Enhancement Considerations

Several environmental enhancements of the former Champion site have been made or are planned by SBT. The most significant enhancement is probably the conversion of the site from a manufacturing facility to a distribution center for marine transportation. Future plans for environmental enhancement include:

- Installation of an asphalt-covered parking area near the boiler building
- Installation of oil/water separators in the parking area storm drains
- Increased ventilation beneath existing warehouses
- Installation of oil booms around the building perimeter in the Ship Canal, to prevent oil released from offsite operations from migrating to the area below existing buildings.

## 2.4 PRELIMINARY RI

Several investigations were performed at the former Champion site, collectively referred to as the preliminary RI. This section summarizes the following investigation reports:

- "Champion Property Environmental Audit" (Parametrix 1985)
- "Champion International Preliminary Site Assessment" (Parametrix 1987)
- "Supplemental Environmental Assessment, Ballard Mill, Seattle, Washington" (K/J/C 1987)
- "Predesign Investigation, PCP Storage Area" (K/J/C 1988a)
- "Remedial Alternative Evaluation, Glue Press Waste, Ballard Mill, Seattle, Washington" (K/J/C 1988b).

Copies of these reports are presented in "Preliminary Remedial Investigation/Feasibility Study/Remedial Action Report" (K/J/C 1989a). Investigation summaries in this section provide an overview of the activities performed and identify the findings of each investigation.

This section also summarizes additional investigations, not directly related to the Champion RI, that provide valuable background information. A cumulative summary of preliminary RI results and a discussion of the more recent supplemental RI activities are presented in Chapters 3.0 and 4.0.

### 2.4.1 Parametrix - Environmental Audit

In August 1985, Parametrix conducted an environmental audit of the former Champion site for the Port of Seattle. It was performed because the Port of Seattle was considering purchase of the Champion property. This audit consisted of a historical data review and a brief field investigation. Parametrix obtained information from: (1) interviews with a former Champion plant operation manager, (2) record review of files obtained from the WDOE and the EPA, and (3) review of historical aerial photographs and warranty deeds.

Based on evaluation of available information, Parametrix identified five areas in which field sampling would be performed. These areas were:

- Area of resin tanks
- Area of ash ponds and old resin tanks
- Area adjacent to Seattle City Light transformers (near the boiler house)
- Area outside maintenance shop
- Areas, identified from aerial photographs, where sawdust might have been stored.

Parametrix field investigation included sampling of soil, monitoring of vapors produced by the drilling operation, and sampling of ambient air for possible volatile organics. Approximate sampling locations are shown in Figures 2-3 and 2-4.

Soil samples were composited and analyzed for the following parameters:

- Volatile organic compounds (VOCs)
- Formaldehyde
- Polynuclear aromatic hydrocarbons (PAHs)
- E.P. toxicity metals
- Total phenol
- Pesticides, polychlorinated biphenyls (PCBs)
- Base/neutral/acid-extractable compounds (BNAs).

Composite samples were formed from discrete samples collected in each area of concern. The rationale for the compositing scheme was not documented.

Concentrations of metals (after E.P. toxicity extraction) in each of the composite samples were either nondetectable or below current WDOE for classification levels as a dangerous waste (WAC 173-303-090) . Barium was detected most frequently at concentrations ranging from 0.02 to 2.04 mg/L. Methylene chloride (reportedly from laboratory contamination) was detected in each composite sample analyzed for VOCs, at concentrations ranging from 44 to 100 ug/kg.

Acetone was detected in two composite samples at concentrations of 65 ug/kg and 270 ug/kg. PAHs, including naphthalene, acenaphthylene, phenacathrene, fluoranthene, pyrene, and chrysene, were detected at concentrations below 5 mg/kg in the composite sample collected from the boiler ash/mill pond area of the site. Pesticide analyses detected aldrin at 0.95 ug/kg in a sample collected from the boiler ash. Formaldehyde was found, at concentrations ranging from 0.3 to 0.6 mg/kg, in three composite samples collected from the boiler ash area and the area outside the maintenance shop (Table 2-1).

Air sample analysis indicated that there were no VOCs in ambient air collected from the site. Based on these results, Parametrix concluded that organic vapors detected during the drilling operation were most likely from methane.

### 2.4.2 Parametrix - Preliminary Site Assessment

In 1986 and 1987, Parametrix performed a second investigation to assess potential concerns identified during the 1985 environmental audit. Sampling was limited to the following areas:

- Drying ovens (Dryers)
- Glue resin storage tanks
- Area below electrical transformer
- Pentachlorophenol (PCP) storage area
- Phenolic glue press area (glue press area)
- PCP/oil storage area
- Salmon Bay/mill pond area of Ship Canal.

Approximate sampling locations are shown in Figures 2-4 and 2-5.

For chemical analysis, 12 soil samples and two water samples were collected. Soil samples were typically collected from the surface to a depth of approximately 3 feet below the top of the sediments. Water samples were collected from the mill pond area. Sample analysis parameters included:

- PAHs
- VOCs
- PCBs
- Selected metals and pH
- Biochemical oxygen demand (BOD).

Analysis methods used on each sample depended on sample location and area-specific concerns. In addition to samples from the areas listed above, a background sample was collected and analyzed for comparison with potentially impacted regions of the site.

Analysis results indicated relatively low or nondetectable chemical concentrations in all areas investigated, except for the glue press drain and the PCP storage area (Parametrix 1987). Anthracene was detected in samples collected from the glue press drain area at concentrations of up to 460 mg/kg. Other PAH compounds detected included fluoranthene, fluorene, and pyrene in concentrations below 4 mg/kg.

Phenanthrene (16 mg/kg) was reportedly detected in a sample from the "Glue Press Drain Cone" (glue pile). Dibenzofuran was also found at a concentration of 1.6 mg/kg in a sample from the glue press drain. Finally, PCP was detected at a concentration of 77 mg/kg in a composite sample collected below the PCP storage area (Figure 2-5).

### 2.4.3 Kennedy/Jenks/Chilton - Supplemental Environmental Assessment

Kennedy/Jenks/Chilton conducted a supplemental environmental assessment, in an effort to characterize chemical compounds in areas of concern identified by previous site investigations. Results of this assessment are presented in a separate report (K/J/C 1987).

Kennedy/Jenks/Chilton's assessment concentrated on areas identified by Parametrix, as well as additional areas believed to warrant further investigation. The PCP storage area and the phenolic glue press area (glue press area) were investigated in detail. Kennedy/Jenks/Chilton also conducted preliminary investigations of several other areas:

- Offshore sediments in Salmon Bay
- Sludge in glue resin storage tank.

Sampling locations are presented in Figures 2-4 and 2-6.

Analytical results for soil samples collected in the PCP storage area indicated that PCP was neither laterally nor vertically extensive. Twelve soil samples were collected from five boring locations (B-1 through B-5) in the PCP storage area. PCP was detected in only two samples, both from boring B-1, located in the center of the sampled area. PCP concentrations ranged from 2100 mg/kg at 0 to 1.5 feet below ground surface to 190 mg/kg at 2.5 to 4.0 feet below ground surface. PCP was not detected in samples collected in the 7.5- to 11.5-foot depth interval, which indicated that vertical migration was probably limited.

Five soil samples were collected from the glue press area and analyzed for BNA compounds. Only anthracene and pyrene were detected in these samples. Anthracene concentrations ranged from 85 to 770 mg/kg. Pyrene was detected in one sample, at a concentration of 4.1 mg/kg. An additional sample (Glue Press Oil Sample) was collected in an area where oil had been noted in the glue press area (Figure 2-4) and analyzed for PCBs. The results from this sample indicate PCBs were not detected at a detection limit of 1.5 mg/kg.

Kennedy/Jenks/Chilton's investigation included sampling of offshore sediments for metals. Two other areas, the glue press area and the PCP storage area, were sampled for dioxins and furans. None of the sampling results indicated the presence of these chemicals at levels of regulatory concern. A more detailed discussion of the sampling results of this investigation is presented in a separate supplemental environmental assessment report (K/J/C 1987).

### 2.4.4 Kennedy/Jenks/Chilton - Predesign Investigation

During the supplemental environmental assessment by Kennedy/Jenks/Chilton, elevated levels of PCP were identified in the PCP storage area. Additional sampling of this area assessed the extent of PCP-containing soil, with the intention of defining limits for soil removal. Investigation results are presented in a predesign investigation report (K/J/C 1988a).

For the predesign investigation, six shallow surface samples were collected. In addition, a grab groundwater sample was collected for evaluation of potential impact to groundwater. PCP concentrations were below detectable limits for all soil samples except one, in which PCP was detected at 9100 mg/kg. PCP was also found in the grab groundwater sample, at 19 mg/L. It was suggested that the detectable levels of PCP were due to high levels of suspended sediments in the groundwater sample. Actual concentrations in groundwater had been anticipated to be much lower.

Based on these results, the limits of PCP-contaminated soil were defined and the soil was removed and disposed of at a permitted disposal facility. Chapter 4.0 provides a more detailed discussion of the activities performed during this investigation.

### 2.4.5 Kennedy/Jenks/Chilton - Remedial Alternative Evaluation

An investigation conducted by Kennedy/Jenks/Chilton in 1987 determined that glue waste located under the floors of buildings at the former Champion site contained several priority pollutant compounds, primarily anthracene. This investigation visually assessed the extent of glue waste and chemically assessed the extent of anthracene in nearby sediments. Investigation results are presented in a separate remedial alternative evaluation report (K/J/C 1988b).

Six glue piles were found under the floor of the glue press area (Figure 2-4), and samples of the glue waste and surrounding sediments were collected. Laboratory analysis of the samples suggested that anthracene was confined primarily to the glue waste piles and nearby sediments. Sample locations were chosen down-gradient from the glue piles, to determine the concentration of anthracene progressively farther away from the piles, and at various other locations on the site. Approximate sampling locations are shown in Figures 2-4 and 2-7.

A remedial alternative study evaluated the potential benefits of four possible remedial actions:

- Removal and offsite disposal
- Limiting potential exposure by covering glue piles with gunnite
- Limiting potential exposure by surrounding each glue pile with a fabric barrier
- Limiting exposure by installing a fabric barrier around the entire area potentially impacted by anthracene.

Based on a review of existing analytical data and in light of the limited mobility of anthracene, it was concluded that the glue piles and surrounding sediments did not pose an immediate threat to human health or the environment. Future use of the property would determine selection of a remedial action.

### 2.4.6 Kennedy/Jenks/Chilton - Solvent Tank Area Investigation

During excavation of PCP-contaminated soil, two underground storage tanks were discovered (Figures 2-4 and 2-8). Prior to removal of the tanks, a mixture containing approximately 70 percent carbon disulfide, 15 percent carbon tetrachloride, 1 percent tetrachloroethylene and chloroform, and 14 percent water was identified in the west tank (solvent waste tank). This mixture was removed to a permitted disposal facility. The east tank was found to be approximately half full of sand and water and was believed to have contained gasoline.

Upon removal of the solvent waste tank, cracks were discovered and strong odors characteristic of carbon disulfide were noted. It was suspected that only a few gallons of material had been released into the environment, since most of the product remained in the tank at the time of removal. Water and soil from the excavation site were sampled and a monitoring well (MW-1) was installed to further determine the extent of contamination. The boring log for MW-1 is provided in Appendix A. Four test pits were excavated and water samples were collected to estimate the lateral extent of contamination.

The results of sampling in the vicinity of the solvent waste tank, presented in a Kennedy/Jenks/Chilton supplemental RI/FS/RA report (K/J/C 1989b), indicated the presence of carbon disulfide, carbon tetrachloride, chloroform, and tetrachloroethylene. Maximum concentrations of these chemicals were detected in the excavation pit following removal of the tank. The lowest concentrations of the chemicals were detected in test pit 1, approximately 20 feet downgradient of the tank excavation area.

Chemical concentrations were in the following ranges:

| Chemicals Detected | Maximum Concentration (mg/L) | Minimum Concentration (mg/L) |
|---|---|---|
| Carbon disulfide | 290 | <1 |
| Carbon tetrachloride | 4.62 | 0.03 |
| Chloroform | 6.25 | 0.26 |
| Tetrachloroethylene | 0.04 | <0.01 |

Chapter 3.0 summarizes subsequent investigations in the solvent tank area.

### 2.4.7 Kennedy/Jenks/Chilton - Bioassay Testing

To evaluate the effects of groundwater in the solvent tank area, samples from monitoring well MW-1 were subjected to additional chemical and biological testing. Following is a summary of solvent levels detected in the sample used for bioassay testing:

| Chemical | Solvent Level (mg/L) |
|---|---|
| Carbon disulfide | 28.3 |
| Carbon tetrachloride | 6.03 |
| Chloroform | 7.06 |
| Tetrachloroethylene | 0.04 |

Bioassay testing of the groundwater at concentrations of 100 mg/L and 1,000 mg/L, using fathead minnows, resulted in 100 percent survival. A more detailed discussion of the results of this testing is presented in Chapter 5.0.

### 2.4.8 Rittenhouse-Zeman and Associates - Geotechnical Evaluation

In 1988, Rittenhouse-Zeman and Associates (Rittenhouse-Zeman) also performed a geotechnical evaluation of the former Champion site to assess the properties of subsurface soils. The work consisted of drilling test borings, excavating test pits, and driving test pilings in areas where future expansion of the site might occur. The results of the investigation are summarized in a separate report (Rittenhouse-Zeman 1988). An evaluation of the hydrogeologic significance of this information to the Champion RI is presented in Section 3.4.1 of Chapter 3.0.

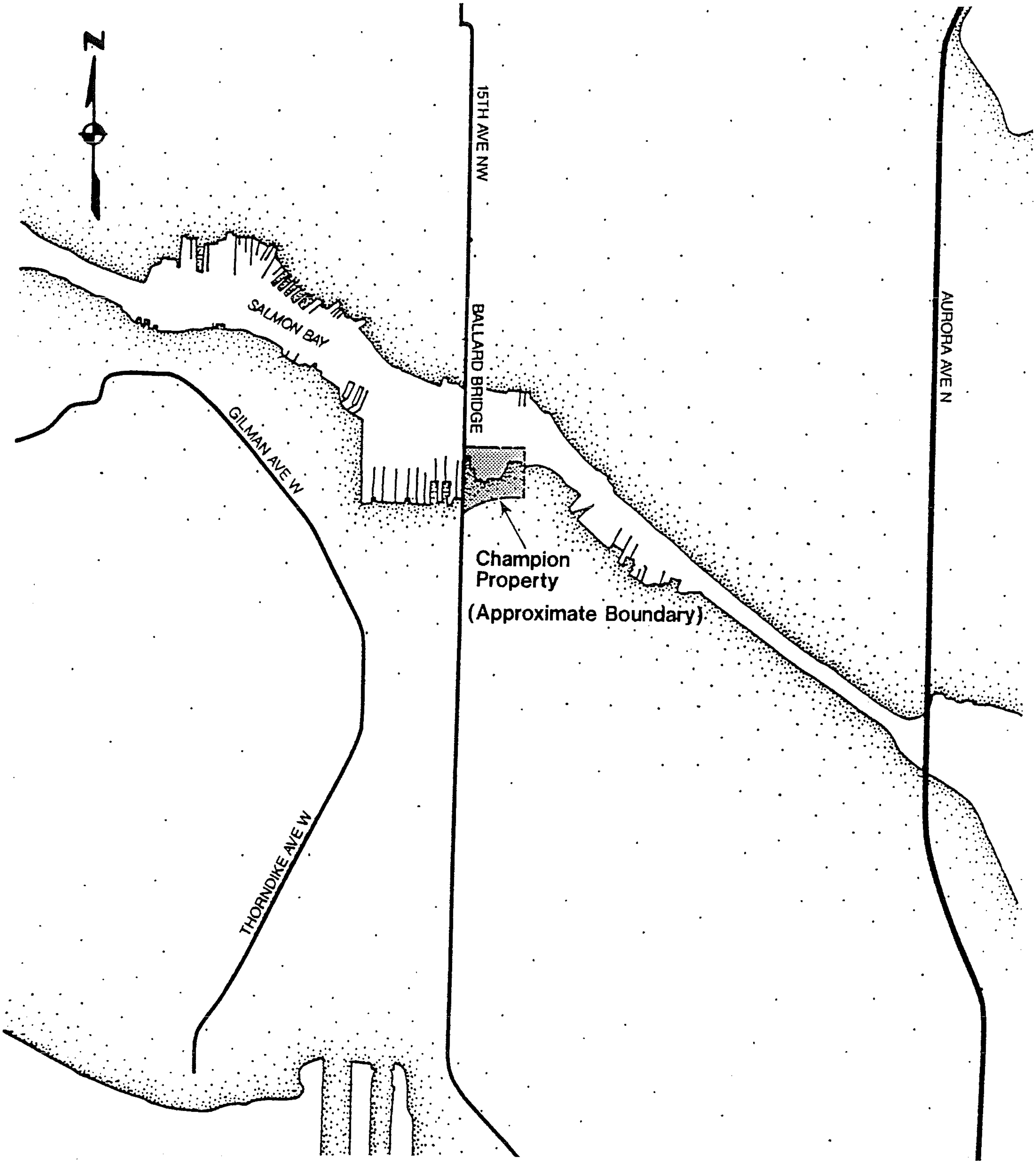
# TABLE 2-1

## SUMMARY OF ANALYTICAL RESULTS FROM PARAMETRIX - ENVIRONMENTAL AUDIT

| Chemical Parameter/Units | Analytical Results | | | | |
|---|---|---|---|---|---|
| | Composite No. 1 | Composite No. 2 | Composite No. 3 | Composite No. 4 | Composite No. 5 |
| E.P. Toxicity Metals (mg/L) | | | | | |
| Cadmium | <0.005 | <0.005 | <0.005 | <0.005 | NT |
| Arsenic | <0.02 | 0.05 | <0.02 | <0.02 | NT |
| Chromium | <0.01 | <0.01 | <0.01 | <0.01 | NT |
| Lead | <0.02 | <0.02 | <0.02 | <0.02 | NT |
| Mercury | <0.005 | 0.017 | <0.005 | <0.005 | NT |
| Selenium | <0.02 | <0.02 | <0.02 | <0.02 | NT |
| Silver | <0.05 | <0.05 | <0.05 | <0.05 | NT |
| Barium | 0.34 | 0.05 | 0.02 | 2.04 | NT |
| Volatile Organic Compounds (mg/kg) | | | | | |
| Methylene Chloride | 44 | 38 | NT | 100 | 81 |
| Acetone | 65 | 270 | NT | ND | ND |
| Semi-Volatile Organics (mg/kg) | | | | | |
| Naphthalene | NT | NT | NT | 4.4 | ND |
| Acenaphthylene | NT | NT | NT | 1.2 | ND |
| Phenanthrene | NT | NT | NT | 0.5 | ND |
| Fluoranthrene | NT | NT | NT | 1.1 | ND |
| Pyrene | NT | NT | NT | 0.7 | ND |
| Chrysene | NT | NT | NT | 0.6 | ND |
| Pesticides/PCBs (mg/kg) | | | | | |
| Aldrin | NT | NT | ND | 0.00095 | ND |
| Formaldehyde | 0.3 | 0.3 | NT | 0.6 | NT |

Notes:

ND - denotes chemical not detected and detection limit not reported.
NT - denotes chemical was not tested.
Composite No. 1 was composited from sampling locations No. 1, No. 2, and No. 3 (Figure 2-3).
Composite No. 2 was composited from sampling locations No. 1, (Figure 2-3).
Composite No. 3 was composited from sampling locations D and E (Figure 2-3).
Composite No. 4 was composited from sampling locations A, B, and C (Figure 2-3).
Composite No. 5 was composited from sampling locations F (Figure 2-3).



Approximate Scale:

0 1000 2000 4000

1" = 2000'

(feet)

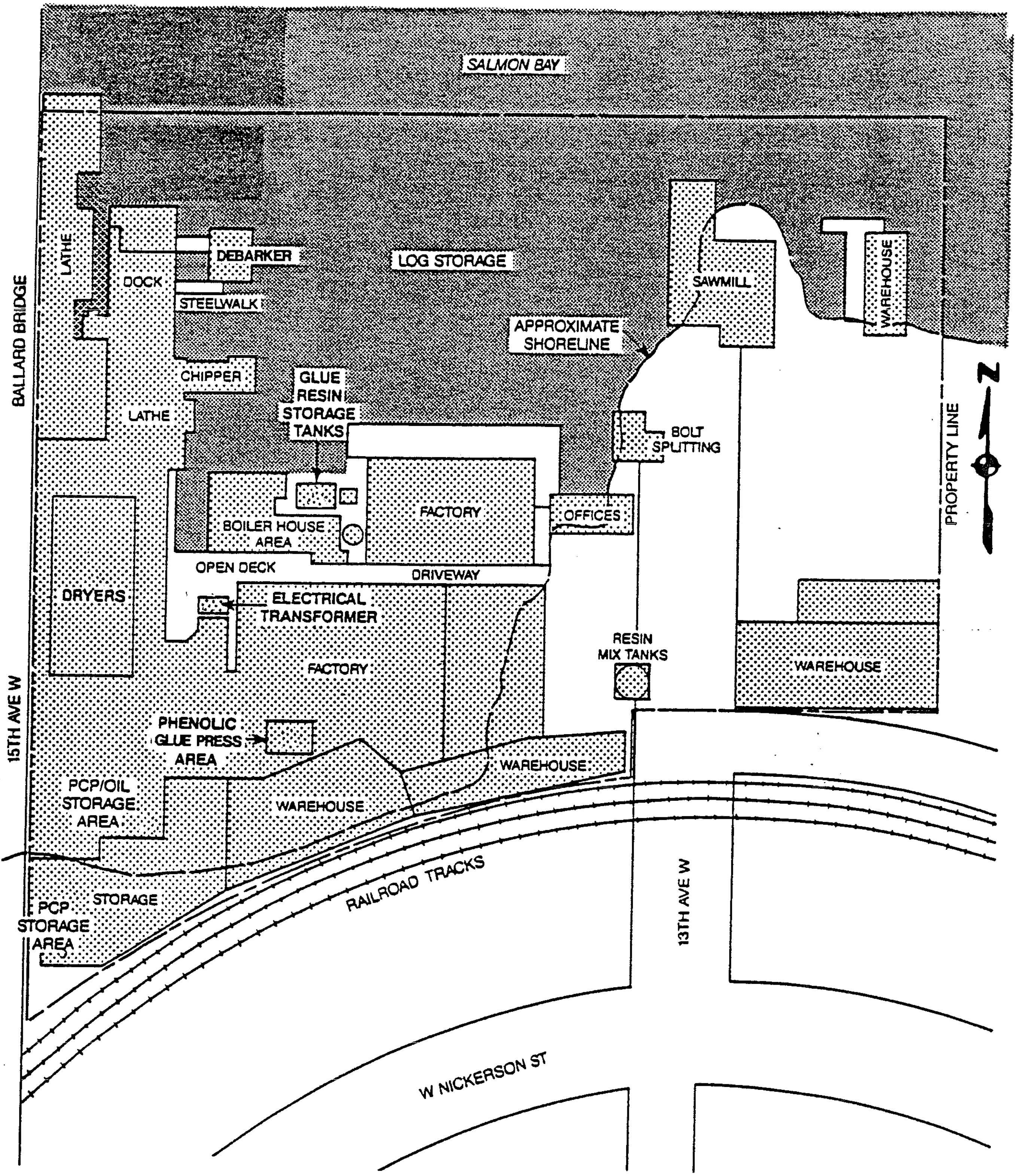
Kennedy/Jenks/Chilton

CHAMPION INTERNATIONAL CORP.
SEATTLE, WA

VICINITY MAP

K/J/C 916016.00/P1SK001

FIGURE 2-1



1"=150' 0 150 225

(feet)

Approximate Scale:

**NOTES**

1. ALL LOCATIONS ARE APPROXIMATE.

2. MAP SOURCE FROM PARAMETRIX,INC., REPORT DATED 3/27/87 (PARAMETRIX,1987).

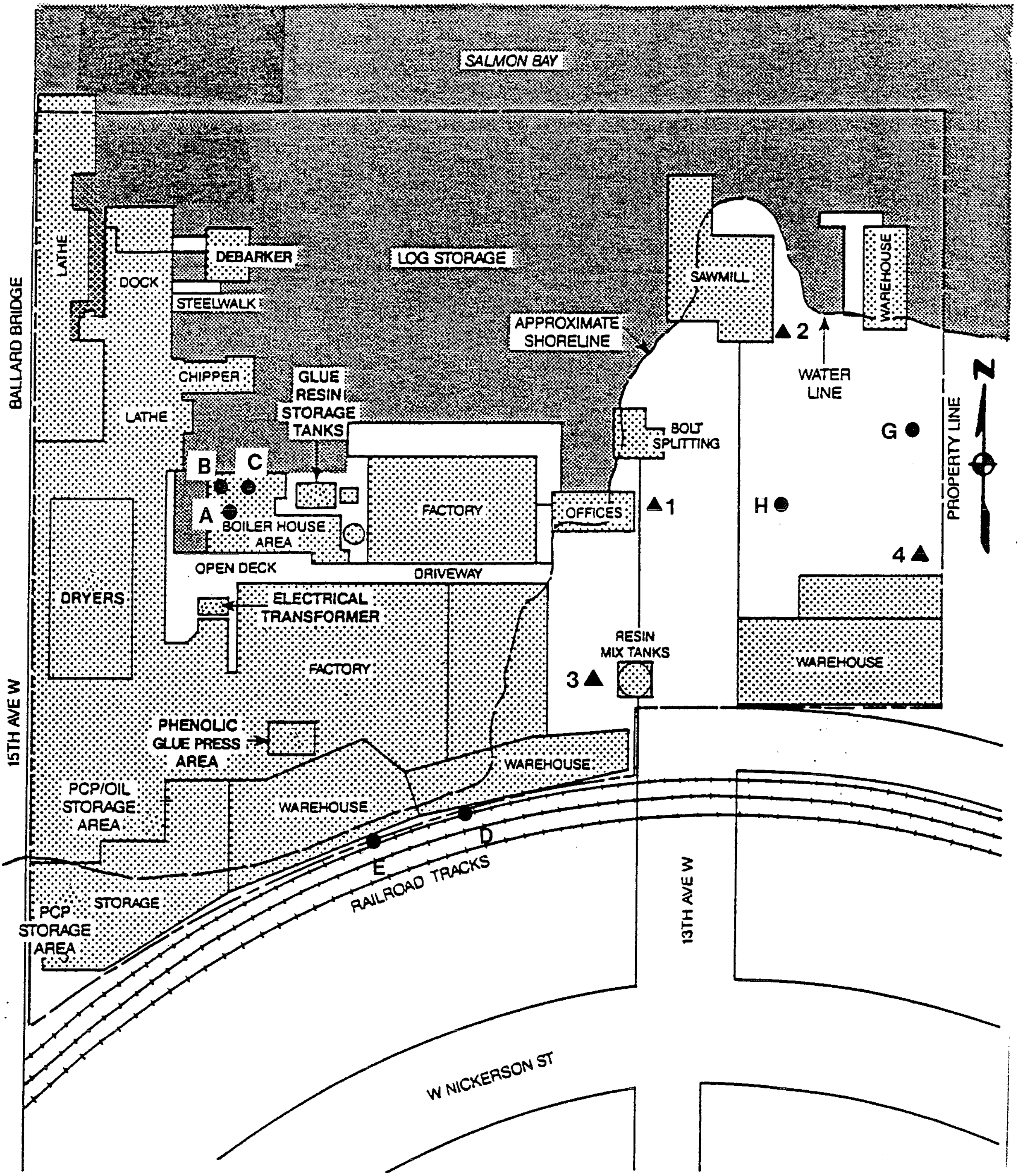
**Kennedy/Jenks/Chilton**

CHAMPION INTERNATIONAL CORP.
SEATTLE, WA

**SITE MAP**

K/J/C 916016.00/P1SK0.03

FIGURE 2-2



1"=150'

0 150 225

(feet)

Approximate Scale

**LEGEND**

● SHALLOW BORING

▲ DEEP BORING (10-15 FEET)

**NOTES**

1. ALL LOCATIONS ARE APPROXIMATE.
2. MAP SOURCE FROM PARAMETRIX, INC., REPORT DATED 3/27/87 (PARAMETRIX, 1987).

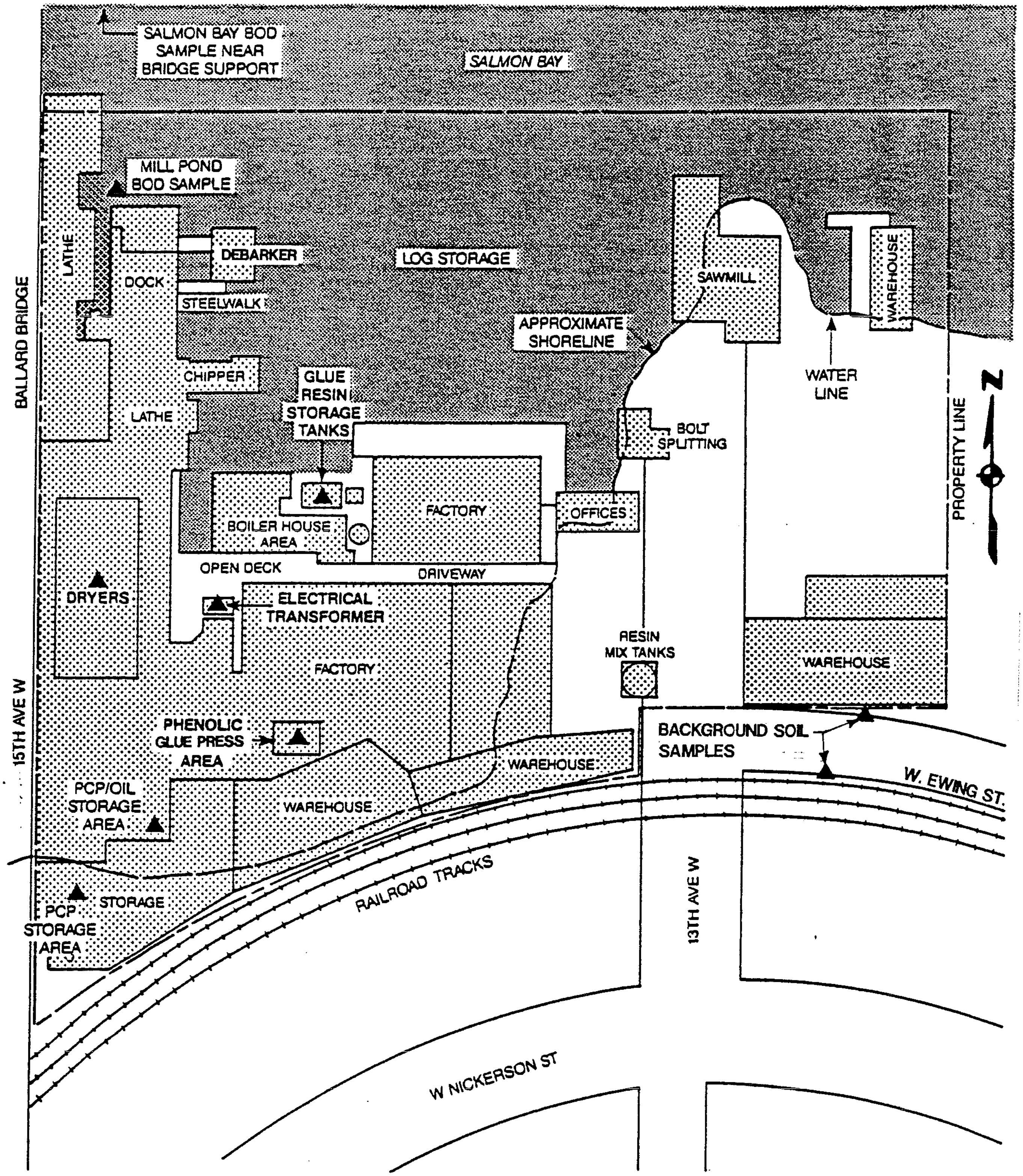
Kennedy/Jenks/Chilton

CHAMPION INTERNATIONAL CORP.
SEATTLE, WA.

PARAMETRIX-SITE AUDIT
SAMPLING LOCATIONS

K/J/C 916016.00/P1SK002

FIGURE 2-3



Approximate Scale: 1"=150"

0 150 225

(feet)

**LEGEND**

▲ APPROXIMATE SAMPLING LOCATION BY PARAMETRIX (MARCH, 1987)

**NOTES**

1. ALL LOCATIONS ARE APPROXIMATE.
2. MAP SOURCE FROM PARAMETRIX, INC., REPORT DATED 3/27/87 (PARAMETRIX, 1987).

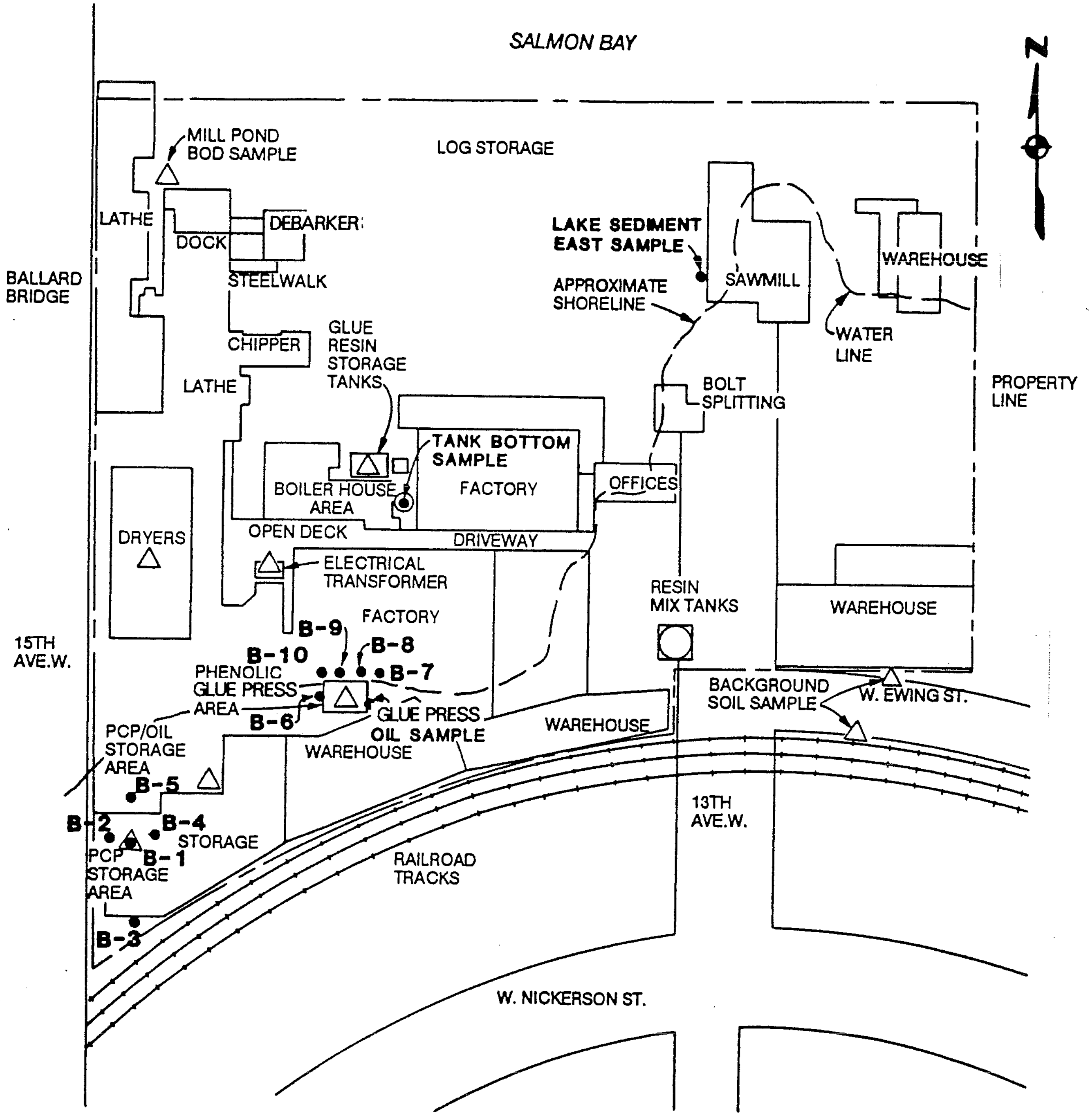
Kennedy/Jenks/Chilton

CHAMPION INTERNATIONAL CORP.
SEATTLE, WA

PARAMETRIX SITE ASSESSMENT
SAMPLING LOCATIONS

K/J/C 916016.00/P1SK004

FIGURE 2-5



## LEGEND

△ SAMPLES BY PARAMETRIX, JAN.-FEB. 1987

● SAMPLES BY K/J/C, JUNE 1987

## NOTE

1. ALL LOCATIONS ARE APPROXIMATE.

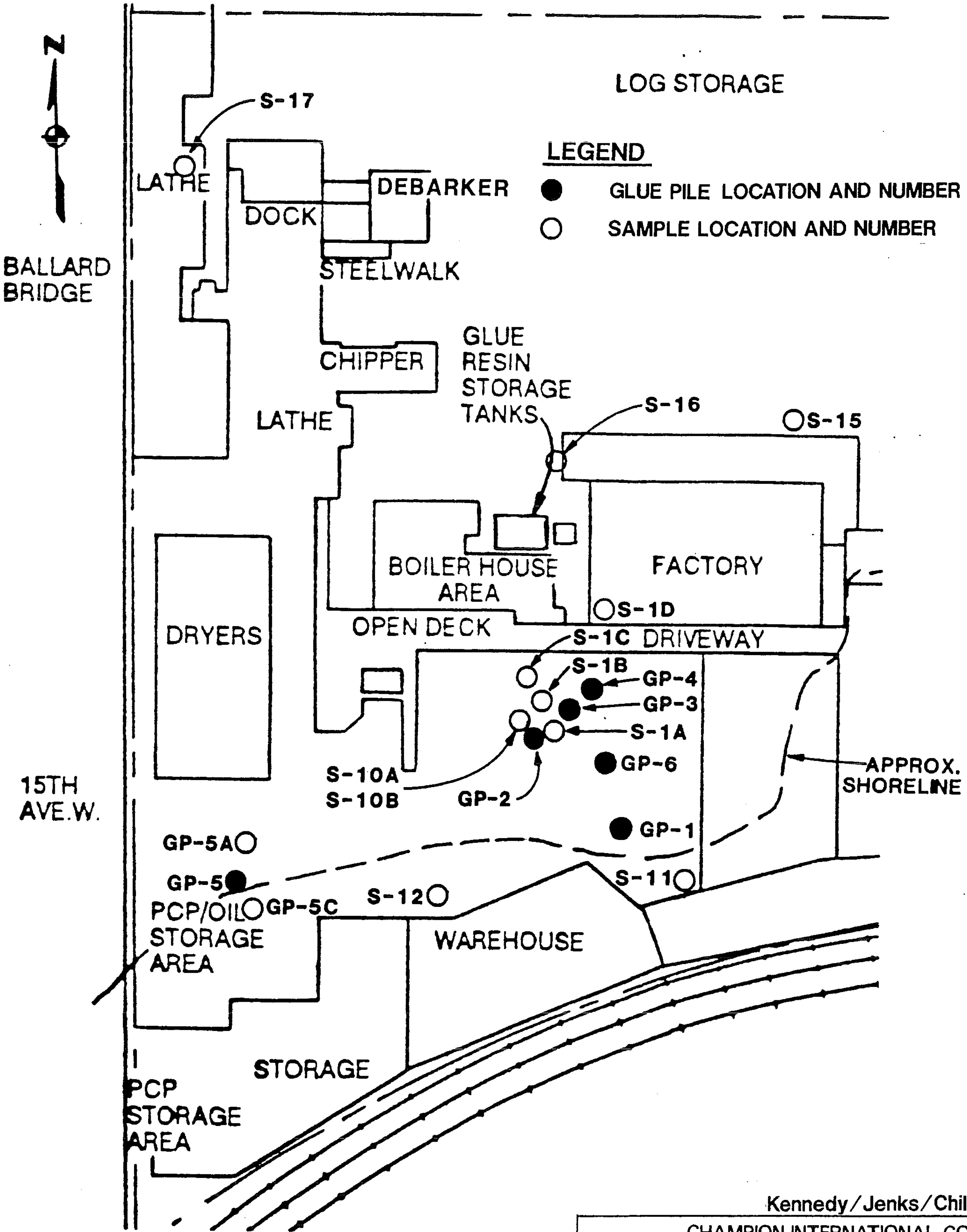
Kennedy/Jenks/Chilton

CHAMPION INTERNATIONAL CORP.
SEATTLE, WA.

**K/J/C-SUPPLEMENTAL
ENVIRONMENTAL ASSESSMENT
APPROXIMATE SAMPLING LOCATIONS**

K/J/C 916016.00/P1SK005

FIGURE 2-6



Approximate Scale:

0 75 150

1" = 75'

(feet)

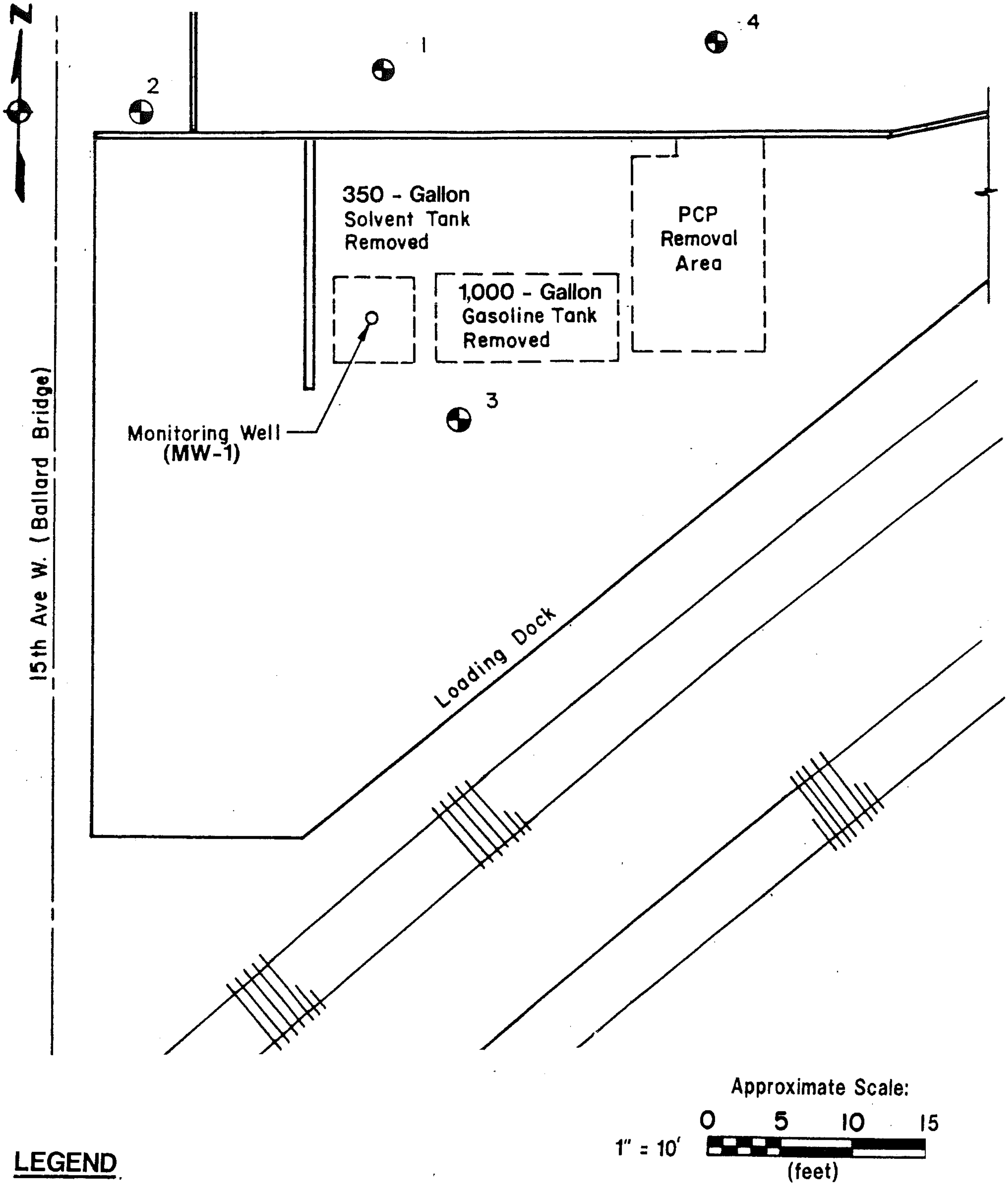
Kennedy/Jenks/Chilton

CHAMPION INTERNATIONAL CORP.
SEATTLE, WA

**REMEDIAL ALTERNATIVE EVALUATION**
**APPROXIMATE SAMPLING LOCATIONS**

K/J/C 916016.00/P1SK006

FIGURE 2-7



## LEGEND

◓ APPROXIMATE TEST PIT LOCATION

Kennedy/Jenks/Chilton

CHAMPION INTERNATIONAL CORP.
SEATTLE, WA.

**UNDERGROUND TANK LOCATIONS**

K/J/C 916016.00/P1SK007

FIGURE 2-8

# 3.0 SUPPLEMENTAL RI

## 3.1 GENERAL

This section describes the technical approach used in the focused supplemental RI for the former Champion site. It begins with a brief discussion of the objectives of the supplemental RI, then continues with descriptions of field sampling activities, chemical analysis techniques, and a summary of investigation findings. The purpose of supplemental RI field activities was to gather data to identify the nature and extent of chemicals at the site. Field procedures were in accordance with the site work plan dated 27 July 1989, except where noted.

## 3.2 OBJECTIVES

Based on the results of previous investigations, the RI identified several separate and distinct "operable units" at the site that appeared to require further evaluation. The operable units were:

- Solvent tank area
- Boiler ash fill
- Glue press area
- PCP storage area
- Offshore sediments

The PCP storage area was not investigated further, since Champion had performed remedial actions in 1988 that removed detectable PCP contamination from the area (see Section 4.1 for more details).

Site-specific factors requiring further evaluation were:

- Overall site hydrogeology
- Surface water drainage
- Methane production
- Additional underground storage tanks
- Containerized waste

Investigations were performed to assess the impact of these factors on the operable units, as well as to determine other contaminants requiring remedial action. Focused evaluations of several areas were needed to adequately characterize the site for risks to human health and the environment inherent in existing conditions and to suggest remedial action alternatives. Therefore, the supplemental RI included the following activities:

| Operable Unit/Area of Interest | Activity |
|---|---|
| Solvent Tank Area | • Delineation of horizontal and lateral extent of chemicals in subsurface soil and groundwater near solvent tank area. |
| | • Evaluation of direction of shallow groundwater migration in solvent tank area. |
| Boiler ash fill | • Estimation of extent of boiler ash fill found in the vicinity of boiler building. |
| | • Characterization of composition of boil ash fill. |
| Surface water | Evaluation of surface water flow patterns in areas of known or suspected chemical contamination. |
| Methane production areas | Estimation of magnitude of methane produced from shallow soils in solvent tank area. |
| Offshore sediments | • Characterization of offshore sediment quality in the Lake Washington Ship Canal both onsite and in the DRN lease area. |
| | • Documentation of background sediment quality. |
| Underground tanks | Evaluation of potential for additional underground storage tanks. |
| Containerized wastes | Characterization and disposal of containerized waste throughout site. |

The glue press area was not investigated during the supplemental RI, since it had been characterized during earlier investigations (see Chapter 2.0).

## 3.3 METHODS OF INVESTIGATION

### 3.3.1 Overall Site Geology/Hydrogeology Investigation Methods

The RI evaluated overall site geology and hydrogeology, using information obtained from previous site investigations by Rittenhouse-Zeman; information from solvent tank area, boiler ash fill, and offshore sediment investigations by Kennedy/Jenks/Chilton; and data readily available for other sites in the area. Evaluation results are presented in Section 3.4.

### 3.3.2 Solvent Tank Area Investigation Methods

The supplemental RI field investigation assessed the potential for migration of chemicals suspected of being released from the solvent waste tank formerly located at the southwest corner of the site (Figure 2-2 in Chapter 2.0). Three wells and four borings were installed in the solvent tank area to assess groundwater hydrogeology and chemistry. Field activities, discussed below, were performed in accordance with the work plan dated 27 July 1989, except as noted in the discussion.

3.3.2.1 Drilling Activities. Drilling took place from 25 January 1990 through 2 February 1990. Field investigation of the solvent tank area included the following activities:

- Installation of two shallow monitoring wells (MW-2 and MW-3) to depths of approximately 11 feet below ground surface. Wells were used to assess potential downgradient migration of previously detected chemicals in the area.

- Installation of a shallow monitoring well (MW-4) upgradient of the source area, to a depth of 13 feet below ground surface. This well was used to identify background levels of VOCs in the area.

- Drilling and sampling of three shallow soil borings (SB-2, SB-3, and SB-4) to depths of approximately 14 feet below ground surface and surrounding the previously installed monitoring well (MW-1). These borings were used in identification of possible lateral dispersion and downward migration of solvents through subsurface soils.

- Installation of one deep soil boring (SB-1D) to a depth of 61.5 feet below ground surface. This boring was to be used to locate a confining layer below the solvent tank location and to assess the potential for dense nonaqueous phase liquids (DNAPLs) that might have accumulated at the base of the uppermost fill aquifer zone. Due to poor recovery of shallow soil samples in boring SB-1D, an additional shallow boring (SB-1S) was drilled to a depth of 18 feet below ground surface.

Locations of the monitoring wells and soil borings are shown in Figure 3-1. The locations for all monitoring wells and soil borings, except MW-4 and SB-4, were based on information from a background literature review. Monitoring well MW-4 and boring SB-4 locations were based on hydraulic gradient information estimated from groundwater elevations in wells MW-1, MW-2, and MW-3.

Soil samples were collected from all soil borings (including wells) to characterize soil types. Four samples collected from different depths were submitted for grain size analysis. The results of these analyses are included in Appendix C. Sampling intervals varied from continuous to once every 5 feet and are shown on boring logs included in Appendix A.

For chemical analysis, soil samples were obtained from borings SB-1D, SB-1S, SB-2, SB-3, and SB-4 drilled in the solvent tank area. Soil samples were not collected for chemical analysis from borings that were finished as wells (MW-2, MW-3, and MW-4). Table 3-1 summarizes sampling depths for soil samples collected in the solvent tank area. After collection, soil samples from the solvent tank area were analyzed for VOCs, including carbon disulfide, by EPA Method 8240.

Monitoring wells were constructed using 2-inch PVC well construction materials, in accordance with the Kennedy/Jenks/Chilton quality assurance plan for the project (K/J/C 1990). Boreholes for the wells were drilled using hollow stem auger techniques. The target depth of each well was identified and the well was installed based on lithologic and hydrogeologic conditions encountered. Each monitoring well was completed at a depth of approximately 11 to 13 feet below ground surface, with a 5-foot section of slotted PVC casing (0.010-inch slot size) installed at the base of the well. Boring logs that document well construction and lithologic conditions encountered are presented in Appendix A.

3.3.2.2 Well Development. On 5 February 1990, monitoring wells MW-2, MW-3, and MW-4 were developed by bailing and surging with a Teflon bailer. Temperature, pH, and specific conductance were monitored, along with turbidity and color. Development of the wells continued until water quality parameters stabilized and purge water was generally free of suspended sediments. See Table 3-2 for a summary of development activities.

3.3.2.3 Groundwater Elevation Monitoring. On 30 January 1990, a preliminary survey of vertical elevations for monitoring wells MW-1, MW-2, and MW-3 was made to estimate groundwater gradient. Using the elevation data, groundwater flow direction was estimated to aid in the placement of monitoring well MW-4, upgradient of the presumed source area, and boring SB-4, downgradient of this area.

A survey of horizontal position and vertical elevation of all monitoring wells was conducted on 26 February 1990. Determinations of horizontal well positions relative to existing site structures (i.e., building corners and property boundaries) were made, and vertical elevations were determined relative to the U.S. Geological Survey (USGS) datum. Water level in each well was monitored on three occasions to help estimate the direction and magnitude of the hydraulic gradient. Water level elevation data is presented in Table 3-3. The results of water level monitoring are discussed in Section 3.4.2.2.

3.3.2.4 Well Sampling. Monitoring wells MW-1, MW-2, MW-3, and MW-4 were sampled on 6 February 1990. All wells were sampled for VOCs, using EPA Method 624. In addition, MW-1 was sampled for the following parameters:

- Metals (unfiltered). Arsenic (As), barium (Ba), cadmium (Cd), calcium (Ca), chromium (Cr), copper (Cu), iron (Fe), lead (Pb), magnesium (Mg), manganese (Mn), mercury (Hg), potassium (K), selenium (Se), silver (Ag), sodium (Na), and zinc (Zn).
- General chemical parameters. Bicarbonate, chloride, color, fluoride, nitrate, silica, specific conductivity, sulfate, total dissolved solids, total hardness, and turbidity.
- PAHs. By EPA Method 610.

A blind field blank (MW-7) and a blind duplicate sample (MW-5) obtained from monitoring well MW-1 were analyzed for the parameters identified above. A blind rinsate blank (MW-6) was also analyzed for VOCs, using EPA Method 624.

Wells were purged while monitoring temperature, pH, specific conductance, turbidity, and color. Samples were taken after approximately three well volumes were purged and the parameters listed above were stabilized. The conductivity meter and the pH meter were calibrated before the purging of each well. A summary of purge data is presented in Table 3-4. Analytical results of sample analyses are discussed in Section 3.4.

### 3.3.3 Boiler Ash Fill Investigation Methods

The extent and composition of the boiler ash fill were assessed during field activities from 31 January to 6 February 1990. Seven borings (SB-5 through SB-11) were drilled for this purpose. Borings were sampled through the ash to a depth where no ash was visible in the soil. Samples for chemical analysis were obtained from borings SB-5 and SB-7 at the top, middle, and bottom of the boiler ash fill. They were submitted for chemical analysis for the following parameters:

- Priority pollutant metals by ICAP. Antimony (Sb), arsenic (As), barium (Ba), cadmium (Cd), t. chromium (Cr), lead (Pb), mercury (Hg), nickel (Ni), selenium (Se), silver (Ag), copper (Cu), thallium (Ti), and zinc (Zn).
- BNA extractables. By EPA Method 8270.

Four soil samples indicating the presence of petroleum hydrocarbons were submitted for analysis of TPH (as gasoline and diesel). Samples for lithologic control were obtained continuously in all borings from depths of more than 3 feet.

### 3.3.4 Surface Water Drainage Investigation Methods

Surface water flow patterns at the former Champion site were assessed during two storm events, on 7 March and 17 April 1990. Assessment entailed mapping surface water drainage patterns to evaluate the impact of flow on known surface contaminant sources, including the glue piles. Available information regarding the stage of the Lake Washington Ship Canal was obtained from the Army Corps of Engineers to determine when and to what extent the glue piles were in direct contact with surface waters in Salmon Bay.

### 3.3.5 Methane Production Area Investigation Methods

During supplementary RI drilling operations, organic vapors were analyzed to assess the extent of methane produced from subsurface soils below the former Champion site. Headspace inside and ambient air outside the augers were monitored for vapors during drilling operations in the solvent tank area. Both a Foxboro organic vapor analyzer (OVA), sensitive to methane, and an HNU vapor detector, not sensitive to methane, were used to monitor organic vapors within the auger flights. While solvent materials produced a response on both instruments, methane was detected only by the OVA. The relative responses of the OVA and the HNU vapor detector were used to estimate methane levels in subsurface soils.

### 3.3.6 Offshore Sediment Investigation Methods

As part of the RI, Phases I and II of the sediment sampling and analysis program were performed through a Kennedy/Jenks/Chilton subconsultant, Jay Spearman. Phase I was based on verbal approval from WDOE in February and September of 1989 to support the SBT plan to dredge sediments and construct a dock in the vicinity of the boiler building. Sampling locations are shown in Figure 3-1. Phase I sediment sampling results are briefly discussed in Section 3.4.6.

Phase II sediment sampling occurred in February and March of 1990. The investigation was performed to:

- Document the background range of chemical concentrations in the Lake Washington Ship Canal.
- Evaluate the potential for chemical migration from the operable units to offshore sediments below existing buildings and to the Department of Natural Resources (DNR) lease area.

Sampling procedures are discussed in the Phase II sediment sampling report, which is included in Appendix E. A summary of the results of Phase II sampling is presented in Section 3.4.6.

### 3.3.7 Underground Tank Investigation Methods

On 14 and 26 February 1990, as part of the supplemental RI, the site was searched for concrete slabs, piping, conduit, or other items that might have been connected to underground tanks. One tank was found in the parking lot, as indicated in Figure 3-1. This tank was sampled on 14 February 1990, and samples were analyzed for the following:

- Total petroleum hydrocarbons (TPHs). Gasoline and diesel.
- Benzene, ethylbenzene, toluene, and xylenes. By EPA Method 8020.

The tank was sampled with a clean Teflon bailer. The results of this investigation are discussed in Section 3.4.7.

### 3.3.8 Containerized Waste Investigation Methods

On 9 February 1990, Kennedy/Jenks/Chilton surveyed the site for the presence of containerized waste materials. Five containers were found and subsequently transferred to one of the onsite warehouses for sampling. The waste was sampled by Kennedy/Jenks/Chilton for the ultimate purpose of disposal. Soil cuttings and purge water produced during supplemental RI field activities were also sampled during the site survey. Sampling procedures were in accordance with those outlined in the Kennedy/Jenks/Chilton quality assurance plan (K/J/C 1990).

Samples were analyzed, as necessary to profile the waste for disposal, for the following parameters:

- Phenols. By EPA Method 420.1 (spectrophotometry).
- pH.
- E.P. toxicity metals. Arsenic (As), barium (Ba), cadmium (Cd), t. chromium (Cr), lead (Pb), mercury (Hg), selenium (Se), and silver (Ag).

Upon receipt of analytical results for the waste materials, drums were segregated, based on disposal requirements. Drums containing waste material requiring offsite disposal were to be staged, overpacked if necessary, profiled for hazardous waste disposal, and labeled using appropriate labels. The wastes were disposed of offsite by Chempro, Inc., at a permitted facility. The waste manifest sheets for the waste are provided in Appendix I.

### 3.3.9 Quality Assurance Data Review

A review of all analytical data collected during the supplemental RI was subjected to a quality assurance data review. The review included the checking of all method blanks, field blanks, and rinsate blanks for detectable compounds. For field duplicates, means, relative percent differences (RPDs), and ranges were determined and it was decided whether or not holding times had been exceeded. A discussion of the results of the quality assurance data review is presented in Appendix F.

## 3.4 INVESTIGATION RESULTS

### 3.4.1 Hydrogeologic Investigation Results

This section summarizes information on subsurface hydrogeologic conditions in the vicinity of the former Champion site. The hydrogeologic evaluation was based on information collected during the supplemental RI and previous site investigations.

3.4.1.1 Geologic Setting. As noted earlier in this report, the site is located on the shore of the Lake Washington Ship Canal, with Lake Washington to the east and Puget Sound to the west. Much of the facility is on shoreline and marginal shoreline. During construction of the Lake Washington Ship Canal (1854-1911), glacially deposited sediments and marine mud were removed by dredging to form a link between Puget Sound and Lake Washington. The dredging spoils were reportedly disposed of on the channel banks. According to a 1988 geologic map prepared by the USGS (USGS, 1988), most of the site is underlain by these man-modified areas. Descriptions of these regions indicate that, due to significant filling, the original geology and topography have been either obscured or greatly modified.

Underlying the dredging spoils are recent marine sediments that consist of very soft silts and clays, and organic material. A glacial till deposit composed of sand and gravel with intervening clay layers, referred to as the Vashon Drift (USGS, 1988), underlies the recent marine sediments.

3.4.1.2 Hydrostratigraphic Units. Several near-surface investigations have been performed at the site to assess chemicals in shallow soil and, to a limited extent, groundwater. However, these investigations provide little information regarding the nature of subsurface soils. Geotechnical evaluations of both the site and neighboring properties provide the basis for hydrogeologic site information. According to these evaluations, the upper 6 to 25 feet of sediments encountered at the site consist predominantly of organic material (wood chips, bark, and lumber) with interbedded zones of silt, silty clay, and sand.

A geotechnical evaluation of the Champion site performed by Rittenhouse-Zeman (Rittenhouse-Zeman 1988) indicates that the original shoreline was south of the railroad tracks located at the south end of the site. The portion of the site currently above the canal level resulted from filling with wood, bark chips, sawdust, dimensional lumber, and other rubble.

Groundwater has been encountered across the site at depths ranging from 2 to 9 feet below ground surface (Rittenhouse-Zeman, 1988). Visual observation of soil samples from the solvent tank area during the RI indicated that organic fill material might extend approximately 18 feet below ground surface. The fill material consisted predominantly of organic material and silty/sandy sediments. Intervening sand and silty clay layers were identified in the solvent tank area. However these layers were probably not extensive, due to the nature of fill deposition. Groundwater was found throughout the fill material; however, interbedded sand zones were assumed to transmit groundwater more readily.

Underlying the organic fill material was a distinct soft gray silty clay/clayey silt unit that appeared to restrict groundwater movement. A visual comparison of the sediments suggested that the confining layer had a lower hydraulic conductivity than the overlying organic debris and sand zones. The silt and clay zone was observed to separate the organic material from a lower-lying sand and gravel layer forming the second zone of saturation.

A review of logs of deep borings drilled on and in the vicinity of the site indicated that the confining layer ranges in thickness from approximately 3 to 25 feet. The confining layer was encountered in all onsite borings greater than 30 feet deep, except for boring SB-1D drilled in the solvent tank area, and was typically encountered at approximately 25 to 30 feet below ground surface. However, a different clayey silt layer encountered in boring SB-1D appeared to be unrelated to the more regional confining layer. The clayey silt unit was approximately 6 feet thick. Available information suggested that this unit might be laterally extensive in the solvent tank area.

A second zone of saturation was encountered at depths ranging from approximately 20 to 45 feet below ground surface. Given its stratigraphic position, this zone appeared to be representative of the Vashon Drift. The unit consisted predominantly of silty sand and poorly graded gravel and was at least 40 feet thick in some areas, as identified in boring SB-1D.

Existing information suggested that the Vashon Drift aquifer was up to 150 feet thick (USGS, 1988). Sediments occurring in the unit were well rounded, indicating fluvial transport. The occurrence of this overlying silt and clay layer suggested that the second aquifer zone in the vicinity of the site was most likely confined or semi-confined.

3.4.1.3 Correlation of Stratigraphic Units. During the RI, two generalized cross-sections were constructed to help depict the correlation of stratigraphic units at and in the vicinity of the site (locations shown in Figure 3-2). Cross-section A-A' (Figure 3-3) utilized data collected from the former Champion site. The figure shows that fill material, consisting predominantly of waste wood products, was encountered across the site at depths of up to 25 feet. A review of logs from shallow borings and test pits indicated that organic fill material decreased in thickness toward the south property boundary of the site (Rittenhouse-Zeman, 1988).

As shown in Figure 3-3, the silt and clay unit (confining layer) underlying the organic fill was not encountered in boring SB-1D drilled in the solvent tank area. Insufficient data was available to characterize the lateral continuity of this unit; however, SB-1D was the only deep boring drilled at the site in which the regional confining layer was not encountered. A clayey silt layer was encountered at depths of 10.5 to 16 feet below the ground surface in boring SB-1D; however, this unit did not appear to be related to the more regional silty clay confining layer. A similar silt layer was identified in other borings sampled in the solvent tank area, suggesting that the layer might be laterally extensive in this operable unit.

Cross-section B-B' (Figure 3-4) identified the correlation between stratigraphic units encountered at the former Champion site and those found on adjacent (Port of Seattle) property to the west. Lithologic data for the Port of Seattle property is presented in a report by Shannon and Wilson, Inc. (Shannon and Wilson, 1987). The surficial fill material encountered to the west showed little similarity to fill material found onsite. However, the silty clay/clayey silt confining layer encountered on Port of Seattle property correlated well with the confining layer identified at the site, indicating that the lack of confining material in the vicinity of boring SB-1D might be a local anomaly. In most areas, coarse-grained sediments, similar to those observed at the former Champion site, were encountered below the silt and clay confining layer. The presence of these sediments indicated that the second aquifer zone was laterally extensive in the area of investigation.

3.4.1.4 Hydraulic Gradients. Three additional monitoring wells (MW-2, MW-3, and MW-4) were installed at the site to help characterize the occurrence and direction of shallow groundwater movement. Water level evaluation data is summarized in Table 3-3. As shown in Figure 3-5, the direction of the hydraulic gradient in the solvent tank area was found to be toward the northwest, generally parallel to the topographic gradient. Groundwater occurring in the shallow fill material was conjectured to discharge directly into the Lake Washington Ship Canal. The magnitude of the hydraulic gradient, as calculated from 14 February 1990 water level data, was 0.0036 (dimensionless).

For the supplemental RI, available hydrologic information was reviewed to determine the direction of the hydraulic gradient within the second zone of saturation. A report prepared by the USGS for the Gas Works Park area (USGS, 1988) indicated that groundwater occurring in the Vashon Drift aquifer zone migrates toward, and is a recharge source for, Lake Union. Assuming that similar stratigraphic conditions prevail in the vicinity of the former Champion site, it was suggested that groundwater in the second zone of saturation also flows toward the Ship Canal.

Vertical hydraulic gradients were not evaluated at or in the vicinity of the site. However, information presented in the USGS evaluation of the Gas Works Park area suggested that there is a net upward vertical gradient within Vashon Drift sediments. If this was the case, it was thought that the gradient would tend to inhibit downward migration of contaminants. Furthermore, based on a review of lithologic data for the upper fill zone collected from the site, it appeared that lateral groundwater movement was accomplished more readily than vertical movement, due primarily to the occurrence of sand lenses within the fine-textured matrix (silt, clay, and organics).

Based on available information, groundwater flow velocity in the solvent tank area was estimated for the RI. This estimate was based entirely on estimated aquifer parameters (except for the hydraulic gradient) using textbook values (Freeze and Cherry, 1979). A hydraulic conductivity value of $1 \times 10^{-3}$ cm/s was used to estimate the groundwater flow rate. Since the upper fill material is comprised primarily of silty sand and organics, the hydraulic conductivity value used is expected to be very conservative. The textbook value was used in lieu of Slug tests because of variability in data which frequently result from performance of this type of in situ test. Groundwater flow velocity was estimated using the following equation:

$$V = (K \times I)/n$$

where:

$V$ = velocity
$K$ = hydraulic conductivity (cm/sec)
$I$ = hydraulic gradient (dimensionless)
$n$ = soil porosity (%)

Using onsite hydraulic gradient information, I was estimated to be 0.0036. Using Freeze and Cherry data, the following aquifer parameters were estimated:

$K = 1 \times 10^{-3}$ cm/sec
$n = 35\%$ (0.35)

Therefore:

$$V = [(1 \times 10^{-3} \text{ cm/sec}) \times 0.0036]/0.35 = 1.03 \times 10^{-5} \text{ cm/sec} = 10.7 \text{ ft/yr}$$

3.4.1.5 <u>Groundwater Quality</u>. Information for the RI regarding regional groundwater quality in the vicinity of the former Champion site was limited. The nearest groundwater supply well that could be identified was located approximately three-fourths of a mile east of the site. Lithologic conditions encountered while drilling the well were similar to those encountered in deep borings onsite.

The groundwater supply well was found to be screened in sand and gravel at 45 to 55 feet below ground surface. The Municipality of Metropolitan Seattle (METRO) owns the well and uses the groundwater for performing bioassay tests. Results of analysis of the water for general minerals and other water quality parameters indicated low to nondetectable levels of ions and metals. None of the priority pollutant compounds found in VOC, BNA-extractable compound, and pesticide analyses was detected. Although it was unlikely that groundwater occurring in the

METRO well could have hydraulic communication with groundwater below the former Champion site, due to the drastic lithological changes that occur over short distances in a fluvially deposited zone, its evaluation gave a general indication of water quality within upper Vashon Drift sediments.

Because the upper fill zone is directly exposed to surface water runoff that may contain elevated levels of heavy metals and other contaminants, the background water quality parameters in the shallow fill zone were expected to be higher than those in a deeper aquifer zone. In addition, the higher turbidity of the shallow zone groundwater most likely exaggerated the actual metal concentrations.

Analysis of a groundwater sample collected from monitoring well MW-1 for general parameters indicated that groundwater occurring in the shallow fill material exceeded the secondary drinking water standards established by the EPA for iron, manganese, sulfate, total dissolved solids (TDS), and color. None of these compounds were believed to have resulted from Champion's operations onsite. High concentrations of secondary contaminants indicated that naturally occurring groundwater in the upper fill zone was unsuitable for human consumption (40 CFR 141, 143). Results of these analyses are summarized in Table 3-5.

### 3.4.2 Solvent Tank Area Investigation Results

As part of the supplemental RI, three groundwater monitoring wells and five soil borings were installed in the solvent tank area. These were sampled to evaluate the horizontal and vertical extent of potential solvent migration, specifically for carbon disulfide (Figure 3-1). This section presents the analytical results of soil and groundwater sampling.

3.4.2.1 Soil Sample Results. The analytical results for soil samples collected during the supplemental RI are summarized in Table 3-6. Three shallow soil borings within 40 feet of the former solvent waste tank were drilled and samples were analyzed to determine possible lateral dispersion and downgradient migration of solvents in shallow soils. Chemicals previously detected in the solvent tank included carbon disulfide, chloroform, carbon tetrachloride, and tetrachloroethylene.

A deep boring was drilled approximately 20 feet downgradient of the former solvent waste tank to address WDOE's concern about possible DNAPL migration to the base of the upper fill aquifer. Due to poor recovery of soil samples in the first 15 feet of the deep boring, a fourth shallow boring was drilled approximately 6 feet away to obtain the missing soil samples due to poor recovery.

Of the 12 soil samples analyzed for VOCs, none contained chemicals previously identified in the former solvent waste tank. However, four EPA non-priority pollutant compounds were detected, including acetone, bicyclo[3,1,1]hepta-2-ene,3,6,6-trimethyl, alpha-pinine, and 2,6-dimethyl-2-octene. The latter three compounds were tentatively identified; so their concentrations were estimated (Table 3-6).

Acetone was detected in one sample from boring SB-1D and one sample from boring SB-2, at concentrations of 37 and 38 ug/kg, respectively. This compound was detected at several other site locations (Parametrix, 1987) and was originally believed to be the result of field decontamination procedures or laboratory cross-contamination. However, laboratory blanks of clean Ottawa sand analyzed as part of this investigation did not indicate the presence of cross-contamination in the laboratory, and acetone was not used in the decontamination of field equipment. Therefore, the acetone detected appeared to represent actual site conditions. Available information suggested that acetone could be produced as a degradation product of fermentation of wood products (Kirk-Othmer, 1978).

Other non-priority pollutants found in shallow soil included alpha-pinene, detected in boring SB-1S at estimated concentrations of 470 and 240 ug/kg; bicyclo[3,1,1]-hepta-2-ene,3,6,6-trimethyl, detected at an estimated concentration of 180 ug/kg; and 2,6-dimethyl-2-octene, detected at an estimated concentration of 58 ug/kg (boring SB-3). These compounds are hydrocarbons that constitute turpentine. During the RI, they were identified as possible natural byproducts of wood degradation.

Four soil samples (from 8.5 to 28.5 feet below grade) from boring SB-1D, located approximately 25 feet downgradient of the former solvent waste tank were analyzed for VOCs. Testing showed that none of the samples contained any chemicals of concern. This indicated that chemicals previously detected in the area were not widespread, since residual contamination would be expected in subsurface soils. It is unlikely that VOCs, such as carbon disulfide, would have sunk below the area that was investigated because residual contaminants would have been detected in surface soil samples. Residual contaminants would be expected because contaminants in water below their solubility limit do not tend to sink within the formation.

3.4.2.2 Groundwater Results. During removal of the solvent tank, a shallow nonstandard monitoring well was installed in the excavation to evaluate potential releases from the tank. Results of initial sampling indicated detectable levels of carbon disulfide, carbon tetrachloride, chloroform, and tetrachloroethylene. To evaluate the extent of possible solvent migration and assess the potential for onsite migration from unknown sources, three additional monitoring wells were installed (see Figure 3-1 for well locations).

All groundwater samples were analyzed for VOCs, and one sample from well MW-1 (previously installed in the solvent waste tank excavation) was analyzed for metals and PAHs. The analytical results for groundwater samples collected from the four wells are summarized in Table 3-5. As indicated, chemicals of concern were detected only in monitoring well MW-1. Carbon disulfide in original and duplicate samples of MW-1 groundwater was detected at 2,900 and 4,600 ug/L, respectively. In the same samples, chloroform was detected at concentrations of 280 and 420 ug/L, respectively.

Since these compounds were not detected in any other samples (soil or groundwater) collected during the supplemental RI, the extent of lateral dispersion and/or downgradient migration was probably limited. The analytical results also indicated that the release of these compounds was probably small in magnitude and may have occurred during tank removal and that the lithologic conditions in the near vicinity of the former tank were effective in reducing further chemical migration. Wells installed at the site fully penetrate the saturated thickness of the fill material, therefore, the possibility of dense nonaqueous phase liquids (DNAPLs) migrating below downgradient wells is unlikely. Furthermore, contaminants occur at concentrations below their solubility limits. Therefore, the potential for dense nonaqueous phase liquids, that would sink below existing monitoring wells, appears remote.

Metal concentrations detected in the sample from well MW-1 are also summarized in Table 3-5. Since processes that might have used metals were not performed at the former Champion property, metal concentrations detected in water probably represented natural conditions. Metal concentrations above natural background levels were also known to be likely in near-surface groundwater occurring in urban areas, especially in the slightly turbid samples collected from onsite wells. Stormwater sampling in the Lake Union area by the City of Seattle indicated the presence of metal concentrations in stormwater runoff and street dust (City of Seattle, 1986). Since surface water runoff is the primary recharge source for shallow groundwater, contaminants in surface water were expected to be found in shallow groundwater.

### 3.4.3 Boiler Ash Fill Investigation Results

Analyses of samples containing boiler ash collected by Parametrix in 1985 did not indicate levels of priority pollutant compounds that would significantly impact the environment. However, analyses performed by Parametrix during the preliminary RI detected slightly elevated pH (at 9.5 and 11.0) in samples containing boiler ash. Results for four samples obtained during the supplemental RI indicated that pH levels in the boiler ash fill ranged from 7.2 to 8.7. Therefore, elevated pH values for the boiler ash fill material described in previous reports were not confirmed during the supplemental RI.

A review of available literature was performed to evaluate the mobility of various metal ions with varying pH levels. The literature indicates that the solubility of selected metal hydroxides and sulfides are at their lowest when pH levels range from 9 to 11 (Industrial Water Engineering, 1973). Other forms of metallic compounds such as oxides and carbonates also tend to be least soluble at these pH. Levels of pH above 11 or below 9 typically resulted in an increase in solubility of these metal ions. The specific metallic ions that occur in the boiler ash are unknown, but are expected to be a mixture of oxides and carbonates. The overall trend of lower aqueous solubility with pH levels from 9 to 11 should reduce potential mobility of metals in the boiler ash.

During the RI, sampling of offshore sediments in the vicinity of the ash pile indicated the presence of several PAH compounds at low concentrations. These compounds included naphthalene, acenaphthene, fluorene, phenanthrene, anthracene, fluoranthene, pyrene, chrysene, benzo(a)anthracene, benzo(k)fluoranthene, benzo(b)fluoranthene, benzo(a)pyrene, and benzo(ghi)perylene.

To decide if the ash was homogeneous or if it might be contributing to offshore sediment contamination, six additional soil samples from two soil borings in the boiler ash were gathered. These were then submitted for analysis of priority pollutant heavy metals and BNA-extractable priority pollutants. Soil samples were collected from the top, middle, and bottom of the boiler ash; and four samples were submitted for pH analysis. In addition, samples exhibiting a petroleum odor were submitted for TPH analysis. To help characterize the lateral and vertical extent of the boiler ash, four additional shallow borings were drilled and sampled (refer to Figure 3-1 for boring locations).

The results of the chemical analysis of soil samples collected in the boiler ash fill are summarized in Table 3-7. Of the six samples analyzed, none showed any BNA-extractable compounds. These results suggested that the boiler ash was not a source of PAH compounds identified in offshore sediment samples.

For the four soil samples having petroleum odors, analysis results indicated levels of TPH (as diesel), ranging from nondetectable to 4 mg/kg. These TPH concentrations were well below the WDOE cleanup goal of 200 mg/kg, as established in the MTCA (WAC 173-340-740). They did not appear to represent a significant environmental concern.

The results of metal analyses of soil samples from the boiler ash fill indicated generally low metal concentrations, within the typical background range for urban soils. The potential risks to human health and the environment for these metal concentrations are discussed in Chapter 5.0.

The extent of the boiler ash was estimated from borings completed during the supplemental RI and from available historical data. The location of the boiler ash and material containing boiler ash differed from locations under previous conditions, due to movement of the material by SBT to facilitate property development. The ash was currently confined to an area west and north of the boiler building. The thickness measurements taken during the RI for ash directly north of the building were approximate, based on extrapolation of data from borings and historical maps made during the investigation. An isopach map was constructed (Figure 3-6) to depict the approximate areal extent and depth of the boiler ash.

During the RI, the volume of boiler ash was estimated at approximately 3,200 cubic yards, approximately half of which was located on or below the exposed land surface. An approximate volume of 700 cubic yards appeared to have been dredged from the area north of the boiler building during activities prior to the RI. The boiler ash did not appear to extend below the boiler building, due to the concrete foundation along its west side.

### 3.4.4 Surface Water Drainage Investigation Results

On two occasions, surface water drainage patterns were observed at and in the vicinity of the former Champion site to document potential migration pathways of chemicals in stormwater runoff (monitoring was performed on 7 March and 17 April 1990). Based on the observations made, a surface water drainage map was constructed (presented in Figure 3-7).

As indicated in the figure, surface water at the site was observed to flow generally toward the Lake Washington Ship Canal. Railroad tracks and associated berms located to the south of the site strongly influenced surface water flow. To the southeast of the site, surface water was observed to flow toward the west in a depressed area adjacent to the railroad tracks. Due to the gentle gradient, puddles frequently formed but were interconnected by the flow of surface water toward the west.

On the south side of the warehouse (glue press area), surface water flowed in a westerly direction, forming shallow puddles and eventually flowing toward the north below the warehouse building. Ultimately, the water in this area discharged to the Lake Washington Ship Canal in the vicinity of the glue press area.

Surface water occurring in the southwest and northwest portions of the former Champion site were observed to flow toward a low-lying area centered between the two regions. As surface water accumulates in this area, two puddles form and eventually discharge to the west into the Lake Washington Ship Canal.

Surface water from the roofs of site buildings discharged directly to the ground or into the Ship Canal. Water runoff in the asphalt-covered parking area to the south of the SBT office collected in a catch basin in the center of the parking area. This water also ultimately drained into the Lake Washington Ship Canal.

Surface water that accumulated on the Ballard Bridge was observed to drain directly from the bridge through catch basins onto the site, or into the Ship Canal. Surface water runoff from the bridge and urban runoff from the vicinity of the site were considered possible sources of the metals, PAHs, and hydrocarbons detected in sediment samples from the former Champion site.

3.4.4.1 Impact of Surface Water on Existing Conditions. The RI discovered that surface water runoff at the site did not appear to significantly affect contaminant migration. Water flowing below the warehouse in the vicinity of the glue piles was not observed to come into contact with these piles. The boiler ash fill might have been impacted by surface water runoff; however, most of the ash was covered with clean fill, reducing the potential for erosion of the sediments. Chemicals occurring in the solvent tank area were not affected by surface water runoff, due to the depth at which they were located. Furthermore, surface water recharge in the solvent tank area might have diluted existing solvent concentrations.

To further evaluate the potential for contaminant migration in the glue press area, the glue piles below the warehouse were inspected to determine their proximity to lake water. In each case, the glue piles were found to be below the level of the Lake Washington Ship Canal. Information obtained from the Army Corps of Engineers (lockmaster for Chittenden Locks) indicated that the lake level at the time of the inspection was 1.5 feet below maximum stage. At the maximum stage of the Lake Washington Ship Canal, the lower portions of the glue piles, which contained anthracene, could be exposed to lake water. However, due to the relative insolubility of anthracene in water, any contaminant migration was probably limited to physical mechanisms. Results of previous sampling of sediments did not indicate significant migration of the anthracene in the glue pile through this mechanism.

3.4.4.2 Potential Onsite Migration of Chemicals. As discussed previously, it was discovered that PAH compounds might be introduced to offshore sediments in the vicinity of the site through drainage from the Ballard Bridge. Another possible source of PAHs was surface water runoff from roadways and parking areas near the site.

According to WDOE files, Pioneer Lumber and Treating Company operates a lumber treatment facility approximately 500 feet to the southeast of the site. Chemicals and materials used and stored at the facility include PCP, creosote, hydraulic oil, and fire retardants. Surface water runoff in the vicinity of Pioneer had been observed to flow west toward the former Champion site. Analysis of shallow soil samples collected by the WDOE indicated the presence of PCP (at 57 mg/kg) in a catch basin on the western portion of the Pioneer Lumber facility. Many of the PAH compounds detected in offshore sediment samples from the site had also been identified in samples collected from the Pioneer Lumber facility. Although PCP was not detected in sediment samples collected near the former Champion site, the potential existed for migration of PCP and other contaminants from offsite sources.

### 3.4.5 Methane Production Area Investigation Results

As described in Section 3.4.1, most of the site appeared to be underlain by significant amounts of organic debris, including wood chips, bark, sawdust, and lumber. The accumulation of organic matter was evidently the source of measurable amounts of methane detected in subsurface soil. Previous investigation by Parametrix (Parametrix, 1985) indicated that methane concentrations detected in subsurface soil during drilling activities were as high as 1,000 ppm.

Additional monitoring of methane levels produced during borehole drilling activities was performed during the supplemental RI to better evaluate the distribution of methane-producing areas. As discussed in Section 3.3.2, the headspaces of borings drilled in the solvent tank area were screened using a Foxboro OVA (sensitive to methane) and an HNU vapor detector (not sensitive to methane). The responses of the monitoring devices (relative to benzene gas) are summarized in

Table 3-8, along with OVA monitoring results of analyses by Parametrix for other portions of the site.

As indicated in Table 3-8, elevated levels of organic vapor (near or greater than 1,000 ppm) were detected during drilling of most borings in the solvent tank area. Methane-monitoring results (Parametrix) indicated similar methane levels. Based on a review of boring logs, it was assumed that high methane levels corresponded well to areas where organic debris was encountered. OVA readings greater than 1,000 ppm were observed in areas where there was less than 1 foot of organic debris. The only boring where high methane levels were not observed (MW-4) also did not show organic debris.

In most cases, methane concentrations were found to be greater than 1,000 ppm directly above the water table. Below the water table, methane levels generally decreased. In several instances, an explosimeter was used to estimate maximum methane levels. The highest explosimeter reading (100 percent of the lower explosive limit) was measured in the headspace of boring SB-6. This reading corresponded to at least 5 percent methane by volume. Further monitoring of ambient air a few inches directly above the boring indicated that methane had diffused quickly and was no longer detectable.

### 3.4.6 Offshore Sediment Investigation Results

In 1989, a two-phase sediment sampling and analysis program was implemented to evaluate any potential impacts to shallow sediments occurring beneath and adjacent to the former Champion site on the Lake Washington Ship Canal. Program objectives were to:

- Identify chemicals occurring at the site that might have migrated from the glue pile, boiler ash, and solvent tank areas.
- Assess the extent of chemical migration.
- Evaluate background levels of chemicals of concern occurring in the Lake Washington Ship Canal, and use these levels to establish a baseline for evaluating chemical concentrations in offshore sediment samples from locations in close proximity to the site.

Phase I sediment sampling results are presented in a report prepared by Jay Spearman, Consulting Engineer, for submittal to WDOE (Spearman, 1989). Phase II results are included in this RI/RA/FS report, in Appendix E. A brief summary of the sediment sampling results is discussed below.

3.4.6.1 Phase I Investigation. Phase I sediment sampling identified the types and levels of chemicals occurring in the former mill log pond area. The sampling program identified chemical levels in this area prior to implementing dredging proposed by SBT. Samples were collected from four sampling locations and 12 offshore sampling locations, and were formed as composites of the first 4 feet of sediments. In addition, surface samples were collected from the top 6 inches of sediments at four of the sampling locations.

A summary of sample analysis results and approximate sampling locations is presented in the Jay Spearman report dated 23 March 1989 (Spearman, 1989). Sediment samples were analyzed by the following methods:

| Chemicals | Test Method |
|---|---|
| Metals | SW-846 |
| PAHs | EPA-8100 |
| VOCs | EPA-8240 |
| PCPs | EPA-8040 |
| TPHs | EPA 418.1 |
| Grain Size | ASTM D-421 |

The results of sample analyses were as follows:

- Metal concentrations in sediment samples from the mill pond area were generally low (below or only slightly above levels detected in the Lake Washington Ship Canal), according to a report prepared by the City of Seattle (City of Seattle, 1986).

- Sample analyses for PAHs in offshore vertical composite samples (first 4 feet encountered) indicated that all chemical concentrations were below detectable limits, except at sampling location 9, where 1.4 mg/kg of fluoranthene was detected.

- Analysis of samples collected from the shallow surface sediments of the offshore sampling locations indicated the presence of several PAH compounds, including anthracene at a maximum concentration of 17 mg/kg.

- Analyses of samples did not detect PCP or carbon disulfide. However, they did detect acetone at a maximum concentration of 410 mg/kg and TPH at a maximum concentration of 9,300 mg/kg.

- Metal concentrations in upland samples collected near or in the boiler ash fill splitting shed sediments were generally higher than those detected in offshore sediments. Arsenic, copper, lead, and zinc occurred most frequently, with maximum concentrations of 73, 610, 450, and 1,800 mg/kg, respectively.

- Neither PAH nor PCP compounds were detected in any upland sediment samples collected during Phase I. However, toluene, methylene chloride, acetone, and TPH were detected in several of these samples. The maximum concentrations of these chemicals were 1,200 ug/kg, 22 ug/kg, 28,000 ug/kg, and 9,300 mg/kg, respectively.

Based on the results of Phase I of the sediment sampling program, the WDOE allowed SBT to proceed with its proposed dredging operation. The area that was sampled (including upland areas where elevated TPH was detected) was subsequently removed through dredging. SBT disposed of most of the dredged spoils at a local landfill. An in-depth discussion of the Phase I investigation is present in the Spearman report (Spearman, 1989).

3.4.6.2 Phase II Investigation. Phase II sediment sampling evaluated chemical constituents in offshore sediments beneath onsite buildings and offshore sediments in the Ship Canal and the DNR lease area. Appendix E presents a detailed discussion of the objectives, sampling methods, and sample results. This section provides an overview of investigation findings.

Sediment samples were collected underneath onsite buildings, in the DNR lease area, and in the Lake Washington Ship Canal (sampling locations are presented in Appendix E and on Figure 3-1, this report). In this document, sediment sample analysis results are given in Table 3-9. The following summarizes the sediment investigation findings:

- TPH concentrations ranged from 7,300 mg/kg to 250,000 mg/kg in sediment samples collected below the buildings. Analysis of two samples showing the highest TPH levels for gasoline and diesel indicated that gasoline was detected at concentrations up to 3.5 mg/kg and diesel was detected at a maximum concentration of 2,000 mg/kg. TPH concentrations detected in the DNR lease area and the Ship Canal were generally lower than those detected below onsite buildings. Diesel was reportedly never used at the former Champion site; therefore, the source was unknown. Available information suggested that it might be the result of urban runoff, releases from nearby facilities, or ship traffic in the Lake Washington Ship Canal. A trend toward high TPH concentrations was observed in samples from offshore areas below existing buildings where previous activities had not taken place. This provided further support to the supposition that the TPH might have traveled on the lake surface and been deposited below the buildings by wave action.

  TPH concentrations measured in offshore sediments were exaggerated as a result of two factors. The first factor was the analytical method used (EPA Method 418.1), in which a broad spectrum of hydrocarbon compounds is identified, not only those on which cleanup criteria are based. Analysis of the two samples for the gasoline and diesel fraction showed much lower TPH concentrations. The second factor exaggerating TPH concentrations was dry weight analysis of the sediment samples. Since the weight of organic material that made up a large portion of the sediment samples was not included in the calculation of TPH concentrations, the actual concentrations were significantly exaggerated.

- Only acetone was detected in VOC analysis of the sediment samples. As discussed previously, acetone can be a fermentation byproduct of wood degradation. Carbon disulfide and other solvents occurring in the solvent tank area were not detected during this investigation.

- PCP was not detected in any sediment samples collected during Phase II.

- PAHs, including phenanthrene, anthracene, fluoranthene, pyrene, benzo(a)anthracene, and benzo(k)fluoranthene, were detected intermittently (a maximum of three times out of eight samples) at relatively low concentrations below onsite buildings. Similar or slightly lower concentrations of these chemicals were detected in the Ship Canal. In the DNR lease area, only fluoranthene was detected, one time, at 0.21 mg/kg. The anthracene in offshore sediment samples possibly resulted from previous activities at the site, since the compound was not found in Ship Canal sediment samples.

  Other PAH compounds and TPHs in offshore sediments were probably the result of chemicals introduced to the area through surface water runoff from the Ballard Bridge and through storm drains. As mentioned previously, surface water runoff from the Ballard Bridge discharges directly into the Lake Washington Ship Canal, where several of the Phase II samples were collected. Therefore, the Ballard Bridge could be a source of PAHs detected in offshore sediments. TPH in offshore sediments might have resulted from releases into the Lake Washington Ship Canal that eventually migrated to stagnant shoreline areas, such as those beneath onsite buildings. SBT noted several times during the winter of 1989/1990 that petroleum products discharged to the Ship Canal had migrated to stagnant areas below buildings.

- Metal concentrations detected in sediment samples below onsite buildings were above the Interim Sediment Quality standards (AET) established by the WDOE for arsenic, lead, mercury, and zinc in marine sediments (WDOE, 1989). These values are summarized below:

| Chemical | Maximum Sediment Concentration (mg/kg)* | Interim Sediment Quality Standard (mg/kg)* |
|---|---|---|
| Arsenic | 67 | 57 |
| Copper | 780 | 390 |
| Lead | 1,200 | 450 |
| Mercury | 3.7 | 0.41 |
| Zinc | 900 | 410 |

* Dry weight basis

- The AETs have been developed for use with marine sediments, and are presented for comparison purposes only.
- Metal concentrations detected in samples from the DNR lease area and in the Ship Canal are typically as much as an order of magnitude less than the concentrations detected below onsite buildings.

### 3.4.7 Underground Tank Investigation Results

On 9 February 1990, Kennedy/Jenks/Chilton conducted a search of the former Champion site for possible underground storage tanks. The survey included a site inspection and interviews with current site occupants and former personnel. In addition, the City of Seattle Fire Department was requested to review its file regarding possible underground tanks on the property.

In the course of the search, one underground fuel tank was discovered, located on the northeast corner of the intersection of 13th Avenue W and W Ewing Street (Figure 3-1). From discussions with former Champion employees, it was determined that the 1,000-gallon tank might have contained gasoline used to refuel company vehicles. The tank was about half full of water at the time it was discovered.

A sample of tank contents was collected and analyzed for TPH (as gasoline and diesel) and for dissolved gasoline components by EPA Method 8020. The results of the sample analysis are summarized below:

| Chemical | Concentration (mg/L) |
|---|---|
| TPH (gasoline) | 160 |
| TPH (diesel) | <0.11 |
| Benzene | 20 |
| Ethylbenzene | 47 |
| p-xylene | 560 |
| m-xylene | 1,400 |
| o-xylene | 1,300 |

Analytical report sheets for this sample are presented in Appendix B.

On 27 September 1990, the tank was removed and the contents disposed of offsite at a permitted disposal facility. Documentation of tank removal, inspection, collection of soil samples, and analytical results are provided in Appendix J.

Tank removal was performed by O'Sullivan Construction Inc. After tank removal, three samples of the backfill were collected for chemical analysis. Two of the samples consisted of soil, the third was predominantly wood chips. Samples were analyzed for TPH by EPA Method 418.1, and for benzene, toluene, ethylbenzene, and xylenes (BTEX) by EPA Method 8020. All analytical results were below detectable levels except for the sample collected from the sidewalls of the excavation that detected TPH at 57.4 mg/Kg and the wood chips sample in which TPH was detected at 1,145 mg/Kg. Because the presence of organic material frequently biases the results of TPH analyses by EPA Method 418.1, the sample was reanalyzed for TPH by EPA modified Method 8015. This analysis resulted in a TPH concentration of less than 50 mg/Kg (total gasoline hydrocarbons), well below MTCA cleanup levels for soil.

### 3.4.8 Removal of Containerized Waste

As discussed in Section 3.3.8, containerized wastes identified at the site were disposed of offsite at a permitted facility by Chempro Inc. Waste profile sheets for these wastes are provided in Appendix I. Refer to Section 3.3.8 for more details.

# TABLE 3-1

## SUMMARY OF SOIL SAMPLING ACTIVITIES DURING THE SUPPLEMENTAL RI

| Chemical | Boring Number/Depth in Feet | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Solvent Tank Area Soil Borings | | | | | | | | | | | | Boiler Ash Area Soil Borings | | | | | | | | | |
| | SB-1S | | | | SB-1D | | | | SB-2 | SB-3 | SB-4 | | SB-5 | | | | SB-7 | | | | | SB-11 |
| | 8.5–9.0 | 3.0–13. | 6.0–16. | 17.5–18.0 | 8.5–9.0 | 18.5–19 | 3.5–24. | 28.0–28.5 | 13.0–13.5 | 13.0–13.5 | 2.5–13. | 13–13.5 | 4.0–4.5 | 7.0–7.5 | 8.5–9.0 | 11.5–12.0 | 3.0–3.5 | 7.5–8.0 | 9.0–9.5 | 3.5–14. | 15.0–15.5 | 16.0–16.5 |
| Volatiles (1) | X | X | X | X | X | X | X | X | X | X | X | X | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| pH | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | X | -- | -- | X | X | -- | -- | X | -- | -- |
| TPH (2) | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | X | -- | -- | -- | -- | X | -- | X | X |
| BNAs (3) | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | X | -- | X | X | X | X | -- | X | -- | -- |
| Metals (4) | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | X | -- | X | X | X | X | -- | X | -- | -- |

Notes:

-- Not analyzed.

(1) VOCs analyzed by EPA Method 8240.

(2) TPH analyzed by EPA Method 418.1.

(3) BNAs analyzed by EPA Method 8270.

(4) Selected metals analyzed by inductively coupled argon plasma emission spectroscopy, or by atomic absorption spectrophotometry.

## TABLE 3-5

## SUMMARY OF GROUNDWATER SAMPLE RESULTS
## SOLVENT TANK AREA WELLS

| Chemical | Units | Sample Number (Collection Date) | | | | |
|---|---|---|---|---|---|---|
| | | MW-1 (02/06/90) | MW-1 (02/06/90) | MW-2 (02/06/90) | MW-3 (02/06/90) | MW-4 (02/06/90) |
| | | | Duplicate | | | |
| Volatiles | | | | | | |
| Methylene chloride | ug/L | <25 | <25 | <5 | <5 | <5 |
| Chloroform | ug/L | 280 | 420 | <5 | <5 | <5 |
| Carbon tetrachloride | ug/L | <25 | <25 | <5 | <5 | <5 |
| Tetrachloroethylene | ug/L | <25 | <25 | <5 | <5 | <5 |
| Acetone | ug/L | <50 | <50 | <10 | <10 | <10 |
| Carbon disulfide | ug/L | 2,900 | 4,600 | <5 | <5 | <5 |
| PAHs | | | | | | |
| Anthracene | mg/L | <0.005 | <0.005 | -- | -- | -- |
| Metals | | | | | | |
| Arsenic (As) (4) | mg/L | 0.010 | 0.008 | -- | -- | -- |
| Barium (Ba) (3) | mg/L | 0.060 | 0.059 | -- | -- | -- |
| Cadmium (Cd) (3) | mg/L | <0.003 | <0.003 | -- | -- | -- |
| T. chromium (Cr) (3) | mg/L | 0.013 | 0.012 | -- | -- | -- |
| Copper (Cu) (3) | mg/L | 0.046 | 0.046 | -- | -- | -- |
| Iron (Fe) (3) | mg/L | 10 | 9.3 | -- | -- | -- |
| Lead (Pb) (4) | mg/L | 0.032 | 0.030 | -- | -- | -- |
| Manganese (Mn) (3) | mg/L | 0.38 | 0.37 | -- | -- | -- |
| Mercury (Hg) (5) | mg/L | <0.0002 | <0.0002 | -- | -- | -- |
| Potassium (K) (4) | mg/L | 7 | 6.8 | -- | -- | -- |
| Selenium (Se) (4) | mg/L | <0.003 | <0.003 | -- | -- | -- |
| Silver (Ag) (4) | mg/L | <0.01 | <0.01 | -- | -- | -- |
| Sodium (Na) (4) | mg/L | 93 | 97 | -- | -- | -- |
| Zinc (Zn) (3) | mg/L | 0.14 | 0.25 | -- | -- | -- |
| General Parameters | | | | | | |
| Total hardness (CaCO3) | mg/L | 250 | 240 | -- | -- | -- |
| Calcium (Ca) | mg/L | 94 | 94 | -- | -- | -- |
| Magnesium (Mg) | mg/L | 4 | 2 | -- | -- | -- |
| Total alkalinity (CaCO3) | mg/L | 210 | 230 | -- | -- | -- |
| Bicarbonate (HCO3) | mg/L | 260 | 280 | -- | -- | -- |
| Sulfate (SO4) | mg/L | 260 | 260 | -- | -- | -- |
| Chloride (Cl) | mg/L | 10 | 10 | -- | -- | -- |
| Nitrate (NO3) | mg/L | 0.02 | <0.02 | -- | -- | -- |
| Fluoride | mg/L | 0.2 | 0.19 | -- | -- | -- |
| pH (laboratory) | unit | 7.4 | 7.3 | -- | -- | -- |
| Conductivity | umhos/cm | 900 | 910 | -- | -- | -- |
| TDS | mg/L | 630 | 640 | -- | -- | -- |
| Silica (SiO2) | mg/L | 40 | 30 | -- | -- | -- |
| Color, true | unit | 22 | 23 | -- | -- | -- |
| Turbidity | NTU | 420 | 420 | -- | -- | -- |

Notes:

-- Not analyzed.

(1) VOCs analyzed by EPA Method 8240. Only those compounds detected in one or more samples, or elsewhere onsite, are reported.

(2) PAHs analyzed by EPA Method 610. None of these compounds was detected; so only the detection limits for anthracene are reported.

(3) Selected metals analyzed by inductively coupled argon plasma emission spectroscopy.

(4) Selected metals analyzed by atomic absorption spectrophotometry.

(5) Mercury analyzed by cold vapor atomic absorption spectrophotometry.

# TABLE 3-6

## SUMMARY OF SOIL SAMPLE RESULTS
## SOLVENT TANK AREA BORINGS

| Chemical | Units | Boring Number (Collection Date)/Depth in Feet | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | SB-1S (2/1/90) | | | | SB-1D (1/26/90) | | | | SB-2 (1/29/90) | SB-3 (1/30/90) | SB-4 (1/30/90) | |
| | | 8.5-9.0 | 13.0-13.5 | 16.0-16.5 | 17.5-18.0 | 8.5-9.0 | 18.5-19 | 23.5-24.0 | 28.0-28.5 | 13.0-13.5 | 13.0-13.5 | 12.5-13.0 | 13-13.5(Dup) |
| Volatiles (1) | | | | | | | | | | | | | |
| Methylene chloride | ug/kg | <5 | <5 | <5 | <5 | <5 | <5 | <5 | <5 | <5 | <5 | <5 | <5 |
| Chloroform | ug/kg | <5 | <5 | <5 | <5 | <5 | <5 | <5 | <5 | <5 | <5 | <5 | <5 |
| Carbon tetrachloride | ug/kg | <5 | <5 | <5 | <5 | <5 | <5 | <5 | <5 | <5 | <5 | <5 | <5 |
| Tetrachloroethylene | ug/kg | <5 | <5 | <5 | <5 | <5 | <5 | <5 | <5 | <5 | <5 | <5 | <5 |
| Acetone | ug/kg | <10 | <10 | <10 | <10 | 37 | <10 | <10 | <10 | 38 | <10 | <10 | <10 |
| Carbon disulfide | ug/kg | <5 | <5 | <5 | <5 | <5 | <5 | <5 | <5 | <5 | <5 | <5 | <5 |
| Alpha-pinene | ug/kg | 470(2) | 240(2) | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| Bicyclo[3,1,1]hepta-2-ene-3,6,6-trimethyl | ug/kg | -- | -- | 180(2) | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| 2,6-Dimethyl-2-octene | ug/kg | -- | -- | -- | -- | -- | -- | -- | -- | -- | 58(2) | -- | -- |

Notes:

-- Not analyzed.

(1) VOCs analyzed by EPA Method 8240. Only those compounds detected in one or more samples, or elsewhere onsite, are reported.

(2) Compound identification is tentative and concentration is estimated.

# TABLE 3-7

## SUMMARY OF SOIL SAMPLE RESULTS
## BOILER ASH FILL

| | | Boring Number (Collection Date)/Depth in Feet | | | | | | | | | | Sample Location (Collection Date)/Depth in Feet | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | SB-5 (1/31/90) | | | | SB-7 (1/31/90) | | | | | SB-11 (2/2/90) | CH-1 (2/6/89) | CH-1 (2/13/89) | | | | CH-2 (2/13/89) | | |
| Chemical | Units | 4.0-4.5 | 7.0-7.5 | 8.5-9.0 | 11.5-12.0 | 3.0-3.5 | 7.5-8.0 | 9.0-9.5 | 13.5-14.0 | 15.0-15.5 | 16.0-16.5 | 3-4.5 | 3-4.5 (Dup) | 12-13.5 | 22-23.5 | 22-23.5(Dup) | 7-8.5 | 12-13.5 | 22-23.5 |
| Total Solids | % | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | 68.0 | 69.4 | 57.9 | 66.6 | -- | 31.0 | 53.5 | 22.8 |
| pH | unit | 7.2 | -- | -- | 7.4 | 8.6 | -- | -- | 8.7 | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| TPH (1) | | | | | | | | | | | | | | | | | | | |
| as gasoline | mg/kg | -- | <0.05 | -- | -- | -- | -- | <0.05 | -- | <0.05 | <0.05 | -- | -- | -- | -- | -- | -- | -- | -- |
| as diesel fuel | mg/kg | -- | <1 | -- | -- | -- | -- | <1 | -- | 1 | 4 | -- | -- | -- | -- | -- | -- | -- | -- |
| Total | mg/kg | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | 110 | <110 | 150 | 160 | -- | 180 | 9300 | 3000 |
| BNAs (2) | | | | | | | | | | | | | | | | | | | |
| Anthracene | mg/kg | <0.330 | -- | <0.330 | <0.330 | <0.330 | <0.330 | -- | <0.330 | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| Metals | | | | | | | | | | | | | | | | | | | |
| Antimony (Sb) (3) | mg/kg | 6.9 | -- | 1.3 | 3.8 | 0.5 | 1.6 | -- | 1.4 | -- | -- | 1.3 | 0.53 | 1.5 | <0.45 | <0.45 | <1 | 2.1 | <1.3 |
| Arsenic (As) (4) | mg/kg | 5.2 | -- | 3.4 | 7.3 | 2.6 | 3.8 | -- | 3.6 | -- | -- | 37 | 40 | 55 | 44 | 44.1 | 41 | 46 | 48 |
| Barium (Ba) (3) | mg/kg | 160 | -- | 470 | 680 | 320 | 740 | -- | 670 | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| Beryllium (Be) (3) | mg/kg | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | <0.03 | <0.03 | <0.034 | <0.03 | <0.03 | <0.064 | <0.04 | <0.09 |
| Cadmium (Cd) (3) | mg/kg | 0.36 | -- | <0.05 | 0.06 | 0.23 | 0.21 | -- | <0.05 | -- | -- | <0.075 | <0.07 | <0.085 | <0.075 | <0.075 | 35 | 0.84 | 9.2 |
| T. chromium (Cr) (3) | mg/kg | 13 | -- | 7.8 | 12 | 22 | 14 | -- | 11 | -- | -- | 15 | 21 | 28 | 32 | 35.2 | 39 | 35 | 64 |
| Copper (Cu) (3) | mg/kg | 93 | -- | 88 | 130 | 130 | 130 | -- | 84 | -- | -- | 180 | 200 | 180 | 130 | 119 | 600 | 290 | 610 |
| Lead (Pb) (4) | mg/kg | 30 | -- | 26 | 120 | 33 | 97 | -- | 43 | -- | -- | 28 | 17 | 31 | 19 | 22.4 | 450 | 22 | 350 |
| Mercury (Hg) (5) | mg/kg | <0.05 | -- | 0.19 | <0.05 | <0.05 | <0.05 | -- | <0.05 | -- | -- | <0.075 | <0.07 | <0.085 | <0.075 | <0.075 | <0.16 | 0.24 | 0.73 |
| Nickel (Ni) (3) | mg/kg | 16 | -- | 9.7 | 10 | 21 | 10 | -- | 7.8 | -- | -- | 14 | 16 | 15 | 29 | 33 | 24 | 22 | 30 |
| Selenium (Se) (4) | mg/kg | <0.3 | -- | <0.3 | <0.3 | <0.3 | <0.3 | -- | <0.3 | -- | -- | <0.15 | <0.14 | <0.17 | <0.15 | <0.15 | <0.32 | <0.2 | 3 |
| Silver (Ag) (4) | mg/kg | 0.1 | -- | <0.1 | <0.1 | <0.1 | <0.1 | -- | <0.1 | -- | -- | 1.8 | 1.9 | 2.3 | 1.3 | 1.4 | 6 | 2.6 | 4.8 |
| Thallium (Tl) (4) | mg/kg | <0.5 | -- | <0.5 | <0.5 | <0.5 | <0.5 | -- | <0.5 | -- | -- | <0.15 | <0.14 | <0.17 | <0.15 | <0.15 | <0.32 | <0.2 | <0.44 |
| Zinc (Zn) (3) | mg/kg | 250 | -- | 120 | 62 | 190 | 440 | -- | 66 | -- | -- | 34 | 50 | 41 | 67 | 50.2 | 1200 | 550 | 1800 |

Notes:
-- Not analyzed.
(1) TPH analyzed by EPA Method 418.1.
(2) BNAs analyzed by EPA Method 8270. No compounds were detected; so only detection limits for anthracene are reported.
(3) Selected metals analyzed by inductively coupled argon plasma emission spectroscopy.
(4) Selected metals analyzed by atomic absorption spectrophotometry.
(5) Mercury analyzed by cold vapor atomic absorption spectrophotometry.

## TABLE 3–8

## SUMMARY OF METHANE MONITORING RESULTS

| Depth Interval (ft) | Supplemental RI – K/J/C OVA/HNU Monitoring Results, ppm as Benzene (1,2) | | | | | | | Environmental Audit – Parametrix, Inc. OVA Monitoring Results, ppm (1) | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | MW–2 | MW–3 | MW–4 | SB–1D | SB–2 | SB–3 | SB–4 | Boring 1 | Boring 2 | Boring 3 | Boring 4 |
| | 01/25/90 | 01/29/90 | 02/01/90 | 01/26/90 | 01/29/90 | 01/30/90 | 01/30/90 | 07/19/85 | 07/19/85 | 07/19/85 | 07/19/85 |
| 0–1 | <1/<1 | 400/<1 | -- | <1/<1 | 800/<1 | 4/<1 | -- | -- | -- | -- | -- |
| 1–2 | 30/<1 | >1,000/<1 | -- | 100/<1 | 600/<1 | >1,000/1 | >1,000/<1 | -- | -- | -- | -- |
| 2–3 | 700/<1 | >1,000/<1 | 6/<1 | >1,000/13 | >1,000/1 | >1,000/2.5 | >1,000/5 | 900 | 1,000 | 20 | >1,000 |
| 3–4 | >1,000/<1 | 500/<1 | -- | 40/5 | 800/<1 | 40/20 | 40/2 | -- | -- | -- | -- |
| 4–5 | >1,000/<1 | 40/<1 | 5/<1 | 500/3 | 30/<1 | 40/<1 | -- | 700 | -- | 300 | 150 |
| 5–6 | 300/<1 | -- | 4.5/<1 | -- | -- | -- | -- | -- | -- | -- | -- |
| 6–7 | -- | -- | 4/<1 | -- | -- | -- | -- | -- | -- | -- | -- |
| 7–8 | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| 8–9 | 300/<1 | -- | 4/<1 | -- | -- | -- | -- | -- | -- | -- | -- |
| 9–10 | -- | -- | -- | -- | -- | -- | -- | 50 | -- | 150 | -- |
| Water Level Depth (ft) | 2.5 | 2.8 | 5.5 | 2 | 2.5 | 3 | 2.5 | 2 | -- | 2 | 2 |

Notes:

-- Not measured.

(1) Parts per million (ppm), reported as benzene.

(2) OVA and HNU calibrated daily to a benzene or a hexane standard.

PHASE 2

# TABLE 3-9

## SUMMARY OF SEDIMENT SAMPLE RESULTS

| | | Under-Building Sediments | | | | | | | | Ship Canal Sediment | | | | | | | DNR Lease Area Sediments | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | B-1 | B-2 | B-3 | B-4 #1 | B-4 #2 | B-5 | B-5 (Dup) | B-6 | C-1 | C-2 | C-3 | C-4 | C-5 | C-6 | C-7 | D-1 | D-2 | D-3 #1 | D-4 | D-5 #1 | D-5 #2 | D-6 |
| | | 901314 | 901315 | 901316 | 901318 | 901317 | 901319 | 901377 | 901320 | 900997 | 900998 | 900999 | 901005 | 901006 | 901007 | 900892 | 901868/9 | 901008 | 901379 | 901013/4 | 901381 | 901382 | 901003 |
| Chemical | Units | 2/26/90 | 2/26/90 | 2/26/90 | 2/26/90 | 2/26/90 | 2/26/90 | 3/1/90 | 2/26/90 | 2/6/90 | 2/7/90 | 2/6/90 | 2/6/90 | 2/6/90 | 2/6/90 | 2/6/90 | 3/23/90 | 2/6/90 | 3/1/90 | 2/6/90 | 3/1/90 | 3/1/90 | 2/6/90 |
| Total Solids (1)(10) | % | 18 | 25 | 23 | 12 | 6.0 | 10 | 24 | 23 | — | — | — | — | — | — | — | 45 | 21 | 67 | 28 | 68 | 69 | 18 |
| Ignition Loss (2)(10) | % | 31 | 24 | 44 | 89 | 73 | 25 | 23 | 20 | — | — | — | — | — | — | — | 8 | 50 | 4 | 22 | 3 | 4 | 46 |
| Percent Moisture | % | 82 | 83 | 72 | 82 | 95 | 95 | 82 | 78 | — | 59 | — | 51 | — | — | 63 | 55 | 82 | 32 | 74 | 35 | 36 | 78 |
| TPH (3)(10) | mg/kg | 14,000 | 16,000 | 32,000 | 250,000 | 190,000 | 67,000 | 18,000 | 7,300 | — | 960 | — | 3,080 | — | — | 508 | <66 | 2,900 | 88 | 3,200 | <46 | <46 | 7,400 |
| VOCs (4)(10) | | | | | | | | | | | | | | | | | | | | | | | |
| Acetone | ug/kg | <53 | 140 | <38 | <59 | <140 | 600 | <50 | <34 | — | <19 | — | — | — | — | 39 | <22 | <48 | <15 | <56 | <15 | <16 | <22 |
| Phenols (5)(10) | | | | | | | | | | | | | | | | | | | | | | | |
| Pentachlorophenol | mg/kg | <2.8 | <52 | <11 | <52 | <100 | <25 | <1 | <1.1 | — | <4.7 | — | — | — | — | <6.9 | <0.56 | <12 | <0.37 | <8.9 | <0.36 | <0.4. | <14 |
| PAHs (6)(10) | | | | | | | | | | | | | | | | | | | | | | | |
| Naphthalene | mg/kg | <1.4 | <25 | <5.7 | <26 | <52 | <13 | <6.5 | <0.57 | <0.24 | <0.24 | 0.23 | <0.25 | <0.35 | <0.43 | 0.50 | <0.29 | <6.2 | <0.65 | <4.6 | <0.19 | <0.21 | <7.2 |
| Acenaphthene | mg/kg | <1.4 | <25 | <5.7 | <26 | <52 | <13 | <6.5 | <0.57 | <0.24 | <0.24 | <0.21 | <0.25 | <0.35 | 0.66 | <0.35 | <0.29 | <6.2 | <0.65 | <4.6 | <0.19 | <0.21 | <7.2 |
| Fluorene | mg/kg | <1.4 | <25 | <5.7 | <26 | <52 | <13 | <6.5 | <0.57 | <0.24 | <0.24 | <0.21 | <0.25 | <0.35 | 0.62 | <0.35 | <0.29 | <6.2 | <0.65 | <4.6 | <0.19 | <0.21 | <7.2 |
| Phenanthrene | mg/kg | <1.4 | <25 | 7.4 | <26 | <52 | <13 | <6.5 | 0.57 | <0.24 | 0.34 | 0.23 | <0.25 | <0.35 | 1.4 | 0.83 | <0.29 | <6.2 | <0.65 | <4.6 | <0.19 | <0.21 | <7.2 |
| Anthracene | mg/kg | <1.4 | <25 | <5.7 | 26 | 65 | <13 | <6.5 | <0.57 | <0.24 | <0.24 | <0.21 | <0.25 | <0.35 | <0.43 | <0.35 | <0.29 | <6.2 | <0.65 | <4.6 | <0.19 | <0.21 | <7.2 |
| Fluoranthene | mg/kg | 2.3 | <25 | 7.4 | <26 | <52 | <13 | <6.5 | 0.96 | <0.24 | 0.57 | 0.50 | 0.44 | <0.35 | <0.43 | 1.0 | <0.29 | <6.2 | <0.65 | <4.6 | <0.19 | 0.21 | <7.2 |
| Pyrene | mg/kg | 2.0 | <25 | <5.7 | <26 | <52 | <13 | <6.5 | 0.61 | <0.24 | 0.45 | 0.37 | 0.35 | <0.35 | 1.9 | 1.1 | <0.29 | <6.2 | <0.65 | <4.6 | <0.19 | <0.21 | <7.2 |
| Chrysene | mg/kg | <1.4 | <25 | <5.7 | <26 | <52 | <13 | <6.5 | <0.57 | <0.24 | <0.24 | <0.21 | <0.25 | <0.35 | <0.43 | 0.36 | <0.29 | <6.2 | <0.65 | <4.6 | <0.19 | <0.21 | <7.2 |
| Benzo(a)anthracene | mg/kg | 2.7 | <25 | <5.7 | <26 | <52 | <13 | <6.5 | <0.57 | <0.24 | 0.26 | <0.21 | <0.25 | <0.35 | <0.43 | 0.50 | <0.29 | <6.2 | <0.65 | <4.6 | <0.19 | <0.21 | <7.2 |
| Benzo(k)fluoranthene | mg/kg | <1.4 | <25 | <5.7 | <26 | 53 | <13 | <6.5 | 2.4 | <0.24 | <0.24 | <0.21 | <0.25 | <0.35 | 7.9 | 0.39 | <0.29 | <6.2 | <0.65 | <4.6 | <0.19 | <0.21 | <7.2 |
| Benzo(b)fluoranthene | mg/kg | <1.4 | <25 | <5.7 | <26 | <52 | <13 | <6.5 | <0.57 | <0.24 | <0.24 | <0.21 | <0.25 | <0.35 | 2.0 | <0.35 | <0.29 | <6.2 | <0.65 | <4.6 | <0.19 | <0.21 | <7.2 |
| Benzo(a)pyrene | mg/kg | <1.4 | <25 | <5.7 | <26 | <52 | <13 | <6.5 | <0.57 | <0.24 | 0.30 | <0.21 | <0.25 | <0.35 | 0.55 | 0.83 | <0.29 | <6.2 | <0.65 | <4.6 | <0.19 | <0.21 | <7.2 |
| Metals | | | | | | | | | | | | | | | | | | | | | | | |
| Antimony (Sb) (7)(10) | mg/kg | 12 | <1.2 | 7.4 | <2.5 | <6 | <3 | <1.25 | <1.3 | — | 1.1 | — | — | 0.81 | — | 1.1 | <0.67 | <1.4 | <0.45 | 2.8 | <0.43 | <0.48 | 26 |
| Arsenic (As) (8)(10) | mg/kg | 67 | 17 | 39 | 17 | 23 | 41 | 20 | 19 | — | 6.6 | — | — | 12 | — | 13 | 1.8 | 12 | 3.6 | 20 | 2.3 | 3.2 | 46 |
| Beryllium (Be) (7)(10) | mg/kg | <0.11 | <0.08 | <0.09 | <0.17 | <0.33 | <0.2 | 0.17 | <0.09 | — | 0.25 | — | — | 0.16 | — | 0.28 | 0.28 | <0.10 | 0.16 | <0.071 | 0.09 | 0.13 | <0.11 |
| Cadmium (Cd) (7)(10) | mg/kg | 3.6 | 1.6 | 1.5 | 1.9 | 3.8 | 3.3 | 1.0 | 1.0 | — | 0.38 | — | — | 0.54 | — | 0.83 | <0.2 | 0.43 | 0.10 | 1.1 | 0.28 | 0.18 | 2.5 |
| T. chromium (Cr) (7)(10) | mg/kg | 190 | 30 | 83 | 22 | 48 | 65 | 42 | 52 | — | 45 | — | — | 46 | — | 50 | 40 | 48 | 21 | 64 | 19 | 21 | 94 |
| Copper (Cu) (7)(10) | mg/kg | 780 | 380 | 160 | 240 | 370 | 230 | 110 | 74 | — | 60 | — | — | 100 | — | 120 | 8.5 | 200 | 16 | 310 | 12 | 18 | 430 |
| Lead (Pb) (8)(10) | mg/kg | 830 | 180 | 1,000 | 190 | 1,200 | 280 | 79 | 83 | — | 38 | — | — | 110 | — | 150 | <11 | 140 | 11 | 280 | <7.2 | <8.1 | 610 |
| Mercury (Hg) (9)(10) | mg/kg | 3.7 | 2 | 0.65 | 0.50 | 1 | 1.9 | <0.21 | 0.30 | — | 0.36 | — | — | 0.76 | — | 1.3 | <0.1 | 0.67 | <0.07 | 1.3 | <0.07 | <0.08 | 2.4 |
| Nickel (Ni) (7)(10) | mg/kg | 67 | 32 | 29 | 12 | 25 | 44 | 46 | 48 | — | 53 | — | — | 57 | — | 53 | 26 | 52 | 27 | 64 | 17 | 21 | 89 |
| Selenium (Se) (8)(10) | mg/kg | 2.2 | <1.2 | <1.3 | <2.5 | <6 | <3 | <1.25 | <1.3 | — | <0.57 | — | — | <0.81 | — | <0.83 | 0.66 | <1.4 | <0.45 | <1.1 | <0.43 | <0.48 | <1.7 |
| Silver (Ag) (8)(10) | mg/kg | 0.72 | <0.4 | 3 | <0.83 | <1.7 | <1 | 1.7 | <0.43 | — | <0.19 | — | — | <0.27 | — | 0.28 | <0.22 | <0.48 | <0.15 | 0.89 | <0.15 | <0.16 | 1.7 |
| Thallium (Ti) (8)(10) | mg/kg | <3 | <2 | <2.2 | <4.2 | <8.3 | <5 | <2.1 | <2.2 | — | <0.94 | — | — | <1.4 | — | <1.4 | 1.4 | <2.4 | <0.75 | <1.8 | <0.72 | <0.8 | 2.8 |
| Zinc (Zn) (7)(10) | mg/kg | 890 | 440 | 360 | 620 | 900 | 520 | 210 | 180 | — | 110 | — | — | 180 | — | 0.56 | 24 | 300 | 33 | 390 | 25 | 34 | 830 |

Notes:

— Not analyzed.

(1) Percent by weight of sample received after drying at 103 degrees Celsius.

(2) Percent by weight of total solids that ignited at 550 degrees Celsius.

(3) TPH analyzed by EP A Method 418.1.

(4) VOCs analyzed by E PA Method 8240. Only those compounds detected in one or more sam ples are reported.

(5) Phenolic compounds analyzed by EPA Method 8040.

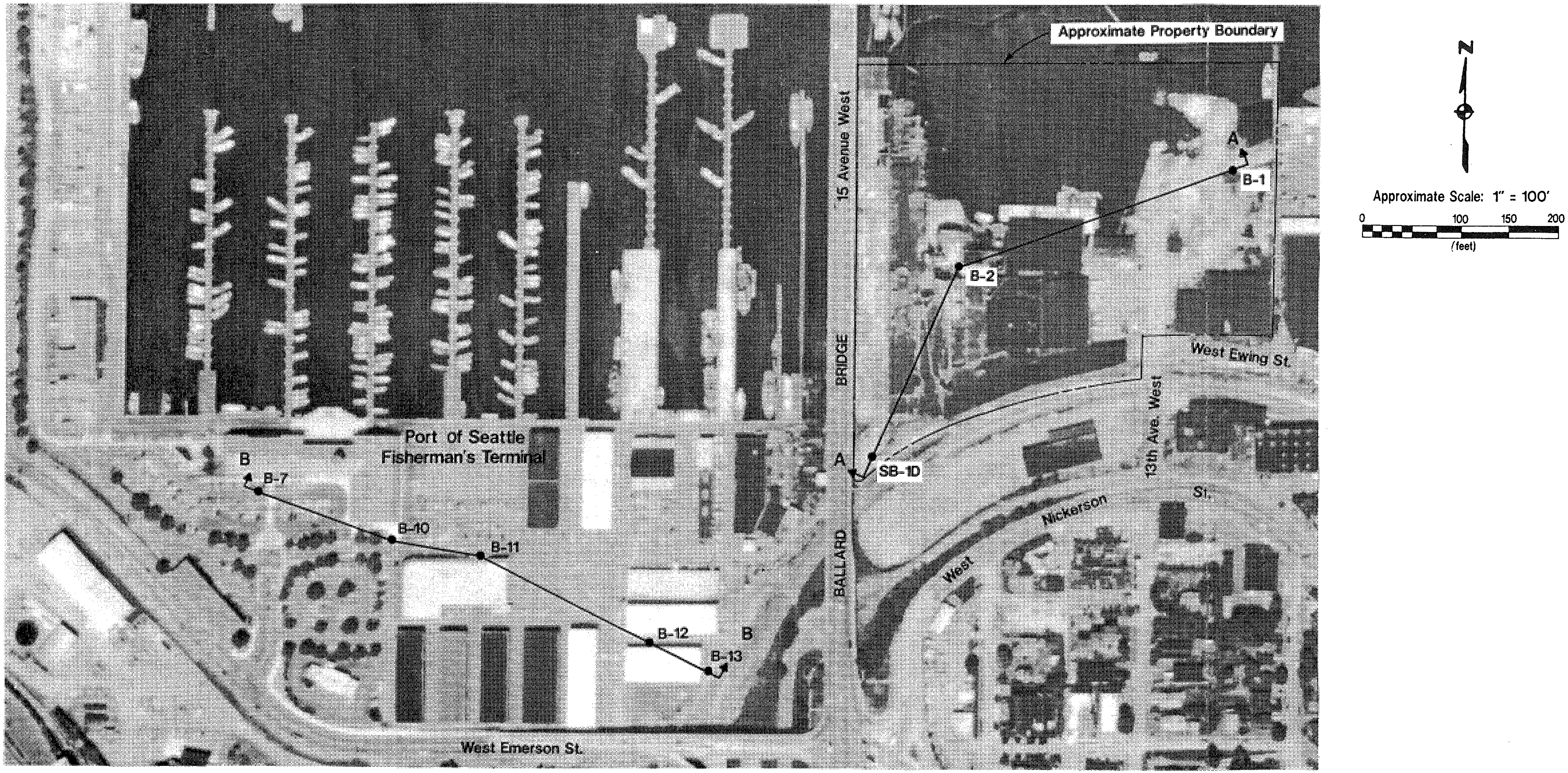
(6) PAHs analyzed by EPA Method 8100.

(7) Selected metals analyzed by inductively coupled argon plasma emission spectroscopy.

(8) Selected metals analyzed by atomic absorption spectrophotometry.

(9) Mercury analyzed by cold vapor atomic absorption spectrophotometry.

(10) All results based on dry weights.



## LEGEND

B-7 ● MONITORING WELL/BORING LOCATION

A ↗ ↘ A APPROXIMATE CROSS-SECTION LOCATION

## NOTES

1. MAP SOURCES FROM AERIAL PHOTOGRAPH OBTAINED FROM WASHINGTON DEPARTMENT OF NATURAL RESOURCES, DATED JULY 1989.
2. ALL LOCATIONS ARE APPROXIMATE.

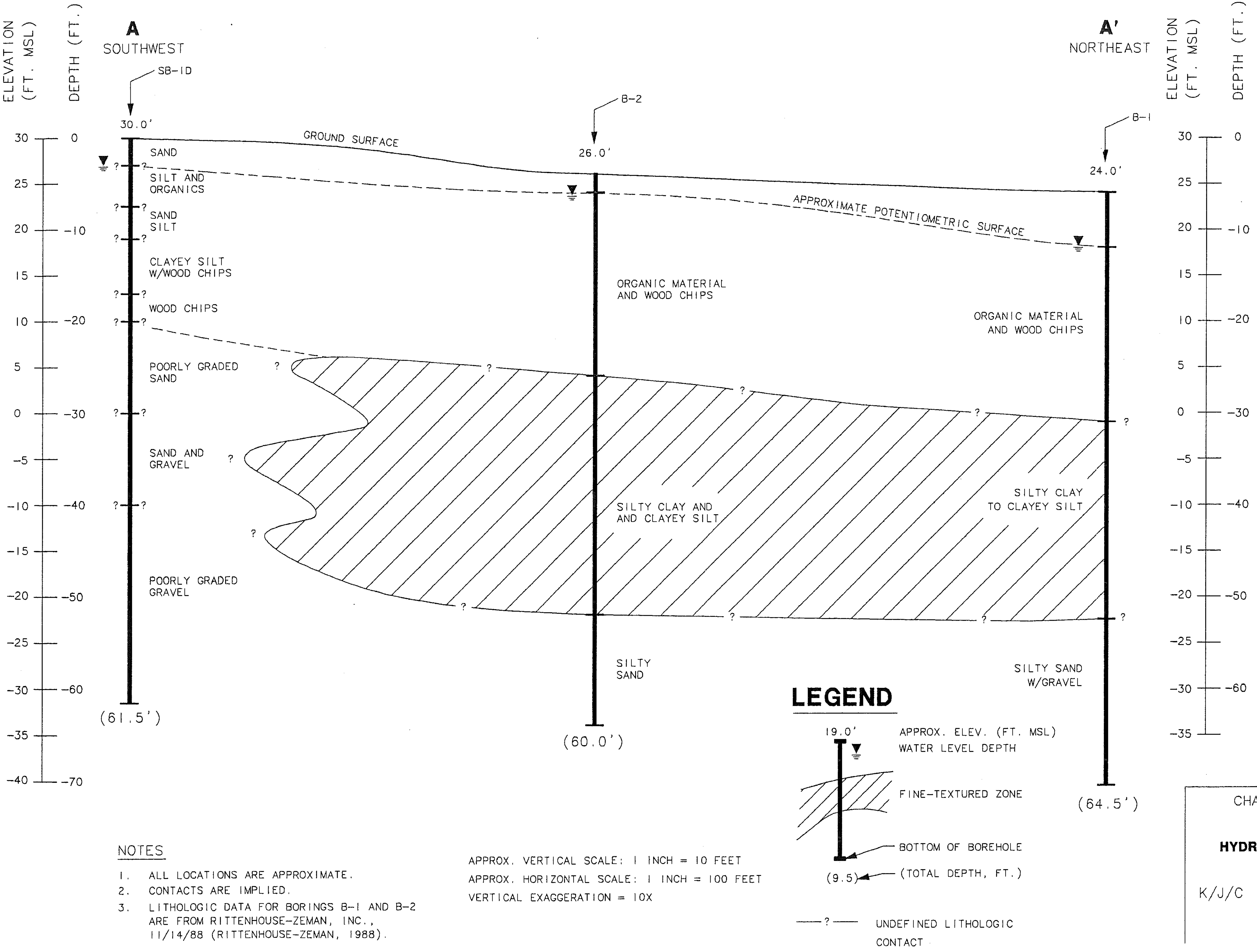
Kennedy/Jenks/Chilton

CHAMPION INTERNATIONAL CORP.
SEATTLE, WA

CROSS-SECTION
LOCATION MAP

K/J/C 916016.00/P1SK011

FIGURE 3-2



NOTES

1. ALL LOCATIONS ARE APPROXIMATE.
2. CONTACTS ARE IMPLIED.
3. LITHOLOGIC DATA FOR BORINGS B-1 AND B-2 ARE FROM RITTENHOUSE-ZEMAN, INC., 11/14/88 (RITTENHOUSE-ZEMAN, 1988).

APPROX. VERTICAL SCALE: 1 INCH = 10 FEET
APPROX. HORIZONTAL SCALE: 1 INCH = 100 FEET
VERTICAL EXAGGERATION = 10X

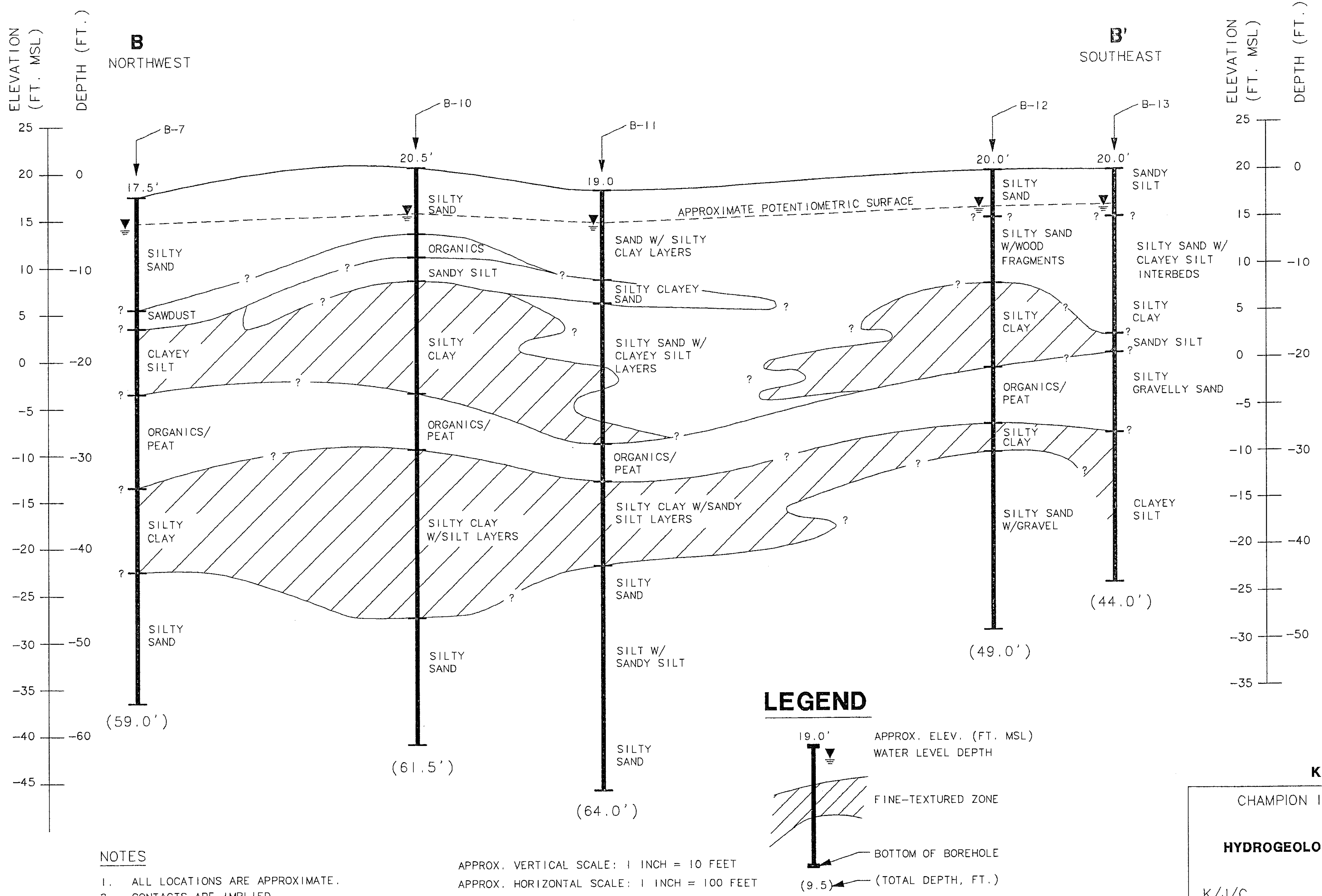
**Kennedy/Jenks/Chilton**

CHAMPION INTERNATIONAL CORP.
SEATTLE, WA

**HYDROGEOLOGIC CROSS-SECTION A-A'**

K/J/C 916016.00/P1SK008

**FIGURE 3-3**



NOTES

1. ALL LOCATIONS ARE APPROXIMATE.
2. CONTACTS ARE IMPLIED.
3. LITHOLOGIC DATA FROM THE REPORT BY SHANNON AND WILSON PREPARED FOR THE PORT OF SEATTLE, DATED 10/8/87.

APPROX. VERTICAL SCALE: 1 INCH = 10 FEET
APPROX. HORIZONTAL SCALE: 1 INCH = 100 FEET
VERTICAL EXAGGERATION = 10X

—?— UNDEFINED LITHOLOGIC CONTACT

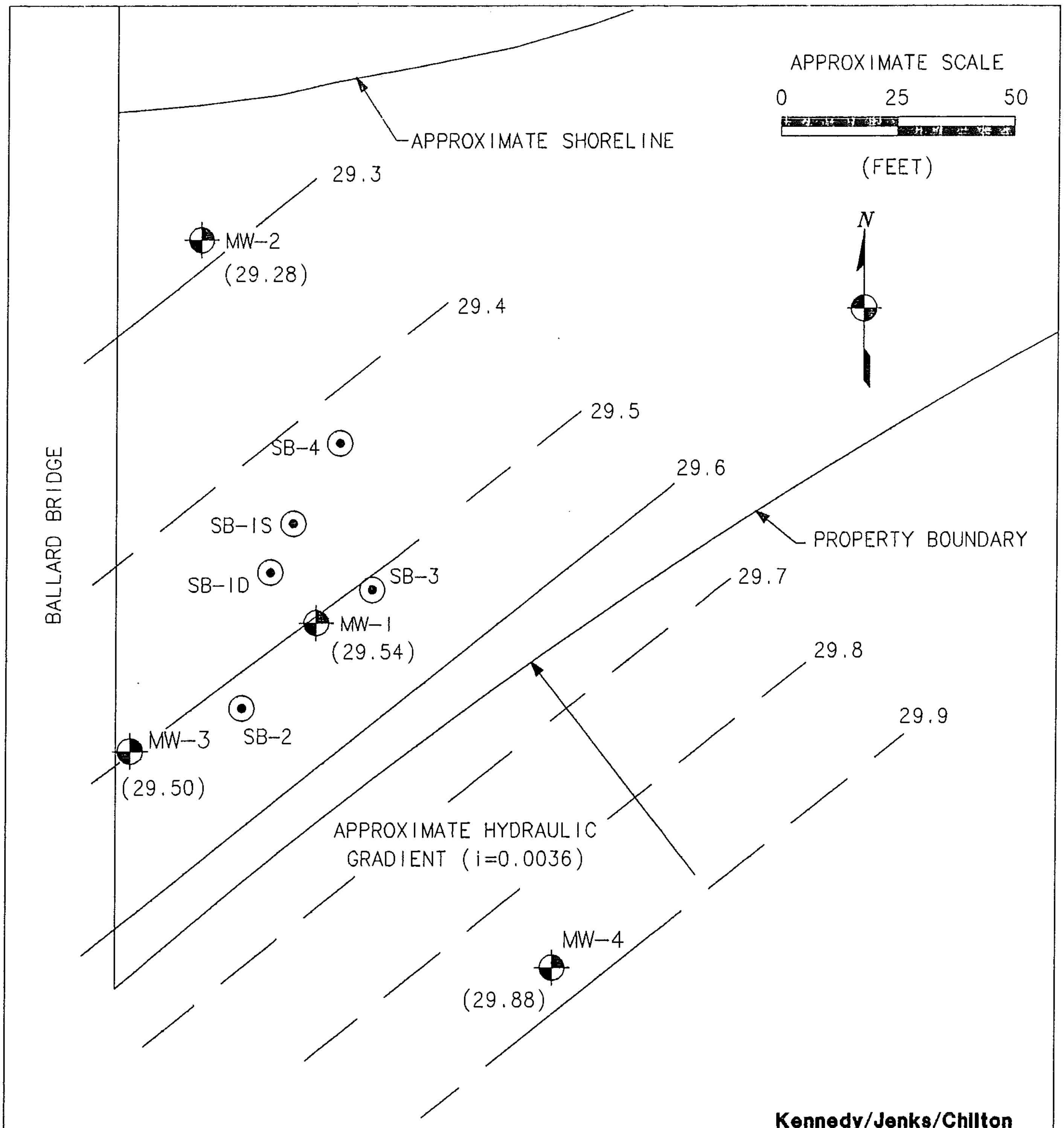
**Kennedy/Jenks/Chilton**

CHAMPION INTERNATIONAL CORP.
SEATTLE, WA

**HYDROGEOLOGIC CROSS-SECTION B-B'**

K/J/C 916016.00/P1SK009

**FIGURE 3-4**



**Kennedy/Jenks/Chilton**

## LEGEND

| | |
|---|---|
| MW-2 ⊕ | MONITORING WELL LOCATION |
| ⊙ SB-2 | SOIL BORING LOCATION |
| (29.50) | POTENTIOMETRIC SURFACE ELEVATION (FEET, MSL, MEASURED 14 FEB. 1990) |
| ⁄ 29.8 | POTENTIOMETRIC SURFACE CONTOUR (CONTOUR INTERVAL IS 0.1 FT, DASHED WHERE IMPLIED) |

## NOTES

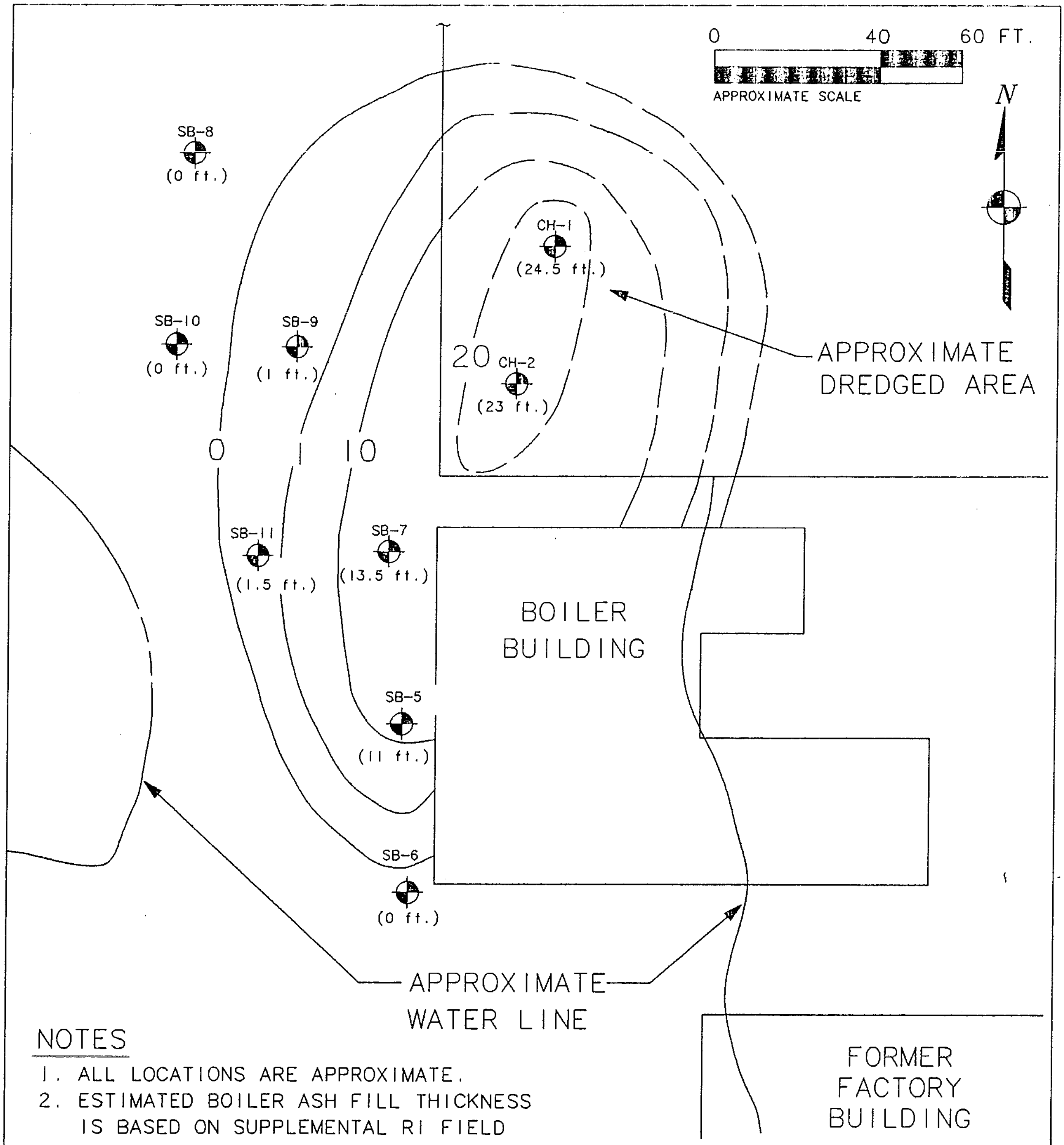
1. ALL LOCATIONS APPROXIMATE.
2. MAP SOURCE : JAY SPEARMAN, CONSULTING ENGINEER, 2 NOVEMBER 1989.
3. WATER LEVEL ELEVATIONS BASED ON A SURVEY PERFORMED BY JAY SPEARMAN, CONSULTING ENGINEER.

CHAMPION INTERNATIONAL CORP.
SEATTLE, WA

**SOLVENT TANK AREA**
**POTENTIOMETRIC SURFACE MAP**

K/J/C 916016.00/P1SK016

**FIGURE 3-5**



## NOTES

1. ALL LOCATIONS ARE APPROXIMATE.
2. ESTIMATED BOILER ASH FILL THICKNESS IS BASED ON SUPPLEMENTAL RI FIELD ACTIVITIES.
3. BOILER ASH IN DREDGED AREA WAS REMOVED IN JULY 1989 AND DISPOSED OF OFFSITE.

## LEGEND

| | |
|---|---|
| CH-2<br>⊕ | BORING LOCATION |
| (23 ft.) | BOILER ASH FILL THICKNESS (FT.) |
| —\|— | ESTIMATED BOILER ASH FILL CONTOUR (FT.) |

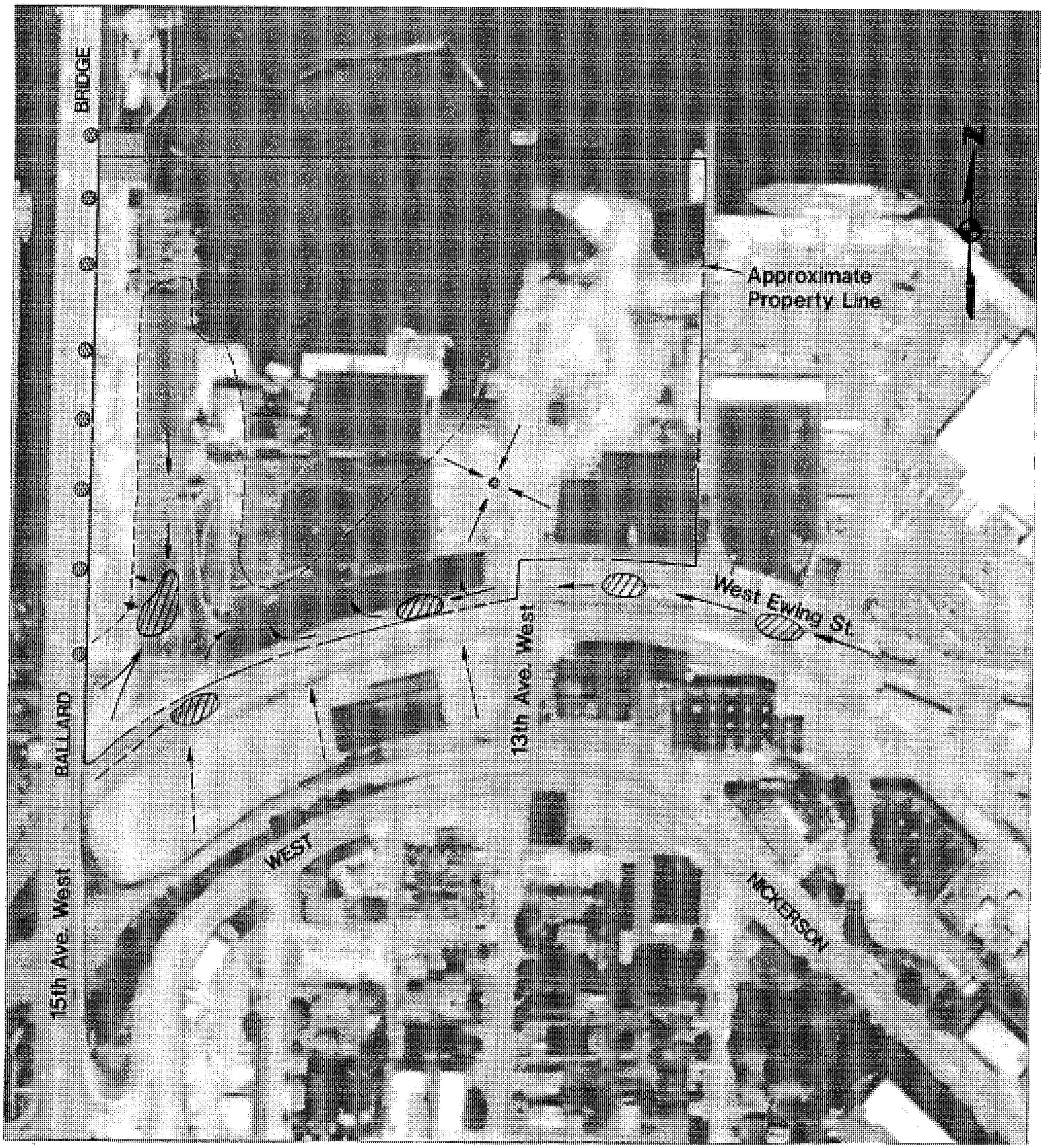
**Kennedy/Jenks/Chilton**

CHAMPION INTERNATIONAL CORP.
SEATTLE, WA

**BOILER ASH FILL ISOPACH MAP**

K/J/C 916016.00/P1SK012

**FIGURE 3-6**



Approximate Scale: 1" = 200'

0 100 200
(feet)

## LEGEND

| | |
|---|---|
| ▥ | STORMWATER CATCH BASIN |
| ↓ | SURFACE WATER DRAINAGE (DASHED WHERE IMPLIED, OBSERVED 7 MARCH AND 17 APRIL 1990) |
| ▨ | SURFACE WATER PUDDLE |
| - - - | APPROXIMATE SHORELINE |

Kennedy/Jenks/Chilton

CHAMPION INTERNATIONAL CORP.
SEATTLE, WA

APPROXIMATE SURFACE
WATER DRAINAGE MAP

K/J/C 916016.00/P1SK015

FIGURE 3-7

# 4.0 SUMMARY OF RI

This section summarizes RI findings and incorporates the results of site investigations. Pertinent data are condensed and summarized to facilitate assessment of potential risks to human health and the environment. Specific topics addressed include:

- Lateral and vertical extent of chemicals of concern
- Assumed origin of these chemicals
- Applicable hydrogeologic and physical conditions that can affect chemical fate and mobility
- Need for additional characterization, if any

In addition, this section identifies mitigation actions already taken by Champion to reduce potential risks inherent to these chemicals.

To simplify discussion of areas potentially affected by chemical contaminants, the following "operable units" have been established:

- Solvent tank area
- Glue press area
- Boiler ash fill
- Methane production areas
- Offshore sediments

Other aspects of the site previously discussed in this report do not represent areas of concern and are not discussed further. These include the underground tanks and containerized waste. As previously discussed, the underground tank was removed and its contents disposed of offsite. Containerized waste, left as a result of previous site operations, was also disposed of offsite at a permitted disposal facility.

## 4.1 POTENTIAL ENVIRONMENTAL CONCERNS

### 4.1.1 Solvent Tank Area

Initial investigations of the solvent tank area focused on characterizing the extent of PCP. During PCP removal activities, two underground tanks were identified and removed. Sampling of the soil and groundwater in close proximity to the tanks detected chlorinated solvents and carbon disulfide. The distribution of PCP, chemicals associated with it, and solvents is discussed below.

4.1.1.1 PCP Distribution. One shallow composite sample was collected by Parametrix (Parametrix 1987) from the former PCP storage area (Figure 2-5 in Chapter 2.0) and analyzed for PCP. Analysis results indicated PCP at a concentration of 77 mg/kg. Based on the results, subsequent investigations of the former PCP storage area were performed by Kennedy/Jenks/Chilton in June and December of 1987. In these investigations, 18 soil samples and one shallow groundwater (grab) sample were collected and analyzed for PCP. Sample analysis results are summarized in previous reports (K/J/C 1987 and 1988a).

Figure 4-1 shows the distribution of PCP detected in soil samples. Detectable levels of PCP were found at sampling locations B-1 and North. Analysis results from the boring B-1 samples indicated PCP in elevated concentrations (up to 2,100 mg/kg) near the surface, decreasing to below detectable levels between 4 and 7.5 feet from ground surface. In a surface sample collected from location North, PCP was detected at a concentration of 9,100 mg/kg. The vertical extent of PCP migration at this location was assumed to be similar to that at boring B-1. Using these sampling results, the area of chemically impacted soil was estimated and the limits of soil excavation were identified (Figure 4-1).

During the Kennedy/Jenks/Chilton's supplemental environmental assessment, an additional sample was collected within the limits of the excavation and analyzed for chlorinated dibenzofurans and dibenzodioxins, which are believed to occur as secondary components of PCP. Octa and hepta homologs were the primary forms of furan and dioxin detected, at individual homolog concentrations between 1.0 and 1.5 ppm. Total chlorinated dibenzofurans and dibenzodioxins were detected at concentrations of approximately 1.7 and 2.0 ppm, respectively. The most toxic of furans and dioxins, the 2, 3, 7, 8 substituted isomers, were not detected.

The supplemental environmental assessment report (K/J/C 1987) summarized pertinent information on the fate, mobility, and toxicity of PCP and chlorinated dibenzofurans and dibenzodioxins. This report concluded that dibenzofuran and dibenzodioxin concentrations detected at the site did not represent a significant threat to human health or the environment. However, to limit possible exposure, chemically impacted soil from an 11.5 x 15-foot area (6 feet deep) was excavated and disposed of at an approved facility. No further investigation or confirmational sampling of this area was performed since PCP was restricted to a small area and vertical migration was limited to the upper 4 feet of soil tested (Figure 4-1).

4.1.1.2 VOC Distribution. During excavation of PCP-affected soil at the site, two underground storage tanks were identified. The first was a 350-gallon solvent waste tank and the second was a 1,000-gallon tank that previously contained gasoline. Prior to removal of the solvent waste tank, a sample of the contents was collected and analyzed. The analytical results revealed that the tank contained a mixture of solvents containing 70 percent carbon disulfide, 15 percent carbon tetrachloride, 1 percent tetrachloroethylene and chloroform, and 14 percent water.

Inspection of the gasoline tank indicated that it was half full of water and sand. The contents of both tanks were pumped out and disposed of as necessary at a permitted disposal facility. The tanks were then cleaned and transported to a metal recycler.

During removal of the solvent waste tank, cracks were identified that might have facilitated the release of small quantities of solvents. Soils occurring in the excavation area had the distinct odor of carbon disulfide. To reduce the potential impact of solvent release, approximately 750 gallons of groundwater were pumped from the excavation area and stored in 55-gallon drums. Soils removed were placed on plastic tarps while awaiting disposal at a permitted facility. Prior to backfilling of the excavation, a nonstandard monitoring/extraction well (MW-1) was placed in the excavation. On two separate occasions, approximately 1,200 gallons of groundwater were pumped from MW-1. The results of analysis of groundwater samples collected after each extraction indicated that solvent concentrations in MW-1 decreased following groundwater withdrawal.

Subsequent investigations of the solvent tank area were made during the supplemental RI to help evaluate the extent of chemicals in soil and groundwater. These investigations included:

- Sampling of shallow soil borings surrounding the location of the removed solvent waste tank to evaluate lateral dispersion in shallow soil
- Installation and sampling of three shallow monitoring wells to characterize the extent of chemical migration in groundwater

Results of groundwater sampling in the solvent tank area are summarized in Table 3-5 (Chapter 3.0). VOC analysis results for recent (supplemental RI) soil samples collected from the area are summarized in Table 3-6.

In summary, no priority pollutant compounds were detected in any of the soil samples analyzed. VOCs, including acetone, alpha-penine, and other hydrocarbons (possible turpentine derivatives), were detected randomly at low concentrations in several of the shallow borings. Analysis results for soil samples collected from the second zone of saturation indicated that no chemicals were detected. Analysis results for groundwater samples collected from the monitoring wells indicated that chemicals of concern (carbon disulfide and chloroform) were detected only in well MW-1.

It was suggested that the fine-grained nature of the soils might restrict groundwater flow and that the abundance of organic material might limit further migration of VOCs in the solvent tank area. An estimate of groundwater velocity in the solvent tank area indicated that a period of approximately 10 years was required for groundwater occurring in this area to reach Salmon Bay. During this time, mechanical dispersion, volatilization, and sorption to organics can greatly reduce VOC concentrations, possibly to nondetectable levels.

### 4.1.2 Boiler Ash Fill

A preliminary investigation of the boiler ash fill was performed by Parametrix in 1985. As part of this investigation, one soil sample (Composite No. 4) from three locations was composited and analyzed for several parameters. Analysis results did not indicate high levels of priority pollutants. However, samples of the boiler ash material have indicated relatively high pH readings. Chemicals detected in sediments in the vicinity of the boiler ash fill included methylene chloride, naphthalene, acenaphthene, phenanthrene, fluoranthene, pyrene, chrysene, aldrin, and formaldehyde (Table 2-1).

As part of the supplemental RI, six soil samples from two soil borings were submitted for analysis of priority pollutant heavy metals and BNA-extractable compounds. In addition, four samples were analyzed for TPH and pH. The results of these analyses are discussed in Chapter 3.0. In summary, no BNA-extractable compounds were detected. Detectable levels of TPH (as diesel) did not exceed 4 mg/kg, which is well below the WDOE cleanup level for soil. Metals were detected at levels similar to typical soil ranges. Samples submitted for pH analysis indicated pH levels ranging from 7.2 to 8.7.

Previous sampling of nearshore sediments in the vicinity of the boiler ash fill during Phase I sediment sampling detected TPH at 9,300 mg/kg in Sample CH-2. Since TPH was detected at a maximum concentration of only 4 mg/kg during the supplemental RI at a sampling location approximately 20 feet away, the extent of possible contamination appears limited. As previously discussed, sediment in the vicinity of Sample CH-2 was removed during dredging and disposed of offsite. Samples of the boiler ash fill were also collected during Phase I of the sediment sampling program conducted by Jay Spearman in March 1989. Analysis results indicated that heavy metal concentrations were slightly elevated above typical background levels. Arsenic, copper, lead, and zinc were detected at 73 mg/kg, 610 mg/kg, 450 mg/kg, and 1,800 mg/kg, respectively. These concentrations were for the most part above the WDOE sediment quality criteria for marine sediments.

Four additional borings were drilled during the RI to help estimate the volume of boiler ash occurring in the vicinity of the boiler building. To depict the results of this investigation, an isopach map was constructed (Figure 3-6) showing the estimated lateral extent and thickness of the boiler ash. Calculations based on this map indicated that the boiler ash volume was approximately 3,200 cubic yards. This estimate was based on the assumption that there was no ash below the boiler building.

### 4.1.3 Glue Press Area

Extensive soil and sediment sampling and analysis were conducted in the glue press area. In 1987, Parametrix sampled the glue waste. Semi-volatile organic analysis of this sample showed four PAH compounds (anthracene, fluoranthene, fluorene, and pyrene), as well as dibenzofuran. Dibenzofuran was detected at levels below those of regulatory concern (K/J/C 1987). Anthracene was detected most frequently and in the greatest concentrations (770 mg/kg) relative to only a few mg/kg for the other compounds. Kennedy/Jenks/Chilton subsequently conducted an extensive investigation to identify the locations of glue piles throughout the site, as well as contaminant levels associated with glue piles and nearby sediments. Glue press area sediment samples collected by Kennedy/Jenks/Chilton were analyzed for polycyclic aromatic hydrocarbons; anthracene was the only compound found in many of the samples (K/J/C 1987).

One glue press area sample was submitted for chlorinated dioxin and furan analyses. Although some detectable concentrations of these compounds were found, they were very low and were thus determined to pose only a minimal threat to the environment. Additional sampling of sediments in close proximity to the glue piles was performed by Jay Spearman during Phase II sediment sampling. The results of these investigations are discussed in Chapter 3.0.

Table 4-1 summarizes analysis results for samples collected from the glue press area. Figure 4-2 shows the distribution of anthracene relative to the glue piles. Six glue piles were identified at the site; the largest was designated GP-1 and was located in the southeast portion of the glue press area. Several investigations were performed to characterize the extent of chemical migration from the glue piles, but sampling focused on glue pile GP-1. Sampling results indicated that the glue piles were similar in chemical makeup.

As indicated in Table 4-1, anthracene was detected most frequently and at the highest concentrations. Pyrene was also detected fairly often, but at much lower concentrations. Sampling results suggested that anthracene concentrations decreased to low or nondetectable levels within approximately 10 feet of the center of most of the glue piles (K/J/C 1988b). Samples collected outside the 10-foot radius were found to contain less than 3 mg/kg of anthracene, a concentration well below background levels for the Lake Washington Ship Canal, up to 6.94 mg/kg (City of Seattle 1986).

As discussed in Chapter 3.0, the glue piles occurred at elevations above or slightly below the water level of the Lake Washington Ship Canal, depending on the season. Because anthracene is relatively insoluble in water, lateral migration was probably restricted to mechanical processes. Due to the location of the glue piles (below the glue press area floor) and because the glue piles were only partially in contact with water, mechanical processes facilitating anthracene migration appeared to be minimal. It was concluded that, since the glue piles had existed below the buildings for over 30 years, any detrimental effects to the surrounding environment would probably have already been manifested.

### 4.1.4 Methane Production Areas

As discussed in Chapter 3.0, most of the former Champion site seemed to be underlain by significant amounts of organic debris. This material appeared to be a source of methane gas, consistently detected at concentrations of 1,000 ppm during drilling operations. At ambient conditions, the methane dissipated to below detectable levels.

Potential adverse effects of methane accumulation included creation of an explosive environment and human or animal asphyxiation due to oxygen displacement in confined spaces.

Chapter 3.0 summarizes the methane monitoring of the solvent tank area during the supplemental RI. The levels of methane detected in the area appeared to be representative of the entire site. The highest methane levels were encountered in boring SB-6 (in the boiler ash fill), where methane concentrations were at least 5 percent by volume.

### 4.1.5 Offshore Sediments

Phase II sediment sampling results are presented in Appendix E. Results of the analyses are discussed in more detail in Section 3.4.6.2 of Chapter 3.0. In summary, levels above background of TPH (as diesel) and selected metals (arsenic, copper, lead, mercury, and zinc) were detected in offshore sediment samples. Several PAHs were detected in offshore sediments at relatively low levels. Similar or slightly lower levels of these compounds were found in Ship Canal sediments. PAHs were not detected in the DNR lease area, except for fluoranthene, which was detected at 0.21 mg/kg at one location.

Metal concentrations detected in the lease area were similar in magnitude to those found below the buildings at the site. Metal concentrations detected in the Ship Canal, the DNR lease area, and beneath onsite buildings typically did not vary by more than an order of magnitude. However, concentrations of metals in offshore areas were typically higher than those detected in the Ship Canal or the DNR lease area (see Figure 1, Appendix E for offshore sampling locations).

The fact that metal concentrations in sediments were generally homogeneous in areas sampled suggested no significant chemical loading through past activities at the site. As indicated, chemical concentrations were high in the offshore areas, which might have indicated minor chemical loading from several sources, including:

- Surface water and stormwater runoff from the surrounding urban/industrial area
- Ongoing ship maintenance and refinishing by neighboring industries, resulting in discharge of metals, including chromium, lead, and zinc

- Petroleum releases and petroleum produced from typical ship traffic in the Ship Canal, which eventually migrates to areas with stagnant lake water

From analytical data collected for sediments at the former Champion site, the extent of contamination resulting from past activities was unclear. Considering several ongoing contaminant sources at and near the site, existing chemical levels in sediments might have indicated background conditions in the urban/industrial setting.

### 4.1.6 Other Areas of Investigation

Several investigations were performed at locations other than those described above. The results of these investigations are presented in Chapter 2.0. Sampling locations included the drying ovens, the area below the glue tanks, the area below the electrical transformers, and offsite background areas. Sampling results for these investigations are summarized in previous reports prepared by Parametrix and Kennedy/Jenks/Chilton. Sampling locations are shown in Figure 2-4 of Chapter 2.0. A brief summary of sampling results is presented below:

- The dryers were in an area where caustic cleaners were reportedly used. A composite sample collected in sediments below the ovens was analyzed for selected metals and semi-volatile organic compounds. Chromium and zinc were detected at 84.8 mg/kg and 422 mg/kg, respectively. These metal concentrations were of similar magnitude to those detected in offshore sediment samples below existing buildings. No semi-volatile organic compounds were detected.

- A composite sediment sample was collected from below the former glue resin tank located on the north portion of the site. This sample was analyzed for PAHs; analysis results indicated the presence of anthracene at 0.3 mg/kg and did not appear to be of significant concern.

- A Seattle City Light electrical transformer located on the site might have contained PCB-contaminated oils. EPA Method 8080 was used to analyze for PCP compounds in a composite sample collected from below the drain holes in the concrete pad supporting the transformer. Analysis results indicated no PCB compounds.

- An offsite background sample was collected for comparison purposes. This sample was analyzed for selected metals, semi-volatile organics, and PCBs. Chromium and zinc were detected at 124 mg/kg and 7,300 mg/kg, respectively. No semi-volatile organics or PCBs were detected. The samples were collected on the south property boundary where no known activities had occurred in the past. Therefore, the chemical concentrations detected possibly represented background conditions for the site.

As indicated, the results of these investigations did not warrant further investigation in the areas concerned. The areas did not appear to represent a significant threat to human health or the environment.

## 4.2 MITIGATION ACTIONS

Several mitigation actions were taken to reduce potential exposure to chemicals occurring at the former Champion site. These remedial actions, discussed in previous sections of this report, included:

- Excavation of soil contaminated with PCP and offsite disposal at a permitted facility
- Removal of three underground tanks; disposal at a permitted facility of contaminated materials occurring in and around the tanks
- Extraction of groundwater in the vicinity of the solvent waste tank on two occasions, followed by offsite disposal of the water at a permitted facility
- Characterization and disposal of containerized waste.

To reduce future mobility of, and exposure to, low levels of chemicals occurring at the site, SBT covered the outlying portions of the boiler ash fill with clean fill material. The material acts as a barrier between potentially contaminated soils and possible human and/or biologic recipients. Additional steps that may be taken by SBT to mitigate potential effects of the boiler ash fill are discussed in the FS reported in Chapter 6.0. Risks associated with the chemical levels detected and the need for additional remedial action are discussed in Chapter 5.0.

TABLE 4-1

## CUMULATIVE SUMMARY OF SOIL SAMPLE RESULTS
## GLUE PRESS WASTE AREA

| | | Collection Date/Sample Number | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 6/03/87 | | | | | 2/18/88 | | | | 3/08/88 | | | | | | | | |
| Chemical (1) | Units | B-6 | B-7 | B-8 | B-9 | B-10 | S-1A | S-1B | S-1C | S-1D | S-10A | S-10B | S-11 | S-12 | GP-5A | GP-5C | S-15 | S-16 | S-17 |
| PAHs (2) | | | | | | | | | | | | | | | | | | | |
| Naphthalene | mg/kg | <17 | <3.3 | <3.3 | <33 | <33 | <1.25 | <12.5 | <5 | <0.125 | -- | -- | -- | -- | <1 | 2.3 | -- | -- | -- |
| Acenaphthene | mg/kg | <17 | <3.3 | <3.3 | <33 | <33 | <1.25 | <12.5 | <5 | <0.25 | -- | -- | -- | -- | <1 | <1 | -- | -- | -- |
| 2-Methylnaphthalene | mg/kg | <17 | <3.3 | <3.3 | <33 | <33 | -- | -- | -- | -- | -- | -- | -- | -- | 3.1 | 16 | -- | -- | -- |
| Fluorene | mg/kg | <17 | <3.3 | <3.3 | <33 | <33 | <1.25 | <12.5 | <5 | <0.25 | -- | -- | -- | -- | <1 | <1 | -- | -- | -- |
| Phenanthrene | mg/kg | <17 | <3.3 | <3.3 | <33 | <33 | <1.25 | <12.5 | <5 | <0.5 | -- | -- | -- | -- | <1 | <1 | -- | -- | -- |
| Anthracene | mg/kg | 150 | <3.3 | 85 | 770 | 430 | 22 | <12.5 | 14 | 2.4 | 6.5 | 14 | <55 | <3 | <1 | <1 | 1.7 | 1.2 | <3 |
| Fluoranthene | mg/kg | <17 | <3.3 | <3.3 | <33 | <33 | <12.5 | <12.5 | <5 | <1.25 | -- | -- | -- | -- | <1 | <1 | -- | -- | -- |
| Pyrene | mg/kg | <17 | <3.3 | 4.1 | <33 | <33 | <12.5 | <12.5 | <5 | <1.25 | -- | -- | -- | -- | <1 | <1 | -- | -- | -- |
| Chrysene | mg/kg | <17 | <3.3 | <3.3 | <33 | <33 | <12.5 | <12.5 | <5 | <1.25 | -- | -- | -- | -- | <1 | <1 | -- | -- | -- |
| Benzo(a)anthracene | mg/kg | <17 | <3.3 | <3.3 | <33 | <33 | <12.5 | <12.5 | <5 | <1.25 | -- | -- | -- | -- | <1 | <1 | -- | -- | -- |
| Benzo(k)fluoranthene | mg/kg | <17 | <3.3 | <3.3 | <33 | <33 | <12.5 | <125 | <5 | <1.25 | -- | -- | -- | -- | <1 | <1 | -- | -- | -- |
| Benzo(b)fluoranthene | mg/kg | <17 | <3.3 | <3.3 | <33 | <33 | <12.5 | <125 | <5 | <1.25 | -- | -- | -- | -- | <1 | <1 | -- | -- | -- |
| Benzo(a)pyrene | mg/kg | <17 | <3.3 | <3.3 | <33 | <33 | <30 | <125 | <30 | <1.25 | -- | -- | -- | -- | <1 | <1 | -- | -- | -- |
| Dibenzofuran | mg/kg | <17 | <3.3 | <3.3 | <33 | <33 | -- | -- | -- | -- | -- | -- | -- | -- | <1 | 30 | -- | -- | -- |
| Anilene | mg/kg | <17 | <3.3 | <3.3 | <33 | <33 | -- | -- | -- | -- | -- | -- | -- | -- | <1 | 6.1 | -- | -- | -- |
| Metals (3) | | | | | | | | | | | | | | | | | | | |
| T. chromium (Cr) | mg/kg | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | 290 | 59 | -- | -- | -- |
| Copper (Cu) | mg/kg | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | 3.6 | 16 | -- | -- | -- |
| Lead (Pb) | mg/kg | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | 5.9 | 68 | -- | -- | -- |
| Zinc (Zn) | mg/kg | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | 16 | 83 | -- | -- | -- |
| Formaldehyde (4) | mg/kg | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | <1.5 | -- | -- | -- | -- |

Notes:

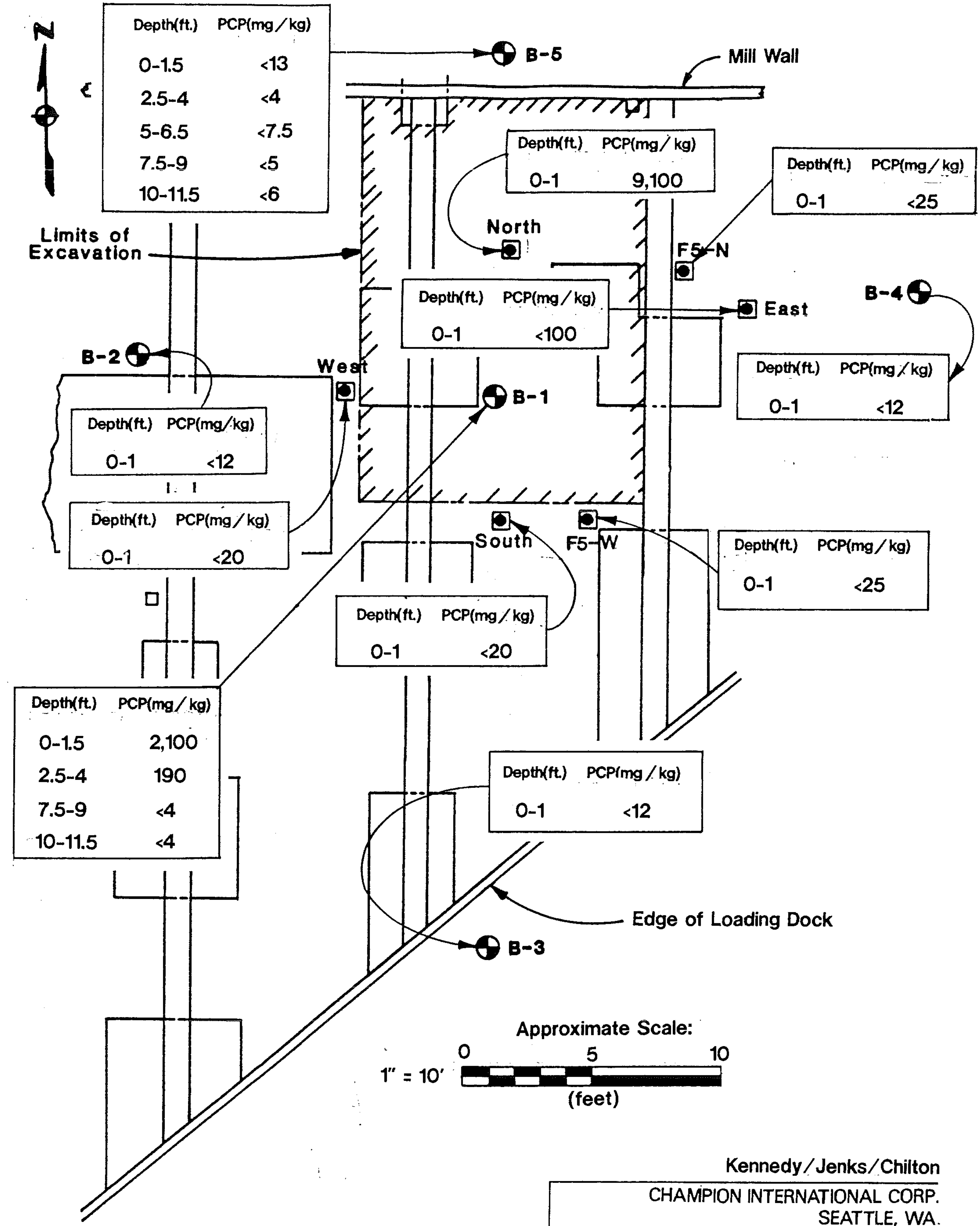
-- Not analyzed.

(1) Selected samples analyzed for VOCs, TPH, and phenols; none detected. Detection limit ranges 10 to 60 ug/kg, 1 to 2 mg/kg, and 1 to 5 mg/kg, respectively.

(2) PAHs analyzed by EPA Method 8270 or EPA Method 8100. Only those compounds detected in one or more samples, or elsewhere onsite, are reported.

(3) Selected metals analyzed by atomic absorption spectrophotometry.

(4) Formaldehyde analyzed by NIOSH Method 3500.



Kennedy/Jenks/Chilton

CHAMPION INTERNATIONAL CORP.
SEATTLE, WA.

SOLVENT TANK AREA
PCP DISTRIBUTION

K/J/C 916016.00/P1SK010

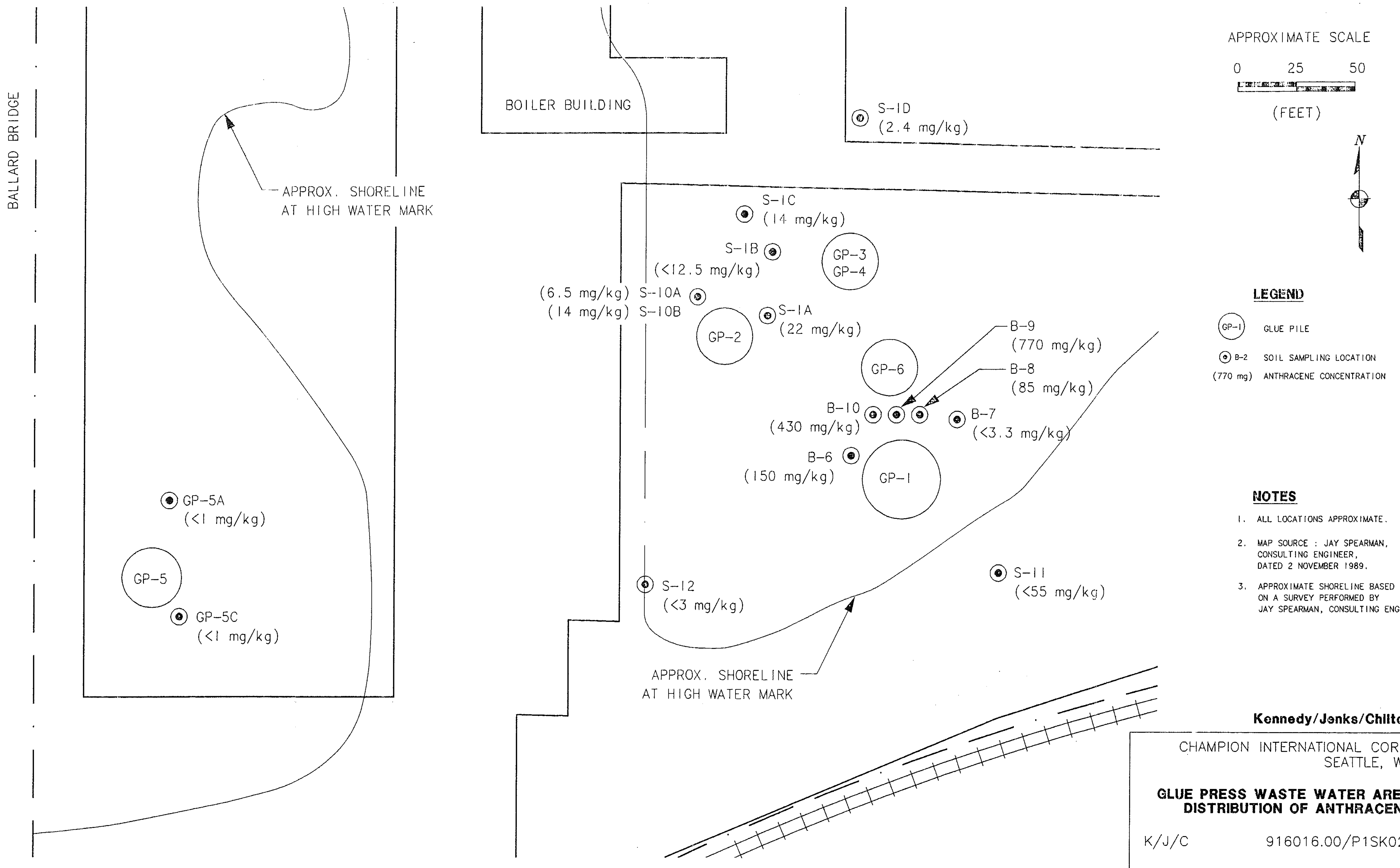
FIGURE 4-1

## LEGEND

⊕ BORING (SAMPLED 1987)

▣ SURFACE SEDIMENT (SAMPLED 1988)

▨ LIMITS OF SOIL EXCAVATION AREA



**NOTES**

1. ALL LOCATIONS APPROXIMATE.
2. MAP SOURCE : JAY SPEARMAN, CONSULTING ENGINEER, DATED 2 NOVEMBER 1989.
3. APPROXIMATE SHORELINE BASED ON A SURVEY PERFORMED BY JAY SPEARMAN, CONSULTING ENGINEER.

**Kennedy/Jenks/Chilton**

CHAMPION INTERNATIONAL CORP.
SEATTLE, WA

**GLUE PRESS WASTE WATER AREA**
**DISTRIBUTION OF ANTHRACENE**

K/J/C 916016.00/P1SK021

**FIGURE 4-2**

# 5.0 RISK ASSESSMENT

## 5.1 INTRODUCTION

The risk assessment (RA) described in this chapter evaluated existing chemical data for site problem areas (operable units) relative to specific regulatory criteria. It also assessed possible public health/environmental impacts that could result from the chemicals. Initially, the RA examined the fate and mobility of detected contaminants, providing the basis for the exposure assessment. The exposure assessment then examined potentially exposed populations and expected routes of exposure, based on physical site conditions. A summary of chemical constituents found in each operable unit was prepared and an initial screening process was carried out to determine the contaminants of concern that would be evaluated further in the RA.

The exposure assessment was followed by a toxicity evaluation, with a summary of potential public health and environmental effects from exposure to chemicals of concern. In addition, applicable laws that could impact the RA were evaluated. Based on exposure and toxicity evaluations, a risk characterization described risks posed by onsite contaminants. Finally, the RA proposed cleanup goals for each specific site area, as necessary, based on applicable regulatory standards and other published toxicity information available from the EPA, the WDOE, and the available literature.

### 5.1.1 Methodology

RA methods consisted of a combination of current EPA guidance for performance of public health and environmental risk assessments, the cleanup standards under the Model Toxics Control Act [MTCA (WDOE, 1991)], and best professional judgement. In many cases, quality criteria, reference doses, and cancer potency slopes for contaminants detected onsite were not available for use in a quantitative risk assessment. In these cases, available literature was reviewed and a qualitative assessment of toxicity and risks was made.

Each of the operable units was addressed separately in the RA, since occurrences of chemicals at the operable units were unrelated. This approach was appropriate for the site because each area of concern had separate physical/chemical characteristics. In each area potential exposure to contaminants was assumed to occur to separate populations. The operable unit approach used in the assessment is widely accepted by the EPA and the WDOE for similar industrial sites.

The five operable site units addressed during the RA include:

- Solvent tank area
- Boiler ash fill
- Glue press area
- Methane production areas
- Offshore sediments.

Descriptions of RA activities for these units are provided in Sections 5.2 through 5.6.

The approach used by Kennedy/Jenks/Chilton to establish indicator chemicals for performance of the RA followed the cleanup standards of MTCA (WDOE, 1991) and general EPA guidance. In general, most of the contaminants detected within each particular area were evaluated quantitatively or qualitatively. However, there were several cases in which compounds detected onsite were screened and eliminated from further consideration, based on the following:

- Lack of toxicity data
- Fact that chemicals and/or their physical characteristics are short-lived and do not persist in the environment, or do not tend to move into and through environmental media, which can result in exposure
- Low frequency of occurrence
- Thoroughness of testing
- Degradation byproducts of naturally occurring material and/or organic fill material
- Natural occurrence in the environment at the detected concentrations.

The reasons for exclusion of compounds are discussed in the text for each operable unit addressed by the RA.

The final criteria used in the RA represented what can be considered background concentrations of contaminants in the environment. While specific background samples were not collected during the course of the assessment, existing literature provided sufficient information to determine background concentration ranges for hazardous substances that occur naturally in soil and/or groundwater, as well as in urbanized areas. This information was used to develop conservative background values for contaminants of concern. Table 5-1 identifies each operable unit (except methane production areas) and the chemicals that were excluded from the exposure assessment based on the criteria discussed above.

### 5.1.2 Scope of the RA

The exposure assessment addressed potentially exposed populations for each operable unit, based on the physical setting of each contaminant and/or its potential migratory characteristics. It also estimated possible routes of entry, depending on physical/chemical characteristics of the individual hazardous substance. Exposure parameters utilized during this assessment included those specified in MTCA cleanup standards (WDOE, 1991). Exposure point concentrations were estimated as a range by using the maximum and arithmetic mean contaminant concentrations within a particular operable unit.

The methodology specified in MTCA (95th percentile confidence interval around the mean) did not appear applicable to the RA, since there was only a small number of data points for each problem area. However, calculations of exposure and subsequent risk, using both maximum and arithmetic mean concentrations, were consistent with the work plan and acceptable methods for small data sets under MTCA cleanup standards.

The toxicity assessment included in the RA for each operable unit utilized published EPA information, when available, including applicable laws, reference doses, and cancer potency slopes published in the EPA Integrated Risk Information System (IRIS) and in the EPA Health Effects Assessment Summary Tables (U.S. EPA, 1991). When information from these databases was not available for a contaminant, it was either screened from further consideration or assessed qualitatively, based on a review of available literature. Chemicals were screened from further consideration only when concentrations were low or infrequent, compared with chemical compounds that are widespread or toxic in nature.

The risk characterization for each operable unit utilized a modification of the formulas presented in the cleanup standards under the MTCA (WDOE, 1991). The modified equation was used to help estimate the dosage to humans based on the mean and maximum chemical concentrations detected. The equation was derived from the soil cleanup equation (WAC 173-340-740) and was considered appropriate for estimating potential adverse human health effects from accidental contact which could result in ingestion and dermal absorption. The RA compared cleanup levels calculated using equations presented in MTCA with concentrations detected at the former Champion site.

## 5.2 SOLVENT TANK AREA

### 5.2.1 Contaminant Summary and Screening

VOCs and inorganic (heavy metal) compounds were detected in soil and groundwater in the solvent tank area (see Table 3-6, Chapter 3.0). Acetone was detected in soil at two locations (SB-1D, SB-2) at a depth between 8 and 14 feet, in concentrations ranging from 37 to 38 ug/kg.

Three tentatively identified compounds, possibly wood waste degradation byproducts, were detected in borings SB-1S and SB-3, at a depth between 8 and 14 feet. These chemicals included alpha-penine, bicyclo[3,1,1]- hepta-2-ene,3,6,6-trimethyl, and 2,6-dimethyl-2-octene, detected at estimated concentrations of 470, 180, and 58 ug/kg, respectively.

Carbon disulfide and chloroform were detected only in a groundwater sample from MW-1, at maximum concentrations of 4600 and 420 ug/L, respectively. Concentrations of these compounds were more than an order of magnitude lower than those detected in samples collected from well MW-1 in 1987 during the preliminary RI. Two other compounds previously detected in groundwater from this well, carbon tetrachloride and tetrachloroethylene, were not detected during the more recent sampling.

Since toxicological information was available for acetone, carbon disulfide, and chloroform, these compounds were evaluated further in the RA. However, the other three tentatively identified compounds were not further evaluated, since their presence was most likely due to the common degradation of wood.

Eleven inorganic (heavy metal) compounds, at relatively low concentrations, were detected in groundwater at MW-1 (see Table 5-1). These levels probably represented naturally occurring concentrations of the compounds ubiquitous in the environment. Little information was available to suggest that there were sources of the compounds onsite. The detected concentrations represented total metals in somewhat turbid groundwater. Therefore, it was possible that they did not represent, and possibly overstated, actual concentrations that could migrate in the environment. However, these chemical compounds were further evaluated during the RA, since little documented information was available regarding their background concentrations in groundwater.

### 5.2.2 Mobility of Detected Contaminants

The three VOCs detected in the solvent tank area were expected to be relatively mobile in the environment, due to their high aqueous solubility and low partition coefficient. However, all these compounds were expected to rapidly degrade over time. The half-life of chloroform was determined to be approximately 30 minutes under laboratory conditions. The half-lives of acetone and carbon disulfide were not found in the available literature. However, for the RA, they were assumed to be similar, given the physical properties of the compounds. These physical/chemical properties were apparent from an evaluation of past sampling data compared with more recent data that showed a sixfold decrease in carbon disulfide concentrations and a sixteenfold decrease in chloroform concentrations in less than two years.

It should be noted that, while the solubility and expected mobility of carbon disulfide and chloroform were high, there was little evidence of migration of these compounds from the area where they were initially detected (MW-1). They were not detected in samples from the other monitoring wells or soil borings onsite. Lateral and downgradient migration of these compounds in the solvent tank area may be limited, due to the nature of fine-grained soils at this location and the occurrence of significant amounts of organics in the area that serve to absorb VOCs.

The fate and mobility of heavy metals detected onsite was found to vary depending on the compound. However, it could be stated generally that the dissolved and colloid fraction of these compounds was able to freely migrate from the solvent tank area in the direction of groundwater flow, toward the Ship Canal. As previously indicated, it was considered likely that detected concentrations of heavy metal contaminants were typical of background concentrations in urbanized areas; however, little data was available to confirm this assumption. None of the inorganic compounds was expected to decompose over time. An expanded discussion of the aquatic fate of the heavy metal contaminants detected onsite is presented in Section 5.3.2, for the boiler ash fill.

### 5.2.3 Exposure Assessment

5.2.3.1 Potentially Exposed Populations. Due to the proximity of the solvent tank area to the Ship Canal, it appeared that the population most likely to be exposed to chemical compounds in this area was aquatic life within the Ship Canal and Lake Union. As previously indicated, volatile and heavy metal constituents detected in soil and groundwater in the solvent tank area had the potential of migrating to the Ship Canal. However, available data did not suggest that existing compounds had already migrated or would migrate above detectable levels. Since migration to the canal was possible, each of the indicator compounds in the solvent tank area was assessed for environmental effects during the RA.

It was evaluated in the RA that it was unlikely for existing human populations to be exposed to chemicals of concern, due to current land use, the fact that the chemicals were present at depth, and the fact that they were confined to a very limited area of the site. However, it was thought that a remotely plausible human exposure scenario could involve a construction worker exposed to contaminants during future subsurface construction activities onsite. Given this possibility, limited human exposure was considered further in the RA. In addition, human exposure during future development of the site as a residential or commercial property was considered possible.

Exposure of the general population to contaminants in drinking water did not appear likely, for several reasons. First, the former Champion site is situated in an urbanized area where water is supplied to local businesses and residents through the city water department and water sources far removed from the site. Second, the upper fill material (where contaminants were detected) is discontinuous and yields groundwater only through random sand and silt lenses. Therefore, the sustained yield of this saturated unit would not be high enough to supply adequate water supply for domestic use. Furthermore, the upper fill material appears to be isolated from other water producing units that could be used by domestic users. Groundwater in the zone is unsuitable for domestic use, due to high amounts of iron, manganese, sulfate, color, turbidity, and TDS. Therefore, the solvent tank area cannot be used as a drinking water source.

Furthermore, samples collected during the RA were taken from a shallow fill zone containing groundwater (8 to 13 feet below grade). State of Washington regulations currently require at least an 18-foot seal between the ground surface and a water supply well screen. Therefore, contaminants within the shallow fill material would be screened off and most likely could not be ingested. Solvent tank area soil samples collected at a depth below the upper fill material confirmed that VOCs detected in the upper fill material were not migrating vertically into areas that were potential sources of drinking water.

5.2.3.2 Routes of Exposure. The routes of exposure for humans, for example under the construction worker scenario described above, were determined to be dermal absorption and inadvertent ingestion of contaminated soil/groundwater. During future construction activities at the site, it was thought possible that contaminated material would come into contact with the skin and be either dermally absorbed or inadvertently ingested, possibly causing adverse health effects. As discussed above, ingestion of contaminated materials in drinking water was an unlikely scenario and therefore was not considered by the RA to be a potential route of exposure.

Inhalation was not considered to be a likely exposure route because organic compounds are solubilized in water and are not expected to volatilize significantly. In addition, any volatile organic compounds that do volatilize would be expected to dilute quickly at ambient conditions. Furthermore, equations used to estimate risks via inhalation are based on daily exposure over 30 years. Any potential exposure as a result of the construction worker scenario would be limited to a few hours. Therefore, existing equations used to estimate inhalation risks do not appear appropriate for the solvent tank area.

5.2.3.3 Exposure Point Concentrations. Potential exposure of human populations to chemicals of concern in the solvent tank area appeared to be limited, due to the small areal extent of these chemicals and their depth below ground surface. However, it was determined that workers could be accidentally exposed during subsurface excavations, possibly made during installation of underground utilities or pipelines. In addition, human exposure during future development of the site as a residential or commercial property was considered possible. A potential route of exposure to contaminated soil and groundwater was considered to be inadvertent contact, resulting in dermal absorption or ingestion. To quantify possible human health effects and environmental impacts, exposure point concentrations were summarized as shown in Table 5-2.

5.2.3.4 Estimation of Chemical Intake - Noncarcinogenic Effects. An estimation of the expected dose for the compliance cleanup scenario discussed above was calculated for each chemical detected in the solvent tank area. Using a modification of the soil cleanup level equation (Method B cleanup levels) outlined in the WDOE cleanup standards (WAC 173-340-740), the mean and maximum expected doses for noncarcinogenic effects of each contaminant were calculated using the following equation:

$$\text{Expected Dose} = \frac{\text{Conc.} \times \text{SIR} \times \text{ABI} \times \text{FOC}}{\text{ABW} \times \text{UCF2} \times \text{HQ}}$$

where:

Conc. = contaminant concentration mean or maximum (mg/kg or mg/L)
SIR = ingestion rate (200 mg/day or 200 mL/day)
ABI = gastrointestinal absorption rate (1.0)
FOC = frequency of contact (1.0)
ABW = average body weight (16 kg)
UCF2 = unit conversion factor (1,000,000 mg/kg or mg/L)
HQ = hazard quotient (1.0)

The above equation was used to calculate the expected dose through accidental exposure and is based on a conservative assumption of 100 percent absorption of a contaminant through the lining of the stomach and intestinal tract. As discussed in Sections 5.2.3.1 and 5.2.3.2, risks due to consumption of drinking water and inhalation were not considered feasible; therefore, the expected dose through these exposure routes was not estimated. Actual absorption values depend on the chemical species and the age and health of the individual.

Other assumptions in accordance with WDOE guidance that were included in this model were:

- Average soil ingestion rate of 200 mg/day with a frequency of contact with contaminated soil or groundwater of once per day
- Average body weight of exposed individual of 16 kg.

The mean and maximum expected doses based on this model are presented in Table 5-3.

5.2.3.5 Estimation of Chemical Intake - Carcinogenic Effects. Two potential carcinogens (chloroform and arsenic) were identified from samples collected from well MW-1 in the solvent tank area. The mean and maximum chemical concentrations are summarized in Table 5-2. Expected doses for potential carcinogenic effects of arsenic and chloroform were calculated, using the following equation in accordance with the compliance cleanup model described in WAC 173-340-740.

$$\text{Expected Dose} = \frac{\text{Conc.} \times \text{SIR} \times \text{AB1} \times \text{DUR} \times \text{FOC}}{\text{ABW} \times \text{Life} \times \text{UCF1}}$$

where:

Expected Dose = mg/kg-day
Conc. = detected concentration (mg/kg or mg/L)
SIR = soil ingestion rate (200 mg/kg)
ABI = gastrointestinal absorption rate (1.0)
DUR = duration of exposure (6 years)
FOC = frequency of contact (1.0)
ABW = average body weight over exposure period (16 kg)
Life = lifetime (75 years)
UCF1 = unit conversion factor (1,000,000 mg/kg)

Expected doses for potential carcinogenic effects for arsenic and chloroform are summarized below:

| Chemical | Concentration Mean/Maximum mg/L | Expected Dose Mean/Maximum mg/kg-day |
|---|---|---|
| Arsenic | 0.009/0.010 | $9 \times 10^{-9}/1 \times 10^{-8}$ |
| Chloroform | 0.35/0.42 | $3.5 \times 10^{-7}/4.2 \times 10^{-7}$ |

As discussed in Section 5.2.3.4, the model was based on conservative assumptions, including 100 percent absorption through the intestinal tract. This value was used in the absence of more information.

5.2.3.6 Potential Nonhuman Recipients. Potential exposure of nonhuman recipients did not appear to be likely, given the following:

- Heavy metal concentrations detected in well MW-1 were low and probably represented natural background conditions.
- Solvents detected in MW-1 did not migrate significantly from the source area. Using an estimated groundwater flow rate, it was concluded that solvents detected in the vicinity of MW-1 might require up to ten years or more to reach the Lake Washington Ship Canal. During this time, contaminant levels would be significantly reduced (possibly to below detectable levels) through mechanical dispersion, sorption to organics, and volatilization.

Based on existing site conditions, exposure of nonhuman populations did not appear to be likely. Nevertheless, exposure point concentrations were used for a conservative evaluation of the potential exposure of aquatic life in the Lake Washington Ship Canal to chemicals in the solvent tank area. The risk characterization used mean and maximum detected concentrations for the exposure point concentrations.

A literature search was conducted to identify applicable information to characterize potential risk to human health and the environment. The literature search included a computer search of IRIS, the National Technical Information Service (NTIS), the Toxic Substances Control Act (TSCA), and Aquatic Science and Fisheries Abstracts online databases. Applicable information identified from the database searches was obtained through EPA libraries in San Francisco, California and Seattle, Washington.

In a literature review for chemicals occurring at the site, little or no useful information was found regarding the ecological effects of carbon disulfide or chloroform. As part of the preliminary RI, a bioassay test was performed using groundwater collected from well MW-1 to evaluate potential ecological effects of carbon disulfide and other solvents found in groundwater from the well. Chemical analysis of groundwater used for the bioassay test showed the following chemical levels:

| Chemical | Concentration Used in Bioassay Test (mg/L) | Current Chemical Concentration (mg/L) |
|---|---|---|
| Carbon disulfide | 28.3 | 4.6 |
| Carbon tetrachloride | 6.03 | Not detected |
| Tetrachloroethylene | 0.04 | Not detected |
| Chloroform | 7.06 | 0.42 |

The bioassay test was performed using fathead minnows (*Pimephales Promelas*). Reconstituted fresh water was combined with water from MW-1 at concentrations of 100 mg/L and 1,000 mg/L. The test was completed after five days with 100 percent survival at both concentrations.

As indicated, the current chemical concentrations were less than those used to perform the bioassay test. The reduction was probably a result of degradation, volatilization, and dilution of chemicals occurring in the source area. In addition, it was expected that chemical concentrations would be diluted immediately upon reaching the Ship Canal, which would further decrease them. As identified in the RI, transport of these chemicals through groundwater to the Ship Canal could require up to ten years or more. During this time, chemical concentrations would be expected to reduce further due to dispersion and volatilization. As a result, the potential effects on aquatic life in the Ship Canal would most likely be much lower than indicated by the bioassay test.

### 5.2.4 Toxicity Assessment

5.2.4.1 Noncarcinogenic Chemical Effects. Table 5-4 presents available RfDs for subchronic and chronic effects of chemicals detected at the site. The RA obtained RfDs for oral administration from the IRIS, WDOE and EPA Health Effects Assessment Summary Tables, dated January 1991.

5.2.4.2 Carcinogenic Chemical Effects. Two potentially carcinogenic compounds, arsenic and chloroform, were identified in groundwater samples from well MW-1 in the solvent tank area. Carcinogenic effects of the chemicals were assessed using the EPA carcinogenic potency factors (or slope factor, SF). Slope factors for arsenic and chloroform are presented in Table 5-4. These values were derived from epidemiological studies on the incidence of cancer per unit dose of contaminated material, and represented mathematical extrapolation from high doses to lower doses for exposed populations. The SF value for arsenic (1.8 kg-day/mg) was obtained through WDOE.

5.2.4.3 Toxicity Values and Relevant Guidelines. Other criteria of potential relevance to the RA included maximum contaminant limits (MCLs) established by the EPA under the Safe Drinking Water Act. MCLs are enforceable standards established for use with water for domestic purposes. As discussed previously, the upper saturated fill material in the solvent tank area could not be used as a domestic water source, due to shallow depth of the zone, poor quality (exceeding secondary MCLs), and low yield. Furthermore, chemicals of concern did not appear to be migrating to the lower-lying aquifer zone, which can be used for domestic water supply. Therefore, MCLs did not seem to be applicable guidance criteria under existing site conditions. However, MCLs for the chemicals occurring in the solvent tank area, as presented in Table 5-2, were used for comparison purposes during the RA.

The RA evaluated potential adverse impacts to fresh water aquatic life from chemicals identified at the former Champion site through comparison with the Ambient Water Quality Criteria (AWQC) established by the EPA. These values were derived from scientific assessments of human health and ecological effects induced by the chemicals.

AWQC are applicable to ambient concentrations of chemicals in surface waters, not specifically groundwater. The RA assumed that groundwater from the site probably was discharging to surface water; but a direct comparison of groundwater concentrations with those of surface water was not possible. Comparison based on AWQC therefore represented a very conservative approach to potential aquatic impacts. The AWQC for chemicals identified in the solvent tank area are summarized in Table 5-2.

### 5.2.5 Risk Characterization

5.2.5.1 Noncarcinogenic Chemical Effects. Risk characterization of noncarcinogenic chemicals included calculation of hazard indices using the mean and maximum expected doses. An index was found for each chemical by obtaining the expected dose, calculated from the exposure model equation, and dividing the resultant value by the RfD.

$$\text{Hazard Index} = \frac{\text{Expected Dose}}{\text{RfD}}$$

Mean and maximum hazard indices for subchronic and chronic exposure effects for the solvent tank area are presented in Table 5-3. Typically, RfDs for subchronic and chronic effects were the same for a given chemical. When they differed, however, the smallest (most conservative) value that resulted in the highest hazard index was used in the calculation.

Using the hazard index approach, an unacceptable risk for adverse health effects can result when the hazard index is greater than 1 for an individual contaminant or for the sum of all the contaminants. Subchronic and chronic risks were estimated by taking the ratio of estimated exposures (expected dose), derived as shown in Section 5.2.3.4, to EPA tolerance dose (RfD). The interpretation of this ratio was that a value greater than 1 for the sum of all potential contaminants represented an unacceptable human health risk. For the solvent tank area, the sum, based on the maximum detected concentration, was $1.4 \times 10^{-3}$. Therefore, the existing chemical concentrations did not represent an unacceptable risk of subchronic or chronic human health effects.

5.2.5.2 Carcinogenic Chemical Effects. Potential carcinogenic risks from exposure to arsenic and chloroform were calculated using the following equation:

Carcinogenic Risk = Expected Dose x Slope Factor

where:

Carcinogenic Risk = acceptable cancer risk level (1 in 1,000,000)

Expected Dose = calculated dose from exposure assessment (mg/kg-day)

Slope Factor = carcinogenic potency slope factor (kg-day/mg)

Calculations of maximum potential carcinogenic risks indicated that risks for chloroform and arsenic were $2.6 \times 10^{-9}$ and $1.8 \times 10^{-8}$, respectively. A person exposed to these contaminant levels could be subjected to an increased cancer risk of $2.1 \times 10^{-8}$, i.e., approximately two additional cancers in one hundred million exposed individuals could be expected. Based on existing EPA and WDOE guidance criteria, this carcinogenic risk value was well below the acceptable risk range of $1 \times 10^{-6}$ (compliance cleanup level).

5.2.5.3 Applicable Laws for Human Health and Environmental Effects. As mentioned in Section 5.2.4.3, MCLs were not applicable criteria for evaluating contaminants of concern detected in well MW-1. The reasons for this were:

- Upper saturated fill zone was laterally discontinuous and did not supply the volumes of water necessary for domestic use
- Saturated zone was too shallow and did not meet WDOE guidance (WAC 173-160) criteria for installation of water supply wells
- General water quality parameters (secondary MCLs) indicated that groundwater in this zone was unsuitable for human consumption (elevated turbidity, iron, manganese, sulfate, and TDS).

AWQC were also used in the RA to evaluate chemical impacts to organisms occurring in the Lake Washington Ship Canal. As indicated in Table 5-2, maximum chemical concentrations detected in MW-1 exceeded acute AWQC for copper and zinc only. The maximum chemical concentrations for copper and zinc were 12 percent and 2 percent, respectively, higher than the corresponding acute AWQC values. However, because concentrations of all metals detected in Well MW-1, including copper and zinc, most likely represent background conditions, they do not appear to pose a threat to aquatic life occurring in the Ship Canal.

The bioassay study discussed in Section 5.2.3.6 demonstrated that the solvent tank area groundwater probably posed little, if any, detrimental impact to existing aquatic life in the Ship Canal, even if previously detected levels of solvents in groundwater reached the canal. As mentioned previously, groundwater in this area could require up to ten years or more to reach the canal. During this time, chemical concentrations would be expected to decrease further due to the mechanisms described above, possibly to below detectable levels.

## 5.3 BOILER ASH FILL

### 5.3.1 Contaminant Summary and Screening

Heavy metals (including antimony, arsenic, barium, cadmium, total chromium, copper, lead, mercury, nickel, silver, and zinc) were identified during the RI in soil samples from the boiler ash fill. Previous samples collected by Parametrix indicated that the boiler ash also exhibited relatively high pH values (up to 11). However, several more recent samples collected during the supplemental RI showed a maximum pH of 8.7. Therefore, it was concluded that previous reports of elevated pH were probably anomalous.

Low levels of TPH (as diesel) were also detected in the boiler ash fill at a maximum concentration of 4 mg/kg. Because TPH was detected infrequently, at relatively low concentrations, it was not included in the RA.

As discussed in Section 3.4.6.1, sampling of near shore sediments was performed to evaluate the chemical concentration ranges detected in the former mill log pond area prior to implementing dredging proposed by SBT. Sample CH-2 from the boiler ash fill area (boiler ash piles) detected TPH at a concentration of 9,300 mg/Kg. After submittal of the investigation results in a report dated 24 March 1989, WDOE approved the proposed dredging operation. During dredging of the log mill pond in July 1989, all areas that were sampled during the Phase I sediment sampling were dredged and disposed of offsite at a permitted landfill (6/17/91 personal communication with H. Thompson, Salmon Bay Terminals). The dredge spoils were reportedly disposed of at Newcastle Landfill.

The boiler ash fill, with an estimated volume of 3,200 cubic yards, is located on the north and northwest sides of the boiler building. It was observed at depths of up to 24.5 feet and came into contact with the Lake Washington Ship Canal at several locations. Mean and maximum concentrations of heavy metals detected in the boiler ash fill are summarized in Table 5-5.

Included in Table 5-5 is a summary of average background levels of heavy metals that can be expected under natural conditions (Lindsay, 1979). As indicated, maximum detected chromium and nickel concentrations found during the RI in the boiler ash fill were lower than selected average concentrations in background soil for these metals. It is probable that metal concentrations were indicative of natural conditions. Therefore, they were excluded from future consideration in the RA (see Table 5-1).

### 5.3.2 Mobility of Detected Contaminants

The primary contaminants of concern in the boiler ash fill were the heavy metals identified above, which can vary widely in the range of aqueous solubilities. The transport and fate of metals, in general, are controlled by sorption of sediments to organics and metal oxides. Therefore, organic content of the soil and the water column is very important in evaluating the transport of heavy metals. Unfortunately, the metal-organic relationships have not been thoroughly investigated (U.S. EPA, 23 1979). As a result, the sorptive abilities of the soil could not be quantified by the RA.

Table 5-6 summarizes factors/conditions impacting environmental fate and mobility of heavy metals. As noted above, sorption and physical mechanisms are important processes that influence transport of metals in aquatic environments. Available literature indicated that sorption varied frequently with the amount of organics, pH and Eh, and hydrous metal oxides. As indicated previously, free organic carbon appeared to be very prevalent at and in the vicinity of the site. According to available literature, photolysis was not found to be an important process in determining the aquatic fate of metals, except in the case of mercury. It was not clear what overall impact photolysis had on the aquatic fate of this compound.

Biotransformation of several metals has been found to occur naturally in aquatic environments; however, the overall toxicity of these compounds is generally not reduced. Biotransformation typically occurs through methylation or biomethylation, which can remobilize the contaminants from the sediments back into the water column (U.S. EPA, 1979).

### 5.3.3 Exposure Assessment

5.3.3.1 Potentially Exposed Populations. Exposure of human populations to contaminants from the boiler ash fill appeared to be unlikely, given the low concentrations detected (see Table 3-7) and the fact that most of the fill had been covered with up to 3 feet of clean fill material. However, human exposure was considered possible under existing site land use through the construction worker scenario described in Section 5.2.3.1. Such exposure can occur inadvertently during construction or maintenance work conducted in the vicinity of the boiler ash fill. Human exposure through inhalation of the boiler ash is unlikely since the boiler ash is covered with 3 feet of clean fill and the boiler ash typically occurs in saturated soil conditions, therefore minimizing the potential for fugitive dust.

As discussed earlier, exposure of nonhuman populations to boiler ash fill contaminants was also found to be possible. Because the fill is in partial contact with the Lake Washington Ship Canal, metals can leach from the fill to the canal, allowing dissolved metals to absorb into organics in the water column and to be deposited in nearby sediments. Since the boiler ash fill has been in place for approximately 30 years, it was assumed during the RA that metals would probably have already leached from the ash if this were going to happen.

In February 1989, extensive sediment sampling (Phase I) was performed in the vicinity of the boiler building to identify the impacts of a dredging program proposed by SBT. Phase I sediment sampling results indicated relatively low levels of metals (similar to typical background soil ranges). As a result of the low detected chemical concentrations, the WDOE concluded that sediments near the boiler building did not pose a significant threat. SBT was allowed to proceed with dredging and sediment removal in support of dock construction.

Through the dredging process, at least 5 feet of upper sediments from around the boiler building were removed and disposed of offsite. The RA concluded that potentially impacted sediments and boiler ash had probably already been removed and no longer posed a threat to aquatic organisms. Dredged areas include all areas sampled during Phase I sediment sampling. As a result, potential nonhuman receptors were not evaluated as part of the assessment.

5.3.3.2 Routes of Exposure. Routes of exposure with human health impact were determined to be dermal absorption and inadvertent ingestion of contaminated soil. It was concluded in the RA that inhalation of boiler ash material did not appear likely, since the material was covered with up to 3 feet of clean fill and the ash occurred in saturated soil. Furthermore, equations used to estimate risk through inhalation, which are based on 30 year exposure duration, would not be applicable to the industrial worker scenario where potential exposure would be limited to a few hours at most.

5.3.3.3 Exposure Point Concentrations. For reasons noted above, the RA used arithmetic mean and maximum chemical concentrations to represent exposure point concentrations for the boiler ash fill. These concentrations are presented in Table 5-5.

5.3.3.4 Estimation of Human Chemical Intake - Noncarcinogenic Effects. The RA used the Method B cleanup level equation of MTCA (WAC 173-340-740) to estimate the expected doses for subchronic and chronic health effects on human populations. The estimates were calculated using the equation presented in Section 5.2.3.4. Values derived appeared to be generally conservative for the following reasons:

- Gastrointestinal absorption rate of 100 percent was assumed. Actual contaminant absorption through the lining of the gut depends on the chemical species and the age and health of the individual, and is likely to be much lower than 100 percent.

- A soil ingestion rate of 200 mg/day was assumed with this model. Actual ingestion of soil is probably much lower, unless an individual is extremely careless.

- An average body weight of 16 kg is also assumed by the model. This is very conservative considering the average adult weight is approximately 70 kg.

Additional assumptions on which the equation was based are discussed in Section 5.2.3.4. The mean and maximum expected doses for chronic and subchronic effects of chemicals occurring in the boiler ash fill are summarized in Table 5-7.

5.3.3.5 Estimation of Chemical Intake - Carcinogenic Effects. Arsenic was the only potential carcinogen detected in the boiler ash fill. Estimates of arsenic uptake for potential carcinogenic effects, for the residential scenario, used the equation presented in Section 5.2.3.5. The mean and maximum expected doses for arsenic in the boiler ash fill were $2.3 \times 10^{-5}$ and $5.5 \times 10^{-5}$ mg/kg-day, respectively.

5.3.3.6 Potential Nonhuman Recipients. As discussed in Section 5.3.3.1, potential nonhuman recipients were not evaluated in the RA. Chemical levels identified in sediment samples from areas adjacent to the boiler ash fill appeared to be below levels of regulatory concern, based on Phase I sediment sampling. It was likely that the sediments/boiler ash chemicals had already been removed.

### 5.3.4 Toxicity Assessment

5.3.4.1 Noncarcinogenic Chemical Effects. Table 5-4 summarizes available RfDs for chronic and subchronic exposure to chemicals detected in the boiler ash fill. As discussed in Section 5.2.4.1, for the solvent tank area, RfDs were obtained from IRIS, WDOE and the EPA Health Effects Assessment Summary Tables, dated January 1991.

5.3.4.2 Carcinogenic Chemical Effects. Arsenic, a potential carcinogen, was detected in the boiler ash fill at mean and maximum concentrations of 23.2 and 55 mg/kg, respectively. A carcinogenic potency slope factor for ingestion of arsenic ($1.8 \times 10^0$ mg/kg-day) was obtained from Ecology.

### 5.3.5 Risk Characterization

5.3.5.1 Noncarcinogenic Chemical Effects. The hazard index approach was used to estimate chronic and subchronic human health effect risks for chemicals (heavy metals) detected in the boiler ash fill. The resultant hazard indices are presented in Table 5-7.

The hazard index is the ratio between the expected dose and the RfD derived by the EPA. A ratio value greater than 1 for a particular contaminant or the sum of all contaminants represents an unacceptable risk. For boiler ash fill material, the sums using average concentrations and maximum concentrations were $6.5 \times 10^{-1}$ and 2.3, respectively. Therefore, the average chemical concentration identified for the boiler ash fill did not present unacceptable risks for chronic and subchronic human health effects. Using maximum concentrations, the acceptable cumulative hazard index of 1 was exceeded.

It should be noted that while the MTCA Method B cleanup levels were exceeded (hazard index greater than 1) for maximum chemical concentrations in the boiler ash fill, the detected contaminant concentrations did not exceed cleanup levels for industrial sites specified in WAC 173-340-745. Using the formula for calculating risk for industrial sites, the cumulative hazard index (maximum contaminant concentrations) was $5.3 \times 10^{-2}$.

5.3.5.2 Carcinogenic Chemical Effects. Calculations for potential carcinogenic intake of arsenic are discussed in Section 5.3.4.2. The mean and maximum potential carcinogenic risks for arsenic, $4.1 \times 10^{-5}$ and $9.9 \times 10^{-5}$, respectively, were calculated by multiplying the expected dose by the slope factor for arsenic. The risks indicated that persons exposed to arsenic at the maximum level detected, under the conservative assumptions made, would be subjected to an increased risk of approximately nine cancers in 100,000 exposures. This result was in excess of Method B cleanup levels under the MTCA cleanup standards. However, using the risk calculation formula for industrial sites (WAC 173-340-745,B,iii), the maximum carcinogenic risk was $7.5 \times 10^{-6}$, below the acceptable risk of one in 100,000 specified in the regulations.

As discussed previously, the estimates appeared to be conservative, due to the assumptions made in the exposure model. Assumptions that could significantly impact the carcinogenic exposure risk for arsenic included 100 percent absorption of arsenic through the gut lining and 100 percent absorption through the skin surface. These assumptions were made because of the absence of data in the scientific literature on gastrointestinal and dermal permeability of metals. However, it should be noted that the assumptions probably overestimated potential risks by as much as a factor of ten.

## 5.4 GLUE PRESS AREA

### 5.4.1 Contaminant Summary and Screening

As discussed in Chapters 3.0 and 4.0 of this report, the glue press area includes regions underneath two existing buildings, where glue press wastes (phenolic glue and wood chips) have accumulated. PAHs were the primary chemicals of concern during the RI examination of this operable unit. Two samples were also analyzed for selected metals (chromium, copper, lead, and zinc). Detected levels were within background ranges observed in natural soil, and therefore, were excluded from the RA.

In addition to the PAH compounds, aniline and dibenzofuran were detected in one sample (GP-5C) at concentrations of 30 mg/kg and 6.1 mg/kg, respectively. Because concentrations of these compounds were low and because they were not detected in other samples in the glue press area, they were also excluded from the RA.

Anthracene was the primary chemical of concern detected in the glue press area. It was found at levels up to 770 mg/kg in sediments adjacent to the glue piles. As discussed in the RI report, lateral migration of anthracene appeared to be limited to within 10 feet of each glue pile.

Other PAH compounds, including naphthalene, 2-methylnaphthalene, and pyrene, were detected in samples from the glue press area. Naphthalene was detected once at a concentration of 2.3 mg/kg, while 2-methylnaphthalene was detected twice at a maximum concentration of 16 mg/kg. Pyrene was detected one time at a concentration of 4.1 mg/kg. Because these compounds were detected infrequently and at relatively low concentrations, and because they are generally associated with media contaminated with anthracene, they were not addressed further in the RA. Table 5-1 summarizes the compounds detected in the glue press area that were excluded from the RA, along with reasons for their exclusion.

### 5.4.2 Environmental Fate and Mobility of Anthracene

Anthracene was the only compound of concern detected consistently in the glue press area. However, there was relatively little information on human health and environmental effects available for this compound. The only available information was summarized in a report prepared by the EPA entitled "Health and Environmental Effects Profile for Anthracene," April 1987 (U.S. EPA, 1987). Based on this data, anthracene was reported by the RA as having the following characteristics:

- It is almost insoluble in water. Solubility was observed to decrease with increasing salt content.
- The compound was found to be strongly sensitive to photolysis, which frequently reduces contaminant concentration significantly. Photodegradation depends on the depth of the water, turbidity, and water temperature. The average half-life of anthracene in water, in the top 35 meters in the Gulf of Mexico, was computed to be 6 hours. This might have been one reason that anthracene was detected below onsite buildings (not exposed to light) and not in the other sediments (exposed to light).
- Sorption to organics is a significant factor in the loss of anthracene from the water column. Anthracene absorbed into organics is unaffected by photolysis.
- In deep, slow-moving muddy water, microbial degradation and adsorption may account for major losses of anthracene.
- Anthracene volatilizes readily in shallow, fast-flowing clear water. However, volatilization is dependent on several factors, including water temperature and intensity of solar radiation. Therefore, volatilization probably does not play a significant role below existing structures at the former Champion site.
- Anthracene bioconcentrates moderately in aquatic organisms. However, uptake of anthracene sorbed to organics is significantly lower than the bioconcentration of dissolved anthracene in interstitial water.
- Anthracene is relatively immobile in soil, due to its high Henry's Law constant. However, it can leach through soils that have attained a breakthrough capacity.

### 5.4.3 Exposure Assessment

5.4.3.1 Potentially Exposed Populations. Because the glue piles are located below the floors of existing site buildings, human contact with this waste is limited. However, the RA determined that human exposure was possible in the event of construction or maintenance work below a building, as well as through future site development. Human contact with potentially contaminated surface water through activities such as swimming and wading did not appear to be a potential exposure scenario for the following reasons:

- The glue press area is highly industrialized and shorelines are predominantly obscured by existing buildings and structures, which limits potential access of swimmers and waders.
- Recreational use of the Ship Canal is not advised by the Seattle Department of Parks and Recreation, due to the high fecal coliform bacteria levels and the high amount of ship traffic.

It was determined that exposure of aquatic organisms to contaminants was possible, given the close proximity of the glue piles to the Ship Canal. As indicated in Chapter 3.0, the stage of the canal fluctuates by approximately 2 feet during the year. At the maximum stage, a portion of several of the glue piles may be in direct contact with Ship Canal water. At low stage, the glue piles are not in contact with the water in the canal.

Other factors that may facilitate anthracene migration from the glue piles are such physical mechanisms as surface water runoff, which results in erosion and flaking. Since the glue piles did not appear to be affected by surface water runoff and were protected from other erosion effects due to their location below the buildings, such physical mechanisms did not appear to be legitimate concerns for the RA. This conclusion was supported by the fact that the glue piles have been in place for over 30 years, but lateral migration has generally been limited to within 10 feet of the glue pile edges.

Finally, because anthracene has a high affinity for sorption to organics, dissolved anthracene would be less available for consumption by aquatic organisms in the turbid, organic rich environment where the glue piles are located. For these reasons, it was assumed that the amount of anthracene that could be consumed by aquatic organism was severely limited.

5.4.3.2 Routes of Exposure - Human. Exposure routes of potential impact to human health were determined to be dermal absorption and inadvertent ingestion of contaminated soil and surface water.

5.4.3.3 Routes of Exposure - Nonhuman. The RA determined that nonhuman populations (aquatic organisms) could be exposed to glue press area contaminants by consumption or absorption. However, few, if any, aquatic organisms were expected to reside below the buildings where the anthracene is located, due to inappropriate habitat (lack of sunlight) in the area. Previous studies conducted onsite found a lack of appropriate habitat and organisms below onsite buildings, due to light deprivation (IES Associates, 1988). Also, as mentioned previously, anthracene sorbs readily to organic matter. Sorbed anthracene appeared to be less toxic to aquatic organisms than dissolved anthracene, which further minimizes potential adverse effects on the organisms.

5.4.3.4 Exposure Point Concentrations. Mean and maximum chemical concentrations detected in the glue press area are presented in Table 5-8. As previously discussed, only anthracene was found consistently throughout this operable unit. Therefore, the other chemicals (which included naphthalene, 2-methylnaphthalene, pyrene, dibenzofuran, aniline, chromium, copper, lead, and zinc) were excluded from further evaluation. Based on the results of 14 samples collected from the glue press area, the mean and maximum exposure point concentrations for anthracene are 109 and 770 mg/kg, respectively.

5.4.3.5 Estimation of Chemical Intake - Noncarcinogenic Effects. Chemical intake for potential human recipients through inadvertent exposure in a residential setting was estimated by use of the equation presented in Section 5.2.3.4. The RA estimated mean and maximum expected doses for anthracene to be $1.4 \times 10^{-3}$ and $9.6 \times 10^{-3}$ mg/kg-day, respectively.

As discussed previously, the conservative assumptions made in this exposure model probably overestimated the expected dose. However, in the absence of specific information regarding human gastrointestinal and dermal absorption rates, the most conservative assumptions (100 percent absorption through the gut lining and skin surface) were made.

5.4.3.6 Estimation of Chemical Intake - Carcinogenic Effects. Anthracene has been classified as a Group D chemical that does not exhibit carcinogenic effects. Therefore, carcinogenic intake was not assessed.

### 5.4.4 Toxicity Assessment

5.4.4.1 Noncarcinogenic Chemical Effects. Table 5-4 summarizes available RfDs for chronic and subchronic exposure to chemicals detected in the glue press area. As previously discussed, RfDs were obtained from IRIS, WDOE and the EPA Health Effects Assessment Summary Tables, dated January 1991. The RfD of 3.0 E-1 mg/Kg/day was used to calculate the hazard index for anthracene (see Section 5.4.5).

5.4.4.2 Carcinogenic Chemical Effects. During the RA, information about potential carcinogenic effects of anthracene was found in the available literature. Investigation discovered few, if any, carcinogenic effects in the study group. Information presented in the EPA document (U.S. EPA, 1987) indicated that there is no evidence that anthracene is a carcinogen. As a result, the EPA classifies anthracene as a Group D chemical, according to the weight of evidence system.

5.4.4.3 Aquatic Toxicology. PAHs, as a general class of chemicals, are acutely toxic to aquatic organisms at concentrations ranging from 50 to 1,000 ug/L. Sublethal effects on these organisms have been observed at concentrations ranging from 0.1 to 5.0 ug/L [U.S. Fish and Wildlife Service (FWS), 1987]. However, these values are representative of benzo(a)pyrene, a chemical not detected in offshore sediments, and do not necessarily reflect potential effects of anthracene. In fact, available information indicates that anthracene in the absence of other PAH compounds has limited toxicological effects to aquatic organisms (U.S. EPA, 1987).

Acutely toxic anthracene concentrations range from 1.9 ug/L for *Daphnia pulex* to 3,030 ug/L for *Daphnia magna* (U.S. EPA, 1987). The toxicity of anthracene has been found to increase significantly in the presence of sunlight and ultraviolet radiation. This may explain the variability in the acutely toxic concentrations noted above. However, in areas not exposed to solar radiation, anthracene has been found to be nontoxic within solubility limits.

The ability of aquatic organisms to metabolize and eliminate anthracene varies considerably among different species. In tests of fish (rainbow trout, dolly varden char, and bluegill), anthracene has not appeared to be metabolized rapidly (U.S. EPA, 1987). However, small aquatic insects (*Chironomus riparius*) have been observed to metabolize and eliminate anthracene quickly (U.S. EPA, 1987).

### 5.4.5 Risk Characterization

5.4.5.1 Noncarcinogenic Chemical Effects. The hazard index approach was used to estimate chronic and subchronic health effect risks for anthracene. Based on the expected doses, a mean and maximum hazard index of $4.7 \times 10^{-3}$ and $3.2 \times 10^{-2}$, respectively, were calculated. These calculated hazard indices are well below the level of which adverse human health effects would be expected.

5.4.5.2 Carcinogenic Chemical Effects. Anthracene was determined to be a Group D chemical (not classified as a carcinogen), according to the EPA weight of evidence system.

## 5.5 METHANE PRODUCTION AREAS

### 5.5.1 Methane Occurrence and Distribution

As discussed in Section 3.3.5, for the RI, methane-producing organic debris appeared in subsurface soils throughout the site. Although it was not possible to fully characterize the thickness of the organic debris in all locations across the site, available information suggested that the upper 6 to 25 feet of subsurface material consisted of significant amounts of organic debris.

Organic vapor monitoring information collected during borehole drilling indicated significant quantities of methane (at least 5 percent by volume) identified during borehole advancement. However, these levels were probably exaggerated, due to enhanced volatilization from friction of the hot augers as they pass through organic-rich zones. The highest quantities of methane seemed to be produced in soils occurring above or slightly below the water table. Methane levels encountered at depths of approximately 10 feet below the water table dropped off dramatically. Levels greater than 1,000 ppm were observed in areas where less than 2 feet of organic debris was encountered. However, areas where no organic debris was found during drilling showed very low methane levels (below 10 ppm).

### 5.5.2 Potentially Exposed Populations

Potential adverse effects of methane accumulation include the creation of explosive environments and human or animal asphyxiation due to oxygen displacement in confined spaces. As discussed in Chapter 3.0, Section 3.3.5, methane at the former Champion site was observed to dissipate immediately to below detectable levels at ambient conditions. Given the existing condition of the site, with buildings elevated above ground surface and often openly exposed to ambient air, accumulation of methane did not seem feasible. Therefore, the possibility of methane accumulation resulting in explosive levels or human asphyxiation appeared to be unlikely, considering site use and conditions. It was thought, however, that future site use might be different. Therefore, potential explosive hazards were addressed further in the FS (see Chapter 6.0).

## 5.6 OFFSHORE SEDIMENTS

### 5.6.1 Contaminant Summary and Screening

During the RI, sediment samples were collected from below onsite buildings, the DNR lease area, and the Lake Washington Ship Canal. They were analyzed for the following parameters:

| Chemical | Test Method |
|---|---|
| Metals | SW-846 |
| PAHs | EPA-8100 |
| VOCs | EPA-8240 |
| PCPs | EPA-8040 |
| TPHs | EPA-418.1 |
| Grain size | ASTM D-421 |

The results of these analyses are discussed in Section 3.4.6 of Chapter 3.0, reported on a dry weight basis. Phase I sediment sampling was performed in the former log mill pond area. Since the time of sampling, this area has been dredged and approximately 5 feet of sediments have been removed and disposed of at a local landfill. Therefore, sample results were not assessed in the RA.

Phase II sampling was performed in areas below existing buildings, in the DNR lease area, and in the Ship Canal. The results of analyses of samples collected below the buildings were the focus of the RI for offshore sediments. Concentrations of chemicals in the DNR lease area were either below background conditions or below detectable levels. These chemicals were also detected relatively infrequently and, therefore, were not assessed further in the RA (refer to Table 3-9 in Chapter 3.0). The remaining sediment samples in the Ship Canal were collected to evaluate background ranges of chemicals in nearby sediments.

The arithmetic mean and maximum levels of chemicals detected in areas below existing buildings are summarized in Table 5-9. As indicated, potential chemical contaminants of concern primarily included PAH compounds and heavy metals, although TPH and acetone were also detected.

TPH was detected in every sediment sample, with a maximum concentration of 250,000 mg/kg and an average concentration of 75,329 mg/kg (dry weight). Gas chromatography was used to analyze the samples containing the highest TPH levels for fuel products (by EPA Modified Method 8015). Results indicated the presence of diesel at a maximum concentration of 2,000 mg/kg. Because analysis results were reported on a dry weight basis, a fourfold to fivefold concentration increase was observed, as compared to what was observed on a wet weight basis (as received). Acetone was detected in two samples, at a maximum concentration of 0.6 mg/kg. Available information suggested that acetone was probably a byproduct of wood degradation and should not, therefore, be evaluated further in the RA.

PAH compounds detected in offshore sediments included phenanthrene, anthracene, fluoranthene, pyrene, benzo(a)anthracene, and benzo(k)fluoranthene. Anthracene and benzo(k)fluoranthene were detected at the highest concentrations, 65 mg/kg and 53 mg/kg, respectively. The other identified PAHs were detected at concentrations below 8 mg/kg. The maximum concentration of all PAHs detected in offshore sediment samples, except for pyrene, was in excess of the AETs established for marine sediments in Puget Sound.

AETs are not applicable to freshwater sediments but were used as comparison data in the absence of established freshwater criteria. They are based solely on toxicological effects to marine organisms; therefore, there are no direct correlations with possible effects on freshwater organisms. However, AWQC are generally lower for saltwater aquatic life than for freshwater aquatic life, indicating that AETs may be overly conservative in estimating risks to freshwater aquatic organisms. Since pyrene was not detected at concentrations greater than the AETs, it was excluded from further analysis.

Because there was no information for ecological effects of TPH as diesel, WDOE's freshwater sediment criteria specialist (Mr. Jim Cubbage) was consulted. He suggested assessment of potential detrimental effects of TPH through analysis of individual compounds that make up diesel. In such an analysis, the net expected effects value consists of the sum of effects of VOCs, such as benzene, toluene, ethylbenzene, and xylenes, and the sum of the effects caused by low molecular weight (two- and three-ring) PAHs. Since none of the anticipated VOCs was detected, ecological effects for TPH were determined according to the occurrence of low molecular weight PAHs, including anthracene and phenanthrene.

Heavy metals detected in samples collected beneath onsite buildings included antimony, arsenic, beryllium, cadmium, chromium, copper, lead, mercury, nickel, selenium, silver, and zinc. For comparison purposes, Table 5-9 presents mean and maximum background levels of metals detected in Lake Union sediments, based on a report prepared by the City of Seattle, June 1986 (City of Seattle, 1986). As indicated, maximum background levels of arsenic and zinc detected in the Lake Union study were greater than those in samples collected below the onsite buildings.

In 1986 and 1987, an extensive study by the City of Seattle and Kennedy/Jenks/Chilton evaluated contaminant loadings to Lake Union and the Ship Canal. As part of this study, sediment samples were collected from 11 selected stormwater catch basins around Lake Union and the canal.

Sediment samples were analyzed for heavy metal constituents, with mean results as presented in Table 5-9. Mean concentrations detected in stormwater sediments in the Lake Union drainage area were greater than all the maximum metal concentrations detected below the site, except for chromium, copper, lead, mercury, and selenium. Since sediment samples collected from below onsite buildings were from areas close to stormwater discharge areas, the results were interpreted to represent background ranges for offshore sediments. Thus detected arsenic and zinc levels were assumed to reflect background conditions occurring in this industrial area and were not included in the RA for offshore sediments.

Metal concentrations in sediments below onsite buildings were found to exceed the AETs for arsenic, zinc, copper, lead, and mercury. However, since the levels of arsenic and zinc are most likely reflective of background conditions occurring in urban areas, these metals were not evaluated further in the RA. Beryllium was excluded from further evaluation because the maximum concentration was below the background average found in Lake Union. Silver was also excluded because the maximum concentration was below the AET value. Copper, lead, and mercury were above levels for background conditions and were therefore evaluated further in the RA. Table 5-1 presents a summary of chemicals excluded from evaluation in the RA and the reasons for their exclusion.

### 5.6.2 Mobility and Fate of Detected Compounds

5.6.2.1 PAHs. PAHs are relatively persistent in the environment. As a group, they have a strong tendency to sorb to organics and clays in aquatic environments. As organic material drops out of suspension in the water column, PAH compounds become incorporated in the sediment material. Fate and degradation of these compounds are functions of several mechanisms and processes, including:

- Mechanical movement
- Consumption by aquatic organisms
- Photolysis
- Volatilization
- Biodegradation and oxidation

These processes are discussed briefly in the following paragraphs.

Because PAHs have a strong tendency to sorb to organics, their mobility is a function of sediment mobility. Processes likely to enhance sediment mobility include dredging, high boat traffic, and, to a limited extent, wave action. It was assumed, therefore, that overall mobility of these contaminants in offshore sediments was minimal, given existing conditions. However, future activities at the site could have a significant impact on the mobility of the contaminants.

Overall reduction of PAHs in an aquatic environment depends on several processes, including consumption and absorption by aquatic organisms and plants, photolysis, volatilization and biodegradation, and oxidation. Several low molecular weight PAH compounds are strongly affected by volatilization, the rates of which are a function of intensity of solar radiation, depth of water, water temperature, and water turbidity. However, the ultimate fate of PAHs that accumulate in sediments is believed to depend on biotransformation and biodegradation by benthic organisms (U.S. FWS, 1987).

5.6.2.2 Heavy Metals. The mobility and fate of heavy metals in aquatic environments are discussed in Section 5.3.2.

### 5.6.3 Exposure Assessment

5.6.3.1 Potentially Exposed Populations. Human exposure to sediments underneath buildings and in close proximity to the shore did not seem feasible, for the following reasons:

- The area is highly industrialized and shorelines are predominantly obscured by existing buildings and structures, which limits potential access of swimmers and waders.

- Recreational use of the Ship Canal is not advised by the Seattle Department of Parks and Recreation, due to the high fecal coliform bacteria levels and the large amount of ship traffic.

As a result, potential recipients of contaminated sediments were determined to be limited to aquatic organisms and possibly waterfowl.

5.6.3.2 Exposure Point Concentrations. Possible exposure routes for aquatic organisms in the Lake Washington Ship Canal appeared to be direct contact with or consumption of chemically impacted sediments. As already discussed, chemical contaminants including TPH, PAHs, and heavy metals were detected in offshore sediment samples from the former Champion site. The degree to which these contaminants represented background conditions in an industrial setting was unclear.

Except for anthracene and selenium, chemicals detected in samples from beneath onsite buildings were also found in sediment samples from the Lake Union Ship Canal. Anthracene was the only compound that could be attributed to former operations at the site. It was suspected that anthracene was present below site buildings, and not in other sediments, because of the lack of light beneath the buildings, which is known to limit degradation of anthracene. Concentrations of all contaminants in the Ship Canal were generally an order of magnitude less than those found beneath onsite buildings. However, scouring of Ship Canal sediments due to ship traffic and natural currents was expected to transport contaminants towards more stagnant areas.

The combination of relatively stagnant water beneath onsite buildings and urban runoff tended to allow contaminants to accumulate in nearby sediments. Furthermore, many chemicals detected in offshore sediment samples had also been detected elsewhere. These chemicals had been found regionally in stormwater and sediment samples collected around the Lake Washington area. They also had been detected locally in sediment samples from stormwater catch basins at and near the Pioneer Lumber Treating Company site, which is located approximately 500 feet southeast of the former Champion site.

Investigations performed by the City of Seattle in 1984 indicated that street dust was a significant source of heavy metal contaminants in urban stormwater runoff (Galvin, 1984). The Galvin report indicated mean concentrations in street dust for arsenic, copper, chromium, lead, mercury, and zinc of 25 mg/kg, 93 mg/kg, 97 mg/kg, 520 mg/kg, 0.06 mg/kg, and 310 mg/kg, respectively. These metal concentrations were similar in magnitude to the mean metal concentrations identified in offshore sediment samples collected below onsite buildings. Freshwater sediments subjected to several years of stormwater runoff with elevated contaminant levels were expected to show elevated concentrations of persistent chemicals, such as metals. PAHs were also found to be a significant component of street dust and runoff (Galvin and Moore, 1982). The sources of these PAHs included automobile emissions.

Further chemical impact to sediments was expected in areas where chemicals were consistently used in such a manner that they could be induced into the aquatic environment. Shoreline areas were considered to be particularly susceptible to metal contamination in places where ships and boats were painted and refinished. Chemicals frequently associated with marine paints and primers include lead, zinc, and chromium. Since these chemicals were found below onsite buildings but had never been used during previous activities at the site, they might have originated with other sources, such as boat maintenance operations, near the site.

Maximum and mean exposure point concentrations for the site are presented in Table 5-9. These concentrations are based on samples collected from beneath onsite buildings. Maximum and mean chemical concentrations found in samples from the Ship Canal during Phase II investigations are also presented in Table 5-9. Since chemical concentrations detected in sediment samples from the DNR lease area were of a magnitude similar to that of concentrations detected in Ship Canal samples, they were considered representative of background ranges and were not further evaluated in the RA.

5.6.3.3 Potential Human Intake. Given existing site conditions, human exposure to chemicals occurring in sediments was improbable, for the reasons discussed in Section 5.6.3.1. Therefore, potential human recipients were not evaluated.

5.6.3.4 Potential Nonhuman Recipients. As discussed in Section 5.6.3.1, aquatic organisms and waterfowl were determined to be the only potential recipients of contaminants occurring in sediments at the site. Aquatic organisms that could be exposed included sediment-dwelling organisms, such as aquatic insects, mollusks, and small fish. Since many of the contaminants in offshore sediments are bioaccumulated, fish that feed on these organisms may also be exposed.

Fish and crustacean populations that reside in the Lake Washington Ship Canal include yellow perch, northern squawfish, large mouth bass, black crappie, brown bullhead, carp, and crayfish (City of Seattle, 1988). Nonresident aquatic populations that can also be exposed include anadromous fish, such as salmon, steelhead, and cutthroat trout, which use the Ship Canal as a migratory route between the Puget Sound and the Lake Washington drainage area.

Since water in the Ship Canal channel is deep, and therefore cold, the RA assumed that migratory fish would seek this area (City of Seattle, 1986). As a result, there appeared to be little chance that migratory fish would move into areas where chemical contaminants had been found below onsite buildings. Therefore, impact to nonresident fish populations from chemicals in offshore sediments appeared slight. Based on the City of Seattle report, the RA concluded that contaminant levels in the Lake Washington Ship Canal would not have a significant impact on migratory fish because of the low likelihood of exposure and its short duration of exposure.

### 5.6.4 Toxicity Assessment

5.6.4.1 Environmental Effects. Toxicological endpoints were researched by reviewing available ecological literature. Information sources included:

- EPA AWQC documents for individual metals and PAHs
- U.S. FWS contaminant hazard review for individual metals and PAHs
- Available EPA ecological profile documents for chemicals of concern

As discussed in Section 5.6.1, chemicals evaluated in the RA included phenanthrene, anthracene, fluoranthracene, benzo(a)anthracene, copper, lead, benzo(k)fluoranthene, and mercury. Elimination of other chemicals from the RA was based on comparison with background ranges of metals in south Lake Union, stormwater sediment sample results for Lake Union, and AETs.

Available information on the potential toxicological effects of these chemicals is summarized below:

- Phenanthrene, Fluoranthracene, Benzo(a)anthracene, and Benzo(k)-fluoranthene. Specific information regarding phenanthrene, fluoranthracene, benzo(a)anthracene, and benzo(k)fluoranthene was not identified during the literature review. However, information on anticipated ecological effects was found in the U.S. FWS document for PAH compounds (U.S. FWS, 1987). This report discusses the potential effects of PAHs in an aquatic environment and is based primarily on investigations involving benzo(a)pyrene. This chemical was not detected in sediments at the site. It is generally considered more toxic than the other PAH compounds identified above. Available information suggested that uptake of PAHs by aquatic organisms was very species-dependent; organisms such as algae and mollusks, which are unable to metabolize PAHs, showed the highest uptake.

  During the RA, bioconcentration factors were observed to increase with increasing molecular weight of a PAH compound. In addition, acute toxicity increased with increasing PAH molecular weight. In all but a few cases, PAH levels that were acutely toxic to aquatic organisms were several orders of magnitude higher than levels found in heavily polluted waters (U.S. FWS, 1987). It was decided that some contaminated sediments might contain PAH concentrations similar to those that are acutely toxic to aquatic organisms, but their limited bioavailability would probably render them substantially less toxic than PAHs in solution (U.S. FWS, 1987). Available toxicity information for chemicals of concern is summarized in Table 5-10.

- Anthracene. Available toxicity information for anthracene is discussed in Section 5.4.4.3.

- Copper. Available information presented in the EPA AWQC on the toxicity of copper was based on total copper content in water. However, toxicity was observed during the RA to vary among different inorganic and organic copper complexes. A summary of toxicological information for freshwater organisms is presented in Table 5-10.

  Acute toxicity concentrations ranged from 6.5 ug/L for *Daphnia magna* in hard water to 10,200 ug/L for bluegill in hard water. The toxicity of copper was observed to decrease with increasing calcium hardness and carbonate alkalinity. Furthermore, some species were observed to be more resistant to copper at lower water temperatures.

  It was observed that copper sorbed readily to organics in the water column, resulting in sediment deposition. Therefore, sorption to sediments was determined to be important in the overall reduction in bioavailability of copper in the aquatic environment.

- Lead. Selected toxicity information for lead is presented in Table 5-10. All dose values represented the acid-extractable fraction only. Available information presented in the EPA AWQC document indicated that many freshwater species were more sensitive to lead in soft water than to lead in hard water.

- Mercury. Several factors affected the toxicity of mercury in the aquatic environment. These included alkalinity, ascorbic acid, chloride, dissolved oxygen hardness, pH, and temperature. Selected toxicity information for mercury (acid-extractable portion) is presented in Table 5-10.

5.6.4.2 Toxicity Values and Relevant Guidance Criteria. As mentioned previously, it was found in the RA that no current established criteria in use by the WDOE or EPA for evaluating contaminant concentrations in freshwater sediments. Previously presented toxicity information was generally applicable to contaminant concentrations in water, but not those in sediments. The only criteria available for sediments were AETs, which have been developed for marine sediments. However, in the absence of freshwater criteria, AETs were evaluated to provide useful comparison data.

As previously indicated, AETs are based on the minimum apparent effects that occur to a select study group of marine organisms. Thus, there are no direct correlations with possible effects on freshwater organisms. As a result, the actual effects threshold for freshwater organisms may be significantly different from the AET. However, AWQC are generally lower for saltwater aquatic life than for freshwater aquatic life, indicating that the AETs may be overly conservative for estimation of risk to aquatic organisms. This assumes that AWQC have a correlation with effects on sediment-dwelling biota. AETs for the contaminants of concern in offshore sediments are listed in Table 5-9.

There were numerous limitations that had to be considered when using AETs as comparison criteria for offshore sediments. First, AETs are not cleanup standards, even for marine sediments. The WDOE is currently developing sediment management standards in which minimum cleanup requirements are considerably higher than the sediment standards (based on AETs). Table 5-11 presents the draft sediment standards (AET), minimum cleanup requirements based on the 29 June 1990 draft sediment regulations, and concentrations detected at the site. As can be seen from the table, standards/cleanup levels differed from the AETs in that PAH compound concentrations were normalized to organic carbon. Essentially, the higher the organic carbon content, the higher the PAH standard, due to the tendency of PAHs to sorb to organic carbon, thereby reducing bioavailability.

Analysis of sediments for total organic carbon (TOC) was not part of the RI, although concentrations were expected to be high, partially due to detected TPH concentrations and partially due to the extensive presence of wood wastes. Therefore, the PAHs were expected to be strongly associated with the sediments. While the toxicity of TPH compounds was not well understood, it was known that TPH concentrations can be reduced over time by natural degradation. However, PAH compounds tend to remain, due to their persistence in the environment. It was important to compare PAH concentrations in sediments with natural (not TPH-based) organic carbon content.

Since organic carbon (not TPH-based) was expected to remain over time, it would perhaps be the only carbon available to which PAHs could sorb. Therefore, three selected sediment samples were subjected to TOC analysis to make an assessment of TOC content and thus sorption capacity and related toxicity. TOC, TPH, and calculated non-TPH TOC values are presented below for the three samples subjected to analysis. These results had to be interpreted with caution, due to the length of time between sediment sampling and TOC analysis.

| Location | TPH (Conc. (mg/kg) | TOC Conc. (mg/kg) | Non-TPH TOC Conc. (mg/kg) |
|---|---|---|---|
| B-4 #1 | 250,000 | 500,000 | 250,000 |
| B-5 | 67,000 | 280,000 | 213,000 |
| B-6 | 7,300 | 296,000 | 288,700 |

During the RA, this information indicated that non-TPH TOC in sediments ranged from 20 to 30 percent. Normalizing sediment results for PAHs to non-TPH TOC and comparing these results with the draft cleanup criteria for marine sediments demonstrated that none of the PAH compounds at the site exceeded the cleanup criteria. Therefore, it was concluded that these compounds might not require remediation.

Metal concentrations, however, did exceed draft cleanup criteria for marine sediments. Concentrations of copper, lead, and mercury were in this category, although none of these compounds was known to have been used at the site.

### 5.6.5 Risk Characterization

Available toxicological effect information for chemicals of concern is summarized in Table 5-10. Comparison of this information with the maximum chemical concentrations detected for offshore sediments (Table 5-9) suggested during the RA that adverse effects on some aquatic organisms were possible. (It must be noted, however, that a direct correlation between sediment and water concentrations was not meaningful, i.e., contaminants were sorbed to sediments and were not readily bioavailable.) This assumption was based on the results of existing studies indicating that contaminant concentrations in water causing adverse effects in several freshwater organisms were similar to those detected in sediment samples from the former Champion site.

As indicated previously, several factors were found at the site that would tend to limit potential exposure of aquatic organisms. These are summarized below:

- Due to the lack of penetrating light below existing buildings, aquatic plants are unable to survive. As a result, available dissolved oxygen is reduced, as are potential food sources. Therefore, organisms requiring significant oxygen and/or food are not likely to reside in areas below the buildings where contamination occurs.
- Most contaminants identified in offshore sediments have a strong tendency to sorb to organics. The sorbed organics are typically deposited on the lake floor. Therefore, their bioavailability is significantly reduced for several important aquatic organisms, such as salmon and steelhead trout.

The only compound present that could be positively attributed to the site was anthracene. The other compounds, and possibly some of the contribution of anthracene, were attributed to general urban runoff in the area. Comparison of existing site sediment data with draft marine sediment cleanup standards showed that PAHs, including anthracene, might not be of concern. However, several metals exceeded cleanup standards (although their sources did not appear to be associated with the site). It was noted that marine sediment standards were not directly applicable to freshwater sediments.

Available information, in light of the existing site conditions, suggested that adverse effects on aquatic organisms could result from the presence of chemical contaminants in the offshore sediments. However, considering the limited information available regarding the toxicity of freshwater sediments, it was not possible to accurately estimate potential impacts to aquatic biota.

## TABLE 5-1

## SUMMARY OF CONTAMINANT SCREENING

| Chemicals Detected | Maximum Concentration Detected | Results of Preliminary Screening, Including Reasons for Chemical Exclusion, If Applicable (1) |
|---|---|---|
| Solvent Tank Area | | |
| Acetone | 38 ug/kg | (2) |
| Alpha-penine | 0.47 mg/kg | Excluded; natural byproduct of wood degradation; limited toxicity information. |
| Bicyclo [3,1,1] hepta-2-ene-3,6,6-trimethyl | 0.18 mg/kg | Excluded; natural byproduct of wood degradation; limited toxicity information. |
| 2,6-Dimethyl-2-octene | 0.058 mg/kg | Excluded; natural byproduct of wood degradation; limited toxicity information. |
| Carbon disulfide | 4.60 mg/L | (2) |
| Chloroform | 0.42 mg/L | (2) |
| Arsenic | 0.010 mg/L | (2) |
| Barium | 0.060 mg/L | (2) |
| T. chromium | 0.013 mg/L | (2) |
| Copper | 0.046 mg/L | (2) |
| Iron | 10 mg/L | (2) |
| Lead | 0.032 mg/L | (2) |
| Manganese | 0.38 mg/L | (2) |
| Potassium | 7 mg/L | (2) |
| Sodium | 97 mg/L | (2) |
| Zinc | 0.25 mg/L | (2) |
| Boiler Ash Fill | | |
| Antimony | 6.9 mg/kg | (2) |
| Arsenic | 55 mg/kg | (2) |
| Barium | 740 mg/kg | Excluded; detected concentration falls within the range for natural soils. |
| Cadmium | 35 mg/kg | (2) |
| T. chromium | 39 mg/kg | Excluded; detected concentration is below the selected average for chromium in natural soils. |
| Copper | 600 mg/kg | (2) |
| Lead | 450 mg/kg | (2) |
| Mercury | .24 mg/kg | (2) |
| Nickel | .024 mg/kg | Excluded; detected concentration is below the selected average for nickel in natural soils. |
| Silver | 6 mg/kg | (2) |
| Zinc | 1,200 mg/kg | (2) |
| Glue Press Waste Area | | |
| Naphthalene | 2.3 mg/kg | Excluded; detected once out of ten samples at low concentrations. |
| 2-Methylnaphthalene | 16 mg/kg | Excluded; detected twice at low concentrations. |
| Anthracene | 770 mg/kg | (2) |
| Pyrene | 4.1 mg/kg | Excluded; detected once at low concentrations. |

## TABLE 5-1

## SUMMARY OF CONTAMINANT SCREENING

| Chemicals Detected | Maximum Concentration Detected | Results of Preliminary Screening, Including Reasons for Chemical Exclusion, If Applicable (1) |
|---|---|---|
| Glue Press Waste Area | | |
| Dibenzofuran | 30 mg/kg | Excluded; detected at this concentration is evaluated to pose a minimal threat to human health and the environment (K/J/C, 1987). |
| Aniline | 6.1 mg/kg | Excluded; detected once at low concentrations. |
| T. chromium | 290 mg/kg | Excluded; within the range found in natural soils. |
| Copper | 16 mg/kg | Excluded; within the range found in natural soils. |
| Lead | 68 mg/kg | Excluded; within the range found in natural soils. |
| Zinc | 83 mg/kg | Excluded; within the range found in natural soils. |
| Offshore Sediments | | |
| TPH | 250,000 mg/kg | Excluded; no toxicological data found in the literature search. |
| Acetone | 0.60 mg/kg | Excluded; most likely a natural degradation product of wood. |
| Phenanthrene | 7.4 mg/kg | (2) |
| Anthracene | 65 mg/kg | (2) |
| Fluoranthene | 7.4 mg/kg | (2) |
| Pyrene | 2.0 mg/kg | Excluded; maximum pyrene concentration detected is below AET value. |
| Benzo(a)anthracene | 2.7 mg/kg | (2) |
| Benzo(k)fluoranthene | 53 mg/kg | (2) |
| Antimony | 12 mg/kg | Excluded; maximum detected concentration is below AET value. |
| Arsenic | 67 mg/kg | Excluded; maximum detected concentration is slightly above AET value and within the background range found in Lake Union. |
| Beryllium | .17 mg/kg | Excluded; maximum detected concentration is below background average for Lake Union. |
| Cadmium | 3.8 mg/kg | Excluded; maximum concentration is below AET value. |
| T. Chromium | 190 mg/kg | Excluded; maximum concentration is below AET value. |
| Copper | 780 mg/kg | (2) |
| Lead | 1,200 mg/kg | (2) |
| Mercury | 3.7 mg/kg | (2) |
| Nickel | 67 mg/kg | Excluded; maximum concentration is below AET value. |
| Selenium | 2.2 mg/kg | Excluded; maximum concentration falls within background soil range. |
| Silver | 3 mg/kg | Excluded; maximum concentration is below AET value. |
| Zinc | 900 mg/kg | Excluded; maximum concentration is within background range found in Lake Union. |

Notes:

(1) Additional details for exclusion of certain chemicals can be found in Chapter 5.

(2) Included in the RA.

TABLE 5–2

## SUMMARY OF EXPOSURE POINT CONCENTRATIONS
## SOLVENT TANK AREA

| Chemical | Concentration (mg/L) |  | EPA | AWQC |  |
|---|---|---|---|---|---|
|  | Mean | Maximum | MCL (mg/L) | Acute (mg/L) | Chronic (mg/L) |
| Acetone (6) | 0.038 | 0.038 | NL (5) | NL | NL |
| Carbon disulfide | 3.75 | 4.60 | NL | NL | NL |
| Chloroform | 0.35 | 0.42 | 0.1 | 28.9 (1) | 1.24 (1) |
| Arsenic | 0.009 | 0.01 | 0.05 | 0.36 | 0.19 |
| Barium | 0.06 | 0.06 | 1.0 | NL | NL |
| T. chromium | 0.013 | 0.013 | 0.05[3] | 3.56 (2,3) | 0.424 (2,3) |
| Copper | 0.046 | 0.046 | 1.0(SMCL) (4) | 0.04 (2) | 0.025 (2) |
| Iron | 9.65 | 10.0 | 0.3(SMCL) | NL | 1 |
| Lead | 0.031 | 0.032 | 0.05 | 0.252 (2) | 0.0098 (2) |
| Manganese | 0.38 | 0.38 | 0.05(SMCL) | NL | NL |
| Potassium | 6.9 | 7.0 | NL | NL | NL |
| Sodium | 95 | 97 | NL | NL | NL |
| Zinc | 0.20 | 0.25 | 5.0(SMCL) | 0.246 (2) | 0.223 (2) |

Notes:

(1) Insufficient data to develop criteria. Value presented is lowest observed effect level.

(2) Calculated value based on water hardness of 240 mg/L.

(3) Based on chromium (III).

(4) SMCL denotes "Secondary Drinking Water Regulations, maximum contaminant level."

(5) NL denotes "not listed."

(6) Acetone only detected in soil (mg/kg).

## TABLE 5-3

## SUMMARY OF RISK CHARACTERIZATION CALCULATIONS
## SOLVENT TANK AREA

| Chemical | Expected Dose (1) (mg/kg-day) | | Hazard Index (1) | | Carcinogenic Risk (1) (Oral Administration) | |
|---|---|---|---|---|---|---|
| Solvent Tank Area | Mean | Maximum | Mean | Maximum | Mean | Maximum |
| Acetone | 4.8E-07 | 4.8E-07 | 4.8E-06 | 4.8E-06 | NA | NA |
| Arsenic | 1.1E-07 | 1.3E-07 | 1.1E-04 | 1.3E-04 | 1.6E-08 | 1.8E-08 |
| Barium | 7.5E-07 | 7.5E-07 | 1.5E-05 | 1.1E-05 | NA | NA |
| Carbon disulfide (3) | 4.7E-05 | 5.8E-05 | 4.7E-04 | 5.8E-04 | NA | NA |
| Chloroform (3) | 4.4E-06 | 5.3E-06 | 4.4E-04 | 5.3E-04 | 2.1E-09 | 2.6E-09 |
| T. chromium (4) | 1.6E-07 | 1.6E-07 | 1.6E-06 | 1.6E-06 | NA | NA |
| Copper | 5.8E-07 | 5.8E-07 | 1.6E-05 | 1.6E-05 | NA | NA |
| Iron | 1.2E-04 | 1.3E-04 | NA (2) | NA | NA | NA |
| Lead | 3.9E-07 | 4.0E-07 | NA | NA | NA | NA |
| Manganese | 4.8E-06 | 4.8E-06 | 1.4E-04 | 1.4E-04 | NA | NA |
| Potassium | 8.6E-05 | 8.8E-05 | NA | NA | NA | NA |
| Sodium | 1.2E-03 | 1.2E-03 | NA | NA | NA | NA |
| Zinc | 2.5E-06 | 3.1E-06 | 1.3E-05 | 1.6E-05 | NA | NA |
| Total | | | 1.2E-03 | 1.4E-03 | 1.8E-08 | 2.1E-08 |

Notes:

(1) See Section 5.2 for a discussion of calculations for expected dose, hazard index, and carcinogenic risk values.

(2) NA denotes "not applicable"; RfD or potency slope information is not available.

(3) Expected dose based on levels detected in soil.

(4) Total chromium as chromium (III).

(5) The mean and maximum expected doses for arsenic and chloroform carcinogenic risk using the Method B cleanup exposure model are 9.0E-9 and 1.0E-8 mg/kg-day and 3.5E-7 and 4.2E-7 mg/kg-day, respectively.

TABLE 5-4

SUMMARY OF RfD AND CANCER POTENCY SLOPE INFORMATION

| Chemical Detected | RfD (1,2,3,4,7) | | | | Cancer Potency Slope-Unit Risk (1,8) | |
|---|---|---|---|---|---|---|
| | Inhalation Exposure | | Oral Exposure | | | |
| Organic Compounds | Subchronic | Chronic | Subchronic | Chronic | Inhalation | Oral |
| Acetone | ND | ND | ND | 1E-1 | NR | NR |
| Aniline | NR | NR | NR | NR | NR | 5.7E-3 |
| Anthracene | NR | NR | NR | 3.0E-1 | NR | NR |
| Carbon Disulfide | NR | NR | NR | 1E-1(5) | NR | NR |
| Chloroform | ND | ND | 1E-2 | 1E-2 | 8.1E-2 | 6.1E-3 |
| Dibenzofuran | * | * | * | * | NR | NR |
| 2-Methylnaphthalene | NR | NR | NR | NR | NR | NR |
| Naphthalene | ND | ND | 4E-3 | 4E-3 | NR | NR |
| Pyrene | * | * | * | 3.0E-2 | NR | NR |
| Inorganics | | | | | | |
| Antimony | ND | ND | 4E-4 | 4E-4 | NR | NR |
| Arsenic | ND | ND | 1E-3 | 1E-3(6) | 5.0E+1 | 1.8(6) |
| Barium | 1E-3 | 1E-4 | 5E-2 | 7E-2 | NR | NR |
| Cadmium | ND | ND | ND | 5E-4 | 6.1E+0 | ND |
| Chromium III | ND | ND | 1E-1 | 1E+0 | NR | ND |
| Copper | ND | ND | ND | 3.7E-2(6) | NR | NR |
| Iron | * | * | * | * | NR | NR |
| Lead | ND | ND | ND | ND | ND | ND |
| Manganese | 3E-4 | 3E-4 | 5E-1 | 3.3E-2(6) | NR | NR |
| Mercury | ND | ND | 3E-4 | 3E-4(6) | NR | NR |
| Nickel | ND | ND | 2E-2 | 2E-2 | 8.4E-1 | ND |
| Potassium | NR | NR | NR | NR | NR | NR |
| Selenium | 1E-3 | 1E-3 | 3E-3 | 5E-3 | NR | NR |
| Silver | NR | NR | NR | 3.0E-3(6) | NR | NR |
| Sodium | NR | NR | NR | NR | NR | NR |
| Thallium | ND | ND | 7E-4 | 7E-5 | NR | NR |
| Zinc | ND | ND | 2E-1 | 2E-1(6) | NR | NR |

Notes:

(1) Information source is EPA, Health Effects Assessment "Summary Tables," fourth quarter 1989 and first quarter 1991.
(2) * denotes that data is inadequate for a quantitative risk assessment.
(3) NR denotes "data not reported."
(4) ND denotes "not determined."
(5) Oral RfD for chronic effects obtained from IRIS.
(6) Cancer potency slope for arsenic (oral consumption) obtained from WDOE, June 1991.
(7) Units are mg/kg-day.
(8) Units are kg-day/mg.

## TABLE 5-5

## SUMMARY OF EXPOSURE POINT CONCENTRATIONS
## BOILER ASH FILL

|  | Detected Concentration mg/kg |  | Background Levels (1) mg/kg |  |
|---|---|---|---|---|
| Chemical | Mean | Maximum | Soil Range | Selected Average |
| Antimony | 1.95 | 6.9 | NR (2) | NR |
| Arsenic | 23.26 | 55 | 1–50 | 5 |
| Barium | 506.7 | 740 | 100–3,000 | 430 |
| Cadmium | 3.35 | 35 | .01–.7 | .06 |
| T. chromium | 19.8 | 39 | 1–1,000 | 100 |
| Copper | 191.8 | 610 | 2–100 | 30 |
| Lead | 81.55 | 450 | 2–200 | 10 |
| Mercury | .068 | .24 | .01–.03 | .03 |
| Nickel | 15.04 | 24 | 5–500 | 40 |
| Silver | 1.36 | 6 | .01–5 | .05 |
| Zinc | 273.0 | 1,200 | 10–300 | 50 |

Notes:
(1) Soil ranges and selected averages based on "Chemical Equilibria in Soil" (Lindsay, 1979).
(2) NR denotes "value not reported."

## TABLE 5-6

## SUMMARY OF CONCLUSIONS FOR TRANSPORT AND FATE OF METALS

| Chemical | Is the Process Important for Aquatic Transport? (See Key Below) | | | Is the Process Important in Determining Aquatic Fate? (See Key Below) | | |
|---|---|---|---|---|---|---|
| | Volatilization | Sorption | Transport Downstream | Photolysis | Bioaccumulation | Biotransformation/ Biodegradation |
| Antimony | UNCT(2) | YES(2) | YES(2) | NO(3) | NO(2) | YES(3) |
| Arsenic | YES(1) | YES(1) | YES(1) | NO(3) | YES(2) | YES(1) |
| Cadmium | NO(2) | YES(1) | YES(1) | NO(3) | YES(1) | NO(3) |
| T. chromium | NO(3) | YES(1) | YES(2) | NO(3) | YES(1) | NO(3) |
| Copper | NO(3) | YES(1) | YES(1) | NO(2) | YES(1) | NO(3) |
| Lead | UNCT(1) | YES(1) | YES(1) | UNCT(1) | YES(1) | YES(1) |
| Mercury | YES(1) | YES(1) | YES(1) | YES(2) | YES(1) | YES(1) |
| Silver | NO(3) | YES(1) | YES(1) | NO(2) | UNCT(1) | NO(3) |
| Zinc | NO(3) | YES(1) | YES(1) | NO(3) | YES(1) | NO(3) |

Note: Table from "Water-Related Environmental Fate of 129 Priority Pollutants," prepared by the EPA, December 1979.

Key:

For each chemical and related process, two ratings are presented. The first is a statement of importance and can be one of the following: YES, NO, or UNCT (for uncertain). The second is a numerical rating, dealing with available supporting data, as explained below:

(1) There is environmental data available to support this conclusion.
(2) There is no direct conclusive environmental data; some laboratory data can be extrapolated to support conclusions.
(3) There is no supporting data available; evidence is drawn from theoretical calculations, estimates, results for similar chemicals, and inferences.

## TABLE 5-7

## SUMMARY OF RISK CHARACTERIZATION CALCULATIONS
## BOILER ASH FILL

| Chemical | Expected Dose (1) mg/kg-day | | Hazard Index | | Carcinogenic Risk (3) (Oral Administration) | |
|---|---|---|---|---|---|---|
| Boiler Ash Fill | Mean | Maximum | Mean | Maximum | Mean | Maximum |
| Antimony | 2.4E-05 | 8.6E-05 | 6.1E-02 | 2.2E-01 | NA | NA |
| Arsenic | 2.9E-04 | 6.9E-04 | 2.9E-01 | 6.9E-01 | 4.1E-05 | 9.9E-05 |
| Barium | 6.3E-03 | 9.3E-03 | 1.3E-01 | 1.9E-01 | NA | NA |
| Cadmium | 4.2E-05 | 4.4E-04 | 8.4E-02 | 8.8E-01 | NA | NA |
| Copper | 2.4E-03 | 7.6E-03 | 6.5E-02 | 2.1E-01 | NA | NA |
| Lead | 1.0E-03 | 5.6E-03 | NA (2) | NA | NA | NA |
| Mercury | 8.5E-07 | 3.0E-06 | 2.8E-03 | 1.0E-02 | NA | NA |
| Silver | 1.7E-05 | 7.5E-05 | 5.7E-03 | 2.5E-02 | NA | NA |
| Zinc | 3.4E-03 | 1.5E-02 | 1.7E-02 | 7.5E-02 | NA | NA |
| Totals | | | 6.5E-01 | 2.3E+00 | 4.1E-05 | 9.9E-05 |

Notes:

(1) See Section 5.2 for discussion of calculations for expected dose, hazard index, and carcinogenic risk.

(2) NA denotes "Not applicable"; RfD or potency slope information is not available.

(3) The mean and maximum expected doses for arsenic carcinogenic risk calculations using the Method B exposure model are 2.3E-5 and 5.5E-5 mg/kg-day, respectively.

## TABLE 5-8

## SUMMARY OF EXPOSURE POINT CONCENTRATIONS AND RISK CALCULATIONS GLUE PRESS WASTE AREA

| Chemical | Detected Concentration | |
|---|---|---|
| Organics (ug/kg) | Mean | Maximum |
| Naphthalene | 5,698 | 2,300 |
| 2-Methylnaphthalene | 9,129 | 16,000 |
| Anthracene (1)(2) | 109,243 | 770,000 |
| Pyrene | 6,325 | 4,100 |
| Dibenzofuran | 10,757 | 30,000 |
| Aniline | 7,342 | 6,100 |
| Inorganics (mg/kg) (3) | | |
| T. chromium | 174.5 | 290 |
| Copper | 9.8 | 16 |
| Lead | 36.95 | 68 |
| Zinc | 49.5 | 83 |

Notes:

(1) Anthracene is the only chemical detected consistently in the glue press waste area. The remaining chemicals were not evaluated in the RA.

(2) The mean and maximum expected dose for anthracene was calculated to be 1.4E-3 mg/kg-day and 9.6E-3 mg/kg-day, respectively. The mean and maximum hazard index was calculated to be 4.7E-3 and 3.2E-2, respectively.

(3) Only two samples from the glue press waste area (GP-5A, GP-5C) were analyzed for selected heavy metals.

## TABLE 5-9

## SUMMARY OF EXPOSURE POINT CONCENTRATIONS
## OFFSHORE SEDIMENTS

| Chemical | Offshore Sediment Results (1,5,11) | | Background | | | | Lake Union-Mean | Marine Sediment |
|---|---|---|---|---|---|---|---|---|
| Organics (ug/kg) | Mean | Maximum | Ship Canal-Mean (5) | Ship Canal-Max. (5) | Lake Union-Mean (6) | Lake Union-Max. (6) | Stormwater Sediments | Criteria (AET) (2) |
| TPH | 75,329,000 | 250,000,000 | 1,516,000 | 3,080,000 | NR (9) | NR | NR | NR |
| Acetone | 130 | 600 | 29 | 39 | NR | NR | NR | NR |
| Phenanthrene | 8,415 | 7,400 | 460 | 1,400 | NR | NR | NR | 1,500 |
| Anthracene | 14,310 | 65,000 | ND(10) | ND | NR | NR | NR | 960 |
| Fluoranthene | 8,664 | 7,400 | 431 | 1,000 | NR | NR | NR | 1,700 |
| Pyrene | 8,014 | 2,000 | 637 | 1,900 | NR | NR | NR | 2,600 |
| Benzo(a)anthracene | 8,016 | 2,700 | 216 | 500 | NR | NR | NR | 1,300 |
| Benzo(k)fluoranthene | 11,450 | 53,000 | 1,277 | 7,900 | NR | NR | NR | 3,200 (8) |
| Total LPAHs (3) | 22,725 | 72,000 | 1,039 | 3,180 | 3.8 (7) | NR | NR | 5,200 |
| Total HPAHs (4) | 36,189 | 65,100 | 3,457 | 14,490 | 5,849 (7) | NR | NR | 12,000 |
| Inorganics (mg/kg) | | | | | | | | |
| Antimony | 3.378 | 12 | 1.003 | 1.1 | NR | NR | NR | 150 |
| Arsenic | 30.375 | 67 | 10.533 | 13 | 41.287 | 247 | 207 | 57 |
| Beryllium | .0881 | .17 | .23 | .28 | NR | NR | 2 | NR |
| Cadmium | 2.212 | 3.800 | .583 | .83 | .906 | 1.3 | 8.2 | 5.1 |
| T. Chromium | 66.5 | 190 | 47 | 50 | 20.149 | 57.2 | 96 | 260 |
| Copper | 293 | 780 | 93.333 | 120 | 93.326 | 471 | 358 | 390 |
| Lead | 480 | 1,200 | 99.333 | 150 | 201.584 | 634 | 1,052 | 450 |
| Mercury | 1.269 | 3.7 | .806 | 1.3 | NR | NR | .710 | .41 |
| Nickel | 37.875 | 67 | 54.333 | 57 | 20.694 | 54 | 193 | 140 |
| Selenium | 1.309 | 2.2 | ND | ND | NR | NR | 1.4 | NR |
| Silver | .95 | 3 | .17 | .28 | .754 | 2.2 | 2.7 | 5.9 |
| Zinc | 515 | 900 | 96.853 | 180 | 237.933 | 1,107 | 1,763 | 410 |

Notes:

(1) Offshore sediment results are for samples collected below former Champion site buildings, February, 1990. Only chemicals detected are listed. Means sometimes exceed maximums when detection limits are high, due to use of one-half the detection limits to calculate means.

(2) AETs based on criteria developed by WDOE, August, 1988.

(3) LPAHs include naphthalene, acenaphthene, fluorene, and phenanthrene.

(4) HPAHs include fluoranthene, pyrene, chrysene, benzo(a)anthracene, benzo(k)fluoranthene, benzo(b)fluoranthene, and benzo(a)anthracene.

(5) Sediment samples collected by Jay Spearman, February, 1990.

(6) Lake Union sediment sample results based on a report prepared by the City of Seattle, June, 1986. Mean and maximum values based on report by Galvin, et al., 1984, and South Lake Union Pilot Project Report, 1986.

(7) Based on report by Galvin, et al., 1984.

(8) AETs based on sum of all benzo-fluoranthenes.

(9) NR denotes "not reported."

(10) ND denotes "not detected."

(11) See Table 5-1 for chemicals excluded from evaluation during the RA and the reasons for exclusion.

# TABLE 5-10

# SUMMARY OF AVAILABLE TOXICITY INFORMATION FOR FRESHWATER ORGANISMS

| Compounds, Organisms, and Other Variables | Concentration in Medium (ug/L) | Effect [1] | Reference [2] |
|---|---|---|---|
| Benzo(a)anthracene: | | | |
| • Bluegill, *Lepomis macrochirus* | 1,000 | LC-87 (6m) | U.S. EPA, 1980 |
| Benzo(a)pyrene: | | | |
| • Sandworm, *Neanthes arenceodentata* | >1,000 | LC-50 (96h) | Neff, 1979 |
| Fluoranthene: | | | |
| • Sandworm | 500 | LC-50 (96h) | Neff, 1979 |
| Phenanthrene: | | | |
| • Grass Shrimp | 370 | LC-50 (24h) | U.S. EPA, 1980 |
| • Sandworm | 600 | LC-50 (96h) | |
| Copper: | | | |
| • Worm, *Nais sp.* | 1,700 | LC-50 | Rehwoldt, et al., 1973 |
| • Cladeoceran, *Daphnia magna* | 6.5 | LC-50 | Cabejszek and Stasiak, 1960 |
| • Sockeye Salmon (Smolt), *Oncorhynchus nerka* | 240 | LC-50 | Davis and Shand, 1978 |
| • Cutthroat Trout, *Salmo clark* | 367 | LC-50 | Chakoumokes, et al., 1979 |
| • Bluegill, *Lepomis macrochirus* | 10,200 | LC-50 | Pickering and Henderson, 1966 |

# TABLE 5-10

## SUMMARY OF AVAILABLE TOXICITY INFORMATION FOR FRESHWATER ORGANISMS

| Compounds, Organisms, and Other Variables | Concentration in Medium (ug/L) | Effect $^{(1)}$ | Reference $^{(2)}$ |
|---|---|---|---|
| Lead: | | | |
| • Cladeoceran, *Daphnia magna* | 1,950 | LC-50 | Chapman, et al., manuscripts |
| • Rainbow Trout, *Salmo gairderi* | 471,000 | LC-50 | Geotti, et al., 1972 |
| • Fathead Minnow, *Pimephales promelas* | 482,000 | LC-50 | Pickering and Henderson, 1966 |
| Mercury: | | | |
| • Worm, *Nais sp.* | 1,000 | LC-50 | Rehwoldt, et al., 1973 |
| • Cladeoceran, *Daphnia magna* | 3.2 | LC-50 | Canton and Anderson, 1978 |
| • Rainbow Trout, *Salmo gairderi* | 420 | LC-50 | Daoust, 1981 |
| • Fathead Minnow, *Pimephales promelas* | 150 | LC-50 | Call, et al., 1983 |

Notes:

Table from U.S. FWS Contaminant Hazard Review (U.S. FWS, 1987).

(1) m = months, d = days, h = hours.
(2) Each reference applies to data in the same row and in the rows immediately following for which no other reference is indicated.

# TABLE 5-11

## COMPARISON OF SEDIMENT CONCENTRATIONS WITH AVAILABLE CRITERIA AND STANDARDS

| | Maximum Detected Conc. | TOC Normal Conc. ppm(1) | Marine Sediment Cleanup Criteria ppm(2) | Marine Sediment Standard ppm(3) |
|---|---|---|---|---|
| Phenanthrene | 7.4 | 37 | 480 | 100 |
| Anthracene | 6.5 | 325 | 1,200 | 220 |
| Fluoranthene | 7.4 | 37 | 1,200 | 160 |
| Benzo(a)anthracene | 2.7 | 13.5 | 270 | 110 |
| Benzo(k)fluoranthene | 53.0 | 265 | 450 | 230 |
| Pyrene | 2.0 | 10 | 1,400 | 1,000 |
| Total LPAH | 72.0 | 360 | 780 | 370 |
| Total HPAH | 65.1 | 326 | 5,300 | 960 |
| Arsenic | 67 | --- | 93 | 57 |
| Cadmium | 3.8 | --- | 6.7 | 5.1 |
| Chromium | 190 | --- | 270 | 260 |
| Copper | 780 | --- | 390 | 390 |
| Lead | 1,200 | --- | 530 | 450 |
| Mercury | 3.7 | --- | 0.59 | 0.41 |
| Silver | 3.0 | --- | 6.1 | 6.1 |
| Zinc | 900 | --- | 960 | 410 |

(1) TOC normalized concentration calculated in accordance with WAC 173-204-320.
(2) Proposed marine sediment cleanup levels for Puget Sound, WAC 173-204-520 public review draft dated 29 June 1990.
(3) Proposed marine sediment quality standards, WAC 173-204-320 public review draft dated 29 June 1990.

# 6.0 FEASIBILITY STUDY

## 6.1 PURPOSE AND ORGANIZATION

The feasibility study (FS) developed and evaluated remedial alternatives to effectively eliminate or minimize sources of contamination and their effects at the former Champion site. This FS report follows the format outlined in the Model Toxics Control Act Cleanup Regulations (WAC 173-340) and in Guidance for Conducting Remedial Investigations and Feasibility Studies Under CERCLA (Interim Final) (U.S. EPA, 1988). It incorporates available guidance information from the Model Toxics Control Act (MTCA) (WAC 173-340-350). As indicated in Chapter 1.0, it is the third part of a comprehensive report on conditions at the site. The FS report does not stand alone but is designed to be used in conjunction with the RI reports (Chapters 3.0 and 4.0) and the RA report in Chapter 5.0.

The remainder of this section briefly describes the site and characterizes the nature and extent of contamination found during the RI. It continues with a summary of the results of the RA. Section 6.2 outlines remedial action objectives and describes the development of general response actions. It also specifies technologies potentially suitable for remediating site problems that pose human health and environmental risks. Also discussed is the preliminary screening process used to narrow the list of technologies to those most likely to apply to the site.

Section 6.3 provides a detailed description of each remedial alternative and gives a preliminary indication of the expected benefits of the alternatives.

Section 6.4 provides an evaluation of each alternative relative to established criteria. Alternatives were assessed for their overall protection of human health and the environment; short-term effectiveness; long-term effectiveness; compliance with applicable laws; reduction of contaminant mobility, toxicity, or volume; implementability; cost; community acceptance; degree of recycling, reuse, and waste minimization. The last part of Section 6.4 presents the results of comparison of the final alternatives with each evaluation criterion and identifies the preferred alternative for each operable unit.

### 6.1.1 Background

As discussed in Chapter 2.0 of this report, the former Champion site has been used for the manufacture of plywood for over 75 years. Residual contamination and debris resulting from past activities are found at many site locations. During the RI, conducted by Parametrix and K/J from 1985 through 1990, five areas of concern (operable units) were identified. These areas are briefly described below.

6.1.1.1 Solvent Tank Area. The solvent tank area includes an area approximately 150 by 150 feet in the southwest corner of the site. Items of concern in this area include a former PCP storage area and two former underground tanks. During the preliminary RI, the extent of PCP contamination was identified, and the affected soils were removed and disposed of offsite at a permitted landfill. One of the underground tanks was determined to have contained gasoline. At the time of identification, this tank was partially abandoned in place, and it did not appear to present a concern. Subsequent sampling in the vicinity of the tank has verified that petroleum hydrocarbons do not occur in the area.

The other underground tank was found to contain waste solvents, including carbon disulfide, carbon tetrachloride, chloroform, and tetrachloroethylene. Recent sampling of wells near the excavation areas indicates limited contamination. Chemicals of concern do not appear to have migrated far from their original source. Furthermore, analytical results of sampling indicate that contaminant concentrations have decreased by nearly an order of magnitude since they were first detected in 1987. Recent groundwater sampling results indicate that carbon tetrachloride and tetrachloroethylene concentrations are below detectable levels. Table 6-1 provides mean and maximum concentrations detected during the most recent sampling in the solvent tank area.

6.1.1.2 Boiler Ash Fill. The boiler ash fill was identified during the preliminary RI as a potential source of PAH compounds, high pH, and detectable metal concentrations. Subsurface drilling activities indicated that the boiler ash fill covers an area of approximately 250 by 70 feet.

The supplemental RI (summarized in Chapters 3.0 and 4.0) found PAH compounds to be below detectable levels and soil pH to be only slightly elevated (8.7, with 7.0 being neutral). Metal concentrations detected were frequently within the range expected for natural soils. Analysis of four samples for TPH indicated a maximum level of 4.0 mg/kg (as diesel). Table 6-1 provides a summary of mean and maximum concentrations of contaminants detected in the boiler ash fill that were evaluated in the RA.

6.1.1.3 Glue Press Area. It was found in the RI that the glue press area of the former plywood mill utilized urea-formaldehyde, phenolic, and aliphatic resins. Waste wood and glue materials produced from the glue presses were routed to unlined areas below the building floor. There, a total of six glue piles, consisting of excess glue and wood chips, had accumulated on the sediments beneath two existing buildings.

Sampling of the glue piles and surrounding sediments indicated the presence of anthracene at levels up to 770 mg/kg. Analysis results indicated that anthracene migration was limited to within approximately 10 feet of the glue piles. The lack of lateral migration was believed to be a function of the very low aqueous solubility of anthracene. The chemically impacted area covers an area of approximately 150 by 180 feet.

6.1.1.4 Methane Production Areas. Past activities at the former plywood mill included filling with wood chips and other wood debris. Investigations have indicated the presence of waste wood products in the subsurface soils at most site locations. Methane concentrations detected during subsurface drilling activities were measured at levels of at least 5 percent by volume. Further monitoring of the methane levels slightly above the borehole indicated that methane levels dissipated to below detectable levels at ambient conditions.

6.1.1.5 Offshore Sediments. Sampling of offshore sediment areas around site buildings indicated the presence of PAHs, TPH (as diesel), and metals. Sediments were sampled during two phases, in areas below existing buildings, in the DNR lease area, and in the Lake Washington Ship Canal. Ship Canal sediment samples were collected for comparison purposes in identifying background concentrations. An evaluation of sample results indicated that areas below existing buildings had concentrations of PAHs, TPH, and metals above those detected in the Ship Canal (background). Samples collected in the DNR lease area showed low or nondetectable concentrations indicative of background conditions in the Ship Canal and surrounding areas.

It remains unclear whether or not chemical concentrations detected in offshore sediments represent contamination from activities performed at the site. Many of the detected contaminants could have resulted from chemical loading through stormwater runoff in local urban and industrial areas. Because of ship traffic, the Lake Washington Ship Canal was identified as a potential source of petroleum hydrocarbons. Table 6-1 provides a summary of mean and maximum concentrations of contaminants detected in offshore sediments beneath onsite buildings and evaluated during the RA.

Results of RI sampling activities are detailed in Chapters 3.0 and 4.0. Chapter 4.0 gives an in-depth discussion of remedial activities already performed at the site to mitigate the effects of chemical contamination. These remedial activities included the following:

- Excavation of soil contaminated with PCP and offsite disposal at a permitted facility.
- Removal of two underground tanks and disposal (at a permitted facility) of contaminated material found inside the tanks and in surrounding soils.
- Extraction of groundwater from the solvent tank area and disposal at a permitted facility.
- Characterization and disposal of containerized waste at the site (currently in progress).

### 6.1.2 RA Summary

As part of the RI/RA/FS, possible risks to human health and the environment from contaminants at the site were assessed (as reported in Chapter 5.0). This subsection summarizes the results of the RA, which assessed potential risks associated with each operable unit. Assessments were in accordance with current EPA guidance and the MTCA (WDOE, 1991).

During the RA, potential human health risks for each operable unit were assessed in accordance with current EPA and WDOE guidance. Human health risks relative to the residential exposure model were assessed using current EPA RfD and cancer potency slope (SF) values. When RfDs or SFs were not available for a certain chemical, available current literature was reviewed for a qualitative assessment of potential risks. Potential adverse effects on aquatic organisms were determined by use of the following information:

- U.S. EPA Ambient Water Quality Criteria (AWQC)
- U.S. EPA ecological profile documents
- U.S. FWS contaminant hazard reviews
- Site-specific bioassay information.

Because of the lack of toxicity data for freshwater sediments, the RA did not establish the magnitude of risk, if any, posed by the offshore sediments to aquatic organisms. In the absence of established or applicable criteria for evaluating potential effects on these organisms, the RA used AETs as comparison values. It was understood that these apparent effects threshold values (AETs) had been developed for use with marine sediments in the Puget Sound area and were not directly relevant to freshwater sediments. However, they did represent an available means by which freshwater sediments could be evaluated.

When chemical concentrations were detected infrequently or at concentrations representative of background conditions, the chemical involved was eliminated from further evaluation. A summary of chemicals detected at the site and results of the screening are presented in Chapter 5.0 (Table 5-1). An overview of RA results, by operable unit, is provided in the subsections below.

6.1.2.1 Solvent Tank Area. A list of chemicals evaluated for the solvent tank area is presented in Table 6-1. Potential human health risks for chronic and subchronic effects, and for possible carcinogenic effects, are summarized in Table 5-3 (Chapter 5.0). These risk values are based on potential exposure through accidental contact or inadvertent ingestion. Risks based on oral consumption of groundwater and inhalation were evaluated to be unlikely during performance of the risk assessment (refer to Section 5.2.3). As shown, the total hazard index for chronic and subchronic effects is well below the value at which adverse human health effects might be expected. Only two potential carcinogens, chloroform and arsenic, were evaluated in the RA. The total carcinogenic risk, based on maximum concentrations of these chemicals, was less than one in one million, below the acceptable risk level under MTCA (WAC 173-340-740).

AWQC were used in the RA to evaluate potential adverse effects to Ship Canal aquatic organisms that can be exposed to chemicals in the solvent tank area. Maximum chemical concentrations for copper and zinc, detected in well MW-1, were 12 percent and 2 percent, respectively, higher than the corresponding acute AWQC. These results were combined with results of previous bioassay testing of water from MW-1, in which there was a 100 percent survival rate. The combined result indicated that the chemically impacted shallow groundwater, at the concentrations used, did not have acute effects on tested species of aquatic organisms.

✓

For the solvent tank area, solvent concentrations in groundwater were found to have decreased significantly over the two years since they were originally detected. An estimate of groundwater flow rate indicated that the water might require ten years or more to reach the Ship Canal. During this time, chemical concentrations were expected to decrease further through volatilization, sorption, and dispersion. Any low levels of chemicals of concern reaching the Ship Canal were expected to dilute immediately, possibly to nondetectable levels.

Based on the results of the RA for the solvent tank area, it appeared that potential risk to human health was well below cleanup standards (Method B) under MTCA, as established by the WDOE. Because potential human health effects appeared very low, and potential adverse effects on aquatic organisms in the Ship Canal were unlikely, the RA suggested that the solvent tank area represented no unacceptable human health or environmental risks. Therefore, this area was not selected for further consideration during the FS, with the understanding that long-term groundwater monitoring would be performed to identify changing site conditions (this is further discussed for the preferred alternative in Subsection 6.4.4). ✓

6.1.2.2 Boiler Ash Fill. Inadvertent ingestion and dermal absorption by workers were identified as the existing potential human exposure routes at the site. Inhalation by construction workers was not considered a plausible exposure route because the boiler ash is covered with 3 feet of clean fill and occurs in saturated soil conditions. Furthermore, because potential exposure would occur over a very short duration (several hours at most), existing risk equations in MTCA, which assess risk over a 30 year period, are not appropriate. It was found that chemicals of concern in the boiler ash fill were limited to heavy metals (specifically antimony, arsenic, cadmium, copper, lead, mercury, silver, and zinc). Areas within the boiler ash that previously were found to contain TPH were removed from the site during dredging operations and construction of a new wharf at the site.

Table 5-7 (Chapter 5.0) provides hazard index calculations, based on the maximum detected concentrations, for possible chronic and subchronic risks and potential carcinogenic risks. These calculations indicated that subchronic and chronic human health risks, based on maximum detected concentrations, were above acceptable levels and might require cleanup consideration according to WDOE guidance. Potential carcinogenic risk of $9.9 \times 10^{-5}$ (9.9E-5) for exposure to arsenic at the maximum concentration detected also exceeded acceptable risk levels ($1 \times 10^{-6}$), based on the MTCA cleanup regulations. However, when WDOE formulas for assessing cancer and noncancer risks at industrial sites were utilized, the maximum chemical concentrations detected onsite did not represent an unacceptable risk. Therefore, the boiler ash would require no action, if the cleanup included institutional controls requiring site use consistent with the industrial scenario.

6.1.2.3 Glue Press Area. Table 6-1 provides the mean and maximum anthracene concentrations detected in glue press waste. During the RI, several other chemicals were detected in these sediments, including PAHs, dibenzofuran, and heavy metals. All chemicals except anthracene were detected infrequently and at relatively low concentrations. As a result of this data, these chemicals were eliminated from further evaluation. Calculation of non-carcinogenic risks for anthracene using the maximum detected concentration of 770 mg/kg resulted in a hazard index of $3.2 \times 10^{-2}$ (3.2E-2). From a review of available EPA human health information, it was found that anthracene was considered a Group D chemical (not classified as a carcinogen). As a result, adverse human health effects are not expected at the maximum concentration detected.

During the RA, available information suggested that, in the absence of other PAHs, anthracene had little effect on aquatic organisms. The RA found anthracene toxicity to increase with exposure to sunlight. However, in the absence of solar radiation, the compound was nontoxic within solubility limits. Although available toxicological information did not indicate an unacceptable risk, the glue press area was analyzed further during the FS.

6.1.2.4 Methane Production Areas. As discussed in Subsection 6.1.1, methane-producing soils occur throughout the site. During subsurface drilling activities for the RI, methane concentrations of at least 5 percent by volume were measured. Methane levels were also observed to decrease to below detectable levels at ambient conditions. Since methane is not a toxic substance, the only potential adverse effects were evaluated to be the formation of explosive environments and human asphyxiation. Given the open and exposed condition of the site, it was evaluated in the RA that methane accumulation was unlikely. Nevertheless, methane controls were considered in the FS to address future development considerations.

6.1.2.5 Offshore Sediments. Given the industrial setting of the site, and due to the fact that the Seattle Department of Parks and Recreation discourages swimming and wading in the Ship Canal, populations with the potential for exposure to

Table 6-1 provides a summary of chemicals evaluated as part of the RA, along with the mean and maximum concentrations at which they were detected. Chemicals of concern primarily included PAHs and metals, although TPH (as diesel) was also detected at a maximum concentration of 2,000 mg/kg. As discussed earlier in this document, TPH readings detected in sediment samples were most likely exaggerated, because of the high amount of moisture and volatile solids in the samples and the method used for quantification. See Subsection 3.4.6.2 in Chapter 3.0 for further details.

In the absence of freshwater sediment criteria from which to evaluate these chemical concentrations, a qualitative risk assessment was performed during the RA. The results suggested that chemical concentrations occurred at levels that might induce adverse effects in aquatic organisms, although it was unlikely. The potential for such effects was determined to be significantly reduced by the factors identified below:

- Due to the lack of light penetrating below existing buildings, aquatic plants were unable to survive. As a result, available dissolved oxygen was reduced, as were potential food sources. Therefore, organisms requiring significant oxygen and/or food most likely did not reside in areas below site buildings.

- Most contaminants identified in offshore sediments had a strong tendency to sorb to organics. Sorbed organics are typically deposited on the lake floor. As a result, their bioavailability was found to be significantly reduced for several important aquatic organisms, such as salmon and steelhead trout.

- The toxicity of anthracene, and presumably other PAH compounds, was less when they were sorbed to organics than when they occurred in a dissolved state (U.S. EPA, 1987).

Therefore, based on available information, the RA concluded that there was limited potential for adverse effects on aquatic organisms, especially those with possible commercial value (including four salmon species). Metal concentrations in sediments were elevated relative to background concentrations and available comparison criteria. Therefore, possible remediation for PAHs and metals of the offshore sediments was evaluated in the FS.

6.1.2.6 Fate and Mobility of Detected Contaminants. The fate and mobility of detected contaminants are discussed in detail in the RA report in Chapter 5.0.

## 6.2 IDENTIFICATION AND SCREENING OF TECHNOLOGIES

This section describes the FS evaluation of remedial actions appropriate for the site. Objectives for protecting human health and the environment are identified.

Following this is a discussion of general response actions, which are steps that might be taken to achieve these objectives. General response actions include identification and screening of technologies and process options, and their evaluation against implementability and cost.

### 6.2.1 Identification of Remedial Action Objectives

To achieve a suitable level of safety, remedial action objectives were identified to guide the selection of general response actions. From these actions, technologies were chosen to diminish the effects or eliminate site contamination. Remedial action objectives:

- Specify type and level of contamination
- Describe exposure routes and receptors
- Aid development of acceptable contaminant levels for each exposure route, based on the RA and on applicable laws
- Express remediation in terms of the medium of interest and proposed target cleanup levels.

Remedial action objectives for the site are described in the following paragraphs.

6.2.1.1 Potential Waste Material. Potential waste material at the site included boiler ash, glue waste, wood waste, soil, miscellaneous material, underlying natural soil, groundwater, and offshore sediments.

6.2.1.1.1 Exposure Routes and Human Receptors. The RA identified potential exposure routes, based on physical conditions of the site, contaminated media, and chemicals of concern at each operable unit (refer to Chapter 5.0). Potential exposure routes, based on current land use, included:

| Operable Unit | Potential Exposure Route |
|---|---|
| Solvent Tank Area | 1. Inadvertent dermal absorption and ingestion by site workers.<br>2. Ingestion and absorption by aquatic organisms. |
| Boiler Ash Fill | Inadvertent dermal absorption and ingestion by site workers. |
| Glue Press Area | 1. Inadvertent dermal absorption and ingestion by site workers.<br>2. Ingestion and absorption by aquatic organisms. |
| Methane Production Areas | Asphyxiation/explosion hazard. |
| Offshore Sediments | Ingestion and absorption by aquatic organisms. |

6.2.1.1.2 Applicable Laws and Other Comparison Criteria. Criteria to protect human health evaluated in the RA included EPA MCLs and MTCA cleanup standards (WDOE, 1991). MCLs are inapplicable for use at the site, since impacted shallow fill groundwater could not be used as a drinking water source and the next lower-lying aquifer zone, which had the potential for use as a potable water source, was apparently unaffected. Therefore, the WDOE cleanup standards for soil and groundwater were used to evaluate chemical concentrations at the site (refer to Chapter 5.0).

Criteria used to evaluate potential impacts to aquatic organisms included AETs and AWQC. Although not directly relevant to groundwater or fresh water sediments, these criteria were used for comparison purposes to assess ambient water quality and sediment quality in the Ship Canal. Appendix G provides a list of all laws considered in defining applicable laws during the FS.

6.2.1.2 Remedial Action Cleanup Goals. The FS developed remedial action cleanup goals according to results of the RA and applicable laws to present acceptable cleanup levels for each exposure route. The target goals are presented in Table 6-2. Rationales behind development of the goals are discussed below, by operable unit.

6.2.1.2.1 Solvent Tank Area. From the RA results, it was determined that maximum chemical levels detected in the solvent tank area did not pose an unacceptable human health risk relative to existing WDOE guidance. According to bioassay studies using site groundwater, adverse effects on higher class aquatic organisms appeared unlikely. Therefore, chemical levels in the solvent tank area groundwater did not appear to warrant further evaluation in the FS.

6.2.1.2.2 Boiler Ash Fill. It was determined in the RA that maximum chemical levels detected in the boiler ash fill might represent an unacceptable human health risk under the Method B cleanup scenario for a residential site. However, contaminants in the boiler ash represented an acceptable risk under an industrial use scenario. The FS addressed options that might reduce or eliminate potential routes of exposure of current and future populations at this location.

6.2.1.2.3 Glue Press Area. Because anthracene is relatively non-toxic to aquatic organisms in the absence of other PAHs and because freshwater sediment criteria have not been developed, the target cleanup levels for the anthracene occurring in the glue press area is based on the Method B soil cleanup equation presented in MTCA (WAC 173-340-740). Evaluation of chemical levels in the glue press area indicate that adverse human health effects are not expected. However, the glue press area was evaluated further to identify an alternative that would effectively mitigate potential ecological effects.

6.2.1.2.4 Methane Production Areas. Since methane levels in methane production areas did not present threats to human health from a toxicity perspective, development of a cleanup level for these areas was not warranted. However, future improvements of the site might create conditions that cause methane to accumulate. Engineering controls that prevent methane accumulation should be evaluated in the event of future site development. Such controls are discussed later in this chapter.

6.2.1.2.5 Offshore Sediments. Established cleanup criteria, developed for use with freshwater sediments, were not available for use during the FS. Therefore, area background levels established as part of the Lake Union study by the City of Seattle (City of Seattle, 1986), or Ship Canal samples collected during the FS, were used to develop target cleanup levels for offshore sediments. Background concentrations, while not necessarily representing "clean" sediments, do provide information regarding nearby and ongoing pollutant loadings unrelated to a site. When background chemical concentrations were unavailable for reference, as in the case of PAHs, AETs were used for comparison. Information on background chemical levels for Lake Union and AETs is presented in Table 5-9 of Chapter 5.0.

### 6.2.2 Screening of General Response Actions

After developing remedial action cleanup goals, the FS identified the activities that satisfy them. These activities, termed general response actions, are broad categories of methods applicable to the cleanup of specific media. Examples of general response actions for soil remediation include containment, treatment, excavation, disposal, institutional controls (as defined by WAC 173-304-440), and water and land use restrictions.

6.2.2.1 Identification and Screening of Technologies and Process Options. Remedial action objectives and general response actions were key factors in determining technologies and process options applicable to the site. After defining the broad categories of site cleanup actions, the FS identified technologies and process options and evaluated their technical implementability.

Technologies are general classes of remedial measures, such as extraction, solidification, and capping. Process options are specific means within each technology class. The FS evaluated general response actions, technologies, and process options for their ability to effectively address contamination at the site. Technical screening was used to eliminate technologies and process options that were not applicable. Table 6-3 presents screening results and lists general response actions, technology groups, and process options, along with brief descriptions. The table column entitled "Determination of Applicability" provides a rationale for each process option. The process options and technologies designated "not applicable" (NA) were eliminated from further consideration in the FS.

6.2.2.2 Evaluation of Technologies and Selection of Representative Technologies. After the initial screening process, remaining technology groups and process options were evaluated to select one option to represent each group. Selecting only one process option simplified the development of remedial alternatives, described in Section 6.4 of this report. The selection of more than one process was considered throughout the evaluation process, especially if the difference in performance or effectiveness among process options was significant. However, a process option was eliminated if it was not applicable to existing site conditions.

Effectiveness, implementability, and cost were the three criteria used to rate process options during this phase of the FS evaluation. Primary emphasis was given to effectiveness, with implementability and cost playing lesser roles. Effectiveness concerns the relative value of a process option, compared to other options of the same technology type. An effective process option should:

- Address estimated contaminated area or volume
- Meet contaminant reduction goals
- Protect human health and the environment during the construction and implementation phase
- Demonstrate reasonable probability for successful handling of wastes under consideration.

The second evaluation criterion, implementability, includes the technical ability of a process option to be implemented and its ability to fulfill institutional requirements, such as obtaining permits. The FS further screened options for institutional implementability, in addition to the initial screening described in Subsection 6.2.2.1.

The final screening criterion, cost, played a lesser role during this phase of the FS. Costs of process options for the FS were based on engineering judgments instead of detailed estimates, and were ranked as high, medium, and low, relative to process options, technologies, and general response actions. Process options judged similar in effectiveness and implementability, yet costing several times more than other options, were eliminated from further consideration during this phase of the FS.

Table 6-4 examines the remaining process options on the basis of effectiveness, implementability, and cost. Based on these three criteria, judgments were made about further examination of each option. The process options determined to be most promising were developed into remedial alternatives as described in Section 6.3 below.

## 6.3 DEVELOPMENT OF ALTERNATIVES

This section describes the development of alternatives for each operable unit. Process options were first assembled and refined by quantifying areas or volumes scheduled for consideration. Detailed information about process options was then obtained to more thoroughly define them. These process options became the final alternatives that have been subjected to detailed analysis (refer to Section 6.4).

### 6.3.1 Remedial Alternative Description

Remedial alternatives for each operable unit are presented below. Alternatives to address methane production and no action were deemed applicable to the entire site and are therefore presented separately. Each of the alternatives are discussed with respect to the quantity of contaminated material involved, details of treatment technologies, descriptions of interactions among media, degree of protectiveness and remedial timeframes. Descriptions of the remedial alternatives are presented in the following paragraphs, in terms of the entire site first and then each operable unit.

#### 6.3.1.1 Entire Site

6.3.1.1.1 Remedial Alternative ES-1 - No Action. WAC 173-340 requires a no action alternative for the FS, under which no protective activities occur. Ongoing monitoring is included in Remedial Alternative ES-1, with sampling and analysis of groundwater in the solvent tank area and sediments in the glue press area and the offshore sediments every five years. This alternative also includes periodic review of the site every five years in accordance with WAC 173-340-420. Periodic review will facilitate re-assessment of conditions at the glue press area and offshore sediments to identify the need for future remedial action with the development of freshwater sediment criteria.

Expected Benefits. Remedial Alternative ES-1 does not mitigate possible methane accumulation in confined spaces of the site or establish controls that prevent accumulation given current site conditions. Remedial Alternative ES-1 has no effect on limiting potential exposure of humans or aquatic organisms in the boiler ash fill and glue press area or in offsite sediments. However, the glue piles and offshore sediments are generally inaccessible to humans. Therefore, potential adverse human health effects resulting from exposure to chemicals in these areas are probably unlikely. Furthermore, maximum concentrations of anthracene detected at the site do not represent an unacceptable human health risk based on available information. No action does not address chemicals of concern that occur in offshore sediments. However, continued contaminant loading from urban runoff limits the effectiveness of any remedial action in this area. Long-term monitoring and periodic review of the site every five years will help assess changes in site conditions that may warrant future remedial action.

6.3.1.1.2 Remedial Alternative ES-2 - Land and Water Use Restrictions. Remedial Alternative ES-2 includes the same activities provided by Remedial Alternative ES-1 but also adds land and water use restrictions. Land and water use restrictions include prohibiting use of site groundwater as a drinking water source and assuring that remedial solutions instituted at the site are not compromised. "No Trespassing" notices are also provided and recreational activities are prohibited at the site. In addition, ongoing monitoring is included in this alternative with sampling and analysis of the solvent tank area and periodic review of the site areas every five years in accordance with WAC-173-340-420 . This alternative also includes assurances that future development will not create conditions that may allow methane to pose an explosion or asphyxiation hazard. Evaluation of future steps that might be necessary to reduce potential problems associated with methane accumulation in the event of future site development, is included in ES-2. Future steps that may be implemented include:

- Installation of continuous monitoring devices to identify potentially explosive environments
- Architectural design of buildings that would facilitate ventilation of the sub-flooring areas
- Installation of blowers to increase the flow of air and reduce potential methane accumulation.

Restrictions are instituted through an order or agreement between the site owner and WDOE.

> Expected Benefits. Land and water use restrictions prohibit the general public from utilizing the site and limit potential exposure to site groundwater as a drinking water source. Controls on future development activities reduce potential hazards associated with methane. Land and water use restrictions also limit possible disturbance to offshore sediments. These restrictions assure that implemented remedial actions are maintained and not compromised.

### 6.3.1.2 Boiler Ash Fill Operable Unit

6.3.1.2.1 Remedial Alternative BA-1 - Institutional Controls. Remedial Alternative BA-1 imposes restrictions on the property deed that limit human contact with and exposure to the boiler ash fill. Controls limit potential contact with boiler ash by placing restrictive covenants in the warranty deed. Site personnel performing maintenance work in these areas are warned of site conditions and are required to use adequate personal protective equipment when working in chemically affected regions. As required by regulations under WAC 173-340-440, institutional controls:

- Prohibit activities onsite that can interfere with a cleanup action, operation and maintenance, long-term monitoring, or other measures necessary to assure integrity of the cleanup action.
- Prohibit activities that may result in the release of a hazardous substance contained as part of the cleanup action.
- Require notice to the WDOE of the owner's intent to convey any interest in the site. No conveyance of title, easement, lease, or other interest in the property is consummated by the property owner without adequate and complete provision for continued operation and maintenance of the cleanup action and prevention of releases and exposures (see above).
- Grant the WDOE and its designated representatives the right to enter the site at reasonable times to evaluate compliance with the cleanup action plan. Rights granted include taking of samples, inspecting operation of cleanup actions, and inspecting records.

In addition, under institutional controls, the WDOE may require the potentially liable party to provide financial assurances through a trust fund or equivalent financial mechanism approved by the department. Assurances are sufficient to cover all costs of long-term care and maintenance, including but not limited to monitoring and undertaking appropriate corrective measures.

Expected Benefits. The institutional controls described above have no impact on reducing contaminant concentration or toxicity. Potential impact on human health is reduced by prohibiting future use of the site by the general public. In addition, conditional cleanup levels for the boiler ash are met.

6.3.1.2.2 Remedial Alternative BA-2 - Removal and Offsite Disposal of Boiler Ash. As part of this remedial alternative, chemically affected soils in the boiler ash fill are removed for offsite disposal. Only soils exposed at land surface are excavated for disposal. The approximate area of soil to be removed (approximately 1,600 cubic yards) is shown in Figure 6-1. Sediment removal utilizes a backhoe. Excavation is expected to extend approximately 17 feet below ground surface. Excavated soils are transported offsite for disposal at a sanitary landfill. Upon completion of soil removal, the excavation is backfilled with clean fill.

Significant difficulty may be encountered in removing boiler ash, due to its nearness to the boiler building. Prior to removal of boiler ash, an engineering evaluation of the building substructure and support mechanisms must be made to evaluate potential adverse impacts to the building from undermining of soil along the west side. If the building is fully supported by pilings, little damage is expected. However, if it is supported by concrete along its perimeter, demolition and removal or additional support may be necessary to prevent it from collapsing during excavation. Available information from SBT indicates that the building rests on pilings.

Methods and Sequence of Work. The following methods and sequence of work are anticipated for Remedial Alternative BA-2:

- An engineering evaluation of the boiler building substructure and support system is made to evaluate requirements necessary for additional support of the building during excavation. Based on results of the evaluation, a determination is made about: (1) demolition of the building prior to excavation, (2) need for additional structural support for the building to help prevent possible structural failure, and (3) continuation of the excavation without provisions of additional support for the building.

  Available information from SBT suggests that the building is supported by pilings and may not experience structural failure if the surrounding shallow soils are removed or disturbed. Therefore, the steps listed below assume that the pilings provide sufficient support to the boiler building to allow excavation along the west side without structural failure. To prevent possible damage to the building and to reduce slumping of soil, installation of sheet piling along the west side of the building may be necessary. If structural failure is a potential problem, based on the results of engineering evaluation of the building, the scope of Remedial Alternative BA-2 may have to be greatly expanded.

- To prohibit the building from possible damage during the excavation, temporary sheet piling is installed along the west side of the boiler building to an approximate depth of 20 to 25 feet below ground surface.

- A backhoe is used to excavate the boiler ash fill. The depth of soil removed is variable, depending on the thickness of the boiler ash fill at each particular location. As illustrated in Figure 6-1, the boiler ash fill appears to increase in thickness, from less than 1 foot to approximately 13.5 feet, along the side of the building. As a result, soil removal is not expected to extend more than approximately 18 feet below ground surface. The anticipated volume of material to be removed is estimated at 1,600 cubic yards. However, the actual volume of material removed will be based on field observations of the extent of the boiler ash fill.

- The contractor places the boiler ash material in lined trucks for transportation to a local sanitary landfill. Available information suggests that disposal of fill material at a hazardous waste landfill is not warranted.

- Upon completion of soil removal, the resulting excavation is backfilled with clean fill material and temporary sheet piling is removed.

<u>Expected Benefits</u>. Excavation and removal of the boiler ash fill is expected to remove most of the chemically impacted soil. The residual soils are expected to have metal concentrations within background ranges found in natural soils. Backfilling of the excavation with clean fill material is expected to virtually eliminate future exposure of humans. Offsite disposal of waste material without treatment is generally disfavored by the WDOE and may have a negative impact to the disposal area.

6.3.1.2.3 <u>Remedial Alternative BA-3 - Solidification/Fixation and Onsite Disposal of Boiler Ash</u>. To reduce mobility and resulting potential human exposure, this alternative utilizes solidification to immobilize heavy metals found in the boiler ash. Soils that are exposed at land surface and that exceed the cleanup goals (approximately 1,600 cubic yards) are excavated, stabilized onsite using silica-based fixation methods, and returned to the excavation pit as fill material.

Significant difficulty may be encountered in removing boiler ash, due to its nearness to the boiler building. Prior to removal of boiler ash, an engineering evaluation of the building substructure and support mechanisms must be made to evaluate potential adverse impacts to the building from undermining of soil along the west side. If the building is fully supported by pilings, little damage is expected. However, if it is supported by concrete along its perimeter, demolition and removal or additional support may be necessary to prevent it from collapsing during excavation. Available information from SBT indicates that the building rests on pilings.

Methods and Sequence of Work. Since the building is presumed to rest on pilings, the following methods and sequence of work are anticipated for Remedial Alternative BA-3:

- An engineering evaluation of the building substructure is made to determine requirements necessary for additional support of the building during excavation of chemically impacted soils. Based on results of the building evaluation, decisions are made about whether or not the building should be demolished prior to excavation and whether or not additional support needs to be provided for the building to prevent possible structural failure during excavation. The steps below assume that the building is sufficiently supported by pilings to allow excavation along the west side without structural failure. Installation of sheet piling along the west side of the building may be necessary to prevent damage to the existing building during excavation. If structural failure is a potential problem, as determined by the engineering evaluation, it is anticipated that the scope of Remedial Alternative BA-3 will be expanded significantly.

- A bench-scale test is run to evaluate potential success of different chemical additives in the boiler ash. The chemical additive providing the best long-term sorbability is used in fixation of the boiler ash.

- To protect the boiler building from possible damage during excavation and to prevent slumping of soil below the building, temporary sheet piling is installed along the building to a depth of approximately 20 to 25 feet below ground surface. At the completion of backfilling, the sheet piling is removed.

- Using a backhoe, the soils are excavated and placed in a hopper, awaiting solidification/fixation. The volume of boiler ash that requires fixing is estimated at 1,600 cubic yards, based on RI results. This estimate does not include soil expansion that can occur after excavation.

- Chemically impacted ash is fixed, using the best silica-based fixation process identified in the bench-scale test.

- Once the treatment process is complete, the fixed soil is returned to the excavation site. Since the fixed soil is probably of greater volume than the original excavated soils, the remaining fixed soil is used as fill material as needed across the site. Because chemical concentrations in the boiler ash are generally low prior to treatment, leaching of metals from the fixed soil does not appear to present a significant concern. As a result, a secondary containment system is not warranted.

Expected Benefits. Solidification/fixation of the boiler ash fill with onsite disposal is expected to significantly reduce any chemical migration and limit human exposure. Since dermal contact and ingestion by humans are the only exposure routes identified in the RA, the residual human risks after implementation of Remedial Alternative BA-3 appear to be low. To provide further protection from perceived risks, land use restrictions limiting human activity in the boiler ash fill are implemented in Remedial Alternative BA-3.

6.3.1.2.4 Remedial Alternative BA-4 - Installation of Soil or Asphalt Cap Over the Boiler Ash Fill. Capping of the boiler ash fill limits potential human contact with boiler ash material. The cap is constructed primarily of clean fill or an asphalt cover. Areas requiring additional support can be paved with concrete, if necessary. The capped area will most likely serve as an additional parking area for SBT.

Methods and Sequence of Work. The following methods and sequence of work are anticipated for Remedial Alternative BA-4:

- Using a small dozer, the capped area is leveled. Since SBT has already placed a sand cap (up to 3 feet thick) over most of the boiler ash, during Remedial Alternative BA-4 it is only necessary to install additional clean sand fill over the impacted area, as required to form a consistent and uniform base.

- To control surface water drainage, a catch basin with an oil/water separator is installed in a central portion of the capped area. The catch basin ultimately discharges to the Lake Washington Ship Canal.

- The sand cap is compacted to a density sufficient to prevent slumping and is capable of supporting the weight of an asphalt cap and several vehicles (if the area is to be used for parking).

Expected Benefits. Installation of a sand or asphalt cap prevents human contact with the low levels of metals occurring in the boiler ash fill. The principal routes of potential human exposure are dermal absorption and ingestion. With installation of the cap, these routes of exposure are virtually eliminated. Cap installation also has other benefits, including reduction of erosion of the boiler ash fill into the Ship Canal and reduction of surface water infiltration that can contribute to the leaching of metals from the boiler ash material. It would also avoid the potential difficulties created by excavating the boiler ash adjacent to existing buildings. The integrity of the cap would be assured with annual inspection and maintenance as required.

#### 6.3.1.3 Glue Press Area Operable Unit

6.3.1.3.1 Remedial Alternative GP-1 - Land Use Restrictions. Land use restrictions include restricting the use of the glue press area to assure the soil, sediments and waste materials are not disturbed. "No Trespassing" notices are provided and recreational activities are prohibited at the site. Contaminated areas are reinvestigated every five years in accordance with MTCA regulations (WAC 173-340-420). This alternative also assures that any maintenance/construction work performed in the glue press area will be completed by workers with the appropriate personal protective equipment and training. However, based on the results of the RA, potential adverse human health effects are not expected at the concentrations detected. Land use restrictions are instituted through an order or an agreement between the site owner and the WDOE.

Expected Benefits. Land use restrictions prohibit the general public from contacting potentially contaminated material occurring the glue press area. Site maintenance workers are required to wear the appropriate personal protective equipment and have the appropriate hazardous waste training. With these controls, human exposure, to the materials which may pose a human threat, appear to be minimal. Based on the RA, adverse human health effects are not expected at the concentrations detected.

6.3.1.3.2 Remedial Alternative GP-2 - Removal and Offsite Disposal of Glue Piles. As part of this remedial alternative, the glue piles and nearby sediments are removed and transported from beneath onsite buildings. The approximate areas to be addressed are shown on Figure 6-2. This work can be done with mechanical equipment where access is possible, but it is anticipated that manual labor utilizing hand-held dredges will also be required because of the confined spaces and various interferences.

In addition to visually identified glue and debris, lake sediments 1 foot below the glue piles and extending 10 feet north, east, and west of the piles are excavated. Lake sediments 1 foot deep and extending 5 feet south (upgradient) of each glue pile are also removed.

Methods and Sequence of Work. The following methods and sequence of work are anticipated for Remedial Alternative GP-2.

- Floor planking in the vicinity of the glue piles is removed to access the piles. The contractor numbers the planks and prepares a location drawing so that they can be reinstalled in their original locations.

- After several planks have been removed by hand to allow access, a backhoe can be used to easily pry the remaining planking from the floor. Planks are removed from the work area and stacked awaiting reinstallation. Some joists may also require removal. Beams, piling, piping, and conduit remain in place during the work.

- A lake water level of less than 19.5 feet MSL, which frequently occurs in August and September, is required during glue pile and sediment removal work.

- The contractor removes glue piles, contaminated debris, and contaminated sediments from under site buildings and transports them to trucks or containers waiting outside.

- Residual sediments are sampled and analyzed to assess the adequacy of the removal operation. Additional sediment removal may be necessary, based on the results of the sampling; however, this work is not included in cost estimates for Remedial Alternative GP-2.

- Planks and joists are reinstalled in their original positions.

- Trucking and disposal of waste material are handled by another contractor.

- Disposal costs are estimated with the assumption that the material will be accepted at a local sanitary landfill. (According to available chemical data, disposal at a hazardous waste landfill is not required, and there is no data to indicate that the material will be unacceptable at a sanitary landfill.)

Expected Benefits. Removal of glue piles and nearby sediments is expected to reduce anthracene levels to just above those found in other sediments in Lake Union. While some anthracene remains onsite, glue waste itself (containing the highest concentrations of anthracene) is removed and transported offsite to a controlled landfill. Removal of the majority of anthracene contamination reduces long-term risks to aquatic biota, with bottom-dwelling aquatic life realizing the greatest benefit. However, available information suggests that there is little, if any, aquatic life below existing site buildings, due to light deprivation. Based on WDOE guidance, disposal of contaminated waste without treatment is generally disfavored. Removal may also increase the short-term bioavailability of the contaminants in the shallow sediments surrounding the glue piles, which may have adverse ecological impacts.

6.3.1.3.3 Remedial Alternative GP-3 - Capping Glue Piles with Concrete or Clay. The glue piles and surrounding sediments include the areas shown in Figure 6-2. Capping of these areas primarily utilizes manual labor to minimize disturbance to the existing buildings and to enable accurate placement of the cap in confined spaces beneath buildings.

Cap material is either 6 inches of sprayed-on concrete or a 1/4-inch-thick clay veneer sandwiched between two porous fabric sheets. A combination of the two capping materials may also be effective. The fabric sheets provide strength and stability to the clay sheet and reduce the potential for thin areas. With adequate installation, the clay cap can reportedly provide an effective barrier with vertical hydraulic conductivities as low as $1 \times 10^{-9}$ cm/sec. Concrete may be more suitable for application on the glue piles themselves, to assure the best coverage.

Methods and Sequence of Work. The following methods and sequence of work are anticipated for Remedial Alternative GP-3.

- Floor planking and necessary joists are removed to increase access to the glue piles and other areas in which access is limited. The contractor numbers the pieces removed to facilitate reinstallation.
- Debris below the building in the vicinity of the cap is removed to increase the effectiveness of the cap.
- If concrete is used, a temporary form constructed around the perimeter of each glue pile may be necessary. The cap is sprayed onto the piles, using pH-adjusted concrete. If a clay mat is used, it is placed on a roll resembling carpet and positioned using a forklift or front-end loader with appropriate attachments. The clay mat material is then unrolled and carried by several laborers for placement in the appropriate position. Each sheet is cut and formed to ensure the best possible fit around existing building supports. Seams are eliminated by overlapping the clay mat sheets.
- A concrete cap requires no support. Once in place, a clay mat must be secured in position with steel spikes.
- A concrete cap does not require a sand cap. However, if a clay cap is used, a sand cap approximately 6 inches thick is placed on top of the clay material to protect the clay cap from possible erosion and to provide a suitable environment for aquatic organisms.

- Planks and joists are reinstalled in their original positions.
- Annual inspections and periodic replacement of all caps are anticipated with implementation of Remedial Alternative GP-3.

Expected Benefits. Capping of the glue piles and surrounding sediments is expected to reduce potential exposure of humans and biota. However, at the concentrations detected, anthracene is not expected to result in adverse human health effects. Placement of a cap provides added protection to aquatic biota from potential adverse effects of anthracene. Since the glue piles are not removed during implementation of Remedial Alternative GP-3, there is some concern about vertical mobility of anthracene through underlying sediments. However, because anthracene is relatively insoluble and has a high affinity for sorption to organics, the possibility of vertical migration through the sediments is limited.

#### 6.3.1.4 Offshore Sediments Operable Unit

6.3.1.4.1 Remedial Alternative OS-1 - Land Use Restrictions. Land use restrictions include restricting activities in the vicinity of the offshore sediments. Contaminated areas are reinvestigated every five years in accordance with MTCA regulations (WAC 173-340-420). "No Trespassing" notices will be posted and site recreational uses will be prohibited. Site maintenance requiring direct contact with the sediments will be restricted to workers with the appropriate personal protective equipment and training. Land use restrictions are instituted through an order or an agreement between the site owner and the WDOE.

Expected Benefits. Land use restrictions will prohibit recreational uses of the site. With implementation of this alternative, potential migration of contaminated sediments will be minimized thereby limiting the bioavailability of the contaminants. Based on the RA, potential human contact or ingestion of sediments was not considered a viable exposure route; however, future recreational uses of the area will be controlled to assure human contact is not a concern. Long-term monitoring will inform regulatory agencies of changing contaminant concentrations, if any.

6.3.1.4.2 Remedial Alternative OS-2 - Capping Offshore Sediments with Sand or Concrete. This alternative entails capping of offshore sediments with sand or concrete to reduce potential migration of chemically impacted sediments and essentially eliminate exposure of aquatic organisms to offshore sediments. The area to be covered with sand or concrete is shown in Figure 6-3. Capping is expected to be generally labor-intensive and requires close attention to covering all areas of concern.

Underwater divers ensure that the appropriate amount of material, at least 18 inches of sand or 6 inches of concrete, is applied in all areas of concern. The sand or concrete cap provides protection to potential human and aquatic recipients in all accessible areas below the existing buildings, including glue piles and surrounding sediments. Since concrete is relatively permanent and resists decomposition, low maintenance for this type of cap is expected.

Methods and Sequence of Work. The following steps are anticipated to complete installation of the cap by the contractor.

- Sediments are accessed by cutting holes in the floors of existing buildings. For installation of a concrete cap, access holes only need to be large enough to allow insertion of a grout hose.
- A diver removes debris from below buildings as necessary to assure consistent application of the cap.
- A temporary form is constructed around the perimeter of the cap area, using steel sheet piling and plywood in areas of limited access. The form controls the flow of sand or concrete and reduces migration of turbid water produced during cap application.
- Offshore sediments are capped with sand or pH-adjusted concrete. Minimum cap thickness is approximately 18 inches of sand or 6 inches of concrete. An estimated volume of 16,200 cubic yards of sand or 5,400 cubic yards of concrete is expected to be needed to complete the cap.
- Access holes in building floors are repaired.

Expected Benefits. Capping of offshore sediments with sand or concrete is expected to decrease or eliminate potential exposure of humans and aquatic organisms to chemically impacted sediments and glue piles. Since this alternative addresses the concerns of two operable units (glue press area and offshore sediments), its cost-effectiveness is increased.

6.3.1.4.3 Remedial Alternative OS-3 - Installation of Silt Curtain Around Offshore Sediments. This alternative involves placement of a fabric barrier around offshore sediments to keep aquatic life from coming into contact with chemically impacted sediments and to limit outward migration of this material. The area to be contained by the barrier is shown in Figure 6-4. Selection of a specific barrier material was not assessed in the FS, although fabric-type materials are frequently used under these conditions and were chosen for estimating purposes. Installation of a barrier is labor-intensive and the cost of materials is only a fraction of the cost of labor. Tears and breaks in the curtain would significantly reduce its effectiveness.

Methods and Sequence of Work. The anticipated methods and sequence of work are presented below.

- The barrier route is laid out. Figure 6-4 includes the proposed route for the silt curtain used to determine costs.
- Planks and selected joists are removed as necessary to gain access to areas of concern below the floor.
- A temporary silt curtain is installed to contain disturbed sediments.
- Trenching is used to clear debris along the barrier line. This work is done by hand and air-jetting. All materials and debris remain under the floor.
- The fabric barrier is installed. A stainless steel cable is run between pilings along the barrier route. The top of the net/fabric is attached to the stainless steel cable. The bottom of the barrier is attached to a steel rod and buried in the sediment (approximately 2 feet deep).
- Floor planks and joists are replaced.

Expected Benefits. Installation of a silt curtain around chemically impacted sediments at the site may reduce exposure of the biota and decrease possible sediment migration. Installation of the curtain has no impact on reducing volume or toxicity of contaminated sediments.

6.3.1.4.4 Remedial Alternative OS-4 - Dredging and Offsite Disposal of Offshore Sediments. Dredging and offsite disposal of offshore sediments are extremely labor-intensive and expensive, possibly involving removal of over 15,000 cubic yards of sediment (3 feet in depth over the affected area) using diver-operated hand-held dredges. Use of conventional dredging equipment is not feasible in most areas because of limited access to chemically affected sediments below existing buildings. Remedial Alternative OS-4 also includes removal of glue piles and surrounding sediments as described in Subsection 6.3.1.3.2. Once sediments have been dredged, free liquids must be removed prior to transporting materials offsite for disposal.

Methods and Sequence of Work. The following activities have been identified, in addition to those needed for removal of glue piles, to complete Remedial Alternative OS-4.

- Installation of a temporary silt curtain is necessary to control migration of disturbed sediments produced during dredging. Curtain material may consist of heavy gauge plastic sheeting anchored at the bottom with concrete blocks to eliminate currents through the impacted area.

- Prior to dredging of sediments, two dewatering lagoons are constructed onsite. The lagoons cover approximately a 75 by 75 foot area and each has an estimated volume of approximately 750 cubic yards. Lagoons are constructed of layers of concrete, bentonite clay, and sand. Piping is installed to facilitate removal of the water, and decanted water is returned to the Ship Canal.
- Sediments are removed by use of a hand-held dredge at a rate of approximately 30 cubic yards per day. Dredged sediments are pumped directly to the dewatering lagoons. Dredging starts on the upgradient side of the affected area and work proceeds downgradient.
- Coincident with dredging, sediments are dewatered and transferred to lined trucks for offsite disposal.
- Dredging proceeds by sections. Following completion of dredging in a particular section, the area is sampled to evaluate the need for deeper dredging. (During the FS, there was no information on the vertical depth of chemically impacted sediments. A maximum of three feet of sediment removal was assumed.)

Expected Benefits. Removal and offsite disposal of sediments have the long-term effects of removing glue piles that are the source of anthracene and also removing sediments impacted by other PAHs and metals. Because additional contaminant loading is likely through stormwater runoff, aquatic organisms would not be expected to realize substantially improved conditions.

Short-term adverse impacts to the environment are probably significant, with resuspension of contaminants into the water column. The chemically impacted sediments are ultimately expected to be redeposited in the location from which they were removed. Dangers associated with underwater work can pose risks to the health of the divers.

## 6.4 DETAILED ANALYSIS OF ALTERNATIVES

Section 6.3 identified several alternatives for each operable unit appearing capable of mitigating contamination at the former Champion site. The alternatives are thoroughly analyzed, as described in this section, to provide decision makers with sufficient information to select the best remedy. The alternatives for each operable unit are identified below:

- Entire Site
  - ES-1 - No action
  - ES-2 - Land and water use restrictions

- Boiler Ash Fill
  - BA-1 - Institutional controls
  - BA-2 - Removal and offsite disposal
  - BA-3 - Solidification/fixation and onsite disposal
  - BA-4 - Capping with sand or asphalt

- Glue Press Area
  - GP-1 - Land use restrictions
  - GP-2 - Removal and offsite disposal
  - GP-3 - Capping with concrete or clay

- Offshore Sediments
  - OS-1 - Land use restrictions
  - OS-2 - Capping with sand or concrete
  - OS-3 - Silt curtain around affected sediments
  - OS-4 - Hand-dredging and offsite disposal

Regulations under the MTCA list the following nine criteria for evaluating remedial alternatives WAC 173-340:

- Overall protection of human health and the environment
- Compliance with applicable laws
- Short-term effectiveness
- Long-term effectiveness and permanence
- Permanent reduction of toxicity, mobility, or volume
- Implementability
- Cost
- Community acceptance (the degree to which community concerns are addressed).
- Degree of recycling, reuse, and waste minimization

The detailed analysis provided in this section evaluates each of the alternatives relative to the nine criteria.

### 6.4.1 Criteria Description

A brief description of each criterion is presented below.

6.4.1.1 Overall Protection of Human Health and the Environment. Under this criterion, the FS summarizes long-term effectiveness, permanence, and short-term effectiveness of each alternative. Other information that might be relevant but is not considered under other criteria is discussed.

6.4.1.2 Compliance with Applicable Laws. The FS evaluates how each alternative complied with applicable federal and state laws. Other guidance could be added to the list of laws, even if not strictly an applicable law, if the governmental agencies overseeing the cleanup determine that the inclusion of the guidance is necessary. Applicable laws are typically chemical-specific, but can also be action- or location-specific. Table 6-5 presents a list of action-, location-, and chemical-specific laws that are applicable to the site and considered in the detailed evaluation. Applicable laws evaluated as part of the FS are listed in Appendix G.

6.4.1.3 Short-Term Effectiveness. Under this criterion the FS assesses effects during construction and implementation. The detailed evaluation described in this section built on the work discussed in Section 6.3, but it also evaluates additional material. For example, short-term effectiveness is considered to include risks to the health of the community and site workers, and effective safeguards to minimize these risks. Under this criterion, the FS also explores the impact of a particular remedy on the environment. In addition, the amount of time needed until remedial response objectives could be achieved is assessed.

6.4.1.4 Long-Term Effectiveness and Permanence. The long-term effectiveness criterion is used to assess risks to human health and the environment remaining after remedial action objectives are met. Long-term effectiveness is determined by examining the exposure routes addressed and investigating the ability of the controls (if any) to manage remaining risks.

6.4.1.5 Reduction of Toxicity, Mobility, or Volume. Under this criterion, the FS evaluates the ability of the alternatives to significantly reduce toxicity, mobility, and volume of hazardous substances. Included are evaluations of treatment processes and their irreversibility; quantities of hazardous materials destroyed; and reduction of toxicity, mobility, and volume.

6.4.1.6 Implementability. The implementability criterion is used by the FS to address technical and administrative feasibility of assembling and operating technologies designed to treat site contaminants. The ability of each technology to meet specified performance goals is assessed; and potential need for future remedial actions and need for monitoring effectiveness of a system is explored. Finally, in terms of implementability, administrative feasibility (requirements for receiving permits and government approvals) is studied.

6.4.1.7 Cost. Detailed cost estimates for each alternative are provided in Appendix H. Whereas cost played a relatively unimportant role in alternative screening, it is much more significant for the detailed alternative analyses. Cost estimates are expected to meet an accuracy of +50 percent to -30 percent (U.S. EPA, 1988). Furthermore, to be comparative, costs are described using present worth methodology. Present worth represents an amount of money that, if invested in a base year, provides adequate funds for the life of the remedial project.

Each cost estimate contains a description of direct and indirect capital costs, as well as annual O&M costs. The cost estimates provided were not meant to be budgetary, but are suitable for comparison among alternatives. Only typical engineering and construction costs associated with normal remediation activities are presented. Costs associated with additional planning, testing, and monitoring during implementation or other unanticipated regulatory agency requirements is not included.

For purposes of the FS, direct capital costs were considered to include payments for equipment, labor, and materials needed to implement remedial measures. Indirect costs included expenditures for legal, engineering, and financial services; overhead; permits; and contingencies. Annual O&M costs consisted of those for ongoing labor, equipment maintenance, supplies, utilities, disposal of waste by-products, insurance, and contingency funds to cover equipment replacement costs.

6.4.1.8 Community Acceptance. Under the criterion of community acceptance, the FS assesses public comments concerning any of the actions taken so far in the RI or the FS.

6.4.1.9 Degree of Reuse, Recycling, and Waste Minimization. Under the final criterion, the FS identifies the extent to which reuse, recycling, and waste minimization are employed in a final remedial alternative.

### 6.4.2 Alternative Analyses

Alternative analysis results are presented in Table 6-6. This method of presentation gives decision makers a convenient means for examining pertinent information and making rapid comparison among alternatives.

### 6.4.3 Comparison Among Alternatives

The final step in the FS is to weigh the alternatives against one another relative to evaluation criteria discussed in Subsection 6.4.1. This procedure identifies advantages and disadvantages of each alternative so that important tradeoffs can be evident to the decision makers.

Since protection of human health and the environment and compliance with applicable laws are generally expected of any alternative, these criteria serve as the basis for choosing an alternative. Short-term effectiveness; long-term effectiveness; reduction of toxicity, mobility, or volume; implementability; and cost involve the most discussion because many of the important tradeoffs concerned one of these five criteria.

6.4.3.1 Entire Site Operable Unit. Two alternatives are identified under the Entire Site Operable Unit, and address different concerns. Therefore, a direct comparison of the alternatives may not be appropriate.

6.4.3.1.1 Overall Protection of Human Health and the Environment. Alternative ES-1 (no action) provides no protection to human health or the environment, while Alternative ES-2 contributes minimal protection to human health relative to future groundwater consumption and methane accumulation. Alternative ES-2 provides protection to the entire site through restricting access by possible trespassers and limiting future recreational use.

6.4.3.1.2 Compliance with Applicable Laws. Neither Alternative ES-1 nor ES-2 meets chemical-specific laws. Both provide long-term monitoring that can help assess changing conditions at the site. Since no remedial activities would take place, location-specific and action-specific laws are not applicable.

6.4.3.1.3 Short-Term Effectiveness. Since there are no remedial activities taking place with these alternatives, no negative impacts to the community, or workers, are expected. Future dangers that may result from methane accumulation are addressed by Alternative ES-2. In addition, warnings are posted across the site in areas of concern that warn of site conditions.

6.4.3.1.4 Long-Term Effectiveness. Residual risks posed by the site, if any, are unchanged by Alternatives ES-1 and ES-2. With long-term monitoring, changes in site chemical conditions can be monitored and corrective measures implemented as warranted. Both Alternatives ES-1 and ES-2 provide reinvestigation of the site contamination every five years. Alternative ES-2 reduces the risk associated with exposure to contaminants by the general public. In addition, restrictions on water and land use address chemicals of concern in the solvent tank area and possible risks posed by methane across the site.

6.4.3.1.5 Reduction in Toxicity, Mobility and Volume. Since no active corrective measures are employed, neither Alternative ES-1 nor ES-2 reduces contaminant toxicity, mobility or volume. Only protection from potential human contact to site contaminants is provided by Alternative ES-2.

6.4.3.1.6 Implementability. Both alternatives are easily implementable; however, regulatory opposition may make Alternative ES-1 less desirable.

6.4.3.1.7 Cost. The costs to implement both alternatives are generally low. The present worth cost of Alternative ES-1 is estimated at $62,800, whereas Alternative ES-2 would cost approximately $84,200 to implement.

6.4.3.1.8 Degree of Recycling, Reuse and Waste Minimization. Neither of the alternatives include recycling, reuse or waste minimization since active controls are not employed.

6.4.3.2 Boiler Ash Operable Unit. Four possible remedial alternatives were identified for the boiler ash fill area. These alternatives include:

- BA-1 - Institutional controls
- BA-2 - Removal and offsite disposal of the boiler ash material
- BA-3 - Solidification of the boiler ash and onsite disposal
- BA-4 - Capping of the boiler ash with sand or asphalt

A comparison of the four alternatives against the evaluation criteria (identified in Section 6.4.1) is presented below:

6.4.3.2.1 Overall Protection of Human Health and the Environment. Each of the alternatives, except BA-1, employ active engineering controls and would be effective in reducing potential human exposure to within acceptable levels as identified by WAC 173-340-740. Alternative BA-1 introduces institutional controls which limit potential human exposure by restricting access and subsequent activities to the area. All four alternatives address the exposure routes identified in the RA by eliminating or restricting contact with the potentially contaminated materials.

Alternatives BA-2, BA-3 and BA-4 likely provide a similar level of protection against possible human exposure. Alternatives BA-2 and BA-3 both require removal of the chemically affected materials. This disturbance may increase the bioavailability of contaminants to the nearby Ship Canal. Therefore, Alternative BA-4, which effectively limits possible human contact and does not result in increased bioavailability, may be preferable over removal or solidification alternatives.

6.4.3.2.2 Compliance with Applicable Laws. Institutional controls (Alternative BA-1) change the status of this operable unit from residential to industrial. As a result of this change, conditional chemical-specific laws are met. The remaining alternatives meet chemical-specific laws by employing engineering controls which limit the contaminant's mobility. Alternatives BA-2 and BA-4 do not meet cleanup preferences for reduction in toxicity or volume or the preference for a permanent solution as established by the WDOE (WAC 173-340-360). Implementation of Alternatives BA-2 and BA-3 would result in additional action-specific and location-specific laws that would have to be met.

6.4.3.2.3 Short-Term Effectiveness. Since Alternative BA-1 does not employ active engineering controls, no adverse short-term effects are expected to the community. Alternatives BA-2 and BA-3, which employ waste removal, may result in the production of fugitive dust. Proper water spraying techniques would most likely control potential dust production problems that may occur during soil excavation. Workers implementing the remedial alternatives are required to have the proper training and use the appropriate personal protective equipment. Therefore, no exposure of the workers to site contaminants is expected.

Due to the close proximity of the boiler ash fill with the Ship Canal, excavation of the boiler ash necessary for Alternatives BA-2 and BA-3 may result in increased bioavailability of contaminated sediments. Capping (Alternative BA-4) would result in less disturbance of the boiler ash material, thereby avoiding possible adverse affects to the Ship Canal biota.

6.4.3.2.4 Long-Term Effectiveness. Chemically impacted soil would be unaffected by Alternative BA-1, while still meeting the conditional cleanup objectives. Alternative BA-2 (removal and offsite disposal) offers the lowest residual risk to humans. Alternatives BA-3 and BA-4 pose only a slightly higher residual risk than Alternative BA-2. Regarding adequacy of controls given existing site conditions, each alternative would meet the desired cleanup objectives. Alternative BA-2, which involves offsite disposal of the waste, may result in future groundwater problems if the landfill does not have an appropriate leachate collection/monitoring system. The long-term reliability of solidification (Alternative BA-3) will be dependant on the fixation agents used and site geochemistry; therefore, leaching of contaminants from the fixed material is possible. Alternative BA-4 would control surface water drainage in the vicinity of the boiler ash. Depending on the design of the cap, this alternative may also limit erosion, infiltration of surface water, and potential leaching of contaminants to the Ship Canal.

6.4.3.2.5 Reduction of Toxicity, Mobility and Volume. Alternatives BA-2, BA-3, and BA-4 reduce the mobility of the contaminants but do not reduce the volume or toxicity of the waste material. Alternative BA-3 has a negative impact of increasing the volume of the waste material that requires disposal. However, this material would be disposed of onsite as opposed to a local landfill. Alternative BA-1 has no impact on reducing the toxicity, mobility or volume of the contaminated material. Only potential human exposure to the waste material is controlled.

6.4.3.2.6 Implementability. None of the alternatives appear to pose technical or administrative problems that would prevent their execution. Alternatives BA-2 and BA-3, which require removal of the boiler ash, may require additional support of the boiler building to prevent undermining of the structure. Alternative BA-3 will require a pilot study to determine the best mix of solidification agents. Alternative BA-4 is the most easily implemented alternative.

6.4.3.2.7 Cost. The present worth cost to implement these alternatives ranges from $71,000 for Alternative BA-1 to $1,469,800 for Alternative BA-3 (solidification of the boiler ash). The most cost-effective alternative appears to be Alternative BA-4, which incorporates a sand or asphalt cap to prevent human exposure to the chemically impacted boiler ash while meeting the cleanup objectives. A comparative cost analysis summary is presented in Table 6-7.

6.4.3.2.8 Degree of Recycling, Reuse and Waste Minimization. None of the alternatives directly employ recycling, reuse, or waste minimization techniques. Alternative BA-3 may indirectly utilize waste minimization concepts to the extent that waste materials are disposed of onsite and not in a sanitary landfill.

6.4.3.3 Glue Press Area. Three remedial alternatives were examined closely in Section 6.4.1 for the glue press area. These alternatives include:

- GP-1 - Land use restrictions
- GP-2 - Removal and offsite disposal of the glue piles and surrounding sediments
- GP-3 - Capping of the glue piles and surrounding sediments with concrete or clay.

A comparison of the three alternatives against the evaluation criteria (identified in Section 6.4.1) is presented below.

6.4.3.3.1 Overall Protection of Human Health and the Environment. Since the RA indicates there are no expected adverse human health effects from anthracene at the concentrations detected, potential ecological effects appear to be the only plausible concern. Alternative GP-1 provides minimal added protection against possible ecological effects. Alternative GP-1 (land use restrictions) is the only alternative that has no potential adverse environmental impacts. Alternatives GP-2 and GP-3 reduce potential exposure of the glue press waste and surrounding sediments to aquatic organisms by controlling the contaminants' mobility, either by capping or removal and offsite disposal.

6.4.3.3.2 Compliance with Applicable Laws. In the absence of data to suggest that anthracene poses a human health threat and in the absence of freshwater sediment criteria, each of the alternatives meets existing chemical-specific laws. Existing conditions meet cleanup criteria developed in the FS; however, the cleanup criteria are not considered applicable laws. Implementation of Alternatives GP-2 and GP-3 may introduce additional location-specific or action-specific laws that would need to be addressed.

6.4.3.3.3 Short-Term Effectiveness. Each of the alternatives utilizes commonly used technologies that are used in standard construction processes; therefore, adverse impacts to the community are not expected. Potential dangers associated with underwater work necessary for Alternatives GP-2 or GP-3 may make these alternatives less desirable. Implementation of either Alternative GP-2 or GP-3 would require workers to have the appropriate personal protective equipment and training. Increased bioavailability caused by disturbance of the sediment may make Alternative GP-2 (removal and offsite disposal) less attractive. However, a temporary silt curtain installed around the excavation area could help to reduce contaminant migration. Dewatering of dredged sediments and disposal of the effluent may have negative impacts on the Ship Canal.

6.4.3.3.4 Long-Term Effectiveness. Residual risks resulting from implementation of the three alternatives are difficult to evaluate since original risks (prior to alternative implementation) are unknown for aquatic organisms. Human exposure risks are reduced by each of the alternatives through limiting potential contact with the contaminated material. However, potential adverse human health effects, at the concentrations detected onsite, are not expected. Alternative GP-1 restricts access of humans in the glue press area. In the absence of information to suggest human or environmental risk, this may provide adequate control. Alternatives GP-2 and GP-3 provide a similar level of protection against exposure to aquatic organisms, while Alternative GP-1 provides no increased protection to the biota. Continued contaminant loading from urban runoff and nearby industries may counteract the beneficial effects of Alternatives GP-2 and GP-3.

6.4.3.3.5 Reduction in Toxicity, Mobility and Volume. Since a treatment process is not employed in any of the three alternatives, the toxicity or volume of the waste material is not reduced. Only Alternatives GP-2 and GP-3 reduce the mobility of the waste material through active engineering controls. Alternative GP-2, which includes offsite disposal of waste, does not meet the preferred cleanup objectives established by WDOE (WAC 173-340-360).

6.4.3.3.6 Implementability. None of the alternatives pose a technical or administrative obstacle that would prohibit their possible implementation. Alternative GP-1 does not include active controls; therefore, it is probably the least complicated to implement. Alternative GP-2 requires contaminant removal and disposal and is likely the most difficult to implement. Implementation of Alternative GP-2 may also require additional structural support for the existing building.

6.4.3.3.7 Cost. The costs to implement each of the alternatives vary significantly from $71,000 for land use restrictions to $641,400 for excavation and removal of the glue press waste and surrounding sediments. Since anthracene has no known toxicological affects to humans, the protection offered by Alternative GP-1 appears to the most cost-effective. A comparative cost analysis summary is presented in Table 6-7.

6.4.3.3.8 Degree of Recycling, Reuse and Waste Minimization. None of the alternatives employ the desired characteristics of recycling, reuse or waste minimization.

6.4.3.4 Offshore Sediments Operable Unit. Four alternatives were identified in Subsection 6.3.1 to address chemically impacted freshwater sediments within close proximity of the site. These alternatives include:

- OS-1 - Land use restrictions
- OS-2 - Capping the offshore sediments with sand or concrete
- OS-3 - Installation of a silt curtain around affected sediments
- OS-4 - Hand dredging and offsite disposal of sediments

An evaluation of these four alternatives against the evaluation criteria identified in Subsection 6.3.1 is presented below.

6.4.3.4.1 Overall Protection of Human Health and the Environment. Human contact or ingestion was not identified as a viable exposure route. Therefore, the goal of each of the alternatives would be to limit possible exposure of aquatic organisms through the sediments.

The four remedial alternatives provide varying degrees of protection to aquatic organisms. The highest level of protection in the short-term is offered by Alternative OS-4, which entails hand-dredging of the nearshore sediments and offsite disposal. Capping the sediments with sand or concrete (Alternative OS-2) would provide an effective barrier between chemically impacted sediments and potential aquatic recipients. A silt curtain (Alternative OS-3) would serve to limit possible offsite migration of sediments while preventing larger aquatic organisms from coming in contact with chemically affected areas. Given the low levels of contaminants detected in offshore sediments, land use restrictions (Alternative OS-1) that limit future recreational uses may be all that is warranted at this time. Ongoing contaminant loading from urban runoff and nearby industries (ship rebuilding) would counteract the affects of Alternatives OS-2 and OS-4.

6.4.3.4.2 Compliance with Applicable Laws. In the absence of established freshwater sediment criteria, there appear to be no chemical-specific laws which must be met. Cleanup goals are exceeded in several instances by existing site conditions. However, the cleanup goals are based on background levels of chemical in sediments and AETs and do not represent applicable laws. With the implementation of Alternatives OS-2 through OS-4, additional location-specific or action-specific laws may be introduced. Compliance with these laws typically requires the acquisition of a permit and may present a significant obstacle.

6.4.3.4.3 Short-Term Effectiveness. None of the alternatives identified for this operable unit appear to pose a threat to the community. Each of the alternatives, except OS-1, would require varying degrees of underwater work, which poses a minimal risk to the workers. All alternatives requiring active controls would be performed by workers with the appropriate personal protective equipment and training. All the alternatives could be accomplished in a relatively short duration, except Alternative OS-4 which may require up to 1.5 years or more to complete.

Implementation of Alternative OS-4 would result in a disruption of the sediments and ultimately increased bioavailability of contaminants. Implementation of Alternative OS-2 may result in a temporary increase in the pH of the water column and surrounding sediments. These characteristics reduce the appeal of these two alternatives.

6.4.3.4.4 Long-Term Effectiveness. The magnitude of residual risk posed by the sediments, if any, is difficult to quantify in the absence of existing sediment criteria. Each of the alternatives would have beneficial impacts on limiting the migration of contaminated sediments. However, beneficial impacts resulting from implementation of Alternatives OS-2 and OS-4 may be counteracted by ongoing contaminant loading from urban runoff and nearby industry.

Regarding reliability of controls, Alternative OS-4 offers the highest reliability, assuming that a suitable landfill is chosen with a leachate collection and monitoring system. Alternative OS-2 would be reliable; however, cracks and weathering may produce thin areas in the cap. Silt curtain installation likely provides the least reliability because small tears in the curtain, which are difficult to identify, could significantly compromise the effectiveness of the control. Alternative OS-1 appears to be the most effective, given the problems identified for the other alternatives.

6.4.3.4.5 Reduction in Toxicity, Mobility and Volume. Because no treatment process is employed there is no reduction in toxicity or volume of waste. Only the mobility of the contaminants is reduced by Alternatives OS-2 through OS-4.

6.4.3.4.6 Implementability. Each of the alternatives except Alternative OS-1 would require some level of technical expertise to implement. Alternative OS-1 is probably the easiest to implement, requiring only an agreement with the WDOE. Alternatives OS-2 and OS-3 would require a low level of technical expertise to implement. Alternative OS-4 (hand-dredging and offsite disposal) would require significant technical expertise and possibly some modification of equipment to meet existing site conditions.

Implementation of Alternatives OS-2 through OS-4 would result in additional administrative requirements that would have to be met. Although the administrative requirements may result in significant delays in implementation (up to nine months or more), they are not considered significant enough to prohibit the execution of the remedial alternatives.

Continuing contaminant loading from urban runoff or nearby industries would probably counteract any beneficial impacts that Alternatives OS-2 and OS-4 may offer. Alternative OS-3 would prevent large aquatic organisms from entering contaminated areas and would not be comprised by the effects of urban runoff. However, small rips and tears, which are difficult to locate, would cause the alternative to be less effective. It is also unclear what effect this alternative would have on overall reduction of risk to aquatic life.

Only Alternative OS-1 would restrict the future use of the property, thereby preventing future recreational uses of nearshore areas.

6.4.3.4.7 Cost. Costs to implement the four alternatives range from low ($71,000) for Alternative OS-1 to extremely high ($8,339,100) for Alternative OS-4. The present worth cost to implement Alternatives OS-2 and OS-3 are estimated at $1,405,100 and $1,108,400, respectively. Alternative OS-1 appears to be the most cost effective alternative given existing site conditions. A comparative cost analysis summary is presented in Table 6-7.

6.4.3.4.8 Degree of Recycling, Reuse and Waste Minimization. None of the alternatives utilize recycling, reuse, or waste minimization.

### 6.4.4 Preferred Remedial Alternative

Based on a review of the alternative comparative analysis (Subsection 6.4.3), the preferred remedial alternatives have been selected for each operable unit. The selections of the preferred remedial alternatives was based on their ability to meet the desired cleanup objectives while satisfying as many of the nine evaluation criteria as possible. The preferred alternatives and the rationale for their selection, for each operable unit, are provided below.

6.4.4.1 Entire Site Operable Unit. Based on a thorough review of the comparative analysis, Alternative ES-2 (land use restrictions) was selected for this operable unit. The reasons for selection of this alternative are provided below:

- Alternative ES-2 addresses concerns of future potential explosive environments resulting in methane accumulation and assures that the shallow groundwater will not be used by future site occupants as a drinking water source.

- Alternative ES-2 assures that remedial measures, if any, performed at the site are not compromised during future improvements/ modification to the site.

- Alternative ES-1 is a required alternative under the National Contingency Plan and the Model Toxics Control Act and would not address site contamination concerns to the extent that Alternative ES-2 does.

6.4.4.2 Boiler Ash Operable Unit. Based on review of the alternative comparison, Alternative BA-4 (capping with sand or asphalt) was chosen for the following reasons:

- Capping provides the desired level of human protection without the detrimental side effects (fugitive dust, increased bioavailability and potential building damage) that may result from implementation of alternatives that incorporate waste removal.
- Capping provides the desired cleanup goals without the encumbrances imposed by institutional controls.
- Depending on the remedial design, capping may limit erosion, infiltration of surface water, and the potential leaching of contaminants while providing needed parking space for the site.
- Capping meets preferred cleanup objectives by not employing waste removal and offsite disposal and not increasing the volume of waste material as a result of solidification.
- Capping is the least technically sophisticated, with the exception of Alternative BA-1, and could be implemented with the most ease and reliability.
- Realizing the ability of Alternative BA-4 to meet the desired cleanup objectives, it appears to be the most cost effective.

6.4.4.3 Glue Press Waste Operable Unit. Because available information indicates that anthracene does not pose a human health risk at the concentrations detected, and in the absence of established freshwater sediment criteria, implementation of extensive engineering controls in the glue press area is unjustified. Further, the available engineering solutions pose short- and long-term risks to the environment that are not justified by any clear benefit. Therefore, Alternative GP-1, which incorporates land use restrictions, is the preferred alternative.

If implemented correctly, land use restrictions would protect against potential human exposure by (1) limiting future access to the area, and (2) requiring the appropriate personal protective equipment and training for workers engaged in site maintenance or upgrade, thereby limiting potential human exposure and subsequent risk. Potential adverse affects to the biota are not addressed by this alternative; however, in the absence of established freshwater criteria, such actions do not appear warranted. Future cleanup criteria for fresh water sediments or adequate information suggesting adverse human health effects may demonstrate a need for active remedial controls.

6.4.4.4 Offshore Sediments Operable Unit. Given the industrial setting of the site and the occurrence of offshore sediments (below buildings and below water), potential dermal contact, ingestion or consumption by humans was not considered a viable exposure route during the RA. Because applicable freshwater sediment criteria are currently non-existent, potential adverse impacts to the biota posed by the offshore sediments are unknown. Therefore, the need for extensive engineering controls, which may eventually be compromised by ongoing urban runoff and nearby industrial activity, is presently unjustified. The selected alternative for offshore sediments is Alternative OS-1 (land use restrictions). If implemented, land use restrictions would limit recreational activities in the vicinity of offshore sediments. As a result, disruption of the sediments would be minimized and bioavailability of contaminants sorbed to sediments would be reduced. In addition, land use restrictions would limit future human activity in the area, thereby reducing potential human contact with sediments containing low levels of contaminants. Future development of sediment criteria may include the need for active engineering controls.

6.4.4.5 Summary of Preferred Alternatives. As discussed in Subsection 6.4.4, the preferred remedial alternatives are chosen based on the existing need to correct site contamination conditions and the ability of the remedial alternative to meet the cleanup objectives without possible adverse affects to the environment or the community. This section briefly summarizes the preferred alternatives chosen for each operable unit to address all site contamination conditions. Additional details leading to the selection of these alternatives are presented in the preceding sections.

- Entire Site Operable Unit
    - Land use restrictions with long-term monitoring and periodic review in accordance with WAC 173-340-420
- Boiler Ash Operable Unit
    - Capping with sand or concrete
- Glue Press Waste Operable Unit
    - Land use restrictions with long-term monitoring and periodic review in accordance with WAC 173-340-420
- Offshore Sediments Operable Unit
    - Land use restrictions and long-term monitoring and periodic review in accordance with WAC 173-340-420 pending development of freshwater sediment criteria.

In summary, based on existing risks presented by the site, the above alternatives provide the most cost-effective protection to both human health and the environment.

TABLE 6–1

## SUMMARY OF EXPOSURE POINT CONCENTRATIONS

| Operable Unit | Chemicals of Concern (1) | Chemical Concentrations Mean/Maximum (2) (mg/kg or mg/L) |
|---|---|---|
| Solvent Tank Area | Acetone | 0.038/0.038 |
| | Carbon disulfide | 3.75/4.6 |
| | Chloroform | 0.35/0.42 |
| | Arsenic | 0.009/0.01 |
| | Barium | 0.06/0.06 |
| | T. chromium | 0.013/0.013 |
| | Copper | 0.046/0.046 |
| | Iron | 9.65/10 |
| | Lead | 0.031/0.032 |
| | Manganese | 0.38/0.38 |
| | Zinc | 0.20/0.25 |
| | | |
| Boiler Ash Fill | Antimony | 1.95/6.9 |
| | Arsenic | 22.26/55 |
| | Cadmium | 3.35/35 |
| | Copper | 191.4/610 |
| | Lead | 81.55/450 |
| | Mercury | 0.07/0.24 |
| | Silver | 1.36/6 |
| | Zinc | 273/1,200 |
| | | |
| Glue Press Waste Area | Anthracene | 109.24/770 |
| Offshore Sediments | Anthracene | 14.31/65 |
| | Fluoranthene | 8.66/7.4 |
| | Benzo(a)anthracene | 8.02/2.7 |
| | Benzo(k)fluoranthene | 11.45/53 |
| | Copper | 293/780 |
| | Lead | 480/1,200 |
| | Mercury | 1.27/3.70 |

Notes:

(1) Only chemicals evaluated in the RA included.

(2) In certain instances, the mean chemical concentration exceeded the maximum concentration when detection limits were high due to matrix interference.

# TABLE 6-2

## SUMMARY OF TARGET CLEANUP GOALS

| Operable Unit | Chemicals of Concern | Maximum Chemical Concentrations (ppm) | Target Concentration (ppm) |
|---|---|---|---|
| Solvent Tank Area | Acetone | 0.038 | 8,000(1) |
| | Carbon disulfide | 4.6 | 8,000(1) |
| | Chloroform | 420 | 1.24(5) |
| | Arsenic | 0.010 | 0.19(5) |
| | Barium | 0.060 | NA(3) |
| | T. chromium | 0.013 | 0.42(1) |
| | Copper | 0.046 | 0.025(5) |
| | Iron | 10 | 1.0(5) |
| | Lead | 0.032 | 0.01(5) |
| | Manganese | 0.38 | NA(3) |
| | Zinc | 0.25 | 0.22(5) |
| Boiler Ash Fill | Antimony | 6.9 | 32(1) |
| | Arsenic | 55 | 20(2) |
| | Cadmium | 35 | 2(2) |
| | Copper | 610 | 2,960(1) |
| | Lead | 450 | 250(2) |
| | Mercury | 0.24 | 1(2) |
| | Silver | 6 | 240(1) |
| | Zinc | 1,200 | 16,000(1) |
| Glue Press Waste Area | Anthracene | 770 | 24,000(1) |
| Offshore Sediments | Anthracene | 65 | Not Available(4) |
| | Fluoranthene | 7.4 | Not Available(4) |
| | Benzo(a)anthracene | 2.7 | Not Available(4) |
| | Benzo(k)fluoranthene | 53 | Not Available(4) |
| | Phenanthrene | 7.4 | Not Available(4) |
| | Copper | 780 | Not Available(4) |
| | Lead | 1,200 | Not Available(4) |
| | Mercury | 3.7 | Not Available(4) |

(1) Health-based cleanup level.
(2) As identified in WAC 173-340-740.
(3) NA denotes "not applicable"; RfD or cleanup level information not available.
(4) Cleanup level cannot be developed due to lack of toxicity data. AETs are an available comparison criteria but are not applicable to freshwater sediments. See text for further discussion.
(5) Cleanup level based on chronic AWQC for freshwater.

## TABLE 6–3

## INITIAL SCREENING OF REMEDIATION TECHNOLOGIES

| General Response Action | Remedial Technology | Process Options | Description | Determination of Applicability |
|---|---|---|---|---|
| Gas migration controls | Capping | Clay | Compacted clay covered with soil over area of contamination. | Potentially applicable to offshore sediments and glue waste. |
| | | Asphalt | Asphalt layer over area of concern. | Potentially applicable to offshore sediments and glue waste. |
| | | Concrete | Concrete slab over area of concern. | Potentially applicable to offshore sediments and glue waste. |
| | | Multimedia | Clay and synthetic membrane covered by soil/vegetation over area of contamination. | Potentially applicable to offshore sediments and glue waste. |
| | | Synthetic membranes | Heavy–duty synthetic covering surrounding affected area. | Suitable as a component within multimedia cap but not applicable as the sole feature, due to its susceptibility to damage. |
| | | Chemical sealants and stabilizers | Add chemicals to create less permeable surface. | NA. Decrease in permeability is not likely to be sufficient to significantly reduce vapor migration. |
| | Gas collection/ recovery | Passive pipe vents | Methane gas vented to surface through installed pipe vent. | Potentially applicable to methane. |
| | | Passive trench vents | High–permeability trenches provide controlled access route for methane. | Potentially applicable to methane. |
| | | Active gas collection | Control of gas migration through use of mechanical means to alter pressure gradients and paths of gas movement. | NA. Site subsurface characteristics are not suitable for vadose zone vapor extraction due to shallow water table conditions. |
| | Increase Ventilation | Installation of blowers | Reducing potential methane accumulation through installation of blowers in confined spaces. | Potentially applicable to methane. |
| Surface water controls | Capping (see gas migration controls) | | | |
| | Grading | Scarification, tracking, contour furrowing. | Reshaping land surface to control runoff and infiltration. | Potentially applicable to offshore sediments and glue waste. |

## TABLE 6-3

## INITIAL SCREENING OF REMEDIATION TECHNOLOGIES

| General Response Action | Remedial Technology | Process Options | Description | Determination of Applicability |
|---|---|---|---|---|
| Surface water controls (cont.) | Revegetation | Grasses, legumes, shrubs, and trees | Vegetative cover to stabilize land surface. | NA. Industrial site and contaminated areas not suitable for revegetation. |
| | Diversion/ collection | Dikes, berms, ditches, trenches, diversions,terraces, benches, chutes, downpipes, seepage basins,sedimentation basins/ponds,levees, and floodwalls | Various surface water diversion and collection methods. | NA. Site access is too limited to implement. |
| Solid material migration control | Capping (see gas migration controls) | | | |
| | Grading (see surface water controls) | | | |
| | Revegetation (see surface water controls) | | | |
| | Excavation/ removal | Backhoe, cranes and attachments, front-end loaders | Excavation of landfill material using various types of removal equipment. | Potentially applicable to offshore sediments and glue waste. |
| | | Scrapers | Remove surface soil. | Potentially applicable to offshore sediments and glue waste. |
| | | Pumps or vacuums | Remove free liquids or semi-liquid materials (sludge). | NA. Sludge materials do not occur at the site. |
| | | Drum grapplers | Mechanical attachments for removing drum containers. | NA. Site does not contain drum waste requiring excavation. |

# TABLE 6-3

## INITIAL SCREENING OF REMEDIATION TECHNOLOGIES

| General Response Action | Remedial Technology | Process Options | Description | Determination of Applicability |
|---|---|---|---|---|
| Contaminated sediment removal and containment | Sediment removal | Mechanical dredging (backhoe, dragline, or clamshell), hydraulic dredging (plain suction cutterhead and dustpan), pneumatic dredging (airlift, pneumatic, oozer) | Removing bottom sediments from offshore areas. | Potentially applicable to offshore sediments. |
| | Sediment turbidity controls and containment | Curtain barriers | Hydraulic isolation of sediments to allow control of sediment migration. | Potentially applicable to offshore sediments and glue waste. |
| In situ treatment | Chemical | Neutralization | Adding acid/bases to adjust pH. May serve as pretreatment to biodegradation. | NA. High/low pH problems do not occur onsite. |
| | | Precipitation | Formation of insoluble metal precipitate reduces contaminant mobility. | NA. Not appropriate for use with soils or sediments. |
| | | Oxidation | Chemical treatment with oxidizing agent to detoxify, precipitate, or solubilize metal contaminants. | NA. Primarily used with the treatment of cyanide. |
| | | Reduction | Treatment with reducing agent to convert metals to nontoxic state. | NA. Metals are only a concern in sediments. Chemical addition to sediments may be toxic to aquatic biota. |
| | | Chemical dechlorination | Chemical treatment strips chlorine atoms from organic molecules. | NA. Chlorinated organic molecules do not occur in sufficient quantities to warrant treatment. |
| | | Polymerization | Convert low molecular weight organics to longer chains that can reduce contaminant mobility. | NA. Not effective with inorganic metals. |
| | | Hydrolysis | Decomposition of chemical compound by reaction with elements of water. | NA. Not useful for heavy metal contamination. |
| | Biological (aerobic bioreclamation) | Nutrient supplement, microbial seeding | Altering environmental conditions in presence of oxygen to degrade contaminants. | NA. Not practical for sediments in situ. |

## TABLE 6–3

## INITIAL SCREENING OF REMEDIATION TECHNOLOGIES

| General Response Action | Remedial Technology | Process Options | Description | Determination of Applicability |
|---|---|---|---|---|
| In situ treatment (cont.) | Biological (anaerobic bio–reclamation) | Nutrient supplement, microbial seeding | Altering environmental conditions in absence of oxygen to degrade contaminants. | NA. Aerobic conditions required for biological treatment. |
| | Physical | Soil washing (solvent flushing) | Injection of acids/bases to solubilize metals, followed by extraction of metal ions. | NA. Application of acids or bases is not feasible in the vicinity of the Ship Canal. |
| | | Permeable treatment bed | Excavated trench placed perpendicular to groundwater flow and filled with appropriate material to treat plume as it flows through. | NA. Difficult to properly manage, given physical conditions. Groundwater contaminant levels do not warrant remediation. |
| | Solidification/ stabilization/ fixation | Cement–based | Mixing with Portland cement to form strong, durable waste–concrete composite. | NA to offshore sediments. Metals can solubilize and leach at treatment pH levels. |
| | | Silicate–based | Siliceous material is mixed with lime, gypsum, and other agents to produce waste block of high structural integrity. | NA to offshore contaminants. |
| | | Thermoplastic microencapsulation | Isolate waste by drying and dispensing it through heated plastic matrix (usually asphalt, bitumin, or paraffin). | NA. Used mainly for nuclear industry. |
| | | Surface microen–capsulation | Wastes are sealed in an organic binder or resin. | Potentially applicable to offshore sediments and glue waste. |
| | | Organic polymer binding | Use of polymer–forming organic chemicals to physically encapsulate wastes in a binder or resin. | NA to offshore contaminants. |
| | Thermal | Vitrification | Combine wastes with molten glass at high temperatures and then cool to a noncrystalline solid. | NA. Not possible to vitrify contaminants in water. |
| | | Radio frequency heating | Thermal destruction by radio frequency heating. | NA. Not useful for metals. |

## TABLE 6–3

## INITIAL SCREENING OF REMEDIATION TECHNOLOGIES

| General Response Action | Remedial Technology | Process Options | Description | Determination of Applicability |
|---|---|---|---|---|
| In situ treatment (cont.) | Thermal (cont.) | Ground freezing | Freezing surrounding soil to create physical barrier to contamination migration. | NA. Not a permanent solution. |
| Direct treatment | Biological (aerobic) | Activated sludge, trickling filters, rotating biological contactor, oxidation ditch, lagoon, sequencing batch reactor, fluidized farming | Biological treatment in presence of oxygen to remove organic matter from waste stream. | Potentially applicable for organic compounds. |
| | (anaerobic) | Single stage, two stages, two phases, fixed bed, fluidized bed, solide contact | Biological treatment in oxygen–deficient environment to remove organic matter from waste stream. | NA to solids. |
| Direct treatment (cont.) | Chemical | Neutralization | See in situ treatment. | NA. High/low pH not present. |
| | | Precipitation | See in situ treatment. | NA to solids. |
| | | Activated carbon adsorption | Adsorption of hazardous organic constituents onto carbon granules. | NA to solids. |
| | | Ion exchange | Toxic ions are exchanged with non–toxic ions in an exchange medium. | NA to solids. |
| | | Coagulate/flocculate | Chemical addition and gentle mixing causes contaminants to settle out. | NA to solids. |
| | | Reduction | See in situ treatment. | NA to solids. |
| | | Hydrolysis | See in situ treatment. | NA to solids. |
| | | Chemical de–chlorination | See in situ treatment. | NA to solids. |
| | | Ultraviolet radiation/ozonation | Used to disinfect aqueous streams and remove soluble refractory organics. | NA. Ineffective with heavy metal con–tamination. |

## TABLE 6–3

## INITIAL SCREENING OF REMEDIATION TECHNOLOGIES

| General Response Action | Remedial Technology | Process Options | Description | Determination of Applicability |
|---|---|---|---|---|
| Direct treatment (cont.) | Physical | Flow equalization | Management of aqueous stream to achieve constant flow rate. | NA to solids. |
| | | Sedimentation | Suspended solid removal in aqueous stream by gravity. | NA to solids. |
| | | Reverse osmosis | See in situ treatment. | NA to solids. |
| | | Liquid–liquid extraction | Solvent extraction of organics. | NA to solids. |
| | | Gravity flotation (oil/water) | Separation of materials of different specific gravities. | NA. No two–phase product at the site. |
| | | Steam distillation | Generally used for extraction of VOCs. | NA. VOCs are not present in significant concentrations. |
| | | Air stripping | Volatile contaminants in water are transferred to air. | NA. VOCs are not present in significant concentrations. |
| | | Steam stripping | Used in removal of VOCs, ammonia, and hydrogen sulfide. | NA. VOCs are not present in significant concentrations. |
| | | Filtration | Suspended particles are removed by forcing fluid through porous medium. | NA. VOCs are not present in significant concentrations. |
| | | Dissolved air flotation | Separation of solid or liquid particles from liquid phase using pressurized air. | NA to solids. |
| | Physical (cont.) | Dewatering (screens, hydraulic classifiers scalpers, centrifuges, gravity–thickening belt presses, filter presses, drying bed, vacuum filtration) | Physical operation to reduce water content of slurries and sludges. | NA. Sludges are not a concern at the site. |
| | Physical (solidification and stabilization) | Cement–based | See in situ treatment. | Potentially applicable to offshore sediments and glue waste. |
| | | Lime–based | See in situ treatment. | Potentially applicable to offshore sediments and glue waste. |

## TABLE 6–3

## INITIAL SCREENING OF REMEDIATION TECHNOLOGIES

| General Response Action | Remedial Technology | Process Options | Description | Determination of Applicability |
|---|---|---|---|---|
| Direct treatment (cont.) | Physical (solidification and stabilization) (cont.) | Thermoplastic microencapsulation | See in situ treatment. | Potentially applicable to offshore sediments and glue waste. |
| | | Organic polymer binding | See in situ treatment. | Potentially applicable to offshore sediments and glue waste. |
| | | Self–cementation | Used with wastes containing high calcium sulfate and calcium sulfite amounts. | NA. Site wastes do not contain required contaminants. |
| | | Surface encapsulation | Sealing wastes in high–density poly–propylene liner. | NA to site contaminants. |
| | | Vitrification | See in situ treatment. | Potentially applicable. |
| | | Fly ash, sawdust, or polymer amendment | Sorbents to eliminate free liquids and improve waste handling characteristics. | Potentially applicable. |
| | (thermal) | Glassification | Fuse into glassy solid by combining wastes with molten glass. | NA. Waste types are not suitable for this technology. |
| | | Rotary kiln, multiple hearth, molten salt, pyrolysis, molten glass, molten salt, wet air oxidation, liquid injection, cement kiln, plasma arc combustion, high temperature, fluid wall reactor | Thermal destruction of hazardous waste using high–temperature oxidation under controlled conditions. | Potentially applicable to offshore sediments and glue waste. |
| Disposal | Wastewater | Discharge to water treatment plant | Discharge treated water to sanitary sewer. | NA to solids. |
| | | Discharge to water body | Discharge treated water to Lake Washington Ship Canal. | NA to solids. |

## TABLE 6-3

## INITIAL SCREENING OF REMEDIATION TECHNOLOGIES

| General Response Action | Remedial Technology | Process Options | Description | Determination of Applicability |
|---|---|---|---|---|
| Disposal (cont.) | Wastewater (cont.) | Evaporation | Discharge treated water to evaporation pond. | NA. Evaporation is not appropriate for solids. |
| | | Deep well injection | Inject treated water into subsurface. | NA. Not acceptable to environmental agencies. |
| | | Thermal destruction | Incineration or other heating method to vaporize treated water. | NA to solids. |
| | Solid waste | Land application | Using wastes as nutrients for farming. | Potentially applicable for nonhazardous items. |
| | | Landfill (onsite or offsite) | Place waste materials in appropriate landfill. | Potentially applicable in offsite location. Insufficient area for onsite landfill. |
| | | Ocean dumping | Disposal of wastes in ocean waters. | NA. Prohibited by Ocean Dumping Ban of 1988. |
| | | Reuse/recycle | Reclaim heavy metals. | NA. Not applicable, given contaminant consideration. |
| Institutional controls | Access restrictions | Land/water use restrictions | Changes to property deed to restrict site land and water use. | Potentially applicable. |
| | | Fencing or other barriers | Use barrier to limit access to site. | Potentially applicable. |
| | | Building/improvement restrictions | Stipulation of improvements prior to construction of buildings. | Potentially applicable. |
| Contaminated utilities | | In situ cleaning, leak repair, relining, sleeving, excavation and removal, replacement or relocation, diversion wall | Methods to clean public water or sewer systems. | NA. Contaminated utilities are not considered a potential problem. |
| Contaminated water supply | | Alternate water source and onsite treatment | Treating contaminated water or supplying clean source to affected areas. | NA. All local water supplies are delivered through piping. |

## TABLE 6–4

## PROCESS OPTION EVALUATION

| General Response Action | Remedial Technology | Process Options | Effectiveness | Implementability | Cost | Investigate Further | Justification |
|---|---|---|---|---|---|---|---|
| No action | None | Groundwater monitoring | Response action does not achieve remedial action objectives. | No action option is usually unacceptable to state/federal agencies. | Low | Yes | Required by National Contingency Plan and the Model Toxics Control Act. |
| Gas and solid material migration controls | Capping | Clay | Effective for preventing surface water infiltration and further migration of contaminants. Effective in isolating contaminants from environment. Requires long-term monitoring and maintenance. Restricts future land use. | Not technically difficult to implement. Might require construction permit. | Moderate | Yes | Can be effective in immobilizing glue press waste and reducing future contaminant migration to the Ship Canal clay caps. Can have a hydraulic conductivity as low as 1E-7 cm/sec. Not effective to place a clay cap on offshore sediments. |
| | | Asphalt | Effectiveness similar to that of clay cap. Potential problems with cracking and deterioration, allowing surface water infiltration. Long-term maintenance and monitoring needed. Restricts future land use. | Not technically difficult to implement. Might require construction permit and landfill siting approval. | Low | Yes | Can be effective in reducing contaminant migration in the boiler ash fill. Not possible to construct in sediment and glue press waste areas. Asphalt caps represent single-layer covers and appear to offer very low permeability rates (1E-7 cm/sec) when special materials are used. Furthermore, asphalt covers are particularly effective single-layed caps, as periodic applications of special surface sealants can greatly extend asphalt life and maintain low permeability of asphalt. |
| | | Sand | Effective in isolating contaminants from the environment. May be used at surface or below water. May be affected by weathering and erosion. Requires long-term monitoring. | Surface application would not pose technical difficulty; however, subsurface application in the Ship Canal would require technical expertise. | Moderate to high | Yes | A sand cap would effectively immobilize contaminated soil/sediments in the boiler ash area and in the offshore sediments. |
| | | Concrete | Effectiveness similar to that of clay cap. Problems with surface cracking, deterioration, and subsequent surface water infiltration. Restricts future land use. | Not technically difficult to implement. Might require construction permit and landfill siting approval. | Moderate | Yes | Can be effective for encapsulating glue pile wastes and reducing potential for offsite migration of anthracene, while serving as a basis for future construction needs. |
| | | Multimedia clay and synthetic liner covered by soil | Highly effective for preventing surface water infiltration and subsequent migration of contaminants. Liner and clay system is more likely to remain impermeable than other types of covers. | Not constructable over small glue piles. Cannot place multilayer caps or synthetic liner on offshore sediments. | High | No | Not warranted for boiler ash. Cannot be constructed in sediment and glue waste areas. |
| | Gas collection and recovery | Passive pipe vents/ trench vents | Effective in collecting convective gas flow in porous media. | Difficulties with synthetic membrane installation (gaps caused by poor workmanship or tears caused by rocks). Might need permit by Puget Sound Air Pollution Authority. | Moderate | No | High costs for backfilling trenches and use of synthetic membrane as a barrier to limit gas migration, plus uncertain collection efficiency, suggest that this option is not feasible. Also, high groundwater table prohibits effective recovery of methane. |
| | Increase ventilation | Installation of blowers | Effective in reducing methane accumulation in semi-confined spaces. | Easily implemented. | Low | No | Methane accumulation not found to be current problem onsite. Can be implemented as a result of long-term monitoring or future construction activities onsite. |
| Surface water controls | Capping (see gas and solid material migration controls) | | | | | | |
| | Grading | Scarification, tracking, and contour furrowing | Especially effective in rerouting stormwater runoff from large acreage. Transfers contaminants from urban areas to other areas of Ship Canal. | Easily implemented. Might require grading and filling permit. | Low | No | Grading can be useful for minimizing storm runoff to the Ship Canal on the former Champion site. However, contaminants from urban runoff are deposited in other places within the Ship Canal. |

## TABLE 6-4

## PROCESS OPTION EVALUATION

| General Response Action | Remedial Technology | Process Options | Effectiveness | Implementability | Cost | Investigate Further | Justification |
|---|---|---|---|---|---|---|---|
| Solid waste excavation and removal | Excavation/ removal | Backhoe, front-end loader, scraper | Highly effective in removing source of contaminants. | Easily implemented technically. Applicable with other process options. | Low | Yes | Excavation is a necessary technology for any alternative involving removal of material for disposal or treatment. |
| | Grading (see surface water controls) | | | | | | |
| | Capping (see gas and solid material migration controls) | | | | | | |
| Contaminated sediment removal and containment | Mechanical dredging | Backhoe or clamshell | Very effective in removing existing shallow sediment contamination. | This method of sediment removal may be ideally suited for removing the glue piles. Additional structural support may be necessary. | Moderate | No | Low effectiveness since dredged area will be recontaminated by ongoing urban runoff. Much more costly than capping. |
| | Hydraulic dredging (hand-dredging) | Plan suction dredge, bucket, ladder cutterhead dredge | Very effective in removing shallow sediments while reducing the amount of turbidity emitted. Does not address ongoing contamination. | Easily implemented. Equipment is readily accessible and easily barge-mounted. | High | No | Hydraulic dredging may be the most effective technology, given existing site conditions and obstacles that can be encountered. |
| | Sediment turbidity control | Curtain barriers, silt curtains | Very effective in limiting migration of particulates. | Easily implemented. May be less effective in areas where currents exceed 1 knot. | Moderate | Yes | Can be effective in limiting sediment migration. Can also be used to control turbidity associated with dredging. |
| Direct treatment (solids) | Solidification, stabilization, fixation | Cement/lime-based solidification, flyash/sawdust | May be very effective in stabilizing metals within the boiler ash fill. | Implementation requires technical expertise. | Moderate | Yes | May be appropriate to immobilize metals in boiler ash fill. |
| | | Thermoplastic solidification, microencapsulation | Experimental technology that requires pilot testing. Similar in effectiveness to cement/lime-based solidification. Most effective on very dry solids. | Requires skilled labor and high energy requirements. | High | No | High costs associated with unproven technology. Glue matrix not suitable for technology. High water content of glue/sediments not suitable for application. |
| | | Vitrification | Offers greatest degree of containment. | Skilled labor needed; intensive energy requirements. | Very high | No | Experimental technology more suited to highly toxic contaminants. |
| | Physical | Surface encapsulation | Effective for preventing leaching. | Skilled labor needed; intensive energy requirements. | Moderate | No | Glue matrix not suitable. More expensive than solidification |
| | Biological | Fluidized forming | Biological transformation of organic compounds is possible. | May require expert technical skill to successfully treat waste. Treatability study likely. | High | No | Potential for successful treatment of carbon disulfide in the solvent tank area is not high enough to warrant further investigation. |
| | Thermal | Multiple hearth and rotary kiln | Very effective in reducing volume and toxicity of organic contaminants. | Easily implemented; might require offsite transport. | High | No | Not effective for inorganic compounds in sediments. For glue waste, disproportionate cost compared with benefits, given low contaminant concentrations and other lower-cost disposal options. |
| Land disposal for solid materials | Offsite disposal | Solid waste landfill | Effective in removing source of contaminants. Requires offsite transport. | Easily implemented. Might require public health department approval. | High | Yes | Suitable disposal option for nonhazardous and slightly hazardous wastes. May be very cost-effective for some areas. |
| | | Hazardous waste landfill | Effective in removing source of contaminants. Requires offsite transport. Risk of future contamination if offsite landfill protective system fails. | Easily implemented. | High | Yes | Suitable disposal option for hazardous solid waste. High cost because of potentially large quantities requiring disposal. |

## TABLE 6-4

## PROCESS OPTION EVALUATION

| General Response Action | Remedial Technology | Process Options | Effectiveness | Implementability | Cost | Investigate Further | Justification |
|---|---|---|---|---|---|---|---|
| Land disposal for solid materials | Onsite | Land application | Effective as a disposal method for clean wastes. Does not reduce migration of metals or PAHs in sediments or glue waste. | Environmental agency and public objections to this disposal method might arise. Might need ongoing surface water and groundwater monitoring. | Moderate | No | Can be very cost-effective for disposal of clean wastes, but simply transfers wastes from offshore to onshore. Migration offsite possible. Little space available for land application. |
| Institutional controls | Access restrictions | Land/water use restrictions | Does not reduce contamination. Exposure routes and exposed populations are minimized. | Legal requirement easy to implement. | Low | Yes | Required for restricting land use if affected soil and groundwater remain in place. |
| | | Fencing | Reduces chance for dermal contact. | Easily implemented. | Moderate | No | Site access already restricted. |
| | Groundwater monitoring | | Effective for detecting changes in contaminant type and quantity. | Easily implemented. | Moderate | Yes | Might be required for some remedial alternatives, such as capping. |

## TABLE 6-5

## SUMMARY OF APPLICABLE LAWS USED DURING THE FS

### Chemical-Specific Laws

Clean Water Act (33 U.S.C. 1251), requirements established pursuant to Section 303, water quality standards

### Action-Specific Laws

- National Ambient Air Quality Standards (40 CFR part 50)
- OSHA requirements for workers engaged in response or other hazardous waste operations (29 CFR 1910.120)
- WAC 173-470, Ambient Air Quality Standards
- WAC 173-304, Minimum Functional Standards for Solid Waste Handling
- WAC 173-340, Hazardous Waste Cleanup
- WAC 173-201, Water Quality Standards for Waters of the State of Washington
- WAC 173-154, Protection of Upper Aquifer Zones
- WAC 173-160, Minimum Standards for Construction and Maintenance of Water Wells

### Location-Specific Laws

- Coastal Zone Management Act of 1972, 16 U.S.C. 1451
- Rivers and Harbors Act (33 U.S.C. 403)
- WAC 173-17, Shoreline Management Act - Enforcement Regulations
- WAC 173-18, Shoreline Management Act - Streams and Rivers Constituting Shorelines of the State

### To Be Considered

WAC 173-340, Model Toxics Control Act Cleanup Regulation 28 February 1991

## TABLE 6-6

## SUMMARY OF DETAILED ANALYSIS OF ALTERNATIVES

| Evaluation Criteria | Entire Site Operable Unit, Alternative ES-1 |
|---|---|
| Alternative Description | **No action (at all operable units); includes reinvestigation of site every five years for 30 years** |
| Overall Protection of Human Health and the Environment | Alternative ES-1 does not have an impact on potential risks that may be a result of onsite chemical contaminants. This alternative does not reduce current risks to human health and the environment, although current risks to these populations appear minimal. |
| Compliance with Applicable Laws | Applicable laws appropriate for the site are not addressed through this Alternative ES-1. This alternative does not address contaminants detected at levels above other comparison criteria. |
| Short-Term Effectiveness | Since no action is taken, potential exposure of workers is not increased. Possible impacts to the community remain unchanged. |
| Long-Term Effectiveness | Alternative ES-1 does not mitigate potential human health or environmental impacts. The lack of controls to limit future land use can expose sensitive populations to hazardous substances or environments. |
| Reduction in Toxicity, Mobility, or Volume | Alternative ES-1 has no impact on reduction of the volume or mobility of contaminants identified at the site. Toxicity of organic contaminents in glue/sediments is likely to be reduced through dilution and degradation. This process will probably be slow, due to the lack of light below the buildings. |
| Implementability | There are no administrative or technical issues to complicate implementation of this alternative. Extensive monitoring to assess changes in contaminant concentrations is easily accomplished. |
| Cost | Since additional monitoring is minimal, there is little cost for implementation. The present worth cost for this alternative is $62,800. Additional details regarding cost are presented in Appendix H. |
| Community Acceptence | The public has not offered comments on acceptance of this alternative. Comments, if available, will be included following public review. |
| Degree of Recycling, Reuse, and Waste Minimization | This alternative does not involve the use of recycling, reuse, or waste minimization. |

## TABLE 6-6

## SUMMARY OF DETAILED ANALYSIS OF ALTERNATIVES

| Evaluation Criteria | Entire Site Operable Unit, Alternative ES-2 |
|---|---|
| Alternative Description | **Land and water use restrictions and long-term monitoring.** |
| Overall Protection of Human Health and the Environment | Protection to human health is significantly increased by addressing the most significant exposure routes, direct contact and ingestion. Land and water use restrictions provide assurance that site groundwater will not be used as a drinking water source and that future development of the site will not create an explosive or asphyxiation hazard due to methane accumulation. Human contact with site materials would also be significantly reduced by prohibiting trespassing and recreational site use. |
| Compliance with Applicable Laws | This alternative restricts future land use and does not address laws associated with potential human exposure to soil and groundwater (drinking water or common uses of the site by other populations). This alternative does not introduce additional action-specific and location-specific laws. |
| Short-Term Effectiveness | Implementation of this alternative would not result in an increased risk to the community or the environment. Future activities requiring maintenance or upgrade of the site would be performed by workers with hazardous waste training and appropriate personal protective equipment. Under such circumstances, no increased risk to workers is expected. |
| Long-Term Effectiveness | Land and water restrictions effectively limit the magnitude of residual risk by notifying current and future landowners of site contamination problems. Notices at the site would indicate that activities in problem areas should be conducted by workers with appropriate personal protective equipment and training. Long-term monitoring warns site occupants/regulatory agencies of changing conditions onsite. |
| Reduction in Toxicity, Mobility or Volume | With this alternative there is no reduction in toxicity, mobility or volume of waste materials. Only the potential for human contact is decreased. |
| Implementability | No technical or administrative difficulties are expected with implementation of this alternative. Land and water use restrictions are easily implemented through an order or agreement with the WDOE. |
| Cost | The present worth cost for implementation of this alternative are anticipated to be approximately $84,200. Additional details regarding cost are presented in Appendix H. |
| Community Acceptance | The public has not offered comments on the acceptance of this alternative. Comments, if available, will be included following public review. |
| Degree of Recycling, Reuse and Waste Minimization | This alternative does not involve recycling, reuse or waste minimization. |

## TABLE 6-6

## SUMMARY OF DETAILED ANALYSIS OF ALTERNATIVES

| Evaluation Criteria | Boiler Ash Fill, Alternative BA-1 |
|---|---|
| Alternative Description | **Institutional controls and long-term monitoring.** |
| Overall Protection of Human Health and the Environment | Protection of human health is significantly increased by addressing the most significant exposure routes, direct contact and ingestion by the general public. Since the contaminants are not readily available for human contact (below an existing sand cap) this control lends increased protection to existing low risk levels. |
| Compliance with Applicable Laws | This alternative restricts future land use in the boiler ash area and does not address laws associated with potential human exposure to soil. However, since the boiler ash fill is currently covered with a sand cap, potential human exposure appears to be very limited. |
| Short-Term Effectiveness | Implementation of this alterative would not result in an increased risk to the community or the environment. Future activities at the site requiring maintenance or upgrade would be performed by workers with the appropriate personal protective equipment and training. |
| Long-Term Effectiveness | Institutional controls effectively limit the magnitude of residual risks by notify current and future land owners of site contamination problems. Notices in the deed indicate that activities in the boiler ash fill area should be conducted by workers with the appropriate personal protective equipment and training. |
| Reduction in Toxicity, Mobility, or Volume | With this alternative there is no reduction in toxicity, mobility or volume of the waste. Only the potential for human exposure is reduced. |
| Implementability | There are no technical or administrative obstacles anticipated with implementation of this alternative. Institutional controls are easily implemented by initiating deed restrictions in accordance with WAC 173-340-440. |
| Cost | The present worth cost associated implementation of this alterative are estimated at $71,000. Additional details regarding cost are presented in Appendix H. |
| Community Acceptance | The public has not offered comments on acceptance of this alternative. Comments, if available, will be included following public review. |
| Degree of Recycling, Reuse, and Waste Minimization | This alternative does not involve the use of recycling, reuse, or waste minimization. |

## TABLE 6-6

## SUMMARY OF DETAILED ANALYSIS OF ALTERNATIVES

| Evaluation Criteria | Boiler Ash Fill, Alternative BA-2 |
|---|---|
| Alternative Description | **Removal of boiler ash fill and offsite disposal.** |
| Overall Protection of Human Health and the Environment | Removal and offsite disposal of the boiler ash fill provides the highest level of protection against potential human exposure. The primary human exposure routes (dermal absorption and ingestion) would be virtually eliminated with the application of clean fill in the excavation. |
| Compliance with Applicable Laws | Contaminants detected in the boiler ash at levels above the cleanup criteria are removed through this alternative and disposed of offsite, thereby, addressing chemical-specific laws. |
| Short-Term Effectiveness | Few detrimental impacts to the surrounding community are expected during boiler ash removal. Protection would be implemented to prevent blowing dust and direct contact by the contractors. In addition, procedures are necessary to prevent boiler ash from being discharged into Lake Union during excavation. |
| Long-Term Effectiveness | Long-term impacts to humans through exposure to the boiler ash are mitigated with the removal of this material. The magnitude of residual risks are expected to be within acceptable levels for the compliance cleanup exposure model. |
| Reduction in Toxicity, Mobility, or Volume | This alternative does not involve a treatment process, therefore, there is no reduction in toxicity or volume. The mobility of the boiler ash would be significantly reduced or eliminated through disposal of the material at a sanitary landfill. Disposal of the material at a landfill with an inadequate leachate collection/treatment system may result in future groundwater problems. This material would also affect landfill capacity. |
| Implementability | Removal of the boiler ash can be accomplished using readily available equipment and personnel. Shoring and installation of sheet piling may be necessary to prevent damage to existing buildings. Administrative difficulties are not anticipated to present a significant obstacle. |
| Cost | The present worth cost for excavation, removal and disposal of the boiler ash are estimated at $940,000. Additional details regarding cost are presented in Appendix H. |
| Community Acceptance | The public has not offered comments on acceptance of this alternative. Comments, if available, will be included following public review. |
| Degree of Recycling, Reuse, and Waste Minimization | This alternative does not involve the use of recycling, reuse, or waste minimization. |

## TABLE 6-6

## SUMMARY OF DETAILED ANALYSIS OF ALTERNATIVES

| Evaluation Criteria | Boiler Ash Fill, Alternative BA-3 |
|---|---|
| Alternative Description | **Solidification of the boiler ash and onsite disposal.** |
| Overall Protection of Human Health and the Environment | Solidification of the boiler ash provides a high level protection against potential human exposure to the boiler ash material. Contaminants are virtually immobilized through fixation, therefore; potential human exposure routes are greatly reduced. |
| Compliance with Applicable Laws | The preference for permanent solution by WDOE and compliance with chemical-specific laws are addressed by this alternative. This alternative also complies with action-specific and location-specific laws. |
| Short-Term Effectiveness | The solidification process presents minimal short-term impacts to the surrounding community. However, the excavation of the boiler ash may produce fugitive dust. Therefore, dust control measures would be implemented to address this concern. Excavation may also increase the bioavailability of contaminants to the Ship Canal. |
| Long-Term Effectiveness | Solidification of the boiler ash requires little maintenance, if any, and is more permanent than capping. It is possible that metal could leach from the fixed ash in the long-term, although leachability appears to be low. The amount of residual risk is expected to be well within acceptable ranges established under the compliance cleanup exposure model. |
| Reduction in Toxicity, Mobility, or Volume | Solidification reduces the mobility of the boiler ash and associated contaminants, although the toxicity is not affected. The volume of the waste material is increased with the addition of solidification agents. |
| Implementability | Technologies are available to fix the boiler ash material; however, a bench-scale test would be necessary to confirm the best mix of solidification agents. Excavation of the boiler ash is easily accomplished except in the vicinity of the boiler building where shoring and sheet piling may be necessary to prevent undermining of the building. No administrative obstacles are expected with implementation of this alternative. |
| Cost | The present worth capital cost associated with implementation of this alternative are estimated at $1,469,800. Additional details regarding cost are presented in Appendix H. |
| Community Acceptance | The public has not offered comments on acceptance of this alternative. Comments, if available, will be included following public review. |
| Degree of Recycling, Reuse, and Waste Minimization | This alternative does not involve the use of recycling, reuse, or waste minimization. |

## TABLE 6-6

## SUMMARY OF DETAILED ANALYSIS OF ALTERNATIVES

### Boiler Ash Fill, Alternative BA-4

| Evaluation Criteria | |
|---|---|
| Alternative Description | **Capping with sand or asphalt.** |
| Overall Protection of Human Health and the Environment | Risks posed by the boiler ash are addressed through installation of a cap; however, long-term maintenance of the cap is required to ensure the integrity of the remedial measure. Completion of the cap would greatly reduce the risks to humans, if any, by eliminating the exposure routes (ingestion and dermal absorption). |
| Compliance with Applicable Laws | A cap placed over the boiler ash material would meet the desired cleanup goals. Shoreline and grade/fill permits may be required for implementation. Action-specific and location-specific laws are addressed by this alternative. |
| Short-Term Effectiveness | Implementation of this alternative does not result in detrimental impacts to the community. Workers conducting the activities are required to have the appropriate personal protective equipment and training. Under such circumstances, no increased risks are expected for the workers. Implementation of this alternative would not result in potentially detrimental impacts to humans or the environment which may occur with other remedial alternatives for the boiler ash. |
| Long-Term Effectiveness | Installation of a cap is expected to be effective in limiting potential human exposure to the boiler ash material. Residual human risk, if any, would be minimal. Long-term effectiveness of the this alternative would require regular maintenance. |
| Reduction in Toxicity, Mobility, or Volume | Toxicity and volume of the waste material is not reduced since no treatment process is employed. However a reduction in contaminant mobility is realized immediately upon installation of a cap. |
| Implementability | Installation of a cap over the boiler ash does not pose technical or administrative difficulties. |
| Cost | Capital cost associated with implementation of this alternative are estimated at $307,300. Present worth O&M cost over 30 years are expected to be $5,100. Additional details regarding cost are presented in Appendix H. |
| Community Acceptance | The public has not offered comments on acceptance of this alternative. Comments, if available, will be included following public review. |
| Degree of Recycling, Reuse, and Waste Minimization | This alternative does not involve the use of recycling, reuse, or waste minimization. |

## TABLE 6-6

## SUMMARY OF DETAILED ANALYSIS OF ALTERNATIVES

| <u>Evaluation Criteria</u> | Glue Press Area, Alternative GP-1 |
|---|---|
| Alternative Description | **Land use restriction in the glue press waste area and long-term monitoring.** |
| Overall Protection of Human Health and the Environment | The potential risk, if any, is reduced with implementation of this alternative. Land use restriction provide assurance that human contact with the glue piles and surrounding sediments (which contain anthracene) is restricted. Land use restrictions do not address potential environmental impacts, however, based on the RA potential impacts to aquatic organism are unknown and may be minimal. |
| Compliance with Applicable Laws | No chemical-specific laws apply to anthracene. However, available information does not indicate that the glue piles and surrounding area present a human health risk. This alternative would meet identified applicable laws. |
| Short-Term Effectiveness | Implementation of this alternative would not result in an increased risk to the community or the environment. Future activities in this portion of the site would be performed by workers with hazardous waste training and the appropriate personal protective equipment. Under such circumstances, no increased risk to the workers is expected. |
| Long-Term Effectiveness | Land use restrictions actively limit the magnitude of residual risk by notifying current and future land owners of possible contamination problems. Notices at the site would be posted indicating that workers performing activities in this area should have the appropriate personal protection and training. |
| Reduction in Toxicity, Mobility, or Volume | There is no reduction in toxicity, mobility or volume with implementation of this alterative. Only potential human exposure is reduced. |
| Implementability | No technical or administrative difficulties are expected with implementation of this alternative. Land use restrictions are easily implemented through an agreement or order with the WDOE. |
| Cost | The present worth cost for implementation of this alternative are estimated at $71,000. Additional details regarding cost are presented in Appendix H. |
| Community Acceptance | The public has not offered comments on acceptance of this alternative. Comments, if available, will be included following public review. |
| Degree of Recycling, Reuse, and Waste Minimization | This alternative does not involve the use of recycling, reuse, or waste minimization. |

## TABLE 6-6

## SUMMARY OF DETAILED ANALYSIS OF ALTERNATIVES

### Glue Press Area, Alternative GP-2

| Evaluation Criteria | |
|---|---|
| Alternative Description | **Removal of glue piles and surrounding sediments and offsite disposal.** |
| Overall Protection of Human Health and the Environment | Removal and offsite disposal of the glue piles and surrounding sediments offers the highest level of protection to human health and the environment. Potential human risks are virtually eliminated through removal of the waste material. Potential environmental effects are reduced in the long-term; however, turbidity caused by waste removal may increase the short-term bioavailability of the contaminants. |
| Compliance with Applicable Laws | Removal and offsite disposal meets chemical-specific laws, although available information indicates that anthracene may not pose a human health risk. Location-specific and action-specific laws are also addressed by this alternative. Disposal at a landfill without treatment is disfavored based on current WDOE guidance. |
| Short-Term Effectiveness | Removal of the glue piles and surrounding sediments would require installation of a temporary silt curtain to control migration of disturbed sediments. With control of turbidity, reduced risks to the community or nearby aquatic life are expected. Some detrimental impacts are expected from dewatering of sediments and disposal of effluent. |
| Long-Term Effectiveness | The magnitude of existing risks can not be quantified, because of limited information on effects of anthracene on human health and environment. Therefore, residual risk is difficult to estimate. If anthracene results in adverse human health or environmental effects, long-term impacts are significantly mitigated with removal of a major source and surrounding impacted sediments. Reliability of ultimate control (i.e., disposal) of contaminated material at a sanitary landfill should be high, since the material is generally insoluble and the landfill would have a leachate collection and treatment system. |
| Reduction in Toxicity, Mobility, or Volume | This alternative does not involve a treatment process, except for dewatering of waste material that will probably be required prior to disposal in the landfill. Placing material in a landfill having a protective liner should decrease its ultimate mobility. Overall volume and toxicity of the material are not affected. |
| Implementability | Technical difficulties may be encountered in gaining access to the glue press waste area. Removal of glue piles requires partial removal of the floor boards and joists of the existing building. Additional effort would be needed to install suitable access and support for backhoe equipment. Administrative needs may include acquisition of a shoreline building permit and/or a SEPA permit. The reliability of excavation and disposal is high. |
| Cost | Costs for excavation, removal, and disposal of waste material are expected to be moderate because of the difficulty of accessing waste material. The present worth estimate for this alterative is $641,400. Additional details regarding costs are presented in Appendix H. |
| Community Acceptance | The public has not offered comments on acceptance of this alternative. Comments, if available, will be included following public review. |
| Degree of Recycling, Reuse, and Waste Minimization | This alternative does not involve the use of recycling, reuse, or waste minimization. |

## TABLE 6-6

## SUMMARY OF DETAILED ANALYSIS OF ALTERNATIVES

### Glue Press Area, Alternative GP-3

| Evaluation Criteria | |
|---|---|
| Alternative Description | **Capping the glue piles and surrounding sediments with concrete or clay.** |
| Overall Protection of Human Health and the Environment | There is limited data on potential toxicological effects on humans and aquatic organisms from exposure to anthracene. Therefore, potential impacts and protection provided are difficult to evaluate. Risks posed by the glue piles and nearby sediments are addressed through cap installation; however, long-term maintenance is required to ensure the integrity of a cap. A cap can be a very effective barrier between potentially contaminated materials and human and aquatic recipients. |
| Compliance with Applicable Laws | A cap placed over the glue press waste area would meet the desired cleanup objectives. Shoreline and grade/fill permits may be required for implementation and should not present a significant obstacle. |
| Short-Term Effectiveness | Risk to the surrounding community is not expected to increase during construction of a clay or concrete cap, although the concrete cap may cause a slight pH increase in nearby water. Installation of a temporary silt curtain may be necessary to control increased turbidity and subsequent contaminant migration. |
| Long-Term Effectiveness | The magnitude of residual risks, if any, to human health and the environment would be significantly reduced. However, due to a lack of toxicological data, risks to humans or aquatic organisms cannot be quantified. Controls are expected to be very effective in limiting exposure of potential human recipients and aquatic life in the vicinity of the glue piles. Continued contaminant loading from urban runoff may counteract the affects of the cap. |
| Reduction in Toxicity, Mobility, or Volume | Toxicity or volume of the waste materials is unaffected, since no treatment processes are employed. A reduction in contaminant mobility is realized immediately upon installation of the cap, even though waste materials are not treated. |
| Implementability | Installation of clay mats or concrete over the glue waste probably does not pose technical or administrative difficulties. Concrete or clay mats are frequently used as liners for ditches and canals as a hydraulic barrier. Materials for construction are readily available. Installation of a cap is very labor-intensive. Permits for installation of all caps may be necessary. Annual inspections are easily implemented to evaluate the effectiveness of the option. |
| Cost | Capital costs for installation of a cap in the glue press area are estimated at $231,200. Present worth costs over a 30-year period are expected to be approximately $46,700. Additional details regarding cost are presented in Appendix H. |
| Community Acceptance | The public has not offered comments on the acceptance of this alternative. Comments, if available, will be included at the conclusion of the public comment period. |
| Degree of Recycling, Reuse, and Waste Minimization | This alternative does not involve the use of recycling, reuse, or waste minimization. |

## TABLE 6-6

## SUMMARY OF DETAILED ANALYSIS OF ALTERNATIVES

| Evaluation Criteria | Offshore Sediments, Alternative OS-1 |
|---|---|
| Alternative Description | **Land use restrictions and long-term monitoring.** |
| Overall Protection of Human Health and the Environment | Land use restrictions will limit human disturbance of offshore sediments, thereby limiting the bioavailability of the contaminants. Human contact is not a concern, although trespassing and recreational use of the site would be restricted in the future. This alternative would not address future urban runoff which appears to be a potential contaminant source. |
| Compliance with Applicable Laws | Contaminants detected in the nearshore sediments at levels above background in the Lake Union or AETs are not addressed, although AETs are not considered applicable laws which are relevant to freshwater sediments. |
| Short-Term Effectiveness | Implementability of this alternative would not result in an increased risk to the community or the environment. Future activities requiring direct contact with the sediments would be performed by workers with the appropriate personal protective equipment and appropriate training. |
| Long-Term Effectiveness | This alternative limits potential disturbance of the offshore sediments thereby minimizing potential bioavailability to aquatic organisms. This alternative does not reduce the residual risk, if any, presented by chemically impacted sediments. Continual contaminant loading through urban runoff and nearby industry (ship refinishing) which presents a source of contamination, is not addressed by this alternative. |
| Reduction in Toxicity, Mobility, or Volume | With this alternative there is no reduction in toxicity, mobility, or volume of the waste material. Only the human contact with, and disturbance of, the sediments are reduced. |
| Implementability | No technical or administrative difficulties are expected with implementation of this alterative. Land use restrictions are easily implemented with or through an order or an agreement with the WDOE. |
| Cost | The present worth costs for implementation of this alternative are estimated at $71,000. Additional details regarding cost are presented in Appendix H. |
| Community Acceptance | The public has not offered comments on acceptance of this alternative. Comments, if available, will be included following public review. |
| Degree of Recycling, Reuse, and Waste Minimization | This alternative does not involve the use of recycling, reuse, or waste minimization. |

## TABLE 6-6

## SUMMARY OF DETAILED ANALYSIS OF ALTERNATIVES

| Evaluation Criteria | Offshore Sediments, Alternative OS-2 |
|---|---|
| Alternative Description | **Capping offshore sediments with sand or concrete.** |
| Overall Protection of Human Health and the Environment | A sand or concrete cap over the offshore sediments provides a semi-permanent barrier between potential aquatic recipients and contaminated sediments, thus achieving the desired cleanup goals. Continued contaminant loading from urban runoff is likely to counteract the beneficial effects of the cap. |
| Compliance with Applicable Laws | This alternative reduces the mobility of contaminants identified in the offshore sediments, thereby addressing contaminant concentration detected above the cleanup criteria. However, the identified cleanup criteria are not considered applicable laws. |
| Short-Term Effectiveness | Installation of concrete in industrial areas is a frequent occurrence. Therefore, no increased risks to the community are expected. Workers, expect for divers, do not come into contact with the sediments during cap installation; so, no increased risks are expected. High pH discharges during concrete placement (if used) can impact aquatic life. Divers needed to inspect the cap during and after construction may require some type of personal protective equipment and may realize a minimal increase in risk. |
| Long-Term Effectiveness | A cap creates an effective barrier between chemically impacted sediments and potential aquatic recipients that reside below existing buildings. Residual risks to aquatic life, if any, are expected to be very limited because a cap essentially covers all areas below existing buildings, including the glue piles. Cracking appears to be the only factor that can impact the effectiveness of a concrete cap. However, overall effectiveness is not likely to be reduced. A serious concern is recontamination of a cap through nearby industry and continued urban runoff from the surrounding area, including the Ballard Bridge. |
| Reduction in Toxicity, Mobility, or Volume | Toxicity and volume of contaminants occurring in sediments below onsite buildings are not affected by this alternative. However, potential mobility of contaminants sorbed to sediments is significantly reduced or eliminated when sediments are capped, even though contaminants are not directly treated. The technology is not irreversible, although excavation of the cap would be required to access underlying sediments. |
| Implementability | Installation of sand fill or concrete in shallow water is relatively common, although installation below buildings is more difficult. Equipment and materials needed to construct the cap are locally available. Considerable technical expertise does not appear necessary. Agency acceptance may be difficult because of the potential for increasing the pH of the surrounding water column. Increased pH can be addressed with application or buffers to concrete mixtures. Due to limited access, cap installation is expected to be moderately labor-intensive. Because a sediment cap is fixed (especially concrete), ongoing maintenance or monitoring of aquatic impacts would be minimal. |
| Cost | Capital costs for institutional controls and capping boiler ash, glue piles, and offshore sediments are estimated at $1,405,100. Costs for over 30 years are estimated at $1,442,100 based on present worth value. Additional details regarding cost are presented in Appendix H. |
| Community Acceptance | The public has not offered comments on acceptance of this alternative. Comments, if available, will be included following public review. |
| Degree of Recycling, Reuse, and Waste Minimization | This alternative does not involve the use of recycling, reuse, or waste minimization. |

## TABLE 6-6

## SUMMARY OF DETAILED ANALYSIS OF ALTERNATIVES

| Evaluation Criteria | Offshore Sediments, Alternative OS-3 |
|---|---|
| Alternative Description | **Installation of silt curtain around offshore sediments.** |
| Overall Protection of Human Health and the Environment | The potential exposure of larger aquatic organisms (fish and mammals) is effectively reduced by limiting their mobility within chemically impacted areas (glue press waste area and offshore sediments). In addition, the silt curtain can be up to 90 percent effective in limiting the mobility of contaminated sediments inside the controlled area. Potential human exposure would be unaffected; however, the RA concluded that direct contact and ingestion by humans was not a viable exposure route. |
| Compliance with Applicable Laws | Low concentrations of contaminants in offshore sediments are not directly addressed by this alternative, except in the limitation of offsite transport of suspended sediments. |
| Short-Term Effectiveness | Minimal risk to workers is expected during installation of a silt curtain, because prolonged contact with sediments containing very low contaminant levels is not anticipated. Short-term impacts to the environment can be realized during installation, resulting in increased turbidity due to increased activity in the area. The magnitude of any short-term environmental impacts is unknown. No increased risks to the community are expected with this alternative. |
| Long-Term Effectiveness | The magnitude of residual risk to aquatic organisms is significantly reduced by adequately limiting access to chemically impacted areas and by reducing the amount of suspended sediments migrating from the site. Ongoing pollutant loadings are also addressed, since a silt curtain restricts access of larger aquatic organism to contaminated areas and limits migration of ongoing contaminant sources. Tears and rips in a silt curtain can have a significant impact on effectiveness of the alternative, possibly decreasing protection of surrounding aquatic life. |
| Reduction of Toxicity, Mobility, or Volume | Silt curtain installation does not have an impact on reduction of toxicity or volume of the contaminated sediments. Overall mobility of contaminated glue waste and sediments is reduced, although not through active treatment. |
| Implementability | Silt curtain implementation is technically feasible, given existing site constraints. No administrative complications are anticipated. Installation is likely to require permits from the Army Corps of Engineers and the Washington Department of Fisheries. Silt curtains are frequently installed to control suspended sediment movement in industrial areas. There is no expectation of increased difficulty during installation of a curtain onsite. Inspection of a curtain for rips and tears is necessary to monitor its effectiveness. Materials needed for construction may not be locally available. |
| Cost | Capital costs associated with this alternative are estimated at $1,009,800. Total costs over a 30-year period are estimated at $1,108,400, based on present worth value. Additional details regarding cost are presented in Appendix H. |
| Community Acceptance | The public has not offered comments on the acceptance of this alternative. Comments, if available, will be included at the conclusion of the public comment period. |
| Degree of Recycling, Reuse, and Waste Minimization | This alternative does not involve recycling, reuse, or waste minimization. |

## TABLE 6-6

## SUMMARY OF DETAILED ANALYSIS OF ALTERNATIVES

| Evaluation Criteria | Offshore Sediments, Alternative OS-4 |
|---|---|
| Alternative Description | **Hand-dredging of offshore sediments and offsite disposal.** |
| Overall Protection of Human Health and the Environment | Potential human exposure was not considered as a viable exposure route during conduct of the RA. Long-term effects of dredging and offsite disposal of sediments are expected to improve the living environment for aquatic organisms somewhet, although, resuspension of contaminants during dredging and subsequent deposition of contaminated sediments would likely reduce possible beneficial effects. Ongoing contaminant loading would also counteract the effects of this alternative. |
| Compliance with Applicable Laws | Removal of a contaminated sediment would address cleanup goals established in the FS. However, cleanup goals based on AETs and background condition are not considered applicable laws. Implementation of this alternative would result in additional location-specific and action-specific laws which would need to be addressed. These laws may include acquiring permits from the Army Corps of Engineers, Washington Department of Fisheries and the City of Seattle. |
| Short-Term Effectiveness | Removal of sediments would not result in increased risks to the community although the environment may realize increased short-term contaminant concentrations through resuspension of sediment. A silt curtain would be required to control contaminent migration. Workers would be required to use the appropriate personal protective equipment and have adequate hazardous waste training. Divers, necessary for implementation, may realize a minimal increase in risk. |
| Long-Term Effectiveness | With confirmation sampling, the reliability of hand-dredging would be relatively high. However, the beneficial effects of dredging and offsite disposal of the sediments may be counteracted by resuspension of the contaminants during dredging or through continued contaminant loading form ongoing urban runoff. In the absence of continued contaminant loading, dredging and offsite disposal would meet the site cleanup objectives identified in the FS. Leaching of the contaminants from the landfill would not be a concern with an adequate liner and leachate collection system. |
| Reduction in Toxicity, Mobility, or Volume | This alternative does not employ a treatment process, therefore, the toxicity or volume of the sediments are not affected. Only the mobility of the contaminated sediments are reduced with disposal in a sanitary landfill. |
| Implementability | Offshore sediments can be manually or hydraulically removed using available equipment. However, significant difficulty would be encountered when removing sediments below existing buildings. In these areas labor-intensive hand-dredging would be required. Dredging operations may have a deleterious impact on SBT's operations by limiting or obstructing ship traffic. Implementation would require acquisition of permits from the Army Corps of Engineers, Washington Department of Fisheries and the City of Seattle. The time required to complete this project is estimated at over 1.5 years with permit acquisition. |
| Cost | Present worth cost to implement this alternative are extremely high and have been estimated at $8,339,100. Additional details regarding cost are presented in Appendix H. |
| Community Acceptance | The public has not offered comments on acceptance of this alternative. Comments, if available, will be included following public review. |
| Degree of Recycling, Reuse, and Waste Minimization | This alternative does not involve the use of recycling, reuse, or waste minimization. |

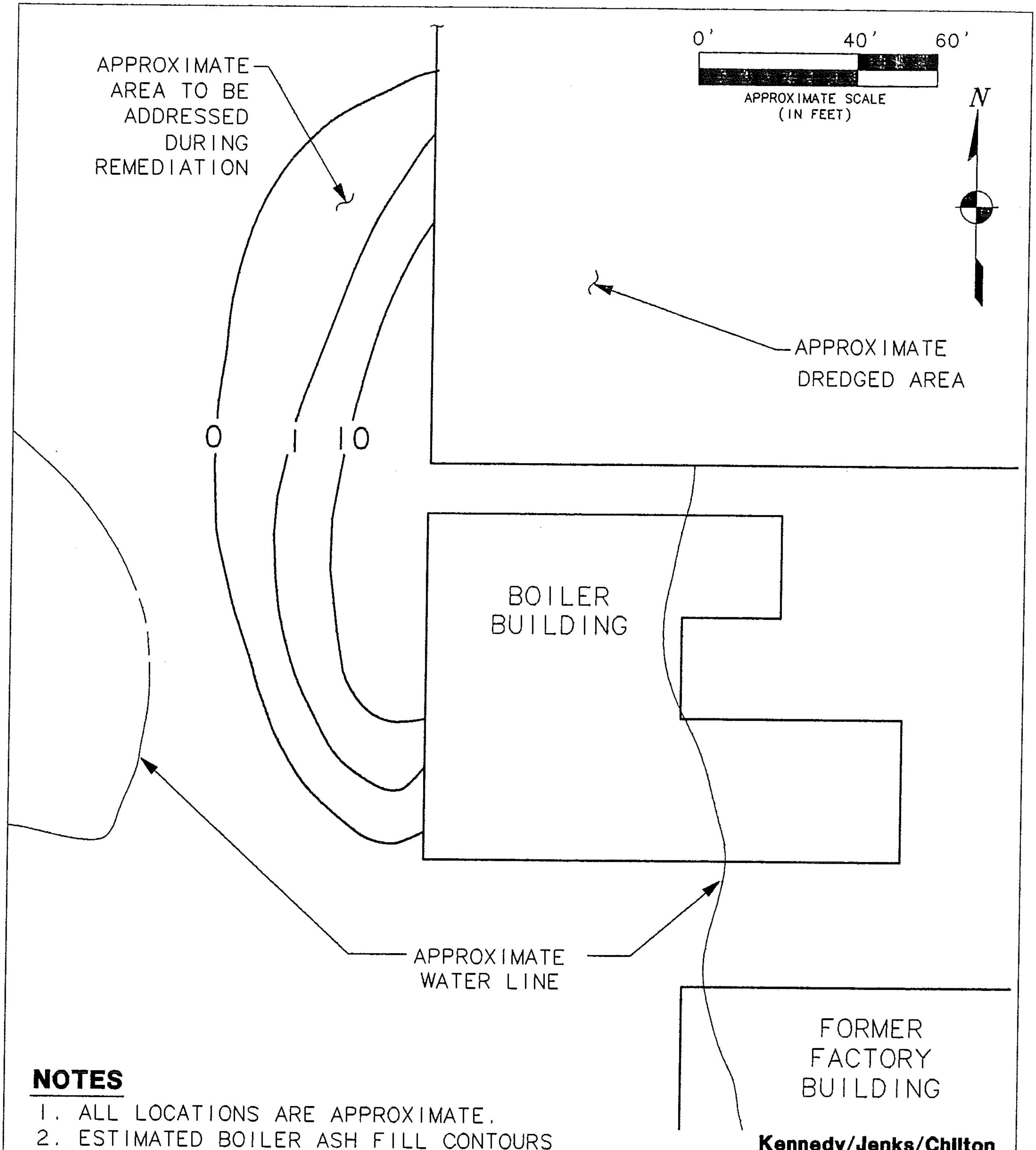
# TABLE 6-7

## COMPARATIVE ANALYSIS COST SUMMARY

| Description of Remedial Alternative | Capital Cost Subtotal | O & M Cost Subtotal | Net Present Worth[1] |
|---|---|---|---|
| <u>Entire Site Operable Unit</u> | | | |
| ES-1 - No Action | $ 11,300 | $ 51,500 | $ 62,800 |
| ES-2 - Land & Water Use Restrictions | 32,700 | 51,500 | 84,200 |
| <u>Boiler Ash Fill Operable Unit</u> | | | |
| BA-1 - Institutional Controls | $ 19,500 | $ 51,500 | $ 71,000 |
| BA-2 - Removal and Offsite Disposal | 940,000 | -0- | 940,000 |
| BA-3 - Solidification/Fixation | 1,469,000 | -0- | 1,469,800 |
| BA-4 - Capping with Sand or Asphalt | 307,300 | 5,100 | 312,400 |
| <u>Glue Press Waste Operable Unit</u> | | | |
| GA-1 - Land Use Controls | $ 19,500 | $ 51,500 | $ 71,000 |
| GP-2 - Removal and Offsite Disposal | 641,400 | -0- | 641,400 |
| GP-3 - Capping with Concrete or Clay | 231,200 | 46,700 | 277,900 |
| <u>Offshore Sediments Operable Unit</u> | | | |
| OS-1 - Land Use Restriction | $ 19,500 | $ 51,400 | $ 70,900 |
| OS-2 - Capping with Sand or Concrete | 1,405,100 | 37,000 | 1,442,100 |
| OS-3 - Silt Curtain Installation | 1,009,800 | 98,600 | 1,108,400 |
| OS-4 - Hand-Dredging & Offsite Disposal | 8,133,600 | 205,500 | 8,339,100 |

Notes:

(1) Additional details regarding cost are presented in Appendix H.



## NOTES

1. ALL LOCATIONS ARE APPROXIMATE.
2. ESTIMATED BOILER ASH FILL CONTOURS SHOW APPROXIMATE AREA TO BE ADDRESSED DURING REMEDIATION.

## LEGEND

—|— ESTIMATED BOILER ASH FILL CONTOUR (FT.)

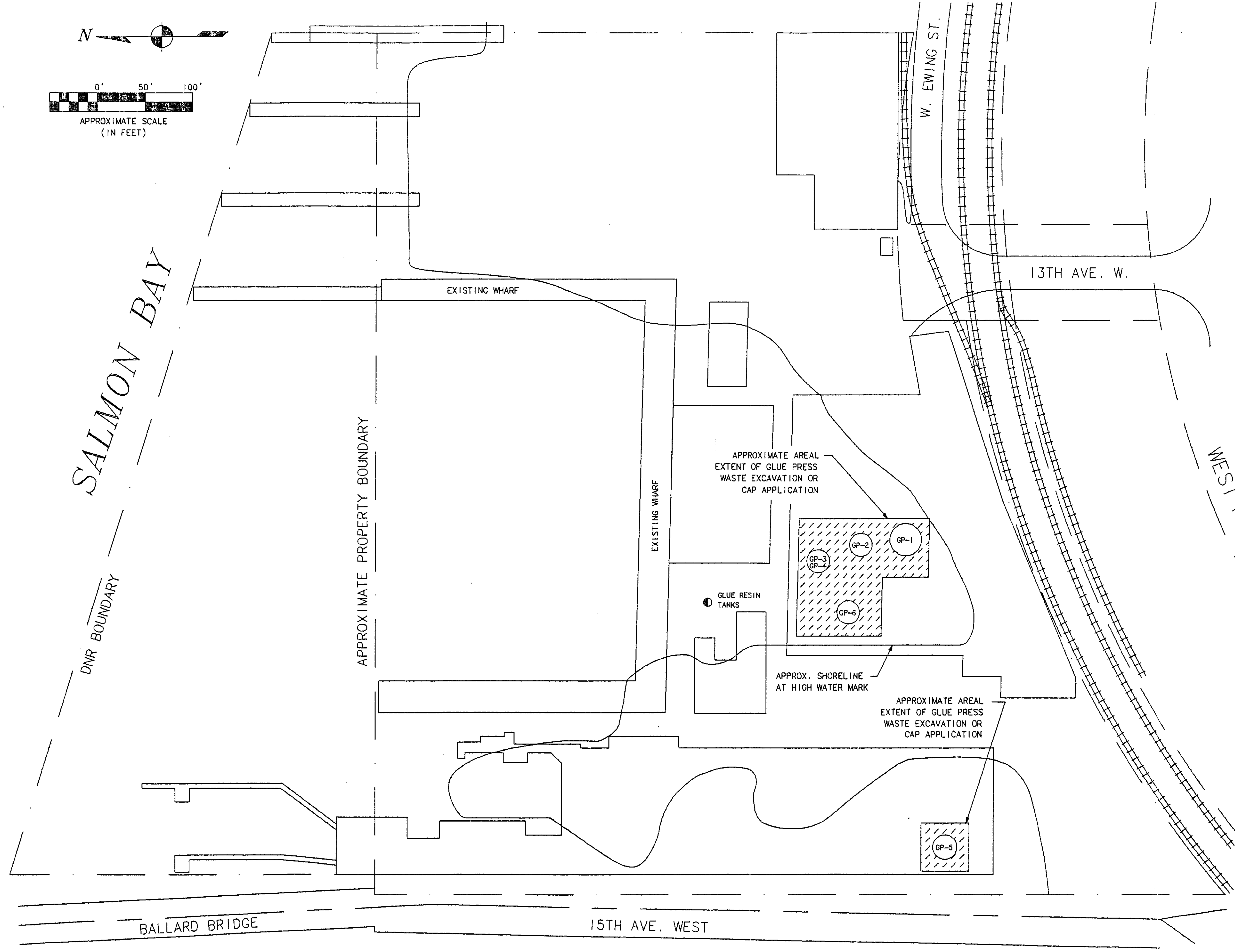
**Kennedy/Jenks/Chilton**

CHAMPION INTERNATIONAL CORP.
SEATTLE, WA

**APPROXIMATE EXTENT OF BOILER ASH TO BE REMEDIATED**

K/J/C 916016.00/P1SK025

**FIGURE 6-1**



## LEGEND

▨ APPROX. AREAL EXTENT OF GLUE PRESS WASTE EXCAVATION OR CAP APPLICATION.

(GP-5) APPROX. LOCATIONS OF GLUE PILES.

## NOTES

1. ALL LOCATIONS ARE APPROXIMATE.
2. MAP SOURCE: JAY SPEARMAN, CONSULTING ENGINEER, 11/20/89.

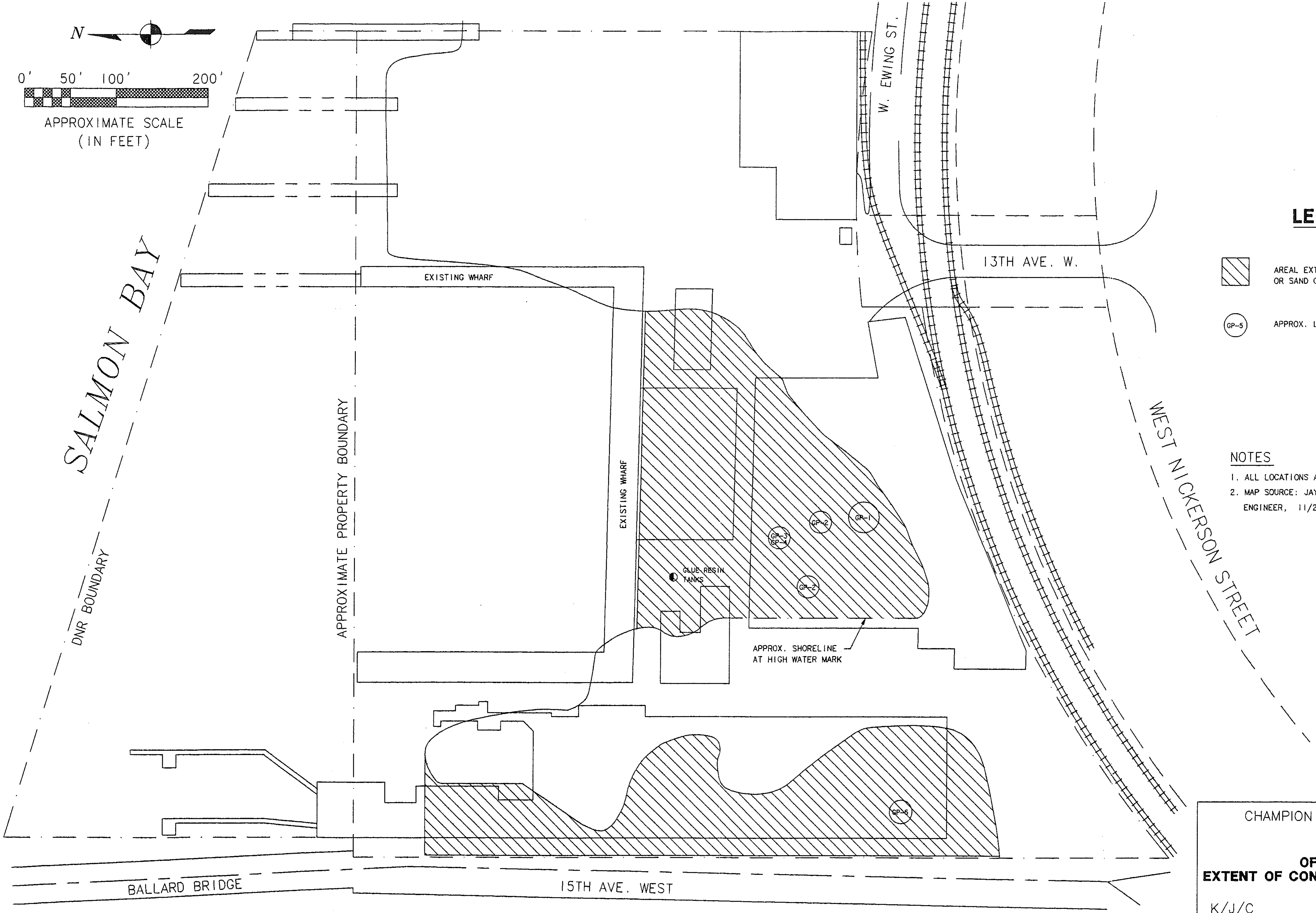
**Kennedy/Jenks/Chilton**

CHAMPION INTERNATIONAL CORP.
SEATTLE, WA

**GLUE PRESS WASTE AREA - AREAL EXTENT OF SEDIMENT EXCAVATION & CLAY OR CONCRETE CAP APPLICATION**

K/J/C 916016.00/P1SK026

**FIGURE 6-2**



## LEGEND

| | |
|---|---|
| ▨ | AREAL EXTENT OF CONCRETE OR SAND CAP |
| (GP-5) | APPROX. LOCATIONS OF GLUE PILES |

NOTES

1. ALL LOCATIONS ARE APPROXIMATE.
2. MAP SOURCE: JAY SPEARMAN, CONSULTING ENGINEER, 11/20/89.

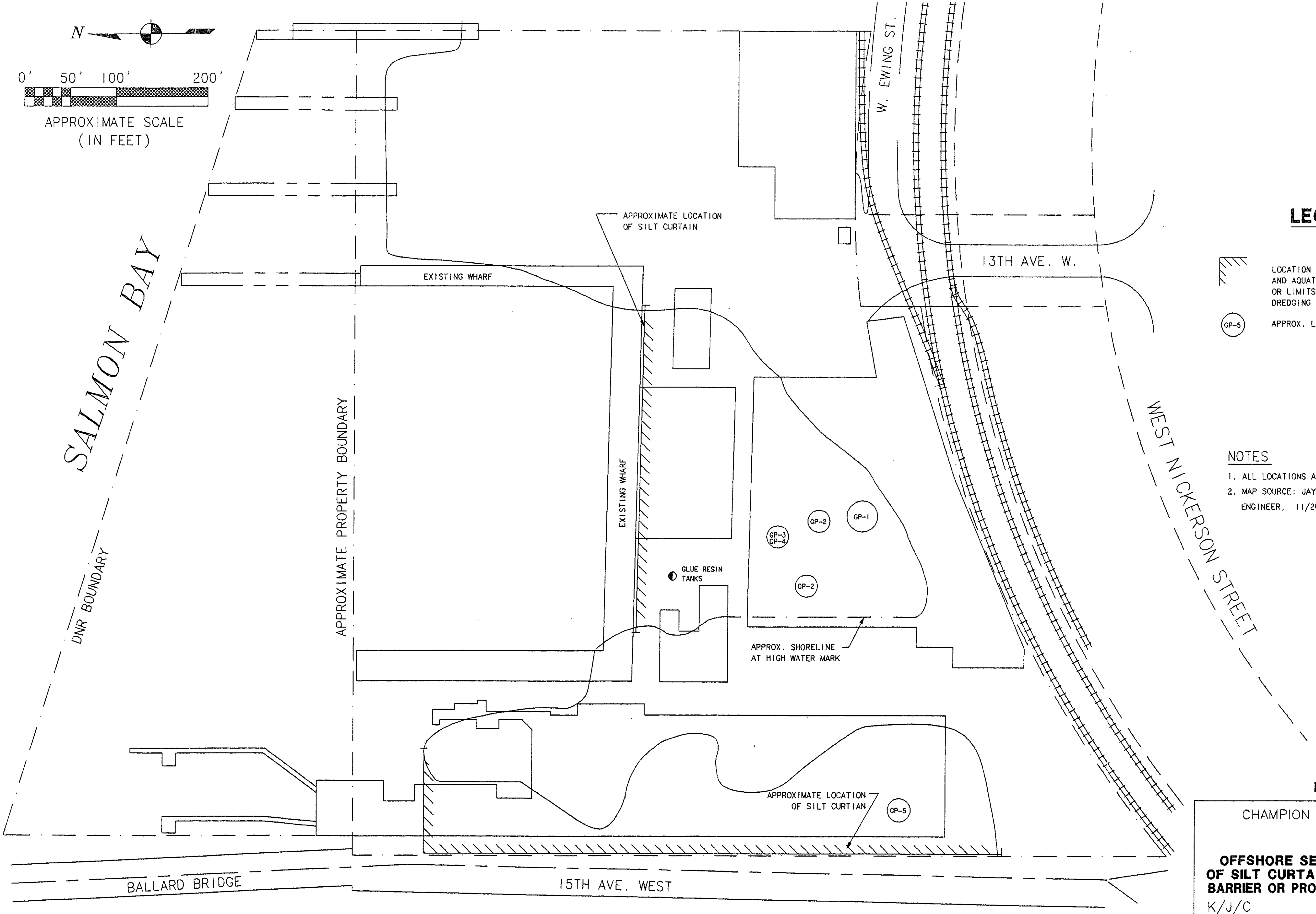
**Kennedy/Jenks/Chilton**

CHAMPION INTERNATIONAL CORP.
SEATTLE, WA

**OFFSHORE SEDIMENTS -**
**EXTENT OF CONCRETE OR SAND CAP**

K/J/C 916016.00/P1SK020

**FIGURE 6-3**



## LEGEND

| | |
|---|---|
| ▨ | LOCATION OF SILT CURTAIN AND AQUATIC LIFE BARRIER OR LIMITS OF PROPOSED DREDGING AREA |
| (GP-5) | APPROX. LOCATIONS OF GLUE PILES |

NOTES

1. ALL LOCATIONS ARE APPROXIMATE.
2. MAP SOURCE: JAY SPEARMAN, CONSULTING ENGINEER, 11/20/89.

**Kennedy/Jenks/Chilton**

CHAMPION INTERNATIONAL CORP.
SEATTLE, WA

**OFFSHORE SEDIMENTS - LOCATION OF SILT CURTAIN AND AQUATIC LIFE BARRIER OR PROPOSED DREDGING AREA**

K/J/C 916016.00/P1SK019

**FIGURE 6-4**