FINAL DRAFT
FEASIBILITY STUDY REPORT
TERMINAL 91 SITE
SEATTLE, WASHINGTON
NOVEMBER 2009

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PORT OF SEATTLE TERMINAL 91 SITE
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LIST OF ACRONYMS

1998 AO	Agreed Order No. DE 98HW-N108
ACM	Asbestos-Containing Materials
AOC	Area of Concern
APH	Air-Phase Petroleum Hydrocarbons
API	Asian Pacific Islander
API	American Petroleum Institute
BD	Bridge Document
BDR1,2,3	Bridge Document Reports 1, 2, 3
BEI	Burlington Environmental, Inc.
bgs	Below Ground Surface
BMLLW	Below Mean Low Low Water
BTEX	Benzene, Toluene, Ethylbenzene, and Xylenes
CAA	Cleanup Action Alternative
CAO	Cleanup Action Objective
CAP	Cleanup Action Plan
CFR	Code of Federal Regulations
Chempro	Chemical Processors, Inc.
COPCs	Chemicals of Potential Concern
CPOC	Conditional Point of Compliance
CSM	Conceptual Site Model
CULs	Cleanup Levels
cy	Cubic Yards
CWA	Clean Water Act
DGI	Data Gaps Investigation
DNAPL	Dense Non-Aqueous Phase Liquid
DO	Dissolved Oxygen
DRO	Diesel-Range Organics
Ecology	Washington State Department of Ecology
ECOTOX	U.S. EPA’s Ecotoxicology Database
EPA	Environmental Protection Agency
ESE	Environmental Science & Engineering
FAMM	Fuel and Marine Marketing
FS	Feasibility Study
ft	Feet
GAC	Granular Activated Carbon
GRO	Gasoline-Range Organics
GWSAP	Groundwater Sampling and Analysis Plan
HQ	Hazard Quotient
IHS	Indicator Hazardous Substance
IQR	Interquartile Range
JE	Johnson and Ettinger
Lease Parcel	Terminal 91Tank Farm Lease Parcel
LNAPL	Light Non-Aqueous Phase Liquid

LIST OF ACRONYMS (CONTINUED)

MADEP	Massachusetts Department of Environmental Protection
MCL	Maximum Contaminant Level
MDO	Marine Diesel Oil
mg/kg	Milligram per Kilogram
mg/L	Milligrams per Liter
µg/L	Microgram per Liter
MLLW	Mean Low Low Water
MNA	Monitored Natural Attenuation
MTCA	Model Toxics Control Act
NAPL	Non-Aqueous Phase Liquid
ND	Non-Detect
NPDES	National Pollutant Discharge Elimination System
NPV	Net Present Value
O&M	Operation and Maintenance
ORNL	Oak Ridge National Laboratory
PAHs	Polycyclic Aromatic Hydrocarbons
PCBs	Polychlorinated Biphenyls
PCS	Port Construction Services
PES	PES Environmental, Inc.
PID	Photoionization Detector
PIONEER	PIONEER Technologies
PLP	Potentially Liable Person
PLRD	Passive LNAPL Recovery Device
PNO	Pacific Northern Oil Corporation
POC	Points of Compliance
PVC	Polyvinyl Chloride
Port	The Port of Seattle
PSC	Philip Services Corporation
RAIS	U.S. Department of Energy's Risk Assessment Information System
RCRA	Resource Conservation and Recovery Act
RCW	Revised Code of Washington
RFA	Terminal 91 RCRA Facility Assessment
RFI	RCRA Facility Investigation
RI	Remedial Investigation
RI/DE	Remedial Investigation/ Data Evaluation
RSSL	Residual Saturation Screening Level
SPOC	Standard Point of Compliance
sq ft	Square Feet
SVE	Soil Vapor Extraction
SVOC	Semi-Volatile Organic Compound
SVSAP	Soil Vapor Sampling and Analysis Plan
SVTM	Soil Vapor Technical Memorandum

LIST OF ACRONYMS (CONTINUED)

SWMU	Solid Waste Management Unit
TFAA	Tank Farm Affected Area
TPH	Total Petroleum Hydrocarbon
TSCA	Toxic Substances Control Act
UCU	Upper Confining Unit
USGS	U.S. Geological Survey
UST	Underground Storage Tank
VCP	Voluntary Cleanup Program
VOC	Volatile Organic Compound
WAC	Washington Administrative Code
WPADC	Work Plan for Additional Data Collection
WPGSE	Work Plan for Groundwater Seepage Evaluation

1.0 INTRODUCTION

1.1 Purpose

PES Environmental, Inc. (PES), in conjunction with Roth Consulting and PIONEER Technologies (PIONEER), has prepared this Feasibility Study (FS) Report on behalf of the Port of Seattle (Port), as required by Agreed Order No. DE 98HW-N108 (1998 AO). The purpose of this FS Report is to document the development and evaluation of cleanup action alternatives (CAAs) to address contamination present in the Terminal 91 Tank Farm Site (Site), a portion of the Port's Terminal 91 Complex[1] in Seattle, Washington. The FS Report was prepared consistent with the *Feasibility Study Work Plan* (FS Work Plan; PES, Roth Consulting, PIONEER, 2005a) and the Model Toxics Control Act (MTCA, WAC 173-340), and is designed to provide the necessary documentation so that the Washington State Department of Ecology (Ecology) can select the most appropriate CAA.

1.2 Background

As described in more detail in the following sections, industrial activities have taken place at the Terminal 91 Complex since the late 1800s, and bulk petroleum storage and handling have occurred at the Site since the 1920s. Beginning in the early 1970s, operations at the Site expanded to include waste oil recovery and wastewater treatment, and from 1980 to 1995 further expanded to include permitted dangerous waste management activities. Bulk petroleum storage and management continued at the Site throughout this period, until all operations were terminated in 2003.

Beginning in 1988, a series of environmental investigations began at the Site and continued into recent years. The findings and conclusions of these environmental investigations were summarized in the *Remedial Investigation Summary Report for the Terminal 91 Tank Farm Site in Seattle, Washington* (RI Summary Report; Roth Consulting, 2007). The RI Summary Report provides a summary of relevant sections from the *Draft Remedial Investigation and Data Evaluation Report* (RI/DE Report; Philip Services Corporation [PSC], 1999) and subsequent reports and plans, including the "Bridge Documents" that were prepared in accordance with the *Proposed Bridge Document Work Plan* (Roth Consulting, 2000c). The RI Summary Report also includes information developed pursuant to the *Monitored Natural Attenuation (MNA) Work Plan* (PES 2005b). The MNA evaluation was performed as part of the data gap investigations under the FS Work Plan (PES et al., 2005a), and the results were reported in the *MNA Evaluation Final Technical Memorandum* (PES 2006a). The RI Summary Report was approved by Ecology on October 2, 2007.

[1] See Section 2.1 for detailed definitions of terms associated with the various portions of the Terminal 91 Complex.

Additional investigations and evaluations critical to the development of the FS were implemented pursuant to the FS Work, including:

- Development of cleanup levels (CULs) for the Site, including identification of indicator hazardous substances, development of a conceptual site model, and the calculation of risk-based CULs for protection of both human health and ecological receptors. This evaluation was documented in the technical memorandum entitled *Terminal 91 Tank Farm Site Feasibility Cleanup Level* (FS CUL Memorandum; Pioneer, 2008a).

- Establishing final CULs for the Site, identification of points of compliance (POC), and comparison of recent groundwater monitoring data to these final CULs. These tasks were summarized in the technical memorandum entitled *Comparison of Groundwater Data to Feasibility Study Cleanup Levels* (Groundwater Comparison Memorandum; Pioneer, 2008b).

- Evaluation of the soil-to-groundwater pathway through the development of residual saturation screening levels (RSSLs) for the Site. The initial evaluation of RSSLs was reported in the *Soil-to-Groundwater Pathway Evaluation, Residual Saturation Screening Levels* (PES, 2006d). Based on this initial evaluation, the Port prepared a work plan for a phased data gap investigation at the site (PES, 2007a), and implemented the investigation in late 2007 through 2008. The results of the data gaps investigation were documented in three technical memoranda (PES, 2007b, 2008a, 2008d). Based on the information collected during the data gaps investigation, the *Final Residual Saturation Screening Level Evaluation* technical memorandum was prepared (PES, 2008c).

The information summarized in the RI Summary Report, as well as the other documents prepared pursuant to the FS Work Plan, provide the basis for this FS Report. Sections 2 through 5 of this FS Report provide an overview of the RI information. Section 7 summarizes the CUL development process.

Concurrent with the environmental investigations described in the RI Summary Report, a series of interim remedial actions were undertaken at the Site including the closure and demolition of the aboveground portions of the tank farm. These previous remedial actions are summarized in Section 6 of this FS report.

1.3 Report Organization

Section 1 – Introduction: Describes the background, purpose, and organization of this report.

Section 2 – Site Background: Provides a summary of the site location and history.

Section 3 – Environmental Setting: Summarizes the environmental background of the Site, including climate, hydrology, and geology.

Section 4 – Previous Investigations: Summarizes and provides references for the previous environmental investigations at the Site, including the RI Summary Report.

Section 5 – Summary of Investigation Results: Summarizes the results and major conclusions of previous environmental investigations related to the site geology, groundwater flow, and nature and extent of contamination.

Section 6 – Previous and Ongoing Cleanup Actions: Summarizes the closure activities and other related cleanup actions.

Section 7 – Conceptual Site Model and Cleanup Level Development: Provides a summary of the contaminant sources, indicator hazardous substances, exposure pathways, and receptors, and develops cleanup standards for the Site.

Section 8 – Feasibility Study Scoping: Summarizes the regulatory requirements and develops cleanup action objectives.

Section 9 – Identification and Screening of Remedial Technologies: Identifies general response actions for the site and cleanup technologies that will be effective at the Site.

Section 10 – Development of Cleanup Action Alternatives: Assembles the cleanup technologies into a range of CAAs.

Section 11 – Evaluation of Cleanup Action Alternatives: Evaluates the CAAs against the criteria defined in WAC 173-340-360.

Section 12 – Comparative Evaluation and Recommended Cleanup Action: Compares the alternatives to each other and recommends a CAA, provides the rationale for the recommendation, and discusses the implementation of the preferred CAA.

Section 13 – References: Lists the sources of information referenced in the document.

2.0 SITE BACKGROUND

This section summarizes information provided in the RI Summary Report and related documents.

2.1 Site Location and Description

2.1.1 Definition of Site

The Site is defined in the Agreed Order as "the Tank Farm Lease Parcel and areas where releases of dangerous constituents originating from the Tank Farm Lease Parcel operations have come to be located". The Tank Farm Lease Parcel (Lease Parcel) is a contiguous parcel, approximately four acres in size, located within the confines of the Port Terminal 91 Complex. The Terminal 91 Complex is located at 2001 West Garfield Street, Seattle, Washington and encompasses approximately 216 acres, including adjacent water areas and upland areas. These definitions were set forth in the 1998 AO. The site location map is provided as Figure 2-1.

The Site is within the "facility" as defined under the Resource Conservation and Recovery Act (RCRA) for the purpose of corrective action for solid waste management units (SWMUs). The Port was notified of this determination in a letter from the U.S. Environmental Protection Agency (EPA) to the Port dated May 1, 1992. The entire facility is subject to a dangerous waste corrective action permit, and areas outside the Site are being cleaned up under the Voluntary Cleanup Program (VCP) and as independent cleanup actions under MTCA. Ecology and the Port are currently negotiating a new Agreed Order that would apply to the entire facility.

The new Agreed Order is expected to contain revised definitions for areas within the Terminal 91 Complex. The revised definitions are expected to include:

- Tank Farm Affected Area (TFAA)--essentially equivalent to Site as defined in the 1998 AO
- Terminal 91 Facility --essentially equivalent to Terminal 91 Complex as defined in the 1998 AO

The Upland and Submerged Land portions of the Terminal 91 Facility, as well as the TFAA, would be addressed in the new Agreed Order[2]. Figure 2-2 is an aerial photograph of the Terminal 91 Facility showing the approximate boundaries of the TFAA, Lease Parcel, Upland, Short Fill, and Submerged Land. For the purposes of this FS Report, however, the definitions provided in the 1998 AO will be retained. Hence, cleanup of the Upland and Submerged Lands are not addressed in this FS Report.

2.1.2 Description of Tank Farm Lease Parcel

The Lease Parcel is a contiguous parcel approximately four acres in size located at the north end of the Site. The primary historical feature of the Lease Parcel is the presence of bulk petroleum

[2] The Submerged Lands are addressed in the new Agreed Order by deferring actions for this portion of the Terminal 91 Facility to a later date.

storage since the 1920s (see Section 2.2 for detailed history). The aboveground portion of the tank farm, including all of the tanks and containment walls and other aboveground piping and equipment, was demolished and removed in 2005 as part of an interim remedial action. Low areas were backfilled with concrete and/or clean fill and the Lease Parcel and adjacent upward alley were paved with asphalt. See Section 6 for details regarding the interim remedial action.

During the latter stages of its operational history prior to the 2005 demolition activities, the Lease Parcel was defined in the 1998 AO as consisting of three tank yards and associated buildings and is divided into the following areas (Figure 2-3):

- **The Black Oil Yard** located at the south end of the Lease Parcel. This yard consisted of three large tanks ranging in size from approximately 570,000 to 1, 470,000 gallons that were used to store heavy fuel oils (e.g., Bunker C);
- **The Marine Diesel Oil Yard** located in the center of the tank farm. This yard consisted of 12 main tanks ranging in size from 46,000 to1,530,000 gallons that were used to store a variety of products including diesel, kerosene, and other middle distillates as well as wastewater and waste oil;
- **The Small Yard** was located at the north end of the tank farm and consisted of 10 main tanks ranging in size from 39,000 to 46,000 gallons and a number of smaller tanks. The small yard was used to store a variety of petroleum products including gasoline and diesel and also a variety of wastewater and other waste materials. The tank bases for the tanks located in the Small Yard were also removed during the 2005 demolition activities (Figure 2-3).
- **The main warehouse** is located just north of the three tank yards. This building still exists at the Site; and
- **Additional areas** including the pipe alley between the Small Yard and the Marine Diesel Oil Yard, the decommissioned oil-water separator west of the Small Yard, and the foam mixing area at the north end of the Lease Parcel.

The Black Oil Yard and the Marine Diesel Oil Yard were surrounded by concrete product-containment walls approximately 15 feet (ft) high. The Small Yard was surrounded by a concrete product-containment wall approximately three ft high. All three tank yards were fully paved with concrete; the Small Yard was paved in 1982 while the paving of the Marine Diesel Oil and Black Oil Yards occurred in 1986. Aboveground and subsurface piping systems were used to transfer product within the tank yards.

2.2 Site History and Development

This section describes the history of the Terminal 91 Complex and its development since the late 1800s through the present day.

2.2.1 History of the Tank Farm Lease Parcel and Related Operations

From the late 1800s through 1920, owners of the Terminal 91 Complex included various railroads, land development companies, and private individuals. The Great Northern Railroad began to develop the area in the early 1900s by filling the area between Magnolia Bluff and Queen Anne Hill. Fill material was added to the area through 1920.

The tank farm at the Lease Parcel was constructed in the 1920s. The Lease Parcel initially may have been used as a gasoline refinery by California Petroleum Company as early as 1925 (Converse Consultants NW [Converse], 1993). The Texas Company appears to have operated the tank farm as a fuel storage facility in the late 1920s and 1930s. The U.S. Navy acquired the entire Terminal 91 Complex in 1942 through condemnation, and operated the tank farm until 1972. During the Navy's possession of the Terminal 91 Complex, the Lease Parcel was used primarily as a fuel and lubricating oil transfer station. The Navy began leasing the Terminal 91 Complex back to the Port in 1972 and deeded it to the Port in 1976.

At about the time the Port leased Terminal 91 back from the Navy, Chemical Processors, Inc. (Chempro), a predecessor of Burlington Environmental, Inc. (BEI) and PSC, subleased the Lease Parcel from the Port. The main activities conducted by Chempro and its successors were waste oil recovery and wastewater treatment. Typical waste streams included oil and coolant emulsions, industrial wastewater, and industrial waste sludge. Bilge and ballast waters were primarily received from ships and transferred to the Lease Parcel via pipeline. Other wastes and wastewater were received via tankers or in drums.

Chempro notified EPA of its dangerous waste activities at the Lease Parcel on November 14, 1980, and was granted interim status under the RCRA regulations for its dangerous waste management operations. Federal permitting requirements became effective November 19, 1980 under 40 CFR 264. BEI and the Port (as operator and owner, respectively) were issued a Part B RCRA permit effective August 22, 1992 for the continued operation of a permitted dangerous waste management facility at the Lease Parcel. In September 1995, BEI ceased operations at the Lease Parcel and terminated its lease with the Port. BEI subsequently performed aboveground closure activities at all permit-related facility equipment, secondary containment, and treatment units pursuant to a closure plan approved by Ecology. No dangerous waste operations requiring a permit (other than corrective action) have been conducted at the Lease Parcel since September 1995, and all regulated waste units at the Lease Parcel have undergone closure. This aboveground closure was approved by Ecology in October 2003 (Ecology, 2003b). A Part B permit remains in effect for corrective action.

From approximately 1974 through 1995, Chempro and its successors also sublet a portion of the Lease Parcel to Pacific Northern Oil Corporation (PNO) for storage of non-regulated bunker oil and other fuels product. PNO used aboveground and underground piping systems at the Site to transfer bunker oil and fuels within the Lease Parcel and other areas of the Terminal 91 Complex. PNO operations at the Site included blending and storage of marine boiler fuel, diesel, and other petroleum products. PNO conducted these activities under a throughput agreement with Chempro from 1974 through 1981, and under a sublease with PSC and its predecessors from 1981 until PSC ended its occupancy in 1995.

Following PSC's aboveground closure action, PNO entered a new lease for the entire Lease Parcel. PNO continued operation of a bunker oil, lube oil, and fuel products storage and blending facility until 1999. In 1999, PNO terminated its lease with the Port and discontinued its fuels product and blending operations at the Site. Subsequently, the Port entered into an agreement with Fuel and Marine Marketing (FAMM), and that entity conducted bunker oil and fuel product storage, blending and marketing operations at the Site until early 2003, when FAMM terminated its lease. FAMM also subleased the lube-oil portion of the operation to

Rainier Petroleum during that period. Rainier Petroleum continued to operate tankage at the tank farm until August 2003. Delta Western was hired to provide terminaling operations during this period, and, after August 2003, monitored the facility during its caretaker status until the tank farm demolition activities were initiated in the spring of 2005.

Because the facility would no longer be used as a tank farm, the Port decided to remove the remaining aboveground equipment to reduce risks of hazardous substance releases. In the spring of 2005, the Port initiated product removal and demolition activities, including final paving of the Lease Parcel, as part of an independent interim remedial action. That interim action was completed in the summer of 2005. An independent cleanup report documenting the interim action was submitted to Ecology on October 20, 2005 (Roth Consulting, 2005b).

2.2.2 History of the Vicinity Surrounding the Tank Farm Lease Parcel

Another tank farm was historically located in the area southwest of the Lease Parcel. This former tank farm was identified as the Old Tank Farm and was called out as Area of Concern (AOC) 11 in the Terminal 91 RCRA Facility Assessment (RFA) (EPA, 1994). Figure 2-4 shows the approximate footprint of the Old Tank Farm (AOC 11).

The former tank farm in AOC 11 was reportedly active between 1927 and 1942. Operators included Signal Oil & Gas and Richfield Oil Company. This tank farm was demolished before the United States Department of the Navy took over the site in December 1942. The former AOC 11 tank farm consisted of two concrete-walled yards containing aboveground tanks. The two yards were bisected by a pair of rail spurs that serviced Pier 91. A second set of rail spurs, which also serviced Pier 91, was located on the eastern side of the eastern yard. The western yard contained a large tank identified as a gasoline tank, and four small, unidentified tanks. The eastern yard contained eight smaller tanks identified as oil tanks. Pumphouses were located north and south of the eastern yard, and an unidentified aboveground tank, an oil shed, a concrete platform, a foamite building, and other unidentified buildings were located north of the eastern yard. A boiler house, shop, gas pump, cafe, and two filling towers were located across the rail spurs, east of the eastern yard.

Other areas of interest at the Site include SMWU 30, which is the location of a pipeline break that occurred in 1989 near the north end of Pier 91 (Figure 2-4), and former fuel transfer pipelines that ran in and around the Lease Parcel and out towards Piers 90 and 91. An underground storage tank (UST) was formerly located on the north side of the Building W-39; this diesel UST was removed in 1989.

Other uses of the area in the vicinity of the Lease Parcel, particularly those that could have been potential contaminant sources, were described in Converse (1993), Kennedy/Jenks Consultants (1997), the Bridge Document Report 2 (BDR2) (Roth Consulting, 2003a), and Pinnacle (2006).

3.0 ENVIRONMENTAL SETTING

This section summarizes the general environmental background of the Site, including the regional hydrology and geology, climate, and groundwater use.

3.1 Site Physiography

The Site is located at the Terminal 91 Complex, which encompasses approximately 216 acres, including adjacent water and upland areas (Figures 2-1 and 2-2). The Site lies at the south end of a lowland area referred to as the Interbay Region, which was created by glacial and/or post-glacial downcutting, followed by historic landfilling. The Interbay Region is approximately 1.5 miles long and 1,000 to 2,000 ft wide and extends from the Lake Washington Ship Canal on the north to Elliott Bay on the south. The Interbay Region lies within a larger physiographic region, known as the Puget Sound Lowland, a topographic and structural basin bordered by the Cascade Range on the east and the Olympic Mountains on the west. The Puget Sound Lowland is underlain by thousands of feet of unconsolidated glacial and non-glacial sediments.

Both the upland areas and piers at the Site overlie a portion of the Smith Cove inlet that was initially modified by filling in the early 1900s. Adjacent surface water bodies include Elliott Bay and the Short Fill Impoundment, an isolated water body located just south of the Garfield Street Viaduct. The Short Fill Impoundment, which is approximately 30 ft deep, is a remnant of the former central slip between Piers 90 and 91 that was isolated from Elliott Bay in 1988 during infilling of about 400 ft of the landward portion of the slip. Although permits authorized complete fill, the Short Fill Impoundment was left in place due to concerns that infilling could cause settlement and jeopardize the structural integrity of the West Garfield Street viaduct.

Bulkheads of various types bound the seaward portions of the Site and form the perimeter of the fill-cored piers. The east, center and west slips adjacent to the piers have been maintained to dredged depths of about -35 ft mean low low water (MLLW). An exception to this is the landward ends of the east and west slips, where four intertidal habitat sites are located (two on the northeast corner of the east slip and two on the west margin of the west slip)[3].

3.2 Climate

Air masses originating over the Pacific Ocean strongly affect the climate of the Puget Sound Lowland, with generally overcast, cool, damp, and mild weather during the autumn, winter, and spring, and warm and dry weather during the summer. The annual precipitation ranges from

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[3] Four fish and wildlife habitat sites are present in the shallow sub-tidal and exposed inter-tidal aquatic areas at the Terminal 91 Complex. The aquatic habitat sites were constructed by the Port and are maintained as compensatory restoration areas linked with previous development actions at the Terminal 91 Complex. Approximately 1.6 acres at the northwest margin of the west slip, northwest of Pier 91, were restored as intertidal habitat, constructed by removal of previously placed fill material. The water-ward portion of the confined dredged material disposal site in the center slip, between Piers 90 and 91, includes approximately 0.8 acres of intertidal berm surface improved as habitat substrate. The east slip, east of Pier 90, includes two inter-tidal restoration areas: (1) a constructed intertidal mound, approximately 0.4 acres in size, consisting of habitat substrate placed in the subtidal aquatic area at the north end of the east slip, creating a habitat area subject to daily tidal exposure; and (2) approximately 0.75 acres of intertidal mud-sand substrate at the northeast margin of the east slip, restored by removal of previously placed fill material, re-exposing low-slope aquatic habitat conditions.

about 30 to over 60 inches in the lowland. The average annual precipitation in the area is about 38 inches, with approximately 75 percent of the precipitation falling between October and March.

3.3 Regional Geology

The Puget Lowland is underlain at depth by Tertiary volcanic and sedimentary bedrock, and is filled to the present-day land surface with glacial and non-glacial sediments deposited during the Quaternary Period (within the last 2 million years). Only the late Quaternary deposits are exposed at land surface in the Site area. The Quaternary geologic history of the Puget Sound region is dominated by a succession of at least six dated and named periods of continental glaciation. During these episodes of cooler mean global temperatures, continental ice sheets originating in Canada flowed south, covering much of low-lying northern North America with glacial ice, over a mile thick in places. In the Puget Lowland, the most recent continental glacier was present as a lobe of ice that reached its maximum extent just south of Olympia during the Vashon stade of the Fraser glaciation. Glacial ice was about 3,000 ft thick in the project area (Thorson, 1980).

As the glaciers advanced, glaciolacustrine silt and clay (known as the Transition Beds) were deposited, followed by sand and gravel (Advance Outwash); silt, sand, and gravel compacted by glacial ice (till), and a succession of sand and gravel (Recessional Outwash) and silt (Recessional Lucustrine Deposits) as the glaciers receded. Between glaciations (the non-glacial periods), erosional and depositional processes worked much like they do today, with broad lowland rivers and streams filling the deep glacially modified channels, and erosion on the steep upland slopes forming ravines. Deposits from the non-glacial periods generally consisted of interbedded sand, silt, clay, and peat in an environment similar to the pre-development Green and Duwamish River valleys.

Geologic processes following the Vashon glaciation are dominated by erosion of the uplands and deposition of recent alluvium and lacustrine deposits in the valleys and water bodies of the Puget Lowland. Extensive filling of former wetlands and tideflats in the Interbay area and grading for construction projects has further modified the land surface.

3.4 Regional Hydrogeology

The groundwater flow systems in western Washington can be grouped into regional and local flow systems. The regional flow systems are generally deep, long-flow path systems that are recharged via precipitation in the elevated foothills and plateaus, and discharge to the lower floodplains and to the marine waters of Puget Sound. These regional systems are of broad extent and generally involve aquifers comprised of thick glacial advance outwash deposits formed during Vashon or older glacial periods. Local groundwater flow systems overlap or overlie these regional systems, are of a smaller scale generally limited to lowlands between the elevated foothills and plateaus, and are controlled by local topographic and geologic conditions. These local flow systems generally include localized recessional glacial outwash, recent non-glacial alluvial and nearshore marine deposits, fill placed on inland low areas, and filled areas adjoining Puget Sound. The aquifer systems of interest at the Site are local groundwater flow systems within fill and near-shore marine deposits.

3.5 Groundwater Use

No drinking water supply wells are present on or downgradient from the Site. Two deep water-supply wells, neither of which is currently in use, have been identified within approximately a one-half-mile radius of the Lease Parcel. Both wells are within the Terminal 91 Complex owned by the Port. Both wells are screened or perforated at depths of greater than about 250 ft below ground surface (bgs) in artesian aquifers, and one of the two wells is upgradient from the Site. The *Proposed Final Bridge Document Report 1* (BDR1; Roth Consulting, 2001b) concluded that groundwater at the Site is nonpotable, based on the criteria provided in MTCA [WAC 173-340-720(2)].

4.0 SITE INVESTIGATIONS AND EVALUATIONS

A number of investigations were performed at the Site between 1985 and 2008 that have characterized the types and distribution of contaminants in soil and groundwater and provide the basis for developing and evaluating CAAs for the Site. This section briefly summarizes the purpose, scope, and major findings of the investigations.

4.1 Pre-1998 Agreed Order Site Investigations

This section provides a summary of environmental activities and major findings of environmental investigations performed at the Site.

- **Contaminated Soil in Storm-Drain Trench, 1985:** Evidence of petroleum hydrocarbons in soil was observed just south of the Lease Parcel by Port personnel in 1985 (Figure 4-1; EPA, 1994). The soil was being excavated to relocate a storm drain. No additional information was collected regarding this area of potential soil contamination.
- **Short Fill Area, Groundwater Monitoring Well Installation, 1986-1987:** In 1986 and 1987, the Port authorized installation of groundwater monitoring wells in the area south of the Lease Parcel to provide groundwater quality data in the area hydraulically upgradient from the newly constructed short-fill area and the Short Fill Impoundment (Figure 4-1). Well W-10 historically was monitored to provide water quality data from the Shallow Aquifer beneath the Lease Parcel.
- **City Ice Facilities Expansion, 1987:** Petroleum hydrocarbon odors were detected and a sheen was observed in soil samples from Boring 2 during geotechnical drilling for a proposed facilities expansion at the City Ice lease, just west of the Lease Parcel (GeoEngineers, 1987a). The drilling was performed in January 1987 in the area north of building W-39, at the current location of building W-390 (Figure 4-1). During that drilling, five soil borings were installed inside the footprint of the future Building W-390. One boring was installed near each building footprint corner (Borings 1 through 4), and one boring (Boring 5) was installed near the center of the building footprint. Petroleum hydrocarbon odors were noted only in the log for Boring 2, which was located at the southeast corner of Building W-390.

  In June 1987, a monitoring well (MW-1) was installed near Boring 2 to estimate the lateral distribution (under the proposed building) of the hydrocarbons detected during geotechnical drilling (GeoEngineers, 1987b). In August 1987, samples of the vapor and groundwater were collected from the well for laboratory analyses (GeoEngineers, 1987c). Methane and toluene were detected in the vapor samples (20 milligrams per liter [mg/L] and between 1 and 5 mg/L, respectively). Total petroleum hydrocarbons (TPH), benzene, and xylenes were detected in the groundwater sample at concentrations of 30 mg/L, 20 mg/L, and 5 mg/L, respectively.
- **Phase I Hydrogeologic Investigation, 1988:** A Phase I Hydrogeologic Investigation of the Site was completed by Sweet-Edwards/EMCON in 1988 (Sweet-Edwards/EMCON, 1988) to provide a preliminary environmental characterization.

- **Phase II Hydrogeologic Investigation, 1989:** A Phase II Hydrogeologic Investigation of the Site was completed by Sweet Edwards /EMCON in 1989 (Sweet-Edwards/EMCON, 1989) to meet the requirements of BEI's RCRA 3013 Order.
- **City Ice Facilities Expansion, 1989:** Five geotechnical borings were drilled in the area to the west of City Ice buildings W-39 and W-390 in support of a proposed facility expansion (Figure 4-1). Groundwater observation wells were installed in Borings 1, 4, and 5 to measure water levels over time. Petroleum hydrocarbons were not noted in the boring logs for the project (Kennedy/Jenks Consultants, 1997).
- **UST Decommissioning, Tank T-91N, 1990:** Harding Lawson Associates (1990) installed three groundwater monitoring wells in the vicinity of an UST (Tank T-91-N) to assess potential impacts to soil and groundwater (Figure 4-1). The results of these investigations indicated the presence of free-phase liquid hydrocarbons in two of the three monitoring wells, including one well located upgradient from Tank T-91N.
- **RCRA Facility Investigation, 1992/1993:** BEI performed RCRA Facility Investigation (RFI) fieldwork at the Site between 1992 and 1993 in accordance with the final April 1992 RFI Work Plan (BEI, 1992). The results of these activities were reported in the draft RFI for the Site (BEI, 1995).
- **Triangular Area Investigation, 1992-1995; 2007:** Four soil borings were installed in October 1992 in the triangular area just east of the Lease Parcel (Figure 4-1). The borings were installed by Environmental Science & Engineering (ESE) on behalf of the Port (ESE, 1992). The purpose of the borings was to assess the subsurface soil conditions in the area prior to installation of an UST. Soil samples and a grab sample of groundwater were collected from the borings. TPH as gasoline, diesel, and oil was detected in soil samples, with concentrations for individual TPH constituents ranging as high as 15,000 milligrams per kilogram (mg/kg). TPH as oil was detected at a concentration of 900 mg/L in the groundwater sample. Dames & Moore (1993) performed a geotechnical investigation by drilling one soil boring at the triangular area and installing a piezometer to evaluate soil conditions prior to installation of tank T-91T at this location. In May 1995, tank T-91T was installed in the triangular area. A grab groundwater sample was collected from the tank excavation and analyzed for polychlorinated biphenyls (PCBs) and polycyclic aromatic hydrocarbons (PAHs). Neither PCBs nor PAHs were detected in the grab groundwater sample (Port, 1996). This tank was removed in December 2007 as it was no longer in use. The UST and buried lines and dispensers appeared to be in excellent condition, and no evidence of a release from the tank system was observed. Soil samples collected during the site assessment did not contain constituents above the MTCA Method A CULs for unrestricted land use. It should be noted that this area is located outside of the Site boundaries, but is discussed here for continuity with previous reports which included this area in the larger Terminal 91 Complex investigations. Future actions related to this area, will be addressed as part of the Upland Area unless new information indicates that the Site is affecting this portion of the facility.
- **Lube Warehouse Soil Sampling, 1995:** In April 1995, PNO demolished the two-story foam tank building and the adjacent single-story machine shop at the north end of the Lease Parcel (Figure 4-1). In May 1995, five soil samples were collected from beneath the demolished buildings. Two samples were collected from 0.5 ft bgs. Three samples

were collected from 2.5 ft bgs (Pacific Northern Geoscience, 1995a). Groundwater was not encountered during these sampling activities.

TPH as diesel and oil was detected at concentrations as high as 772 mg/kg in the soil samples collected from 0.5 ft bgs. TPH was not detected in the soil samples collected from 2.5 ft bgs.

- **PNO Pipeline Alignment Soil Remediation, Pier 90, 1995:** Petroleum hydrocarbons were detected in soil just outside the southeast corner of the Lease Parcel during excavation for installation of a new pipeline by PNO at Pier 90 in late 1995 (Figure 4-1). About 9 tons of petroleum-impacted soil were excavated and disposed of at Rabanco (Pacific Northern Geoscience, 1995b).
- **Soil Sampling Beneath Warehouse M-19, 1995:** In August 1995, the Port authorized the collection of four composite shallow soil samples from beneath the main warehouse in the north part of the Lease Parcel (Figure 4-1; Kennedy/Jenks Consultants, 1996). The soil samples were each composited from two to four individual grab samples. TPH as diesel and oil was detected in these composite soil samples at concentrations as high as 12,000 mg/kg.

The results of the Phase I Hydrogeologic Investigation (Sweet-Edwards/EMCON, 1988), the Phase II Hydrogeologic Investigation (Sweet-Edwards/EMCON, 1989), and the Draft RFI Report (BEI, 1995) were used as the primary basis for development of the Remedial Investigation/Data Evaluation (RI/DE) Report.

4.2 1998 Agreed Order RI/FS Site Investigations and Evaluations

The Agreed Order required the Potentially Liable Person (PLP) group, which included the Port, PSC, and PNO, to prepare the RI/DE Report (PSC, 1999). After completing the Draft RI/DE Report, the PLP group concluded that additional work would be necessary prior to evaluating cleanup options for the Site in an FS under MTCA. In June 1999, the PLP group submitted a letter (Roth Consulting, 1999a) to Ecology summarizing the proposed additional work and suggesting a meeting to discuss the proposed approach. The PLP group recommended that a piezometer be installed in the area between the Lease Parcel and the slip east of Pier 90, and that a Bridge Document (BD) be prepared to evaluate existing Site data with respect to potential cleanup alternatives, to focus future data collection efforts. The PLP group also recognized that significant groundwater data had been collected at the Site during past groundwater monitoring events. The PLP group also proposed that groundwater monitoring be performed semiannually instead of quarterly.

After meeting with Ecology on August 10, 1999, the PLP group and Ecology agreed on the terms of the modified groundwater monitoring program, on the installation of the piezometer, and on the concept of the BD work. The terms of the revised groundwater monitoring program are described in a letter to Ecology dated September 17, 1999 (Roth Consulting, 1999b). The *Proposed Piezometer Work Plan* (Roth Consulting, 2000b) was submitted to Ecology on August 21, 2000, and a piezometer was installed at the Site in February 2001. A second piezometer was installed between the first piezometer and the Site in May 2001 at the suggestion of Ecology per a meeting with the PLP group on March 8, 2001. Subsequent to the piezometer installation, after determining that the piezometers were downgradient from the Lease Parcel, the wells were incorporated into the groundwater sampling program and are now considered "monitoring wells". The well construction information for these monitoring wells was provided to Ecology in the *Piezometer Installation Report* dated March 2002 (Roth Consulting, 2002a). The PLP group also incorporated five downgradient wells, which were installed by the Port as part of its Terminal 91 Upland independent cleanup, into the groundwater monitoring program for the Site. The well construction information for those wells was provided to Ecology in the *Downgradient Well Installation Report* dated September 2002 (Roth Consulting, 2002b).

The BD work was described in the BD Work Plan (Roth Consulting, 2000c) and approved by Ecology in a letter dated November 17, 2000 (Ecology, 2000). The BD work included preparation of the BD Reports 1, 2, and 3 (BDR1, BDR2, and BDR3), soil vapor investigation reports, related work plans, and a groundwater sampling and analysis plan. Investigative activities and methods covered by these documents are further described in Section 4.2.2.

4.2.1 RI/DE Report

The objectives of the RI/DE Report consisted of the following:

- Provide a comprehensive report of investigative work completed to date to assist in preparation of a feasibility study and selection of potential cleanup actions;
- Evaluate the horizontal and vertical distribution of chemicals at the Site;
- Identify potential sources of contamination;
- Identify potential transport mechanisms of contaminants; and
- Identify potential data gaps.

The results of the groundwater monitoring program indicated that the distribution and concentrations of contaminants in groundwater beneath the Site had stabilized. However, a comparison between findings of the RI/DE Report and the objectives set forth in the 1998 AO resulted in the following recommendations to address data gaps:

- **Evaluation of the horizontal distribution of chemicals at the Site.** The vertical distribution of chemicals at the Site appeared to have been adequately characterized. However, the horizontal extent of impacted soil and groundwater appeared to extend beyond the boundaries of the monitoring network. The RI/DE Report proposed incorporation of available data from adjacent properties into the existing data set to further define the horizontal extent of chemicals at the Site.
- **Modification of the groundwater monitoring program.** Historical groundwater monitoring data and information gathered through incorporation of data from adjacent properties would be used to evaluate and make recommendations for revisions to the groundwater monitoring program. This was to include preparation of a comprehensive sampling and analysis plan identifying the proposed monitoring network, well purging and sampling procedures, sample frequency, and proposed revisions to the current analytical methodology, as appropriate.
- **Identification of potential off site source areas.** Information generated through incorporation of available data from adjacent properties would be assessed to evaluate potential source areas located outside the boundaries of the Lease Parcel.

- **Evaluation of the volume of LNAPL accumulations.** The horizontal extent of light non-aqueous phase liquid (LNAPL) accumulations on the Shallow Aquifer beneath the Site appeared to have been adequately characterized. However, insufficient data was available to fully assess the actual volume and potential recoverability of the LNAPL accumulations. The RI/DE Report recommended performing a series of bail-down tests in wells with historic LNAPL accumulations to generate additional data and assess the actual volume of LNAPL available for potential recovery.
- **Performance of Groundwater and Expanded Beneficial Use Survey**. The RI/DE Report recommended evaluation of existing data to establish the maximum beneficial use of groundwater potentially affected by activities at the Lease Parcel.

4.2.2 Bridge Document Investigations and Reports

Following the completion of the RI/DE Report, additional investigative activities were performed and documented under the previously mentioned Bridge Documents. This section describes the phased work that was performed as part of the BD investigations.

Two groundwater monitoring wells (CP_GP01 and CP_GP02) were installed at the Site in February and May 2001, respectively. These wells initially were to be used only for water-level measurements, but were found to be downgradient from the Lease Parcel and were subsequently incorporated into the groundwater sampling program. Activities and methods for this work were described in the *Proposed Piezometer Work Plan* (Roth Consulting, 2000b) and the *Piezometer Installation Report* (Roth Consulting, 2002a).

Five groundwater monitoring wells (CP_GP03 through CP_GP07) were installed at the Site February through May 2001 as part of the Terminal 91 Upland work. These wells were found to be downgradient from the Lease Parcel and subsequently were incorporated into the Site groundwater sampling program. Activities and methods for this work were described in the *Terminal 91 Upland Independent Cleanup Proposed Work Plan No. 1* (Roth Consulting, 2000a) and the *Downgradient Well Installation Report* (Roth Consulting, 2002b).

The BDR1 (Roth Consulting, 2001b) included the findings of the following tasks:

- Identified potential exposure pathways, performed an analysis of the highest beneficial use of groundwater, determined if a terrestrial ecological exclusion was warranted, developed screening levels for groundwater based on site-specific potential exposure pathways and highest beneficial use of groundwater, and assessed potential points of compliance for groundwater; and
- Reviewed existing data relative to site-specific potential exposure pathways and potential cleanup alternatives, and identified data gaps with respect to site-specific potential exposure pathways and potential cleanup alternatives.

The BDR2 (Roth Consulting, 2003a) included the findings of the following tasks:

- Reviewed and revised the list of chemicals of potential concern (COPCs), plotted concentrations of selected COPCs on Site maps, and assessed the distribution and possible sources of COPCs;

- Reviewed and revised groundwater screening levels, and evaluated existing groundwater data relative to the groundwater screening levels, including identification of monitoring wells with screening level exceedances;
- Reviewed the passive LNAPL recovery program results and expanded review of data from property outside the Lease Parcel; and
- Reviewed monitoring well locations and the then-current sampling program, and prepared the *Groundwater Sampling and Analysis Plan* (GWSAP) (PSC 2003b), with recommended additional work to be performed and reported in the BDR3.

The BDR3 (Aspect Consulting [Aspect], 2004a) included the findings of the following tasks:

- Well abandonment and installation, hydraulic conductivity testing, and soil sample collection for physical and hydraulic property testing;
- Installation, development, short-term tidal monitoring, and decommissioning of 11 Shallow Aquifer temporary piezometers;
- Month-long tidal and water-level monitoring in five shallow and deep well pairs;
- Assessment of potential stratification of contaminants in groundwater by depth-specific groundwater sampling;
- Collection of LNAPL samples and LNAPL bail-down testing;
- Compilation of bulkhead construction data and a review of underground utilities information to assess the potential for contaminant migration along preferred pathways; and
- Revision of the conceptual site model (CSM) for the Site.

The activities and methods for the BDR3 work were described in a memorandum titled *Preliminary Results—Limited Tidal Monitoring Study, Piers 90 and 91* (Aspect, 2003), the *Final Work Plan for Additional Data Collection* (WPADC) (PSC and Geomatrix, 2003), the BD Work Plan (Roth Consulting, 2000c), and BDR3 (Aspect, 2004a).

4.2.3 Soil Vapor Investigations

Based on the findings of the BDR1, a soil vapor investigation was initiated in 2001 in the vicinity of Building M-28, located immediately to the southwest of the Lease Parcel. The initial investigation consisted of the following tasks:

- Installation of three soil vapor ports through the concrete slab inside Building M-28, collection of soil vapor samples, and analysis of the samples for volatile organic compounds (VOCs);
- Collection of two geotechnical soil samples for laboratory analysis of physical parameters; and
- Modeling concentrations of VOCs in soil vapor to concentrations in indoor air using the Johnson and Ettinger (JE) Model for Subsurface Vapor Intrusion into Buildings.

A report of these activities was provided in the Soil Vapor Technical Memorandum No. 1 (SVTM1; PSC, 2001b). Subsequent to the SVTM1, additional investigation of the soil vapor pathway was performed in 2002 in the vicinity of Building M-28. The additional investigation consisted of the following tasks:

- Collection of soil vapor samples from the three soil vapor ports in May 2002 and analysis for VOCs;
- Investigation of sumps inside Building M-28 that could act as preferential pathways for soil vapor migration into the building; and
- Modeling concentrations of VOCs in soil, soil vapor, and groundwater to concentrations in indoor air using the JE Model.

The activities and methods for this work were described in the *Soil Vapor Technical Memorandum No. 2* (SVTM2) (PSC, 2003a) (which also incorporates the work done as part of the SVTM1) and the *Soil Vapor Sampling and Analysis Plan* (SVSAP) (PSC, 2001a).

A supplemental soil vapor evaluation was performed in and near Building M-28 in July 2004 to evaluate petroleum-hydrocarbon-related soil vapor constituents and their potential to impact indoor air quality. The following tasks were performed as part of this evaluation:

- Collection of one sub-slab soil vapor sample and one ambient air sample from outside Building M-28;
- Laboratory analysis of vapor and air samples for air-phase petroleum hydrocarbons using the Massachusetts Department of Environmental Protection (MADEP) Method of the Determination of Air-Phase Petroleum Hydrocarbons (APH); and
- Development of MTCA Method C air CULs for the sampled constituents.

The activities and methods for this work were described in the *Soil Vapor Evaluation, Building M-28* (PIONEER, 2004), the SVSAP (PSC, 2001a), and the *Soil Vapor Sampling and Analysis Plan Addendum* (SVSAP Addendum) (PSC, 2003c).

As part of the soil vapor investigative work, several floor structures were identified that had the potential for acting as preferential pathways for migration of vapors from soil to indoor air in Building M-28. Those floor structures were filled in early October 2003 and March 2005. The activities and methods for this work were described in a letter to Ecology (Roth Consulting, 2003b), in the *Status Report for Fourth Quarter 2003* (Roth Consulting, 2004a), and in the *Status Report for First Quarter 2005* (Roth Consulting, 2005a).

4.2.4 Tidal Studies and Groundwater Seepage Evaluation

A tidal study was performed in the summer of 2001 as part of the work required under the 1998 AO. The tidal study consisted of the following tasks:

- Automatic measurement of water levels in 13 groundwater monitoring wells over a 72-hour period, with automatic measurement of pH, dissolved oxygen (DO), and specific conductivity in 10 groundwater monitoring wells;

- Collection of groundwater samples from the seven furthest downgradient wells (GP-01 through GP-07) at times representing the low low tide in each well; and
- Assessment for the presence of LNAPL in 23 monitoring wells and one piezometer.

The activities, methods, and findings for this work were described in the *Tidal Study Report* (Port and Fitzgerald, 2002), the *Terminal 91 Upland Independent Cleanup Proposed Work Plan No. 1* (Roth Consulting, 2000a), and the *Proposal for Shallow Aquifer Tidal Study and Ground Water Sampling* (Roth Consulting, 2001a).

A groundwater seepage evaluation was performed in 2004 to refine the CSM. The work performed included the following tasks:

- Installation, development, and decommissioning of 16 Shallow Aquifer temporary piezometers on Piers 90 and 91;
- Performance of a 22-day tidal study in August/September 2004;
- Modeling the Shallow Aquifer along the piers and the Deep Confined Aquifer from upland areas to the downgradient offshore limit of the Deep Confined Aquifer using the U. S. Geological Survey (USGS) groundwater flow model MODFLOW; and
- Evaluation of groundwater discharge to Elliott Bay, revision of the CSM, and recommendation of compliance monitoring wells and an approach for evaluating groundwater compliance.

The activities and methods were described in the *Groundwater Seepage Evaluation Report* (Seepage Report) (Aspect, 2004c) and the *Work Plan for Groundwater Seepage Evaluation* (WPGSE) (Aspect, 2004b).

4.2.5 Installation of Additional Downgradient and Conditional Points of Compliance Wells

Three Shallow Aquifer monitoring wells (CP_GP08, CP_GP09, and CP_GP10) were installed and developed in December 2004. Conductivity profiling was performed on each of these three Shallow Aquifer monitoring wells. The methods used were described in the *Letter Report re Shallow Aquifer Well Installation and Development* (Aspect, 2005) and in a letter from Roth Consulting to Ecology dated December 13, 2004 (Roth Consulting, 2004b). Groundwater samples were collected from these wells beginning in December 2004 and subsequently on a quarterly basis. Methods used for groundwater sample collection were provided in the GWSAP (PSC, 2003b).

On March 17 and 18, 2005, four new groundwater monitoring wells (CP_GP11 through CP_GP14) were installed and developed as part of the Terminal 91 Upland independent cleanup activities (Port, 2005). Based on an assessment of the results of the March 2005 water level measurement event for the Site, together with the water level measurements from the four new wells, the wells were determined to be in the groundwater flowpath downgradient from the Lease Parcel and were incorporated into the Site monitoring program beginning in March 2005.

4.2.6 Monitored Natural Attenuation Evaluation

An MNA evaluation was conducted in 2005 and 2006 to provide sufficient additional groundwater quality data to evaluate natural attenuation at the Site, and the potential efficacy of MNA as a remedial technology at the Site. The evaluation was completed consistent with Ecology's MNA guidance document (Ecology, 2005a) and an approved work plan (PES, 2005b), by considering data collected along three groundwater flow paths from the former tank farm: Pier 90, Pier 91, and AOC 11. Source, plume, and sentinel wells were used along each flowpath. The wells used and the flowpaths evaluated in the study are shown in Figure 4-2.

Groundwater samples were collected from the MNA wells in September and December 2005, and March, April, and June 2006. Each groundwater sample was analyzed in the field for a variety of MNA parameters and was submitted for laboratory analysis of PAHs, and MNA parameters. Groundwater levels were also measured in each well during each sampling event.

The data were evaluated by reviewing the MNA chemistry data tables, assessing historical petroleum hydrocarbon data, and by using Ecology's natural attenuation analysis tool package (Ecology, 2005b). The MNA monitoring results were compared to the screening levels presented in BDR2 (Roth Consulting, 2003a), and were evaluated relative to the five natural attenuation criteria specified in Ecology's MNA guidance (Ecology, 2005a).

The MNA evaluation showed:

- Concentrations of gasoline-range organics (GRO); diesel-range organics (DRO); benzene, toluene, ethylbenzene, and xylenes (BTEX); and PAHs below the screening levels at the sentinel wells;
- A generally stable or shrinking groundwater plume;
- Strong indications that biodegradation is occurring along each of the three flowpaths evaluated; and
- Geochemical indicator concentrations demonstrating that the aquifer along each of the three flowpaths has more than sufficient assimilative capacity to biodegrade the concentrations of GRO and DRO present at the Site.

Based on the very low-level or non-detect results for VOCs, PAHs, semi-volatile organic compounds (SVOCs), and oil-range organics, the stable GRO/DRO plumes, and the favorable geochemical results, the evaluation concluded that MNA at the Site can be a viable component of a cleanup alternative and recommended that MNA be included as a technology considered in the FS. Ecology agreed with the conclusion in a letter dated December 28, 2006.

4.2.7 Data Gaps Investigations (RSSL & PCB Evaluations)

Data gaps investigations were conducted to provide the data necessary to conduct the soil-to-groundwater pathway evaluation, and in particular to assess the potential for concentrations of constituents to exceed RSSLs in the three investigated areas (Figure 2-4): the Lease Parcel, AOC 11, and SWMU 30. The investigations addressed data gaps identified during preliminary development of site-specific RSSLs (PES, 2006a) and during performance of a LNAPL pilot study (PES, 2006b), as well as provided additional data to support development of remedial action alternatives within the Lease Parcel. Three phases of field investigations were conducted in 2006 and 2007.

An evaluation of RSSLs was conducted in an attempt to estimate the maximum residual soil concentrations at which LNAPL will not accumulate on or in groundwater. The evaluation focused on the Lease Parcel and immediately adjacent areas, using reported spills and releases to target specific hazardous substances for evaluation. The RSSL evaluation was conducted in two phases, the first in 2006 using data available at that time and the second in 2008 using data generated in the data gaps investigations.

4.2.7.1 Preliminary Residual Saturation Screening Level Evaluation

The preliminary RSSL evaluation involved: (1) screening the hazardous substances needing evaluation; (2) compiling Site chemistry, LNAPL characteristics, and LNAPL monitoring data; (3) calculating RSSLs for individual hazardous substances using the MTCA four-phase partitioning model spreadsheets; and (4) calculating RSSLs for petroleum hydrocarbon mixtures using site data and published industry references for the different types of petroleum mixture fractions or for the most conservative fraction. Based on the bulk storage and documented release information, the preliminary evaluation considered two petroleum mixtures (Bunker C fuel oil and middle distillate fuel oil) and one chemical (toluene) as the hazardous substances that have the potential for LNAPL formation.

RSSL ranges were calculated for Bunker C fuel oil, middle distillate fuel oil, and toluene to address the variation in soil type at the Site. The lower end of the ranges represented product in medium to coarse sand, and the upper end of the ranges represented more weathered product in fine to medium sand. RSSL ranges were calculated using Site-specific data and were compared to similar ranges determined from Ecology and American Petroleum Institute (API) tables. The results are summarized below:

- For Bunker C fuel oils, the calculated RSSL range using Site-specific data was 16,084 to 47,853 mg/kg, compared to the range of RSSL concentrations from 17,419 mg/kg to 53,067 mg/kg listed in Ecology and API references;
- For middle distillate fuel oils, the calculated RSSL range using Site-specific data was 7,410 to 14,130 mg/kg, compared to the range of RSSL concentrations from 7,742 mg/kg to 13,333 mg/kg listed in Ecology and API references; and
- For toluene, the calculated RSSL using Site-specific data was 845 mg/kg. Data in Ecology and API references were not available for toluene.

The preliminary evaluation proposed: (1) that there is no potential for non-aqueous phase liquid (NAPL) to migrate from soil to groundwater if concentrations of hazardous substances in soil are below the low value of the RSSL range; (2) that there may be the potential for NAPL to migrate from soil to groundwater if concentrations of hazardous substances in soil are above the high value of the RSSL range; and (3) that additional data may be needed to further evaluate the potential for NAPL accumulation if concentrations of hazardous substances in soil at a specific location are within the RSSL range. A review of the existing soil data during the preliminary evaluation noted exceedances of the preliminary RSSLs in the Lease Parcel and nearby vicinity.

4.2.7.2 Phase 1 Data Gaps Investigation

As noted above, the purpose of the data gaps investigation was to provide additional information on the distribution of TPH in and adjacent to the Lease Parcel to support further development and evaluation of RSSLs and to support development of CAAs within the Lease Parcel.

Per the *Data Gaps Investigation Work Plan* (PES, 2007a), 88 soil borings (DG-1 through DG-88) were drilled and sampled in the Lease Parcel, AOC 11, and SWMU 30 in May 2007. Continuous soil samples were collected from each boring. The samples were field screened for VOCs with a photoionization detector (PID) and observed for lithology and indications of contamination. Selected vadose zone, smear zone, and saturated zone soil samples were submitted for laboratory analysis of petroleum hydrocarbons using Ecology Method NWTPH-Gx (in some locations), diesel and oil range TPH using Ecology Method NWTPH-Dx (with silica gel cleanup), and toluene (in some locations) using EPA Method 8021b.

The results (see Section 5.4) were compared to the preliminary RSSLs in the *MNA Evaluation Technical Memorandum* (PES, 2006a) and were used in the second phase of the RSSL evaluation (see Section 4.2.7.5). Based on elevated TPH results, a second phase of the investigation was proposed. The results of the first phase of work, together with a work plan addendum (PES, 2007b) proposing a second phase of work were submitted for Ecology review and approval.

4.2.7.3 Phase 2 Data Gaps Investigation

The objective of the second phase was to install shallow monitoring wells in order to monitor for the presence of LNAPL and direct-push borings to explore the horizontal extent of soil with concentrations exceeding the preliminary RSSLs. In the second phase of work, ten LNAPL monitoring wells (CP-PR03 through CP-PR12) were installed in the Lease Parcel, one LNAPL monitoring well (CP-PR13) was installed in AOC 11, and six direct-push "step-out" borings (DG-89 through DG-94) were drilled on the south, east, and north sides of the Lease Parcel. The Phase 2 direct-push borings were sampled, and laboratory analyses were performed as in the first phase of work. The monitoring wells were developed and subsequently monitored for the presence of LNAPL.

The results (see Section 5.4) were compared to the preliminary RSSLs (PES, 2006a) and were used in the second phase of the RSSL evaluation (see Section 4.2.7.5). The results of the Phase 2 data gaps investigation were submitted to Ecology in a technical memorandum (PES, 2008a), and an addendum to the work plan for a third phase of investigation was subsequently submitted (PES, 2008b).

4.2.7.4 Phase 3 Data Gaps Investigation

The third phase of the data gaps investigation was conducted to investigate three areas in and near the Lease Parcel. Three borings (DG-95, DG-96, and DG-97) were drilled to the west, north, and east, respectively, of DG-94 to investigate the extent of the DG-94 exceedances of the preliminary RSSLs. One boring (DG-98) was drilled along the Lease Parcel boundary to the northeast of DG-92 to investigate the extent of the DG-92 smear zone exceedances of the lowest preliminary RSSL. Seventeen borings (DG-99 through DG-115) were drilled in and west of the pumphouse area, in the Small Yard, and in the Marine Diesel Oil Yard to provide PCB data necessary to develop disposal costs for use in soil excavation alternatives. The Phase 3 direct-push borings were sampled, and laboratory analyses were performed as in the first phases of work. Additionally, LNAPL was monitored in the wells installed in the Phase 2 data gaps investigation, as discussed in Section 4.2.8.

None of the results from step-out borings DG-95 through DG-98 were above the lower limit of the preliminary RSSL ranges. None of the vadose zone results from PCB investigation borings DG-99 through DG-115 were above the lower limit of the preliminary RSSL ranges for petroleum products. Similarly, none of the gasoline-range and lube oil-range results were above the lower limit of the preliminary RSSL ranges. Smear and/or saturated zone samples from three borings (DG-100, DG-102, and DG-114) were within the diesel preliminary RSSL range. Two smear zone samples were above the upper limit of the preliminary diesel RSSL range: those from DG-101 and DG-104. Soil PCB concentrations were low compared to the elevated PCB result that initiated the PCB investigation, with the highest total PCB concentration at 9.3 mg/kg in DG-104. The results of the Phase 3 data gaps investigation were submitted to Ecology in a technical memorandum (PES, 2008d).

4.2.7.5 Final Residual Saturation Screening Level Evaluation

The final RSSL evaluation involved: (1) updating the RSSLs using soil physical property data and LNAPL characteristic data collected in first two phases of the data gaps investigation; (2) comparing TPH concentrations in data gaps investigation soil samples to RSSLs; and (3) comparing data gaps investigation soil TPH concentrations to observations from shallow monitoring wells to determine if there is an empirical relationship that may be used to predict LNAPL occurrence.

Revised RSSLs were developed for toluene, gasoline, middle distillate petroleum products (diesel range), and fuel oil. The MTCA four-phase partitioning model spreadsheets were used to develop the revised toluene RSSL, and Ecology and other published industry references were used to develop the revised RSSLs for gasoline, middle distillate petroleum products, and fuel oil. As in the preliminary evaluation, RSSL ranges were calculated with the lower end of the ranges representing product in coarse sand and gravel, and the upper end of the ranges representing product in fine to medium sand. All of the revised RSSLs were within the initial range of values developed in the preliminary evaluation (PES, 2006a):

- For fuel oils, the calculated RSSL range was 8,727 to 30,000 mg/kg;
- For middle distillate petroleum products, the calculated RSSL range was 3,879 to 13,333 mg/kg;
- For gasoline, the calculated RSSL range was 1,636 to 5,625 mg/kg; and
- For toluene, the calculated RSSL was 832 mg/kg.

Based on the comparison of TPH concentrations in data gaps investigation soil samples, shallow monitoring well LNAPL monitoring results, and RSSLs, the evaluation found the following:

- The many complex and competing factors at the Site do not allow clear or precise conclusions regarding the comparison of TPH concentrations in soil, RSSLs, and presence or absence of LNAPL at the Site as a whole (Lease Parcel, AOC 11, SWMU 30);

- The wide range of TPH concentrations measured in soil samples adjacent to monitoring wells both with and without measurable LNAPL do not allow a Site-wide empirical demonstration that measured soil concentrations either will or will not result in the accumulation of LNAPL on or in groundwater. Many variables in the evaluation may lead to inconsistencies between the soil and LNAPL data, including uncertainties in the locations of historical releases, the period of time since such releases have occurred, spatial variations in soil properties, variability in LNAPL weathering, and variability of LNAPL mixtures. These variables cannot be quantified using the existing data set, and it does not seem likely that additional data will provide significant clarity; and
- Although there are inconsistencies when evaluating single data points, the RSSLs appear to have at least some utility as a predictor of the current or potential occurrence of LNAPL, at least within the portions of the Lease Parcel and immediately adjacent areas (e.g., western portion of the Marine Diesel Yard, and area around the pumphouse).

4.2.8 LNAPL Monitoring Program

The nature and extent of LNAPLs at the Site has been investigated through measurements conducted monthly from February 1992 through December 1995, quarterly from early 1996 through 1999, and then monthly since 1999 (PSC et al., 1999; Port and Fitzgerald, 2002; Roth Consulting, 2003a; Aspect Consulting, 2004a). The SWMU 30 wells have been monitored on a quarterly or semiannual basis for the last several years. In early August 2008, monitoring well UT-MW39-2 was added to the monitoring program. Based on the amount of LNAPL present in select wells (CP-PR04, CP-PR07, and CP-PR12), LNAPL monitoring, and where appropriate recovery (see Section 6.7) has been conducted on at least a weekly basis since early March 2008.

LNAPL accumulations (including a sheen to measurable LNAPL) have been detected in 23 current or former wells within the Site. See Section 5.4.1 for a detailed list of these wells and a summary of the measured product thicknesses.

Former wells CP-109, CP-116, CP-117, CP-118, and CP-119, which were located inside the tank farm secondary containment walls, were abandoned in August 2004, prior to demolition of aboveground structures at the tank farm in the spring and summer of 2005. These wells were replaced by CP-PR01 through CP-PR12. As part of the FS work described in the FS Work Plan (PES et al., 2005a), CP-PR01 and CP-PR02 were installed in August 2005 for use in a pilot study. The purpose of the pilot study was to evaluate the recoverability of LNAPL at the Lease Parcel. CP-PR01 and CP-PR02 were installed at locations where former wells showed the highest LNAPL recovery rate, near CP-117 and CP-118, respectively. From the time of installation until the early November 2005 monthly LNAPL monitoring event, only sheens were detected in the two pilot study wells. Therefore, the two pilot study wells were incorporated into the monthly LNAPL monitoring program until sufficient LNAPL had accumulated to perform the pilot study. Wells CP-PR03 through CP-PR12 were installed in October 2007 as part of the data gaps investigation discussed above.

4.2.9 Groundwater Monitoring Program

Groundwater monitoring currently is being performed at the Site on an annual basis using selected wells. The current groundwater monitoring program is as follows:

- Measurement, on an annual basis, of groundwater levels and LNAPL thickness (where present) in 45 Shallow Aquifer monitoring wells, 10 Deep Confined Aquifer monitoring wells, 1 deep short fill monitoring well, and 1 shallow piezometer. The annual event is performed during the dry season (September/October);

- Collection of groundwater samples from 8 Shallow Aquifer monitoring wells (CP-103A, CP-106A, CP-108A, CP-114, CP-GP08, CP0GP09R, CP-GP10, and CP-GP14) and 5 Deep Confined Aquifer monitoring wells (CP-108B, CP-203B, CP-205B, CP-GP01B, and PNO-MW06B) (Figure 4-3) on an annual basis (in conjunction with groundwater and LNAPL level measurement events); and

- Laboratory analysis of the groundwater samples for TPH as gasoline, diesel, and lube-oil-range hydrocarbons; PAHs; the SVOCs carbazole, dibenzofuran, and 1-methylnaphthalene; the VOCs 1-4 dichlorobenzene and vinyl chloride; and the metals arsenic and zinc.

These wells are sampled and the laboratory analyses performed as required under the terms of the 1998 AO as modified by the following documents:

- Letters from Roth Consulting to Ecology dated September 17, 1999 and October 1, 2002;
- Ecology’s approval letters dated October 1, 1999, October 15, 1999, and November 7, 2002;
- A letter from Roth Consulting to Ecology dated September 10, 2003 regarding sampling additional potential background wells;
- Ecology’s approval of sampling additional potential background wells, emailed from Galen Tritt to Susan Roth on September 25, 2003;
- Final GWSAP (PSC, 2003b);
- A letter from Roth Consulting to Ecology dated December 13, 2004 requesting approval to add three new monitoring wells (CP_GP08 through CP_GP10);
- Ecology’s letter of approval dated December 15, 2004 to add three new monitoring wells;
- A letter from Roth Consulting dated March 4, 2005 with an attached memo from (PIONEER, 2005), proposing to discontinue groundwater sampling at selected monitoring wells beginning with the March 2005 event;
- Ecology's April 26, 2005 letter of approval for discontinuing sampling at selected wells;
- MNA Work Plan (PES, 2005b); and
- A letter from Roth Consulting dated May 17, 2007 requesting approval to move seven monitoring wells to the semiannual groundwater monitoring program and Ecology's approval letter dated May 24, 2007.

- A letter from Roth Consulting dated February 24, 2009 requesting a reduction in the groundwater monitoring program from semiannual to annual, including a reduction in the wells and constituents monitored; and Ecology's approval letter dated February 27, 2009.

5.0 SUMMARY OF INVESTIGATION RESULTS

This section summarizes the results and major conclusions of the environmental investigations summarized in Section 4 related to the site geology, groundwater flow, and nature and extent of contamination.

5.1 Local Geology

Five mappable lithologic units have been identified beneath the Lease Parcel and adjacent upland areas of the Site. These units in order of increasing depth include:

- The Shallow Sand Unit;
- The Silty Sand Unit and the Gravel Layer within the Silty Sand Unit;
- The Deep Sand Unit; and
- The Silty Clayey Sand Unit.

Five geologic cross-sections were generated and documented in the RI/DE Report using stratigraphic information from boring logs to illustrate subsurface conditions beneath the Lease Parcel. Copies of the cross section location map and cross sections are provided in Appendix A1. RI/DE Report Figure 4-1 provides a plan view of the Lease Parcel showing the locations of each of the geologic cross-sections. The five cross-sections are displayed in RI/DE Report Figures 4-2 through 4-6.

5.1.1 Shallow Sand Unit

The Shallow Sand Unit consists of fill material emplaced over shallow marine and tidal marsh deposits of Smith Cove during the early 1900s. It consists primarily of olive to gray, moderately to poorly sorted, fine- to medium-grained, unconsolidated sand, with laminations of silty sand and gravel lenses occurring locally. The unit contains trace amounts of silt, shell fragments, and wood debris. The Shallow Sand Unit extends vertically from just below the paved ground surface to between 15 and 20 ft bgs and appears to be laterally continuous across the Lease Parcel, beneath the upland areas, and beneath the piers (Hart Crowser, 1999, 2002).

5.1.2 Silty Sand Unit

The Silty Sand Unit is comprised of gray or olive, moderately sorted, fine- to medium-grained, silty sand with traces of coarse sand, shell debris, and wood debris. This unit is interpreted to be native marsh, intertidal, and shallow marine sediments that formed the pre-fill surface in the Smith Cover Waterway and the adjacent tidelands.

Beneath the Lease Parcel and adjacent upland areas, the Silty Sand Unit generally occurs at depths of 15 to 20 ft bgs, and varies from 20 ft thick beneath the rail yard, east of the Lease Parcel, to 5 ft or less in the southwest corner of the Lease Parcel. To the southeast of the Lease Parcel beneath the head of Pier 90, the Silty Sand Unit generally occurs at depths of 25 to 30 ft bgs and varies in thickness from 10 to 16 ft. The Silty Sand Unit appears to be absent in the area southwest of the Lease Parcel, beneath the inner (shoreward) half of Pier 91, beneath the center slip between Piers 90 and 91, and beneath most of the outer portion of Pier 90. The area where the Silty Sand Unit is absent, suggests the presence of a former channel extending inland from Smith Cove into the upland area west of the Lease Parcel. This channel may have been an area of either erosion and/or minimal sediment deposition, which would account for the lack of tidal marsh and shallow marine sediments typical of the Silty Sand Unit in this area. An isopach map (Figure 4-1 of BDR3) of the Silty Sand Unit is provided in Appendix A2.

A light gray to brown, moderately to poorly sorted, silty sandy Gravel Layer was encountered within the Silty Sand Unit at some boring locations. This Gravel Layer, labeled as the Intermediate Zone in the cross-sections, is likely representative of a gravel lag deposited in the floor of a tidal channel within the former tidal marsh, where current conditions were sufficient to winnow away much of the finer sand and silt.

5.1.3 Deep Sand Unit

The Deep Sand Unit is composed primarily of olive to gray, poorly to moderately sorted, medium- to coarse-grained sand and gravelly sand, with only isolated occurrences of silt. Shell and wood debris were noted at some locations. However, beneath the northern portion of the Lease Parcel (borings CP-115B and CP-205B), the Deep Sand Unit is composed of only 6 to 8 ft of sand, gravelly sand and sandy gravel, with the remaining deeper portions of the unit characterized by interbedded silty sand and sand. To the south beneath the piers and center slip, the Deep Sand Unit consists of dense to very dense fine to coarse sand, gravelly sand, and sandy gravel, with some thin interbeds of silty sand, silt and clayey silt. Shells are present throughout the Deep Sand Unit.

The Deep Sand Unit directly underlies the Silty Sand Unit, except in the southwest corner of the Lease Parcel and beneath the south part of Pier 91 and the center slip, where the Silty Sand Unit appears absent and the Deep Sand Unit directly underlies the Shallow Sand Unit. The depth to the top of the Deep Sand Unit varies from approximately 25 ft bgs, at the center of the Lease Parcel to as much as 45 ft beneath the north end of Pier 90. The thickness of the unit increases from a minimum of 23 ft beneath the northeastern portion of the Lease Parcel (boring CP-205B) to in excess of 100 ft beneath the outer ends of Piers 90 and 91 (Hart Crowser, 1999, 2002).

The Deep Sand Unit is interpreted to be a nearshore marine deposit, sourced by erosion of the adjacent headlands during periods of lowered levels after the last Vashon glacial period.

5.1.4 Silty Clayey Sand Unit

The Silty Clayey Sand Unit is composed of soft to stiff, olive to gray, fine-grained sediments, primarily silty clay and clayey silt, with lesser amounts of silt and silty, clayey sand. Traces of shell debris and wood debris are present throughout the unit. The top of the Silty Clayey Sand Unit is shallowest beneath the eastern portion of the Lease Parcel, where it occurs as shallow as 42 ft bgs, in boring CP-106B. Depth to the top of the unit increases to the south and west, with the top of the unit in excess of 100 ft bgs beneath the middle portions of Piers 90 and 91 (Hart Crowser 1999, 2002).

The Silty Clayey Sand Unit underlies the Deep Sand Unit throughout the upland portion of the Site and southward beneath the landward portions of Piers 90 and 91. Borings installed by Hart Crowser (1999, 2002) on the outer portions of both piers suggest that the Silty Clayey Sand Unit thins southward and pinches out landward of the ends of the piers.

The base of the Silty Clayey Sand Unit was not encountered in any of the borings beneath the Lease Parcel or upland areas. Where present in borings installed in the inner portions of the piers, north of where the Silty Clayey Sand pinches out, the Silty Clayey Sand Unit is underlain by very dense, silty and gravelly sand. This underlying silty and gravelly sand is lacking in shells, and is likely Vashon glacial deposits.

5.2 Hydrostratigraphy

Analysis of the geologic and hydrogeologic data collected during investigations at the Site indicates the presence of five primary hydrostratigraphic units beneath the Lease Parcel. These units roughly correspond to the five primary stratigraphic units discussed above. The list below summarizes the five hydrostratigraphic units and their corresponding stratigraphic units. The site plan and cross sections of these units beneath the Lease Parcel are provided in Appendix A1:

- Shallow Aquifer (unconfined) – Shallow Sand Unit
- Upper Confining Unit – Silty Sand Unit
- Intermediate Zone – Gravel Layer within Silty Sand Unit
- Deep Confined Aquifer – Deep Sand Unit
- Lower Confining Unit – Silty Clayey Sand Unit

The Shallow Aquifer corresponds to the Shallow Sand stratigraphic unit. The Shallow Aquifer is unconfined, and contains an unsaturated zone extending from ground surface to approximately 5 ft bgs. The saturated thickness of the Shallow Aquifer is estimated to be about 10 to 15 ft. The Shallow Aquifer is laterally continuous across the Lease Parcel.

The Upper Confining Unit corresponds to the Silty Sand stratigraphic unit. The Upper Confining Unit is fully saturated and appears to be laterally continuous across the Lease Parcel. Figure 4-7 in Appendix A1 shows a contour map of the elevation of the top of the Silty Sand Unit beneath the Lease Parcel. The top of the unit forms a northwest-southeast oriented ridge along the western side of the Lease Parcel between CP-103B and CP-113. The surface elevation slopes to the west, towards well CP-111, and to the east, towards CP-109. The top of the unit in the area beneath the tank yards forms a broad and shallow topographic low (trough) approximately 5 ft deep near well CP-109. In the area between wells CP-104B, CP-107, and CP-112, the surface forms a high saddle. Along the east side of the saddle, in the area west of the Small Yard, the surface slopes eastward toward the topographic low.

A map showing the estimated thickness of the silty sand unit is provided in RI/DE Figure 4-8, Appendix A1. The unit is thickest (approximately 29 ft) along the eastern boundary of the Lease Parcel between borings CP-108B and CP-106B and thins to between 13 and 15 ft along the western boundary of the Lease Parcel, between borings CP-103B and CP-104B.

The Deep Confined Aquifer corresponds to the Deep Sand stratigraphic unit. The Deep Confined Aquifer appears to be laterally continuous across the southern and central portions of the Lease Parcel. It is uncertain if the Deep Confined Aquifer exists beneath the northern portion of the Site. The Deep Confined Aquifer is confined above by the Silty Sand Unit (Upper Confining Unit) and below by the Silty Clayey Sand Unit (Lower Confining Unit).

5.3 Groundwater Flow Direction and Velocity

5.3.1 Shallow Aquifer

Water level data collected in conjunction with a groundwater seepage evaluation (Aspect, 2004b) and during routine monitoring of monitoring wells at the Site show that the dominant unconfined groundwater flow direction is towards the south beneath the Lease Parcel and to the southwest beneath AOC 11 (Figure 5-1). Water levels in the wells typically range between 3 and 7 ft bgs (Aspect, 2004b) and generally correspond to seasonal variations in precipitation rates, with the highest water levels observed during the wetter winter months. The typical Site horizontal gradient beneath the Lease Parcel is approximately 0.001 ft per foot (Aspect, 2004b).

South of the Lease Parcel, water levels and tidal response data indicate that the relatively impermeable east-west trending, shore-parallel bulkheads and fine-grained Short Fill soil exert significant control over Shallow Aquifer groundwater flow, effectively “channeling” groundwater between the bulkheads within the inner portions of Piers 90 and 91. The shore-parallel bulkhead west of Pier 91 appears to direct shallow groundwater flow to the west southwest of AOC 11. Hence, the Short Fill itself does not appear to be within the flow path of shallow ground water originating from the Site.

Aspect (2004a) reported that downward vertical gradients between the Shallow Aquifer and Deep Confined Aquifers were noted throughout the Site. Vertical gradients ranged from approximately 0.018 to 0.040 ft/foot, with vertical gradients decreasing to the south. Despite the presence of downward vertical gradients, significant downward movement of Shallow Aquifer groundwater under most of the Site is considered unlikely due to the low measured vertical permeabilities in the upper confining unit. From the southeast corner of the Lease Parcel southward where the upper confining unit appears to be absent, some net movement of Shallow Aquifer groundwater into the Deep Confined Aquifer is likely occurring.

5.3.2 Deep Confined Aquifer

Tidally-averaged groundwater elevation data (Aspect, 2004a) confirm that the groundwater flow direction in the Deep Confined Aquifer beneath and shoreward of the Lease Parcel is towards the south. As in the Shallow Aquifer, water levels in the Deep Confined Aquifer respond to seasonal variations in precipitation rates, with the highest water levels observed during the wetter winter months. The typical Deep Confined Aquifer horizontal gradient is relatively constant at approximately 0.003 ft/foot beneath the Site, with a flattening of the horizontal gradient beneath and southward of the east-west trending, shore-parallel bulkheads.

Unlike in the Shallow Aquifer, most of the existing shore-parallel and pier-perimeter bulkheads do not exert an influence on groundwater flow in the Deep Confined Aquifer due to their shallow depth. The material in the Short Fill, and the deeper sheet pile installations on Pier 90, extend into the upper portions of the Deep Confined Aquifer and may affect Deep Confined Aquifer groundwater flow direction and gradient. However, as discussed in later sections of this report, COPCs have not been detected within the past two years at concentrations exceeding Site CULs outside the Lease Parcel and immediate vicinity, so the Deep Confined Aquifer beneath the Short Fill does not appear to be impacted by the groundwater originating from the Lease Parcel. Hence, the area of the Short Fill, by definition, is not within the Site.

5.3.3 Tidal Influence and Seepage

5.3.3.1 Tidal Influence

The shore-parallel bulkheads and the fine-grained Short Fill soil at the Site exert significant control over Shallow Aquifer flow, effectively "channeling" groundwater between the bulkheads within the inner portions of Piers 90 and 91. Shallow groundwater enters the fill in the piers and then discharges to Elliott Bay, apparently from the more seaward portions of the piers, where the pier bulkheads appear to exercise less control on groundwater flow. In the case of the Deep Confined Aquifer, the existing shore-parallel and pier-perimeter bulkheads generally do not appear to affect groundwater flow or tidal influence, resulting in discharge to Elliott Bay parallel to the shoreline, either where the Deep Confined Aquifer crops out or through sediments.

The two primary measurements of tidal response are tidal efficiency and tidal lag. Tidal efficiency is defined as the relative proportion of observed groundwater fluctuation to tidal fluctuation. High tidal efficiency can be due to direct exchange between groundwater and surface water or a confined pressure response with little actual transfer of water between the surface water body and the aquifer.

Tidal efficiencies were generally highest near the southern ends of the piers and decreased progressively inland towards the east-west trending, shore-parallel bulkheads. Tidal efficiencies were notably higher on Pier 91, as compared to the piezometers located at similar positions on Pier 90. The general decrease in tidal efficiency near the north ends of the slips may result from the accumulation of silt on the fill wedges present between the bulkheads and the outer edge of the pier aprons (see RI/DE Report Figure 3.8, Appendix A1). The degree of siltation on these fill wedges likely decreases seaward towards the south end of the piers, where wave action is higher and any sediment accumulating along the pier perimeters would be coarser and more permeable. Better vertical connection between the Shallow Aquifer and Deep Confined Aquifer may also contribute to the observed higher tidal efficiencies to the south along the piers.

Calculated tidal efficiencies for Pier 91 were higher in piezometers on the west-facing side than for similar locations along the east side, bordering the vacated Smith Cove waterway. Differences in bulkhead construction are not believed to account for the variations in tidal efficiency, as bulkhead construction is similar along the entire perimeter of Pier 91. Higher degrees of siltation on the fill wedges along the east side of Pier 91, as compared to the western, seaward facing side, may be a factor in the lower tidal efficiencies observed along the east side of Pier 91.

Calculated tidal efficiencies for Pier 90 were generally higher in piezometers on the east side than for similar locations along the west side of the pier bordering the vacated Smith Cove Waterway. Although variations in siltation may be a factor, the primary cause for this asymmetry is believed to be the presence of interconnected steel sheet piles installed to -40 ft below mean low low water (BMLLW) along the entire west side of Pier 90. These sheet piles may effectively limit lateral tidal exchange in the Shallow Aquifer along west side of Pier 90.

Tidal lag is defined as the time required for groundwater levels to respond to changes in tidal fluctuations. Tidal lags measured in the Shallow Aquifer piezometers installed during this investigation ranged from 47 minutes on the west side of Pier 91, near the end of the pier, to a maximum of 3 hours and 22 minutes on the west side of Pier 90. The generally long tidal lag times in the Shallow Aquifer, as compared to tidal lags measured for the Deep Confined Aquifer (Aspect Consulting, 2004b), indicate that delayed lateral drainage is the primary component of tidal influence in the Shallow Aquifer in these areas, as would be expected in an unconfined aquifer setting.

Lag times were generally longer along the sides of the piers facing the vacated Smith Cove Waterway, than at corresponding locations on the other sides. The same factors involved in attenuation of tidal efficiency (variable siltation and the sheet piles at Pier 90) may be responsible for the observed variations in tidal lag.

5.3.3.2 Seepage

Groundwater models of Pier 90 and Pier 91 were used to evaluate groundwater seepage along the pier faces. A flow budget analysis was used to compute the percent of inflow that discharges along the pier faces. The relative discharge should not be interpreted as representing an actual flow rate, but as showing areas of relatively high or low zones of discharge. For instance, areas that may appear as zero seepage are not necessarily zero, just much lower seepage than other areas along the piers. Areas of relatively high or low seepage are a factor in determining compliance monitoring strategies for each pier.

The model-predicted percent discharge for the two pier models, plotted along the faces of Piers 90 and 91, is shown in Figure 5-2. The plots show cumulative discharge along the pier. Higher rates of groundwater discharge occur in segments along the pier where the slope of the cumulative discharge line is steep. For each pier, the east and west faces are plotted separately. More groundwater discharges along the face with the higher cumulative discharge (i.e. the east face of both piers). Residual discharge not accounted for on the cumulative plots discharges through the outer end of the piers.

Both piers show very different patterns of seepage. Pier 90 shows a mostly steady seepage along the length of the pier on both faces beyond the Short Fill. Water levels show an overall gradient from the upland end of the pier down the length of the pier. Water levels along the pier are above the tidally averaged water level in Elliott Bay indicating some level of seepage along the entire length of the pier.

Pier 91 also shows a low seepage between the shoreline and the end of the Short Fill. However, there is an area with substantial seepage along the east face, just beyond the Short Fill. Seepage decreases beyond this point, but increases again toward the end of the pier. Seepage toward the end of the pier is greater on the west face than on the east face. Figure 3.6 from the Seepage Report (Aspect, 2004b), included in Appendix A3 shows the primary areas of model-predicted Shallow Aquifer seepage zones on both piers.

The discharge analysis for the Deep Confined Aquifer indicates that discharge from the Deep Confined Aquifer is nearly uniformly distributed between the vacated Smith Cove Waterway between Piers 90 and 91 and the slip east of Pier 90. Figure 3.7 from the Seepage Report (Appendix A3) shows the model-predicted discharge areas for the Deep Confined Aquifer discharge. Groundwater in the Deep Confined Aquifer flows toward Elliott Bay from the north and discharges to Elliott Bay in areas where the Upper Confining Unit is missing. The Upper Confining Unit is missing throughout the vacated Smith Cove Waterway and much of the waterway on the east side of Pier 90. However, sediments do not allow groundwater to discharge only at the head of the waterways. Consequently, groundwater seeps offshore, and the groundwater discharge is distributed in different parts of the waterways as shown in Figure 3.7, Appendix A3.

5.4 Nature and Extent of Contamination

This section summarizes the distribution of LNAPL as well as the nature and extent of contaminants in soil and groundwater at the Site based on the investigations described in Section 4.

5.4.1 NAPL

As described in Section 4.2.8, NAPL monitoring at the Site has been ongoing since February 1992. All NAPL detected in the Shallow Aquifer has been LNAPL; NAPL of any kind has not been detected in any Deep Confined Aquifer monitoring well.

Dense NAPL (DNAPL) has not been detected in any well. The potential DNAPL-forming compounds, such as chlorinated solvents, have not been detected at high enough concentrations in groundwater to indicate the potential for a DNAPL source. In October 2002, as part of preparation of the updated GWSAP (PSC 2003b), the Port performed a DNAPL measurement event of all monitored wells at the Site to check for the presence of DNAPL in well sumps and end caps. The results from this measurement event are summarized in the table included in Appendix A4, and show that no DNAPL was observed in any of those monitored Site wells.

Historically, the apparent LNAPL thicknesses measured in the monitoring wells varied seasonally, with LNAPL thicknesses generally decreasing during periods of rising water levels (PSC et al., 1999). Throughout the entire monitoring history, LNAPL accumulations (including a sheen to measurable LNAPL) have been detected in the following current or former 23 wells within the Site:

- **Small Yard:** existing wells CP-PR01, CP-PR11, and CP-PR12, and former wells CP-116 and CP-117;
- **Marine Diesel Oil Yard:** existing wells CP-PR02, CP-PR07, and CP-PR08, and former wells CP-118 and CP-119;
- **Black Oil Yard:** existing wells CP-PR03 and CP-PR04, and former well CP-109;
- **Between the Lease Parcel and AOC 11:** existing wells CP-107, CP-110, UT-MW39-2, and UT-MW39-3;

- **AOC 11:** PNO-MW104[4]; and
- **SWMU 30:** existing wells PNO-EW1, PNO-MW03, PNO-MW06A, PNO-MW102, and PNO-MW103.

Table 5-1 provides a summary of the historical LNAPL monitoring data and the maximum apparent product thickness measured in 2008. The apparent LNAPL thicknesses observed exhibited a slight increasing trend between 1993 and 1998 (PSC et al., 1999). Historically, the apparent LNAPL thicknesses measured in the monitoring wells varied seasonally, with LNAPL thicknesses generally decreasing during periods of rising water levels (PSC et al., 1999). Currently, the wells with the thickest accumulations of LNAPL are located in and directly to the west of the Lease Parcel. In recent years, LNAPL has not often been detected in the SWMU 30 wells. In 2008, LNAPL accumulations have been detected in the following 11 wells within the Site (see Figure 5-3):

- **Small Yard:** CP-PR01, CP-PR11, and CP-PR12;
- **Marine Diesel Oil Yard:** CP-PR02 and CP-PR07;
- **Black Oil Yard:** CP-PR03 and CP-PR04;
- **Between the Lease Parcel and AOC 11:** CP-110, UT-MW39-2, and UT-MW39-3;
- **AOC 11:** PNO-MW104; and
- **SWMU 30:** none.

LNAPL characteristics data were collected from several of the original LNAPL monitoring wells in the Lease Parcel, the adjacent former pipeline area in 1993 and 2003, and from data gap investigation wells in 2008. Recent LNAPL density and viscosity testing data supports the historical understanding that the LNAPL may include a mixture of petroleum products (Aspect, 2004a) with a predominance of diesel-range hydrocarbons (PSC et al., 1999). Test results for the LNAPL sample collected from CP-PR04 indicates that the LNAPL in the Black Oil Yard may be distinct from the LNAPL in other areas of the Site. The LNAPL in CP-PR04 has a viscosity that is similar to a heavier fuel oil, typical of the bulk petroleum product historically stored in the Black Oil Yard. A summary of all historical LNAPL physical testing data is included in Table 5-2.

5.4.2 Soil

Soil sampling at the Site can be divided into two general time periods: (1) the sampling conducted from 1992 through 1995 that is summarized in the RI/DE Report (PSC et al., 1999) which evaluated a broad range of contaminants includes VOCs, SVOCs, TPH, PCBs, and metals; and (2) sampling associated with the data gaps investigations conducted in 2007 and 2008 which focused on TPH and PCBs. In the summary below, information for VOCs, SVOCs, and metals is taken exclusively from the RI/DE Report while the TPH and PCB discussions are based primarily on the data collected in the data gaps investigations.

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[4] Although well PNO1MW104 is located in the extreme eastern edge of AOC 11, LNAPL observed at this location is likely related to operations in the former pipeline corridor located between AOC 11 and the Lease Parcel.

5.4.2.1 VOCs

Twenty VOCs were detected in soil samples collected at the Site. The VOC detections included 12 chlorinated VOCs (PCE, TCE, cis-1,2-DCE, 1,2-DCE (total), 1,1,1-TCA, 1,1,1-DCA, chloroethane, chloroform, methylene chloride, chlorobenzene, Freon 113, and 1,1-dicloropropene) and 8 non-chlorinated VOCs (acetone, benzene, 2-butanone, carbon disulfide, ethylbenzene, 2-hexanone, toluene, and total xylenes). The detections were in samples collected from borings in or near the former Lease Parcel tank yards.

BTEX compounds represent the most widely distributed group of VOCs in Site soil, detected in all but three borings (PSC et al., 1999). The highest concentration of total BTEX (5,000 mg/kg) was found in a soil boring in the eastern portion of the Small Yard, with concentrations above 10 mg/kg in other borings drilled in the Lease Parcel tank yards. PSC et al. (1999) reported that the distribution of BTEX compounds in soil was consistent with the distribution of LNAPL observed in Site wells. The highest concentrations of benzene were found in a boring just outside the northeast corner of the Small Yard, and the highest concentrations of toluene were found in borings in the Small Yard.

PCE was detected in one or more soil samples from twelve borings in all three Lease Parcel tank yards. The highest concentration of PCE (6,300 µg/kg) was detected in boring TB-7, just outside the northeast corner of the Small Yard. TCE was detected in six borings in or near the Small Yard, in a boring northwest of the Main Warehouse, and in a boring east of the Marine Diesel Oil Yard. The highest concentration of TCE detected was 2,000 µg/kg, also in boring TB-7 just northeast of the Small Yard. Cis-1,2-DCE was detected in two Small Yard borings, with a maximum concentration of 260 µg/kg in boring CP-117, and 1,2-DCE (total) was detected in one boring east of the Small Yard and one boring east of the Marine Diesel Oil Yard.

1,1,1-TCA was detected in five borings in or near the Small Yard and in the north end of the Lease Parcel, with the highest concentrations (17,000 µg/kg) in boring TB-7, just outside the northeast corner of the Small Yard. 1,1-DCA was detected in six borings in or near the Small Yard and in the Marine Diesel Oil Yard. The highest 1,1-DCA concentration (3,100 µg/kg) was in boring TB-7. Chloroethane was only detected in one boring just outside the northeast corner of the Small Yard at a concentration of 4 µg/kg. Chloroform was detected in three borings in and near the Small Yard and just east of the Marine Diesel Oil Yard, with a maximum concentration of 110 µg/kg in a boring just outside the northeast corner of the Small Yard. Freon 113 was detected in six borings in all three tank yards with a maximum concentration of 58,700 µg/kg in a boring in the eastern portion of the Small Yard.

Methylene chloride was detected in over half of the soil samples reported in the RI/DE report. However, in the majority of cases, methylene chloride was detected in the laboratory method blank as well as in the sample. Since methylene chloride is a common laboratory reagent used in the extraction procedure during preparation of samples for VOC analysis, many of the reported detections may be the result of laboratory contamination. Chlorobenzene and 1,1-dichloropropene were each detected in only one sample.

Acetone concentrations above 1,000 µg/kg were observed in a boring east of the Small Yard, in a boring just west of the Main Warehouse, and in a boring at the south end of the former AOC-11 tank farm. The source of acetone in Site soil is unclear. However, like methylene chloride, acetone is a common laboratory reagent and was detected in the laboratory method blanks associated with many of the samples tested.

2-butanone was detected in a boring in the Small Yard, in a boring at the south end of the former AOC-11 tank farm, and in a boring just east of the Main Warehouse. The highest concentrations of 2-butanone (4,100 µg/kg and 6,900 µg/kg) were detected in the Small Yard boring. 2-hexanone was detected in only one boring at the north end of the former AOC-11 tank farm at a concentration of 5.6 µg/kg. Carbon disulfide was detected in six borings in or near the Small Yard, in or near the Marine Diesel Oil Yard, in the Black Oil Yard and upgradient of the Site. The highest concentration of carbon disulfide at the Site (3,500 µg/kg) was detected in a boring at the southeast corner of the Black Oil Yard.

5.4.2.2 SVOCs

SVOCs were detected in most borings drilled at the Site. The detected SVOCs consisted of:

- PAHs: Naphthalene, 2-methylnaphthalene, acenaphthalene, acenaphthene, fluorene, phenanthrene, anthracene, fluoranthene, pyrene, benzo(a)anthracene, chrysene, benzo(b)fluoranthene, benzo(k)fluoranthene, benzo(a)pyrene, indeno(1,2,3-c,d)pyrene, dibenzo(a,h)anthracene, and benzo(g,h,i)perylene;

- Phthalates: di-n-butyl phthalate, butylbenzylphthalate, bis(2-ethylhexyl) phthalate, and di-n-octylphthalate; and

- Other SVOCs: 1,2,4-trichlorobenzene, 4-chloro-3-methylphenol, benzyl alcohol, dibenzofuran, and N-nitrosodiphenylamine.

Total PAH compounds in concentrations greater than 10,000 µg/kg and total phthalate concentrations in excess of 40,000 µg/kg were detected in soil samples from each of the three Lease Parcel tank yards.

1,2,4-trichlorobenzene, n-nitrosodiphenylamine, benzyl alcohol, and dibenzofuran were only detected in single borings located in or east of the Small Yard.

5.4.2.3 TPH

Soil sampling has shown the widespread occurrence of TPH in shallow soil at the Site. Most of the samples have been collected in and near the Lease Parcel, although, samples have also been collected in AOC 11 and SMWU 30. Historical samples were collected and analyzed for TPH between 1992 through 1995. These samples were collected in and near the Lease Parcel from 33 shallow soil borings, 4 deeper soil borings, and 4 shallow composite sampling locations (PSC et al., 1999; Roth Consulting 2007). More recently, in 2007 and 2008 as part of a data gaps investigation, 115 soil borings were drilled across the Site. Selected vadose zone, smear zone, and saturated zone soil samples were submitted for laboratory analysis of TPH (gasoline range, diesel range, and motor oil range) and toluene. For the purposes of this report, the results of the data gaps investigation are used to describe the nature and extent of TPH in soil. As described in Section 4.2.7, this data was collected in three phases:

- Phase 1 Data Gaps Investigation. The first phase of the investigation (PES, 2007a) included drilling and sampling 88 direct push soil borings (DG-1 through DG-88) in the

Lease Parcel, AOC 11, and SWMU 30 in May 2007. Selected soil samples were submitted for laboratory analysis of TPH and toluene. Results of the first phase of work are summarized in the work plan for the second phase of work (PES, 2007b).

- Phase 2 Data Gaps Investigation. The second phase of the investigation (PES, 2007b) included drilling and sampling six direct-push "step-out" borings (DG-89 through DG-94) on the south, east, and north sides of the Lease Parcel in October 2007. Selected soil samples were submitted for laboratory analysis of TPH and toluene. The work also included installing eleven shallow monitoring wells (CP-PR03 through CP-PR13) at the Site (Lease Parcel and AOC 11) for the purposes LNAPL monitoring (see Section 4.2.7). Results of this second phase of work are summarized in a technical memorandum (PES, 2008a).
- Phase 3 Data Gaps Investigation. The third phase of the investigation (PES, 2008b) included drilling a total of 21 direct push soil borings (DG-95 through DG-115). Selected soil samples were submitted for laboratory analysis of TPH from ten of the soil borings (DG-95 through DG-102, DG-104, and DG-114). The majority of the soil borings (DG-99 through DB-115) were drilled to provide PCB data (see Section 5.4.2.4). Results of this third phase of work are summarized in a technical memorandum (PES, 2008d).

The samples containing the highest TPH concentrations are generally located in and around the Lease Parcel area. The highest concentrations of gasoline range TPH (up to 22,000 mg/kg) are contained in smear zone samples from soil borings in the Small Yard, the northern end of the Lease Parcel, and the southern end of AOC 11. The highest concentrations of diesel range TPH (up to 130,000 mg/kg) and motor oil range TPH (up to 41,000 mg/kg) are contained in vadose and smear zone samples from soil borings in the Marine Diesel Oil Yard and the Black Oil Yard. However, as described in Section 5.4.1, the nature of the TPH impacts in the Black Oil Yard appear to be distinct from the rest of the Site due to the heavier oil bulk product that were stored in this tank farm.

The following is a summary of total TPH impacts (i.e., sum of gas, diesel, and motor oil TPH ranges) at the site by area:

- **Black Oil Yard.** A total of 30 samples were collected in this area: 14 vadose zone samples and 16 smear and saturated zone samples. Total TPH concentrations in soil samples ranged from 152 to 42,000 mg/kg in vadose zone samples, and 16 to 78,000 mg/kg in smear and saturated zone samples. A total of 22 samples contained greater than 10,000 mg/kg total TPH, and 7 samples contained greater than 30,000 mg/kg. Total TPH concentrations in this area are entirely from the diesel and motor oil TPH fractions.
- **Marine Diesel Oil Yard.** A total of 63 samples were collected in this area: 28 vadose zone samples and 35 smear and saturated zone samples. Total TPH concentrations in soil samples from the vadose zone ranged from 408 to 57,700 mg/kg in vadose zone samples, and 6,760 to 156,200 mg/kg in smear and saturated zone samples. A total of 47 samples contained greater than 10,000 mg/kg total TPH, and 8 samples contained greater than 30,000 mg/kg. The average total TPH concentrations in this area are approximately 81 percent from the diesel and motor oil TPH fractions.

- **Small Yard.** A total of 53 samples were collected in this area: 21 vadose zone samples and 32 smear and saturated zone samples. Total TPH concentrations in soil samples from the vadose zone ranged from 177 to 38,500 mg/kg in vadose zone samples, and 105 to 51,000 mg/kg in smear and saturated zone samples. A total of 38 samples contained greater than 10,000 mg/kg total TPH, and 7 samples contained greater than 30,000 mg/kg. Although this area includes the greatest concentrations of gasoline range TPH, the average total TPH concentrations in the Small Yard are approximately 85 percent from the diesel and motor oil TPH fractions.
- **Northern Lease Parcel Area.** A total of 25 samples were collected in this area: 8 vadose zone samples and 17 smear and saturated zone samples. Total TPH concentrations in soil samples from the vadose zone ranged from 45 to 447 mg/kg in vadose zone samples, and 26 to 11,200 mg/kg in smear and saturated zone samples. A total of 9 samples contained greater than 1,000 mg/kg total TPH, and 2 samples contained greater than 10,000 mg/kg. Although approximately 25 percent of the samples in this area contain predominantly gasoline range TPH, the average total TPH concentrations in this area are approximately 70 percent from the diesel and motor oil TPH fractions.
- **Area between the Lease Parcel and AOC 11.** A total of 32 samples were collected in this area: 12 vadose zone samples and 20 smear and saturated zone samples. Total TPH concentrations in soil samples from the vadose zone ranged from 47 to 12,090 mg/kg in vadose zone samples, and 1,702 to 24,800 mg/kg in smear and saturated zone samples. A total of 12 samples contained greater than 10,000 mg/kg total TPH, and 2 samples contained greater than 20,000 mg/kg. The average total TPH concentrations in the area are approximately 88 percent from the diesel and motor oil TPH fractions.
- **AOC 11 Area.** A total of 26 samples were collected in this area: 13 vadose zone samples and 13 smear and saturated zone samples. Total TPH concentrations in soil samples from the vadose zone ranged from 23 to 350 mg/kg in vadose zone samples, and 27 to 8,070 mg/kg in smear zone samples. The greatest majority of the samples contained less than 300 mg/kg total TPH, and only 4 samples contained greater than 5,000 mg/kg. Although approximately 20 percent of the samples in this area contain predominantly gasoline range TPH, the average total TPH concentrations in this area are approximately 65 percent from the diesel and motor oil TPH fractions.
- **SMWU 30 Area**. A total of 12 samples were collected in this area: 6 vadose zone samples and 6 smear and saturated zone samples. Total TPH concentrations in soil samples from the vadose zone ranged from 22 to 240 mg/kg in vadose zone samples, and 1,030 to 21,400 mg/kg in smear zone samples. The majority of the smear zone contained less than 6,000 mg/kg total TPH, and only 2 samples contained greater than 20,000 mg/kg. Total TPH concentrations in this area are entirely from the diesel and motor oil TPH fractions.

Laboratory TPH and toluene results are summarized in Table 5-3. Soil sampling locations are shown on Figures 5-4, 5-5, and 5-6. The figures also include shading to highlight soil borings with relatively high TPH concentrations (see Section 7.5).

5.4.2.4 PCBs

Soil and LNAPL sampling has shown the presence of PCBs in shallow soil and in LNAPL within and directly west of the Lease Parcel. The following samples have been collected at the Site:

- **Soil Samples:** Prior to 1999, soil samples were collected and analyzed for PCBs from 19 soil borings in the Lease Parcel area (PSC et al., 1999). In September 2008, during Phase 3 Data Gaps Investigation, soil samples were collected from 17 soil borings and analyzed for PCBs (PES, 2008d). Soil samples were collected from several depth intervals in the soil borings.
- **LNAPL**: In the period between 2005 and 2008 (prior to the Phase 3 Data Gaps Investigation), LNAPL samples were collected analyzed for PCBs. LNAPL samples were collected from four monitoring wells with sufficient volumes of LNAPL (CP-PR02, CP-PR07, CP-PR12, and UT-MW39-3), one surface seep (Seep 4), and one waste LNAPL disposal characterization sample (PES, 2008b).

Soil sampling results indicate only one soil result above the 50 mg/kg level regulated under the Toxic Substances Control Act (TSCA). That sample was collected prior to 1999 from soil boring HA-03 at 6 ft bgs. The sample contained 85 mg/kg PCBs. The remaining soil PCB concentrations were low compared to the elevated PCB result (85 mg/kg) in historical boring HA-03. The next highest total PCB concentration was 9.3 mg/kg (DG-104). The remaining total PCB concentrations ranged between non-detect (ND) and 4.2 mg/kg. Locations and results of total PCBs in soil samples are shown on Figure 5-7, Figure 5-8, and Table 5-4.

Prior to the Phase 3 Data Gaps Investigation in September 2008, a disposal characterization for LNAPL was collected from the Lease Parcel LNAPL monitoring wells and analyzed for PCBs. A concentration of 145 mg/kg was reported in this sample, which represented a composite of the Lease Parcel wells from which LNAPL had been recovered. Due to the elevated PCB result, LNAPL samples were subsequently collected from wells with sufficient volumes of LNAPL (PR-07, PR-12, and UT-MW39-3) and analyzed for PCBs. Two of these LNAPL samples (222 mg/kg in PR-12 and 125 mg/kg in UT-MW39-3) were above the 50 mg/kg level regulated under TSCA. Locations and results of total PCBs in LNAPL samples are shown on Figure 5-7. It should be noted that a composite sample of LNAPL previously collected at the Site was analyzed and found to contain PCBs at a concentration of 49 mg/kg.

5.4.2.5 Metals

Soil samples were analyzed for 12 metals: arsenic, barium, beryllium, cadmium, chromium, copper, mercury, nickel, lead, selenium, silver, and zinc. Except for selenium, each of these metals was detected in at least one soil sample. The results for all metals but lead were consistent with background concentrations for metals concentrations in the Puget Sound Basin (Ecology, 1994). Arsenic, barium, chromium, copper, nickel, and zinc were detected in every soil sample analyzed. Lead was detected in the majority of the samples analyzed, and beryllium and cadmium were detected in the majority of shallow soil samples analyzed, but not in the deeper soil samples analyzed. Mercury was detected in a minority of the samples analyzed, and silver was only detected in two soil samples. Lead, the only metal detected above the Puget Sound Basin background concentrations, was detected in concentrations ranging from 0.91 to 326 mg/kg. The highest lead concentrations were found in and near the Small Yard.

5.4.3 Groundwater

The results of the 2007 and 2008 groundwater sampling at the Site are discussed in this section[5]. Groundwater samples were collected from 28 monitoring wells in March 2007, September 2007, and March 2008, and from 29 monitoring wells in September 2008. The results of the 2007 and 2008 groundwater monitoring are summarized in the *Annual Ground Water Report for 2007* (Roth Consulting, 2008) and the *Annual Ground Water Report for 2008* (Roth Consulting, 2009b).

The results are organized into the following analyte groups – VOCs, SVOCs, TPH, PCBs, and metals. Figures 5-9 through 5-19 show selected monitoring results for the groundwater monitoring wells that were sampled during 2007 and 2008.

<u>5.4.3.1 TPH</u>

TPH as gasoline and diesel have been detected in groundwater at the Site, with the highest concentrations and most of the detections in the vicinity of the former Lease Parcel and AOC-11 tank farms and SWMU 30. TPH was not detected in the wells farthest downgradient.

Figures 5-9 and 5-10 show the concentrations of gasoline-range hydrocarbons in the shallow monitoring wells in 2007 and 2008, respectively. For the Shallow Aquifer, gasoline-range hydrocarbons were detected only in CP-103A, CP-104A, CP-106A, CP-108A, CP-W210, CP-GP11, CP-GP12, and PNO-MW06A in both years. The highest concentration of gasoline-range hydrocarbons in these wells was 2,000 µg/L in CP-106A in 2007, and 2,100 µg/L in CP-106A in 2008. Figure 5-11 shows the concentrations of gasoline-range hydrocarbons in the Deep Confined Aquifer in 2007. Gasoline-range hydrocarbons were detected at lower concentrations in Deep Confined Aquifer wells CP-203B and PNO-MW06B in 2007. The highest concentration of gasoline-range hydrocarbons detected during 2007 was 660 µg/L in well CP-203B. Similar concentrations of gasoline-range hydrocarbons were detected in the same wells in 2008 (i.e., 680 and 500 µg/L in CP-203B in March and September 2008, respectively; and 670 and 720 µg/L in PNO-MW06B in March and September, respectively).

Diesel-range hydrocarbons were less widely distributed than gasoline-range hydrocarbons in groundwater and were not detected in 2007 or 2008 in any Deep Confined Aquifer wells[6]. The highest concentrations of diesel-range hydrocarbons in Shallow Aquifer groundwater samples collected in 2007 and 2008 were detected in PNO-MW06A (990 µg/L in in March 2007 and 580 µg/L in March 2008). Figures 5-12 and 5-13 show concentrations of diesel-range hydrocarbons in shallow monitoring wells for 2007 and 2008, respectively. Concentrations of diesel-range hydrocarbons were detected only in CP-103A, CP-104A, PNO-MW06A, and CP_W210 in 2007, and only in PNO-MW06A and CP_W210 in 2008. The highest concentrations of diesel-range hydrocarbons detected each year were 990 µg/L in PNO-MW06A in March 2007 and 580 µg/L in the same well in March 2008.

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[5] Note that a more extensive data set is used to develop and evaluate CULs in Section 7 of this report. The 2007 and 2008 results described in Section 5.4.3 are intended to describe the current nature and extent of contamination.

[6] Although diesel-range hydrocarbons were not detected in the monitoring wells sampled during the 2007 and 2008 monitoring events, not all wells were monitored. The removal of certain wells from the monitoring program was approved by Ecology. Diesel was detected prior to 2007 in several deep monitoring wells, including wells CP_106B and CP_203B.

5.4.3.2 VOCs

Seventeen VOCs were detected in groundwater samples collected in 2007 and 2008. The VOC detections included three chlorinated VOCs (chlorobenzene, chloroethane, and dichlorodifluoromethane) and 14 non-chlorinated VOCs (acetone, benzene, n-butylbenzene, carbon disulfide, ethylbenzene, hexane, isopropyl benzene, n-propylbenzene, o-xylene, p-isopropyl toluene, sec-butylbenzene, tert-butylbenzene, toluene, and total xylenes). The detections were all relatively low (i.e., less than 20 µg/L) and were distributed in wells located around the former tank farms in the Lease Parcel and AOC-11.

5.4.3.3 SVOCs

Twenty-two SVOCs were detected in one or more groundwater samples from all wells monitored in 2007 and 2008. The SVOC detections included 15 PAHs (acenaphthene, acenaphthylene, anthracene, benzo(a)anthracene, benzo(a)pyrene, benzo(b)fluoranthene, benzo(g,h,i)perylene, benzo(k)fluoranthene, chrysene, fluoranthene, fluorene, indeno(1,2,3-c,d)pyrene, naphthalene, phenanthrene, and pyrene) and 7 other SVOCs (2,4-dimethylphenol, 2-methyl naphthalene, 2-methylphenol, bis(2-ethylhexyl) phthalate, dibenzofuran, diethyl phthalate, and phenol).

Low-level PAH detections were widespread but intermittent in groundwater at the Site. One or more of the PAH compounds have been detected in all the wells monitored with the exception of CP-115B. Some of the PAHs such as naphthalene are distributed across the Site. Other PAHs occur at limited and scattered locations. Figures 5-14 through 5-19 depict examples of some typical PAH occurrences (chrysene and naphthalene) in Site groundwater.

The other seven SVOCs detections were infrequent and localized. Six of the seven other SVOCs (2,4-dimethylphenol, 2-methyl naphthalene, 2-methylphenol, dibenzofuran, diethyl phthalate, and phenol) were detected in isolated wells distributed around the former Lease Parcel and AOC-11 tank farms. The maximum detection of these six SVOCs was 180 µg/L of 2,4-dimethylphenol, which was only detected in CP-GP12. Bis(2-ethylhexyl) phthalate was detected sporadically in CP-GP05, CP-GP06, CP-GP07, CP-GP09R, CP-GP11, CP-GP12, CP-GP14, and CP-GP03BR, with a maximum detection of 56 µg/L in CP-GP12.

5.4.3.4 PCBs

Aroclor 1260 was detected in one Shallow Aquifer monitoring well (PNO-MW06A) at a concentration of 0.016 µg/L in March 2008. PCBs were not detected in any other groundwater samples collected at the Site in 2007 or 2008.

5.4.3.5 Metals

Groundwater samples were analyzed for eight metals (total arsenic, barium, chromium, lead, mercury, selenium, silver, and zinc) in 2007 and 2008. Arsenic was detected in most samples, with the highest concentration (19 µg/L) detected in CP-GP12. Barium was analyzed only in 2008 and was detected in all samples, with the highest concentration (328 µg/L) in CP-GP13. Chromium was detected in 10 to 16 wells in each sampling event, with the highest concentration (13.6 µg/L) in CP-115B. Lead was detected in one well (CP-114) during two events with a maximum concentration of 9.4 µg/L. Mercury was detected (0.0235 µg/L) in only one sample, which was collected from CP-111. Selenium was analyzed only in 2008 and was detected in 7 to 12 wells per sampling event, with the highest concentration (20 µg/L) in CP-GP03AR. Silver was analyzed only in 2008 and was not detected in any of the wells. Zinc was detected in 3 to 12 wells per event, with the highest concentration (200 µg/L) in CP-103A.

6.0 PREVIOUS AND ONGOING CLEANUP ACTIONS

This section summarizes the previous closure activities and other interim cleanup actions conducted at the Site. Many of these historical actions have focused on the former tank farm and the Lease parcel, but other cleanup actions outside the Lease Parcel but within the Site boundaries are also described.

6.1 RCRA Closure Activities

In September 1995, PSC ceased operations at the Lease Parcel, and terminated its lease with the Port. PSC subsequently performed aboveground closure activities of all RCRA Part B permit-related facility equipment, secondary containment, and treatment units, pursuant to a closure plan approved by Ecology (PSC, 1996). Specific activities conducted during the closure included:

- Decontamination of the concrete floor and walls of the oil/water separator using high pressure water spraying followed by abrasive blasting;
- Decontamination of the loading pad/ramp area associated with the middle yard and the secondary containment area for tanks 109-112 using high pressure water spraying;
- Cleaning of Tank 164 (portable tank not shown in FS figures but located immediately northwest of Tank 110) and ancillary equipment (associated piping); and
- Collection of concrete chip samples from tank yards in the vicinity of loading pads and sumps to confirm closure standards were met.

These closure activities were documented and closure certified in a letter from PSC submitted to Ecology in 1997 (PSC, 1997). The aboveground closure was approved by Ecology in October 2003 (Ecology 2003a). The rest of the Lease Parcel previously used to store dangerous waste was closed under an interim status closure plan (PSC, 1997).

6.2 LNAPL Recovery at SWMU 30

This SMWU is the location of a pipeline break that occurred in 1989, near the north end of Pier 91 (Figure 2-4). In 1989, oil was observed seeping on the Short Fill Impoundment. Hart Crowser (1989) performed an initial investigation on behalf of the Port in July 1989 to determine the source and extent of oil contamination. Eleven soil borings were drilled, and soil samples were collected for laboratory analysis. Four of the borings (B-2, B-3, B-6, and B-11) were completed as monitoring wells and currently are referred to as PNO_MW02, PNO_MW03, PNO_MW06, and PNO_MW11. Diesel was detected in soil samples collected from just above the water table, and monitoring well B-3 (later renamed MW-3 and currently referred to as PNO-MW03) contained LNAPL. The source of the contamination was not determined, but pipelines were considered to be potential sources. Subsequent pressure testing of the pipeline verified the pipeline failure, and the section of pipeline around the area of contamination was abandoned by PNO (Converse GES, 1990a).

A preliminary hydrogeologic assessment was performed by Converse in November 1989 (Converse GES, 1989) and the four existing monitoring wells were sampled. Groundwater levels were measured over a period of about 24 hours to evaluate tidal influence. A product recovery test was performed to develop preliminary design criteria for a product extraction system. Groundwater levels in the monitoring wells were determined to be tidally influenced. The data from the preliminary hydrogeologic assessment was used to site four additional monitoring wells (MW-101, MW-102, MW-103, and MW-104). These wells were installed in November 1989 and sampled in December 1989 as part of the Phase I Remedial Investigation (Converse GES, 1990a). Free product was measured in monitoring wells MW-3 and MW-104. These two wells were separated by wells that did not contain free product, suggesting the possible presence of two separate sources.

Groundwater levels were measured in April and July 1990, and a pump test was performed on monitoring well MW-6 to evaluate hydraulic characteristics of the aquifer (Converse GES, 1990b). Using this data, an interim product extraction system for free product recovery in the pipeline break area was designed by Converse in 1990 (Converse GES, 1990b) on behalf of PNO. The system consisted of an extraction well with a pneumatic total fluids pump, and an oil/water separator. The oil was to be recycled into PNO's bulk fuel supply, and the water was to be discharged to the sanitary sewer under an industrial waste discharge permit from King County Metro.

The product recovery system began operation in January 1991 (Converse, 1994). The system operated as a skimming system in recovery well EW-1, cycling on and off periodically. In 1991, the system removed about 30 gallons of liquid hydrocarbons (Converse, 1992). In 1992, the system removed about 23.5 gallons of liquid hydrocarbons. Effluent water was discharged after separation to the sanitary sewer.

Product thickness was observed to increase downgradient with time, and in March 1993 a passive skimming system also was installed in downgradient monitoring well MW-102. By April 1994, the system had recovered about 76.4 gallons of liquid hydrocarbons. Because of the poor recovery rates, the pneumatic recovery system was decommissioned in 1994. Passive LNAPL skimming systems were then installed in monitoring wells EW-1 and MW-102 (Pacific Northern Geoscience, 1996). Liquid hydrocarbons in monitoring well MW-3 were removed by hand bailing during the period of April through December 1995.

PNO continued hand bailing of selected monitoring wells and monitored the fluid levels in the remaining wells at this location on a semiannual basis through 2000. In 2001, as part of the Terminal 91 Upland independent cleanup work, PNO began a quarterly monitoring program that consisted of measuring fluid levels in 10 monitoring wells, maintaining LNAPL skimmers in 3 monitoring wells (EW-1, MW-3, and MW-102), and collecting ground water samples from MW-2, MW-6, MW-11, and MW-103 for TPH analysis. This program was continued through the second quarter of 2002. At that time, the total LNAPL recovered from the skimmers since their installation in April 1994 was about 23.3 gallons (Aspect, 2002). TPH was detected in all of the four monitoring wells sampled. PNO then discontinued the quarterly monitoring and LNAPL recovery program. The Port is currently monitoring the fluid levels in these wells as part of the annual ground water monitoring program for the Site. The Port also has added wells in this area containing LNAPL to its regular monitoring and LNAPL-removal program.

6.3 2005 Tank Farm Demolition Interim Remedial Action

In the spring and early summer of 2005, the Port performed an independent interim remedial action known as the Tank Farm Demolition (Tank Farm Demo). The Tank Farm Demo interim action consisted of the demolition and removal of aboveground fuel storage tanks, fuel stations, pump stations, water and waste piping, steam boiler, structures, and all incidental equipment. At the time the Tank Farm Demo was initiated, the tanks contained various fuel products. The following activities were performed as part of the Tank Farm Demo:

- Removal and disposal of asbestos-containing materials (ACM);
- Removal and recycling or disposal of residual petroleum products from aboveground storage tanks;
- Removal of paint chips and debris containing lead-based paint generated during demolition activities and disposal as hazardous waste;
- Demolition of steam boiler, piping, and apparatus in Building 19 and disposal of remaining boiler chemicals as hazardous waste;
- Removal of petroleum-impacted soil from pipe chases in the Lube Oil Yard and the Marine Diesel Oil (MDO) Yard and disposal as non-hazardous waste;
- Purging of fuel piping inside the tank farm;
- Demolition of all aboveground storage tanks except for tank bases with the exception of the small yard, where aboveground storage tanks and their tank bases were demolished (Tanks 105 through 114 – see Figure 2.3); demolition of concrete containment walls, buildings, gangways and catwalks, aboveground fuel piping, and other structures; recycling of metals and concrete, and resulting generation of demolition debris such as metal, brick, and concrete (for recycling) and some solid waste;
- Purging of three underground fuel transmission lines from the tank farm to the fuel riser station on Pier 90, cleaning of underground fuel piping, and capping of both ends of piping with a foot of concrete to abandon in place;
- Demolition of exposed fuel piping and valves in four underground vaults, and the fuel riser station, at Pier 90;
- Backfilling of low areas and vaults with crushed concrete and/or clean fill;
- Backfilling of abandoned oil/water separator with crushed concrete and/or clean fill; and
- Paving of the Lease Parcel and adjacent, previously unpaved, alley immediately north of the Seafood Processing Building (M-28).

The independent interim remedial action report documenting these activities was prepared by Roth Consulting (2005b) and submitted to Ecology.

6.4 Seeps Remedial Actions

After demolition of the former tank farm and repaving of the area in 2005, three oily seeps (Seeps 1, 2, and 3) appeared on the pavement surface at three locations in the summer of 2006

(Figure 6-1). The Port removed the asphalt from those locations in an effort to identify the sources of the seeps. The sources were identified as oily sand within the double-layered tank bases, which had been left in place as part of the demolition activities. The oil appeared to have moved upward through the clean fill material and through the asphalt paving. The oily sand was removed and disposed of at a permitted facility, and the locations were backfilled with clean soil and repaved.

A fourth oil seep (Seep 4) about six inches in diameter was first observed on the former tank farm surface pavement in June 2007 (Figure 6-1). The seep was monitored periodically throughout the summer of 2007. The oil was contained by placement of sorbent pads. Oil seepage appeared to stop during periods of cooler temperatures.

On November 5, 2007, Port Construction Services (PCS) excavated the soil at the Seep 4 location to the depth of the former tank farm surface which had been covered during the tank farm demolition project in 2005. A small area of oil-stained fill material was present just above the southern edge of a former tank base left in place as part of the demolition work.

Upon confirming that the source of the seep was a former tank base, the shallow excavation was backfilled and completed with a utility-type vault to provide monitoring access to the tank bottom, and to improve containment in the event that the seep were to become active again. The excavation area around the vault was repaved, and the vault is monitored periodically for LNAPL occurrences. Sorbent pads were placed in the vault after oil was observed entering the vault from the tank base. During monitoring activities, oil-saturated pads are removed and wrung out, and the recovered oil is disposed with LNAPL recovered from LNAPL monitoring wells. If more oil is present than the pads can absorb (typically one inch in thickness or less to date), the oil is pumped from the vault. During the summer months, only a sheen of oil on water in the vault has been observed.

In May 2008, oil was observed again at the location of Seep 2, which was initially excavated in 2006. The seep was monitored periodically, and in September 2008, the seep was re-excavated and a vault was installed, similar to the vault at Seep 4. The vault is monitored periodically for LNAPL occurrence. Sorbent pads also have been placed in the Seep 2 vault. To date, less oil has been observed in the Seep 2 vault than the Seep 4 vault, with only a sheen on water observed and no pumping of oil required.

6.5 Fuel Pipeline Cleaning Remedial Actions

In June 2007, the Port performed an interim remedial action along the west side of the Lease Parcel. The remedial action was performed at the location of a water line break. In order to access the water line for repair, the Port needed to cut and remove some underground fuel lines at this location (Figure 6-1). On June 25, Emerald Services (contractor to the Port) performed the remedial activities, which included removal of less than 50 gallons of oil from the pipes and recycling of the oil at Emerald's Seattle facility. Several small sections of pipe were removed and recycled as scrap metal. The remaining cut sections of the pipe that remained in place were plugged with grout.

On July 1, 2008 during excavation activities conducted along the southeast corner of the Lease Parcel as part of the Port’s Seattle City Light Duct Bank project, PCS discovered an underground fuel pipeline that had not been decommissioned. PCS had been removing the pipelines that had been decommissioned as part of the 2005 tank farm demolition project, and found that there was a section that had not been filled with grout and still contained oil. The interim remedial action that was performed in September 2008 consisted of removing the oil from the pipeline (Figure 6-2), cleaning the pipeline, and disposing of the oil and piping at appropriate facilities.

6.6 Limited Soil Excavation Remedial Action

During excavation activities outside the southeast corner of the Lease Parcel as part of the Seattle City Light Duct Bank project, soil was encountered with concentrations of TPH exceeding MTCA Method A CULs (Figure 6-1). The contaminated soil was located to the north of the September 1998 pipeline cleaning remedial action location and appears to be unrelated. This soil was stockpiled, and soil samples were collected from the stockpiled material. The non-hazardous TPH-contaminated soil (about 252 tons) was hauled to the Allied Waste Regional Disposal Company's Roosevelt Regional Landfill in Roosevelt, Washington for disposal.

6.7 LNAPL Recovery Program and Pilot Study

In the fall of 1999, passive LNAPL recovery devices (PLRDs) were installed in eight wells that contained or had previously contained LNAPL. At that time, a monthly product monitoring/recovery program was initiated to monitor the occurrence of LNAPL in these wells and to recover LNAPL. Since that time, five of the wells within the Lease Parcel have been decommissioned (prior to initiation of the Tank Farm Demo) and 13 new LNAPL monitoring/pilot study wells have been installed. About 91 gallons of LNAPL/water mixture have been removed from one or more of the 24 LNAPL monitoring/pilot study wells and two seeps since the first PLRDs were installed in October 1999 through the end of 2008.

As described in the FS Work Plan (PES et al., 2005a), an LNAPL recovery pilot test was designed to evaluate the feasibility of active LNAPL recovery within the tank farm. Two recovery wells (PR_01 and PR_02) were installed in areas that previously showed the highest LNAPL recovery rates, but monitoring did not detect more than a sheen in the wells, and the pilot test was terminated in 2006.

6.8 December 2008 Water Line Break

A water main located just south of Building M-28 and under the Magnolia Bridge ruptured in December 2008. In order to repair the break, Port Maintenance performed a limited soil excavation to less than 6 ft bgs. Water removed from the excavation was pumped into Baker tanks and sampled, and the water was discharged to the sanitary sewer under a temporary discharge authorization. Concentrations of chemicals detected in soil samples collected from the stockpiled soil did not exceed MTCA Method A CULs. Port Maintenance personnel conducted the hauling of the soil to the Allied Waste's 3rd and Lander transfer station in May 2009 for disposal at the Roosevelt Regional Landfill.

7.0 CONCEPTUAL SITE MODEL AND CLEANUP LEVEL DEVELOPMENT

This section of the FS provides a summary of the CSM for the Site and outlines the development of CULs, drawing primarily on the following documents prepared by PIONEER and others:

- FS Work Plan (PES et al., 2005a);
- Background Groundwater Evaluation (PIONEER, 2007);
- FS CULs (PIONEER, 2008a); and
- Comparison of Groundwater Data to FS CULs (PIONEER, 2008b).

This section of the FS will be used to:

- Identify and describe potentially complete and complete exposure pathways;
- Identify indicator hazardous substances (IHSs) and determine CULs; and
- Select points of compliance where CULs will be achieved.

7.1 Site Description and Contaminant Sources

The Site is defined in Section 2.1 and includes the Lease Parcel and areas where releases of constituents originating from the Lease Parcel operations have come to be located. The Lease Parcel formerly consisted of three tank yards and associated buildings, and covers approximately four acres within the Site. The rest of the Site is located downgradient from the Lease Parcel, towards Elliott Bay. The aboveground portion of the tank farm and associated buildings were demolished in 2005, and the tank farm area was paved following demolition activities. A Site Plan showing the former tank farm features is presented in Figure 2-3.

7.1.1 Potential Sources of Contamination at the Tank Farm Lease Parcel

7.1.1.1 Documented Releases

A summary of documented releases at the Lease Parcel is provided in the *Terminal 91 Facility Solid Waste Management Unit Report* (Chempro, 1988). Based on information obtained from this report, the largest releases occurred on November 15, 1978 and July 5, 1980 (PSC et al., 1999).

The November 15, 1978 event reportedly consisted of a release of 420,000 gallons of Bunker C fuel from Tank 91. The release occurred within the diked area of the Black Oil and Marine Diesel Oil Yards. The release was reportedly contained within the diked area, although the floor of the area was unpaved at the time. Actions taken following the release are described in Section 2.4.1 of the RI/DE Report.

The July 5, 1980 event of a release involving 63,000 to 113,400 gallons of oil occurred as a result of operator error during a transfer of products between tanks in the Black Oil and Marine Diesel Oil Yards. The valve was left open, causing an overflow into a graveled, unpaved diked area. The majority of the soil was moved to an approved off-site disposal facility. Actions taken following the release are described in Section 2.4.1 of the RI/DE Report. Several smaller releases at the Lease Parcel were documented in the Chempro (1988) report.

7.1.1.2 Undocumented Releases

No releases have been documented at the Lease Parcel prior to 1971, although historical unreported releases are suspected. Periodic releases of oily liquids have reportedly occurred at the Lease Parcel since the 1930s and are discussed in Section 2.4.2 of the RI/DE Report (PSC et al.,, 1999).

7.1.2 Potential Sources of Site Contamination Outside the Tank Farm Lease Parcel

Several locations were identified as SWMUs or AOCs by EPA in the 1994 RFA (EPA, 1994), and Ecology and the Port agreed they required further action. The RFA was part of the RCRA process for implementing corrective action at the Pier 91 dangerous waste treatment and storage facility (located at the Lease Parcel). The RFA was expanded to include certain other portions of the Terminal 91 Complex, in addition to the Lease Parcel. The RFA identified and labeled a number of SWMUs and AOCs that were present when the visual site inspection was performed, on October 20 and 21 1992, by EPA representatives. For a complete list of SWMUs and AOCs identified, see BDR2 (Roth, 2003a).

There are three other potential sources of contamination located within the Site, but outside the Lease Parcel, which will be addressed in this FS:

- **SWMU 30 –** This SMWU is the location of a pipeline break that occurred in 1989 near the north end of Pier 91 (Figure 2-4). An estimated 340 to 1,370 gallons of product were released before the pipeline was repaired. A product recovery system was installed and operated between 1991 and 1994 and recovered a total of 76 gallons. Passive product recovery (i.e., bailing) continued after 1994 with limited amounts of product recovered.
- **AOC 11 –** AOC 11 was a former tank farm located west of the Lease Parcel (Figure 2-4). The former tank farm in AOC 11 was reportedly active between 1927 and 1942 and used to store a variety of petroleum products, including gasoline and oil. The AOC 11 tank farm was reportedly demolished when the United States Department of the Navy took over the site in December, 1942. There are no documented releases from the AOC 11 tank farm.
- **Former Fuel Transfer Pipelines –** Over the history of the site, petroleum and other materials were transferred between ships at Piers 90 and 91, the tank farms, and waste management areas located within the Site, typically via above and belowground pipelines. Figure 6-2 shows the portions of the site where above or belowground pipeline corridors were (and in some cases still are) located. Because the pipelines and many utilities were installed by occupants of the Site prior to the Port's occupancy, and due to their age, there is limited information on exact locations of these underground structures. Figure 6-2 shows the approximate expected locations of pipeline runs, based on archive drawings. Finding the actual locations of pipelines for decommissioning purposes would require a combination of utility location services, review of available archive drawings, and test pit excavations (i.e., "potholing"). It should be noted that the aboveground portion of the pipelines in and around the Lease Parcel were removed during the 2005 Tank Farm Demo.

7.2 Exposure Pathways and Receptors

A draft of the CSM for the Site was presented in BDR1 (Roth Consulting, 2001b). Figure 7-1 presents the final version of the CSM, based on current known and planned future Site conditions. All of the potentially complete exposure pathways are summarized below. More detailed descriptions of these pathways are presented in BDR1 and in the FS Work Plan (PES et al., 2005a).

7.2.1 Soil

Based on work performed as part of BDR1, three potentially complete exposure pathways related to soil were identified: (1) direct contact with soil by utility or construction workers; (2) soil to indoor air; and (3) soil to groundwater (which ultimately may impact aquatic receptors). These pathways are addressed in detail below.

7.2.1.1 Direct Contact with Soil Pathway

Direct soil contact by workers (or trespassers) was not retained as a pathway of concern for the Site because soils are currently covered by pavement or buildings. If any future excavation or underground utility work takes place, workers could potentially be exposed to soil, and direct contact with soil would become a pathway of concern. However, institutional controls and standard worker health and safety procedures will be implemented and would provide adequate protection in such instances.

7.2.1.2 Soil to Indoor Air Pathway

This pathway is only potentially applicable at the tank farm, and possibly in areas immediately adjacent to the tank farm. Previous studies (PSC, 2002; PIONEER, 2004) have documented that there are no unacceptable current[7] risks. Ecology concurred with the determination of no unacceptable current risks in its letter to the Port dated June 16, 2005. The only potential future exposures via this pathway would result from future Site development activities. The approach for addressing these potential future exposures will be to implement institutional controls, such as notices on parcel deeds of the potentially impacted properties, which would require either:

(1) Including engineering controls (e.g., vapor barriers, sub-slab venting systems) in Site development plans to mitigate the potential exposure; or

(2) Conducting a development-specific evaluation of the soil to indoor air pathway (i.e., developing risk-based CULs for the specific-potential exposures related to the proposed development).

If concentrations of IHSs exceed the CULs developed under the second option, appropriate supplemental remedial actions will be evaluated and implemented as part of Site development activities. Engineering controls may be implemented instead of or in conjunction with other remedial actions, as appropriate. Calculating CULs at the time of development, if that is the selected response, would allow for the specific location (e.g., northeast corner of the tank farm), nature of the development (e.g.,

[7] Currently there are no unacceptable risks associated with this pathway. However, there is a possibility that the situation may change with future exposures. These future exposures will be managed, if necessary, via institutional/engineering controls.

industrial or commercial), and building-specific factors (e.g., slab-on-grade warehouse, ground-level parking) to be accounted for in the cleanup level calculations.

7.2.1.3 Soil to Groundwater Pathway

As with the soil to indoor air pathway, the soil to groundwater pathway is only potentially applicable to the tank farm and immediately adjacent areas. This area generally coincides with areas where LNAPLs have been observed, generally corresponding with associated elevated concentrations of IHSs in groundwater. The FS Work Plan (PES et al., 2005a) describes the process for determining CULs for the soil to groundwater pathway. Specifically, the soil to groundwater pathway would be evaluated consistent with WAC 173-340-747, which states that concentrations of hazardous substances in soil shall not cause contamination of groundwater at levels that exceed groundwater CULs. This demonstration requires that two criteria be met at the Site:

- Soil concentrations shall not cause an exceedance of groundwater CULs; and
- Soil concentrations shall not result in the accumulation of LNAPL on or in the groundwater.

Potential for Soil Causing Exceedance of Groundwater CULs. A portion of the soil to groundwater pathway will be evaluated empirically. If groundwater concentrations are below CULs at the POC or conditional POC (CPOC), then by definition, the concentrations of IHSs in soil are not causing exceedances of groundwater CULs[8]. Conversely, if groundwater concentrations at the POC exceed CULs, then soil to groundwater CULs will be developed for those constituents at that time.

Potential for Accumulation of LNAPL. As summarized in Section 4.2.7, the potential for contaminants in soil to result in accumulations of LNAPL was evaluated using RSSLs.

This report will address the LNAPL and residual groundwater contamination through evaluation of LNAPL recovery approaches and development of groundwater CULs.

7.2.2 Groundwater

Based on work performed as part of the BDRs (Roth Consulting, 2001b and 2003a; Aspect, 2004a), two potentially complete exposure pathways related to groundwater were identified: (1) groundwater to indoor air; and (2) groundwater to surface water/sediment. These pathways are addressed below.

7.2.2.1 Groundwater to Indoor Air Pathway

Inhalation of indoor air impacted by vapor intrusion from groundwater does not represent an unacceptable risk to workers at the Site under current conditions (PSC 2001b, 2002; PIONEER

[8] Soil IHSs could potentially cause future exceedances of groundwater CULs via future leaching to groundwater. However, it should be noted that groundwater has been monitored at this site for over a decade, and there have been no releases of hazardous substances over that period. Therefore, it is highly unlikely that a significant number of additional constituents will be detected in groundwater at concentrations exceeding CULs as a result of leaching from soil.

2004). However, this remains a potentially-complete exposure pathway for the Site and may be of concern for future commercial land-use scenarios.

7.2.2.2 Groundwater to Surface Water/Sediment Pathway

These pathways are the primary pathways of concern for the Site. Impacted groundwater from the Site could be released to Elliott Bay via the groundwater to surface water pathway and/or groundwater to sediment pathway, potentially resulting in exposure to aquatic receptors (i.e., fish or invertebrates), or to people consuming seafood collected from Elliott Bay.

7.2.3 Terrestrial Ecological Exclusion

An assessment of Site conditions was performed in order to determine the need for a terrestrial ecological evaluation under WAC 173-340-7490. The Site qualifies for an exclusion from the terrestrial ecological evaluation process, as documented in BDR1 (Roth Consulting, 2001b), which was approved by Ecology in a letter dated May 30, 2002 (Ecology, 2002b).

7.3 Development of Cleanup Standards

This section presents the approach for developing cleanup standards for the Site per MTCA requirements. Cleanup standards, as explained in WAC 173-340-700 (3), consist of the following:

a) CULs for hazardous substances present at the Site;
b) The location where these CULs must be met (i.e., the POC); and
c) Other regulatory requirements that apply to the Site because of the type of action and/or location of the Site (i.e., applicable state, local, and federal laws).

The approach to developing CULs for the Site consists of the following steps:

- Selection of IHSs;
- Development of CULs; and
- Selection of the point(s) of compliance.

As discussed in Section 7.2, most of the potentially applicable soil exposure pathways (e.g., direct contact, soil to indoor air) are either not currently complete or do not currently present a risk. As a result, IHSs will not be identified for soil and no risk-based CULs will be developed at this time for soil related exposure pathways. Potential future risks associated with these soil-related pathways will be addressed through implementation of engineering and institutional controls. The portion of the soil to groundwater pathway related to preventing accumulation of LNAPL in the groundwater is a potentially complete pathway, and the RSSLs developed for the Site will be evaluated for use as remediation levels.

7.3.1 Selection of Indicator Hazardous Substances

Cleanup levels were developed for constituents in groundwater that could potentially contribute significantly to human health or ecological risks. Under MTCA, these constituents are considered IHSs. IHSs were identified for the Site according to the guidelines provided in WAC 173-340-703, which allows those constituents that do not contribute significantly to the risk associated with a Site to be eliminated from further consideration. Constituents that contributed only a small percentage to the risk were identified based on a stepwise process that evaluated:

- The frequency that a specific constituent occurred in groundwater;
- The geographic distribution of detections for that constituent;
- The magnitude of the concentration for that constituent; and
- The constituent's chemical/physical properties (e.g., persistence in the environment, toxicity to humans or aquatic organisms, and the potential to bioaccumulate).

Initially, the frequency of detection for each constituent was calculated for the entire groundwater data set, which was comprised of sampling rounds from 2000 to 2007. Constituents that were never detected were removed from further consideration. Constituents that were detected in less than or equal to five percent of the samples were flagged for potential elimination from further consideration. However, before eliminating a constituent with a low frequency of detection, the locations of the detections were examined. If the detections were geographically clustered (i.e., adjacent to one another), possibly indicating a potential source area, the constituent was retained. High concentrations were identified as concentrations greater than the 75th percentile plus three times the interquartile range (IQR), where the IQR equals the 75th percentile value minus the 25th percentile value (NIST, 2005). Even if the detections were not near one another, they still might be indicative of a source if the concentrations were high. Therefore, constituents that were infrequently detected, but had high concentrations, were retained for further evaluation. If the maximum detected value was greater than the 75th percentile plus three times the IQR, then the constituent was retained for further consideration. Constituents that were detected in more than five percent of the samples were automatically retained as IHSs. See Table 7-1 for a complete list of IHSs.

<u>7.3.1.1 Development of Background Concentrations</u>

Area background groundwater concentrations were based on analytical results from five on-site wells and five upland wells (see Figure 7-2). The analytical results were combined to calculate the area background concentrations for inorganics, based on the decision rule presented in WAC 173-340-709. Figure 7-3 presents a flowchart of the decision rule.

WAC 173-340-709 defines the decision rule for determining area background concentration as:

1. For non-normally distributed datasets (i.e., all data sets other than normal), background is equivalent to the 90th percentile or (4 times the 50th) percentile, whichever is lower.

2. For normally distributed data sets, background is equivalent to the 80th percentile or 4 times the 50th percentile, whichever is lower.

3. Non-detected results were included in the statistical calculations using a surrogate concentration equivalent to one half of the detection limit.

Table 7-2 presents the area background groundwater concentrations for the Site. See *Background Groundwater Evaluation* (PIONEER, 2007) for further discussion.

Due to reasons discussed in the *Comparison of Groundwater Data to Feasibility Study Cleanup Levels Report* (PIONEER, 2008b), arsenic concentrations found on the Site have been determined as area background. Ecology has concurred with this conclusion, and arsenic was not considered in the development of CULs described below.

7.3.2 Determination of Cleanup Levels

Human health and ecological CULs were developed for the following complete exposure pathways, identified in the CSM presented in the *Feasibility Study Cleanup Levels* technical memorandum (PIONEER, 2008a): (1) groundwater to indoor air; (2) groundwater to surface water; and (3) groundwater to sediment. CULs were based on the protection of indoor air, surface water, and sediment quality according to MTCA requirements (WAC 173-340-750, WAC 173-340-730, and WAC 173-204, respectively). A detailed description of the derivation of human health and ecological CULs is presented in the FS CUL Memorandum (PIONEER, 2008a). Table 7-3 presents final CULs for shallow groundwater and Table 7-4 presents final CULs for deep groundwater.

The RSSLs developed for the Site are included as potential remediation levels.

7.3.2.1 Human Health Cleanup Levels

Groundwater Cleanup Levels Based on Protection of Indoor Air. Groundwater CULs protective of indoor air quality were calculated to address the groundwater to indoor air pathway, which was considered a potentially complete exposure pathway for the Shallow Aquifer. MTCA Method C (WAC 173-340-750 (4)) CULs for indoor air were derived using equations 750-1 (for noncarcinogens) and 750-2 (for carcinogens) from WAC 173-340-750. Groundwater CULs were then calculated by dividing the indoor air CULs by groundwater to indoor air attenuation factors developed based on the EPA's JE Model[9]. A hazard quotient (HQ) of one was used for calculating noncarcinogenic CULs. The target risk used for calculating carcinogenic CULs was 1×10^{-5}.

Groundwater Cleanup Levels Based on Protection of Surface Water and Sediment. Human health CULs were developed to protect people who may consume seafood from Elliott Bay (including Asian Pacific Islander [API] Fisher) in the vicinity of the Site, in accordance with WAC 173-340-730. Human health CULs were based on surface water CULs, assuming no dilution from groundwater to surface water (WAC 173-340-730[6][b]). MTCA Method B CULs for surface water (WAC 173-340-730 [3][b][iii]), based on protection of human health, were derived using equations 730-1 (for noncarcinogens) and 730-2 (for carcinogens). In addition, modified exposure parameters were used for the API Fisher population, per the MTCA Science Advisory Board Meeting, September 2006 (Ecology, 2006). An HQ of one was used for calculating the noncarcinogenic CULs. The target risk used for calculating carcinogenic CULs was 1×10^{-6}. Groundwater CULs based on protection of surface water were considered applicable to both Shallow Aquifer and Deep Confined Aquifer groundwater.

[9] http://www.epa.gov/oswer/riskassessment/airmodel/johnson_ettinger.htm

7.3.2.2 Ecological Cleanup Levels

Ecological CULs were based on surface water CULs, assuming no dilution from groundwater to surface water (WAC 173-340-730[6][b]). Ecological CULs were developed to protect aquatic organisms that may be exposed to surface water and sediment in Elliott Bay, which may be potentially impacted by groundwater from the Site, in accordance with WAC 173-340-730 (3)(b)(i) and (ii). These CULs were identified based on:

- Washington State Water Quality Standards (WAC 173-201A);
- Federal Ambient Water Quality Criteria (Section 304 CWA);
- National Toxics Rule (40 CFR 131); and
- Environmental Effects. Where there were no existing standards or criteria for IHSs, groundwater CULs were derived from concentrations that would likely result in no or minimal adverse effects to aquatic organisms (including benthic invertebrates). The sources that were investigated for effects data included EPA's Ecotoxicology (ECOTOX) database, United States Department of Energy's Risk Assessment Information System (RAIS), Oak Ridge National Laboratory (ORNL) ecological benchmarks, and the USGS aquatic toxicity benchmarks for VOCs.

7.3.2.3 RSSLs

As summarized in Section 4.2.7, final RSSLs were developed using Site-specific soil physical property data and LNAPL characteristic data, collected in the first data gaps investigation. RSSLs were developed for toluene, gasoline, middle distillate petroleum products (diesel range), and fuel oil. The MTCA four-phase partitioning model spreadsheets were used to develop the revised toluene RSSL, and Ecology and other published industry references were used to develop the revised RSSLs for gasoline, middle distillate petroleum products, and fuel oil. The final RSSL ranges are as follows:

- For fuel oils, the calculated RSSL range was 8,727 to 30,000 mg/kg;
- For middle distillate petroleum products, the calculated RSSL range was 3,879 to 13,333 mg/kg;
- For gasoline, the calculated RSSL range was 1,636 to 5,625 mg/kg; and
- For toluene, the calculated RSSL was 832 mg/kg.

The lower end of the ranges represents product in coarse sand and gravel, while the upper end of the ranges represents product in fine to medium sand.

7.3.3 Groundwater Point of Compliance

As defined in the MTCA regulations, a POC is the point or points at which CULs must be attained. MTCA defines both a standard POC (SPOC) and a conditional POC (CPOC). The groundwater SPOC, as described in WAC 173-340-720(8)(b), includes all groundwater within the saturated zone beneath the Site and in any area affected by releases from the Site. A CPOC is used at the Site when it can be demonstrated under WAC 173-340-350 through 173-340-390 that it is not practicable to meet the CULs at the SPOC throughout the Site within a reasonable restoration timeframe.

As discussed below, IHSs are present at concentrations above CULs at a number of SPOC wells, primarily in and adjacent to the source areas in the interior portions of the Site. As a result of these exceedances, CPOC wells are proposed and evaluated. The demonstration of the practicability of achieving CULs at the SPOC (i.e., throughout the Site), and the appropriateness of using a CPOC, is made in Section 10 and 11 of this report.

7.4 Areas Exceeding Groundwater Cleanup Levels

Groundwater data collected from monitoring wells at the Site were compared to the final FS CULs to determine whether or not the Site detected groundwater concentrations exceeded final FS CULs at the POC (i.e., monitoring wells at the Site). The data evaluated included data collected from two separate sampling periods. The first set of data was collected from wells sampled from 2006 to 2008. The second set of data was collected from seven wells sampled from 2000 to 2004[10]. In the *Evaluation of Groundwater Data from the Terminal 91 Tank Farm Site: Proposal to Discontinue Groundwater Sampling at Selected Wells Memorandum* (PIONEER, 2005), the Port requested that sampling at these seven wells be discontinued after 2004 because groundwater concentrations had stabilized and additional sampling was not warranted. In a letter dated April 21, 2005, Ecology agreed to the Port's proposal to discontinue ground water sampling at selected monitoring wells beginning with the March 2005 groundwater monitoring event (Ecology, 2005c). Table 7-5 presents the groundwater wells included in this evaluation and Figure 7-2 locations. The groundwater data used in this evaluation can be found in Appendix B of *Comparison of Site Groundwater Concentrations to Cleanup Levels* (PIONEER, 2008b).

7.4.1 Standard Points of Compliance

The SPOC includes all wells located within the Site boundaries. To determine whether or not groundwater data exceeded the final FS CULs at the Site, the IHS groundwater concentrations in each well were compared to final FS CULs. Locations of SPOC wells are shown in Figure 7-2. Results of this comparison for all Site monitoring wells are presented in Appendix C of *Comparison of Site Groundwater Concentrations to Cleanup Levels* (PIONEER, 2008b).

Five wells considered in the evaluation (CP_106A, CP_106B, CP_114, CP_205A, and CP_205B) were identified as on-Site background wells, used to determine background concentrations of inorganic IHSs. Concentrations of inorganic IHSs in these wells were not compared to CULs, since they were used to define background. A detailed description of the derivation of area background concentrations is presented in the *Terminal 91 Tank Farm Site Background Groundwater Evaluation Memo* (PIONEER, 2007).

7.4.1.1 Shallow Groundwater

Maximum detected IHS concentrations in shallow groundwater exceeded final FS CULs in 15 wells. The locations of these wells are presented in Figure 7-4. Table 7-6 presents IHSs that exceeded final FS CULs. The main IHSs that exceeded final FS CULs were PAHs, diesel, and gasoline. The location of shallow wells with concentrations of PAHs exceeding final FS CULs

[10] Because of the changes to the monitoring program over time, the data sets used in this section to compare against the final FS CULs represent a larger timeframe than the data presented in Section 5.4 for purposes of documenting current Site conditions (including in Figures 5-9 through 5-19). The data presented in the Section 7 tables (7-1 through 7-6) may not correlate with that discussed in Section 5.

are shown in Figure 7-5, and those with diesel or gasoline concentrations exceeding the final FS CULs are shown in Figure 7-6. As shown in these figures, wells with PAH, diesel, or gasoline concentrations exceeding the final FS CULs were concentrated around the former tank farm, SWMU-30, and AOC-11.

7.4.1.2 Deep Groundwater

Maximum detected IHS concentrations in deep groundwater exceeded final FS CULs in six wells. The locations of these wells are presented in Figure 7-7. The main IHSs exceeding final FS CULs were PAHs, diesel, and gasoline. Table 7-6 presents IHS concentrations exceeding the final FS CULs. The locations of deep wells with PAH concentrations exceeding the final FS CULs are shown in Figure 7-8, and those with diesel or gasoline concentrations exceeding the final FS CULs are shown in Figure 7-9. As shown in these figures, wells with PAH, diesel, or gasoline concentrations exceeding the final FS CULs were clustered around the Lease Parcel.

7.4.2 Conditional Points of Compliance

Because there were exceedances of the final FS CULs at the SPOCs within the Site, compliance at CPOCs was evaluated. Under WAC 173-340-720(8)(c), Ecology may approve use of a CPOC if it can be demonstrated that it is impracticable to meet CULS at the SPOC in a reasonable timeframe; this demonstration is made in Sections 10 and 11 of this report. Groundwater final FS CULs must be met at the CPOC, and in areas downgradient of the CPOC.

Four shallow groundwater wells (i.e., CP-GP14, CP-GP10, CP_GP09R and CP_GP08) and two deep groundwater wells (i.e., PNO_MW06B and CP_GP01B) are proposed CPOC wells (Figure 7-4). The proposed CPOC wells were used as the “sentinel” wells in the *Monitored Natural Attenuation Final Technical Memorandum* (MNA Memo; PES and Roth, 2006a). The sentinel wells are the wells closest to potential discharge points on Elliott Bay. The MNA Memo provides detailed information on the groundwater flow pathways across the Site and provides justification for the use of the identified sentinel wells. Depending on the preferred cleanup action to be implemented at the Site, the CPOC wells may need to be reevaluated or adjusted.

There were no IHSs detected in CPOC wells exceeding final FS CULs in shallow or deep wells.

7.5 Areas Exceeding RSSLs

The final RSSLs defined in Section 7.3.2.3 were compared to the results from the 219 soil samples analyzed the first two phases of the data gaps investigation plus the 31 additional samples analyzed in the third phase of the investigation. For the purposes of this comparison, the fuel oil RSSL is compared to motor oil range TPH concentrations at the Site, and the middle distillate petroleum product RSSL is compared to diesel range TPH concentrations. TPH and toluene laboratory results from the data gaps investigation are described in Section 5.4.2.3 and summarized on Table 5-3. Figures 5-4 through 5-6 highlight soil borings with samples that exceeded the RSSLs for both the individual TPH fractions and for total TPH (i.e., the sum of the gasoline, diesel, and motor oil ranges).

The greatest number of samples with TPH concentrations greater than RSSLs are located in and around the Lease Parcel. These samples are largely distributed across vadose zone and smear zone sample depths, although there are also some exceedances in the saturated zone. The toluene RSSL is exceeded in only 2 smear zone samples in the Small Yard. The following is a summary of TPH related RSSL exceedances in and around the Lease Parcel (PES 2008c):

Black Oil Yard. Of the 18 soil borings in and around the Black Oil Yard, sample results exceed the RSSLs for diesel range, oil range, and/or total TPH in seven locations in the vadose zone and four locations in the smear zone.

Marine Diesel Oil Yard. Of the 25 soil borings located in the MDO Yard, sample results exceed the RSSLs for diesel range, oil range, and/or total TPH at six locations in the vadose zone and fifteen locations in the smear zone.

Small Yard. Of the 22 soil borings in or adjacent to the Small Yard area, sample results exceed the RSSLs for gasoline range, diesel range, oil range, and/or total TPH at nine locations in the vadose zone; eleven locations in the smear zone; and two locations in the saturated zone. Additionally, the Small Yard included the only two soil borings in the Data Gaps Investigation (DGI) which exceeded the toluene RSSL (smear zone samples).

Northern Lease Parcel Area. Of the eight soil borings located in this area, there is only one soil boring where the sample result exceeds the RSSL for gasoline range TPH in the smear zone; and three locations which exceed RSSL for gasoline range TPH in the saturated zone. There are no soil borings in the vadose zone which exceed any of the RSSLs in this area.

Area between the Lease Parcel and AOC 11. Of the 14 soil borings located in this area, sample results exceed the RSSLs for diesel range and/or total TPH at five locations in the smear zone; and one location in the saturated zone. There are no soil borings in the vadose zone which exceed any of the RSSLs in this area.

The other areas of the Site (AOC 11 and SMWU-30) have only a few smear zone soil samples with TPH concentrations greater than RSSLs. The data gaps investigation in AOC 11 identified only a single sample in one soil boring (DG-80) that exceeded an individual TPH-range RSSL, in this case, the RSSL for gasoline. None of the monitoring wells in AOC 11, including well PNO-MW101 located near DG-80, had measurable LNAPL in 2008[11]. With respect to SMWU-30, there were two borings (DG-83 and DG-86) each with one sample that exceeded the diesel-range TPH RSSL in the smear zone, and well PNO-MW102 had measurable LNAPL in 2008.

[11] It should be noted that several locations at the extreme eastern edge of AOC 11, including monitoring well PNO-MW104, had measureable LNAPL in 2008, which are likely related to operations in the former pipeline corridor rather than activities in AOC 11. As such, these wells will be evaluated as part of the Lease Parcel.

8.0 FEASIBILITY STUDY SCOPING

The process of developing CAAs and selecting a final cleanup action includes the following steps:

- Determine cleanup goals and levels;
- Identify applicable regulations and standards;
- Define cleanup action objectives (CAOs);
- Identify general response actions;
- Identify and screen cleanup action technologies;
- Develop and evaluate CAAs; and
- Select the preferred alternative.

The CULs for the site were developed in Section 7. This section describes the next two steps including defining the CAOs. CAOs are media-specific goals that provide the framework for developing and evaluating CAAs. Section 9 identifies the general response actions and applicable cleanup action technologies on the basis of the CAOs and site-specific information. Section 10 describes the development of a range of potentially applicable CAAs, while Section 11 describes the detailed evaluation of these alternatives. The preferred alternative is described in Section 12.

8.1 Scope of the Feasibility Study and Overall Approach to CAA Development

The FS is focused on developing and evaluating CAAs for the Site, which is a portion of the larger Terminal 91 Complex (see Section 2.1). Other portions of the Terminal 91 Complex, including the Upland and Submerged Land portions, are outside the scope of this FS and will be addressed pursuant to other environmental investigations and/or cleanup actions.

Within the Site, there are several areas or activities that will be addressed in the FS, including:

- The Lease Parcel, including the former tank farm itself;
- Other waste or product management areas including:
  - SWMU 30;
  - AOC 11;
  - Below-ground pipelines that have not been previously abandoned; and
- Groundwater located downgradient of the Lease Parcel.

The Lease Parcel is the primary source of contamination within the Site, and as such will be the focus of much of the CAA development and evaluation process described in Sections 9 through 11.

8.2 Regulatory Requirements

The following regulations may be applicable to specific technologies or CAAs. The evaluation of specific regulations will be conducted as necessary during the development and detailed analysis of CAAs in Sections 10 and 11, respectively.

8.2.1 Model Toxics Control Act

Ecology's MTCA regulations were the primary regulations used to guide the performance of the FS. Specifically, the FS was conducted following the procedures outlined in WAC 173-340-350.

The current 1998 AO was issued pursuant to MTCA and the Port's corrective action obligations under the 1998 AO are enforceable conditions of the dangerous waste management permit issued pursuant to Washington Dangerous Waste Regulations (see 8.2.2 below).

8.2.2 Washington Dangerous Waste Regulations

8.2.2.1 Corrective Action Requirements

As noted in Section 2, activities associated with the former tank farm included the treatment and storage or dangerous wastes, which are regulated under Chapter 70.105 Revised Code of Washington (RCW), the Hazardous Waste Management Act of 1976, as amended, and regulations codified in WAC 173-303. Pursuant to these regulations, Ecology issued Permit No. WAD000812917 on August 26, 1992, to the Port to conduct corrective action at the Terminal 91 Complex.

Ecology is requiring that the Port fulfill corrective action responsibilities for the facility, as defined by WAC 173-303-040, using the MTCA regulations as well as the Dangerous Waste Regulations [WAC 173-303 and specifically WAC 173-303-646]. The corrective actions taken must meet or exceed all substantive corrective action requirements of the state Hazardous Waste Management Act, and Dangerous Waste Regulations as well as RCRA.

8.2.2.2 Dangerous Waste Management Requirements

The Dangerous Waste Regulations provide the framework for how to manage the various wastes, debris, and environmental media generated during cleanup actions at the Site. The regulations in WAC 173-303 establish the general procedures and standards related to the definition, management, and disposal of dangerous wastes.

The approach to managing impacted environmental media (e.g., soil, groundwater) and debris (e.g., concrete and steel associated with the former tank farm) that may be generated during cleanup actions is complicated by the range of both dangerous and non-dangerous wastes managed throughout the Lease Parcel, and by the status of the Lease Parcel as a permitted facility. Discussions between the Port and Ecology have lead to the development of two memoranda that provide guidance on this subject:

- *Guidance for Waste Designation Procedures at Terminal 91* (See Appendix B); and
- *Management of the Port of Seattle's T-91 Facility's Tank Farm Site Subsurface Debris* (Appendix B).

8.2.3 Applicable State and Federal Laws

As noted above, MTCA's threshold requirements listed in WAC 173-340-360(2) include the requirement to "comply with applicable state and federal laws," which are further defined in WAC 173-340-710. The following Federal and Washington State laws and their associated regulations may be applicable to the CAAs developed for the Site:

- **Federal Clean Water Act; (33 U.S.C. §1251 et seq)** contains standards protective of human health and aquatic life. Specific portions of the Clean Water Act applicable to the Site include:
  - Ambient Water Quality Standards (Section 304); and
  - Standards issued under the National Toxics Rule (40 CFR 131).
- **Washington Water Well Construction Regulations (WAC 173-160)** establish state standards for installing, maintaining, and decommissioning groundwater monitoring and recovery wells.
- **Washington Ground Water Quality Standards (WAC 173-201)** establish standards to protect groundwater quality (e.g., maximum contaminant levels [MCLs]) and beneficial uses.
- **Washington State Sediment Management Standards (WAC 1732-204)** establish sediment quality standards protective of aquatic life.
- **Washington Surface Water Quality Standards (WAC 173-201A)** are applicable to surface waters of the state, are protective of aquatic life and other beneficial uses, and can be applicable if an alternative includes discharge of treated water.
- **Washington State NPDES Program Regulations (WAC 173-220)** would be applicable for discharge to surface waters under a National Pollutant Discharge Elimination System (NPDES) permit.
- **Washington Dangerous Waste Regulations (WAC 173-303)** establish procedures and standards related to the definition, management, and disposal of dangerous wastes. The Dangerous Waste Management Permit and related corrective requirements are summarized in Section 8.2.2 above.
- **Washington Clean Air Act Regulations (WAC 173-400)** provide standards and procedures for managing the discharge of contaminants to the atmosphere.
- **Washington Industrial Safety and Health Act Regulations (WAC 296-62)** contain health and safety training requirements for on-site workers. They also contain permissible exposure limits for conducting work at the Site.

8.3 Cleanup Action Objectives

CAOs form the basis for evaluating potential cleanup technologies and actions for the Site. CAOs are based on an evaluation of the data collected during previous investigations (summarized in Sections 4 through 6 above) and on the CULs established in Section 7. The focus of the CAOs is protection of human health and the environment. As described in Section 7.2, the Site qualifies for an exclusion from a terrestrial ecological evaluation in accordance with the requirements of WAC 173-340-7491(c). Therefore, no terrestrial ecological-based CAOs are developed.

CAOs for the protection of human health and ecological receptors proposed for use at the Site are discussed below. As described in more detail in Section 7.2, the primary potential groundwater exposure pathway is the groundwater to surface water/sediment pathway. The process for developing CULs for this pathway incorporated both human health receptors (consumption of fish) as well as ecological receptors (i.e., aquatic life), with the final CULs based on the most stringent applicable standard. As a result, CAOs that are based on achieving groundwater CULs are protective of both human health and ecological receptors.

As discussed in Section 7, potential risks associated with most of the soil exposure pathways (e.g., direct contact, soil to indoor air) will be addressed through implementation of engineering and institutional controls. CAOs will be proposed to address the portion of the soil to groundwater pathway related to preventing accumulation of LNAPL on the groundwater.

8.3.1 Soil Cleanup Action Objectives

The CAOs for potential exposure to IHSs from soil are as follows:

- Prevent incidental ingestion of and dermal contact with soil, and inhalation of particulates and vapors from soil, by future subsurface construction workers on-Site;
- Prevent inhalation of vapors from soil by future workers and trespassers on-Site at concentrations above risk-based levels;
- Control, to the extent practicable, migration of IHSs from soil to groundwater that would result in IHS concentrations in groundwater exceeding the applicable CULs at the POC; and
- Control, to the extent practicable, the migration of IHSs from soil to groundwater in quantities that would result in the accumulation of LNAPL on the groundwater.

8.3.2 Groundwater Cleanup Action Objectives

The CAOs for protection of human and ecological receptors via potential exposure to groundwater at the Site are as follows:

- Prevent inhalation of vapors from groundwater by future workers and trespassers on-Site at concentrations above CULs;

- Prevent inhalation of vapors from groundwater by future subsurface construction workers on-Site;
- Control, to the extent practicable, the accumulation of LNAPL on the groundwater; and
- Prevent the migration of groundwater containing IHSs at concentrations exceeding the applicable CULs beyond the POC.

9.0 GENERAL RESPONSE ACTIONS AND CLEANUP ACTION TECHNOLOGIES

This section identifies the general response actions and cleanup action technologies that will be used to develop the CAAs in Section 10.

9.1 General Response Actions

General response actions are the general approaches that can be used, either alone or in combination with other response actions, to meet the CAOs. Like the CAOs, general response actions are medium-specific.

9.1.1 General Approach to Addressing CAOs

The CAOs for soil and groundwater listed in Section 8.3 focus on four primary exposure or migration pathways:

- Exposure of future subsurface construction workers to IHSs in soil, particulates, and soil vapors;
- Exposure of future workers and trespassers to IHSs in vapors originating from soil and/or groundwater via indoor air;
- Groundwater discharge to surface water and/or sediment and the subsequent potential for impacts on aquatic life or humans consuming fish; and
- The presence of LNAPL on the groundwater and/or the migration of contaminants from soil that results in the accumulation of LNAPL on groundwater.

The development of CULs summarized in Section 7 and the CAOs listed in Section 8.3, combined with the current concentrations of IHSs in the soil and groundwater, indicate that there are no current exposures above risk-based criteria on the Site. As a result, the general approach for addressing the CAOs is described below.

The first two of these exposure pathways (direct contact with soil and vapor migration to indoor air) will be addressed through implementation of engineering and institutional controls. This approach was originally proposed in the FS Work Plan (PES et al., 2005a), and again in the *Feasibility Study Cleanup Levels* document (Pioneer, 2008a), both of which have been approved by Ecology.

Because long-term groundwater monitoring has documented that concentrations of IHSs at the CPOC are below risk-based CULs, the third exposure pathway (groundwater discharge to surface water and sediment) does not appear to present a current risk to human health and the environment. Furthermore, the *Monitored Natural Attenuation Evaluation, Final Technical Memorandum* (PES et al., 2006c) documented that naturally occurring attenuation mechanisms have resulted in stable plumes of petroleum related compounds originating in the tank farm, SMWU 30, and other potential sources; and future CULs are likely to continue to be met at the

CPOC. As a result, the groundwater to surface water/sediment pathway will be addressed by implementation of an MNA program at the Site.

With the first three pathways being addressed by the presumptive actions described above, the final pathway (LNAPL accumulation on groundwater or the potential migration of LNAPL from soil to groundwater) will be the primary focus for the development of the CAA and evaluation process.

9.1.2 Soil General Response Actions

The general response actions for soil at the Site are as follows:

- Institutional controls (e.g., monitoring, deed restrictions, worker protection);
- Engineering Controls (e.g., surface paving or cap, vapor barriers);
- In situ treatment;
- Excavation; and
- Off-Site treatment/disposal.

With the exception of in situ treatment, these general response actions are readily implementable at the Site and would address the CAOs either alone or in combination. Implementing in situ treatment of soil at the Site would be challenging, primarily because of the wide range of petroleum hydrocarbons present. As described in Section 5.4, petroleum types from gasoline-range to heavy oil-range are present in a complex mixture throughout the Lease Parcel and secondary source areas. In situ technologies potentially applicable to the primary Site contaminants, and the rationale for including or excluding them from consideration, are:

- **In situ bioremediation** – This general class of technologies can be useful in reducing moderate concentrations of gasoline and diesel-range hydrocarbons, but is generally ineffective for heavy oils and for very high concentrations (i.e., NAPL) of gasoline and diesel-range compounds. Given the widespread presence of these recalcitrant compounds, in situ bioremediation is not retained for consideration.

- **Soil vapor extraction (SVE) –** This technology is applicable to the lighter more volatile hydrocarbon fractions and other VOCs present at the Site. Given the significant distribution of middle and heavier-end hydrocarbons which have limited to essentially no volatility, standard SVE would be ineffective for the majority of the Site and is not retained for consideration. Furthermore, this technology would have limited effectiveness for volatile compounds below the water table.

- **In situ thermal treatment –** This general remediation approach uses a combination of soil heating by various methods and vacuum extraction to volatilize and remove contaminants from the subsurface. The methods typically used for soil heating include steam injection, electrical resistance heating, and conductive heating. Once the soil is heated, the volatilized contaminants (and water vapor) are extracted and treated or collected for disposal. Given the extensive in situ systems and power required to implement these technologies, in situ thermal treatment is considerably more expensive than excavation and off-site disposal for non-hazardous waste soils such as the petroleum-impacted soils present at the Site. As a result, in situ thermal treatment is not retained for use in development of CAAs.

Another factor to consider regarding the use of in situ treatment for soil at the Site is the potential for significant disruptions to ongoing industrial and commercial activities, and the impairment of future development of portions of the Site. All of the in situ technologies described above require extensive above and below ground infrastructure (e.g., piping, extraction equipment, support facilities, injection and extraction wells) that would be in place for at least 2 years and in the case of SVE and in situ bioremediation for a period of 5 to 10 years or longer.

As a result of the technical, cost, and implementability concerns summarized above, the common in situ soil treatment technologies are not retained for use in developing CAAs in Section 10.

9.1.3 Groundwater General Response Actions

The general response actions for groundwater at the Site are as follows:

- Institutional controls (e.g., monitoring, deed restrictions);
- Engineering controls (e.g., surface paving or cap, vapor barriers);
- Groundwater containment (e.g., hydraulic controls, vertical barriers);
- LNAPL recovery;
- Monitored natural attenuation;
- Groundwater extraction;
- Ex situ treatment; and
- Discharge to surface water or sanitary sewer.

The last three general response actions (groundwater extraction, treatment, and discharge) are included for purposes of managing groundwater that may be extracted as part of a hydraulic control action, or removed during dewatering activities associated with soil excavation. In situ treatment of groundwater using such technologies as enhanced bioremediation and chemical oxidation could be applied at two locations of the Site: (1) in the primary source area (i.e., Lease Parcel) and (2) in the downgradient areas between the source area and the receptors (surface water and sediment). The use of in situ treatment for groundwater within the source area would be ineffective unless the NAPL and soil contamination present in this 4 to 5 acre area was cleaned up to low levels that would not result in future groundwater contamination. Given the current and expected future land use of this area, the approach to addressing the CAOs for the site, and the difficulties and cost of treating the soil in this large of a source area, in situ treatment of groundwater in the source area is not practicable at the Site.

With respect to the downgradient portions of the Site, MNA has been demonstrated to be effective in controlling IHS concentrations in groundwater to below the final FS CULs at the CPOC wells. Implementing more active in situ treatment technologies (e.g., enhanced bioremediation, in situ chemical oxidation) across the 17-acre downgradient portion of the Site would be extremely difficult given the intense industrial and commercial activities ongoing, would be very expensive, and would not provide a higher degree of protection to the potential surface water and sediment receptors. As a result, in situ treatment of groundwater in the downgradient areas was not retained; see Section 10.2.4 for additional discussion. If at some point in the future MNA is determined to be ineffective at meeting the CAOs, the use of in situ treatment of groundwater may be reconsidered.

9.2 Cleanup Technology Identification

Cleanup action technologies are specific actions that represent the general response actions above. These technologies are combined into CAAs in Section 10.

The potentially applicable technologies considered for the Site, organized by general response action, are listed in Table 9-1. This list of technologies was compiled based on the nature of the primary contaminants at the Site (i.e., TPH), the environmental media impacted (soil and groundwater), and the types of exposures that need to be addressed (as defined by the CAOs). These are common and straightforward technologies (e.g., surface cap/paving, excavation, vapor barriers, etc.), which given the focused nature of the CAOs and general response actions defined above, do not require additional screening or evaluation. Additional details regarding these technologies will be provided in the description of the CAAs in which they are utilized.

The technologies associated with the presumed response actions defined in Section 9.1.1 are included in Table 9-1. Specifically, engineering and institutional controls will be used to control potential exposure via the soil/groundwater to indoor air and direct contact by subsurface worker pathways and the groundwater to surface water/sediment pathway will be addressed by implementation of MNA.

10.0 DEVELOPMENT OF CLEANUP ACTION ALTERNATIVES

CAAs are combinations of technologies designed to meet the CAOs. The technologies identified in Section 9 were assembled into a range of CAAs that address the CAOs and meet MTCA's minimum requirements. This section presents a detailed description of the CAAs with respect to conceptual design, implementation, and estimated cost. The conceptual design is developed in sufficient detail to evaluate the effectiveness, performance, and estimated restoration timeframe in the detailed evaluation of CAAs presented in Section 11 and to conduct the comparative evaluation of the alternatives presented in Section 12.

The costs of the CAAs discussed below were developed by accounting for capital costs as well as recurring and future costs. Capital costs include work plans, design reports, other Ecology-required documents, and construction to implement the remedy. Recurring and future costs include groundwater monitoring, operation and maintenance (O&M), and reporting for 30 years. Consideration of a longer period for recurring and future costs will not materially impact the CAAs cost evaluation.

A construction contingency cost of 20 percent was added to each alternative to reflect a level of uncertainty in the estimated costs given the conceptual design of the CAAs. The contingency on capital cost reflects uncertainty in design, permitting, and construction costs. A 10 percent contingency on recurring and future costs generally reflects uncertainty of the O&M costs and the duration of the remedy. The cost estimates are rounded to the nearest $10,000.

Cost details are provided in Tables 10-1 through 10-9. These cost estimates do not include the significant investigation- or remediation-related project costs incurred to date including previous site assessments, routine monitoring, reporting, and costs for previous closure and interim actions. The net present value (NPV) for future and recurring costs is based on a discount rate of 5 percent, which is the rate the Port uses for its financial planning. All costs are presented in 2009 dollars.

10.1 <u>Approach to CAA Development</u>

10.1.1 Presumptive Cleanup Actions and Approach to Lease Parcel

As described in Section 9.1.1, the majority of the potential exposure pathways will be addressed using presumptive response actions (i.e., engineering controls, institutional controls, and MNA). The cleanup actions associated with the presumptive response actions, including the rationale for selecting these actions, are described in Section 10.2.

The remaining parts of the Site not addressed by these presumptive cleanup actions are the Lease Parcel and other contaminant source areas. Section 7.1 identified the contaminant sources at the Site, with the Lease Parcel and immediately adjacent areas being by far the most significant source area. Secondary sources identified within the Site boundaries included SWMU 30, AOC 11, and the former fuel transfer pipelines. Compared to the Lease Parcel, these secondary sources are much smaller in size, contain fewer types of contaminants, and have much less contaminant mass associated with them. Given the relative simplicity of these secondary sources, evaluating a range of alternatives for each is not warranted, and specified cleanup actions will be developed for each that will effectively eliminate these as potential long-term contaminant sources. These secondary source cleanup actions will be included in the presumptive actions described in Section 10.2.

For the Lease Parcel and adjacent areas, addressing the CAOs associated with preventing LNAPL accumulation on groundwater and/or the potential migration of LNAPL from soil to groundwater (i.e., source control) will be the primary focus of the CAA development process described in Section 10.3. The combination of the presumptive cleanup actions described in Section 10.2 and one of the CAAs developed in Section 10.3 will constitute the overall cleanup action for the Site.

10.1.2 Evaluation of Required CAAs

The MTCA regulations regarding the performance of feasibility studies in WAC 173-340-350(8) require that the following two specific alternatives be evaluated: (1) an alternative that uses the SPOC, and (2) a "permanent cleanup action". Under certain circumstances these required alternatives can be dropped from consideration. How this FS addresses these two required alternatives is discussed below.

10.1.2.1 Alternative Using Standard Point of Compliance

WAC 173-340-350(8)(c)(i)(F) requires that the FS include alternatives with the SPOC for each environmental media unless those alternatives have been eliminated from consideration pursuant to WAC 173-340-350(8)(b). In a similar manner, WAC 173-340-360(2)(c)(i) requires that a permanent groundwater cleanup action that achieves CULs at the SPOC be implemented "where such an action is practicable."

WAC 173-340-350(8)(b) states that alternatives may be eliminated from consideration in the feasibility study including:

> (i) Alternatives that, based on a preliminary analysis, the department determines so clearly do not meet the minimum requirements specified in WAC 173-340-360 that a more detailed analysis is unnecessary. This includes those alternatives for which costs are clearly disproportionate under WAC 173-340-360(3)(e); and
>
> (ii) Alternatives or components which are not technically possible at the site.

Achieving the CULs defined in Section 7 throughout the Site (i.e., SPOC), including in the Lease Parcel, is not practicable or technically possible to achieve for the following reasons:

- The Lease Parcel and immediately adjacent areas represent a 4 to 5 acre source area with elevated concentrations of TPH in soil and groundwater as well as widespread (although relatively small amounts of) LNAPL. Treating this source area would be technically difficult given the range of petroleum products present (e.g., gasoline through heavy oil-range hydrocarbons), site lithology, and the presence of impacted soil beneath the water table. In addition, the ability of treatment technologies to achieve the CULs in groundwater is uncertain at best;

- Outside the primary source area, there are a number of other secondary sources (see above) and residual contamination that would make achieving CULs throughout the approximately 17-acre extent of the Site very difficult to achieve;
- Treatment of the Lease Parcel source area, as well as the secondary sources, to the extent necessary to achieve CULs throughout the Site in soil and groundwater would be extraordinarily expensive;
- Portions of the impacted soil and groundwater are beneath existing buildings or critical infrastructure (Magnolia Bridge), making it extremely difficult if not impossible to treat contamination in these areas;
- As described in Section 7, there are no current exposures to IHSs in soil or groundwater that present unacceptable risks to human health and the environment;
- The Site, including the entire downgradient extent of contamination, is located in the middle of Port-owned property; and
- Land in and around the Site is and will continue to be used for industrial and commercial purposes.

The factors listed above that make achieving CULs at the SPOC impracticable also make it extremely difficult to estimate a restoration time frame for the Site based on the SPOC, but suggest that achieving CULs throughout the Site could require 20 to 30 years, possibly longer.

Based on the information presented previously in this report and summarized above, alternatives that attain CULs at the SPOC are not technically possible, cannot be achieved in a reasonable restoration time frame, and the costs of attempting to implement such an alternative are clearly disproportionate to the benefits. Therefore, pursuant to WAC 173-340-350(8)(b), alternatives that attempt to achieve CULs at the SPOC will not be considered further in this FS and the CPOC will be used in the development of cleanup actions.

<u>10.1.2.2 Permanent Cleanup Action</u>

WAC 173-340-350(8)(c)(ii)(A) requires that the FS include at least one permanent CAA, unless it can be demonstrated pursuant to subsection (c)(ii)(B) that it is not required. WAC 173-340-360 defines a "permanent cleanup action" as:

". . . a cleanup action in which cleanup standards of WAC 173-340-700 through 173-340-760 can be met without further action being required at the site being cleaned up or any other site involved with the cleanup action, other than the approved disposal of any residue from the treatment of hazardous substances."

For the same reasons described above, development and implementation of a permanent cleanup action is not feasible for this Site because:

- It is not technically possible given current land use [WAC 173-340-350(8)(c)(ii)(B)(II)]; and

- The cost of a permanent cleanup action is so clearly disproportionate that a more detailed analysis is not necessary [WAC 173-340-350(8)(c)(ii)(B)(II)].

WAC 173-340-360(2)(c)(ii) requires that in cases such as the Site, where achieving a "permanent" cleanup of groundwater is determined to be impracticable and/or unnecessary to protect human health or the environment, a nonpermanent action can be implemented as long as the following actions are taken:

- Source areas shall be treated or removed, including removal of LNAPL from groundwater using accepted engineering practices; and

- Groundwater containment is implemented to the maximum extent practicable to avoid lateral and vertical expansion of the groundwater volume affected by the hazardous substances.

The extent to which these two requirements are addressed will be evaluated as part of the CAA development and evaluation process described in the remainder of this section and Section 11. As noted above, CAAs for the secondary sources (Section 10.2) and the Lease Parcel (Section 10.3) focus on source control actions (including containment, LNAPL removal, and soil excavation).

10.2 Presumptive Cleanup Actions

Consistent with the approach described above, a series of presumptive cleanup actions will be identified to address following aspects of the Site:

- Preventing exposure via direct contact with contaminated soil and inhalation of vapors by future subsurface workers;

- Preventing exposure via inhalation of indoor air impacted by migration of vapors originating from contaminated soil and groundwater;

- Secondary sources; and

- Groundwater downgradient of the Lease Parcel.

10.2.1 Subsurface Worker Direct Contact and Vapor Inhalation

This pathway addresses potential future exposure of subsurface workers to IHSs in soil and groundwater via the direct contact, vapor inhalation, and particulate inhalation pathways. The cleanup action to address this potential exposure will consist of the following institutional controls:

- Notice on the property deed and in operating procedures implemented by the Port notifying personnel of the potential exposure and requirements to implement standard worker health and safety procedures; and

- Requirement that qualified personnel evaluate soil and/or groundwater that may be removed as part of construction activities and manage the material consistent with applicable regulations.

These institutional controls will be included in an environmental covenant developed consistent with Ecology's Model Restrictive (Environmental) Covenant[12]. The initial costs with these actions are related to developing and implementing the institutional controls, which for purposes of this FS are assumed to be $10,000. The costs associated with implementing worker health and safety measures and managing soil and groundwater that may be encountered in future development activities are project-specific costs that cannot be estimated at this time.

10.2.2 Indoor Air Pathway

As described in Section 7.2, there are no current exposures via the indoor air pathway, and potential exposures via this pathway would occur only if future development activities at the Site include construction of a building or other enclosed structure over contaminated soil or groundwater. The approach for addressing the potential future exposure of workers or trespassers via the indoor air pathway will be to develop an environmental covenant that includes the following institutional controls:

- Placing a notice on the property deed identifying the potential presence of contaminated soil and/or groundwater;

- Requiring that one of the following approaches be taken to address the potential exposure:

  (1) Include engineering controls (e.g., vapor barriers, sub-slab venting systems) in Site development plans to prevent the potential exposure; or

  (2) Conduct a development-specific evaluation of the soil/groundwater to indoor air pathway (i.e., developing risk-based CULs for the specific potential exposures related to the proposed development).

If concentrations of IHSs exceed the CULs developed under the second option, appropriate supplemental remedial actions will be evaluated and implemented or engineering controls implemented, as appropriate.

As with the measures for addressing the direct contact pathway, the initial costs of the actions related to controlling exposure via the indoor air pathway are associated with development of the institutional controls. For purposes of this FS, these costs are assumed to be $10,000. The costs for addressing potential exposure associated with future development activities are project-specific costs and cannot be estimated at this time.

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[12] Ecology's Model Restrictive (Environmental) Covenant can be found at:
www.ecy.wa.gov/programs/TCP/vcp/vcp_boilerplates/Model%20Covenant%20(Quick%20Fix)%20(2).doc

10.2.3 Secondary Source Area Actions

The three secondary source areas within the Site are SWMU 30, AOC 11, and the former fuel transfer pipelines. The approach for addressing each of these is described below.

SWMU 30. As described in the final RSSL memorandum (PES, 2008c), there were two borings each with one sample that exceeded the diesel-range TPH RSSL in the smear zone, and well PNO-MW102 had measurable LNAPL in 2008. Because this evidence indicates that there are still LNAPL sources at these two locations, the presumptive remedy for SMWU 30 includes excavating these two areas (see Figure 10-1). The first area covers approximately 1,800 square feet (sq ft) around well PNO-MW102, which is impacted with LNAPL. The second area covers approximately 2,500 sq ft and surrounds the location of the two adjacent samples impacted with TPH above RSSLs. By removing the observed LNAPL source and soil exceeding the RSSLs, the potential for SWMU 30 to cause future exceedances of CULs at the CPOC will be greatly reduced. Although groundwater monitoring at CPOC wells CP_GP09R and CP_GP10 located downgradient of SMWU 30 indicates that all IHSs are below CULs, the proximity of SMWU 30 to these CPOC wells warrants this source removal action.

Based on the nature of the release in this area (subsurface pipeline leak), it is assumed that soil from the vadose zone (0 – 4 ft bgs) in both areas can be stockpiled on site and reused as backfill. The first area will be excavated to a depth of 12 ft, and the second area will be excavated to a depth of 9 ft. This cleanup action includes decommissioning 3 monitoring wells (PNO-MW-03, PNO-MW-102, and PNO-EW-1), removing the existing pavement, excavation, backfilling, paving, waste handling, and waste disposal. The approximately 1,000 cubic yards of LNAPL and TPH-impacted soil from the smear zone (4-9 ft bgs) and saturated zone (9-12 ft bgs) will be stockpiled separately and profiled for off-site disposal at an approved facility. Soil from the smear zone and saturated zone may need to be dewatered prior to hauling. Other details of the excavation activities will be as described in Alternatives 4 and 5 for the Lease Parcel Area (see Section 10.3.4 and 10.3.5).

The capital costs associated with the proposed SWMU 30 actions are summarized in Table 10-1 and total $260,000. There are no long-term O&M costs associated with this action aside from groundwater monitoring which is addressed in Section 10.2.4.

AOC 11. The data gaps investigation in AOC 11 identified only a single sample in one soil boring (DG-80) that exceeded an individual TPH-range RSSL, in this case the RSSL for gasoline. None of the monitoring wells in AOC 11, including well PNO-MW101 located near DG-80, had measurable LNAPL in 2008[13]. Given that downgradient CPOC well CP_GP14 is below CULs, and the lack of any LNAPL or extensive areas of significant soil contamination that may lead to future LNAPL accumulation, aggressive source removal actions similar to those proposed for SWMU 30 do not appear warranted for AOC 11. The lack of a current LNAPL source is not unexpected given that the AOC 11 tank farm was only operational for 15 years and was demolished over 75 years ago.

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[13] It should be noted that well PNO-MW104, which is located at the extreme southeastern corner of AOC 11, did have measurable product in 2008. The product at this location is likely associated with pipeline operations just to the east of this well, and as such, well PNO-MW104 and the rest of the extreme eastern portion of AOC 11 (e.g., the area just west of well UT_MW39-2) are addressed as part of the Lease Parcel cleanup actions developed in Section 10.3.

The approach for addressing the residual contamination present in AOC 11 will be incorporation into the MNA approach described in Section 10.2.4 below.

Former Fuel Transfer Pipelines. As noted in Section 7.1.2, a number of subsurface fuel and wastewater transfer pipelines running between the Lease Parcel and Piers 90 and 91 remain in place (Figure 6-2). Although some of these remaining pipelines have been recently cleaned or otherwise abandoned in place and in some cases removed, there may be pipelines that remain in place that have not been cleaned and could contain residual petroleum products. Given the age of some of these pipelines, there is little to no documentation available regarding their status. To prevent residual product in the remaining pipelines from becoming a future LNAPL source, the following actions are proposed.

- Prepare an inventory of pipelines known to be remaining in place that have not been properly cleaned and abandoned; and

- Develop and implement a plan to clean and abandon in place the identified pipelines. This plan will include specific procedures for characterizing and managing residual materials in the pipelines, cleaning and abandonment techniques, and reporting and documentation requirements. Unless a pipeline needs to be physically removed for development reasons, it is assumed that all pipelines will be cleaned and abandoned in place. This plan also will identify procedures for handling currently unidentified pipelines that may be discovered in the future during maintenance or site development activities.

The Port did consider removing the pipelines, but did not retain it as an option because: (1) it would not be more effective than cleaning the pipelines; (2) it would have a significant impact on Port operations; and (3) it would be much more expensive than decommissioning the pipelines in place.

Although the exact lineal footage of pipelines remaining is unknown, available information suggests that there could be as much as 22,000 ft of pipelines in and around the Lease Parcel and extending to the piers. Given the uncertainties associated with the amount of pipeline remaining and the type and quantity of residual product contained in the pipes, preparing a detailed cost estimate is difficult at this time. However, using actual costs of previous pipeline abandonment activities, the estimate presented in Table 10-2 has been prepared. Assuming the estimate of 22,000 ft is representative of the actual amount of pipeline remaining, the estimated cost of abandoning the remaining pipelines is approximately $610,000.

10.2.4 Groundwater Downgradient of Lease Parcel

As described in Section 10.1.2.1, achieving CULs at the groundwater SPOC is not practicable or technically feasible at the Site. Therefore, consistent with WAC 173-340-720(8)(c), a CPOC may be established. Section 7.3.3 proposed CPOC wells for use at the site, and monitoring has documented that IHS concentrations in groundwater downgradient of the Lease Parcel are below CULs at the CPOC. The effectiveness of MNA at achieving and maintaining compliance with the CULs was evaluated and documented consistent with Ecology protocols (PES, 2006a). Therefore, groundwater downgradient of the Lease Parcel will be addressed using MNA, and a range of “active” groundwater remediation alternatives will not be evaluated.

The approach of using MNA is consistent with Ecology's expectations outlined WAC 173-340-370(7) in that:

- Source control has been (or will be in this case) conducted to the extent practicable;
- Leaving contaminants on site during the restoration time frame does not pose an unacceptable risk;
- There is evidence that natural biodegradation is occurring and will continue to occur at a reasonable rate; and
- Appropriate monitoring requirements are conducted to ensure that natural attenuation processes are taking place and human health and the environment are protected.

The first three requirements listed above have been addressed elsewhere in this section. The last, providing appropriate monitoring, is addressed by the development and implementation of an MNA program, which is described below.

MNA Program. The Port proposes to implement an MNA program consistent with Ecology's MNA guidance document (Ecology, 2005a and 2005b). To monitor both the primary and secondary sources at the Site, wells along the three flowpaths monitored during the MNA evaluation (PES, 2006a) would be included in the program (Figure 4-2). A well (or wells) upgradient of the Lease Parcel tank farms will be included to confirm the background water quality over time, a well or wells representative of the tank farm source water quality will be included to determine changes in the source area water quality, and wells along the Pier 90, Pier 91, and AOC 11 flowpaths will be included to determine plume water quality and sentinel well water quality. If additional wells are needed to monitor the source area post remediation, or if wells at the site are damaged, the Port will notify Ecology.

Groundwater samples will be included from each network well on a quarterly basis for the first year after cleanup actions are conducted, semiannually for the second and third years after cleanup actions are conducted, and annually for subsequent years. Groundwater levels will be monitored in all Site monitoring wells to confirm the groundwater flow directions after implementation of the cleanup actions. All groundwater samples will be analyzed for the following:

- Gasoline-range, diesel-range, and oil-range hydrocarbons using Ecology Methods NWTPH-Gx and NWTPH-Dx;
- BTEX using EPA Method 8021B; and
- Primary geochemical indicators using field meters, including dissolved oxygen, redox potential, pH, conductivity, and temperature.

Semiannually for the first two years of monitoring and annually thereafter, samples will also be submitted for the analysis of the following secondary geochemical indicators

- Sulfate and nitrate (EPA Method 300.0);
- Manganese (EPA Method 6010B);

- Methane (Modified RSK Method 175);
- Ferrous iron (field kit, Hach Method 8146 or equivalent); and
- Alkalinity (field kit, Hach Method AL AP MG-L or equivalent).

A report will be submitted annually that provides a representative groundwater contour map, tabulated and validated chemical data, and a brief evaluation of chemical concentration trends, plume stability, and the occurrence of biodegradation.

After several years of monitoring, if the plume is determined to be stable or shrinking and less frequent monitoring of the trends would be sufficient to demonstrate that CULs continue to be met, the Port may propose less frequent monitoring to Ecology. At some point, monitoring will likely show that cleanup standards have been met and further monitoring can be discontinued. Criteria for determining when less frequent monitoring would be appropriate, and for when cleanup standards have been met, will be presented in the MNA monitoring plan developed as part of this cleanup action. For purposes of this FS, it is assumed that monitoring will be conducted for 30 years. Given that CULs are currently being met at the CPOC, however, it is possible that the determination that cleanup standards have been met and monitoring can be discontinued may be made sooner.

Capital costs for this action include preparation of an MNA monitoring plan and installation of new monitoring wells. For costing purposes, it is assumed that the same 18 wells used in the MNA evaluation (Figure 4-2; PES, 2005b) will be used, with the addition of two source area wells and the replacement of one additional well. Based on these assumptions, the capital costs for this action are estimated at $40,000. It is assumed that the MNA program will continue for 30 years as described above. The NPV for implementing the MNA program for this time period is estimated to be $450,000. The total estimated cost for developing and implementing the MNA program is $490,000.

10.2.5 Summary of Costs for Presumptive Cleanup Actions

The total capital costs for implementing the presumptive actions is $930,000 and includes:

- $20,000 for developing and implementing institutional controls;
- $260,000 for excavating LNAPL source areas at SWMU 30;
- $610,000 for inventorying, cleaning, and abandoning remaining subsurface pipelines; and
- $40,000 for developing the MNA plan and installing the required additional monitoring wells.

The only estimable long-term O&M cost associated with these actions is the monitoring and reporting that make up the MNA program. The first-year monitoring costs are approximately $63,000, years 2 and 3 costs are approximately $35,000 each, and the annual cost for years 4 through 30 are estimated to be $23,000. The NPV of these monitoring and reporting costs over a 30-year timeframe is $450,000. The total estimated cost for implementing these presumptive cleanup actions is approximately $1,380,000.

10.3 CAA Development for Lease Parcel

In this section, a range of CAAs are developed for the Lease Parcel and immediately adjacent areas. These CAAs are evaluated against the MTCA criteria described in Section 11, and then the preferred CAA is selected in Section 12. The preferred CAA for the Lease Parcel, when combined with the suite of presumptive actions defined above, will comprise the overall CAA for the Site.

10.3.1 Alternative 1 - Existing Asphalt Paving Maintenance and Monitoring

Alternative 1 is considered the baseline option against which the other alternatives are compared and consists of maintaining the existing asphalt paving in place over the former tank farm, LNAPL monitoring in select wells, and long-term compliance monitoring of groundwater.

10.3.1.1 Asphalt Paving Maintenance

The existing asphalt paving covers the entire former tank farm area, encompassing an approximate total area of 135,000 sq ft. The asphalt paving serves two main purposes: preventing direct contact with contaminated soil and minimizing infiltration of precipitation. The existing surface consists of approximately 4 inches of asphalt placed over a subgrade of crushed rock and imported fill that was placed over the at-grade (e.g., concrete, tank bases) and subsurface structures remaining after the aboveground portions of the tank were demolished.

If this alternative is selected, an initial inspection of the asphalt paving will be conducted to document the condition of the asphalt paving and associated stormwater infrastructure. If damage or other problems are noted during the initial inspection, they will be repaired and the asphalt paving returned to good condition to establish a baseline condition against which future inspections can be compared. To maintain the integrity and effectiveness of the existing asphalt paving, annual inspections will be conducted and repairs will be undertaken as necessary to correct the effects of settling, subsidence, erosion, degradation due to extreme weather conditions or other damage. If inspections identify a product seep, similar to the seeps that have previously occurred in the asphalt paving, corrective actions may include installation of a vault to facilitate monitoring and LNAPL recovery or over excavation of the seep and its source.

As part of the annual inspection program, existing stormwater infrastructure will be inspected for any conditions that may cause stormwater runoff to collect on the capped area. The existing security and signage system will be inspected quarterly. The work will include inspecting fence, gates, locks and signs for deterioration or damage, and repairs will be made as necessary.

10.3.1.2 LNAPL Monitoring Well Installation

Four to six new wells will be installed to supplement the existing well network and will be used to monitor for LNAPL accumulation and migration. These additional wells are included in this alternative because it relies primarily on monitoring and passive recovery to establish that LNAPL is not migrating, therefore a more robust LNAPL monitoring/recovery network is warranted.

The wells will be constructed in accordance with WAC-173-163-400 and constructed with Schedule 40 polyvinyl chloride (PVC) well casing and stainless screen with flush–threaded joints. The screened interval of each well will extend from approximately 3 to 13 ft below grade, with the intent that at least 4 ft of screen will be submerged below the water table. The wells will be completed to existing grade with a flush-mounted well monument.

10.3.1.3 LNAPL Monitoring

LNAPL monitoring wells will be monitored quarterly for water level, LNAPL presence, and LNAPL thickness. If significant LNAPL (thickness of 0.25 ft or greater) is present in a well during a monitoring event, it will be removed from the well using a bailer or low-flow peristaltic pump. If a significant thickness of LNAPL is present or if a significant volume of LNAPL is recovered on a consistent basis, an LNAPL pilot recovery test will be recommended for that well.

10.3.1.4 Compliance Groundwater Monitoring

In addition to the MNA program described above, compliance groundwater monitoring will be conducted to determine the concentrations of IHSs at the Site in order to: (1) establish that IHS concentrations remain below CULs at the CPOC; and (2) establish long-term trends in IHS concentrations. Compliance monitoring will be conducted on an annual basis, concurrent with MNA sampling activities, using the 15 wells recently proposed to Ecology (Roth, 2009a) and currently being sampled as part of the annual groundwater monitoring program. Each well will be sampled for low-level PAHs and select SVOCs, VOCs, and metals. TPH compounds and field parameters already are included in the MNA sampling.

Consistent with the approach described for the MNA monitoring above, the Port may propose less frequent monitoring to Ecology if the plume is determined to be stable or shrinking. When monitoring parameters have been documented to be below CULs for a sufficient period of time (i.e., cleanup standards are met for these parameters), they will be dropped from the monitoring program. Criteria for determining when less frequent monitoring would be appropriate, and for when cleanup standards have been met, will be presented in the compliance monitoring plan to be developed as part of this cleanup action. For purposes of this FS, it is assumed that monitoring will be conducted for 30 years, although a shorter time frame may be appropriate based on the monitoring results.

10.3.1.5 Reporting

An annual report will be prepared that documents all of the above activities including asphalt paving inspections and maintenance, LNAPL monitoring and recovery activities, and compliance monitoring results.

10.3.1.6 Costs

For costing purposes, it is assumed that the capital costs associated with Alternative 1 (design and installation) will be implemented in the first year.

Capital costs will include:

- Initial asphalt paving inspection and repair; and
- Monitoring well design and installation.

It is assumed that future and recurring costs include the following costs commencing upon completion of monitoring well installation starting in the first year.

- Annual inspections and asphalt paving maintenance;
- Quarterly LNAPL monitoring and passive recovery activities;
- Compliance groundwater monitoring; and
- Annual reporting to document asphalt paving inspections and repairs, LNAPL monitoring and recovery activities, and the results of the groundwater compliance monitoring.

The estimated capital costs for Alternative 1 are approximately $90,000. Annual O&M costs are estimated at approximately $64,000, and the NPV of the O&M activities for a 30-year time period is $1,070,000. The total estimated present worth costs for Alternative 1 are $1,160,000 (Table 10-4).

10.3.2 Alternative 2 - Containment and Passive LNAPL Recovery

Alternative 2 includes constructing a subsurface slurry wall around the perimeter of the former tank farm, replacing the existing asphalt paving with a composite cap (cap) consisting of new asphalt paving and underlying geomembrane, site drainage improvements, annual cap inspections and repair, LNAPL monitoring and passive recovery, compliance monitoring, and reporting. The purpose of the slurry wall will be to prevent migration of LNAPL from the Lease Parcel and to prevent groundwater from flowing through the source area. The new composite cap will prevent direct contact with impacted soils, minimize infiltration of precipitation, and effectively eliminate the potential for surface LNAPL seeps to occur. A majority of the existing subsurface structures/soil will be left in place. Improvements will be made to existing site drainage infrastructure to prevent stormwater from ponding on the cap. Figure 10-2 shows the major features of Alternative 2.

10.3.2.1 Decommission and Replace Monitoring Wells

Prior to commencing the existing asphalt paving removal and slurry wall construction activities described below, all 16 monitoring wells within the footprint of the former tank farm will be decommissioned per WAC 173-160-460 prior to initiating the demolition. Well decommissioning will consist of filling each well from the bottom to ground surface with bentonite chips, cement grout or neat cement with the casing capped in place. Wells with unstable or inadequate surface seals will be overdrilled with a hollow-stem auger while the casing is pulled. The overdrilled bore hole will be filled with bentonite as the casing is pulled. Decommissioned wells will be capped with cement beneath the level of the new cap.

Decommissioned wells will be replaced with new monitoring wells after completion of construction activities. Wells installed for the purpose of LNAPL monitoring will be constructed as described in Alternative 1.

10.3.2.2 Containment Wall Installation

The containment barrier wall will be approximately 2 ft wide and 1,550 ft long and will extend to an average depth of approximately 20 ft bgs (Figure 10-2). The wall will be constructed with a slurry mix based on site soil types and compatibility with site groundwater and LNAPL. The depth of the wall was established to be approximately 10 ft below the low water table to prevent migration of LNAPL and minimize contact of groundwater from outside the wall with the most impacted source material. This is a "hanging wall" design in that the slurry wall is not keyed into a low permeability unit, although portions of the wall may intersect the top of the silty sand unit.

Construction of the barrier wall will include the following general steps:

- Remove existing asphalt paving and demolish and remove select above ground and subsurface structures/soil located in the containment wall alignment; and

- Construct containment barrier wall.

Existing Asphalt Paving Removal and Demolition of Select Subsurface Structures. The existing asphalt paving over the former tank farm area will be removed and disposed of off site. In the portion of the site in and adjacent to the slurry wall alignment, the existing pavement subgrade and fill material will be removed and stockpiled for reuse. Assuming an average thickness of approximately 1.25 ft, approximately 2,700 cubic yards (cy), or 4,000 tons, of subgrade and fill will be removed. Next, the remaining subsurface structures (tank bases, concrete) along the perimeter of the tank farm will be demolished and removed off site to allow for installation of the trench used for the slurry wall construction (Figure 10-2). Sections of the tank bases for former tanks T90, T91, T92, and T93 will be removed by exposing the steel tank bottom and cutting off the required sections leaving a minimum clearance of thirty feet for the containment wall. Tank bases T99, T101, T102, T103, and T107 will be exposed, demolished and removed completely. The pumphouse, oil water separator and other structures also will be completely demolished and removed.

All demolished structures will be decontaminated on site prior to disposal, and decontamination fluids will be collected and transported off-site for disposal. Waste profiling and designation procedures will be consistent with those established for other Site activities, specifically the *Guidance for Waste Designation Procedures at Terminal 91* and *Management of the Port of Seattle's T-91 Facility's Tank Farm Site Subsurface Debris* (Appendix B).

Slurry Wall Construction. The slurry wall will be constructed in two steps. The first step consists of excavating an approximately 15-ft wide, 3-ft deep operating trench along the entire wall alignment. The trench soil will be stockpiled for reuse as backfill once the slurry wall construction is completed. The one-pass trenching machine will operate inside this trench such that the trench will contain the excess slurry that overflows from the top of the wall. The slurry wall is installed by lowering the combination cutting/mixing boom on the trenching machine until it has reached the target depth. The combination cutting/mixing boom will simultaneously cut the trench to the required depth, inject the bentonite slurry into the subsurface through a tube attached to the boom, and mix the bentonite slurry and native soils. This continuous trenching and in-situ mixing of the slurry and soil will reduce the potential for higher permeability "windows" to form in the slurry wall as compared to other slurry wall construction techniques.

Once the slurry wall has been completed, the trench will be backfilled with the soil stockpiled from the trench excavation.

10.3.2.3 Install New Asphalt Cap

The new cap will be of a composite design with the surface asphalt wearing course underlain by a geomembrane to minimize surface water infiltration and prevent future product seeps from occurring. The new cap will be approximately 135,000 sq ft in size, will extend beyond the slurry wall, and will be sloped to prevent stormwater accumulation on the cap. Along the slurry wall alignment, the subgrade and fill material stockpiled from the removal of the existing asphalt paving will be replaced to restore the surface elevation of the new cap to approximately the level of the existing asphalt paving. A geotextile will be placed on the top of the fill to cushion the geomembrane and another geotextile will be placed on top of the geomembrane prior to placing the base course for the asphalt wearing course. The existing stormwater infrastructure such as storm drains and gradient controls will be maintained and upgraded if necessary to facilitate drainage.

10.3.2.4 Operations and Maintenance

Once the slurry wall and cap have been installed, ongoing O&M activities associated with Alternative 2 include annual cap inspections and maintenance, LNAPL monitoring and passive recovery (e.g., bailing), compliance groundwater monitoring, and reporting. These O&M tasks will be conducted as described for Alternative 1.

10.3.2.5 Costs

For costing purposes, it is assumed that the capital costs associated with Alternative 2 (design and construction) will be implemented in the first year. Capital costs will include

- Mobilization and demobilization;
- Decommissioning existing monitoring wells,
- Removing the existing asphalt paving;
- Excavating select subgrade and fill in slurry wall alignment;
- Demolishing select aboveground and subsurface structures;
- Trench excavation and stockpiling;
- Hauling all demolished and excavated material and decontamination water off site;
- Constructing the slurry wall, including backfilling trench;
- Installing a new cap; and
- Installing new monitoring wells.

It is assumed that future and recurring costs include the following costs commencing upon completion of construction and installation activities in year 2.

- Annual cap inspections and maintenance;
- Quarterly LNAPL monitoring and passive recovery;
- Compliance groundwater monitoring; and
- Annual reporting to document cap inspections and repairs, LNAPL monitoring and recovery activities, and the results of the groundwater compliance monitoring.

The estimated capital costs for Alternative 2 are approximately $1,840,000. Annual O&M costs are estimated at approximately $64,000, and the NPV of the O&M activities for a 30-year time period is approximately $1,070,000. The total estimated present worth costs for Alternative 2 are $2,910,000 (Table 10-5).

10.3.3 Alternative 3 - Active LNAPL Recovery and Subsurface Structure Removal

Alternative 3 is similar to Alternative 2 in that its primary objective is to prevent migration of LNAPL from the Lease Parcel source area and prevent future product seeps from occurring on the asphalt paving, but it achieves these objectives using different approaches. To address LNAPL, Alternative 3 includes a vacuum-enhanced LNAPL recovery system while surface seeps are addressed by removing all of the remaining subsurface structures and tank bases that appear to be the source of the current seeps. Alternative 3 also includes new asphalt paving to prevent direct contact with impacted soils and prevent infiltration of precipitation. Figure 10-3 shows the features of Alternative 3.

10.3.3.1 Decommission and Replace Monitoring Wells

As described for Alternative 2, the existing monitoring wells within the existing asphalt paving will be properly decommissioned and then replaced with new monitoring wells after installation of new asphalt paving. Wells installed for the purpose of LNAPL monitoring will be constructed as described in Alternative 1.

10.3.3.2 Existing Asphalt Paving Removal and Demolition of Subsurface Structures

As with Alternative 2, the existing asphalt paving will be removed and hauled offsite for disposal. For Alternative 3, all of the remaining subsurface structures, including concrete containment wall footings, steel tank bases, concrete tank bottom “floors”, and other structures will be removed (Figure 10-3). This will require removal of all of the subgrade and fill between the existing asphalt paving and the former tank bottom floor and tank bases; based on information from the DGI, the average thickness of this fill is approximately 1.25 ft, for a total of approximately 6,250 cy, or 9,400 tons, of fill. This fill will be stockpiled on site for use as backfill.

The steel tank bases will be decontaminated as necessary and transported off site for recycling as scrap metal. Concrete will be removed and either disposed of off site or broken up and recycled on site for use as backfill.

Once all of the subsurface structures have been removed, the resulting shallow excavation will be backfilled using the stockpiled fill for the existing asphalt paving and/or recycled concrete. Based on the available information, the average thickness of the former tank farm structures to be removed is approximately 1 ft, requiring approximately 5,000 cy, or 7,500 tons, of backfill to reach finish grade.

10.3.3.3 Vacuum-Enhanced LNAPL Recovery System

The overall objective of the vacuum-enhanced recovery system is to remove the recoverable LNAPL to the extent practicable using standard remediation techniques. Based on the recent LNAPL monitoring data (Phase III DGI Report; PES 2008d), portions of the Lease Parcel most likely to contain recoverable LNAPL located in the western portion of the former tank farm area and center around wells PR-07, PR-12, and UT-MW39-3.

The LNAPL system involves operating a soil vapor extraction (SVE) system to maintain a vacuum, and operating LNAPL skimming pumps to remove accumulated LNAPL. Design will include a pilot test using existing monitoring wells and new soil vapor monitoring points. The data will be evaluated and used to select and size LNAPL recovery wells and equipment, the SVE wells, and piping.

For purposes of the FS, the LNAPL recovery system is assumed to consist of 12 shallow LNAPL wells, designed for vacuum-enhanced LNAPL recovery (Figure 10-3). Provisions will be made at the design stage for future expansion of the recovery system to include a total of 24 LNAPL recovery wells, if needed.

LNAPL Recovery Well Installation. Initially 12 shallow extraction wells will be installed for vacuum-enhanced LNAPL recovery. The wells will be constructed with 6-inch diameter stainless steel well casing and stainless screen. The screened interval of each well will extend from approximately 3 to 13 ft below grade with the intent that at least 4 ft of screen will be submerged below the water table. The well screens will be machine-slotted with 0.040-inch slot and the filter pack will extend from approximately 1 foot below the base of the screen to approximately 1 foot above the top of the screen. A bentonite chip annular seal will be placed above the filter pack, extending to just below the bottom of the well vault. The well vaults will be traffic rated with a diamond plate steel cover. The vaults will be mounted flush with grade and will be set in concrete.

LNAPL Recovery System. The LNAPL recovery system will consist of a skimming pump in each well designed to be resistant to petroleum-based LNAPLs and capable of pumping heavy oils as well as lighter petroleum products and have a pumping rate of up to 25 gallons per hour. The pumps will be pneumatically operated and controlled by a programmable control unit capable of operating multiple wells at a time. Pumps will operate intermittently to match LNAPL recharge at each well. The controller will provide individual logging of each skimmer’s operating data. Recovered LNAPL will be pumped into a holding tank with level controls located in a designated secondary containment area. The system will have interlocking alarms and emergency system shut off capability to protect against equipment breakdown and accidental releases.

Soil Vapor Extraction System. The SVE system will consist of a blower connected to each of the LNAPL recovery wells. The extracted soil vapor will enter a moisture separator prior to discharge to the atmosphere. The water collected in the moisture separator will be pumped into a holding tank by a centrifugal pump. The holding tank water will be treated by two liquid phase granular activated carbon (GAC) adsorbers placed in series prior to being pumped into the sanitary sewer. If necessary the extracted soil vapor will be treated prior to discharge to the atmosphere by passing the vapor through two vapor phase GAC adsorbers placed in series. The system will have interlocking alarms and emergency system shut off capability to protect against equipment breakdown and accidental releases.

Remediation Compound. A remediation compound will be constructed to contain the LNAPL recovery equipment, air supply, controller, LNAPL storage, SVE equipment skid, and vapor and liquid phase carbon. The compound's concrete pad will have a berm and a sump and will be enclosed within a chain link fence with locked gates. At a minimum, the secondary containment will have the capacity to contain one and one half of the volume of the holding tanks in the compound. The sump will be outfitted with a transfer pump to transfer accumulated rain water to the holding tank.

10.3.3.4 Install New Asphalt Paving

The new asphalt paving will be designed to prevent direct contact with impacted soil and to minimize stormwater accumulation on the asphalt paving and will consist of a 4-inch thick asphalt paving similar to the existing asphalt paving; a geomembrane composite cap is not required because the source of the seeps (tank bases) will have been removed. Because the existing paving's subgrade material and the subsurface structures all will have been removed, the new asphalt paving will be constructed with a final elevation closely matching the areas surrounding the Lease Parcel, with enough slope provided to promote surface drainage. Runoff from the asphalt paving will be tied into existing stormwater infrastructure such as storm drains, which will be maintained and upgraded if necessary.

10.3.3.5 Operations and Maintenance

O&M activities for Alternative 3 will include operation of the LNAPL system, LNAPL monitoring, compliance groundwater monitoring, and asphalt paving inspection and repair.

Active LNAPL Recovery System Operations and Maintenance. The system will be operated and maintained to maximize performance and efficiency of the LNAPL recovery. Prior to startup, system commissioning and pre-startup testing will be conducted to ensure all equipment, electrical components, instruments and controls are functioning as designed. Once routine operations begin, regular maintenance will be performed on all equipment as specified by equipment manufacturers. Standard O&M procedures with monthly safety and maintenance checklists will be included in the O&M manual for the site. Recovered LNAPL and water will be disposed of as required. Sampling and waste-handling protocols also will be defined in the O&M manual and will be consistent with the guidelines included in Appendix B.

Other O&M Activities. In addition to the operation of the LNAPL recovery system, additional O&M activities will include annual asphalt paving inspections and maintenance, LNAPL monitoring and passive recovery outside the area of influence of the active LNAPL recovery system, compliance groundwater monitoring, and reporting. These O&M tasks will be conducted as described for Alternative 1.

10.3.3.6 Costs

For costing purposes, it is assumed that the capital costs associated with Alternative 3 (design and installation) will be implemented in the first year.

Capital costs will include:

- Mobilization and demobilization;
- Decommissioning existing monitoring wells,
- Removing the existing asphalt paving;
- Removing and stockpiling existing subgrade and fill;
- Demolishing remaining above ground and subsurface structures;
- Hauling all demolished and excavated material, and decontamination water off site;
- Designing and installing LNAPL extraction wells, SVE System, and LNAPL recovery system;
- Preparing the O&M manual for the LNAPL recovery system;
- Replacing asphalt paving; and
- Installing new LNAPL monitoring wells.

It is assumed that future and recurring costs include the following costs commencing upon completion of construction and installation activities in year 2:

- Startup performance sampling and reporting;
- Active LNAPL recovery system O&M and reporting. For purposes of the FS, it is assumed that the recovery system will operate for 10 years;
- Annual asphalt paving inspections and maintenance;
- LNAPL monitoring and passive recovery;
- Compliance groundwater monitoring; and
- Annual reporting to document asphalt paving inspections and repairs, LNAPL monitoring and recovery activities (both active and passive systems), and the results of the groundwater compliance monitoring.

The estimated capital costs for Alternative 3 are $2,600,000. Annual O&M costs vary over time based on the requirements of the LNAPL recovery system as shown in Table 10-6. The total estimated NPV of the O&M costs for Alternative 3 are estimated to be $1,780,000, the majority of this incurred during the 10 years the LNAPL recovery system is assumed to be operational. The total estimated present net worth costs for the capital and O&M costs for Alternative 3 are $4,380,000.

10.3.4 Alternative 4 – Containment, Subsurface Structure Removal, and Enhanced LNAPL Recovery

Alternative 4's primary objective is to prevent migration of LNAPL from the Lease Parcel source area and to prevent future surface product seeps from occurring. This alternative includes: constructing a subsurface slurry wall around the perimeter of the former tank farm; removal of the remaining subsurface structures and tank bases that appear to be the source of the current seeps; removal of highly contaminated soil encountered during the tank bottom removal process; installing an enhanced passive LNAPL recovery system; replacing the existing asphalt paving with new asphalt paving; site drainage improvements; annual asphalt paving inspections and repair; LNAPL monitoring and passive recovery; compliance monitoring, and reporting. The purpose of the slurry wall will be to prevent migration of LNAPL from the Lease Parcel and to prevent groundwater from flowing through the source area. Removing the existing subsurface structures and highly contaminated soil, along with replacing the asphalt paving, will prevent direct contact with impacted soils, minimize infiltration of precipitation, and effectively eliminate the potential for surface LNAPL seeps to occur. Improvements will be made to existing site drainage infrastructure to prevent stormwater from ponding on the asphalt paving. Figure 10-4 shows the major features of Alternative 4.

10.3.4.1 Decommission and Replace Monitoring Wells

Prior to commencing the removal of the existing asphalt paving and subsurface structures, and slurry wall construction, all 16 monitoring wells within the footprint of the former tank farm will be decommissioned per WAC 173-160-460. Well decommissioning will consist of filling each well from the bottom to ground surface with bentonite chips, cement grout, or neat cement with the casing capped in place. Wells with unstable or inadequate surface seals will be overdrilled with a hollow-stem auger while the casing is pulled. The overdrilled bore hole will be filled with bentonite as the casing is pulled. Decommissioned wells will be capped with cement beneath the level of the new asphalt paving.

Decommissioned wells will be replaced with new monitoring wells after completion of construction activities in conjunction with the enhanced LNAPL recovery system described below. Wells installed for the purpose of LNAPL monitoring will be constructed as described in Alternative 1.

10.3.4.2 Existing Asphalt Paving Removal and Demolition of Subsurface Structures

As with Alternatives 2 and 3, the existing asphalt paving will be removed and hauled offsite for disposal. As with Alternative 3, all of the remaining subsurface structures, including concrete containment wall footings, steel tank bases, concrete tank bottom "floors," and other structures will be removed (Figure 10-4). This will require removal of all of the subgrade and fill between the existing asphalt paving and the former tank bottom floor and tank bases. Based on information from the DGI, the average thickness of this fill is approximately 1.25 ft, for a total of approximately 6,250 cy, or 9,400 tons, of fill. This fill will be stockpiled on site for use as backfill.

The steel tank bases will be decontaminated as necessary and transported off site for recycling as scrap metal. Concrete will be removed and either disposed of off site or broken up and recycled on site for use as backfill.

All demolished structures will be decontaminated on site prior to disposal, and decontamination fluids will be collected and transported off site for disposal. Waste profiling and designation procedures will be consistent with those established for other Site activities, specifically the *Guidance for Waste Designation Procedures at Terminal 91* and *Management of the Port of Seattle's T-91 Facility's Tank Farm Site Subsurface Debris* (Appendix B).

10.3.4.3 Removal of Highly Contaminated Surface Soil

It is anticipated that once the existing paving and subsurface structures (including tank bases) are removed and the underlying soil exposed, there will likely be one or more areas of surface soil that are visibly and highly contaminated with petroleum (i.e., product-saturated soil). In order to minimize the potential for these soils to act as a source of future seeps, these areas of highly contaminated surface soil will be removed. It is assumed for purposes of the FS that approximately 240 tons of soil (10 areas each measuring 12 ft square and 3 ft deep) will be removed and the soil disposed of off site.

Waste characterization will be conducted pursuant to the guidelines established by the Port and Ecology for the Terminal 91 Complex (Appendix B). Based on the available sampling results, the majority of the soil is expected to be profiled as petroleum-contaminated soil. Given the previous RCRA-permitted waste management activities that occurred at the Lease Parcel, it is possible that "listed" waste constituents may be present in some of the soil encountered. As described in detail in Appendix B, if soil that contains listed waste is encountered at levels below land disposal restriction limits, a request for a "contained out" determination will be made to Ecology. Assuming it is granted, this material will be managed as a solid waste, although the disposal costs are somewhat higher than with petroleum-contaminated soil. For purposes of the FS, it is assumed that approximately 20 percent, or 48 tons, of the soil will be managed as "contained out" waste.

The Phase III DGI evaluated the nature and extent of PCB contamination in the northwest portion of the former tank farm. Although PCBs were detected in most of the borings in this area, they were all below 10 mg/kg and most were below 2 mg/kg, well below the 50 mg/kg threshold that would require disposal of the soil in a TSCA permitted landfill. Historical PCB data indicated that there may be some minor quantity of soils that contain more than 50 mg/kg of PCBs and would require disposal in a TSCA-permitted facility.

For purposes of this FS, it is assumed that 20 percent, or approximately 48 tons, of soil will require disposal at a TSCA-permitted facility. Soil containing less than 50 mg/kg of PCB can be managed as petroleum-contaminated soil, as long as the PCBs are not known to be from a TSCA source (e.g., electrical transformer).

10.3.4.4 Containment Wall Installation

The containment wall will be constructed following removal of the existing paving, subsurface structures, and highly contaminated surface soil. The containment wall will be approximately 2 ft wide and 1,550 ft long and will extend to an average depth of approximately 20 ft bgs (Figure 10-4). The wall will be constructed with a slurry mix based on Site soil types and compatibility with Site groundwater and LNAPL. The depth of the wall was established to be approximately 10 ft below the low water table to prevent migration of LNAPL and minimize contact of groundwater from outside the wall with the most impacted source material. This is a "hanging wall" design in that the slurry wall is not keyed into a low permeability unit, although portions of the wall may intersect the top of the silty sand unit.

The slurry wall will be constructed in two steps. The first step consists of excavating an approximately 15-ft wide, 3-ft deep operating trench along the entire wall alignment. The trench soil will be stockpiled for reuse as backfill once the slurry wall construction is complete. The one-pass trenching machine will operate inside this trench such that the trench will contain the excess slurry that overflows from the top of the wall. The slurry wall is installed by lowering the combination cutting/mixing boom on the trenching machine until it has reached the target depth. The combination cutting/mixing boom will simultaneously cut the trench to the required depth, inject the bentonite slurry into the subsurface through a tube attached to the boom, and mix the bentonite slurry and native soils. This continuous trenching and in-situ mixing of the slurry and soil will reduce the potential for higher permeability “windows” to form in the slurry wall as compared to other slurry wall construction techniques. Once the slurry wall is complete, the trench will be backfilled with the soil stockpiled from the trench excavation.

10.3.4.5 Expanded LNAPL Recovery System

The overall objective of the enhanced LNAPL recovery system is to remove the recoverable LNAPL to the extent practicable using passive recovery techniques. Based on the recent LNAPL monitoring data (PES, 2008d), portions of the Lease Parcel most likely to contain recoverable LNAPL are located in the western portion of the former tank farm area and center around wells PR-07, PR-12, and UT-MW39-3.

For purposes of the FS, the enhanced LNAPL recovery system involves a series of 5 trenches located in the target areas listed above (see Figure 10-4). These trenches would be approximately 50 to 75 ft long, 2 ft wide, and completed approximately 10 ft below the surrounding grade. Each trench would be backfilled with pea gravel, with a section of 6-inch slotted pipe running the length of the trench installed at average low water table elevation. At both ends of the trench, a cleanout well will be installed. These wells would be completed to the bottom of the trench and also connected to the slotted pipe within the trench. As LNAPL collects within the gravel backfill and the slotted piping and cleanout wells, it would be removed either by bailing or pumping depending on the quantity of LNAPL present.

Wells outside the influence of the enhanced LNAPL recovery system that have minor amounts of measurable product, will be monitored quarterly for water level, LNAPL presence, and LNAPL thickness. As with Alternative 1, if significant LNAPL (thickness of 0.25 ft or greater) is present in a well during a monitoring event, it will be removed from the well using a bailer or low-flow peristaltic pump.

10.3.4.6 Install New Asphalt Paving

Once all of the subsurface structures and highly contaminated surface soils have been removed and the containment wall and enhanced LNAPL recovery system are installed, the resulting shallow excavation will be backfilled using the stockpiled fill for the existing paving and/or recycled concrete. Based on the available information, the average thickness of the former tank farm structures to be removed is approximately 1 ft, requiring approximately 5,000 cy, or 7,500 tons, of backfill to reach finish grade.

The new asphalt paving will be designed to prevent direct contact with impacted soil and to minimize stormwater accumulation on the paving and will consist of a 4-inch thick asphalt paving similar to the existing asphalt paving; a geomembrane composite cap is not required because the source of the seeps (tank bases) will have been removed. Because the existing paving's subgrade material and the subsurface structures all will have been removed, the new asphalt paving will be constructed with a final elevation closely matching the areas surrounding the Lease Parcel, with enough slope provided to promote surface drainage. Runoff from the asphalt paving will be tied into existing stormwater infrastructure such as storm drains, which will be maintained and upgraded if necessary.

10.3.4.7 Operations and Maintenance

Once the slurry wall and asphalt paving have been installed, ongoing O&M activities associated with Alternative 4 include annual asphalt paving inspections and maintenance, LNAPL recovery and monitoring, compliance groundwater monitoring, and reporting.

LNAPL Recovery System Operations and Maintenance. The enhanced LNAPL recovery system will be operated and maintained to maximize performance and efficiency of the LNAPL recovery. Standard O&M procedures with monthly safety and maintenance checklists will be included in the O&M manual for the site. For purposes of the FS, it is assumed that product will be removed from the trenches on a monthly basis for 3 years, bimonthly for an additional 2 years, and quarterly for 5 years (10 years total operation period). Recovered LNAPL and water will be disposed of as required. Sampling and waste-handling protocols also will be defined in the O&M manual and will be consistent with the guidelines included in Appendix B.

Other O&M Activities. In addition to the operation of the enhanced LNAPL recovery system, O&M activities will include annual asphalt paving inspections and maintenance, LNAPL monitoring and passive recovery outside the area of influence of the enhanced LNAPL recovery system, compliance groundwater monitoring, and reporting. These O&M tasks will be conducted as described for Alternative 1.

10.3.4.8 Costs

For costing purposes, it is assumed that the capital costs associated with Alternative 4 (design and construction) will be implemented in the first year. Capital costs will include:

- Mobilization and demobilization;
- Decommissioning existing monitoring wells,
- Removing the existing asphalt paving;
- Removing and stockpiling existing subgrade and fill;
- Demolishing remaining above ground and subsurface structures;
- Removal of highly contaminated surface soil;
- Trench excavation and stockpiling;

- Constructing the slurry wall, including backfilling the trench;
- Constructing the enhanced LNAPL system recovery trenches;
- Preparing the O&M manual for the LNAPL recovery system;
- Hauling all demolished and excavated material and decontamination water off site for disposal;
- Installing new asphalt paving; and
- Installing new monitoring wells.

It is assumed that future and recurring costs include the following costs, commencing upon completion of construction and installation activities in year 2.

- Annual asphalt paving inspections and maintenance;
- Expanded LNAPL recovery system O&M and reporting. For purposes of the FS, it is assumed that the recovery system will operate for 10 years;
- LNAPL monitoring and passive recovery in wells outside of the enhanced LNAPL recovery system;
- Compliance groundwater monitoring; and
- Annual reporting to document asphalt paving inspections and repairs, LNAPL monitoring and recovery activities, and the results of the groundwater compliance monitoring.

The estimated capital costs for Alternative 4 are approximately $2,690,000. Annual O&M costs are estimated to range from approximately $60,000 to $70,000 per year depending on the frequency of LNAPL recovery efforts, and the NPV of the O&M activities for a 30-year time period is approximately $1,190,000. The total estimated present worth costs for Alternative 4 are $3,880,000 (Table 10-7).

10.3.5 Alternative 5 - Limited Excavation of LNAPL Areas

The primary component of Alternative 5 is the removal of the LNAPL source areas in and near the Lease Parcel through excavation and disposal of impacted soil in areas where LNAPL has been observed. Other components of this alternative include removal of the existing asphalt paving and all remaining above ground and subsurface structures in the former tank farm, backfilling the excavation area with clean soil, constructing new asphalt paving, and installing new monitoring wells. Figure 10-5 shows the features of Alternative 5.

10.3.5.1 Existing Asphalt Paving Removal and Demolition of Subsurface Structures

As with Alternative 3 and 4, the existing asphalt paving will be removed and hauled off site for disposal and all of the remaining subsurface structures, including concrete containment wall footings, steel tank bases, concrete tank bottom “floors,” and other structures will be removed (Figure 10-5). This will require removal of approximately 9,400 tons of subgrade and fill soil between the existing asphalt paving and the former tank bottom floor and tank bases; this fill will be stockpiled on site for use as backfill.

10.3.5.2 Decommission and Replace Select Monitoring Wells

As described for Alternative 2, the 16 existing monitoring wells within the existing asphalt paving will be properly decommissioned and then replaced with new monitoring wells after installation of the new paving. Wells installed for the purpose of LNAPL monitoring will be constructed as described in Alternative 1.

10.3.5.3 Excavate Source Area Soil Where LNAPL is Present

Rationale for Extent of Excavation. Once the paving and remaining tank farm structures have been removed, soil will be excavated in areas where LNAPL is present based on recent monitoring data (Figure 10-5). The excavation will be extended to approximately 3 ft below the low water table, which will be about 10.5 ft bgs after removing the paving, subgrade material, and remaining tank farm concrete. By excavating soils to this depth, the entire “smear zone” and the top of the saturated zone, which is where most if not all of the LNAPL is expected to be present, will be removed.

The lateral extent of the excavations shown in Figure 10-5 is estimated based on recent monitoring results and information obtained during the DGI regarding the presence of LNAPL in the Lease Parcel and immediately surrounding areas, including the area west of the Lease Parcel in the alignment of the pipelines leading to Pier 91. If the area of significant LNAPL impacts is observed to extend beyond the boundaries shown in Figure 10-5, the excavation will be expanded until the LNAPL impacted soil is removed or physical/structural limitations to the excavation are reached.

There are four wells in the area west of the Lease Parcel (UT-MW39-2, UT-MW39-3, CP-110, and PNO-MW104) in which LNAPL was observed in 2008. One well, UT-MW39-3, is close to the former pump house, has had recoverable LNAPL, and has been included in the areas to be excavated. The areas around the three remaining wells are not currently identified for excavation primarily because of significant structural impediments in the areas around these wells. UT-MW39-2 and PNO-MW104 are both located less than 20 ft from corners of the Building W-39 building and PNO-MW104 is located very close to footings of the Magnolia Bridge. Although CP-110 is somewhat more accessible, it is in a high traffic area next to a rail line and has had only a trace of LNAPL in recent years. These three wells will be incorporated into the LNAPL monitoring and passive recovery program described below.

Excavation Approach. For the areas shown in Figure 10-5, the excavation of soil to a depth of 10.5 ft below the base of the former tank farm will remove approximately 12,700 cy, or 19,000 tons, of soil. Soil will either be direct loaded into trucks for transportation off site if sufficient data exists to characterize the soil, or stockpiled on site for characterization prior to disposal. Based on previous excavation activities conducted at the Terminal 91 Complex, excavations that only proceed several feet below the water table will not require shoring to stay open and the sides of the excavation will be laid back to form a stable slope. Soil excavated from below the water table will likely require dewatering prior to hauling off site for disposal; this will be accomplished by stockpiling the soil adjacent to the excavation area and allowing the water to drain back into the excavation.

It is expected that as the excavation proceeds below the water table, LNAPL will accumulate on the water surface. This LNAPL will be removed from the excavation using a skimming pump or vacuum hose, the LNAPL/water mixture treated in an oil/water separator, and the LNAPL containerized for characterization and disposal. The water will be further treated as necessary in a temporary water treatment system (e.g., GAC adsorption) and discharged to the sanitary sewer.

Waste Characterization and Disposal. Waste characterization will be conducted pursuant to the guidelines established by the Port for the Terminal 91 Complex (Appendix B). Based on the available sampling results, the majority of the soil is expected to be profiled as petroleum contaminated soil. Given the previous RCRA-permitted waste management activities that occurred at the Lease Parcel, it is possible that “listed” waste constituents may be present in some of the soil encountered. As described in detail in Appendix B, if soil that contains listed waste is encountered at levels below land disposal restriction limits, a request for a “contained out” determination will be made to Ecology. Assuming it is granted, this material will be managed as a solid waste, although the disposal costs are somewhat higher than with petroleum contaminated soil. For purposes of the FS, it is assumed that approximately 5 percent, or 1,000 tons, of the soil will be managed as a “contained out” waste.

The Phase III DGI evaluated the nature and extent of PCB contamination in the northwest portion of the former tank farm. Although PCBs were detected in most of the borings in this area, they were all below 10 mg/kg and most were below 2 mg/kg, well below the 50 mg/kg threshold that would require disposal of the soil in a TSCA permitted landfill. Historical PCB data indicated that there may be some minor quantity of soils that contain more than 50 mg/kg of PCBs and would require disposal in a TSCA-permitted facility.

For purposes of this FS, it is assumed that 2 percent, or approximately 400 tons, of soil will require disposal at a TSCA-permitted facility. Soil containing less than 50 mg/kg of PCB can be managed as petroleum contaminated soil, as long as the PCBs are not known to be from a TSCA source (e.g., electrical transformer).

10.3.5.4 Backfill Excavations

Once the excavation is completed, and the LNAPL accumulations on the water table have been removed, the excavated area will be backfilled with stockpiled soil and clean fill. The composition of the backfill will be dependent on specifications required for future land use but may include recycled concrete generated during the demolition of the subsurface tank farm structures or clean fill removed from beneath the existing asphalt paving. For purposes of the FS, it is assumed that all 9,400 tons of the existing subgrade material will be used as backfill and another 9,600 tons of clean imported soil will be required.

10.3.5.5 Install New Asphalt Paving

The new asphalt paving will be designed and constructed as described for Alternative 3.

10.3.5.6 Operations and Maintenance

O&M activities for Alternative 5 will include annual asphalt paving inspections and maintenance, LNAPL monitoring and passive recovery, compliance groundwater monitoring, and reporting that will be conducted as described for Alternative 1.

10.3.5.7 Costs

For costing purposes, it is assumed that the capital costs associated with Alternative 5 will be implemented in the first year.

Capital costs will include:

- Mobilization and demobilization;
- Decommissioning existing monitoring wells,
- Removing the existing asphalt paving;
- Removing and stockpiling existing subgrade and fill;
- Demolishing remaining above ground and subsurface structures;
- Excavating and disposing of impacted soil in areas where LNAPL is present;
- Managing excavation water and LNAPL from the excavation;
- Backfilling the excavation areas;
- Replacing the existing asphalt paving; and
- Installing new LNAPL monitoring wells.

It is assumed that future and recurring costs include the following costs and will commence upon completion of construction and installation activities in year 2:

- Annual asphalt paving inspections and maintenance;
- Quarterly LNAPL monitoring and passive recovery;
- Compliance groundwater monitoring; and
- Annual reporting to document asphalt paving inspections and repairs, LNAPL monitoring and recovery activities, and the results of the groundwater compliance monitoring.

The estimated capital costs for Alternative 5 are approximately $4,310,000. Annual O&M costs are estimated at approximately $64,000, and the NPV of the O&M activities for a 30-year time period is approximately $1,070,000. The total estimated present net worth costs for Alternative 2 are $5,380,000 (Table 10-8).

10.3.6 Alternative 6 – Excavation of Soils Exceeding RSSLs

Alternative 6 is very similar to Alternative 5 (i.e., source area excavation), except that the boundaries of the excavation are defined by two factors: (1) the areas where LNAPL has been observed as in Alternative 5; and (2) areas where soil contains petroleum hydrocarbons at concentrations exceeding RSSLs. In most cases, the areas exceeding the RSSLs includes all of the areas included in Alternative 5 plus additional soil where LNAPL has not been observed but soil sampling results show TPH concentrations above the RSSLs defined in Section 7. Figure 10-6 shows the features of Alternative 6.

10.3.6.1 Existing Asphalt Paving Removal and Demolition of Subsurface Structures

The existing asphalt paving and remaining subsurface structures will be removed as described for Alternative 5.

10.3.6.2 Decommission and Replace Select Monitoring Wells

As described for Alternative 2, the existing monitoring wells within the existing asphalt paving will be properly decommissioned and then replaced with new monitoring wells after installation of the new cap. Wells installed for the purpose of LNAPL monitoring will be constructed as described in Alternative 1.

10.3.6.3 Excavate Source Area Soil Exceeding RSSLs

Rationale for Extent of Excavation. Once the asphalt paving and remaining tank farm structures have been removed, soil will be excavated in areas where either LNAPL has been observed and/or where sampling results show TPH concentrations exceed the RSSLs (Figure 10-6). As with Alternative 5, the excavation will be extended to approximately 3 ft below the low water table, which will about 10.5 feet bgs after removing the asphalt paving, subgrade material, and remaining tank farm concrete. By excavating soils to this depth, the entire "smear zone" and the top of the saturated zone will be removed where most if not all of the LNAPL is expected to be present.

The lateral extent of the excavation is shown in Figure 10-6. Given the significant variability in the soil concentrations observed during the DGI, and the limited correlation between the RSSLs and presence or absence of LNAPL, the Port will not use confirmation soil samples at the edges of the excavation to determine if soil concentrations are above or below RSSLs. If significant LNAPL impacts are observed to extend beyond the boundaries shown in Figure 10-6, the excavation will be expanded until the LNAPL-impacted soil is removed or physical/structural limitations to the excavation are reached.

As described in Alternative 5, three of the wells adjacent and to the west of the Lease Parcel (UT-MW39-2, CP-110, and PNO-MW104) in which LNAPL was observed in 2008 will be incorporated into the LNAPL monitoring and passive recovery program described below.

Excavation Approach. For the areas shown in Figure 10-6, the excavation of soil to a depth of 10.5 ft will remove approximately 21,500 cy, or 32,300 tons, of soil. The approach for excavating the soil and managing the water and LNAPL that collects in the excavation is as described for Alternative 5.

Waste Characterization and Disposal. Waste characterization will be conducted as described for Alternative 5. For cost estimating purposes, it is assumed that approximately 5 percent, or 1,600 tons, of the soil will be managed as a "contained out" waste and 2 percent, or approximately 600 tons, of soil will require disposal at a TSCA-permitted facility. The remaining 30,100 tons will be managed as petroleum contaminated soil.

10.3.6.4 Backfill Excavations

Once the excavation is completed, and the LNAPL accumulations on the water table have been removed, the excavated area will be backfilled as described for Alternative 5. For cost estimating purposes, it is assumed that all 9,400 tons of the existing asphalt paving subgrade material will be used as backfill and another 22,900 tons of clean imported soil will be required.

10.3.6.5 Install New Asphalt Paving

The new asphalt paving will be designed and constructed as described for Alternative 3.

10.3.6.6 Operations and Maintenance

O&M activities for Alternative 6 will include asphalt paving inspections and maintenance, LNAPL monitoring and passive recovery, compliance groundwater monitoring, and reporting that will be conducted as described for Alternative 1.

10.3.6.7 Costs

For costing purposes, it is assumed that the capital costs associated with Alternative 6 will be implemented in the first year.

Capital costs will include:

- Mobilization and demobilization;
- Decommissioning existing monitoring wells,
- Removing the existing asphalt paving;
- Removing and stockpiling existing subgrade and fill;
- Demolishing remaining above ground and subsurface structures;
- Excavating and disposing of impacted soil in areas where LNAPL is present;
- Managing excavation water and LNAPL from the excavation;
- Backfilling the excavation areas;
- Replacing the existing asphalt paving; and
- Installing new LNAPL monitoring wells.

It is assumed that future and recurring costs include the following costs and will commence upon completion of construction and installation activities in year 2:

- Annual paving inspections and maintenance;
- Quarterly LNAPL monitoring and passive recovery;

- Compliance groundwater monitoring; and
- Annual reporting to document asphalt paving inspections and repairs, LNAPL monitoring and recovery activities, and the results of the groundwater compliance monitoring.

The estimated capital costs for Alternative 6 are approximately $5,920,000. Annual O&M costs are estimated at approximately $64,000, and the NPV of the O&M activities for a 30-year time period is approximately $1,070,000. The total estimated present net worth costs for Alternative 6 are $6,990,000 (Table 10-9).

11.0 EVALUATION OF CLEANUP ALTERNATIVES

This section of the FS provides a detailed evaluation of the CAAs developed in Section 10. The criteria used for analysis of the CAAs are presented in Section 11.1. Because the final cleanup action for the Site will consist of two components – the presumptive cleanup actions and one of the six Lease Parcel CAAs – the analysis of the cleanup actions will be performed in two steps. First, the extent to which the presumptive cleanup actions will address (in part or in full) the MTCA requirements listed above will be evaluated in Section 11.2. Second, the six CAAs for the Lease Parcel will be evaluated against those requirements applicable to the Lease Parcel actions in Section 11.3. The comparative evaluation of the retained remedial alternatives for each evaluation criteria is presented in Section 12.1.

11.1 <u>Evaluation Criteria</u>

MTCA is the primary regulation that outlines the procedure for conducting the FS. With respect to the criteria and procedure for evaluating CAAs, WAC 173-340-360(2) establishes the following requirements:

11.1.1 Threshold Requirements

- Protect human health and the environment;
- Comply with cleanup standards (WAC 173-340-700 through –760);
- Comply with applicable state and federal laws (WAC 173-340-710); and
- Provide for compliance monitoring.

11.1.2 Other Requirements

- Use permanent solutions to the maximum extent practicable;
- Provide for a reasonable restoration time frame; and
- Consider public concerns.

If the evaluation of CAAs concludes that more than one alternative meets the cleanup action selection criteria, a disproportionate cost analysis will be conducted pursuant to WAC 173-340-360(3)(e) to determine if the incremental costs of one alternative over that of a lower cost alternative exceed the incremental degree of benefits provided.

In addition to these criteria, Ecology's expectations for cleanup actions listed in WAC 173-340-370 will also be considered. The CAA selected for implementation will be evaluated against these expectations in Section 12.

11.2 Detailed Evaluation of Presumptive Cleanup Actions

The majority of the CAOs for the Site are addressed through presumptive actions including engineering and institutional controls, implementation of an MNA program, and controlling LNAPL at the secondary source areas. These actions are described in Section 10.2. The only CAOs that are not addressed by the presumptive actions relate to the Lease Parcel and include:

- Controlling, to the extent practicable, the migration of IHSs from soil to groundwater in quantities that would result in the accumulation of LNAPL on the groundwater; and
- Controlling, to the extent practicable, the accumulation of LNAPL on the groundwater.

The combined presumptive actions address the majority of the MTCA requirements for the Site, as discussed below.

11.2.1 Protect Human Health and the Environment

The primary exposure or migration pathways directly relating to risks to human health and the environment are:

- Exposure of future subsurface construction workers to IHSs in soil, particulates, and soil vapors;
- Exposure of future workers and trespassers to IHSs in vapors originating from soil and/or groundwater via indoor air; and
- Groundwater discharge to surface water and/or sediment and the subsequent potential for impacts on aquatic life or humans consuming fish.

The presumptive cleanup actions specifically address these pathways and are protective of human health and the environment. Potential future worker exposures are controlled through engineering and institutional controls. Discharges of groundwater to surface water, which currently meet CULs, will be addressed in the future through implementation of the MNA program. The presumptive cleanup actions for the secondary sources, along with the Lease Parcel CAAs, only enhance the likelihood that the protectiveness will be maintained and improved in the future.

The one aspect of this requirement not addressed directly by the presumptive actions is the potential for worker and trespasser exposure to IHSs via product seeps in the asphalt paving above the former tank farm in the Lease Parcel. Controlling or eliminating exposure to these seeps is specifically addressed in the Lease Parcel CAAs.

11.2.2 Comply With Cleanup Standards

The primary numeric cleanup standard for the Site are the groundwater CULs described in Section 7.3.2 which address protection of human and aquatic receptors. The other cleanup standard applicable to the Site relates to the prevention of LNAPL from accumulating on the groundwater [WAC 173-340-720(7)(d) and WAC 173-340-747(3)(f)]. Compliance with each of the two standards is discussed below.

11.2.2.1 Groundwater Cleanup Standards

As discussed in Section 10.1.2.1, the POC for the Site has been established as the CPOC wells shown in Figure 7-2. Section 7.4 documents that IHS concentrations in groundwater are currently below CULs at all CPOC wells. Implementation of the MNA program included in the presumptive cleanup actions will document that CULs are met at the CPOC in the future (see discussion of restoration time frame below).

11.2.2.2 Prevention of Accumulation of LNAPL

With the exception of the LNAPL observed at SWMU 30, LNAPL (and soils with the potential to result in LNAPL accumulation) is observed primarily in and adjacent to the Lease Parcel. Therefore, the evaluation of whether this cleanup objective is met is addressed mainly in the evaluation of the Lease Parcel CAAs.

With respect to SWMU 30, the presumptive cleanup action removes the observed LNAPL around well PNO-MW102 and the soil impacted with TPH above RSSLs (Figure 10-1). By removing the observed LNAPL source and soil exceeding the RSSLs, the potential for SWMU 30 to cause future exceedances of the LNAPL cleanup standard is eliminated.

11.2.3 Comply With Applicable State and Federal Laws

All of the presumptive cleanup actions will comply with the applicable legal requirements, including MTCA. Off-site management and disposal of wastes will comply with the applicable solid and dangerous waste regulations.

11.2.4 Provide for Compliance Monitoring

The presumptive actions include a comprehensive MNA program that will be developed consistent with Ecology guidelines. Additional compliance monitoring to assess the ongoing performance of the cleanup actions and to monitor compliance with cleanup goals is included in each of the CAAs developed for the Lease Parcel.

11.2.5 Use Permanent Solutions to the Maximum Extent Practicable

As described in Section 10.1.2, the development of a “permanent” cleanup action for the Site is not feasible because of the severe technical challenges and associated extraordinary costs in attempting such a cleanup. Furthermore, the evaluation process for determining whether a cleanup action uses permanent solutions to maximum extent practicable defined in WAC 173-340-360(3), utilizes a disproportionate cost analysis that is not readily applicable to the use of presumptive actions.

That being said, the actions for SWMU 30 and the former fuel transfer pipelines effectively and permanently remove the contaminant sources from these areas and add to the permanence of the overall cleanup action for the Site. The primary evaluation of this requirement will be conducted for the Lease Parcel CAAs in Section 11.3 and in the comparative analysis in Section 12.1.

11.2.6 Provide for a Reasonable Restoration Time Frame

The process for determining if a cleanup provides for a reasonable restoration time frame is described in WAC 173-340-360(4). "Restoration time frame" is defined by MTCA to be the period of time needed to achieve the required CULs at the points of compliance established for the site. For the Site, the POC for groundwater has been established at the CPOC wells shown in Figure 7-2.

Groundwater monitoring results indicate that CULs are currently being met at the CPOC. The actions necessary to maintain compliance will include implementation of the MNA program included in the presumptive cleanup actions. In addition, implementation of the source control actions included in the presumptive cleanup actions, as well as the Lease Parcel CAAs, will help assure that IHS concentrations remain below CULs.

The FS assumes that MNA monitoring would continue for 30 years, although establishing that cleanup standards have been met may take less time, at which point monitoring can be discontinued (i.e., restoration is achieved). A restoration time frame of 20 to 30 years for the Site is considered reasonable based on an evaluation of the factors listed in WAC 173-340-360(4)(b) for determining what is considered a reasonable restoration time frame. Specifically, the Site:

- Poses a low risk to human health and the environment and what risk is present can be readily and effectively controlled through implementation of engineering and institutional controls;
- The current and potential future uses of the Site (i.e., industrial, commercial) are not significantly impacted by the Site contamination and are appropriate uses for the property;
- Existing or potential future water supplies are not affected;
- Monitoring can be effectively implemented throughout the entire site; and
- Natural processes which reduce contaminant concentrations have been documented to occur at the Site.

For these reasons, the presumptive cleanup actions (in conjunction with the Lease Parcel CAAs) are considered to provide a reasonable restoration time frame for the Site.

11.2.7 Consider Public Concerns

Consideration of public concerns will occur following submittal of the FS to Ecology in the context of the public review and comment period.

11.2.8 Ecology Expectations

The evaluation of Ecology's expectations for cleanup actions will be addressed for the combined CAA recommended for implementation in Section 12.2.

11.3 Detailed Evaluation of Lease Parcel CAAs

11.3.1 Approach to Evaluating Lease Parcel CAAs

Because the presumptive cleanup actions address many of the minimum MTCA requirements listed in WAC 173-340-360(2), the evaluation of the six CAAs developed in Section 10.3 will therefore focus on those criteria, or aspects of certain criteria, which address the primary purpose of the Lease Parcel CAAs: preventing LNAPL accumulation on groundwater or the potential migration of LNAPL from soil to groundwater (i.e., source control). Furthermore, the Lease Parcel CAAs are similar in several important aspects which will allow for the detailed analysis of CAAs presented below to further focus on the MTCA requirements that will differentiate the benefits among the CAAs.

11.3.1.1 Minimum Requirements Relevant to Evaluation of Lease Parcel CAAs

The MTCA requirements addressed are essentially the same for all six Lease Parcel CAAs and are summarized below.

- **Comply with applicable state and federal laws.** All of the Lease Parcel CAAs will comply with the applicable legal requirements, including MTCA. Off-site management and disposal of wastes will comply with the applicable solid and dangerous waste regulations.

- **Provide for compliance monitoring.** In addition to the MNA program included in the presumptive cleanup actions, all Lease Parcel CAAs include compliance monitoring to assess the ongoing performance of the alternative and to monitor compliance with cleanup goals.

- **Consideration of Public Concerns.** Consideration of public concerns will occur following submittal of the FS to Ecology in the context of the public review and comment period.

Therefore, the detailed analysis of CAAs will focus on the following four MTCA requirements:

- **Protecting human health and the environment.** The evaluation of protection of human health and the environment will focus on how each Lease Parcel CAA addresses the control, prevention, or elimination of product seeps through the asphalt paving placed over the former tank farm. All of the other aspects of complying with this requirement are addressed by the presumptive cleanup actions.

- **Complying with cleanup standards.** The evaluation of compliance with cleanup standards will consider how the CAA prevents LNAPL accumulation on groundwater or migration from soil to groundwater. This evaluation criterion also evaluates the MTCA requirement that nonpermanent cleanup actions treat or remove the LNAPL sources using accepted engineering practices.

- **Using permanent solutions to maximum extent practicable.** The process for determining whether a cleanup action uses permanent solutions to maximum extent practicable is defined in WAC 173-340-360(3). Since none of the alternatives meet the definition of a permanent cleanup action contained in WAC 173-340-200 (a cleanup action where cleanup standards are met without any further cleanup actions being required), the evaluation of this criteria utilizes a disproportionate cost analysis that focuses on determining which CAA provides the greatest degree of permanence [WAC 173-340-360(3)(e)(ii)(B)]. The approach for conducting the disproportionate cost analysis is described below.

- **Provide for a reasonable restoration time frame.** For the Lease Parcel, evaluation of this criterion will focus on the time required for each CAA to prevent LNAPL accumulation on groundwater or migration of LNAPL from soil to groundwater.

11.3.1.2 Approach for Conducting Disproportionate Cost Analysis

The disproportionate cost evaluation uses the criteria described in WAC 173-340-360(3)(f) to determine which CAA is the most permanent solution. These criteria, including how they will be used to evaluate the Lease Parcel CAAs, are summarized below.

- **Protectiveness**. This is essentially the same as the primary MTCA requirement described above.

- **Permanence**. This criterion focuses on the degree to which the alternative permanently reduces the toxicity, mobility or volume of hazardous substances. For the evaluation of the Lease Parcel CAAs, this criterion will focus on the permanence of addressing the LNAPL on the groundwater and potential sources of LNAPL in soil.

- **Cost**. The overall cost to implement the alternative, including the cost of construction and the NPV of any long-term costs will be used to compare alternatives to each in the cost-benefit analysis.

- **Effectiveness over the long term**. This criterion addresses the degree of certainty that the alternative will be successful, the reliability of the alternative during the period of time hazardous substances are expected to remain on-site, the magnitude of residual risk with the alternative in place, and the effectiveness of controls required to manage treatment residues or remaining wastes. For the evaluation of the Lease Parcel CAAs, the differentiating aspect of this criterion will be the effectiveness and reliability of the LNAPL control and prevention actions.

- **Management of short-term risks**. This criterion addresses the risk to human health and the environment associated with the alternative during construction and implementation, and the effectiveness of measures that will be taken to manage such risks.

- **Technical and administrative implementability**. The ability of an alternative to be implemented including the technical feasibility, availability of necessary off site facilities, administrative and regulatory requirements, access for construction operations and monitoring, and integration with existing facility operations is addressed by this criterion.

- **Consideration of public concerns**. Consideration of specific public concerns will occur following submittal of the FS to Ecology in the context of the public review and comment period. For this evaluation, the potential for a CAA to raise public concerns will be addressed.

The evaluation of these criteria is presented in Table 11-1 and summarized below for each of the alternatives. Based on the evaluation of these criteria, the alternatives will be ranked from the most to the least permanent solution. Next, alternatives will be compared based on cost to determine if the benefits provided by a higher cost alternative (as defined by the permanence of the alternative) outweigh the incremental increase in cost of the alternative. The alternatives will be compared in this manner and the alternative providing the best balance of permanence and cost will be selected for implementation. Where two or more alternatives have equal benefits, the less costly alternative will be selected for implementation. This comparative part of the disproportionate cost analysis is described in Section 12.

The cost sub-criterion will be used as the basis for comparison of the alternatives in the comparative analysis and discussion in Section 12.

11.3.2 Alternative 1 – Existing Asphalt Paving Maintenance and Monitoring

Alternative 1 consists of maintaining the existing asphalt paving in place over the former tank farm, annual asphalt paving inspections and repair, LNAPL monitoring and passive recovery in select wells, and long-term compliance monitoring of groundwater.

11.3.2.1 Protect Human Health and the Environment

Alternative 1 addresses the potential for product seeps through the asphalt paving using periodic inspections to identify the presence of a seep and then implementing corrective actions which may include installation of a vault to facilitate monitoring and product recovery and/or over-excavation of the seep and its source. Although this is a protective approach, a small potential exists for a seep to appear between asphalt paving inspections and a trespasser or worker to be exposed or for runoff to contact seep material and be discharged to the stormwater system. Aside from maintaining the asphalt paving, this alternative does not prevent the seep from occurring or eliminate the source of the seep.

11.3.2.2 Comply with Cleanup Standards

This alternative addresses the accumulation of LNAPL on the groundwater through monitoring and passive recovery activities similar to those currently in use. Alternative 1 relies on maintenance of the asphalt paving to minimize infiltration of precipitation and prevent or minimize the migration of LNAPL from soil to groundwater. Given that approximately 16 years have elapsed since the last known releases at the site (1993), there appears to be limited potential for significant additional LNAPL migration from soil to groundwater.

11.3.2.3 Use Permanent Solutions to the Maximum Extent Practicable

Alternative 1 provides protection through maintenance of the existing asphalt paving, is implementable from both a technical and an administrative standpoint, and has few short-term risks associated with its implementation. This alternative uses only passive LNAPL recovery techniques and it will not significantly reduce the amount of LNAPL present. It also does not take any other actions to contain LNAPL migration. Therefore, the long-term effectiveness of Alternative 1 requires monitoring and maintenance over the long-term (e.g., 30 years or more).

11.3.2.4 Provide For a Reasonable Restoration Time Frame

Alternative 1 continues the ongoing monitoring and passive recovery to reduce the amount of existing LNAPL. Because these passive recovery techniques are not very effective at removing LNAPL from soil, except within a limited radius around each recovery well, it is anticipated that these activities would continue for many years, possibly decades. For cost estimating purposes, it is assumed that passive recovery would continue for 30 years (Table 10-4).

At some point in time, the amount of LNAPL that can be recovered with this approach will drop to the point that it will be discontinued, leaving a small marginally recoverable amount of LNAPL on the groundwater. Although there is no indication that the relatively thin layer of LNAPL left after passive recovery efforts stop would migrate, Alternative 1 does not take any additional action to control possible migration of LNAPL outside of the Lease Parcel area.

To the extent that maintenance of the asphalt paving minimizes infiltration of precipitation and prevents or minimizes the migration of LNAPL from soil to groundwater, this will happen immediately after implementation of the remedy.

11.3.3 Alternative 2 – Containment and Passive LNAPL Recovery

Alternative 2 includes constructing a subsurface slurry wall around the perimeter of the former tank farm, replacing the existing asphalt paving with a new cap and underlying geomembrane, site drainage improvements, annual cap inspections and repair, LNAPL monitoring and passive recovery, compliance monitoring, and reporting. A majority of the existing subsurface structures/soil will be left in place.

11.3.3.1 Protect Human Health and the Environment

Alternative 2 addresses the potential for product seeps through the asphalt paving by constructing a new composite cap (geomembrane beneath asphalt) that should effectively prevent product from forming surface seeps. Also, by removing approximately 30 percent of the remaining subsurface structures from the former tank farm, including several tank bases, some of the potential sources of the seeps will likely be removed. In the unlikely event that a seep would form, cap inspections would identify the seep and corrective actions would be implemented in a manner similar to that in Alternative 1.

11.3.3.2 Comply with Cleanup Standards

This alternative addresses the cleanup standard related to the accumulation of LNAPL on the groundwater in a similar fashion to Alternative 1, through monitoring and passive recovery activities similar to those currently in use. Alternative 2 is much more proactive with respect to preventing possible migration of LNAPL outside the Lease Parcel through construction of a slurry wall around the former tank farm, so even if LNAPL did accumulate, it would be effectively contained at the source.

Regarding preventing migration of LNAPL from soil to groundwater, Alternative 2 primarily relies on maintenance of the composite cap to minimize infiltration of precipitation and prevent or minimize the migration of LNAPL from soil to groundwater. Because some of the subsurface structures and the associated near surface soil are removed as part of the slurry wall construction, some of the potential soil sources for LNAPL migration to groundwater are also removed.

11.3.3.3 Use Permanent Solutions to Maximum Extent Practicable

Alternative 2 provides protection through the construction and maintenance of a new composite cap and removing a portion of the remaining subsurface structures. It is implementable from both a technical and an administrative standpoint and, although there are some short-term risks associated with its implementation (e.g., heavy construction activities, volatilization of VOCs), these risks can be controlled using standard worker health and safety procedures and engineering controls.

Alternative 2 permanently and effectively reduces the mobility of the LNAPL in the Lease Parcel over the long term through construction of the slurry wall; this portion of Alternative 2 requires no long term maintenance. This alternative uses only passive LNAPL recovery techniques and will not significantly reduce the volume of LNAPL present, and monitoring and maintenance is required to assure the long-term effectiveness of the cap and LNAPL recovery activities outside the slurry wall.

11.3.3.4 Provide For a Reasonable Restoration Time Frame

The major component of Alternative 2, construction of the slurry wall around the Lease Parcel, would effectively eliminate potential migration of LNAPL from inside the wall immediately upon completion. Removal of the LNAPL that exists inside the wall, and in the adjacent areas, relies on monitoring and passive recovery. As with Alternative 1, these passive recovery techniques are anticipated to continue for a decade or longer. When the passive LNAPL recovery becomes ineffective, the small amount of residual LNAPL would be contained inside the slurry wall. As with Alternative 1, the cost estimate assumes that passive recovery would continue for 30 years (Table 10-5.)

To the extent that maintenance of the asphalt paving minimizes infiltration of precipitation and prevents or minimizes the migration of LNAPL from soil to groundwater, this will happen immediately upon implementation of the remedy.

11.3.4 Alternative 3 – Active LNAPL Recovery and Subsurface Structure Removal

Alternative 3 includes a vacuum-enhanced LNAPL recovery system, removal of all of the remaining subsurface structures and tank bases, new asphalt paving, annual paving inspections and repair, LNAPL monitoring and passive recovery outside the active LNAPL recovery system, compliance monitoring, and reporting.

11.3.4.1 Protect Human Health and the Environment

Alternative 3 effectively eliminates the potential for product seeps through the asphalt paving by removing all of the remaining subsurface structures, including all of the remaining tank bases, from the former tank farm area and constructing new asphalt paving. The LNAPL recovery system would further reduce the potential for surface seeps.

11.3.4.2 Comply with Cleanup Standards

Alternative 3 uses active LNAPL recovery technologies to remove recoverable LNAPL from the Lease Parcel and adjacent areas. Outside the area where active recovery is feasible, monitoring and passive recovery activities will be used. By removing the recoverable LNAPL, Alternative 3 will greatly reduce the potential for migration of LNAPL from the source area.

Similar to Alternative 1, Alternative 3 relies in part on maintenance of the asphalt paving to minimize infiltration of precipitation and prevent or minimize the migration of LNAPL from soil to groundwater. Because all of the subsurface structures and the associated near surface soil are removed in this alternative, more of the potential soil sources for LNAPL migration to groundwater (compared to Alternative 2) are removed.

11.3.4.3 Use Permanent Solutions to Maximum Extent Practicable

Alternative 3 provides protection through the construction and maintenance of a new asphalt paving and removing all of the remaining subsurface structures. It is implementable from both a technical and an administrative standpoint and, although there are some short-term risks associated with its implementation (e.g., heavy construction activities, volatilization of VOCs), these risks can be controlled using standard worker health and safety procedures and engineering controls.

The vacuum-enhanced LNAPL recovery system will significantly and permanently reduce the volume of the recoverable LNAPL at the Lease Parcel. The passive LNAPL recovery techniques used outside the area affected by the active LNAPL recovery system will not significantly reduce the amount of LNAPL present. Monitoring and maintenance is required to assure the long-term effectiveness of the paving and LNAPL recovery activities in these areas.

11.3.4.4 Provide For a Reasonable Restoration Time Frame

The use of vacuum-enhanced LNAPL recovery technologies in Alternative 3 will remove much more of the recoverable LNAPL from the subsurface, and remove it more quickly, than the passive techniques of Alternatives 1 and 2. For cost estimating purposes, it is assumed that active LNAPL recovery would continue for 10 years (Table 10-6), although it is important to note that the majority of the LNAPL recovered in this time would occur in the first several years of operation. At the end of the 10 years, there should be very little residual LNAPL remaining in the area affected by the LNAPL recovery system. Outside the area where active recovery is feasible, monitoring and passive recovery activities will be used and will continue for 30 years.

As with the other alternatives, preventing or minimizing the migration of LNAPL from soil to groundwater would happen immediately upon implementation by maintaining the asphalt paving. In addition, removal of all of the subsurface structures and the associated near surface soil would further reduce the potential for LNAPL migration immediately.

11.3.5 Alternative 4 – Containment, Subsurface Structure Removal, and Expanded LNAPL Recovery

Alternative 4 includes constructing a slurry wall around the perimeter of the former tank farm, removal of all of the remaining subsurface structures and tank bases, removal of highly contaminated surface soil, installation of an enhanced LNAPL recovery system, new asphalt paving, annual paving inspections and repair, LNAPL monitoring and passive recovery outside the enhanced LNAPL recovery system, compliance monitoring, and reporting.

11.3.5.1 Protect Human Health and the Environment

Alternative 4 effectively eliminates the potential for product seeps through the asphalt paving by removing all of the remaining subsurface structures, including all of the remaining tank bases, as well as removing highly contaminated surface soil from the former tank farm area and constructing new asphalt paving. The enhanced LNAPL recovery system would further reduce the potential for surface seeps.

11.3.5.2 Comply with Cleanup Standards

Alternative 4 addresses the cleanup standards related to LNAPL by using a combination of the enhanced LNAPL recovery system to remove recoverable LNAPL from the Lease Parcel and adjacent areas and construction of a slurry wall around the former tank farm. Outside the area affected by the enhanced LNAPL recovery system, monitoring and passive recovery activities will be used. By removing the recoverable LNAPL and surrounding the former tank farm area with a slurry wall, Alternative 4 will greatly reduce the potential for migration of LNAPL from the source area.

Similar to Alternative 3, Alternative 4 relies in part on maintenance of the asphalt paving to minimize infiltration of precipitation and prevent or minimize the migration of LNAPL from soil to groundwater. Because all of the subsurface structures and the highly contaminated surface soil are removed in this alternative, more of the potential soil sources for LNAPL migration to groundwater (compared to Alternative 2 and 3) are removed.

11.3.5.3 Use Permanent Solutions to Maximum Extent Practicable

Alternative 4 provides protection through the construction and maintenance of new asphalt paving and removing all of the remaining subsurface structures and highly contaminated surface soil. It is implementable from both a technical and an administrative standpoint and, although there are some short-term risks associated with its implementation (e.g., heavy construction activities, volatilization of VOCs), these risks can be controlled using standard worker health and safety procedures and engineering controls.

The enhanced LNAPL recovery system will permanently reduce the volume of the recoverable LNAPL at the Lease Parcel. The passive LNAPL recovery techniques used outside the area affected by the enhanced LNAPL recovery system will not significantly reduce the amount of LNAPL present. The slurry wall constructed around the former tank farm will significantly and permanently reduce the potential migration of LNAPL from this area. Monitoring and maintenance is required to assure the long-term effectiveness of the paving and LNAPL recovery activities in these areas.

11.3.5.4 Provide For a Reasonable Restoration Time Frame

The use of the enhanced LNAPL recovery system in Alternative 4 will remove more of the recoverable LNAPL from the subsurface, and remove it more quickly than the passive techniques of Alternatives 1 and 2 (although potentially not as much or as quickly as the vacuum-enhanced system in Alternative 3). The slurry wall will control migration from the source immediately upon construction. For cost estimating purposes, it is assumed that active LNAPL recovery would continue for 10 years (Table 10-7), although it is important to note that the majority of the LNAPL recovered in this time would occur in the first several years of operation. At the end of the 10 years, there should be very little residual LNAPL remaining in the area affected by the LNAPL recovery system. Outside the area where active recovery is feasible, monitoring and passive recovery activities will be used and will continue for 30 years.

As with the other alternatives, preventing or minimizing the migration of LNAPL from soil to groundwater would happen immediately upon implementation (e.g., removal of all of the subsurface structures and the highly contaminated surface soil, new asphalt paving) and continue by maintaining the asphalt paving.

11.3.6 Alternative 5 – Limited Excavation of LNAPL Areas

Alternative 5 consists of the removal of the LNAPL source areas in and near the Lease Parcel through excavation and disposal of impacted soil in areas where LNAPL has been observed. Other components of this alternative include removal of the existing asphalt paving and all remaining above ground and subsurface structures in the former tank farm, backfilling the excavation area with clean soil, constructing new asphalt paving, installing new monitoring wells, annual asphalt paving inspections and repair, compliance monitoring, and reporting.

11.3.6.1 Protect Human Health and the Environment

Alternative 5 effectively eliminates the potential for product seeps through the asphalt paving by removing all of the remaining subsurface structures, including all of the remaining tank bases, from the former tank farm area and constructing new asphalt paving. In addition, this alternative removes approximately 25 percent of the unsaturated zone soil as well as excavating the areas with observed LNAPL (see Figure 10-5), which would further reduce the potential for surface seeps.

11.3.6.2 Comply with Cleanup Standards

Alternative 5 uses excavation to remove LNAPL in areas where it has been recently observed. Outside the area identified in Section 10.3.5, monitoring and passive recovery activities will be used. By excavating the observed LNAPL, Alternative 5 will greatly reduce the potential for migration of LNAPL from the source area.

By removing a portion of the unsaturated zone soil, the potential for migration of LNAPL from this soil to groundwater is eliminated. For areas not being excavated, Alternative 5 relies on maintenance of the asphalt paving to minimize infiltration of precipitation and prevent or minimize the migration of LNAPL from soil to groundwater. The removal of all of the subsurface structures further reduces the potential for LNAPL migration to groundwater.

11.3.6.3 Use Permanent Solutions to Maximum Extent Practicable

Alternative 5 provides protection through the construction and maintenance of a new asphalt paving, excavation of 19,000 tons of impacted soil, and removal all of the remaining subsurface structures. It utilizes standard construction techniques and is implementable from both technical and administrative standpoint. There are some increased short-term risks associated with its implementation (e.g., heavy construction activities, volatilization of VOCs, off-site truck traffic), but these risks can be controlled or mitigated to a large degree by using standard worker health and safety procedures and engineering controls.

The excavation of LNAPL-containing soil will significantly and permanently reduce the volume of LNAPL at the Lease Parcel, as well as reduce the potential for future migration of LNAPL from soil to groundwater. The passive LNAPL recovery techniques used outside the excavation area will not significantly reduce the amount of LNAPL present. Monitoring and maintenance is required to assure the long-term effectiveness of the asphalt paving and LNAPL recovery activities outside the excavation area.

11.3.6.4 Provide For a Reasonable Restoration Time Frame

By excavating the portions of the Lease Parcel and adjacent areas where LNAPL have been observed, Alternative 4 will effectively remove the LNAPL in these areas upon implementation of the remedy, with little or no residual LNAPL remaining. Outside the excavation area, monitoring and passive recovery activities will be used and will continue for 30 years.

Because the unsaturated zone soil is removed from 25 percent of the Lease Parcel, and all of the subsurface structures and the associated near surface soil are removed, the potential for migration of LNAPL from this soil to groundwater is greatly reduced. Maintaining and repairing the asphalt paving will further minimize the potential migration of LNAPL from soil to groundwater immediately.

11.3.7 Alternative 6 – Excavation of Soils Exceeding RSSLs

Alternative 6 is the same as Alternative 5, except that the boundaries of the excavation are defined by two factors: (1) the areas where LNAPL has been observed as in Alternative 5; and (2) areas where soil contains petroleum hydrocarbons at concentrations exceeding RSSLs.

11.3.7.1 Protect Human Health and the Environment

Alternative 6 effectively eliminates the potential for product seeps through the asphalt paving by removing all of the remaining subsurface structures, including all of the remaining tank bases, from the former tank farm area and constructing new asphalt paving. In addition, this alternative removes approximately 60 percent of the unsaturated zone soil within the Lease Parcel as well as excavating the areas with observed LNAPL and exceeding the RSSLs (see Figure 10-6). The subsurface structure removal combined with the soil excavation activities eliminate the potential for surface seeps.

11.3.7.2 Comply with Cleanup Standards

Alternative 6 uses excavation to remove saturated soil containing LNAPL in areas where it has been recently observed. Outside the area identified in Section 10.3.6, monitoring and passive recovery activities will be used. By excavating the observed LNAPL, Alternative 6 will greatly reduce the potential for migration of LNAPL from the source area.

By removing soils that exceed the RSSLs, the potential for migration of LNAPL from this soil to groundwater is eliminated. For areas not being excavated, Alternative 6 relies on maintenance of the asphalt paving to minimize infiltration of precipitation and prevent or minimize the migration of LNAPL from soil to groundwater. The removal of all of the subsurface structures further reduces the potential for LNAPL migration to groundwater.

11.3.7.3 Use Permanent Solutions to Maximum Extent Practicable

Alternative 6 provides protection through the construction and maintenance of a new asphalt paving, excavation of 32,000 tons of impacted soil, and removal all of the remaining subsurface structures. It utilizes standard construction techniques and is implementable from both a technical and an administrative standpoint. There are some increased short-term risks associated with its implementation (e.g., heavy construction activities, volatilization of VOCs off-site truck traffic), but these risks can be controlled or mitigated to a large degree by using standard worker health and safety procedures and engineering controls.

The excavation of LNAPL-containing soil will significantly and permanently reduce the volume of LNAPL at the Lease Parcel, as well as reduce the potential for future migration of LNAPL from soil to groundwater. The passive LNAPL recovery techniques used outside the excavation area will not significantly reduce the amount of LNAPL present. Monitoring and maintenance is required to assure the long-term effectiveness of the paving and LNAPL recovery activities outside the excavation area.

11.3.7.4 Provide For a Reasonable Restoration Time Frame

By excavating the portions of the Lease Parcel and adjacent areas with soil concentrations above RSSLs and where LNAPL has been observed, Alternative 6 will effectively remove the LNAPL and much of the soil with the potential to release LNAPL immediately upon implementation of the remedy. Outside the excavation area, monitoring and passive recovery activities will be used and will continue for 30 years.

Because the unsaturated zone soil is removed from nearly 60 percent of the Lease Parcel using this Alternative, and all of the subsurface structures and the associated near surface soil are removed, the potential for migration of LNAPL from this soil to groundwater is essentially eliminated. Maintaining and repairing the paving would further minimize the potential migration of LNAPL from soil to groundwater immediately.

12.0 COMPARATIVE EVALUATION AND RECOMMENDED CLEANUP ACTION

In this section, the Lease Parcel CAAs developed in Section 10 and evaluated individually in Section 11.3 are compared against each other for each of the MTCA evaluation criteria. Based on this comparison, the preferred Lease Parcel CAA is recommended for implementation. A description of how the preferred Lease Parcel CAA, in conjunction with the presumptive cleanup actions, meets the MTCA criteria and Ecology expectations is provided.

12.1 <u>Comparison of Lease Parcel Alternatives</u>

12.1.1 Protectiveness

All of the Lease Parcel CAAs, except Alternative 1, provide protection by constructing, inspecting, and maintaining a surface cover over the former tank farm, thereby preventing potential surface product seeps. Alternative 1 maintains the existing asphalt paving, which due to the presence of the remaining tank farm structures has been prone to limited surface seepage. Exposure to the seeps can be minimized through routine inspections, maintenance of the asphalt paving where seeps occur, and corrective actions (e.g., installation of vaults) as necessary. Alternative 2 improves on the protectiveness compared to Alternative 1 by replacing the existing asphalt paving with a composite cap that would be resistant to surface seepage. In addition, by removing a portion of the subsurface tank farm structures, at least some of the sources of the seeps will be removed.

Alternatives 3 through 6 are all more protective compared to Alternatives 1 and 2 because they essentially eliminate the potential for seeps by removing all of the subsurface tank farm structures and then covering the former tank farm area with new asphalt paving. Although it is extremely unlikely that seeps would re-appear once all of the subsurface structures are removed, Alternatives 4, 5, and 6 provide further reduction in the potential for seepage by excavating portions of the unsaturated soil.

12.1.2 Compliance With Cleanup Standards

For the Lease Parcel, compliance with cleanup standards focuses on how each CAA prevents LNAPL accumulation on groundwater or migration from soil to groundwater. Alternative 1 uses passive recovery from wells to remove recoverable LNAPL and will likely recover the least amount of LNAPL and take the longest period of time. Alternative 1 reduces the potential migration of LNAPL from soil to groundwater by maintenance of the existing asphalt paving. Although Alternative 2 does not remove more LNAPL or remove it appreciably faster compared to Alternative 1, it effectively eliminates the potential for LNAPL migration from the Lease Parcel through installation of a slurry wall.

By using vacuum-enhanced LNAPL recovery techniques, Alternative 3 reduces the volume of recoverable LNAPL to a greater extent, and does it faster, than either Alternative 1 or 2. Removal of the recoverable LNAPL, which by definition is the most mobile, will greatly reduce the potential for migration of LNAPL from the source area. As with Alternatives 1 and 2, Alternative 3 reduces the potential for migration of LNAPL from soil to groundwater by removing the remaining tank bases and subsurface structures, which could act as a source of LNAPL, and by maintenance of the asphalt paving.

Alternative 4 combines the benefits of Alternatives 2 and 3 to both reduce the volume of recoverable LNAPL in, and effectively eliminate the potential migration of LNAPL from, the Lease Parcel and adjacent areas. The enhanced LNAPL recovery system will remove the most mobile LNAPL while the slurry wall will contain the residual contamination and unrecoverable LNAPL. Alternative 4 reduces the potential for migration of LNAPL from soil to groundwater by removing the remaining tank bases, subsurface structures, and highly contaminated surface soil that could act as a source of LNAPL and by maintenance of the asphalt paving.

Alternative 5, and to a somewhat greater degree Alternative 6, remove the observed LNAPL via excavation. These two alternatives remove both the more recoverable (and mobile) LNAPL like Alternatives 3 and 4 and the more viscous and generally unrecoverable (and immobile) LNAPL such as that present in the Black Oil Yard. Because this removal is achieved by excavation, it occurs immediately upon implementation of the cleanup. Alternatives 5 and 6 are more effective at reducing potential migration of LNAPL from soil to groundwater by removing a portion of the unsaturated zone soil. Alternative 6 is the most effective in this regard by removing the soils which exceed the RSSLs.

12.1.3 Compliance with Regulatory Requirements

All of the CAAs will comply with the applicable legal requirements, including MTCA. Where off-site management and disposal of wastes is required, the applicable solid and dangerous waste regulations will govern cleanup activities. Alternatives 5 and 6 include discharge to the sanitary sewer of groundwater removed during dewatering of the excavations. For these alternatives, a King County Industrial Waste Discharge Permit will need to be obtained.

12.1.4 Compliance Monitoring

All Lease Parcel CAAs include compliance monitoring to assess the ongoing performance of the alternative and to monitor compliance with cleanup goals. This compliance monitoring, combined with the MNA program included in the presumptive cleanup actions, will provide the documentation necessary to establish that cleanup goals and levels have been achieved.

12.1.5 Use of Permanent Solutions

The comparative evaluation of this criterion is based on the information presented in Table 11-1. Protectiveness is discussed above and all the alternatives compare equally with respect to the implementability and consideration of public concerns criteria. The sub-criteria that are most important in differentiating the six alternatives, which will be used as the basis for the disproportionate cost analysis, are: permanence, long-term effectiveness, management of short-term risks, and cost. These four sub-criteria are discussed below, and the disproportionate cost analysis is presented in Section 12.2.

12.1.5.1 Permanence

For the Lease Parcel CAAs, this criterion focuses on the degree to which the alternative permanently reduces the toxicity, mobility or volume of hazardous substances; specifically LNAPL on the groundwater and potential sources of LNAPL in soil. The comparison of alternatives relative to how they address LNAPL is discussed above for the "compliance with cleanup standards" criterion. Briefly, Alternative 1 is the least permanent. Alternative 2 is somewhat more permanent in that it provides a high level of containment for the Lease Parcel LNAPL. Alternative 3 actively removes the recoverable and mobile LNAPL. Alternative 4 both removes the recoverable LNAPL and provides a high level of containment for the Lease Parcel LNAPL. Alternatives 5 and 6 remove the observed LNAPL, mobile or immobile, through excavation. As a result, Alternative 4 is more permanent than Alternative 3, while Alternatives 5 and 6 are more permanent compared to Alternative 4, with Alternative 6 being the most permanent.

12.1.5.2 Long-Term Effectiveness

Alternative 1 is the least effective in the long term in that it will reduce the amount and/or mobility of the LNAPL the least and take the longest to achieve these reductions, and because it relies on effective performance of O&M activities to maintain protectiveness to the greatest degree. Alternative 2, although still utilizing passive recovery techniques to recover LNAPL, provides a higher level of long-term effectiveness by significantly and immediately limiting the potential mobility of LNAPL at the Lease Parcel with the slurry wall, a technology that requires little or no O&M. Alternative 3, and the vacuum-enhanced recovery system in particular, require a higher degree of O&M over the short to medium term, but because Alternative 3 removes LNAPL from the subsurface, it is more effective than Alternative 2 in the long term.

Alternative 4 utilizes an enhanced LNAPL recovery system and requires a moderate amount of O&M over the short to medium term, but provides long-term effectiveness by removing LNAPL. As with Alternative 2, the slurry wall component of Alternative 4 provides a high level of long-term effectiveness by significantly and immediately limiting the potential mobility of LNAPL at the Lease Parcel with little or no O&M required. Alternative 4 also immediately removes the most highly contaminated surface soil. As a result, Alternative 4 is more effective than either Alternative 2 or 3.

Alternatives 5 and 6, through excavation and off-site disposal of 19,000 and 32,000 tons of soil, respectively, are the most effective of the CAAs in the long-term, although it is unclear how much more effective these two alternatives are with respect to achieving the overall cleanup objectives for the Site compared to Alternative 4. Alternatives 5 and 6 clearly remove the most contaminant mass from the subsurface, although there does not appear to be a significant benefit compared to Alternative 4, which focuses on removing the recoverable and most mobile LNAPL and providing a high level of containment for the source area. Specifically, because the vast majority of potential migration from soil to groundwater has likely occurred, the increased contaminant mass removal provided by Alternative 5 and 6 does not appear to significantly reduce the potential for LNAPL to accumulate on the groundwater or migrate from soil to groundwater.

12.1.5.3 Cost

The costs for the six alternatives are detailed in Tables 10-4 through 10-9, and summarized in Table 11-1. Based on the overall NPV (capital costs plus 30 years of O&M), the alternatives range from a low of $1.16 million (Alternative 1) to a high of $6.99 million (Alternative 6). Alternatives 3 and to a lesser extent Alternative 4 have the highest O&M costs. Both these alternatives have moderate capital costs ($2.60 and $2.69 million, respectively), and, with total estimated costs of $4.38 and $3.88 million, respectively, are approximately midway between Alternative 1 and 6. Alternatives 5 and 6 have the highest capital costs, largely associated with the costs of excavation, off-site disposal of impacted soil, and backfilling.

12.1.5.4 Management of Short-Term Risks

With respect to the risks to human health and the environment associated with the alternative during construction and implementation, and the effectiveness of measures that can be taken to manage such risks, Alternatives 5 and 6 pose the most potential short-term risks. These alternatives involve the most construction, expose the most subsurface soil with the associated risk of volatilization of VOCs, and will result in extensive truck traffic off-site associated with hauling impacted soil for disposal. Alternatives 2, 3, and 4 have fewer short-term risks given the more limited construction activities and reduced potential for volatilization of VOCs, and involve much less off-site traffic impacts. Alternative 1 poses the least short-term implementation risks.

In all cases, it is important to note that these short-term risks can be managed with standard health and safety and engineering controls.

12.1.6 Restoration Time Frame

For the Lease Parcel CAAs, the restoration time frame criterion focuses on the time required for each CAA to prevent LNAPL accumulation on groundwater or migration of LNAPL from soil to groundwater. Alternative 1 uses monitoring and passive recovery to reduce the amount of existing LNAPL, albeit slowly. For purposes of this FS, it is assumed that passive recovery would continue for 30 years, although performance monitoring may indicate that a shorter time frame is reasonable if recovery rates drop to the point of diminishing returns. Regarding minimizing the migration of LNAPL from soil to groundwater, this will happen immediately after implementation of Alternative 1.

Alternative 2 improves on the restoration time frame compared to Alternative 1 in that it eliminates the potential migration of LNAPL from inside the slurry wall around the former tank farm immediately upon construction. Alternative 2 does not reduce the quantity of LNAPL any more or faster than Alternative 1.

Alternative 3 reduces the amount LNAPL present at the Lease Parcel through operation of the vacuum-enhanced LNAPL recovery system. For purposes of this FS, it is assumed that this system will operate for 10 years, although performance monitoring will be used to determine if a shorter time frame is appropriate. In any event, the majority of the LNAPL removed by this system will likely be recovered within the first 3 to 5 years of operation. Alternative 3 immediately reduces the potential for migration of LNAPL from soil to groundwater, compared to Alternatives 1 and 2, by removing all of the subsurface tank farm structures and associated near-surface soil.

Alternative 4 also reduces the amount of LNAPL present at the Lease Parcel, although not likely by as much as Alternative 3, through operation of the enhanced LNAPL recovery system. For the purpose of this FS, it is assumed that this system will operate for 10 years, although performance monitoring will be used to determine if a shorter time frame is appropriate. The majority of the LNAPL removed by this system will likely be recovered within the first 3 to 5 years of operation. Alternative 4 also eliminates the potential migration of LNAPL from inside the slurry wall around the former tank farm immediately upon construction. By removing all of the subsurface tank farm structures and highly contaminated surface soil, Alternative 4 immediately reduces the potential for migration of LNAPL from soil to groundwater, compared to Alternatives 1 through 3.

Alternatives 5 and 6 will effectively remove the observed LNAPL at the Lease Parcel and adjacent areas immediately upon implementation of the cleanup action, with little or no residual LNAPL remaining. Outside the excavation area, monitoring and passive recovery activities will be used and will continue for 30 years.

Alternatives 5 and 6 remove not only the existing subsurface tank farm structures, but 25 percent and 60 percent of the unsaturated zone soil in the Lease Parcel, respectively. As a result, the potential for migration of LNAPL from this soil to groundwater is further reduced when compared to Alternative 4. Maintaining and repairing the asphalt paving will further minimize the potential migration of LNAPL from soil to groundwater immediately.

12.1.7 Public Acceptance

As noted previously, consideration of public concerns for all of the CAAs will be addressed following submittal of this FS to Ecology, in the context of the public review and comment period.

12.2 <u>Disproportionate Cost Analysis and Recommended Cleanup Action</u>

The disproportionate cost analysis is based on comparative evaluation of the Lease Parcel CAAs against the criteria presented in Table 11-1 and summarized above. The alternatives will be ranked from the most to the least permanent solution and then compared based on cost to determine if the benefits provided by a higher cost alternative (as defined by the permanence of the alternative and its ability to meet the CAOs for the Lease Parcel) outweigh the incremental increase in cost of the alternative. The alternative that provides the best balance of permanence and cost will be selected for implementation along with the presumptive cleanup actions. Where two or more Lease Parcel alternatives have equal benefits, the less costly alternative will be selected for implementation.

Alternative 6 ($6.99 million) is the most permanent CAA in that it physically removes the most contaminant mass, including LNAPL and soils exceeding the RSSLs. Alternative 5 ($5.38 million) is only slightly less permanent because it removes approximately 40 percent less soil, but the soil that is removed is where LNAPL has been observed. Alternative 4 ($3.88 million) is the next most permanent alternative; it removes the recoverable and mobile

LNAPL using an enhanced recovery system and also permanently reduces the mobility of LNAPL by surrounding the Lease Parcel with a slurry wall. Alternative 3 ($4.38 million) is the next most permanent alternative; it removes the recoverable and mobile LNAPL using an active recovery system. Alternatives 3 through 6 all significantly reduce the potential for LNAPL migration from soil to groundwater and eliminate the potential for future surface seeps by removing the existing subsurface tank farm structures and repaving the tank farm area. Alternative 2 ($2.9 million) is less permanent than Alternative 3 because it does not remove as much LNAPL and takes much longer to remove the LNAPL; Alternative 2 does permanently reduce the mobility of LNAPL by surrounding the Lease Parcel with a slurry wall. Finally, Alternative 1 ($1.16 million) is the least permanent CAA, and uses monitoring, passive LNAPL recovery, and maintenance of the existing asphalt paving to address LNAPL accumulation and migration.

As can be seen, the qualitative ranking of the CAAs by permanence are generally the same as the rankings by cost; i.e. the least permanent alternative is the least expensive and the most permanent alternative is also the most expensive. The exception to this pattern is Alternative 4, which is more permanent than Alternative 3 yet costs approximately $0.5 million less. Therefore, the disproportionate cost analysis will start by comparing Alternative 1 and 2 to see if the increased cost is proportionate to the increased benefits, and then proceeding up through the alternatives.

Alternative 2 takes two important actions which, when compared to Alternative 1, provide significant benefits with respect to meeting the CAOs: containing the major sources of LNAPL with a slurry wall and upgrading the surface cap to prevent future seeps. Although Alternative 2 costs approximately $1.75 million more than Alternative 1, it is proportional to the additional benefits provided.

Alternative 3 takes additional actions which further enhance its ability to meet the CAOs as compared to Alternative 2; specifically the active removal (as opposed to containment) of the mobile LNAPL at the site and the removal of the remaining subsurface structures and near surface soil. Alternative 3 costs approximately $1.47 million more than Alternative 2, but this is proportional to the benefits provided in the form of permanent source removal actions as compared to the improved containment actions implemented in Alternative 2.

Alternative 4 combines the major components of Alternatives 2 and 3 and as a result provides a higher level of permanence than either Alternative 2 or 3. Alternative 4 removes LNAPL through use of an enhanced recovery system that, while potentially not as effective as the vacuum-enhanced system utilized in Alternative 3, costs much less to construct and operate. Alternative 4 also provides a high level of containment of the source area, removes all of the subsurface structures, and highly contaminated surface soil. As noted above, Alternative 4 costs $0.5 million *less* than Alternative 3 while providing significantly more benefits.

The main differences between Alternatives 3 and 4 and 5 are the amount of LNAPL removed from the site and the manner in which that removal is achieved. Alternative 5 removes (using excavation) more LNAPL than either Alternative 3 or 4, but most of the differential is in the thicker and relatively immobile LNAPL that cannot be recovered using standard engineering techniques. Given that all of these alternatives significantly reduce the amount of mobile LNAPL present in the Lease Parcel, it is not clear how much additional benefit is provided by Alternative 5. Alternatives 3, 4, and 5 remove all of the subsurface structures, effectively eliminating the source of surface seeps. Alternative 5 does remove some of the unsaturated zone soil, but it is not clear that this material is a potential source of surface seepage. Alternative 5 costs approximately $1.0 million more than Alternative 3 and $1.5 million more than Alternative 4, and although there is arguably only a small increase in the benefits provided by Alternative 5, it does not appear that this marginal increase is proportional to the increased cost.

Alternative 6 is very similar to Alternative 5, and the only incremental benefit it provides is the removal of soils that exceed the RSSLs, which would primarily affect the potential migration of LNAPL from soil to groundwater. As noted previously, given the amount of time that has lapsed since the last known release of petroleum in the tank farm area, the vast majority of potential migration from soil to groundwater has very likely occurred. Furthermore, repaving the area will reduce the potential for infiltration of precipitation and the subsequent migration of IHSs from soil to groundwater. At a cost of $6.99 million, Alternative 6 costs $1.61 million more than Alternative 5 and $3.1 million more than Alternative 4. Given the marginal incremental benefit provided by Alternative 6, the significant increase in costs is disproportionate to the added benefit.

Based on the above analysis, Alternative 4 provides the best balance of permanence, the ability to meet the CAOs, and cost, and is therefore recommended for implementation.

12.3 <u>Implementation of Preferred Cleanup Action</u>

The final CAA for the Site will consist of the presumptive actions described in Section 10.2 and Lease Parcel Alternative 4 as described in Section 10.3.3. This overall cleanup action will include the general steps outlined below.

- Preparation of a cleanup action plan (CAP).
- Following final approval of the CAP, initiating cleanup action design.
- Implementation of the presumptive cleanup actions including:
    - Developing and implementing institutional controls;
    - Excavating LNAPL source areas at SWMU 30;
    - Inventorying, cleaning, and abandoning remaining subsurface pipelines; and
    - Developing the MNA monitoring plan, including installing the required additional monitoring wells.
- Implementation of the Lease Parcel cleanup actions including:
    - Removing the existing asphalt paving;
    - Removing and stockpiling existing subgrade and fill, and demolishing the remaining above ground and subsurface structures;
    - Removing highly contaminated surface soil from within the Lease Parcel;

- Constructing a slurry wall around the former tank farm area;
- Hauling all demolished and excavated material and decontamination water off site;
- Designing and installing the enhanced LNAPL recovery trenches;
- Constructing new asphalt paving with associated stormwater system improvements;
- Installing new LNAPL monitoring wells; and
- Initiating the long-term O&M activities including operation of the enhanced LNAPL recovery system, monitoring, asphalt paving inspection and maintenance, passive LNAPL recovery, and reporting.

Following implementation of the preferred cleanup alternative, site development and facility maintenance activities that include subsurface work (e.g., excavation, boring) have the potential to discover additional contamination at the Site. This potential is recognized in the engineering and institutional controls included in the presumptive cleanup actions; these controls will ensure that future subsurface work (e.g., excavation, boring) will utilize appropriate worker health and safety procedures during the subsurface work, and that the appropriate long-term engineering controls (e.g., vapor barriers) are implemented for new developments. Potentially contaminated soil and groundwater removed during these development and maintenance activities will be managed consistent with the specific procedures contained in the Contamination Contingency Plan, which is expected to be part of the new Agreed Order for the entire Terminal 91 Complex.

Compliance with MTCA Requirements. The combined cleanup action outlined above meets all of the minimum requirements in MTCA for selection of cleanup actions listed in WAC 173-340-360(2) as follows:

- Human health and the environment are protected through a combination of institutional and engineering controls and source control actions;
- Cleanup standards will be complied with by documenting that the groundwater CULs continue to be met at the POC and preventing LNAPL from accumulating on groundwater to the extent practicable and minimizing the potential migration of LNAPL from soil to groundwater;
- Applicable state and federal laws are complied with;
- Compliance monitoring is provided;
- Permanent solutions will be used to the extent practicable, as documented in the above disproportionate cost analysis;
- The selected CAA provides for a reasonable restoration time frame. Groundwater CULs are currently being met at the point of the compliance and future compliance will be documented through implementation of the MNA plan. Achieving the LNAPL-related

cleanup objectives will be achieved in 10 years or less; and

- Public concerns will be addressed during the public comment period.

Ecology Expectations. WAC 173-340-370 outlines a series of eight expectations that Ecology has regarding selection and implementation of cleanup actions. Selection of the overall cleanup action summarized above for the Site is consistent with these expectations in that it:

- Uses engineering controls (containment) to contain large volumes of materials where treatment is impracticable;
- Minimizes migration of hazardous substances by preventing precipitation and runoff from contacting contaminated soils and waste materials;
- Takes active measures (source control actions) to prevent releases of hazardous substances to surface waters via groundwater discharges;
- Utilizes natural attenuation appropriately in that:
    - Source control will be conducted to the extent practicable;
    - The contaminants left in place after implementation of the cleanup action do not pose an unacceptable risk to human health and the environment;
    - There is evidence that natural biodegradation is occurring and will continue to occur at a reasonable rate; and
    - Appropriate monitoring requirements are conducted to ensure that natural attenuation processes are taking place and human health and the environment are protected.
    - Does not result in a greater overall threat to human health and the environment compared to other alternatives.

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LIMITATIONS

The services described in this report were performed consistent with generally accepted professional consulting principles and practices. No other warranty, express or implied, is made. These services were performed consistent with our agreement with our client. This report is solely for the use and information of our client unless otherwise noted. Any reliance on this report by a third party is at such party's sole risk.

Opinions and recommendations contained in this report apply to conditions existing when services were performed and are intended only for the client, purposes, locations, time frames, and project parameters indicated. We are not responsible for the impacts of any changes in environmental standards, practices, or regulations subsequent to performance of services. We do not warrant the accuracy of information supplied by others, nor the use of segregated portions of this report.

TABLES

Table 5-1

LNAPL Monitoring Data Summary
Port of SeattleTerminal 91 Feasibility Study
Seattle, Washington

Location	Well	Historical Apparent Thickness Range (feet)	Maximum 2008 Apparent Thickness (feet)	Comments
Lease Parcel, Small Yard	CP-116	0.1 to 0.9	—	No LNAPL recovery since 2001. Well decommissioned in 2004.
	CP-117	0.2 to 1.1	—	Consistent/seasonal recovery until well decommissioned in 2004.
	CP-PR01	0.01 to 0.4	0.09	Pilot test well installed in 2005.
	CP-PR11	Trace to 0.01	0.01	Data gap investigation well installed in 2007.
	CP-PR12	Trace to 1.59	1.59	Data gap investigation well installed in 2007.
Lease Parcel, Marine Diesel Oil Yard	CP-118	0.1 to 1.9	—	Consistent/seasonal recovery until well decommissioned in 2004.
	CP-119	0.1 to 1.6	—	Consistent/seasonal recovery until well decommissioned in 2004.
	CP-PR02	0.01 to 0.3	0.06	Pilot test well installed in 2005.
	CP-PR07	Trace to 0.49	0.49	Data gap investigation well installed in 2007.
	CP-PR08	Trace	Not detected	Data gap investigation well installed in 2007.
Lease Parcel, Black Oil Yard	CP-109	0.2 to 1.2	—	LNAPL thickness decreased to 0.0 to 0.02 ft by 2004. Well decommissioned in 2004.
	CP-PR03	Trace to 0.01	0.01	Data gap investigation well installed in 2007.
	CP-PR04	0.01 to 0.68	0.68	Data gap investigation well installed in 2007.
Between Lease Parcel and AOC 11	CP-107	0.1 to 0.3	Not detected	
	CP-110	0.2 to 0.8	Trace	Periodically contains a PLRD.
	UT-MW39-2	Not detected	0.25 to 0.71	Well monitored between August and December 2008.
	UT-MW39-3	0.1 to 1.6	Trace to 0.99	Periodically contains a PLRD.
AOC 11	PNO-MW104	0.06 to 0.19	0.12	Typical 2008 apparent thickness was 0.01 ft.
SWMU 30	PNO-EW01	0.0 to 1.02	Not monitored	Well under concrete barriers.
	PNO-MW03	0.0 to 1.43	Not detected	Periodically contains a PLRD.
	PNO-MW06A	0.0 to 0.01	Not detected	
	PNO-MW102	0.0 to 0.80	Not detected	
	PNO-MW103	0.0 to 0.08	Not detected	

Notes:

1. Historical LNAPL thickness range is approximate and rounded to the neared 0.1 ft from historical LNAPL monitoring data.
2. PLRD = passive LNAPL recovery device.
3. — = not applicable.

Table 5-2
LNAPL Physical Characteristic Data Summary
Residual Saturation Screening Level Evaluation
Port of Seattle Terminal 91 Feasibility Study
Seattle, WA

Well	Location	Density (g/cm^3)[a]		Viscosity (cStokes)[b]	
		Average	Range	Average	Range
Current LNAPL Monitoring Wells					
PR-02	Marine Diesel Oil Yard	0.89	NA	12.3	NA
PR-04	Black Oil Yard	0.92	NA	143.3	NA
PR-07	Marine Diesel Oil Yard	0.88	NA	8.2	NA
PR-12	Small Yard	0.88	NA	7.0	NA
CP-107	Between Lease Parcel and AOC11	0.87	NA	NA	NA
CP-110		0.95	NA	NA	NA
UT-MW-39-2		0.90	NA	17.0	NA
UT-MW-39-3		0.87	0.87 to 0.88	4.8	NA
Wells Decommissioned in 2004 Prior to Tank Farm Demolition					
CP-109	Black Oil Yard	0.92	0.89 to 0.96	NA	NA
CP-117	Small Yard	0.89	0.82 to 0.98	8.1	7.4 to 8.4
CP-118	Marine Diesel Oil Yard	0.88	0.88 to 0.89	5.2	NA
CP-119		0.91	0.90 to 0.91	NA	NA
Average LNAPL Data Summarized by Lease Parcel and Adjacent Area					
PR-04, CP-109	Black Oil Yard	0.92	0.89 to 0.96	143.3	NA
PR-02, PR-07, CP-118, CP-119	Marine Diesel Oil Yard	0.89	0.88 to 0.91	8.8	5.2 to 12.3
PR-12, CP-117	Small Yard	0.89	0.82 to 0.98	7.0	4.8 to 8.4
CP-107, CP-110, UT-MW-39-2, UT-MW-39-3	Between Lease Parcel and AOC11	0.89	0.87 to 0.95	4.8	NA
Site Wide Average					
	All Wells	0.92		143.3 / 7.2[c]	

Notes:

a) Density measurements are reported at 60 degrees Fahrenheit.

b) Viscosity measurements are reported at 40 degrees Centigrade except for PR-02, PR-04, and PR-07 which are reported at 60 degrees.

c) First value = LNAPL viscosity measured in sample from PR-4 (Black Oil Tank Farm), second value = average LNAPL viscosity from six samples collected from wells in the other lease parcel areas and the former pipeline area.

Table 5-3
Concentrations of Petroleum Hydrocarbons and Toluene in Soil Samples
Port of Seattle Terminal 91 Feasibility Study
Seattle, Washington

Soil Boring Number	Date Drilled	Sample Depth	Soil Saturation Status	Product-Related Observations	Total Petroleum Hydrocarbons (mg/kg) Gasoline Range	Qual	Diesel Range	Qual	Motor Oil Range	Qual	Toluene (mg/kg)	Qual
Phase 1 - Data Gaps Investigation												
	Lease Parcel											
DG-1	5/24/07	3	V	Extensive staining			18,000		23,000	F		
		6.5	Sm	Extensive staining			9,700		12,000	F		
DG-2	5/29/07	3	V				93		400			
		8	Sm				6.0	U	12	U		
DG-3	5/25/07	4	V				110		42			
		5	Sm	Slight staining			8,500		1,400			
		8.5	Sat	Slight staining, strong odor			10,000		1,200	U		
DG-4	5/24/07	3.5	V	Extensive, thick, sticky			14,000		15,000	F		
dup		3.5	V	Extensive, thick, sticky			12,000		12,000	F		
		7	Sm	Extensive, sticky			11,000		10,000			
DG-5	5/24/07	3	V	Thick, sticky, black			8,100		12,000			
		7	Sm	Extensive staining/smearing			13,000		14,000			
DG-6	5/29/07	2	V	Extensive, black, sticky, tar-like smearing			9,100		11,000			
		6.5	Sm	Moderate staining/smearing			11,000		13,000			
DG-7	5/29/07	3	V	Thick, sticky, tar-like smearing			17,000		17,000			
		10	Sat				48		17			
DG-8	5/22/07	2	V				9,100		8,600			
		7	Sm				27		36			
DG-9	5/29/07	3	V	Very extensive, black, sticky, tar-like			20,000		21,000			
		6.5	Sm	Extensive, black, tar-like liquid covering soil			37,000		41,000			
DG-10	5/22/07	2	V	Stained, soaked			8,300		11,000	F		
		8	Sm	Extensive staining			12,000		18,000			
DG-11	5/29/07	3	V	Moderate black, sticky, tar-like smearing			11,000		6,900			
		8	Sm	Extensive dark brown, smearing/staining			11,000		3,300			
DG-12	5/29/07	4	V/Sm				6.0		10	U		
		8	Sm/Sat				620		87	F		
DG-13	5/24/07	3	V	Extensive staining/smearing, sticky			16,000		20,000	F		
		7.5	Sm	Moderate smearing			5,600		8,100			
DG-14	5/24/07	4	V	Extensive smearing, sticky			20,000		22,000	F		
		8	Sm	Moderate smearing			6,700		7,900	F		
DG-15	5/23/07	4	V		19		470		42			
		8	Sm	Droplets	1,600		4,800		360			
		9.5	Sat	Product	4,100		11,000		1,100	U		
DG-16	5/23/07	2.5	V	Extensive smearing	960		9,600		1,600			
		5.5	Sm	Extensive smearing	1,400		7,100		840	J		
DG-17	5/23/07	3	V		550		840		59	J		
		7	Sm	Droplets	4,800		19,000		1,300	U		
		8	Sat	Droplets	3,800		22,000		1,300	J		
DG-18	5/29/07	4	V	Scattered droplets	130		240		38			
		8	Sm	Scattered droplets	3,500		17,000		1,100	U		
DG-19	5/23/07	3.5	V		16		410		170			
		7	Sm	Droplets	5,600		28,000		2,800	J		
		8.5	Sat	Droplets	2,300		7,900		760			
DG-20	5/25/07	2	V	Moderate staining	2,800		12,000		3,600			
		7.5	Sm	Moderate smearing, isolated droplets	3,800		16,000		1,800			
DG-21	5/23/07	2.5	V	Extensive smearing	1,700		11,000		4,700	J		
		8	Sm	Droplets	3,800		18,000		2,600	J		
		11	Sat	Product	3,200		9,200		570			
DG-22	5/23/07	3.5	V		1,200		2,700		280	J		
		7.5	Sm	Droplets, smeared	4,800		22,000	J	3,200	J		
dup		7.5	Sm	Droplets, smeared	4,100		15,000	J	2,500	J		
DG-23	5/25/07	3.5	V		220		770		170			
		7.5	Sm	Moderate staining	3,200		13,000		1,700			
		9	Sat	Moderate staining, strong odor	7,200		10,000		1,200	U		
DG-24	5/25/07	3	V	Moderate, thick, sticky smearing	1,200		7,600		8,400			
		7	Sm	Extensive smearing	3,800		31,000		8,000			
DG-25	5/25/07	3.5	V	Moderate, thick, sticky smearing	1,900		13,000		4,200			
		7	Sm	Moderate, thick, sticky smearing	2,900		17,000		2,000			
dup		7	Sm	Moderate, thick, sticky smearing	3,700		15,000		1,400			
DG-26	5/25/07	4	V	Scattered droplets	3,600		2,400		130			
		8	Sm	Limited visible product, odor	5,600		11,000		1,200	U		
		10	Sat	Scattered droplets	5,100		8,300		950	F		
DG-27	5/25/07	3	V	Extensive, sticky smearing	1,400		12,000		8,400			
		7.5	Sm	Extensive staining	2,300		12,000		3,300			
DG-28	5/31/07	3.5	V	Light smearing, scattered droplets	2,400		4,300		700			
		7.5	Sm	Moderate smearing/staining	5,600		14,000		1,900			
DG-29	5/25/07	2	V	Extensive, thick, sticky staining	1,400		5,400		5,100			
		7.5	Sm	Moderate smearing	5,700		16,000		2,700			
DG-30	5/25/07	1.5	V	Extensive, thick, sticky, tar-like smearing	960		9,800		6,900			
dup		1.5	V	Extensive, thick, sticky, tar-like smearing	1,100		7,600		5,500			
		7.5	Sm	Extensive, thick, sticky smearing	3,100		20,000		14,000			
DG-31	5/25/07	4	V	Odor	1,700		3,600		320			
		8	Sm	Scattered droplets, strong odor	8,000		7,900		570	U		
DG-32	5/22/07	3.5	V	Dark staining	2,400		3,700		2,500			
		8	Sm	Extensive staining	3,900		17,000		9,100			
DG-33	5/22/07	2	V	Dark product staining	680		7,100		5,500			
		7.5	Sm	Smeared	4,100	J	8,600		2,800			
dup		7.5	Sm	Smeared	330	J	9,100		3,000			

Table 5-3
Concentrations of Petroleum Hydrocarbons and Toluene in Soil Samples
Port of Seattle Terminal 91 Feasibility Study
Seattle, Washington

Soil Boring Number	Date Drilled	Sample Depth	Soil Saturation Status	Product-Related Observations	Total Petroleum Hydrocarbons (mg/kg) Gasoline Range	Qual	Diesel Range	Qual	Motor Oil Range	Qual	Toluene (mg/kg)	Qual
DG-34	5/22/07	8	Sm	Scattered droplets	6,200		130,000		20,000			
DG-34A	5/31/07	4	V	Strong odor (hydrocarbon-like?)	5,200		5,000		1,200			
DG-35	5/31/07	2.5	V	Extensive, thick, sticky	1,700	J	27,000		29,000			
dup		2.5	V	Extensive, thick, sticky	840	J	26,000		26,000			
		9	Sat	Moderate to extensive smearing/staining	3,400		8,800		600	U		
DG-36	5/24/07	3.5	V	Extensive, thick, sticky, brown	660		7,000		5,700			
		7	Sm	Extensive, dark brown	2,100		6,200		2,300			
DG-37	5/23/07	4.5	V	Extensive, sticky	2,400		9,100		5,900			
dup		4.5	V	Extensive, sticky	1,800		7,700		4,600			
		9	Sm/Sat	Odor only	3,400		5,600		1,400			
DG-38	5/24/07	4.5	V		390		1,200		1,400	F		
		8	Sm		1,900		5,700		1,200	U		
DG-39	5/24/07	4.5	V	Light to moderate smearing	790		5,800		3,800	F		
		8.5	Sm	Moderate droplets, smearing	1,400	J	4,700		2,100			
dup		8.5	Sm	Moderate droplets, smearing	2,000	J	4,000		2,000			
DG-40	5/25/07	3.5	V		930		5,100		7,200			
		8	Sm	Extensive, dark smearing	1,100		6,600		5,100			
DG-41	5/22/07	4	V	Sticky, stained	1,400		7,900	J	12,000	J		
		6	Sm	Droplets	2,800		5,100		5,300			
DG-42A	5/29/07	4	V	Extensive, heavy, sticky smearing	1,500		15,000		22,000			
		6	Sm	Extensive, heavy, sticky smearing	560		5,700		8,700			
DG-43	5/25/07	5	Sm	Slight staining, scattered droplets, odor	3,100		4,100		3,800			
		9	Sat	Scattered droplets, sheen	2,100		3,100		2,500			
DG-44A	5/31/07	4	V	Light smearing	430		590		1,200			
		8	Sm	Scattered droplets	4,600		2,200		210			
DG-45A	5/29/07	3	V	Slight smearing	360		3,100		6,700			
		6	Sm	Moderate dark brown staining	1,800	J	4,900		5,200			
dup		6	Sm	Moderate dark brown staining	1,100	J	4,600		4,900			
DG-46	5/24/07	3	V	Moderate staining	1,100		12,000		14,000			
		7.5	Sm	Moderate smearing	3,800		11,000		6,900			
DG-47A	5/31/07	2.5	V	Moderate smearing/staining	680		1,900		5,100			
		7	Sm	Occasional droplets	1,600		2,600		3,800			
DG-48A	5/31/07	4	V	Moderate to extensive smearing	1,100		4,300		10,000			
		7.5	Sm	Scattered droplets	800		4,700		9,400			
DG-49A	5/31/07	2	V	Moderate staining	1,400		4,400		5,300			
		7	Sm	Scattered droplets, strong solvent-like odor	13,000		8,100		5,800			
DG-50	5/23/07	2.5	V	Sticky, dark, smeared	1,400		9,500		16,000		3.1	
		7	Sm	Heavy, smeared, stained	21,000		15,000		15,000		520	
DG-51	5/23/07	3	V	Heavy, sticky, stained	3,100		8,300		13,000		32	
		6.5	Sm	Stained, non-hydrocarbon-like odor	22,000		13,000		15,000		1,200	
DG-52	5/23/07	2.5	V	Heavy, sticky, stained	3,800		13,000		18,000		11	
		6.5	Sm	Staining, hydrocarbon-like & other odors	18,000		6,500		11,000		1,700	
DG-53	5/24/07	2	V	Extensive, thick, sticky, dark	280		9,500		20,000	F	1.1	
		7.5	Sm	Extensive smearing	6,100		6,000		6,700		0.74	U
DG-54	5/23/07	3	V	Sticky, stained	540		5,700		13,000	F		
DG-55A	5/31/07	2.5	V	Moderate, thick, sticky	610		3,300		12,000		0.37	
		8	Sm	Light to moderate smearing, strong odor	3,100		10,000		11,000		38	
DG-56	5/23/07	2.5	V	Sticky	1,000		8,500		18,000		0.87	
		7	Sm	Droplets, solvent-like odor	4,800		9,900		8,900		0.57	U
DG-57	5/24/07	4.5	V		1,800		3,200		700			
		8	Sm	Scattered droplets	6,800		11,000		1,200	U		
DG-58	5/18/07	2	V		64		540		310			
		6	Sm	Sticky, heavy	4,900		5,300		6,600			
		10	Sat	Heavy	58		28,000		17,000			
DG-59	5/22/07	2	V		6.0	U	12		27			
		6	Sm		84		33		66	F		
		10	Sat	Sheen, scattered droplets	2,800		510		180			
DG-60	5/29/07	2.5	V		6.9		120		320			
		7	Sat		7.1	U	7.3		12	U		
		11	Sat	Scattered droplets, sheen	34		300		88	F		
DG-61	5/23/07	2	V		27		10	J	14	J		
		7	Sat	Scattered droplets	1,900		1,100		450			
		8.5	Sat	Moderate droplets	9,100		1,100		590	J		
DG-62	5/18/07	3	V/Sm		10	U	8.1		29			
		5	Sm	Hydrocarbon-like odor	3,500		9,400		730	F		
DG-63	5/18/07	2	V		5.7	U	410		220			
		6	Sm	Droplets	2,000		16,000		1,100	F		
DG-64	5/18/07	2	V		1,500		4,000		1,800			
		5	Sm		3,200		13,000		3,700			
		10	Sat	Droplets	2,000		7,500		560	U		
DG-65	5/18/07	1	V		280		4,600		800	F		
		6	Sm	Hydrocarbon-like odor	2,600		21,000		1,200	U		

Table 5-3
Concentrations of Petroleum Hydrocarbons and Toluene in Soil Samples
Port of Seattle Terminal 91 Feasibility Study
Seattle, Washington

Soil Boring Number	Date Drilled	Sample Depth	Soil Saturation Status	Product-Related Observations	Total Petroleum Hydrocarbons (mg/kg) Gasoline Range	Qual	Diesel Range	Qual	Motor Oil Range	Qual	Toluene (mg/kg)	Qual
AOC 11												
DG-66A	5/29/07	3	V		5.1	U	8.7		46			
		9	Sm		26		87		140			
DG-67	5/21/07	4	V		52		5.3	U	24			
		9	Sm		10		11		100			
DG-68	5/29/07	5	Sm	Moderate smearing	1,600		9,500		2,000			
		9	Sm	Moderate to extensive smearing	2,000		10,000		2,400			
DG-69	5/29/07	4	V	Scattered droplets	13		870		1,600			
		9	Sm	Scattered droplets	1,700		4,400		780			
DG-70	5/21/07	4	V		6.5		5.3	U	11	U		
		9	Sm		13		6.9	U	18			
DG-71	5/21/07	3	V		7.8	U	29		170			
		5.5	Sm		22		38		120			
DG-72	5/21/07	3.5	V		8.3	U	5.2	U	17			
		9.5	Sm		280		6.0	U	12	U		
DG-73	5/21/07	3.5	V		8.2		5.2	U	21			
		9.5	Sm		5,600		18		12	U		
DG-74	5/21/07	2.5	V		6.3	U	7.1		17			
		6	Sm		6.0	U	10		70			
DG-75	5/22/07	4	V		6.0		14		66	F		
		9	Sm	Scattered droplets	1,800		5,700		570	U		
dup		9	Sm	Scattered droplets	2,600		4,200		280	UF		
DG-76	5/21/07	3.5	V		12		5.5		10	U		
		8	Sm	Hydrocarbon-like odor	7.7	U	6.4	U	13	U		
DG-77	5/21/07	3	V		16		5.5	U	11	U		
		6	Sm	Hydrocarbon-like odor	95		290		12	U		
DG-78	5/21/07	3	V		20		170		160			
		8	Sm	Droplets	1,600		3,500		240	U		
DG-79	5/21/07	3.5	V		27		18		70			
		7	Sm		180		14		30	F		
DG-80	5/21/07	3.5	V		11		5.5	U	11	U		
		9	Sm		6,000		1,800		120	U		
DG-81	5/21/07	3.5	V		7.6		5.4	U	11	U		
		7.5	Sm		2,300		5,200		570	U		
DG-82	5/21/07	4.5	V		2,400	J	5,800	J	540	U		
dup		4.5	V		1,400	J	10,000	J	690	F		
		9	Sm	Scattered droplets	2,300		3,200		260	F		
dup		9	Sm	Scattered droplets	2,400		4,800		540	U		
SWMU 30												
DG-83	5/18/07	4	V				12		11	U		
		8	Sm	Fine droplets			20,000		1,400	F		
DG-84	5/18/07	4	V				78		210			
		8	Sm				5,000		330	F		
DG-85	5/18/07	3	V				10		12	U		
		8	Sm				800		230			
DG-86	5/18/07	4	V				100		140			
		8	Sm	Scattered droplets			19,000		1,000	U		
DG-87	5/18/07	5	V				32		13	U		
		8	Sm				3,600		320			
DG-88	5/18/07	5	V				9.7		57			
		8	Sm				2,400		250	F		
Phase 2 - Data Gaps Investigation												
DG-89	10/16/07	2	V				42	J	210			
		7	Sm/Sat	@6-7 feet: slight product smearing			4,400		550			
DG-90	10/16/07	3	V				12	U	44			
		6.5	Sm	@7-9 feet: slight hydrocarbon odor			6.7	U	12	U		
DG-91	10/16/07	2.5	V		38		29	J	110		0.160	
		6	Sm	@5.5-12 feet: hydrocarbon odor	2,900		7,000		5,400		0.150	U
		9.5	Sat	@8-12 feet: sheen	2,700		6,400		1,600		0.140	U
DG-92	10/16/07	2	V		100		220	J	800		0.014	U
		6	Sm	@4.5-12 feet: strong hydrocarbon odor	3,500		13,000		13,000		0.130	U
DG-93	10/16/07	3	V/Sm		13		8.6	U	26			
		7	Sat		2,300		360		120			
		10	Sat	Strong hydrocarbon odor, sheen on water	2,500		230		61			
DG-94	10/16/07	2.5	V		20		45	J	170			
		7	Sm/Sat	Hydrocarbon odor, product droplets	7,000		3,200		1,000			
		9	Sat	9-10 feet: strong hydrocarbon odor, sheen on wa	3,900		880		320			

Table 5-3
Concentrations of Petroleum Hydrocarbons and Toluene in Soil Samples
Port of Seattle Terminal 91 Feasibility Study
Seattle, Washington

Soil Boring Number	Date Drilled	Sample Depth	Soil Saturation Status	Product-Related Observations	Total Petroleum Hydrocarbons (mg/kg) Gasoline Range	Qual	Diesel Range	Qual	Motor Oil Range	Qual	Toluene (mg/kg)	Qual
Phase 3 - Data Gaps Investigation												
DG-95	9/16/08	3	V		6.0	U	27	U	54	U		
		7	Sm		7.2	U	31	U	62	U		
		10.5	Sat	@ 10.5 feet: tar-like?	5.7	U	29	U	59	U		
		11.5	Sat		6.4	U	29	U	58	U		
DG-96	9/16/08	3	V		4.5	U	26	U	52	U		
		6	Sm		5.6	U	28	U	56	U		
		10	Sat	@9-14.5 feet: hydrocarbon odor	12	U	870		230			
DG-97	9/16/08	3	V		5.6	U	28		170			
		7	Sm		13	U	260		91			
		11	Sat	@ 10 feet: sheen on water	7.4	U	1,200		630			
DG-98	9/16/08	3	V		5.5	U	44	U	870			
		6	Sm	@6-9 feet: unidentified odor	23	U	4,900		1,100			
		10	Sat		13	U	31	U	61	U		
DG-99	9/16/08	2.5	V		5.2	U	30	U	350			
		6	Sm	@6-13 feet: unidentified odor	30	U	5,500		1,100			
		12	Sat	@6-10 feet, 12-13 feet: sheen on water	12	U	1,400		290	U		
DG-100	9/16/08	3	V		9.8	U	26	U	32	U		
		6	Sm	@8 feet: sheen on water	32	U	13,000		950			
		10	Sat	@10 feet: scattered product droplets	30	U	14,000		810	U		
DG-101	9/17/08	3	V		24	U	2,700		1,200			
		5.5	Sm		53	U	16,000		4,300			
		11	Sat	@9-11 feet: hydrocarbon odor	12	U	2,400		290	U		
DG-102	9/16/08	3	V		10	U	3,000		530			
		6	Sm	@6.5-12 feet: unidentified odor	52	U	14,000		1,500			
		10	Sm/Sat	@10-13 feet: sheen on water	21	U	6,300		350			
DG-104	9/17/08	5.5	Sm		54	U	23,000		7,600			
		9	Sat	@8-10 feet: light brown product	63	U	10,000		910			
		13	Sat	@12-14 feet: sheen on water	61	U	5,200		720			
DG-114	9/17/08	5	Sm	@5-10 feet: light brown product	10	U	4,800		2,600			
		10	Sat	@10-14 feet: sheen on water	120	U	14,000		2,100			
		13	Sat		49	U	7,400		530			

Notes:
1. ft bgs = feet below ground surface.
2. Soil saturation status (based on historical water levels): v = vadose zone (always above the water table), sm = smear zone (seasonally below the water table), and sat = saturated zone (always below the water table).
3. Qual = laboratory or data review qualifier
4. Hydrocarbon identification analyses performed using Ecology Method NWTPH-HCID.
5. Gasoline quantification analyses performed using Ecology Method NWTPH-Gx.
6. Diesel-range and lube oil-range quantification analyses performed using Ecology Method NWTPH-Dx with acid and silica gel cleanup step.
7. Toluene analyses performed using USEPA Method 8021B.
8. > = greater than the concentration shown.
   < or U = not detected at the method reporting limit shown.
   F = the sample chromatographic pattern does not resemble the fuel standard used for quantitation.
   J = the analyte was positively identified. The associated numerical value is the approximate concentration of the analyte in the sample.

Table 5-4
Concentrations of PCBs in Soil Samples
Port of Seattle Terminal 91 Feasibility Study
Seattle, Washington

Soil Boring Number	Date Drilled	Sample Depth	Soil Saturation Status	PCBs (mg/kg) Total PCBs
DG-99	9/16/08	2.5	V	ND
		6	Sm	ND
		12	Sat	ND
DG-100	9/16/08	3	V	ND
		6	Sm	**0.42**
		10	Sat	ND
DG-101	9/17/08	3	V	**0.095**
		5.5	Sm	**0.71**
		11	Sat	ND
DG-102	9/16/08	3	V	**0.22**
		6	Sm	**0.63**
		10	Sm/Sat	ND
DG-103	9/16/08	2.5	V	ND
		5	Sm	ND
		13	Sat	ND
DG-104	9/17/08	5.5	Sm	**9.3**
		9	Sat	**0.21**
		13	Sat	**0.14**
DG-105	9/17/08	4	V/Sm	**2.04**
		7	Sm	**0.47**
		11	Sat	ND
DG-106	9/17/08	4	V/Sm	**0.76**
		8	Sm/Sat	ND
		10	Sat	ND
DG-107	9/17/08	3	V	**1.83**
		6	Sm	**0.91**
		11	Sat	ND
DG-108	9/17/08	3	V	**0.54**
		8	Sm/Sat	**0.70**
		10	Sat	ND
DG-109	9/17/08	4	V/Sm	ND
		5	Sm	ND
		10	Sat	ND
DG-110	9/17/08	4	V/Sm	**0.23**
		8	Sm/Sat	**0.345**
		9.5	Sat	ND
		11	Sat	ND
DG-111	9/18/08	3	V	**0.43**
		3 (dup)	V	**1.10**
		7	Sm	**0.557**
DG-112	9/18/08	4	V/Sm	ND
		7	Sm	ND
		7 (dup)	Sm	ND
		10	Sat	ND

Table 5-4
Concentrations of PCBs in Soil Samples
Port of Seattle Terminal 91 Feasibility Study
Seattle, Washington

Soil Boring Number	Date Drilled	Sample Depth	Soil Saturation Status	PCBs (mg/kg) Total PCBs
DG-113	9/17/08	3	V	ND
		6.5	Sm	**1.58**
		10	Sat	ND
DG-114	9/17/08	5	Sm	**1.6**
		10	Sat	**0.11**
		13	Sat	ND
DG-115	9/18/08	6	Sm	**2.07**
		10	Sat	ND
		12	Sat	ND
		12 (dup)	Sat	ND

Notes:

1. ft bgs = feet below ground surface.
2. Soil saturation status (based on historical water levels):
   - v = vadose zone (always above the water table);
   - sm = smear zone (seasonally below the water table); and
   - sat = saturated zone (always below the water table).
3. PCB analyses performed using EPA Method 8082.

Table 7-1
Groundwater Indicator Hazardous Substances List
Port of Seattle Terminal 91 Feasibility Study
Seattle, WA

CAS Number	Indicator Hazardous Substances (IHS)	Class	Number of Samples Analyzed	Number of Detected Results	Frequency of Detection (%)	Minimum Detected Result (ug/L)	Maximum Detected Result (ug/L)	Keep as IHS Based On the Frequency of Detection? (> 5%)	Keep as IHS Based On the Maximum Detected Results? (Maximum > 75th Percentile + 3 x Interquartile Range [IQR])[1]	Keep as IHS Based on Spatial Evaluation?	Rationale for Spatial Evaluation
7440-38-2	Arsenic	Inorganic	492	412	83.74	0.063	89.2	Yes	--	--	--
7440-39-3	Barium	Inorganic	46	32	69.57	10.6	344	Yes - Per Request from Ecology	--	--	--
7440-47-3	Chromium	Inorganic	492	283	57.52	0.6	61.8	Yes	--	--	--
7439-92-1	Lead	Inorganic	492	84	17.07	1	33.1	Yes	--	--	--
7439-97-6	Mercury	Inorganic	383	34	8.88	0.00557	2.03	Yes	--	--	--
7782-49-2	Selenium	Inorganic	46	26	56.52	1.1	10.2	Yes - Per Request from Ecology	--	--	--
7440-22-4	Silver	Inorganic	46	2	4.08	1.25	1.35	Yes - Per Request from Ecology	--	--	--
7440-66-6	Zinc	Inorganic	492	195	39.63	4	1470	Yes	--	--	--
68334-30-5	Diesel	Petroleum	518	181	34.94	260	19800	Yes	--	--	--
86290-81-5	Gasoline	Petroleum	518	241	46.53	50.6	7010	Yes	--	--	--
541-73-1	1,3-dichlorobenzene	Semi-Volatile	496	9	1.81	2.68	5.84	No	No	Yes	All 9 detections occurred at CP_107. The first detect was on 3/08/2002 and the most recent was on 9/21/2006. Concentrations ranged from 2.68 ug/L to 5.84 ug/L.
90-12-0	1-methylnaphthalene	Semi-Volatile	238	87	36.55	0.0485	189	Yes	--	--	--
105-67-9	2,4-dimethylphenol	Semi-Volatile	454	12	2.64	2.9	161	No	No	Yes	Detected at CP_106A [3/3/2004], CP_108A [10/5/2004], CP_GP12 [3/29/2005, 9/21/2005, 12/14/2005, 6/27/2005, 3/29/2006, 6/07/2006, 9/21/2006, 12/28/2006, 3/13/2007, 9/17/2007]. Concentrations ranged from 2.9 ug/L to 161 ug/L.
121-14-2	2,4-dinitrotoluene	Semi-Volatile	464	7	1.51	13	15.2	No	No	Yes	Detected at CP_114 [9/28/2005], CP_GP03A [9/28/2005], CP_GP05 [9/27/2005], CP_GP06 [10/24/2003], CP_GP08 [9/29/2005], CP_GP10 [9/29/2005], CP_GP11 [9/27/2005]. Concentrations ranged from 13 ug/L to 15.2 ug/L.
91-57-6	2-methylnaphthalene	Semi-Volatile	500	62	12.4	0.0486	69.25	Yes	--	--	--
95-48-7	2-methylphenol	Semi-Volatile	454	5	1.1	7	29	No	No	Yes	Detected at CP-GP12 on 6/27/2005, 9/21/2005, 12/14/2005, 3/13/2007, and 9/17/2007. Concentrations ranged from 7.0 ug/L to 29 ug/L.
106-44-5	4-methylphenol	Semi-Volatile	65	3	4.62	1.1	20	No	No	Yes	All 3 detections occurred at CP_G12 (12/28/2006, 3/13/2007, 9/17/2007). Concentrations ranged from 1.1 ug/L to 20.0 ug/L.
83-32-9	Acenaphthene	Semi-Volatile	500	261	52.2	0.011	115	Yes	--	--	--
208-96-8	Acenaphthylene	Semi-Volatile	494	93	18.83	0.017	4.72	Yes	--	--	--
120-12-7	Anthracene	Semi-Volatile	500	154	30.8	0.011	6.12	Yes	--	--	--
56-55-3	Benzo(a)anthracene	Semi-Volatile	499	36	7.21	0.011	1.21	Yes	--	--	--
50-32-8	Benzo(a)pyrene	Semi-Volatile	499	40	8.02	0.012	1.985	Yes	--	--	--
205-99-2	Benzo(b)fluoranthene	Semi-Volatile	499	43	8.62	0.02	3.96	Yes	--	--	--
UNK-009	Benzo(b,k)fluoranthene	Semi-Volatile	19	1	5.26	0.112	0.112	Yes	--	--	--
191-24-2	Benzo(g,h,i)perylene	Semi-Volatile	500	30	6	0.011	1.09	Yes	--	--	--
207-08-9	Benzo(k)fluoranthene	Semi-Volatile	499	42	8.42	0.01	8.11	Yes	--	--	--

Table 7-1
Groundwater Indicator Hazardous Substances List
Port of Seattle Terminal 91 Feasibility Study
Seattle, WA

CAS Number	Indicator Hazardous Substances (IHS)	Class	Number of Samples Analyzed	Number of Detected Results	Frequency of Detection (%)	Minimum Detected Result (ug/L)	Maximum Detected Result (ug/L)	Keep as IHS Based On the Frequency of Detection? (> 5%)	Keep as IHS Based On the Maximum Detected Results? (Maximum > 75th Percentile + 3 x Interquartile Range [IQR])[1]	Keep as IHS Based on Spatial Evaluation?	Rationale for Spatial Evaluation
65-85-0	Benzoic Acid	Semi-Volatile	454	12	2.64	9.76	22.4	No	No	Yes	Detected at CP_108A (10/05/04, 09/28/05, 09/18/06), CP_103A (03/04/04 & 09/18/06), CP_106B (10/23/03 & 03/03/04), CP_107 (03/10/04), CP_108B (09/20/05), CP_GP06 (10/24/03), PNO_MW06A (10/06/04), PNO_MW06B (10/06/04). Concentrations ranged from 9.76 ug/L to 22.4 ug/L.
86-74-8	Carbazole	Semi-Volatile	371	5	1.35	7.6	52.7	No	Yes	--	--
218-01-9	Chrysene	Semi-Volatile	499	42	8.42	0.01	1.6	Yes	--	--	--
53-70-3	Dibenz(a,h)anthracene	Semi-Volatile	499	23	4.61	0.059	1.58	No	Yes	--	--
132-64-9	Dibenzofuran	Semi-Volatile	465	14	3.01	0.82	37.1	No	No	Yes	Detected at CP_108A [2/25/2000 & 10/4/2000], CP_GP12 [3/29/2005, 9/21/2005, 12/14/2005, 6/27/2005, 3/29/2006, 12/28/2006, 3/13/2007, 9/17/2007], SHFLL_W10 [2/29/2000, 9/22/2006, 3/15/2007, 9/18/2007]. Concentrations ranged from 0.8 ug/L to 37.1 ug/L. Highest concentration detections are located to the east at well CP_GP12.
206-44-0	Fluoranthene	Semi-Volatile	500	167	33.4	0.02	23.4	Yes	--	--	--
86-73-7	Fluorene	Semi-Volatile	499	174	34.87	0.018	45.9	Yes	--	--	--
67-72-1	Hexachloroethane	Semi-Volatile	465	5	1.08	6.78	27.6	No	Yes	--	--
193-39-5	Indeno(1,2,3-cd)pyrene	Semi-Volatile	499	42	8.42	0.013	1.99	Yes	--	--	--
CRESOLS 34	Methylphenol, P-, M-	Semi-Volatile	326	2	0.61	28.4	44.35	No	No	Yes	Both detects occurred at CP_GP12. First detect was in 6/2005 and then 12/2005. Concentrations ranged from 28.4 ug/L to 44.4 ug/L. These 2 hits were separated by a nondetect in 9/21/05 (DL = 4.85 ug/L).
91-20-3	Naphthalene	Semi-Volatile	500	144	28.8	0.011	525	Yes	--	--	--
85-01-8	Phenanthrene	Semi-Volatile	500	164	32.8	0.011	55.25	Yes	--	--	--
129-00-0	Pyrene	Semi-Volatile	500	203	40.6	0.013	16.2	Yes	--	--	--
75-34-3	1,1-dichloroethane	Volatile	490	14	2.86	0.794	5.03	No	No	Yes	Six of the 14 detections were at CP-104A [2/28/2000, 3/1/2001, 3/7/2003, 3/9/2004, 10/4/2000, 10/3/2001] . The other 8 were at CP_104B [2/28/2000, 3/1/2001, 3/7/2003, 3/9/2004, 10/4/2000, 10/28/2003, 10/11/2002, 10/3/2001]. Concentrations ranged from 0.8 ug/L to 5 ug/L. The wells are located close together.
95-63-6	1,2,4-trimethylbenzene	Volatile	471	13	2.76	0.679	2.825	No	No	Yes	Detected at CP_103A [3/5/2003, 10/6/2000, 3/6/2002], CP_104A [10/4/2000, 3/7/2002], CP_108A [3/5/2003, 3/5/2002], CP_GP02 [3/8/2004, 12/12/2005], CP_GP12 [3/29/2005, 6/27/2005, 10/16/2002, 9/21/2006]. Concentrations ranged from 0.68 ug/L to 2.83 ug/L. Detections were scattered around the site. Each well had more than one hit (13 hits @ 5 wells). CP-GP12 didn't have a detection until 2005 - but had the highest detection of 2.83 on 6/27/05.
106-46-7	1,4-dichlorobenzene	Volatile	496	8	1.61	5.14	11.9	No	No	Yes	All 8 detections occurred at CP_107. The first detect was on 3/08/2002 and the most recent was on 9/21/2006. Concentrations ranged from 5.1 ug/L to 11.9 ug/L.
67-64-1	Acetone	Volatile	490	9	1.84	5.4	31.8	No	Yes	--	--
71-43-2	Benzene	Volatile	518	68	13.13	0.55	114	Yes	--	--	--
104-51-8	Butylbenzene,n-	Volatile	375	66	17.6	0.73	8.82	Yes	--	--	--

Table 7-1
Groundwater Indicator Hazardous Substances List
Port of Seattle Terminal 91 Feasibility Study
Seattle, WA

CAS Number	Indicator Hazardous Substances (IHS)	Class	Number of Samples Analyzed	Number of Detected Results	Frequency of Detection (%)	Minimum Detected Result (ug/L)	Maximum Detected Result (ug/L)	Keep as IHS Based On the Frequency of Detection? (> 5%)	Keep as IHS Based On the Maximum Detected Results? (Maximum > 75th Percentile + 3 x Interquartile Range [IQR])[1]	Keep as IHS Based on Spatial Evaluation?	Rationale for Spatial Evaluation
108-90-7	Chlorobenzene	Volatile	490	4	0.82	1.2	1.79	No	No	Yes	Detected at CP_W210. First detect was in 3/30/2005 and the last was 9/18/2007. Concentrations ranged from 1.2 ug/L to 1.79 ug/L.
75-00-3	Chloroethane	Volatile	490	60	12.24	1	20.2	Yes	--	--	--
156-59-2	Cis-1,2-dichloroethene	Volatile	490	11	2.24	0.356	2	No	No	Yes	Detected at CP_106A [2/25/2000, 3/6/2003, 3/3/2004, 10/23/2003, 10/6/2004, 10/14/2002, 3/7/2002, 10/2/2001], CP_104A [2/28/2000 AND 10/4/2000], CP_113 [2/28/2000]. Concentrations ranged from 0.36 ug/L to 2 ug/L.
100-41-4	Ethylbenzene	Volatile	518	29	5.6	0.232	380	Yes	--	--	--
98-82-8	Cumene	Volatile	375	101	26.93	0.564	35.1	Yes	--	--	--
103-65-1	n-Propylbenzene	Volatile	375	80	21.33	0.514	46	Yes	--	--	--
135-98-8	Sec-butylbenzene	Volatile	375	99	26.4	0.54	11.2	Yes	--	--	--
98-06-6	Tert-butylbenzene	Volatile	375	17	4.53	0.626	1.56	No	No	Yes	Detected at CP_103A [03/31/2006], CP_104A [10/04/2000, 10/11/2004], CP_108A [10/04/2000, 03/31/2006], CP_112 [10/04/2000, 10/29/2003, 03/10/2004, 10/12/2004], CP_113 [10/05/2000, 10/28/2003, 03/05/2004, 10/12/2004], CP_203B [03/04/2004, 03/29/2006], PNO_MW06A.[10/06/2004, 03/28/2005]. Concentrations ranged from 0.63 ug/L to 1.56 ug/L.
108-88-3	Toluene	Volatile	518	35	6.76	0.196	10	Yes	--	--	--
75-01-4	Vinyl Chloride	Volatile	490	27	5.51	0.276	4.43	Yes	--	--	--
1330-20-7	Xylenes (total)	Volatile	457	19	4.16	0.659	188.5	No	Yes	--	--

Notes:

-- = Not calculated/evaluated
% = Percent
[1] = IQR was calculated using detected results only
IHS = Indicator Hazardous Substances
IQR = Interquartile range (75^{th} percentile minus the 25^{th} percentile)
n/a = Not applicable – Could not calculate IQR because not enough detected results were available
ug/L = Micrograms per liter

Table 7-2
Area Background Groundwater Concentrations for the Site
Port of Seattle Terminal 91 Feasibility Study
Seattle, WA

CAS No.	Constituent	Class	Number of Samples Analyzed	Number of Detected Results	Distribution Type[2] (α = 0.05)	Lognormal[3] 90th Percentile (ug/L)	Lognormal[3] 4 x 50th Percentile (ug/L)	Background[4] (ug/L)	Basis
7440-38-2	Arsenic	Inorganics	82	65	Unknown	6.64	4.71	4.71	WAC 173-340-709 - 4 x 50th Percentile Background
7440-47-3	Chromium	Inorganics	82	41	Unknown	14.44	7.31	7.31	WAC 173-340-709 - 4 x 50th Percentile Background
7439-92-1	Lead	Inorganics	82	22	Unknown	2.47	3.15	2.47	WAC 173-340-709 - 90th Percentile Background
7439-97-6	Mercury[1]	Inorganics	56	7	Unknown	0.01	0.02	0.01	WAC 173-340-709 - 90th Percentile Background
7440-66-6	Zinc	Inorganics	82	28	Unknown	42.90	38.26	38.26	WAC 173-340-709- 4 x 50th Percentile Background

Notes:

Background concentrations were calculated using both Onsite and Upland Wells.

Non-detected results were included in the calculations using half of the detection limit.

[1] Non-detect results from February 2000 to March 2002 were analyzed using a different analytical method (i.e., SW7470 and SW7470A) than the rest of the dataset (i.e., C245.2, Hg Total CVAF 1631, and SW1631) resulting in significantly higher detection limit (1.0 ug/L) and skewing the background analysis. For this reason, the non-detected mercury results from February 2000 to March 2002 for CP-106A, CP-106B, CP-114, CP-205A, and CP-205B, were not included in the background calculation for mercury.

[2] The distribution type was determined using D' Agostino test. Distribution type = Unknown means that the data are not normally or lognormally distributed per the D' Agostino test. However, per WAC 173-340-709 (3)(b) – The data were assumed to be lognormally distributed unless the distribution test indicated that the data were normally distributed.

[3] Per Ecology's 1992 Statistical Guidance for Ecology Site Managers, the 90th percentile of the lognormally distributed data sets was estimated using the following equation: $X_{90} = e^M$. M = x + ((1.28)*(s)); where, **x** is the mean of the natural log transformed data and **s** is the standard deviation of the natural log transformed data. The 50th percentile of the lognormally distributed data sets was estimated using the following equation: $X_{50} = e^M$. M = x + ((0)*(s)); where, **x** is the mean of the natural log transformed data and **s** is the standard deviation of the natural log transformed data.

[4] Per WAC 173-340-709 (3) (c), the background concentration is equivalent to the minimum of the 90th percentile and four times the 50th percentile.

Table 7-3
Final Cleanup Levels for Shallow[1] Groundwater
Port of Seattle Terminal 91 Feasibility Study
Seattle, WA

CAS Number	Indicator Hazardous Substance	Class	Final Recommended Ecological Cleanup Level for Surface Water (ug/L)	Basis of Final Ecological Cleanup Level	Rationale for Selecting this CUL for Final CUL (if not most protective)	Most Protective Human Health Cleanup Level for Groundwater (ug/L)[2]	Basis of Final Human Health Cleanup Level for Shallow Groundwater	Groundwater PQL[3] (ug/L)	Area Background Concentration for Groundwater[4] (ug/L)	Final FS Shallow Groundwater CUL[5] (ug/L)	Basis for Final FS CUL
7440-38-2	Arsenic	Inorganic	36	State WQS		0.042	API Fisher MTCA Method B - 730-2 Modified Ingestion of Fish	0.2	4.71	**4.7**	Background
7440-39-3	Barium	Inorganic	5,700	ECOTOX		55,300	API Fisher MTCA Method B - 730-1 Modified Ingestion of Fish	0.5		**5,700**	Ecological
7440-47-3	Chromium	Inorganic	74	AWQC		104,000	API Fisher MTCA Method B - 730-1 Modified Ingestion of Fish	0.5	7.31	**74**	Ecological
7439-92-1	Lead	Inorganic	8.10	State WQS	Marine chronic; regulatory threshold	--		1	2.47	**8.1**	Ecological
7439-97-6	Mercury	Inorganic	0.030	State WQS	Marine chronic; regulatory threshold	0.300	AWQC Federal Human Health Consumption of Organisms Only	0.02	0.01	**0.03**	Ecological
7782-49-2	Selenium	Inorganic	71	State WQS	Marine chronic; regulatory threshold	27.6	API Fisher MTCA Method B - 730-1 Modified Ingestion of Fish	0.5		**27.6**	Human Health
7440-22-4	Silver	Inorganic	1.90	State WQS		1,100	API Fisher MTCA Method B - 730-1 Modified Ingestion of Fish	0.2		**1.9**	Ecological
7440-66-6	Zinc	Inorganic	81	State WQS		5,000	AWQC Federal Organoleptic Effect Criteria	4	38.3	**81**	Ecological
68334-30-5	Diesel	Petroleum				500	Petroleum Related MTCA Method A Table 720-1 Values	250		**500**	Human Health
86290-81-5	Gasoline	Petroleum				800	Petroleum Related MTCA Method A Table 720-1 Values	250		**800**	Human Health
541-73-1	1,3-dichlorobenzene	Semi-Volatile	206	ECOTOX		33.2	API Fisher MTCA Method B - 730-1 Modified Ingestion of Fish	1		**33.2**	Human Health
90-12-0	1-methylnaphthalene	Semi-Volatile	1,190	ECOTOX		31.6	API Fisher MTCA Method B - 730-1 Modified Ingestion of Fish	0.01		**31.6**	Human Health
105-67-9	2,4-dimethylphenol	Semi-Volatile	397	ECOTOX		236	API Fisher MTCA Method B - 730-1 Modified Ingestion of Fish	1		**236**	Human Health
121-14-2	2,4-dinitrotoluene	Semi-Volatile	307	ECOTOX		3.40	AWQC Federal Human Health Consumption of Organisms Only	1		**3.4**	Human Health
91-57-6	2-methylnaphthalene	Semi-Volatile	373	ECOTOX		421	API Fisher MTCA Method B - 730-1 Modified Ingestion of Fish	0.01		**373**	Ecological
95-48-7	2-methylphenol	Semi-Volatile	4,020	ECOTOX		8,770	API Fisher MTCA Method B - 730-1 Modified Ingestion of Fish	1		**4,020**	Ecological
106-44-5	4-methylphenol	Semi-Volatile	1,830	ECOTOX		891	API Fisher MTCA Method B - 730-1 Modified Ingestion of Fish	1		**891**	Human Health
83-32-9	Acenaphthene	Semi-Volatile	34	ECOTOX		20	AWQC Federal Organoleptic Effect Criteria	0.01		**20**	Human Health
208-96-8	Acenaphthylene	Semi-Volatile	10.7	SMS		--		0.01		**10.7**	Ecological
120-12-7	Anthracene	Semi-Volatile	2.68	ECOTOX		11,000	API Fisher MTCA Method B - 730-1 Modified Ingestion of Fish	0.01		**2.7**	Ecological
56-55-3	Benzo(a)anthracene	Semi-Volatile	0.276	SMS		0.018	AWQC Federal Human Health Consumption of Organisms Only	0.01		**0.02**	Human Health
50-32-8	Benzo(a)pyrene	Semi-Volatile	0.110	ECOTOX		0.013	API Fisher MTCA Method B - 730-2 Modified Ingestion of Fish	0.01		**0.01**	Human Health
205-99-2	Benzo(b)fluoranthene	Semi-Volatile	0.187	SMS		0.018	AWQC Federal Human Health Consumption of Organisms Only	0.01		**0.02**	Human Health
UNK-009	Benzo(b,k)fluoranthene	Semi-Volatile	0.187	SMS		0.126	API Fisher MTCA Method B - 730-2 Modified Ingestion of Fish	0.01		**0.13**	Human Health
191-24-2	Benzo(g,h,i)perylene	Semi-Volatile	0.012	SMS		--		0.01		**0.01**	Ecological
207-08-9	Benzo(k)fluoranthene	Semi-Volatile	0.187	SMS		0.018	AWQC Federal Human Health Consumption of Organisms Only	0.01		**0.02**	Human Health
65-85-0	Benzoic Acid	Semi-Volatile	2,950	ECOTOX		280,000	API Fisher MTCA Method B - 730-1 Modified Ingestion of Fish	1		**2,950**	Ecological
86-74-8	Carbazole	Semi-Volatile	299	ECOTOX		0.921	API Fisher MTCA Method B - 730-2 Modified Ingestion of Fish	1		**0.9**	Human Health
218-01-9	Chrysene	Semi-Volatile	1,560	ECOTOX		0.018	AWQC Federal Human Health Consumption of Organisms Only	0.01		**0.02**	Human Health
53-70-3	Dibenz(a,h)anthracene	Semi-Volatile	0.003	SMS		0.018	AWQC Federal Human Health Consumption of Organisms Only	0.01		**0.01**	PQL
132-64-9	Dibenzofuran	Semi-Volatile	268	ECOTOX		14.70	API Fisher MTCA Method B - 730-1 Modified Ingestion of Fish	0.01		**14.7**	Human Health
206-44-0	Fluoranthene	Semi-Volatile	4.10	ECOTOX		38.40	API Fisher MTCA Method B - 730-1 Modified Ingestion of Fish	0.01		**4.1**	Ecological
86-73-7	Fluorene	Semi-Volatile	78	ECOTOX		1,470	API Fisher MTCA Method B - 730-1 Modified Ingestion of Fish	0.01		**78**	Ecological
67-72-1	Hexachloroethane	Semi-Volatile	NR			2.27	API Fisher MTCA Method B - 730-2 Modified Ingestion of Fish	1		**2.3**	Human Health
193-39-5	Indeno(1,2,3-cd)pyrene	Semi-Volatile	0.01	SMS		0.018	AWQC Federal Human Health Consumption of Organisms Only	0.01		**0.01**	Ecological
CRESOLS34	Methylphenol, P-, M-	Semi-Volatile	1,250	ECOTOX		--		1		**1,250**	Ecological
91-20-3	Naphthalene	Semi-Volatile	97	ECOTOX		2,110	API Fisher MTCA Method B - 730-1 Modified Ingestion of Fish	0.01		**97**	Ecological
85-01-8	Phenanthrene	Semi-Volatile	22	ECOTOX		--		0.01		**22**	Ecological
129-00-0	Pyrene	Semi-Volatile	35	ECOTOX		1,110	API Fisher MTCA Method B - 730-1 Modified Ingestion of Fish	0.01		**35**	Ecological
75-34-3	1,1-dichloroethane	Volatile	2,800	ORNL		17,500	Commercial MTCA Method C - 750-1 Inhalation of Indoor Air	0.2		**2,800**	Ecological
95-63-6	1,2,4-trimethylbenzene	Volatile	NR			320	Commercial MTCA Method C - 750-1 Inhalation of Indoor Air	0.2		**320**	Human Health
106-46-7	1,4-dichlorobenzene	Volatile	NR			2.07	API Fisher MTCA Method B - 730-2 Modified Ingestion of Fish	0.2		**2.1**	Human Health

Table 7-3
Final Cleanup Levels for Shallow[1] Groundwater
Port of Seattle Terminal 91 Feasibility Study
Seattle, WA

CAS Number	Indicator Hazardous Substance	Class	Final Recommended Ecological Cleanup Level for Surface Water (ug/L)	Basis of Final Ecological Cleanup Level	Rationale for Selecting this CUL for Final CUL (if not most protective)	Most Protective Human Health Cleanup Level for Groundwater (ug/L)[2]	Basis of Final Human Health Cleanup Level for Shallow Groundwater	Groundwater PQL[3] (ug/L)	Area Background Concentration for Groundwater[4] (ug/L)	Final FS Shallow Groundwater CUL[5] (ug/L)	Basis for Final FS CUL
67-64-1	Acetone	Volatile	NR			311,000	API Fisher MTCA Method B - 730-1 Modified Ingestion of Fish	1		**311,000**	Human Health
71-43-2	Benzene	Volatile	NR			9.66	API Fisher MTCA Method B - 730-2 Modified Ingestion of Fish	0.2		**9.7**	Human Health
104-51-8	Butylbenzene,n-	Volatile	NR			--		0.2			
108-90-7	Chlorobenzene	Volatile	NR			20	AWQC Federal Organoleptic Effect Criteria	0.2		**20**	Human Health
75-00-3	Chloroethane	Volatile	230,000	USGS		381	API Fisher MTCA Method B - 730-2 Modified Ingestion of Fish	0.2		**381**	Human Health
156-59-2	Cis-1,2-dichloroethene	Volatile	11,600	USGS		1,360	API Fisher MTCA Method B - 730-1 Modified Ingestion of Fish	0.2		**1,360**	Human Health
100-41-4	Ethylbenzene	Volatile	NR			2,100	AWQC Federal Human Health Consumption of Organisms Only	0.2		**2,100**	Human Health
98-82-8	Cumene	Volatile	NR			850	API Fisher MTCA Method B - 730-1 Modified Ingestion of Fish	0.2		**850**	Human Health
103-65-1	n-Propylbenzene	Volatile	NR			1,160	API Fisher MTCA Method B - 730-1 Modified Ingestion of Fish	0.2		**1,160**	Human Health
135-98-8	Sec-butylbenzene	Volatile	NR			152	API Fisher MTCA Method B - 730-1 Modified Ingestion of Fish	0.2		**152**	Human Health
98-06-6	Tert-butylbenzene	Volatile	NR			152	API Fisher MTCA Method B - 730-1 Modified Ingestion of Fish	0.2		**152**	Human Health
108-88-3	Toluene	Volatile	NR			8,260	API Fisher MTCA Method B - 730-1 Modified Ingestion of Fish	0.2		**8,260**	Human Health
75-01-4	Vinyl Chloride	Volatile	930	RAIS		1.69	API Fisher MTCA Method B - 730-2 Modified Ingestion of Fish	0.2		**1.7**	Human Health
1330-20-7	Xylene (total)	Volatile	NR			1,160	API Fisher MTCA Method B - 730-1 Modified Ingestion of Fish	0.4		**1,160**	Human Health

Notes:

Final FS CULs = These are the most stringent applicable CULs and are the initial CULs that will be considered in the Feasibility Study (FS). As such, they may be adjusted upward or downward based on area background concentrations, practical quantitation limits, or other information, as appropriate, in the FS.
-- = Toxicity value not available to calculate CUL
API Fisher = Asian Pacific Islander Fisherman
AWQC = Federal Ambient Water Quality Criteria (Section 304 of the Clean Water Act)
CR = Cancer Risk
CUL = Cleanup Level
ECOTOX = U.S. EPA Ecotoxicity Database - available on-line at http://www.epa.gov/ecotox/
HQ = Hazard Quotient
MTCA = Model Toxics Control Act (WAC 173-340)
No BCF = No bioconcentration factor was available to calculate the cleanup level
No Alpha = No groundwater to indoor air volatilization factor was available to calculate the cleanup level
No RfD = No Reference Dose was available to calculate the cleanup level
No SF = No Slope Factor was available to calculate the cleanup level
PQL = Practical Quantitation Limit
NR = No value recommended. Difficulties in the exposure methods of the tests used to derive values resulted in values being highly uncertain.
ORNL = Oak Ridge Nation Laboratory Toxicological Benchmarks for Screening Potential Contaminants of Concern for Effects
RAIS = Risk Assessment Information System - available online at http://risk.lsd.ornl.gov/index.shtml
SMS = Sediment Management Standards
USGS 1999 = United States Geological Survey - Selection Procedure and Salient Information for Volatile
WQS = Water Quality Standards
[1]Shallow groundwater wells were screened at a maximum depth of 21 feet below ground surface (bgs)
[2] Based on protection of surface water and protection from vapor intrusion
[3] PQLs were acquired from ARI Laboratories, Inc. *Personal Communication with Susan Dunnihoo, July 22, 2008* .
[4]Based on Terminal 91 Tank Farm Site Background Groundwater Evaluation (PIONEER, 2007)
[5]Based on Terminal 91 Tank Farm Site Feasibility Study Cleanup Levels (PIONEER, 2008)

Table 7-4
Final Cleanup Levels for Deep[1] Groundwater
Port of Seattle Terminal 91 Feasibility Study
Seattle, WA

CAS Number	Indicator Hazardous Substance	Class	Final Recommended Ecological Cleanup Level for Surface Water (ug/L)	Basis of Final Ecological Cleanup Level for Surface Water	Rationale for Selecting this CUL for Final CUL (if not most protective)	Most Protective Human Health Cleanup Level for Groundwater (ug/L)[2]	Basis of Final Human Health Cleanup Level for Deep Groundwater	Groundwater PQL[3] (ug/L)	Area Background Concentration for Groundwater[4] (ug/L)	Final FS Deep Groundwater CUL[4] (ug/L)	Basis for Final FS CUL
7440-38-2	Arsenic	Inorganic	36	State WQS		0.042	API Fisher MTCA Method B - 730-2 Modified Ingestion of Fish	0.2	4.71	**4.7**	Background
7440-39-3	Barium	Inorganic	5,700	ECOTOX		55,300	API Fisher MTCA Method B - 730-1 Modified Ingestion of Fish	0.5		**5,700**	Ecological
7440-47-3	Chromium	Inorganic	74	AWQC		104,000	API Fisher MTCA Method B - 730-1 Modified Ingestion of Fish	0.5	7.31	**74**	Ecological
7439-92-1	Lead	Inorganic	8.10	State WQS	Marine chronic; regulatory threshold	--		1	2.47	**8.1**	Ecological
7439-97-6	Mercury	Inorganic	0.030	State WQS	Marine chronic; regulatory threshold	0.300	AWQC Federal Human Health Consumption of Organisms Only	0.02	0.01	**0.03**	Ecological
7782-49-2	Selenium	Inorganic	71	State WQS	Marine chronic; regulatory threshold	27.6	API Fisher MTCA Method B - 730-1 Modified Ingestion of Fish	0.5		**27.6**	Human Health
7440-22-4	Silver	Inorganic	1.90	State WQS		1,100	API Fisher MTCA Method B - 730-1 Modified Ingestion of Fish	0.2		**1.9**	Ecological
7440-66-6	Zinc	Inorganic	81	State WQS		5,000	AWQC Federal Organoleptic Effect Criteria	4	38.3	**81**	Ecological
68334-30-5	Diesel	Petroleum				500	Petroleum Related MTCA Method A Table 720-1 Values	250		**500**	Human Health
86290-81-5	Gasoline	Petroleum				800	Petroleum Related MTCA Method A Table 720-1 Values	250		**800**	Human Health
541-73-1	1,3-dichlorobenzene	Semi-Volatile	206	ECOTOX		33.2	API Fisher MTCA Method B - 730-1 Modified Ingestion of Fish	1		**33.2**	Human Health
90-12-0	1-methylnaphthalene	Semi-Volatile	1,190	ECOTOX		31.6	API Fisher MTCA Method B - 730-1 Modified Ingestion of Fish	0.01		**31.6**	Human Health
105-67-9	2,4-dimethylphenol	Semi-Volatile	397	ECOTOX		236	API Fisher MTCA Method B - 730-1 Modified Ingestion of Fish	1		**236**	Human Health
121-14-2	2,4-dinitrotoluene	Semi-Volatile	307	ECOTOX		3.40	AWQC Federal Human Health Consumption of Organisms Only	1		**3.4**	Human Health
91-57-6	2-methylnaphthalene	Semi-Volatile	373	ECOTOX		421	API Fisher MTCA Method B - 730-1 Modified Ingestion of Fish	0.01		**373**	Ecological
95-48-7	2-methylphenol	Semi-Volatile	4,020	ECOTOX		8,770	API Fisher MTCA Method B - 730-1 Modified Ingestion of Fish	1		**4,020**	Ecological
106-44-5	4-methylphenol	Semi-Volatile	1,830	ECOTOX		891	API Fisher MTCA Method B - 730-1 Modified Ingestion of Fish	1		**891**	Human Health
83-32-9	Acenaphthene	Semi-Volatile	34	ECOTOX		20	AWQC Federal Organoleptic Effect Criteria	0.01		**20**	Human Health
208-96-8	Acenaphthylene	Semi-Volatile	10.7	SMS		--		0.01		**10.7**	Ecological
120-12-7	Anthracene	Semi-Volatile	2.68	ECOTOX		11,000	API Fisher MTCA Method B - 730-1 Modified Ingestion of Fish	0.01		**2.7**	Ecological
56-55-3	Benzo(a)anthracene	Semi-Volatile	0.276	SMS		0.018	AWQC Federal Human Health Consumption of Organisms Only	0.01		**0.02**	Human Health
50-32-8	Benzo(a)pyrene	Semi-Volatile	0.110	ECOTOX		0.013	API Fisher MTCA Method B - 730-2 Modified Ingestion of Fish	0.01		**0.01**	Human Health
205-99-2	Benzo(b)fluoranthene	Semi-Volatile	0.187	SMS		0.018	AWQC Federal Human Health Consumption of Organisms Only	0.01		**0.02**	Human Health
UNK-009	Benzo(b,k)fluoranthene	Semi-Volatile	0.187	SMS		0.126	API Fisher MTCA Method B - 730-2 Modified Ingestion of Fish	0.01		**0.13**	Human Health
191-24-2	Benzo(g,h,i)perylene	Semi-Volatile	0.012	SMS		--		0.01		**0.01**	Ecological
207-08-9	Benzo(k)fluoranthene	Semi-Volatile	0.187	SMS		0.018	AWQC Federal Human Health Consumption of Organisms Only	0.01		**0.02**	Human Health
65-85-0	Benzoic Acid	Semi-Volatile	2,950	ECOTOX		280,000	API Fisher MTCA Method B - 730-1 Modified Ingestion of Fish	1		**2,950**	Ecological
86-74-8	Carbazole	Semi-Volatile	299	ECOTOX		0.921	API Fisher MTCA Method B - 730-2 Modified Ingestion of Fish	1		**0.9**	Human Health
218-01-9	Chrysene	Semi-Volatile	1,560	ECOTOX		0.018	AWQC Federal Human Health Consumption of Organisms Only	0.01		**0.02**	Human Health
53-70-3	Dibenz(a,h)anthracene	Semi-Volatile	0.003	SMS		0.018	AWQC Federal Human Health Consumption of Organisms Only	0.01		**0.01**	PQL
132-64-9	Dibenzofuran	Semi-Volatile	268	ECOTOX		14.70	API Fisher MTCA Method B - 730-1 Modified Ingestion of Fish	0.01		**14.7**	Human Health
206-44-0	Fluoranthene	Semi-Volatile	4.10	ECOTOX		38.40	API Fisher MTCA Method B - 730-1 Modified Ingestion of Fish	0.01		**4.1**	Ecological
86-73-7	Fluorene	Semi-Volatile	78	ECOTOX		1,470	API Fisher MTCA Method B - 730-1 Modified Ingestion of Fish	0.01		**78**	Ecological
67-72-1	Hexachloroethane	Semi-Volatile	NR			2.27	API Fisher MTCA Method B - 730-2 Modified Ingestion of Fish	1		**2.3**	Human Health
193-39-5	Indeno(1,2,3-cd)pyrene	Semi-Volatile	0.01	SMS		0.018	AWQC Federal Human Health Consumption of Organisms Only	0.01		**0.01**	Ecological
CRESOLS34	Methylphenol, P-, M-	Semi-Volatile	1,250	ECOTOX		--		1		**1,250**	Ecological
91-20-3	Naphthalene	Semi-Volatile	97	ECOTOX		2,110	API Fisher MTCA Method B - 730-1 Modified Ingestion of Fish	0.01		**97**	Ecological
85-01-8	Phenanthrene	Semi-Volatile	22	ECOTOX		--		0.01		**22**	Ecological
129-00-0	Pyrene	Semi-Volatile	35	ECOTOX		1,110	API Fisher MTCA Method B - 730-1 Modified Ingestion of Fish	0.01		**35**	Ecological
75-34-3	1,1-dichloroethane	Volatile	2,800	ORNL		23,000	API Fisher MTCA Method B - 730-1 Modified Ingestion of Fish	0.2		**2,800**	Ecological
95-63-6	1,2,4-trimethylbenzene	Volatile	NR			643	API Fisher MTCA Method B - 730-1 Modified Ingestion of Fish	0.2		**643**	Human Health

Table 7-4
Final Cleanup Levels for Deep[1] Groundwater
Port of Seattle Terminal 91 Feasibility Study
Seattle, WA

CAS Number	Indicator Hazardous Substance	Class	Final Recommended Ecological Cleanup Level for Surface Water (ug/L)	Basis of Final Ecological Cleanup Level for Surface Water	Rationale for Selecting this CUL for Final CUL (if not most protective)	Most Protective Human Health Cleanup Level for Groundwater (ug/L)[2]	Basis of Final Human Health Cleanup Level for Deep Groundwater	Groundwater PQL[3] (ug/L)	Area Background Concentration for Groundwater[4] (ug/L)	Final FS Deep Groundwater CUL[4] (ug/L)	Basis for Final FS CUL
106-46-7	1,4-dichlorobenzene	Volatile	NR			2.07	API Fisher MTCA Method B - 730-2 Modified Ingestion of Fish	0.2		**2.1**	Human Health
67-64-1	Acetone	Volatile	NR			311,000	API Fisher MTCA Method B - 730-1 Modified Ingestion of Fish	1		**311,000**	Human Health
71-43-2	Benzene	Volatile	NR			9.66	API Fisher MTCA Method B - 730-2 Modified Ingestion of Fish	0.2		**9.7**	Human Health
104-51-8	Butylbenzene,n-	Volatile	NR			--		0.2			
108-90-7	Chlorobenzene	Volatile	NR			20	AWQC Federal Organoleptic Effect Criteria	0.2		**20**	Human Health
75-00-3	Chloroethane	Volatile	230,000	USGS		381	API Fisher MTCA Method B - 730-2 Modified Ingestion of Fish	0.2		**381**	Human Health
156-59-2	Cis-1,2-dichloroethene	Volatile	11,600	USGS		1,360	API Fisher MTCA Method B - 730-1 Modified Ingestion of Fish	0.2		**1,360**	Human Health
100-41-4	Ethylbenzene	Volatile	NR			2,100	AWQC Federal Human Health Consumption of Organisms Only	0.2		**2,100**	Human Health
98-82-8	Cumene	Volatile	NR			850	API Fisher MTCA Method B - 730-1 Modified Ingestion of Fish	0.2		**850**	Human Health
103-65-1	n-Propylbenzene	Volatile	NR			1,160	API Fisher MTCA Method B - 730-1 Modified Ingestion of Fish	0.2		**1,160**	Human Health
135-98-8	Sec-butylbenzene	Volatile	NR			152	API Fisher MTCA Method B - 730-1 Modified Ingestion of Fish	0.2		**152**	Human Health
98-06-6	Tert-butylbenzene	Volatile	NR			152	API Fisher MTCA Method B - 730-1 Modified Ingestion of Fish	0.2		**152**	Human Health
108-88-3	Toluene	Volatile	NR			8,260	API Fisher MTCA Method B - 730-1 Modified Ingestion of Fish	0.2		**8,260**	Human Health
75-01-4	Vinyl Chloride	Volatile	930	RAIS		1.69	API Fisher MTCA Method B - 730-2 Modified Ingestion of Fish	0.2		**1.7**	Human Health
1330-20-7	Xylene (total)	Volatile	NR			1,160	API Fisher MTCA Method B - 730-1 Modified Ingestion of Fish	0.4		**1,160**	Human Health

Notes:

Final FS CULs = These are the most stringent applicable CULs and are the initial CULs that will be considered in the Feasibility Study (FS). As such, they may be adjusted upward or downward based on area background concentrations, practical quantitation limits, or other information, as appropriate, in the FS.
-- = Toxicity value not available to calculate CUL
API Fisher = Asian Pacific Islander Fisherman
AWQC = Federal Ambient Water Quality Criteria (Section 304 of the Clean Water Act)
CR = Cancer Risk
CUL = Cleanup Level
ECOTOX = U.S. EPA Ecotoxicity Database - available on-line at http://www.epa.gov/ecotox/
HQ = Hazard Quotient
MTCA = Model Toxics Control Act (WAC 173-340)
No BCF = No bioconcentration factor was available to calculate the cleanup level
No Alpha = No groundwater to indoor air volatilization factor was available to calculate the cleanup level
No RfD = No Reference Dose was available to calculate the cleanup level
No SF = No Slope Factor was available to calculate the cleanup level
PQL = Practical Quantitation Limit
NR = No value recommended. Difficulties in the exposure methods of the tests used to derive values resulted in values being highly uncertain.
ORNL = Oak Ridge Nation Laboratory Toxicological Benchmarks for Screening Potential Contaminants of Concern for Effects
RAIS = Risk Assessment Information System - available online at http://risk.lsd.ornl.gov/index.shtml
SMS = Sediment Management Standards
USGS 1999 = United States Geological Survey - Selection Procedure and Salient Information for Volatile
WQS = Water Quality Standards
[1]Deep groundwater wells were screened at a maximum depth of 60 feet below ground surface (bgs)
[2] Based on protection of surface water and protection from vapor intrusion
[3] PQLs were acquired from ARI Laboratories, Inc. *Personal Communication with Susan Dunnihoo, July 22, 2008*.
[4]Based on Terminal 91 Tank Farm Site Background Groundwater Evaluation (PIONEER, 2007)
[5]Based on Terminal 91 Tank Farm Site Feasibility Study Cleanup Levels (PIONEER, 2008)

Table 7-5
Groundwater Monitoring Wells Included in Cleanup Level Evaluation
Port of Seattle Terminal 91 Feasibility Study
Seattle, WA

Well	Aquifer	Dates Used For Evaluation
CP_103A	Shallow[7]	03/31/2006, 06/06/2006, 09/18/2006, 03/15/2007, 09/20/2007, 03/17/2008
CP_104A	Shallow	04/03/2006, 06/06/2006, 09/19/2006, 03/14/2007, 09/20/2007, 03/18/2008
CP_104B	Deep[8]	02/28/2000, 10/04/2000, 03/01/2001, 10/03/2001, 03/07/2002, 10/11/2002, 03/07/2003, 10/28/2003, 03/09/2004, 10/11/2004
CP_106A	Shallow	03/27/2006, 09/19/2006, 03/13/2007, 09/19/2007, 03/11/2008
CP_106B	Deep	02/25/2000, 10/05/2000, 03/02/2001, 10/02/2001, 03/07/2002, 10/14/2002, 03/06/2003, 10/23/2003, 03/03/2004, 10/06/2004
CP_107	Shallow	03/08/2002, 03/10/2003, 03/10/2004, 10/08/2004
CP_108A	Shallow	03/31/2006, 06/06/2006, 09/18/2006, 03/16/2007, 09/20/2007, 03/17/2008
CP_108B	Deep	03/29/2006, 09/18/2006, 03/16/2007, 09/20/2007, 03/17/2008
CP_111	Shallow	03/29/2006, 09/22/2006, 03/19/2007, 09/18/2007, 03/17/2008
CP_112	Shallow	02/28/2000, 10/04/2000, 03/02/2001, 10/04/2001, 03/08/2002, 10/15/2002, 03/06/2003, 10/29/2003, 03/10/2004, 10/12/2004
CP_113	Shallow	02/28/2000, 10/05/2000, 03/01/2001, 10/03/2001, 03/07/2002, 10/11/2002, 03/07/2003, 10/28/2003, 03/05/2004, 10/12/2004
CP_114	Shallow	03/31/2006, 06/06/2006, 09/19/2006, 03/14/2007, 09/20/2007, 03/18/2008
CP_115A	Shallow	03/28/2006, 09/19/2006, 03/14/2007, 09/19/2007, 03/18/2008
CP_115B	Deep	03/28/2006, 09/19/2006, 03/14/2007, 09/19/2007, 03/18/2008
CP_122B	Deep	02/25/2000, 10/05/2000, 03/01/2001, 10/04/2001, 03/06/2002, 10/11/2002, 03/10/2003, 10/28/2003, 03/03/2004, 10/11/2004
CP_203B[1]	Deep	03/29/2006, 09/21/2006, 03/15/2007, 09/19/2007, 03/18/2008
CP_205A	Shallow	02/29/2000, 10/04/2000, 03/01/2001, 10/03/2001, 03/06/2002, 10/11/2002, 03/10/2003, 10/28/2003, 03/05/2004, 10/12/2004
CP_205B	Deep	03/28/2006, 09/20/2006, 03/14/2007, 09/21/2007, 03/18/2008
CP_GP01A	Shallow	04/03/2006, 06/05/2006, 09/25/2006, 03/16/2007, 09/18/2007, 03/14/2008
CP_GP01B	Deep	03/27/2006, 09/25/2006, 03/16/2007, 09/18/2007, 03/14/2008
CP_GP03AR[2]	Shallow	04/03/2006, 06/01/2006, 03/20/2007, 09/13/2007, 03/11/2008
CP_GP03BR[3]	Deep	03/27/2006, 03/20/2007, 09/13/2007, 03/11/2008
CP_GP04R[4]	Shallow	03/28/2006, 03/21/2007, 09/12/2007, 03/11/2008
CP_GP05	Shallow	04/03/2006, 06/05/2006, 09/20/2006, 03/19/2007, 09/17/2007, 03/12/2008
CP_GP06	Shallow	03/27/2006, 09/25/2006, 03/19/2007, 09/17/2007, 03/12/2008
CP_GP07	Shallow	03/29/2006, 09/22/2006, 03/19/2007, 09/12/2007
CP_GP08	Shallow	04/04/2006, 06/06/2006, 09/25/2006, 12/28/2006, 03/15/2007, 09/21/2007, 03/14/2008
CP_GP09R[5]	Shallow	06/07/2006, 09/19/2006, 12/29/2006, 03/20/2007, 09/13/2007, 03/13/2008
CP_GP10	Shallow	04/03/2006, 06/07/2006, 09/19/2006, 12/28/2006, 03/21/2007, 09/13/2007, 03/13/2008
CP_GP11	Shallow	04/04/2006, 06/07/2006, 09/21/2006, 12/28/2006, 03/13/2007, 09/13/2007, 03/13/2008
CP_GP12	Shallow	03/29/2006, 06/07/2006, 09/21/2006, 12/28/2006, 03/13/2007, 09/17/2007, 03/12/2008
CP_GP13	Shallow	03/29/2006, 06/08/2006, 09/25/2006, 12/28/2006, 03/19/2007, 09/17/2007, 03/13/2008
CP_GP14	Shallow	04/05/2006, 06/07/2006, 09/25/2006, 12/29/2006, 03/15/2007, 09/17/2007, 03/12/2008
CP_W210[6]	Shallow	03/28/2006, 09/22/2006, 03/15/2007, 09/18/2007, 03/17/2008
PNO_MW02	Shallow	04/04/2006, 06/05/2006
PNO_MW06A	Shallow	04/04/2006, 06/05/2006, 09/20/2006, 03/19/2007, 09/17/2007, 03/14/2008
PNO_MW06B	Deep	03/27/2006, 09/20/2006, 03/19/2007, 09/17/2007, 03/14/2008
PNO_MW101	Shallow	04/04/2006, 06/05/2006
PNO_MW103	Shallow	04/05/2006, 06/05/2006

Notes:

[1] Replacement well for CP_103B, which was removed during construction activities.
[2] Replacement well for CP_GP03A, which was removed during construction activities.
[3] Replacement well for CP_GP03B, which was removed during construction activities.
[4] Replacement well for CP_GP04, which was removed during construction activities.
[5] Replacement well for CP_GP09, which was removed during construction activities.
[6] Replacement well for SHFLL_W10, which was removed during construction activities.
[7] Shallow groundwater wells were screened at a maximum depth of 21 feet below ground surface (bgs).
[8] Deep groundwater wells were screened at a maximum depth of 60 feet bgs.

Table 7-6
Wells with Detected IHSs that Exceeded Final Feasibility Study Cleanup Levels
Port of Seattle Terminal 91 Feasibility Study
Seattle, WA

Wells	CAS Number	IHS	Maximum Detected Result (ug/L)	Final FS CUL (ug/L)	Exceedance Factor
Shallow Wells					
CP_103A	86290-81-5	Gasoline	840	800	1.1
	7440-66-6	Zinc	110	81	1.4
CP_104A	83-32-9	Acenaphthene	41.5	20	2.1
	68334-30-5	Diesel	1310	500	2.6
	86290-81-5	Gasoline	1200	800	1.5
CP_106A	90-12-0	1-methylnaphthalene	34.6	31.6	1.1
	68334-30-5	Diesel	2020	500	4.0
	86290-81-5	Gasoline	2100	800	2.6
CP_107	106-46-7	1,4-dichlorobenzene	9.03	2.07	4.4
	90-12-0	1-methylnaphthalene	60.9	31.6	1.9
	68334-30-5	Diesel	3970	500	7.9
	75-01-4	Vinyl Chloride	1.76	1.69	1.0
CP_108A	90-12-0	1-methylnaphthalene	56.35	31.6	1.8
	68334-30-5	Diesel	858	500	1.7
	86290-81-5	Gasoline	980	800	1.2
CP_112	56-55-3	Benzo(a)anthracene	0.0943	0.018	5.2
	50-32-8	Benzo(a)pyrene	0.236	0.013	18.2
	191-24-2	Benzo(g,h,i)perylene	0.0943	0.012	7.9
	207-08-9	Benzo(k)fluoranthene	0.152	0.018	8.4
	218-01-9	Chrysene	0.0943	0.018	5.2
	53-70-3	Dibenz(a,h)anthracene	0.528	0.01	52.8
	68334-30-5	Diesel	1010	500	2.0
	193-39-5	Indeno(1,2,3-cd)pyrene	0.415	0.01	41.5
CP_113	191-24-2	Benzo(g,h,i)perylene	0.179	0.012	14.9
	68334-30-5	Diesel	1640	500	3.3
	86290-81-5	Gasoline	1010	800	1.3
CP_114	50-32-8	Benzo(a)pyrene	0.05	0.013	3.8
	205-99-2	Benzo(b)fluoranthene	0.07	0.018	3.9
	191-24-2	Benzo(g,h,i)perylene	0.05	0.012	4.2
	207-08-9	Benzo(k)fluoranthene	0.933	0.018	51.8
	218-01-9	Chrysene	0.243	0.018	13.5
CP_205A	56-55-3	Benzo(a)anthracene	0.16	0.018	8.9
	50-32-8	Benzo(a)pyrene	0.226	0.013	17.4
	205-99-2	Benzo(b)fluoranthene	0.406	0.018	22.6
	191-24-2	Benzo(g,h,i)perylene	0.132	0.012	11.0
	207-08-9	Benzo(k)fluoranthene	0.217	0.018	12.1
	218-01-9	Chrysene	0.16	0.018	8.9
	53-70-3	Dibenz(a,h)anthracene	0.311	0.01	31.1
	193-39-5	Indeno(1,2,3-cd)pyrene	0.113	0.01	11.3
CP_GP11	50-32-8	Benzo(a)pyrene	0.287	0.013	22.1
	53-70-3	Dibenz(a,h)anthracene	0.273	0.01	27.3
	86290-81-5	Gasoline	1375	800	1.7
	193-39-5	Indeno(1,2,3-cd)pyrene	0.222	0.01	22.2

Table 7-6
Wells with Detected IHSs that Exceeded Final Feasibility Study Cleanup Levels
Port of Seattle Terminal 91 Feasibility Study
Seattle, WA

Wells	CAS Number	IHS	Maximum Detected Result (ug/L)	Final FS CUL (ug/L)	Exceedance Factor
CP_GP12	83-32-9	Acenaphthene	46.5	20	2.3
	120-12-7	Anthracene	6.8	2.68	2.5
	7440-38-2	Arsenic	10.5	4.7	2.2
	56-55-3	Benzo(a)anthracene	0.345	0.018	19.2
	50-32-8	Benzo(a)pyrene	0.322	0.013	24.8
	205-99-2	Benzo(b)fluoranthene	0.125	0.018	6.9
	191-24-2	Benzo(g,h,i)perylene	0.0857	0.012	7.1
	207-08-9	Benzo(k)fluoranthene	0.143	0.018	7.9
	86-74-8	Carbazole	7.6	0.921	8.3
	218-01-9	Chrysene	0.295	0.018	16.4
	53-70-3	Dibenz(a,h)anthracene	0.181	0.01	18.1
	132-64-9	Dibenzofuran	23.5	14.7	1.6
	68334-30-5	Diesel	663	500	1.3
	206-44-0	Fluoranthene	4.55	4.1	1.1
	86290-81-5	Gasoline	1500	800	1.9
	193-39-5	Indeno(1,2,3-cd)pyrene	0.225	0.01	22.5
	91-20-3	Naphthalene	420	97	4.3
CP_W210	90-12-0	1-methylnaphthalene	97.3	31.6	3.1
	7440-38-2	Arsenic	16.8	4.7	3.6
	71-43-2	Benzene	13.8	9.66	1.4
	68334-30-5	Diesel	625	500	1.3
	86290-81-5	Gasoline	1150	800	1.4
PNO_MW02	56-55-3	Benzo(a)anthracene	0.0699	0.018	3.9
	218-01-9	Chrysene	0.0825	0.018	4.6
PNO_MW06A	56-55-3	Benzo(a)anthracene	0.025	0.018	1.4
	50-32-8	Benzo(a)pyrene	0.018	0.013	1.4
	205-99-2	Benzo(b)fluoranthene	0.02	0.018	1.1
	218-01-9	Chrysene	0.037	0.018	2.1
	68334-30-5	Diesel	990	500	2.0
	86290-81-5	Gasoline	840	800	1.1
PNO_MW103	90-12-0	1-methylnaphthalene	56.5	31.6	1.8
	68334-30-5	Diesel	1190	500	2.4
Deep Wells					
CP_104B	191-24-2	Benzo(g,h,i)perylene	0.179	0.012	14.9
	53-70-3	Dibenz(a,h)anthracene	0.217	0.01	21.7
	193-39-5	Indeno(1,2,3-cd)pyrene	0.151	0.01	15.1
CP_106B	68334-30-5	Diesel	721	500	1.4
CP_115B	86290-81-5	Gasoline	2760	800	3.5

Table 7-6
Wells with Detected IHSs that Exceeded Final Feasibility Study Cleanup Levels
Port of Seattle Terminal 91 Feasibility Study
Seattle, WA

Wells	CAS Number	IHS	Maximum Detected Result (ug/L)	Final FS CUL (ug/L)	Exceedance Factor
CP_122B	56-55-3	Benzo(a)anthracene	0.0857	0.018	4.8
	50-32-8	Benzo(a)pyrene	0.229	0.013	17.6
	205-99-2	Benzo(b)fluoranthene	0.269	0.018	14.9
	191-24-2	Benzo(g,h,i)perylene	0.229	0.012	19.1
	207-08-9	Benzo(k)fluoranthene	0.183	0.018	10.2
	218-01-9	Chrysene	0.0762	0.018	4.2
	53-70-3	Dibenz(a,h)anthracene	0.267	0.01	26.7
	68334-30-5	Diesel	629	500	1.3
	193-39-5	Indeno(1,2,3-cd)pyrene	0.2	0.01	20.0
	7440-66-6	Zinc	186	81	2.3
CP_203B	56-55-3	Benzo(a)anthracene	0.024	0.018	1.3
	50-32-8	Benzo(a)pyrene	0.037	0.013	2.8
	205-99-2	Benzo(b)fluoranthene	0.068	0.018	3.8
	191-24-2	Benzo(g,h,i)perylene	0.038	0.012	3.2
	207-08-9	Benzo(k)fluoranthene	0.029	0.018	1.6
	218-01-9	Chrysene	0.059	0.018	3.3
	193-39-5	Indeno(1,2,3-cd)pyrene	0.03	0.01	3.0
CP_205B	56-55-3	Benzo(a)anthracene	0.249	0.018	13.8
	50-32-8	Benzo(a)pyrene	0.35	0.013	26.9
	205-99-2	Benzo(b)fluoranthene	0.314	0.018	17.4
	191-24-2	Benzo(g,h,i)perylene	0.175	0.012	14.6
	207-08-9	Benzo(k)fluoranthene	0.413	0.018	22.9
	218-01-9	Chrysene	0.388	0.018	21.6
	53-70-3	Dibenz(a,h)anthracene	0.059	0.01	5.9
	193-39-5	Indeno(1,2,3-cd)pyrene	0.144	0.01	14.4

Notes:

FS = Feasibility Study

CUL= Cleanup Level

Exceedance Factors were rounded to one decimal point.

Shaded cells represent wells which are both SPOC and CPOC wells

Table 9-1

Cleanup Action Technologies
Port of Seattle Terminal 91 Feasibility Study
Seattle, Washington

General Response Action	Technology
Soil Actions	
Excavation	Excavation
Off-Site Treatment[1]	Thermal desorption Incineration Stabilization
Off-Site Disposal	Solid waste landfill Dangerous waste landfill TSCA-waste landfill
Engineering Controls	Surface cap or cover[2] Subsurface vapor barrier[2] Fencing
Institutional Controls	Land-use restrictions[2] Worker protection measures[2] Access restrictions[2]
Groundwater Actions	
Groundwater Containment	Vertical barriers (containment walls)
LNAPL Recovery	Passive recovery (e.g., bailing, PLRDs) Active skimming Vacuum-enhanced skimming
Monitored Natural Attenuation	Monitored natural attenuation
Groundwater Extraction[3]	Extraction wells/wellpoints Trenches
Groundwater Treatment[3]	Sediment removal/filtration Oil/water separation Granular activated carbon adsorption
Ex Situ Groundwater Discharge[3]	King County Sanitary Sewer
Engineering Controls	Subsurface Vapor Barrier[2]
Institutional Controls	Water-Use Restrictions[2] Worker Protection Measures[2]

Notes:

1. Off-Site treatment soil would only be conducted as necessary to meet landfill standards prior to disposal.
2. Technologies included in presumed response actions to address potential future (1) subsurface worker direct contact exposure pathway and (2) groundwater/soil to indoor air exposure pathway.
3. Groundwater extraction, treatment, and discharge are included for purposes of managing groundwater that may be extracted as part of a hydraulic control action, or removed during dewatering activities associated with soil excavation

Table 10-1
Construction Costs
SMWU-30 - Limited Excavation of LNAPL Source Areas
Port of Seattle Terminal 91 Feasibility Study
Seattle, Washington

Construction Costs										
ITEM	UNIT COST				UNITS	QUANTITY		COST		
	low		high			low	high	low		high
Construction Costs										
1. Mobilization/demobilization	$	10,000	$	15,000	LS	1	1	$ 10,000	$	15,000
2. Excavate clean overburden	$	5	$	7	ton	1,000	1,300	$ 5,000	$	9,100
3. Excavate TPH-impacted soil	$	5	$	7	ton	1,500	1,900	$ 7,500	$	13,300
4. Water management	$	15,000	$	20,000	LS	1	1	$ 15,000	$	20,000
5. Offsite soil disposal										
a) Disposal as solid waste (TPH only)	$	35	$	40	ton	1,500	1,900	$ 52,500	$	76,000
6. Backfill excavated area with clean soil										
a) With excavated "clean soil"	$	10	$	12	ton	1,000	1,300	$ 10,000	$	15,600
a) With imported clean soil	$	26	$	30	ton	1,650	2,100	$ 42,900	$	63,000
7 Replace cap										
a) Remove existing asphalt	$	0.65	$	0.75	SF	4,350	5,400	$ 2,828	$	4,050
b) New asphalt paving	$	2.00	$	2.25	SF	4,350	5,400	$ 8,700	$	12,150
8. Well decommissioning	$	400	$	500	EA	3	3	$ 1,200	$	1,500
Subtotal								$ 155,600	$	229,700
Sales Tax on Materials (9%)								$ 9,300	$	13,800
Engineering and Permitting (10%)								$ 15,600	$	23,000
Construction Cost Contingency (20%)								$ 31,100	$	45,900
Total Estimated Capital Costs								**$ 210,000**	**$**	**310,000**
Average Capital Cost								**$ 260,000**		

Table 10-2
Construction Costs
Former Pipeline Cleaning and Decommissioning
Port of Seattle Terminal 91 Feasibility Study
Seattle, Washington

Construction Costs										
ITEM	UNIT COST				UNITS	QUANTITY		COST		
	low		high			low	high	low		high
Construction Costs										
1. Mobilization/demobilization	$	10,000	$	15,000	LS	1	1	$ 10,000	$	15,000
2. Pipeline cleaning and abandonment	$	16	$	18	LF	22,000	22,000	$ 352,000	$	396,000
3. Offsite disposal of residuals (fuel, sludge)	$	1.5	$	2.0	LF	22,000	22,000	$ 33,000	$	44,000
4. Reporting	$	5,000	$	10,000	LS	1	1	$ 5,000	$	10,000
Subtotal								$ 400,000	$	465,000
Sales Tax on Materials (9%)								$ 36,000	$	41,900
Engineering and Permitting (10%)								$ 40,000	$	46,500
Construction Cost Contingency (20%)								$ 80,000	$	93,000
Total Estimated Capital Costs								**$ 560,000**	**$**	**650,000**
Average Capital Cost								**$ 610,000**		

Table 10-3
Capital and Operations and Maintenance Costs
MNA Program Implementation
Port of Seattle Terminal 91 Feasibility Study
Seattle, Washington

Construction Costs										
ITEM	UNIT COST low		UNIT COST high		UNITS	QUANTITY low	QUANTITY high	COST low		COST high
Construction Costs										
1. Intall/replace monitoring wells	$	4,000	$	7,000	EA	3	3	$ 12,000	$	21,000
2. Develop MNA monitoring plan	$	10,000	$	15,000	LS	1	1	$ 10,000	$	15,000
							Subtotal	$ 22,000	$	36,000
							Sales Tax on Materials (9 %)	$ 1,100	$	1,900
							Construction Cost Contingency (20 %)	$ 4,400	$	7,200
							Total Estimated Capital Costs	**$ 28,000**	**$**	**45,000**
							Average Capital Cost	**$ 37,000**		

Operation and Maintenance Costs				
Activity	**Estimated Annual Cost low**		**Estimated Annual Cost high**	**PW[1] (30 Years)**
1. Year 1 monitoring and reporting	$ 55,000	$	70,000	$ 60,000
2. Year 2 and 3 monitoring and reporting	$ 30,000	$	40,000	$ 62,000
3. Years 3 through 30 monitoring and reporting	$ 20,000	$	25,000	$ 285,000
			Subtotal	$ 407,000
			O&M Cost Contingency (10 %)	$ 40,700
			Total Estimated O&M Costs	**$ 450,000**
TOTAL ESTIMATED PRESENT WORTH COST				**$ 490,000**

[1] PW = present worth, calculated assuming a 5% discount rate using the average annual cost and years of operation indicated in the following formula:

$$PW = A\frac{(1+i)^n - 1}{i(1+i)^n}$$

where: A = average annual cost
i = discount rate
n = number of years of operation

All total costs are in 2009 dollars and rounded to nearest $10,000.

Table 10-4
Capital and Operations and Maintenance Costs
Alternative 1 - Asphalt Paving Maintenance and Monitoring
Port of Seattle Terminal 91 Feasibility Study
Seattle, Washington

Construction Costs							
ITEM	UNIT COST low	UNIT COST high	UNITS	QUANTITY low	QUANTITY high	COST low	COST high
Construction Costs							
1. Initial asphalt paving inspection	$ 5,000	$ 10,000	LS	1	1	$ 5,000	$ 10,000
2. Existing asphalt paving repair	$ 2.00	$ 2.25	SF	7,000	20,000	$ 14,000	$ 45,000
3. Install new monitoring wells	$ 4,000	$ 7,000	EA	4	6	$ 16,000	$ 42,000
					Subtotal	$ 35,000	$ 97,000
					Sales Tax on Materials (9%)	$ 2,700	$ 7,800
					Engineering and Permitting (10%)	$ 3,500	$ 9,700
					Construction Cost Contingency (15 %)	$ 5,300	$ 14,600
					Total Estimated Capital Costs	**$ 50,000**	**$ 130,000**
					Average Capital Cost	**$ 90,000**	

Operation and Maintenance Costs			
Activity	**Estimated Annual Cost low**	**Estimated Annual Cost high**	**PW[1] (30 Years)**
1. Asphalt paving inspection and maintenance	$ 7,000	$ 13,000	$ 154,000
2. LNAPL monitoring and passive recovery	$ 8,000	$ 16,000	$ 184,000
3. Compliance groundwater monitoring	$ 15,000	$ 25,000	$ 307,000
4. Annual reporting (inspections, LNAPL monitoring, groundwater monitoring)	$ 17,000	$ 26,000	$ 331,000
Average Annual O&M Cost	$ 63,500		
		Subtotal	$ 976,000
		O&M Cost Contingency (10 %)	$ 97,600
		Total Estimated O&M Costs	**$ 1,070,000**
TOTAL ESTIMATED PRESENT WORTH COST			**$ 1,160,000**

[1] PW = present worth, calculated assuming a 5% discount rate using the average annual cost and years of operation indicated in the following formula:

$$PW = A\frac{(1+i)^n - 1}{i(1+i)^n}$$

where: A = average annual cost
i = discount rate
n = number of years of operation

All total costs are in 2009 dollars and rounded to nearest $10,000.

Table 10-5
Construction and Operation and Maintenance Costs
Alternative 2 - Containment and Passive LNAPL Recovery
Port of Seattle Terminal 91 Feasibility Study
Seattle, Washington

ITEM	UNIT COST low	UNIT COST high	UNITS	QUANTITY low	QUANTITY high	COST low	COST high
Construction Costs							
1. Mobilization/demobilization	$ 70,000	$ 80,000	LS	1	1	$ 70,000	$ 80,000
2. Remove existing asphalt paving	$ 0.65	$ 0.75	SF	135,000	135,000	$ 88,000	$ 101,000
3. Excavate existing sub base in trench alignment	$ 3.00	$ 5.00	ton	4,000	5,000	$ 12,000	$ 25,000
4. Demolish, decontaminate and haul out existing subsurface structures in trench alignment	$ 160,000	$ 330,000	LS	1	1	$ 160,000	$ 330,000
5. Excavate working trench	$ 3	$ 5	ton	3,900	4,900	$ 12,000	$ 25,000
6. Slurry wall installation	$ 5	$ 10	SF	31,000	31,000	$ 155,000	$ 310,000
7. Stockpile, replace, and compact trench spoils	$ 5	$ 7	ton	3,900	4,900	$ 20,000	$ 34,000
8. Upgrade existing asphalt paving to prevent future seepage							
a) Stockpile, replace, and compact clean sub base	$ 5	$ 7	ton	4,000	5,000	$ 20,000	$ 35,000
b) Install geomembrane liner	$ 1.00	$ 1.25	SF	135,000	135,000	$ 135,000	$ 169,000
c) Install new asphalt paving	$ 2.00	$ 2.25	SF	135,000	135,000	$ 270,000	$ 303,750
9. Site drainage improvements	$ 25,000	$ 50,000	LS	1	1	$ 25,000	$ 50,000
10. Decommission and replace select monitoring wells	$ 5,000	$ 8,000	EA	16	16	$ 80,000	$ 128,000
11. Oversight during construction/construction report	$ 50,000	$ 75,000	LS	1	1	$ 50,000	$ 75,000
Subtotal						$ 1,047,000	$ 1,590,750
Sales Tax on Materials (9%)						$ 94,200	$ 143,200
Engineering and Permitting (10%)						$ 104,700	$ 159,100
Construction Cost Contingency (20%)						$ 209,400	$ 318,200
Total Estimated Capital Costs						**$ 1,460,000**	**$ 2,210,000**
Average Capital Cost						**$ 1,840,000**	

Activity	Estimated Annual Cost low	Estimated Annual Cost high	Baseline O&M Case PW[1] (30 Years)
1. Cap inspection and maintenance	$ 7,000	$ 13,000	$ 154,000
2. LNAPL monitoring and passive recovery	$ 8,000	$ 16,000	$ 184,000
3. Compliance groundwater monitoring	$ 15,000	$ 25,000	$ 307,000
4. Annual reporting (inspections, LNAPL monitoring, groundwater monitoring)	$ 17,000	$ 26,000	$ 331,000
Average Annual O&M Cost	$ 63,500		
Subtotal			$ 976,000
O&M Cost Contingency (10 %)			$ 97,600
Total Estimated O&M Costs			**$ 1,070,000**
TOTAL ESTIMATED PRESENT WORTH COST			**$ 2,910,000**

[1] PW = present worth, calculated assuming a 5% discount rate using the average annual cost and years of operation indicated in the following formula:

$$PW = A\frac{(1+i)^n - 1}{i(1+i)^n}$$

where: A = average annual cost
i = discount rate
n = number of years of operation

All total costs are in 2009 dollars and rounded to nearest $10,000.

Table 10-6
Construction and Operation and Maintenance Costs
Alternative 3 - Active LNAPL Recovery and Subsurface Structure Removal
Port of Seattle Terminal 91 Feasibility Study
Seattle, Washington

Construction Costs

ITEM	UNIT COST low	UNIT COST high	UNITS	QUANTITY low	QUANTITY high	COST low	COST high
Construction Costs							
1. Mobilization/demobilization	$ 20,000	$ 30,000	LS	1	1	$ 20,000	$ 30,000
2. Remove existing asphalt paving	$ 0.65	$ 0.75	SF	135,000	135,000	$ 88,000	$ 101,000
3. Excavate existing sub base	$ 3.00	$ 5.00	ton	9,400	11,750	$ 28,200	$ 58,750
4. Demolish, decontaminate and haul out all existing subsurface structures	$ 520,000	$ 1,100,000	LS	1	1	$ 520,000	$ 1,100,000
5. Drill and install LNAPL extraction wells	$ 3,700	$ 4,000	EA	12	24	$ 44,400	$ 96,000
6. Supply and install well vaults	$ 2,500	$ 2,750	EA	12	24	$ 30,000	$ 66,000
7. Product recovery system (pumps, controls)	$ 5,000	$ 5,000	EA	12	24	$ 60,000	$ 120,000
8. Product recovery and SVE piping	$ 20,000	$ 30,000	LS	1	1	$ 20,000	$ 30,000
9. Construct SVE manifold wellhead plumbing	$ 16,000	$ 20,000	LS	1	1	$ 16,000	$ 20,000
10. Soil vapor extraction system, including treatment	$ 23,000	$ 34,000	EA	1	1	$ 23,000	$ 34,000
11. Electrical installation	$ 20,000	$ 30,000	LS	1	1	$ 20,000	$ 30,000
12. Remediation compound (slab, containment, fence)	$ 15,000	$ 20,000	LS	1	1	$ 15,000	$ 20,000
13. Product containment (instrumentation/holding tanks)	$ 1,250	$ 1,500	EA	4	8	$ 5,000	$ 12,000
14. Stockpile, replace, and compact sub base material	$ 5	$ 7	ton	9,400	11,800	$ 47,000	$ 83,000
15. Install new asphalt paving	$ 2.00	$ 2.50	SF	135,000	135,000	$ 270,000	$ 337,500
16. Site drainage improvements (gradient controls/stormwater drains)	$ 25,000	$ 50,000	LS	1	1	$ 25,000	$ 50,000
17. Decommission and replace select monitoring wells	$ 5,000	$ 8,000	EA	16	16	$ 80,000	$ 128,000
18. Oversight during construction/construction report	$ 50,000	$ 75,000	LS	1	1	$ 50,000	$ 75,000
Subtotal						$ 1,361,600	$ 2,391,250
Sales Tax on Materials (8.8%)						$ 115,400	$ 203,800
Engineering and Permitting (10%)						$ 136,200	$ 239,100
Construction Cost Contingency (20%)						$ 272,300	$ 478,300
Total Estimated Capital Costs						**$ 1,890,000**	**$ 3,310,000**
Average Capital Cost						**$ 2,600,000**	

Operation and Maintenance Costs

Activity	Estimated Annual Cost low	Estimated Annual Cost high	Baseline O&M Case PW[1] (30 Years)
1. Active product recovery system O&M and reporting (10 years)	$ 55,000	$ 90,000	$ 560,000
2. Startup performance sampling and reporting (in addition to routine monitoring; years 1-3)	$ 10,000	$ 20,000	$ 41,000
3. Additional performance sampling and reporting (years 4-10)	$ 5,000	$ 10,000	$ 37,000
4. LNAPL monitoring and passive recovery	$ 8,000	$ 16,000	$ 184,000
5. Asphalt paving inspection and maintenance	$ 7,000	$ 13,000	$ 154,000
6. Compliance groundwater monitoring	$ 15,000	$ 25,000	$ 307,000
7. Annual reporting (inspections, LNAPL monitoring, groundwater monitoring)	$ 17,000	$ 26,000	$ 331,000
Subtotal			$ 1,614,000
O&M Cost Contingency (10 %)			$ 161,400
Total Estimated O&M Costs			**$ 1,780,000**
TOTAL ESTIMATED PRESENT WORTH COST			**$ 4,380,000**

[1] PW = present worth, calculated assuming a 5% discount rate using the average annual cost and years of operation indicated in the following formula:

$$PW = A\frac{(1+i)^n - 1}{i(1+i)^n}$$

where: A = average annual cost
i = discount rate
n = number of years of operation

All total costs are in 2009 dollars and rounded to nearest $10,000.

Table 10-7
Construction and Operation and Maintenance Costs
Alternative 4 - Containment, Subsurface Structure Removal, and Enhanced LNAPL Recovery
Port of Seattle Terminal 91 Feasibility Study, Seattle, Washington

Construction Costs							
ITEM	UNIT COST low	UNIT COST high	UNITS	QUANTITY low	QUANTITY high	COST low	COST high
Construction Costs							
1. Mobilization/demobilization	$ 70,000	$ 80,000	LS	1	1	$ 70,000	$ 80,000
2. Remove existing asphalt paving	$ 0.65	$ 0.75	SF	135,000	135,000	$ 88,000	$ 101,000
3. Excavate existing sub base	$ 3.00	$ 5.00	ton	9,400	11,750	$ 28,000	$ 59,000
4. Demolish, decontaminate and haul out all existing subsurface structures	$ 520,000	$ 1,100,000	LS	1	1	$ 520,000	$ 1,100,000
5. Excavate highly contaminated soils, incl backfill	$ 31	$ 40	ton	250	500	$ 7,750	$ 20,000
6. Dispose highly contaminated soils							
a) Disposal as solid waste (TPH-only, low level PCB	$ 38	$ 43	ton	150	300	$ 5,700	$ 12,900
b) Disposal as TSCA Waste (PCB >50 ppm)	$ 215	$ 240	ton	50	100	$ 10,750	$ 24,000
c) Contained-out waste (e.g., F001-F005)	$ 58	$ 64	ton	50	100	$ 2,900	$ 6,400
7. Excavate working trench for wall installation	$ 3	$ 5	ton	3,900	4,900	$ 12,000	$ 25,000
8. Slurry wall installation	$ 5	$ 10	SF	31,000	31,000	$ 155,000	$ 310,000
9. Stockpile, replace, and compact trench spoils	$ 5	$ 7	ton	3,900	4,900	$ 20,000	$ 34,000
10. Install enhanced LNAPL recovery trenches	$ 65,000	$ 120,000	LS	1	1	$ 65,000	$ 120,000
11. Install new asphalt paving							
a) Stockpile, replace, and compact clean sub base	$ 5	$ 7	ton	9,400	11,800	$ 47,000	$ 83,000
b) Install new asphalt paving	$ 2.00	$ 2.25	SF	135,000	135,000	$ 270,000	$ 304,000
12. Site drainage improvements	$ 25,000	$ 50,000	LS	1	1	$ 25,000	$ 50,000
13. Decommission and replace select monitoring wells	$ 5,000	$ 8,000	EA	16	16	$ 80,000	$ 128,000
14. Oversight during construction/construction report	$ 50,000	$ 75,000	LS	1	1	$ 50,000	$ 75,000
					Subtotal	$ 1,407,100	$ 2,457,300
					Sales Tax on Materials (9%)	$ 127,000	$ 221,000
					Engineering and Permitting (10%)	$ 141,000	$ 246,000
					Construction Cost Contingency (20%)	$ 281,000	$ 491,000
					Total Estimated Capital Costs	**$ 1,960,000**	**$ 3,420,000**
					Average Capital Cost	**$ 2,690,000**	

Operation and Maintenance Costs			**Baseline O&M Case**
Activity	**Estimated Annual Cost** low	**Estimated Annual Cost** high	**PW[1] (30 Years)**
1. Annual asphalt paving inspection and maintenance	$ 7,000	$ 13,000	$ 154,000
2. Monthly LNAPL recovery (years 1-2)	$ 25,000	$ 35,000	$ 56,000
3. Bimonthly LNAPL recovery (years 3-5)	$ 15,000	$ 20,000	$ 43,000
4. Quarterly LNAPL recovery (years 5-10)	$ 10,000	$ 15,000	$ 42,000
5. LNAPL monitoring and passive recovery outside expanded recovery system	$ 6,000	$ 12,000	$ 138,000
6. Compliance groundwater monitoring	$ 15,000	$ 25,000	$ 307,000
7. Annual reporting (inspections, LNAPL recovery and monitoring, groundwater monitoring)	$ 20,000	$ 25,000	$ 346,000
	$ 98,000	$ 145,000	
		Subtotal	$ 1,086,000
		O&M Cost Contingency (10 %)	$ 108,600
		Total Estimated O&M Costs	**$ 1,190,000**
TOTAL ESTIMATED PRESENT WORTH COST			**$ 3,880,000**

[1] PW = present worth, calculated assuming a 5% discount rate using the average annual cost and years of operation indicated in the following formula

where A = average annual cost
i = discount rate
n = number of years of operation

All total costs are in 2009 dollars and rounded to nearest $10,000.

Table 10-8
Construction and Monitoring Costs
Alternative 5 - Limited Excavation of LNAPL Areas
Port of Seattle Terminal 91 Feasibility Study
Seattle, Washington

Construction Costs

ITEM	UNIT COST low	UNIT COST high	UNITS	QUANTITY low	QUANTITY high	COST low	COST high
Construction Costs							
1. Mobilization/demobilization	$ 40,000	$ 60,000	LS	1	1	$ 40,000	$ 60,000
2. Remove existing asphalt paving	$ 0.65	$ 0.75	SF	135,000	135,000	$ 88,000	$ 101,000
3. Excavate existing sub base	$ 3.00	$ 5.00	ton	9,400	11,750	$ 28,200	$ 58,750
4. Demolish, decontaminate and haul out all existing subsurface structures	$ 520,000	$ 1,100,000	LS	1	1	$ 520,000	$ 1,100,000
5. Excavate impacted soil in areas where LNAPL present	$ 5	$ 7	ton	19,000	24,000	$ 95,000	$ 168,000
6. Water and LNAPL management	$ 75,000	$ 150,000	LS	1	1	$ 75,000	$ 150,000
7. Offsite soil disposal			ton				
a) Disposal as solid waste (TPH-only, low level PCB)	$ 38	$ 43	ton	17,600	19,200	$ 668,800	$ 825,600
b) Disposal as TSCA Waste (PCB >50 ppm)	$ 215	$ 240	ton	400	500	$ 86,000	$ 120,000
c) Contained-out waste (e.g., F001-F005)	$ 58	$ 64	ton	1,000	1,250	$ 58,000	$ 80,000
8. Backfill excavations							
a) Stockpile, replace, and compact sub base material	$ 5	$ 7	ton	9,400	11,800	$ 47,000	$ 83,000
b) Backfill remainder of excavation with imported fill	$ 26	$ 30	ton	9,600	12,200	$ 249,600	$ 366,000
9. Install new asphalt paving	$ 2.00	$ 2.25	SF	135,000	146,300	$ 270,000	$ 329,175
10. Site drainage improvements (gradient controls/stormwater drains)	$ 25,000	$ 50,000	LS	1	1	$ 25,000	$ 50,000
11. Decommission and replace select monitoring wells	$ 5,000	$ 8,000	EA	16	16	$ 80,000	$ 128,000
12. Oversight during construction/construction report	$ 100,000	$ 150,000	LS	1	1	$ 100,000	$ 150,000
Subtotal						$ 2,430,600	$ 3,769,525
Sales Tax on Materials (9%)						$ 218,800	$ 339,300
Engineering and Permitting (10%)						$ 243,100	$ 377,000
Construction Cost Contingency (20%)						$ 486,100	$ 753,900
Total Estimated Capital Costs						**$ 3,380,000**	**$ 5,240,000**
Average Capital Cost						**$ 4,310,000**	

Operation and Maintenance Costs

Activity	Estimated Annual Cost low	Estimated Annual Cost high	Baseline O&M Case PW[1] (30 Years)
1. Asphalt paving inspection and maintenance	$ 7,000	$ 13,000	$ 154,000
2. LNAPL monitoring and passive recovery	$ 8,000	$ 16,000	$ 184,000
3. Compliance groundwater monitoring	$ 15,000	$ 25,000	$ 307,000
4. Annual reporting (inspections, LNAPL monitoring, groundwater monitoring)	$ 17,000	$ 26,000	$ 331,000
Average Annual O&M Cost	$ 63,500		
Subtotal			$ 976,000
O&M Cost Contingency (10 %)			$ 97,600
Total Estimated O&M Costs			**$ 1,070,000**
TOTAL ESTIMATED PRESENT WORTH COST			**$ 5,380,000**

[1] PW = present worth, calculated assuming a 5% discount rate using the average annual cost and years of operation indicated in the following formula:

$$PW = A\frac{(1+i)^n - 1}{i(1+i)^n}$$

where A = average annual cost
i = discount rate
n = number of years of operation

All total costs are in 2009 dollars and rounded to nearest $10,000.

Table 10-9
Construction and Monitoring Costs
Alternative 6 - Excavation of Soils Exceeding RSSLs
Port of Seattle Terminal 91 Feasibility Study
Seattle, Washington

ITEM	UNIT COST low	UNIT COST high	UNITS	QUANTITY low	QUANTITY high	COST low	COST high
Construction Costs							
1. Mobilization/demobilization	$ 40,000	$ 60,000	LS	1	1	$ 40,000	$ 60,000
2. Remove existing asphalt paving	$ 0.65	$ 0.75	SF	135,000	135,000	$ 88,000	$ 101,000
3. Excavate existing sub base	$ 3.00	$ 5.00	ton	9,400	11,750	$ 28,200	$ 58,750
4. Demolish, decontaminate and haul out all existing subsurface structures	$ 520,000	$ 1,100,000	LS	1	1	$ 520,000	$ 1,100,000
5. Excavate impacted soil exceeding RSSLs	$ 5	$ 7	ton	32,300	40,000	$ 161,500	$ 280,000
6. Water and LNAPL management	$ 75,000	$ 150,000	LS	1	1	$ 75,000	$ 150,000
7. Offsite soil disposal			ton				
a) Disposal as solid waste (TPH-only, low level PCB)	$ 38	$ 43	ton	30,100	32,000	$ 1,143,800	$ 1,376,000
b) Disposal as TSCA Waste (PCB >50 ppm)	$ 215	$ 240	ton	600	750	$ 129,000	$ 180,000
c) Contained-out waste (e.g., F001-F005)	$ 58	$ 64	ton	1,600	2,000	$ 92,800	$ 128,000
8. Backfill excavations							
a) Stockpile, replace, and compact sub base material	$ 5	$ 7	ton	9,400	11,800	$ 47,000	$ 83,000
b) Backfill remainder of excavation with imported fill	$ 26	$ 30	ton	22,900	28,200	$ 595,400	$ 846,000
9. Install new asphalt paving	$ 2.00	$ 2.25	SF	135,000	146,300	$ 270,000	$ 329,175
10. Site drainage improvements (gradient controls/stormwater drains)	$ 25,000	$ 50,000	LS	1	1	$ 25,000	$ 50,000
11. Decommission and replace select monitoring wells	$ 5,000	$ 8,000	EA	16	16	$ 80,000	$ 128,000
12. Oversight during construction/construction report	$ 150,000	$ 200,000	LS	1	1	$ 150,000	$ 200,000
Subtotal						$ 3,445,700	$ 5,069,925
Sales Tax on Materials (9%)						$ 310,100	$ 456,300
Engineering and Permitting (10%)						$ 344,600	$ 507,000
Construction Cost Contingency (20%)						$ 689,100	$ 1,014,000
Total Estimated Capital Costs						**$ 4,790,000**	**$ 7,050,000**
Average Capital Cost						**$ 5,920,000**	

Operation and Maintenance Costs — Activity	Estimated Annual Cost low	Estimated Annual Cost high	Baseline O&M Case PW[1] (30 Years)
1. Asphalt paving inspection and maintenance	$ 7,000	$ 13,000	$ 154,000
2. LNAPL monitoring and passive recovery	$ 8,000	$ 16,000	$ 184,000
3. Compliance groundwater monitoring	$ 15,000	$ 25,000	$ 307,000
4. Annual reporting (inspections, LNAPL monitoring, groundwater monitoring)	$ 17,000	$ 26,000	$ 331,000
Average Annual O&M Cost	$ 63,500		
Subtotal			$ 976,000
O&M Cost Contingency (10 %)			$ 97,600
Total Estimated O&M Costs			**$ 1,070,000**
TOTAL ESTIMATED PRESENT WORTH COST			**$ 6,990,000**

[1] PW = present worth, calculated assuming a 5% discount rate using the average annual cost and years of operation indicated in the following formula:

$$PW = A\frac{(1+i)^n - 1}{i(1+i)^n}$$

where A = average annual cost
i = discount rate
n = number of years of operation

All total costs are in 2009 dollars and rounded to nearest $10,000.

Table 11-1
Evaluation of Use of Permanent Solutions to Maximum Extent Practicable
Lease Parcel Cleanup Action Alternatives
Port of Seattle Terminal 91 Feasibility Study
Seattle, Washington

Evaluation Criteria	Alternative 1 – Existing Asphalt Paving Maintenance and Monitoring	Alternative 2 – Containment and Passive LNAPL Recovery	Alternative 3 – Active LNAPL Recovery and Subsurface Structure Removal	Alternative 4 – Containment, Subsurface Structure Removal, and Expanded LNAPL Recovery	Alternative 5 – Limited Excavation of LNAPL Areas	Alternative 6 – Excavation of Soils Exceeding RSSLs
Protectiveness	Potential future receptors (potential site workers and/or trespassers) will be protected through inspection and maintenance of the existing asphalt paving, including corrective action to address product seeps that may occur.	Alternative 2 protects potential future receptors (potential site workers and/or trespassers) through construction, inspection, and maintenance of a new composite cap. In addition, removing approximately 30 percent of the remaining subsurface structures from the former tank farm will further reduce the potential for surface seeps.	Alternative 3 effectively eliminates potential exposure by eliminating the source of the product seeps through removal of all remaining subsurface structures and constructing new asphalt paving. The active LNAPL recovery system would further reduce the potential for surface seeps.	Similar to Alternative 3 with additional protection provided by removing highly contaminated surface soil from the former tank farm area.	Potential future receptors are protected by Alternative 5 by eliminating the source of product seeps through removal of all remaining subsurface structures and constructing new asphalt paving. In addition, this alternative removes approximately a quarter of the unsaturated zone soil in the Lease Parcel as well as excavating the areas with observed LNAPL, further reducing the potential for surface seeps.	Very similar to Alternative 5, except more soil (including soil exceeding the RSSLs) is removed.
Permanence	With the exception of the relatively minor amount of LNAPL removed through the passive recovery activities, this alternative does not significantly reduce the toxicity or volume of hazardous substances present at the Lease Parcel. Although the mobility of contaminants, including LNAPL, from the Lease Parcel appears limited, Alternative 1 does not take any actions to further reduce the mobility or contain the contamination at the source.	Through construction of a slurry wall around the perimeter of the Lease Parcel, Alternative 2 significantly reduces the mobility of hazardous substances inside the wall. As with Alternative 1, this alternative removes only a minor amount of LNAPL through passive recovery activities.	Alternative 3 significantly reduces the volume of LNAPL in the Lease Parcel through the construction and operation of an active LNAPL recovery system, and removal of all remaining subsurface structures that are a significant source of the seeps.	Alternative 4 significantly reduces the volume of LNAPL in the Lease Parcel with the expanded LNAPL recovery system and removal of the subsurface structures and highly contaminated soil. By including a slurry wall, Alternative 4 also permanently reduces the mobility of residual hazardous substances inside the wall.	Alternative 5 significantly reduces the volume of LNAPL and hazardous substances present in the in the Lease Parcel by excavating approximately 19,000 tons of impacted soil in areas where LNAPL has been recently observed.	Similar to Alternative 5, except Alternative 6 removes over 32,000 tons of soil that exceeds the RSSLs and/or is situated at locations where LNAPL has been observed.
Cost	**Capital:** $90,000 **O&M (30-yr NPV):** $1,070,000 **Overall Cost:** $1,160,000	**Capital:** $1,840,000 **O&M (30-yr NPV):** $1,070,000 **Overall Cost:** $2,910,000	**Capital:** $2,600,000 **O&M (30-yr NPV):** $1,780,000 **Overall Cost:** $4,380,000	**Capital:** $2,690,000 **O&M (30-yr NPV):** $1,190,000 **Overall Cost:** $3,880,000	**Capital:** $4,310,000 **O&M (30-yr NPV):** $1,070,000 **Overall Cost:** $5,380,000	**Capital:** $5,920,000 **O&M (30-yr NPV):** $1,070,000 **Overall Cost:** $6,990,000
Long-Term Effectiveness	This alternative will require long-term inspection and maintenance of the asphalt paving, groundwater and LNAPL monitoring, and passive recovery of LNAPL. These are all straightforward and effective actions that are reliable as long as they continue to be implemented.	The slurry wall around the Lease Parcel will effectively and reliably control potential migration of LNAPL from the Lease Parcel with little or no maintenance. Also, by isolating the major source of dissolved phase contamination in groundwater, Alternative 2 will reduce downgradient concentrations over time. This Alternative also requires long-term inspection and maintenance of the cap, groundwater and LNAPL monitoring, and passive recovery of LNAPL.	Although the active LNAPL recovery system included in Alternative 3 requires ongoing O&M, the technologies utilized are well established and can be effectively and reliably operated. Also, by reducing a major source of dissolved phase contamination in groundwater, Alternative 3 may reduce downgradient concentrations over time. As with the other alternatives, Alternative 3 requires long-term inspection and maintenance of the asphalt paving, groundwater and LNAPL monitoring, and passive recovery of LNAPL outside the area where the active LNAPL recovery system is operational.	Similar to Alternative 3, the LNAPL recovery system will require O&M (albeit less than the Alternative 3 system) but will reduce a major source of groundwater contamination. The slurry wall around the Lease Parcel will effectively and reliably control potential migration of LNAPL from the Lease Parcel with little or no maintenance. The combination of these actions in reducing and isolating the major source of dissolved phase contamination in groundwater will reduce downgradient concentrations over time.	Excavation of the impacted soil (19,000 tons) in areas where LNAPL has been observed is an effective and reliable approach to removing LNAPL and requires no O&M after implementation. Also, by reducing a major source of dissolved phase contamination in groundwater, Alternative 5 could reduce downgradient concentrations over time. As with the other alternatives, Alternative 5 requires long-term inspection and maintenance of the asphalt paving, groundwater and LNAPL monitoring, and passive recovery of LNAPL as needed outside the excavation area.	The long-term effectiveness of Alternative 6 is expected to be similar to or slightly better than Alternative 5. Given that significant additional impacted soil removal, (70%) it is likely that downgradient dissolved concentrations will decrease over time.

Table 11-1

Evaluation of Use of Permanent Solutions to Maximum Extent Practicable
Lease Parcel Cleanup Action Alternatives
Port of Seattle Terminal 91 Feasibility Study
Seattle, Washington

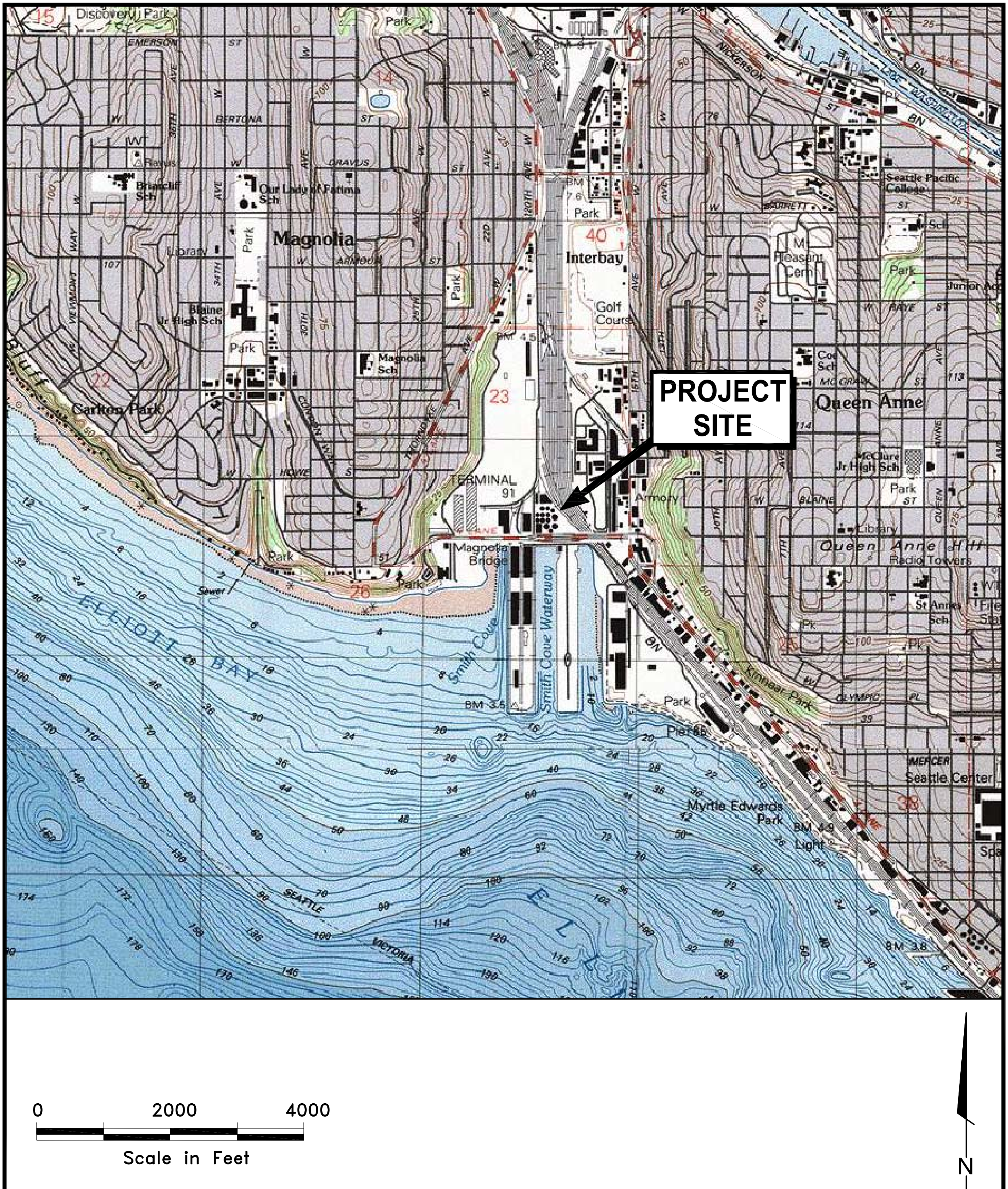
Evaluation Criteria	Alternative 1 – Existing Asphalt Paving Maintenance and Monitoring	Alternative 2 – Containment and Passive LNAPL Recovery	Alternative 3 – Active LNAPL Recovery and Subsurface Structure Removal	Alternative 4 – Containment, Subsurface Structure Removal, and Expanded LNAPL Recovery	Alternative 5 – Limited Excavation of LNAPL Areas	Alternative 6 – Excavation of Soils Exceeding RSSLs
Management of Short-Term Risks	With respect to the Lease Parcel, there are no current or short-term risks to human health or the environment that need to be addressed. Given the limited actions associated with Alternative 1, there are minimal short-term risks associated with its implementation, and what minor risks are present (associated with monitoring, LNAPL recovery, etc.) can be easily mitigated through development and implementation of a site-specific health and safety plan, including appropriate use of engineering controls and personal protective equipment.	As with Alternative 1, there are no current or short-term risks to human health that need to be addressed. Implementation risks associated with Alternative 2 are related to the heavy construction activities involved with placement of the slurry wall and composite surface cap. Potential volatilization of subsurface VOCs should be minimized by the nature of one-pass trencher operations. With appropriate engineering design and careful implementation of health and safety procedures typical for this type of activity, these risks can be adequately controlled.	As with Alternative 1, there are no current or short-term risks to human health that need to be addressed. Implementation risks associated with Alternative 3 include the heavy construction activities associated with removal of the existing asphalt paving, removal of the remaining subsurface structures, and construction of the asphalt paving. Potential volatilization of subsurface VOCs can be minimized by sequencing of excavation and backfilling to minimize the amount of exposed soil. There are also construction-related risks associated with installation of the active LNAPL recovery system (e.g., well installation, trenching, piping and equipment installation). With appropriate engineering design and careful implementation of health and safety procedures typical for this type of activity, these risks can be adequately controlled.	As with Alternative 1, there are no current or short-term risks to human health that need to be addressed. Implementation risks associated with Alternative 4 are similar to those described for Alternative 3, with a slight increase in the construction-related risks associated with construction of the slurry wall. As with Alternative 3, careful engineering design and appropriate use of health and safety procedures can control these risks.	As with Alternative 1, there are no current or short-term risks to human health that need to be addressed. Implementation risks associated with Alternative 5 are related to the heavy construction activities associated with removal of the existing asphalt paving, removal of the remaining subsurface structures, excavation of 19,000 tons of soil, and construction of the asphalt paving. Potential volatilization of subsurface VOCs can be minimized by sequencing of excavation and backfilling to minimize the amount of exposed soil. There are also traffic-related risks associated with the off-site transport of the excavated soil and import of clean backfill material (approximately 900 to 1,000 truck and trailer trips). With appropriate engineering design and careful implementation of health and safety procedures typical for this type of activity, these risks can be adequately controlled.	The short-term risks for Alternative 6 are very similar to those of Alternative 5, except the amount of soil excavation and related truck traffic for off site disposal are approximately 70 percent higher.
Technical and Administrative Implementability	Technical – All of the components are in common use and readily available, and there are no significant technical implementability issues for this alternative. Administrative – There are no significant permits required for implementation of this alternative. Recovered LNAPL would need to be characterized and disposed of consistent with state and federal solid and dangerous/hazardous waste regulations.	Technical – All of the components used in the slurry wall have been demonstrated at full scale at dozens of other sites, and the materials are readily available. The one-pass trencher technology used to place the slurry wall has been demonstrated at the anticipated depths and used many times in similar applications. There are no significant technical implementability issues for this alternative. Administrative – There are no major permits required to implement this alternative as it is constructed entirely onsite. Minor permits that may be required include an Ecology NPDES Construction Stormwater General Permit and a city grading permit. Excavated soils and other waste (LNAPL) would need to be characterized and disposed of consistent with state and federal solid and dangerous/hazardous waste regulations.	Technical – All of the components used in the construction of the active LNAPL recovery system have been well demonstrated at other sites. There are no significant technical implementability issues for this alternative. Administrative – There are no major permits required to implement this alternative as it is constructed entirely onsite. Minor permits that may be required include an Ecology NPDES Construction Stormwater General Permit and a city grading permit. Excavated soils and other waste (LNAPL) would need to be characterized and disposed of consistent with state and federal solid and dangerous/hazardous waste regulations.	Technical – All of the components used in the construction of the expanded LNAPL recovery system and slurry wall have been well demonstrated at other sites. There are no significant technical implementability issues for this alternative. Administrative – There are no major permits required to implement this alternative as it is constructed entirely onsite. Minor permits that may be required include an Ecology NPDES Construction Stormwater General Permit and a city grading permit. Excavated soils and other waste (LNAPL) would need to be characterized and disposed of consistent with state and federal solid and dangerous/hazardous waste regulations.	Technical – All of the components of this alternative are standard construction technologies that have been well demonstrated at other sites. There are no significant technical implementability issues for this alternative. Administrative – There are no major permits required to implement this alternative as it is constructed entirely onsite. Minor permits that may be required include an Ecology NPDES Construction Stormwater General Permit and a city grading permit. Excavated soils and other waste would need to be characterized and disposed of consistent with state and federal solid and dangerous/hazardous waste regulations.	Same as Alternative 5.

Table 11-1

Evaluation of Use of Permanent Solutions to Maximum Extent Practicable
Lease Parcel Cleanup Action Alternatives
Port of Seattle Terminal 91 Feasibility Study
Seattle, Washington

Evaluation Criteria	Alternative 1 – Existing Asphalt Paving Maintenance and Monitoring	Alternative 2 – Containment and Passive LNAPL Recovery	Alternative 3 – Active LNAPL Recovery and Subsurface Structure Removal	Alternative 4 – Containment, Subsurface Structure Removal, and Expanded LNAPL Recovery	Alternative 5 – Limited Excavation of LNAPL Areas	Alternative 6 – Excavation of Soils Exceeding RSSLs
Consideration of Public Concerns	Public concerns associated with the possible implementation of this alternative will be addressed during the public review and comment process for this FS.	Public concerns associated with the possible implementation of this alternative will be addressed during the public review and comment process for this FS.	Public concerns associated with the possible implementation of this alternative will be addressed during the public review and comment process for this FS.	Public concerns associated with the possible implementation of this alternative will be addressed during the public review and comment process for this FS.	Public concerns associated with the possible implementation of this alternative will be addressed during the public review and comment process for this FS.	Public concerns associated with the possible implementation of this alternative will be addressed during the public review and comment process for this FS.

ILLUSTRATIONS



U.S.G.S. Topo Map - Seattle North W, WA, 7.5-minute quadrangle.1983

PES Environmental, Inc.
Engineering & Environmental Services

Site Location Map
Port of Seattle Terminal 91
Seattle, Washington

FIGURE
2-1

948.002.06.008	948-00206008_FS_2-1		1/09
JOB NUMBER	DRAWING NUMBER	REVIEWED BY	DATE

948-00206008_FS-R_2-2

For areas shown as Tank Farm Affected Area ("TFAA") that are outside the Tank Farm Lease Parcel, the TFAA includes only soil and ground water below the water table. Soil above the water table (and outside the Tank Farm Lease Parcel) is outside the TFAA.

Note:

N

0 700 feet

The locations of all features are approximate.

Explanation

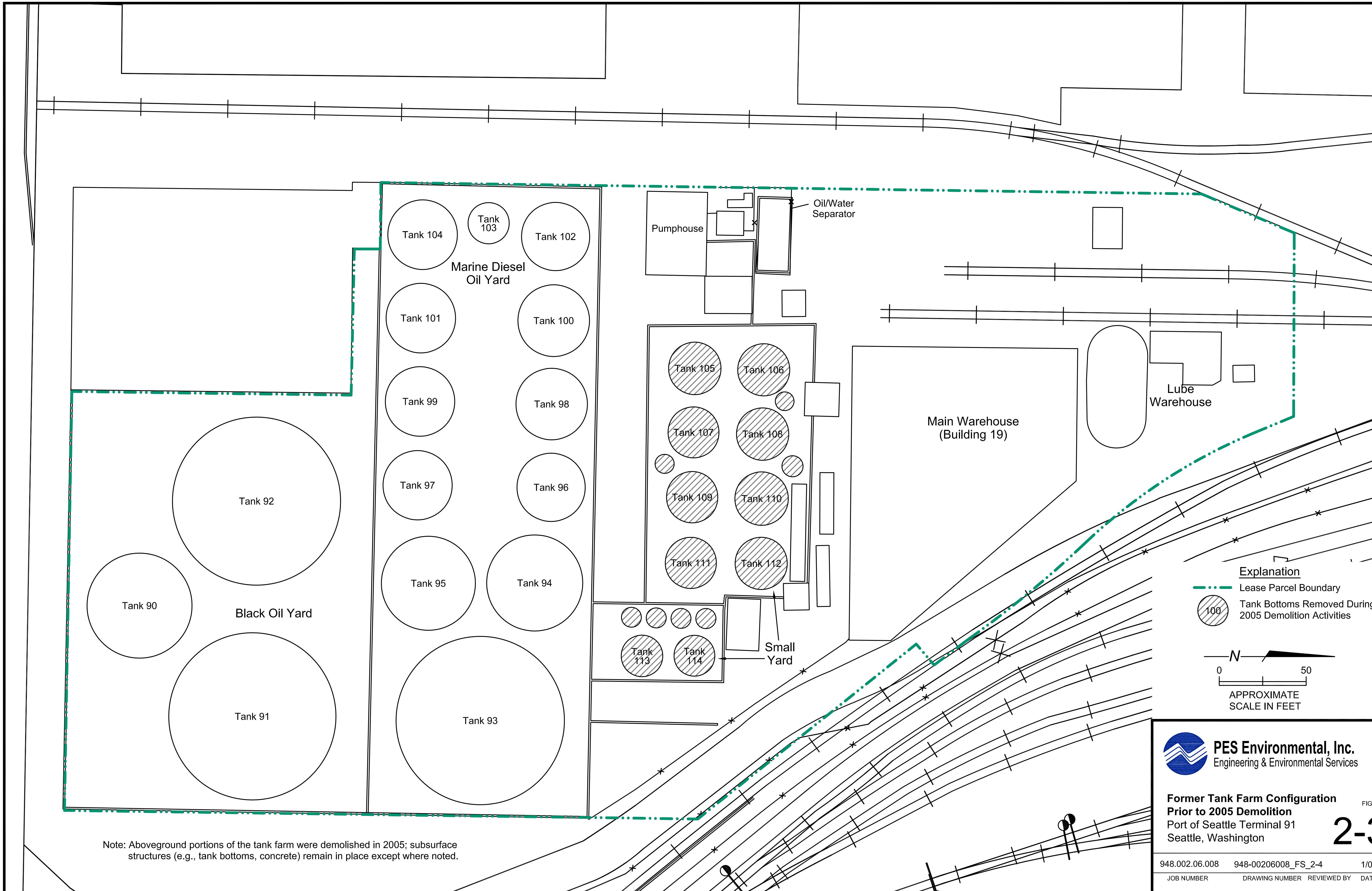
- Port of Seattle Property Limits
- Tank Farm Lease Parcel
- Tank Farm Affected Area
- Submerged Land

PES Environmental, Inc.
Engineering & Environmental Services

FIGURE
2-2

Port of Seattle Terminal 91 Facility and Tank Farm Lease Parcel
Port of Seattle Terminal 91
Seattle, Washington

JOB NUMBER	DRAWING NUMBER	REVIEWED BY	DATE
948.002.06.008	948-00206008_FS-R_2-2		12/09



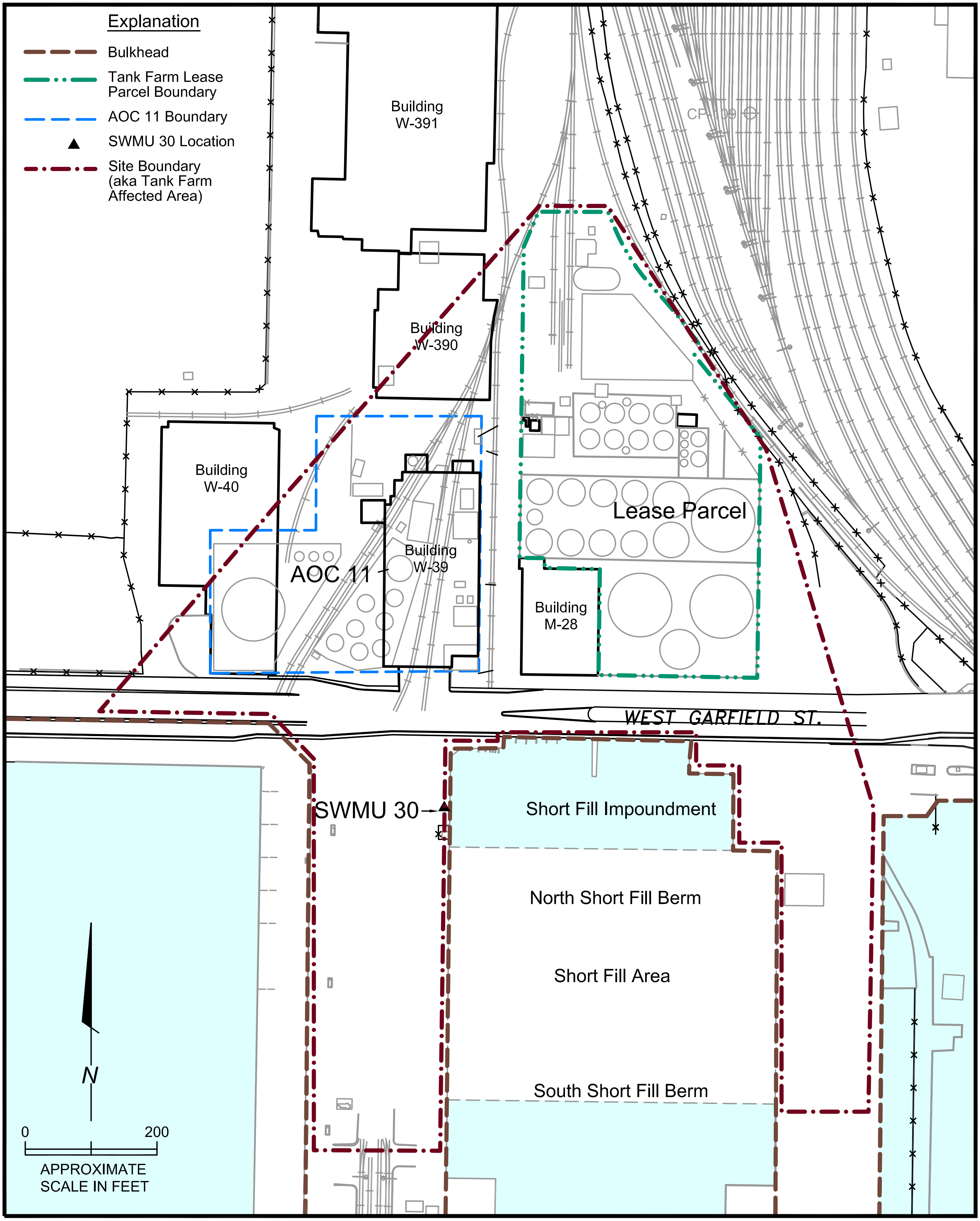
Note: Aboveground portions of the tank farm were demolished in 2005; subsurface structures (e.g., tank bottoms, concrete) remain in place except where noted.

PES Environmental, Inc.
Engineering & Environmental Services

Former Tank Farm Configuration Prior to 2005 Demolition
Port of Seattle Terminal 91
Seattle, Washington

FIGURE
2-3

JOB NUMBER	DRAWING NUMBER	REVIEWED BY	DATE
948.002.06.008	948-00206008_FS_2-4		1/09

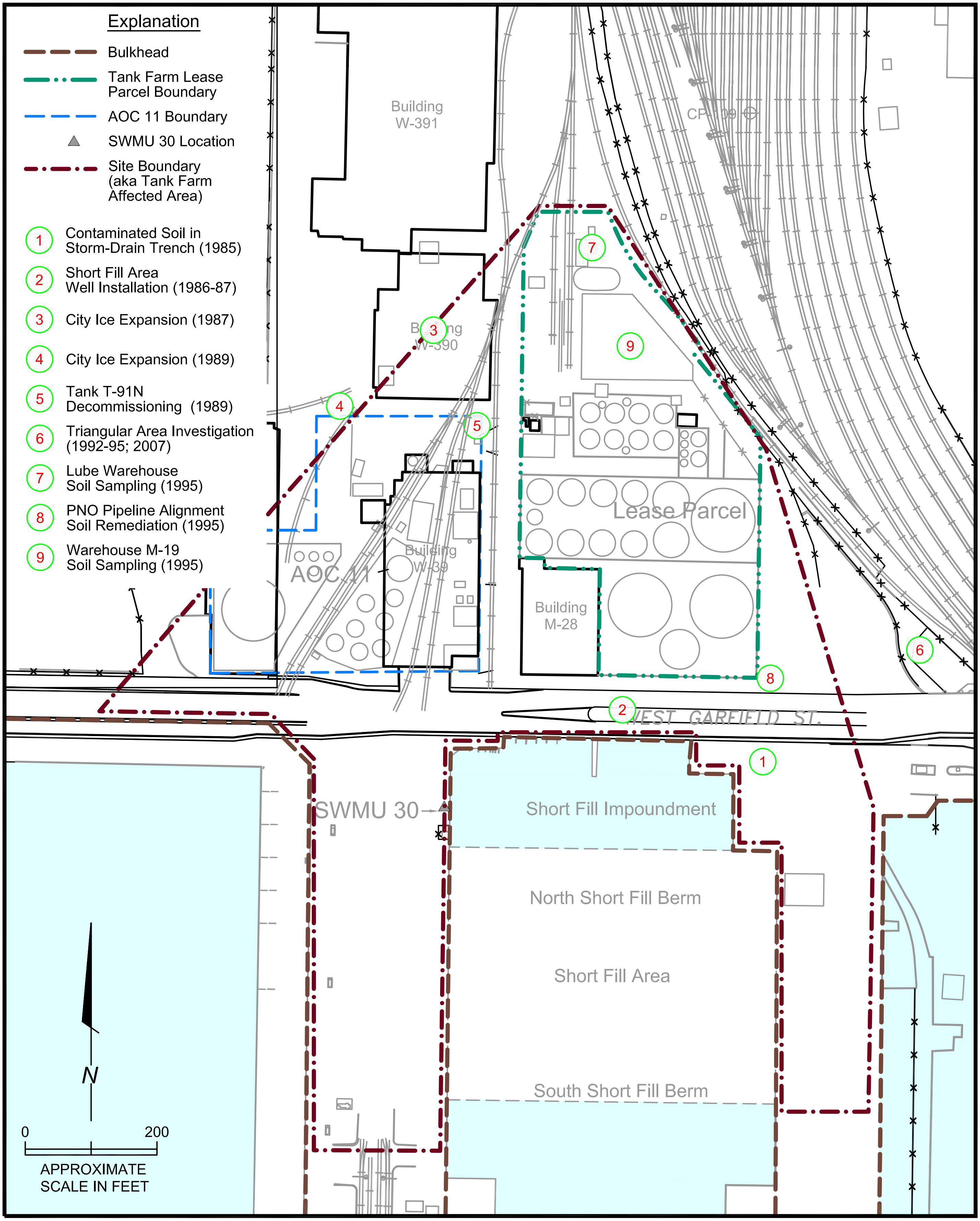


PES Environmental, Inc.
Engineering & Environmental Services

Site Plan
Port of Seattle Terminal 91 Tank Farm Site
Seattle, Washington

FIGURE
2-4

JOB NUMBER	DRAWING NUMBER	REVIEWED BY	DATE
948.002.05.008	948-00206008_FS-R_2-4 6-2		10/09

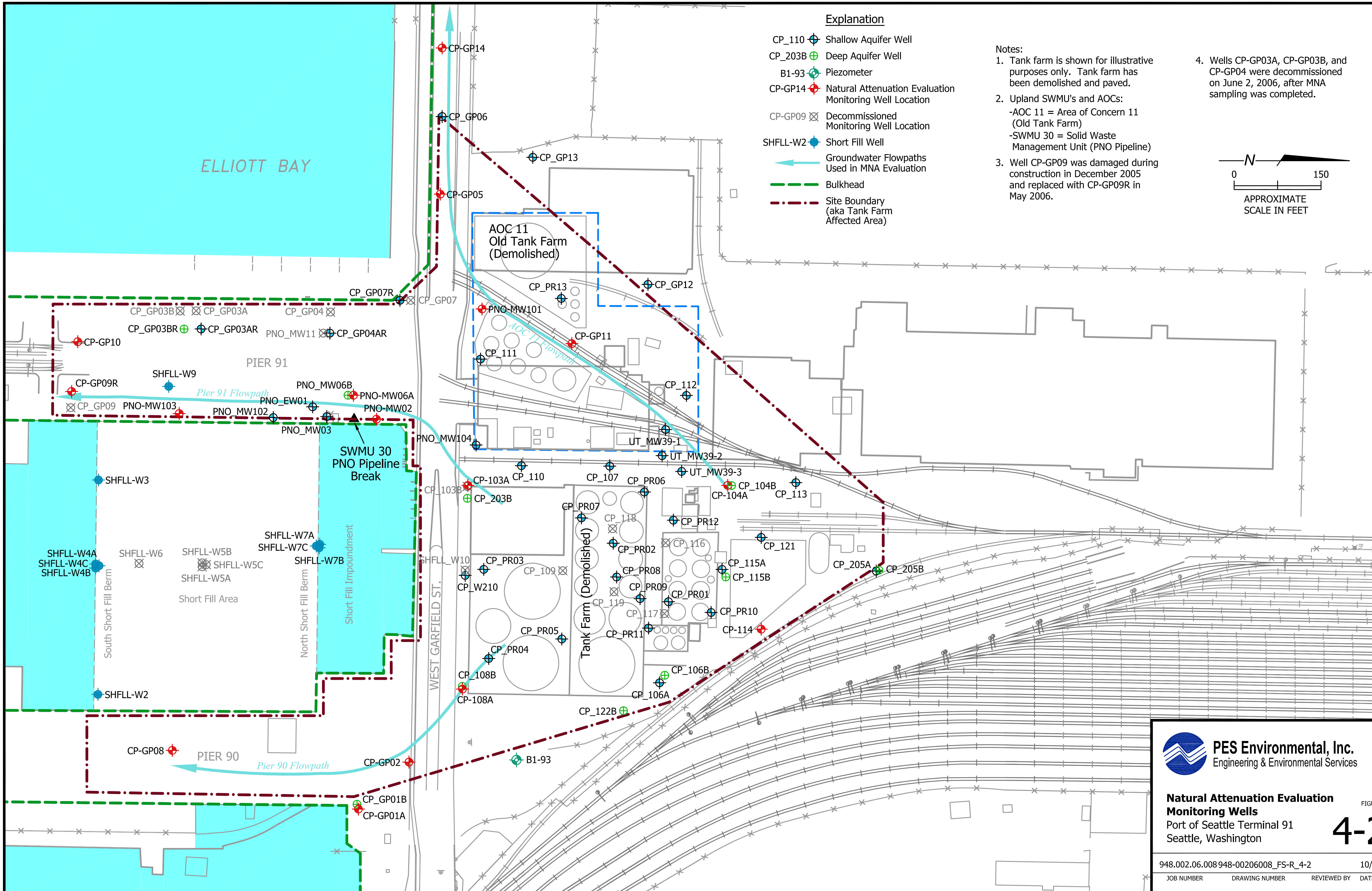


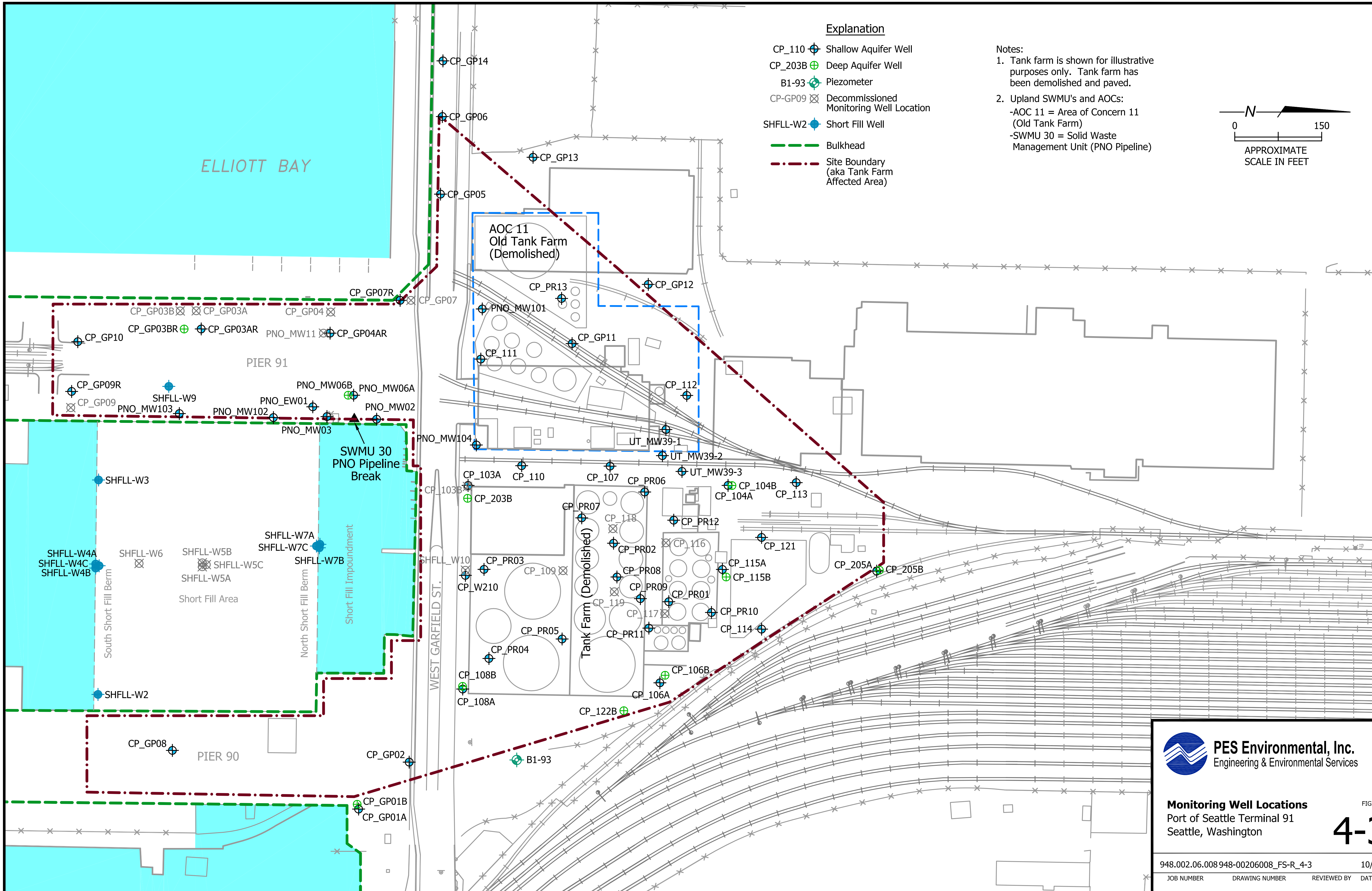
PES Environmental, Inc.
Engineering & Environmental Services

Location of Pre-1998 Investigations
Port of Seattle Terminal 91 Tank Farm Site
Seattle, Washington

FIGURE
4-1

948.002.06.008	948-00206008_FS-R_4-1		10/09
JOB NUMBER	DRAWING NUMBER	REVIEWED BY	DATE


ELLIOTT BAY
Explanation
CP_110 Shallow Aquifer Well
CP_203B Deep Aquifer Well
B1-93 Piezometer
CP-GP14 Natural Attenuation Evaluation Monitoring Well Location
CP-GP09 Decommissioned Monitoring Well Location
SHFLL-W2 Short Fill Well
Groundwater Flowpaths Used in MNA Evaluation
Bulkhead
Site Boundary (aka Tank Farm Affected Area)
Notes:
1. Tank farm is shown for illustrative purposes only. Tank farm has been demolished and paved.
2. Upland SWMU's and AOCs:
-AOC 11 = Area of Concern 11 (Old Tank Farm)
-SWMU 30 = Solid Waste Management Unit (PNO Pipeline)
3. Well CP-GP09 was damaged during construction in December 2005 and replaced with CP-GP09R in May 2006.
4. Wells CP-GP03A, CP-GP03B, and CP-GP04 were decommissioned on June 2, 2006, after MNA sampling was completed.
N
0
150
APPROXIMATE SCALE IN FEET
AOC 11
Old Tank Farm
(Demolished)
AOC 11 Flowpath
SWMU 30
PNO Pipeline
Break
PIER 91
Pier 91 Flowpath
PIER 90
Pier 90 Flowpath
Short Fill Area
South Short Fill Berm
North Short Fill Berm
Short Fill Impoundment
WEST GARFIELD ST.
Tank Farm (Demolished)
CP-GP14
CP_GP06
CP-GP05
CP_GP13
CP_GP12
CP_GP07R
CP_GP07
CP_GP03B
CP_GP03A
CP_GP04
CP_GP03BR
CP_GP03AR
PNO_MW11
CP_GP04AR
CP-GP10
CP-GP09R
CP_GP09
SHFLL-W9
PNO-MW103
PNO_MW102
PNO_EW01
PNO_MW06B
PNO-MW06A
PNO-MW02
PNO_MW03
PNO_MW104
PNO-MW101
CP_PR13
CP-GP11
CP_111
CP_112
UT_MW39-1
UT_MW39-2
UT_MW39-3
CP-103A
CP_103B
CP_203B
CP_110
CP_107
CP_PR06
CP-104B
CP-104A
CP_113
CP_PR07
CP_118
CP_PR12
CP_116
CP_121
CP_PR02
CP_PR03
CP_109
CP_W210
SHFLL_W10
CP_PR08
CP_PR09
CP_PR01
CP_115A
CP_115B
CP_205A
CP_205B
CP_119
CP_117
CP_PR10
CP_PR11
CP-114
CP_PR05
CP_PR04
CP_108B
CP-108A
CP_106B
CP_106A
CP_122B
B1-93
CP-GP02
CP-GP08
CP_GP01B
CP-GP01A
SHFLL-W3
SHFLL-W4A
SHFLL-W4C
SHFLL-W4B
SHFLL-W6
SHFLL-W5B
SHFLL-W5C
SHFLL-W5A
SHFLL-W7A
SHFLL-W7C
SHFLL-W7B
SHFLL-W2
PES Environmental, Inc.
Engineering & Environmental Services
Natural Attenuation Evaluation Monitoring Wells
Port of Seattle Terminal 91
Seattle, Washington
FIGURE
4-2
948.002.06.008
948-00206008_FS-R_4-2
10/09
JOB NUMBER
DRAWING NUMBER
REVIEWED BY
DATE



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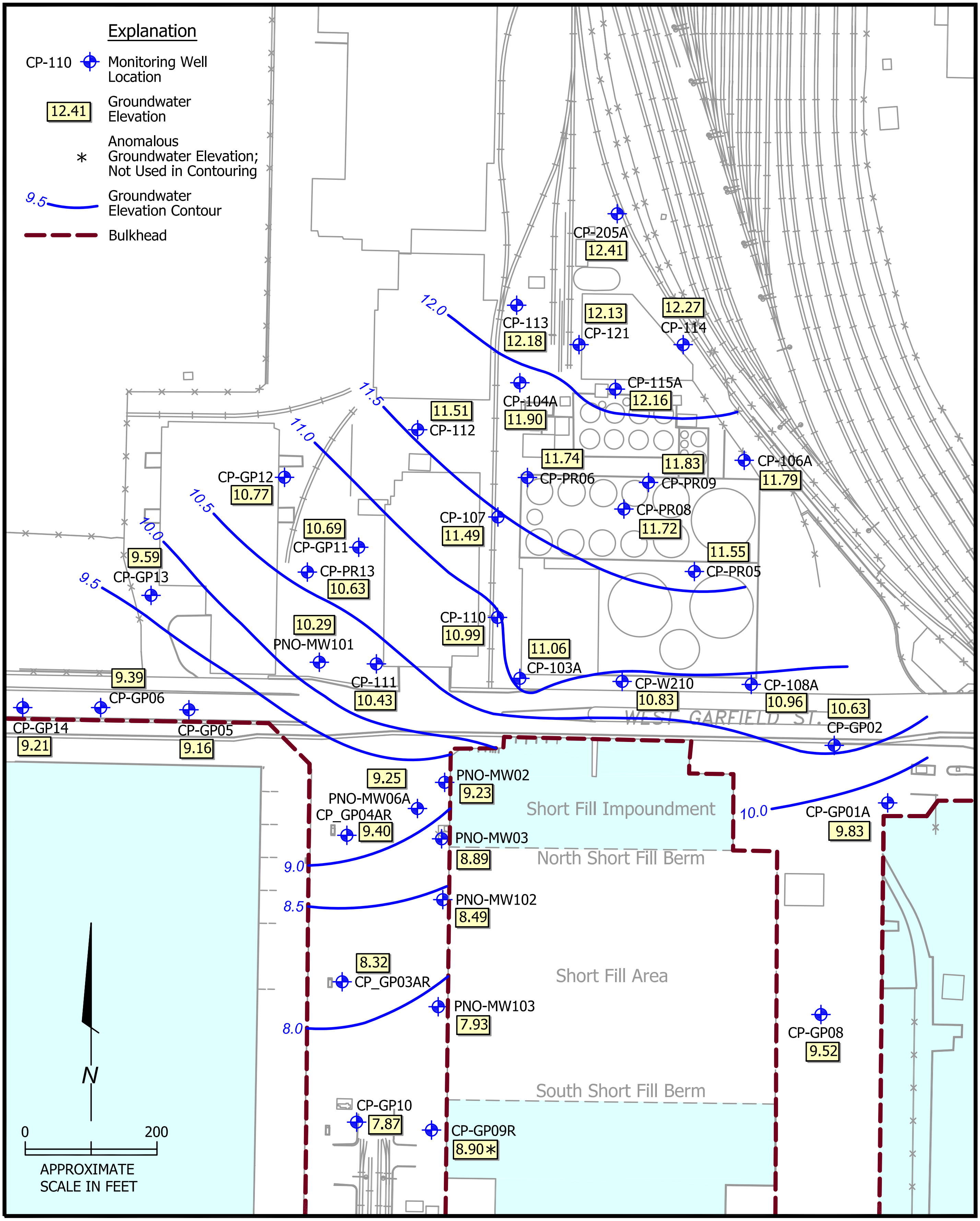
Engineering & Environmental Services

Monitoring Well Locations
Port of Seattle Terminal 91
Seattle, Washington

FIGURE **4-3**

948.002.06.008	948-00206008_FS-R_4-3		10/09
JOB NUMBER	DRAWING NUMBER	REVIEWED BY	DATE

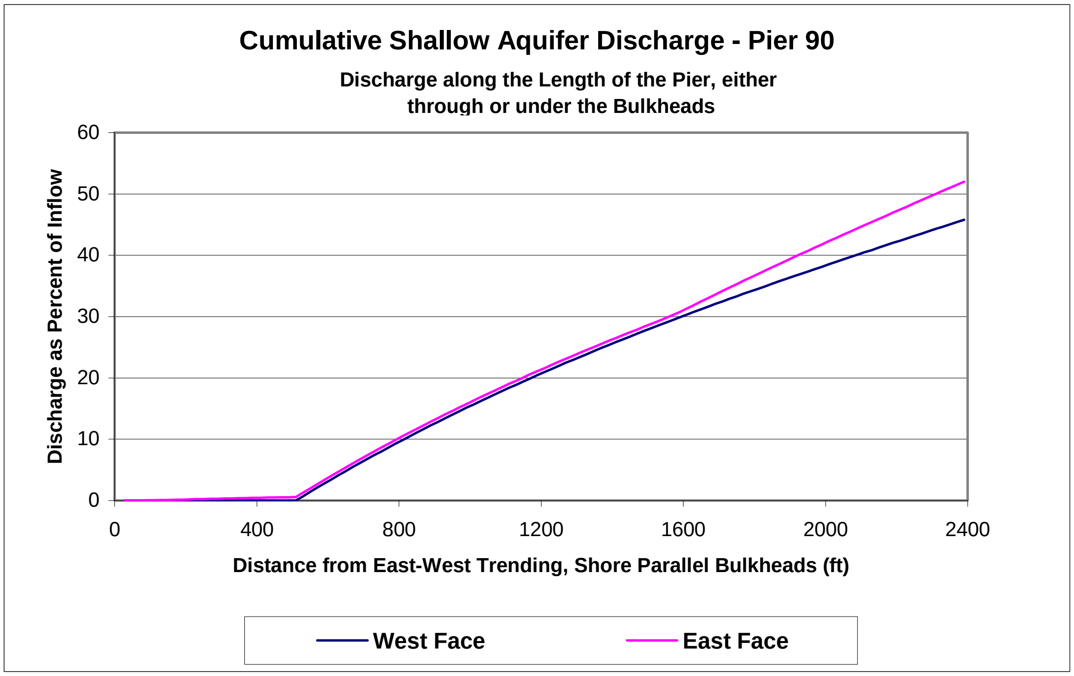


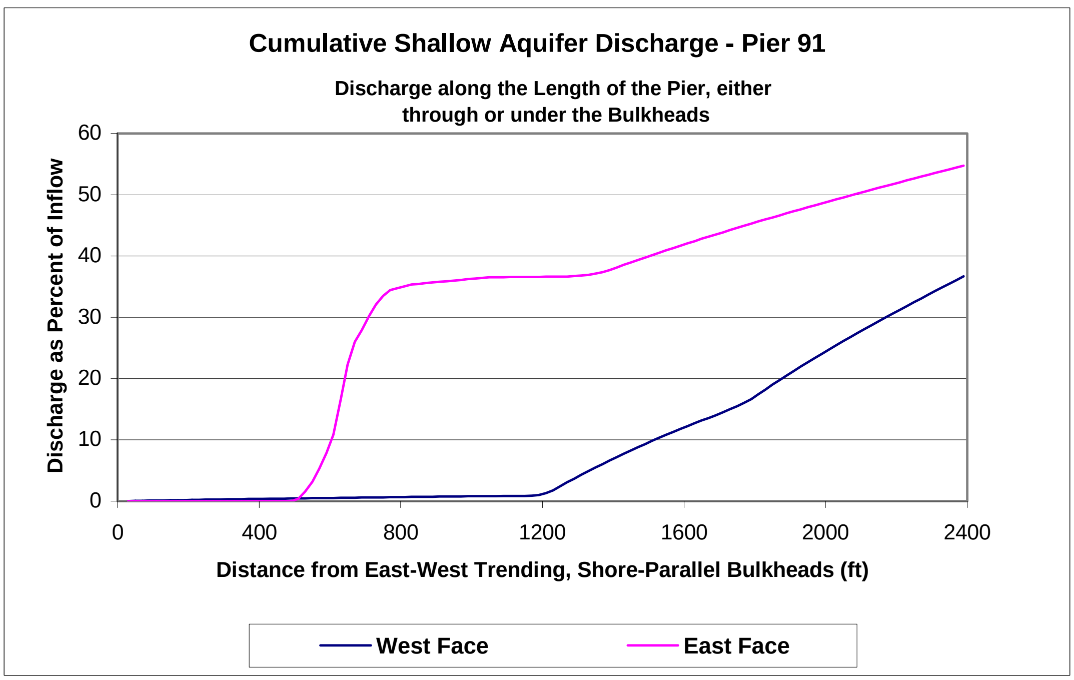
PES Environmental, Inc.
Engineering & Environmental Services

Shallow Aquifer Water Level Elevations - March 10, 2008
Port of Seattle Terminal 91 Tank Farm Site
Seattle, Washington

FIGURE
5-1

JOB NUMBER	DRAWING NUMBER	REVIEWED BY	DATE
948.002.06.008	948-00206008_FS_5-1		1/09





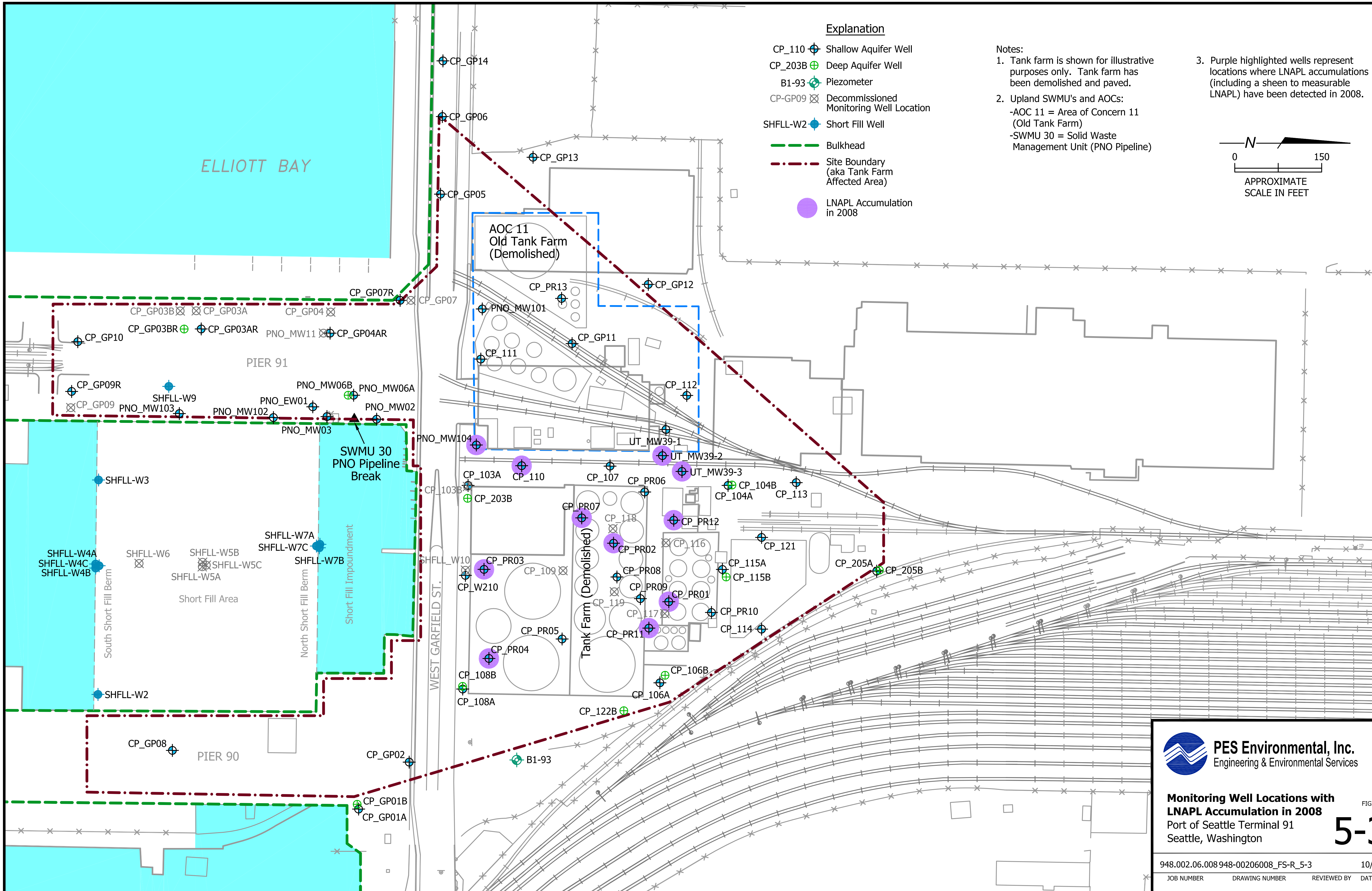
Source - Groundwater Seepage Evaluation Report (Aspect Consulting, 2004)

PES Environmental, Inc.
Engineering & Environmental Services

Shallow Aquifer Discharge, Piers 90 and 91
Port of Seattle Terminal 91
Seattle, Washington

FIGURE
5-2

948.002.06.008	948-00206008_FS_5-2		1/09
JOB NUMBER	DRAWING NUMBER	REVIEWED BY	DATE

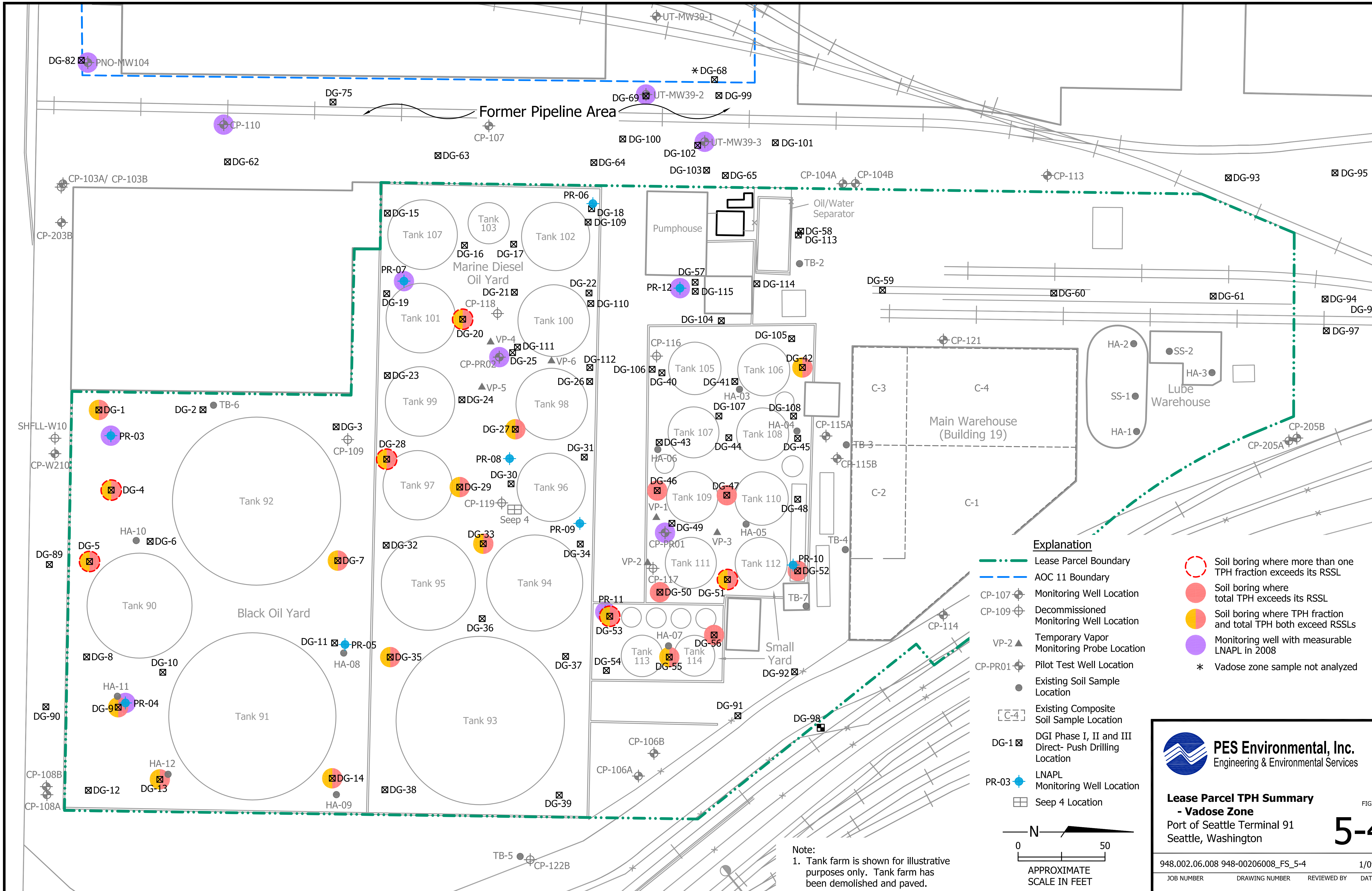


PES Environmental, Inc.
Engineering & Environmental Services

Monitoring Well Locations with LNAPL Accumulation in 2008
Port of Seattle Terminal 91
Seattle, Washington

FIGURE 5-3

JOB NUMBER	DRAWING NUMBER	REVIEWED BY	DATE
948.002.06.008	948-00206008_FS-R_5-3		10/09



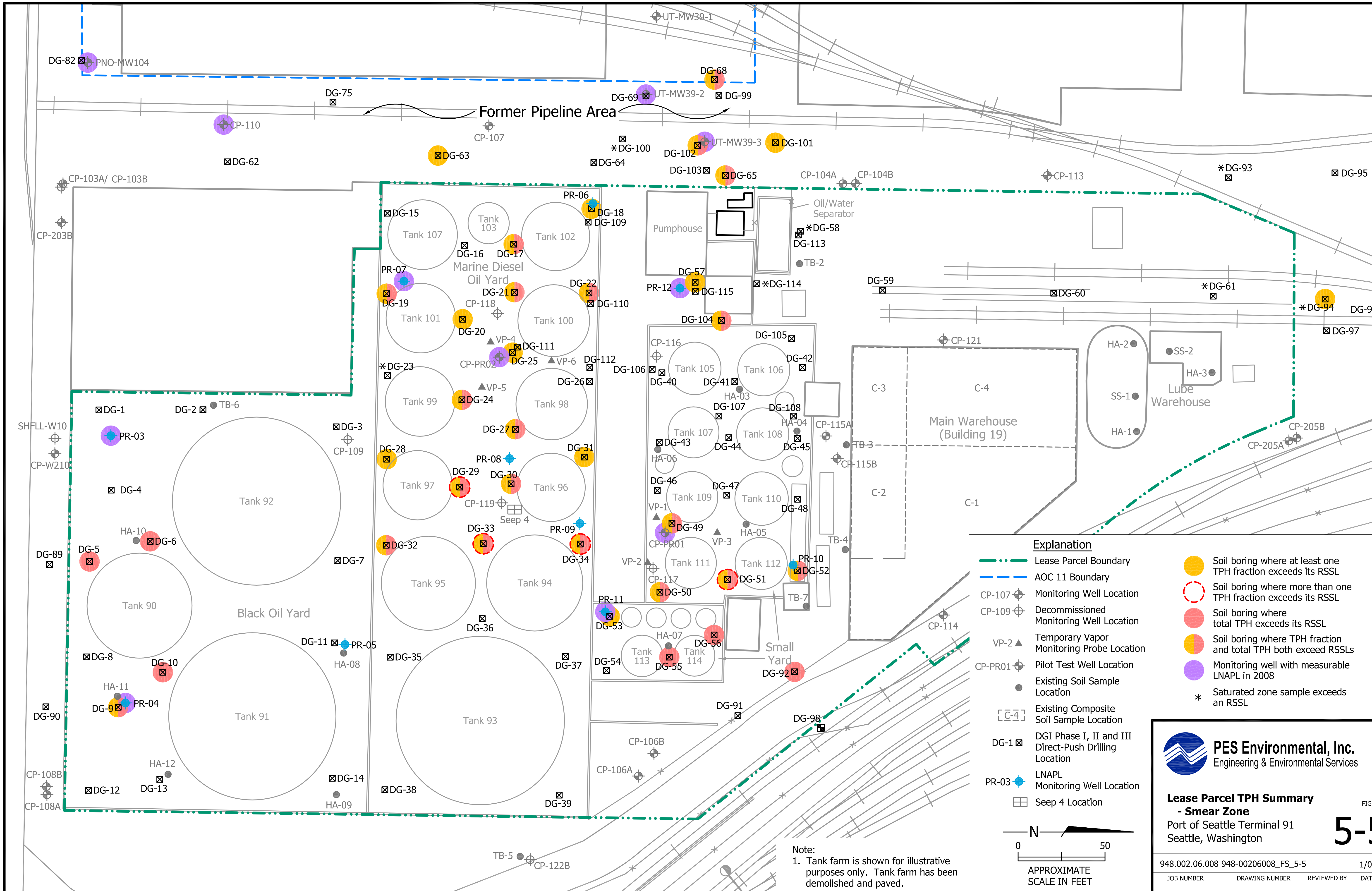
PES Environmental, Inc.
Engineering & Environmental Services

Lease Parcel TPH Summary - Vadose Zone

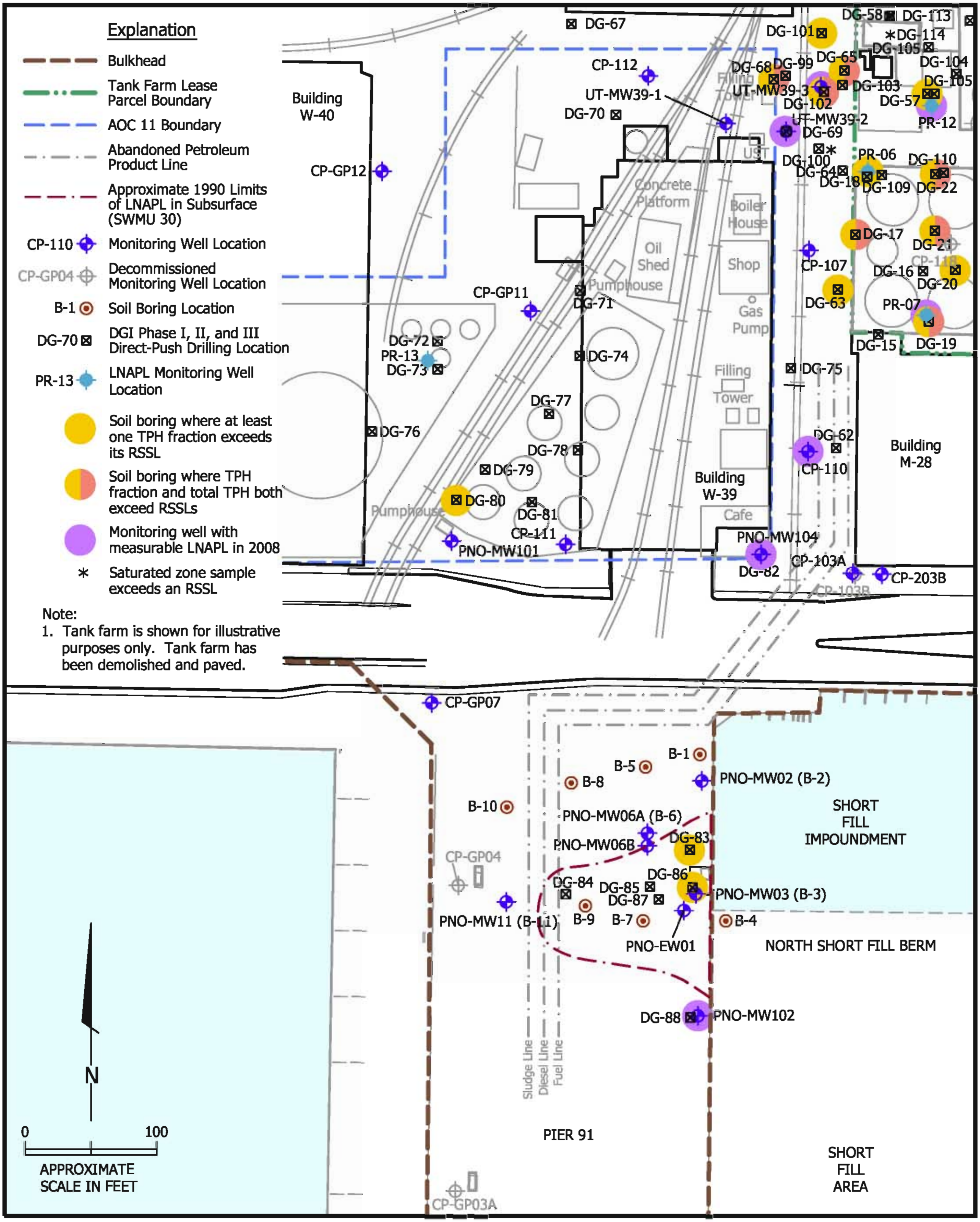
Port of Seattle Terminal 91
Seattle, Washington

FIGURE
5-4

JOB NUMBER	DRAWING NUMBER	REVIEWED BY	DATE
948.002.06.008	948-00206008_FS_5-4		1/09



Former Pipeline Area
Marine Diesel Oil Yard
Black Oil Yard
Main Warehouse (Building 19)
Lube Warehouse
Pumphouse
Oil/Water Separator
Small Yard
Seep 4
Tank 107
Tank 103
Tank 102
Tank 101
Tank 100
Tank 99
Tank 98
Tank 97
Tank 96
Tank 95
Tank 94
Tank 93
Tank 92
Tank 91
Tank 90
Tank 105
Tank 106
Tank 108
Tank 109
Tank 110
Tank 111
Tank 112
Tank 113
Tank 114
C-1
C-2
C-3
C-4
Explanation
Lease Parcel Boundary
AOC 11 Boundary
CP-107 Monitoring Well Location
CP-109 Decommissioned Monitoring Well Location
VP-2 Temporary Vapor Monitoring Probe Location
CP-PR01 Pilot Test Well Location
Existing Soil Sample Location
C-4 Existing Composite Soil Sample Location
DG-1 DGI Phase I, II and III Direct-Push Drilling Location
PR-03 LNAPL Monitoring Well Location
Seep 4 Location
Soil boring where at least one TPH fraction exceeds its RSSL
Soil boring where more than one TPH fraction exceeds its RSSL
Soil boring where total TPH exceeds its RSSL
Soil boring where TPH fraction and total TPH both exceed RSSLs
Monitoring well with measurable LNAPL in 2008
* Saturated zone sample exceeds an RSSL
N
0
50
APPROXIMATE SCALE IN FEET
Note:
1. Tank farm is shown for illustrative purposes only. Tank farm has been demolished and paved.
PES Environmental, Inc.
Engineering & Environmental Services
Lease Parcel TPH Summary - Smear Zone
Port of Seattle Terminal 91
Seattle, Washington
FIGURE
5-5
948.002.06.008
948-00206008_FS_5-5
1/09
JOB NUMBER
DRAWING NUMBER
REVIEWED BY
DATE

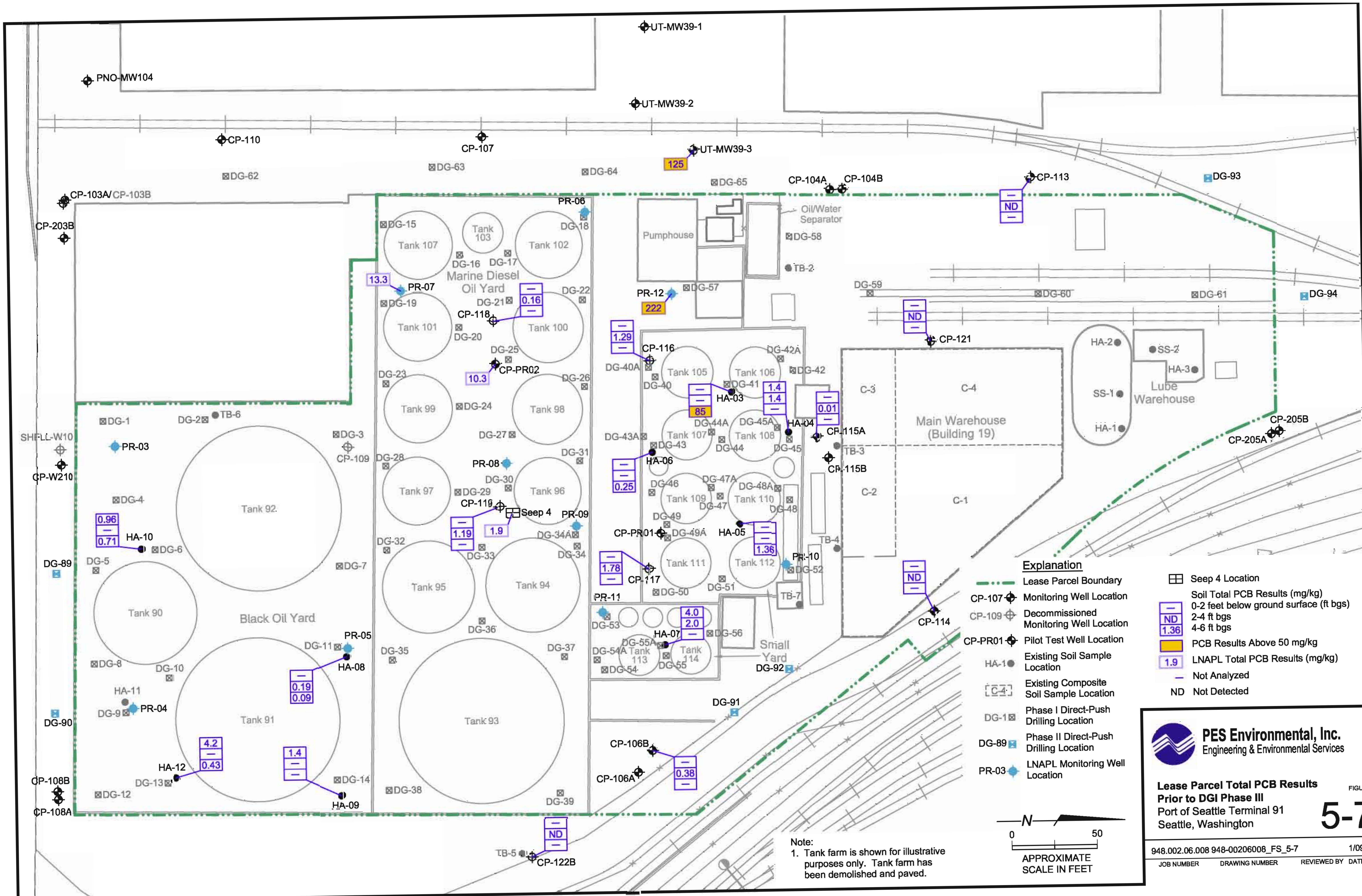


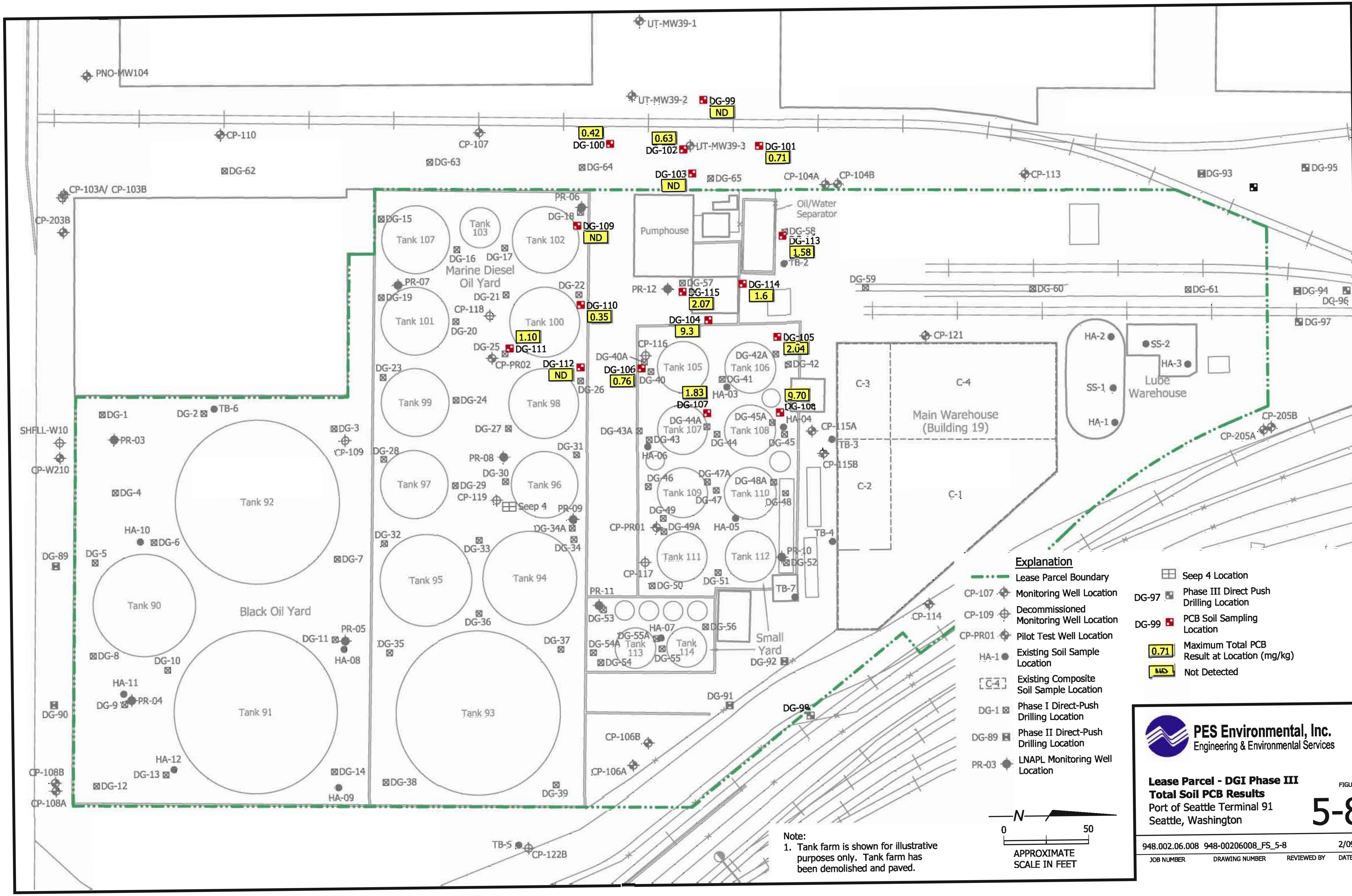
PES Environmental, Inc.
Engineering & Environmental Services

AOC 11 and SWMU 30 TPH Summary - Smear Zone
Port of Seattle Terminal 91
Seattle, Washington

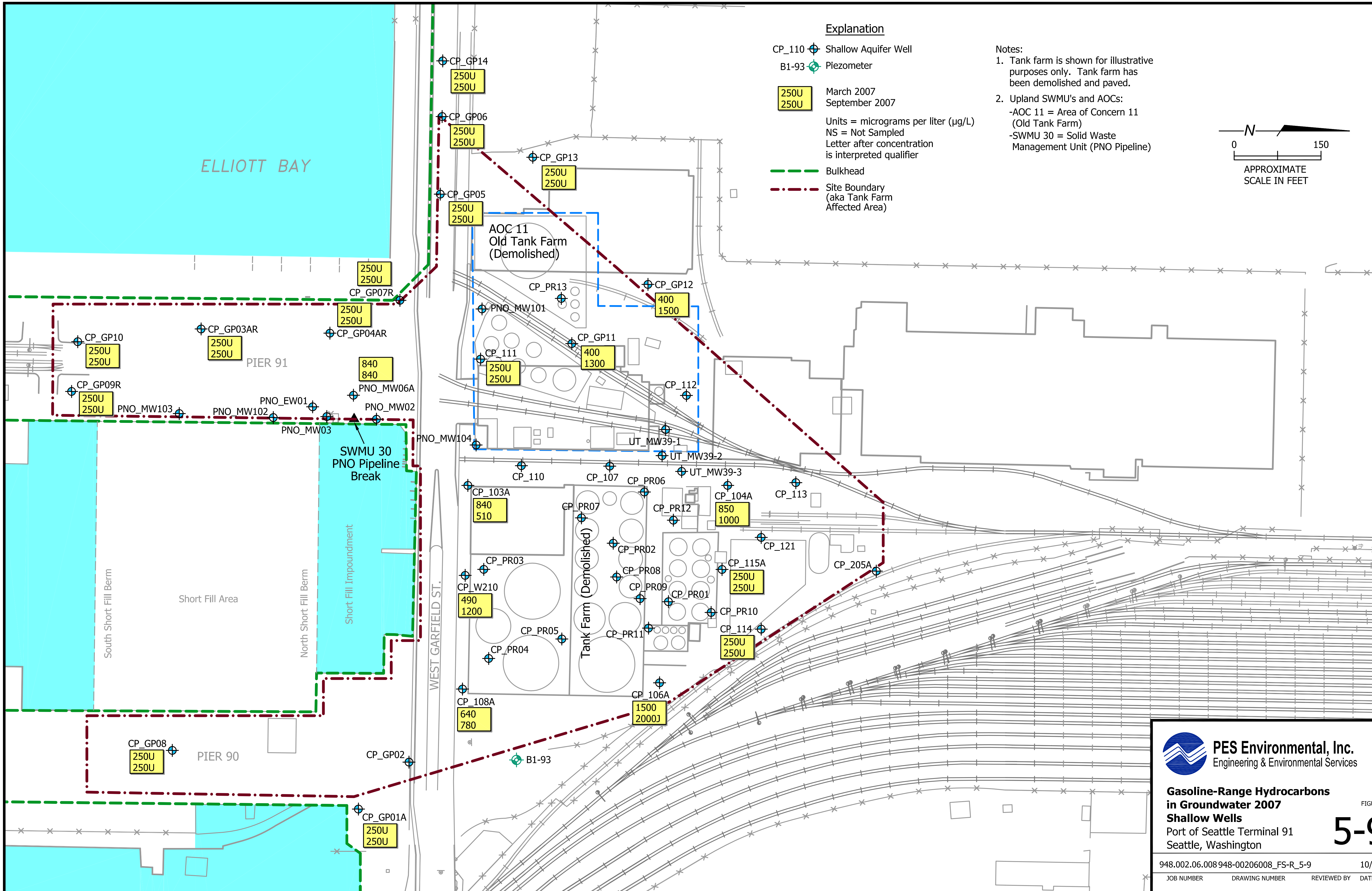
FIGURE 5-6

JOB NUMBER	DRAWING NUMBER	REVIEWED BY	DATE
948.002.06.008	948-00206008_FS-R_5-6		10/09


Explanation
Lease Parcel Boundary
CP-107 Monitoring Well Location
CP-109 Decommissioned Monitoring Well Location
CP-PR01 Pilot Test Well Location
HA-1 Existing Soil Sample Location
C-4 Existing Composite Soil Sample Location
DG-1 Phase I Direct-Push Drilling Location
DG-89 Phase II Direct-Push Drilling Location
PR-03 LNAPL Monitoring Well Location
Seep 4 Location
Soil Total PCB Results (mg/kg)
0-2 feet below ground surface (ft bgs)
2-4 ft bgs
4-6 ft bgs
PCB Results Above 50 mg/kg
1.9 LNAPL Total PCB Results (mg/kg)
– Not Analyzed
ND Not Detected
Tank 92
Tank 90
Tank 91
Tank 93
Black Oil Yard
Marine Diesel Oil Yard
Pumphouse
Oil/Water Separator
Main Warehouse (Building 19)
Lube Warehouse
Small Yard
Note:
1. Tank farm is shown for illustrative purposes only. Tank farm has been demolished and paved.
N
0 50
APPROXIMATE SCALE IN FEET
PES Environmental, Inc.
Engineering & Environmental Services
Lease Parcel Total PCB Results Prior to DGI Phase III
Port of Seattle Terminal 91
Seattle, Washington
FIGURE
5-7
948.002.06.008 948-00206008_FS_5-7 1/09
JOB NUMBER DRAWING NUMBER REVIEWED BY DATE

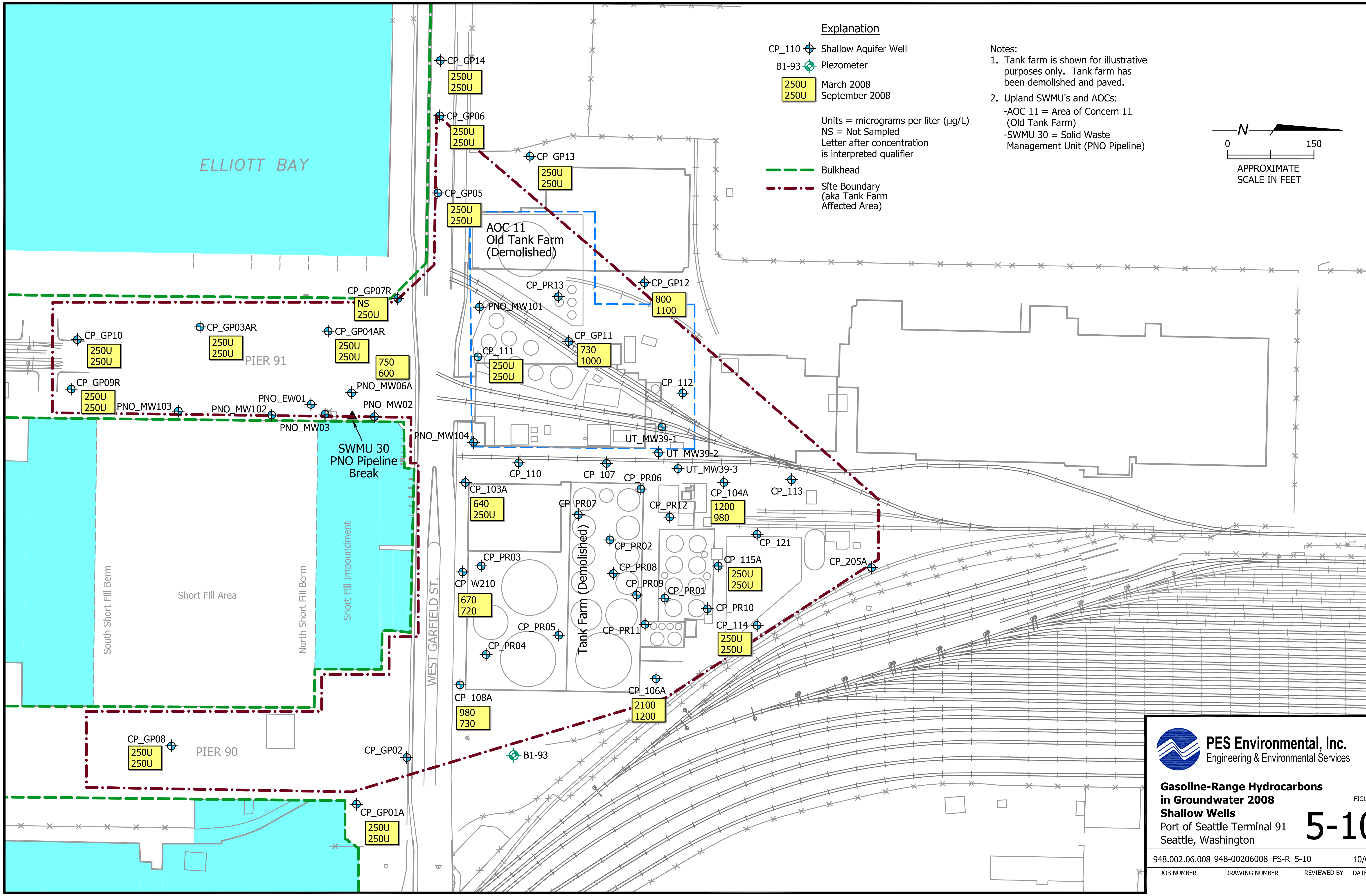


UT-MW39-1
PNO-MW104
UT-MW39-2
DG-99
ND
CP-110
CP-107
0.42
DG-100
0.63
DG-102
UT-MW39-3
DG-101
0.71
DG-62
DG-63
DG-64
DG-103
ND
DG-65
CP-104A
CP-104B
CP-113
DG-93
DG-95
CP-103A/ CP-103B
CP-203B
PR-06
DG-18
DG-109
ND
Pumphouse
Oil/Water Separator
DG-58
DG-113
1.58
TB-2
DG-15
Tank 107
Tank 103
Tank 102
DG-16
DG-17
Marine Diesel Oil Yard
PR-07
DG-19
DG-21
DG-22
DG-57
DG-115
2.07
PR-12
DG-114
1.6
DG-59
DG-60
DG-61
DG-94
DG-96
DG-97
Tank 101
CP-118
DG-20
Tank 100
DG-110
0.35
DG-104
9.3
CP-121
1.10
DG-25
DG-111
CP-PR02
DG-112
ND
DG-105
2.04
DG-23
CP-116
DG-40A
DG-106
0.76
DG-40
Tank 105
DG-42A
Tank 106
DG-41
DG-42
HA-2
SS-2
HA-3
SS-1
HA-1
Lube Warehouse
C-3
C-4
Main Warehouse (Building 19)
Tank 99
DG-24
Tank 98
DG-26
1.83
DG-107
HA-03
9.70
DG-108
HA-04
DG-1
DG-2
TB-6
SHFLL-W10
PR-03
DG-3
CP-109
CP-W210
DG-27
DG-43A
DG-44A
Tank 107
DG-43
DG-45A
Tank 108
DG-44
DG-45
CP-115A
TB-3
CP-115B
CP-205B
CP-205A
DG-28
Tank 97
PR-08
DG-30
DG-29
CP-119
Seep 4
Tank 96
DG-31
HA-06
DG-46
DG-47A
Tank 109
DG-47
DG-48A
Tank 110
DG-48
C-2
C-1
DG-4
Tank 92
PR-09
DG-34A
DG-49
CP-PR01
DG-49A
HA-05
TB-4
HA-10
DG-6
DG-32
DG-33
DG-34
Tank 111
Tank 112
PR-10
DG-52
DG-89
DG-5
DG-7
Tank 95
Tank 94
CP-117
DG-50
DG-51
TB-7
Tank 90
Black Oil Yard
PR-11
DG-53
HA-07
DG-56
Small Yard
CP-114
PR-05
DG-11
HA-08
DG-35
DG-36
DG-37
DG-54A
DG-55A
Tank 113
Tank 114
DG-54
DG-55
DG-92
DG-8
DG-10
HA-11
DG-9
PR-04
Tank 91
Tank 93
DG-91
DG-98
DG-90
CP-106B
CP-106A
HA-12
CP-108B
DG-13
DG-14
DG-38
DG-39
DG-12
HA-09
CP-108A
TB-5
CP-122B
Note:
1. Tank farm is shown for illustrative purposes only. Tank farm has been demolished and paved.
Explanation
Lease Parcel Boundary
CP-107 Monitoring Well Location
CP-109 Decommissioned Monitoring Well Location
CP-PR01 Pilot Test Well Location
HA-1 Existing Soil Sample Location
C-4 Existing Composite Soil Sample Location
DG-1 Phase I Direct-Push Drilling Location
DG-89 Phase II Direct-Push Drilling Location
PR-03 LNAPL Monitoring Well Location
Seep 4 Location
DG-97 Phase III Direct Push Drilling Location
DG-99 PCB Soil Sampling Location
0.71 Maximum Total PCB Result at Location (mg/kg)
ND Not Detected
N
0
50
APPROXIMATE SCALE IN FEET
PES Environmental, Inc.
Engineering & Environmental Services
Lease Parcel - DGI Phase III
Total Soil PCB Results
Port of Seattle Terminal 91
Seattle, Washington
FIGURE
5-8
948.002.06.008
948-00206008_FS_5-8
2/09
JOB NUMBER
DRAWING NUMBER
REVIEWED BY
DATE

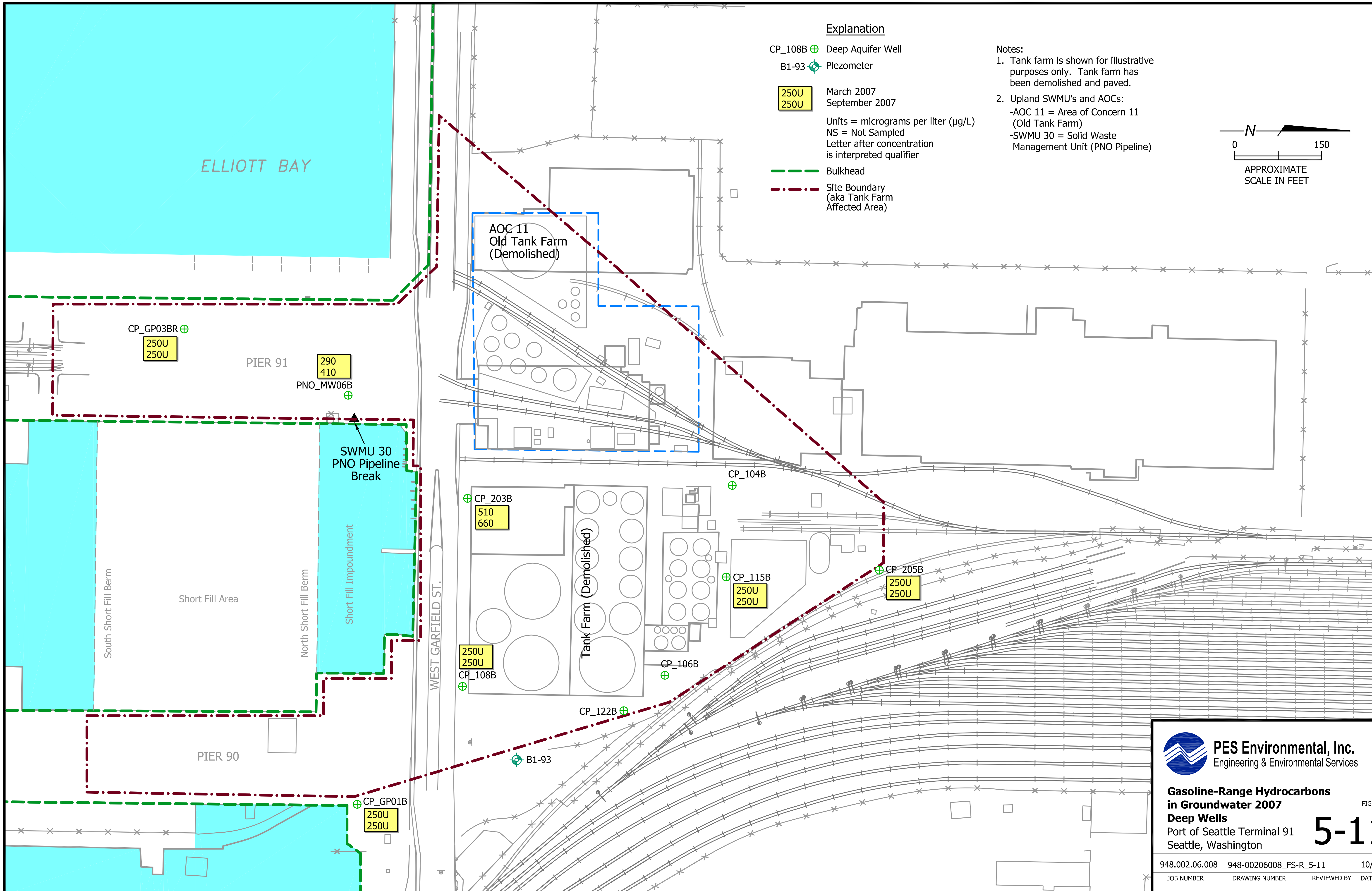


Gasoline-Range Hydrocarbons in Groundwater 2007 Shallow Wells
Port of Seattle Terminal 91
Seattle, Washington

5-9

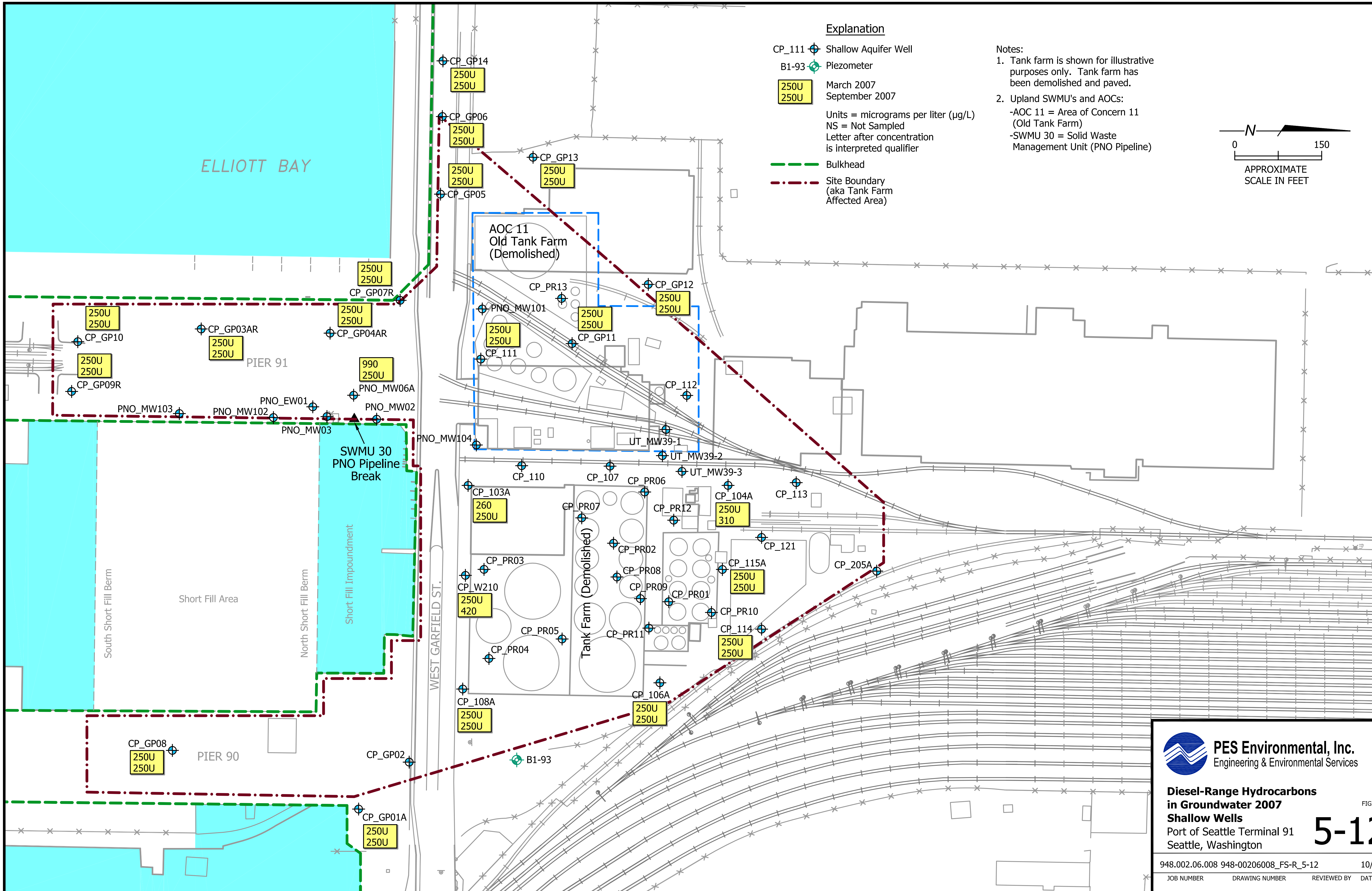


Explanation
CP_110 Shallow Aquifer Well
B1-93 Piezometer
250U March 2008
250U September 2008
Units = micrograms per liter (µg/L)
NS = Not Sampled
Letter after concentration is interpreted qualifier
Bulkhead
Site Boundary (aka Tank Farm Affected Area)
Notes:
1. Tank farm is shown for illustrative purposes only. Tank farm has been demolished and paved.
2. Upland SWMU's and AOCs:
-AOC 11 = Area of Concern 11 (Old Tank Farm)
-SWMU 30 = Solid Waste Management Unit (PNO Pipeline)
N
0
150
APPROXIMATE SCALE IN FEET
ELLIOTT BAY
PIER 91
PIER 90
AOC 11
Old Tank Farm
(Demolished)
SWMU 30
PNO Pipeline
Break
Tank Farm (Demolished)
WEST GARFIELD ST.
Short Fill Area
South Short Fill Berm
North Short Fill Berm
Short Fill Impoundment
CP_GP14 250U 250U
CP_GP06 250U 250U
CP_GP13 250U 250U
CP_GP05 250U 250U
CP_GP12 800 1100
CP_GP07R NS 250U
CP_PR13
PNO_MW101
CP_GP10 250U 250U
CP_GP03AR 250U 250U
CP_GP04AR 250U 250U
750 600
CP_GP11 730 1000
CP_111 250U 250U
CP_112
CP_GP09R 250U 250U
PNO_MW06A
PNO_EW01
PNO_MW02
PNO_MW103
PNO_MW102
PNO_MW03
PNO_MW104
UT_MW39-1
UT_MW39-2
UT_MW39-3
CP_110
CP_107
CP_PR06
CP_103A 640 250U
CP_PR07
CP_PR12
CP_104A 1200 980
CP_113
CP_121
CP_PR02
CP_PR03
CP_W210 670 720
CP_PR08
CP_PR09
CP_PR01
CP_115A 250U 250U
CP_205A
CP_PR10
CP_PR05
CP_PR11
CP_114 250U 250U
CP_PR04
CP_108A 980 730
CP_106A 2100 1200
CP_GP08 250U 250U
CP_GP02
B1-93
CP_GP01A 250U 250U
PES Environmental, Inc.
Engineering & Environmental Services
Gasoline-Range Hydrocarbons in Groundwater 2008
Shallow Wells
Port of Seattle Terminal 91
Seattle, Washington
FIGURE
5-10
948.002.06.008
948-00206008_FS-R_5-10
10/09
JOB NUMBER
DRAWING NUMBER
REVIEWED BY
DATE



Explanation
CP_108B Deep Aquifer Well
B1-93 Piezometer
250U 250U March 2007 September 2007
Units = micrograms per liter (µg/L)
NS = Not Sampled
Letter after concentration is interpreted qualifier
Bulkhead
Site Boundary (aka Tank Farm Affected Area)
Notes:
1. Tank farm is shown for illustrative purposes only. Tank farm has been demolished and paved.
2. Upland SWMU's and AOCs:
-AOC 11 = Area of Concern 11 (Old Tank Farm)
-SWMU 30 = Solid Waste Management Unit (PNO Pipeline)
N
0
150
APPROXIMATE SCALE IN FEET
ELLIOTT BAY
AOC 11
Old Tank Farm
(Demolished)
CP_GP03BR
250U
250U
PIER 91
290
410
PNO_MW06B
SWMU 30
PNO Pipeline
Break
CP_104B
CP_203B
510
660
Tank Farm (Demolished)
CP_115B
250U
250U
CP_205B
250U
250U
South Short Fill Berm
Short Fill Area
North Short Fill Berm
Short Fill Impoundment
WEST GARFIELD ST.
250U
250U
CP_108B
CP_106B
CP_122B
PIER 90
B1-93
CP_GP01B
250U
250U

PES Environmental, Inc.
Engineering & Environmental Services
Gasoline-Range Hydrocarbons in Groundwater 2007 Deep Wells
Port of Seattle Terminal 91
Seattle, Washington
FIGURE
5-11
948.002.06.008
948-00206008_FS-R_5-11
10/09
JOB NUMBER
DRAWING NUMBER
REVIEWED BY
DATE

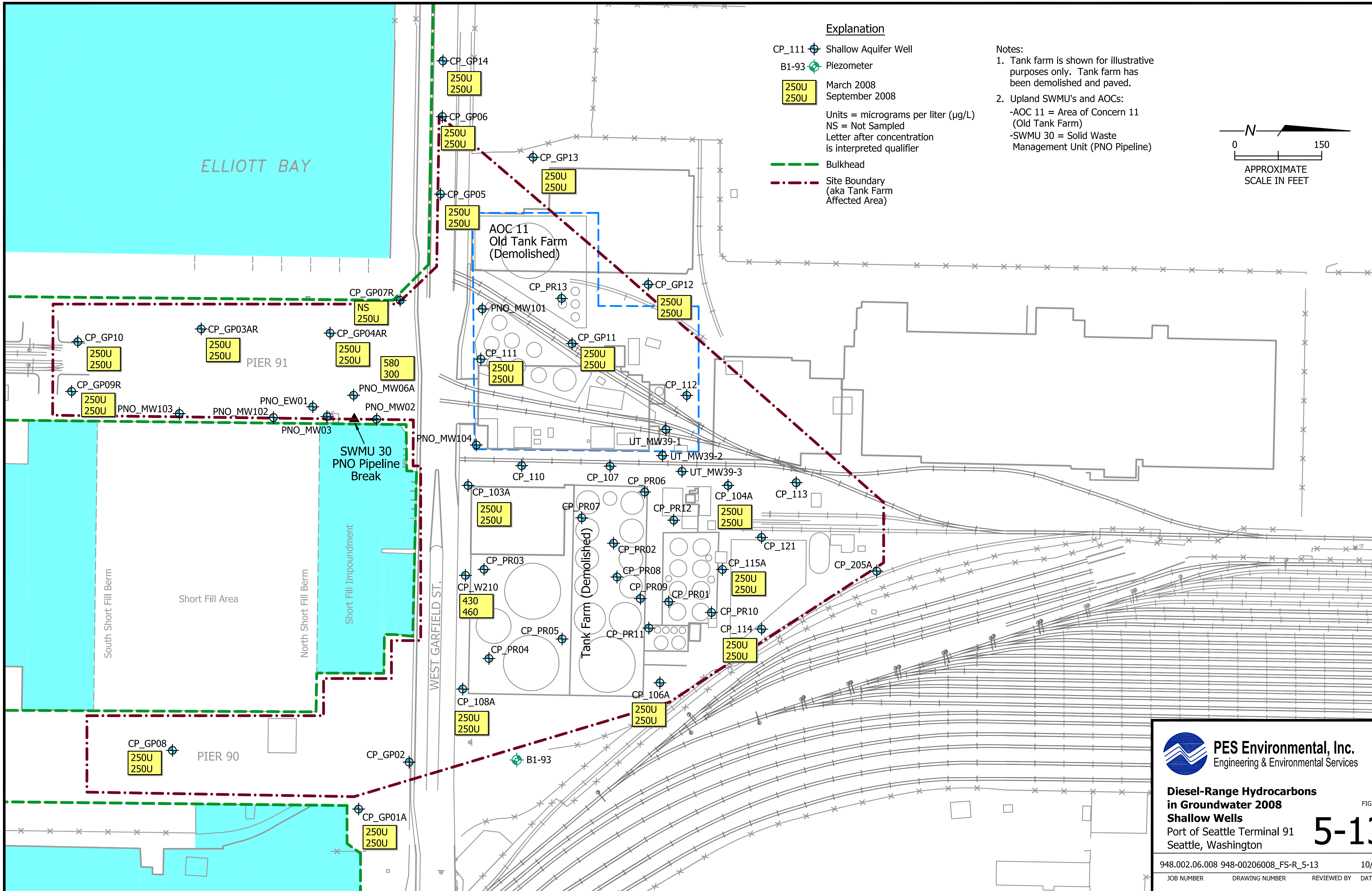


PES Environmental, Inc.
Engineering & Environmental Services

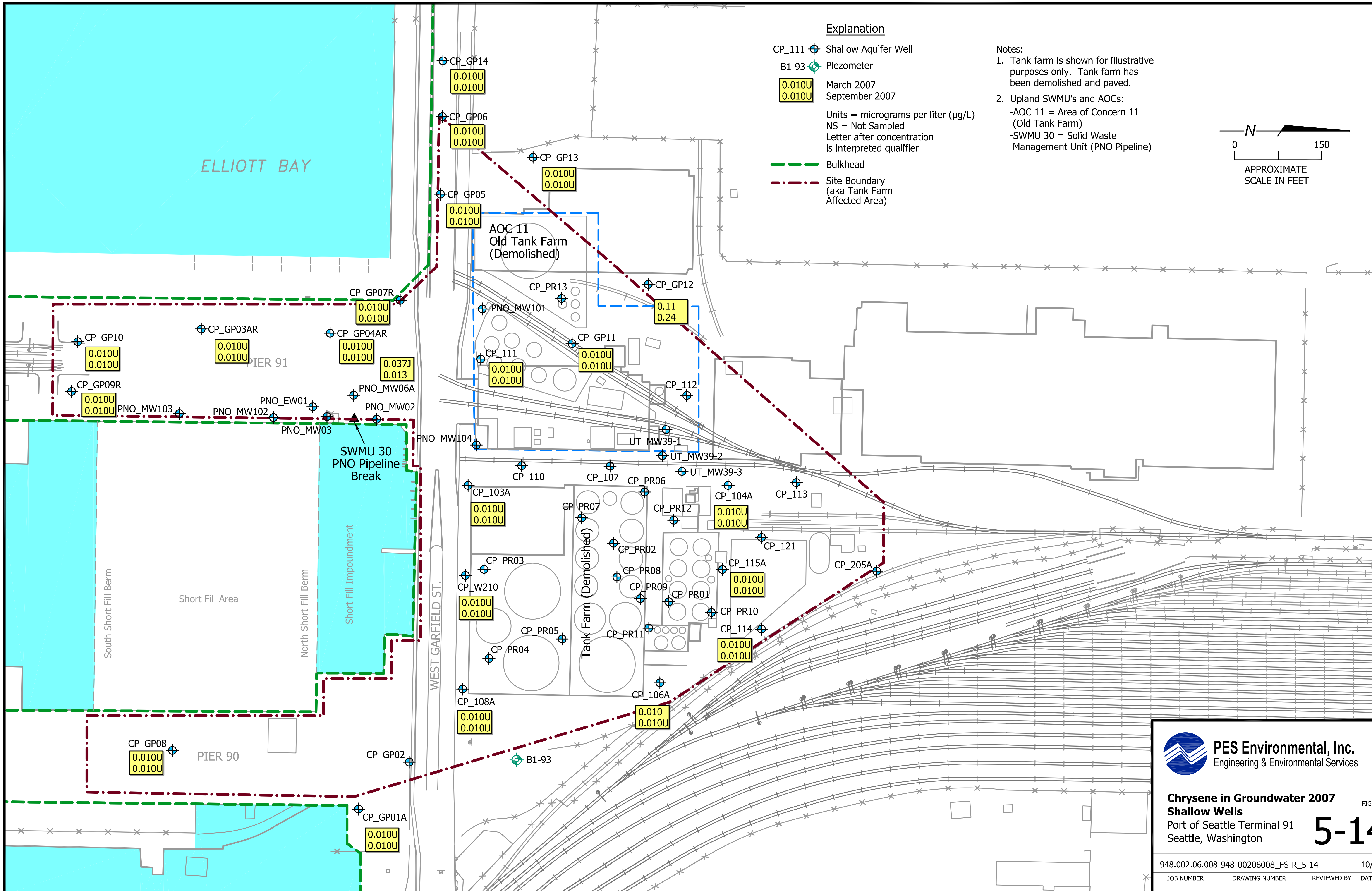
Diesel-Range Hydrocarbons in Groundwater 2007 Shallow Wells
Port of Seattle Terminal 91
Seattle, Washington

FIGURE **5-12**

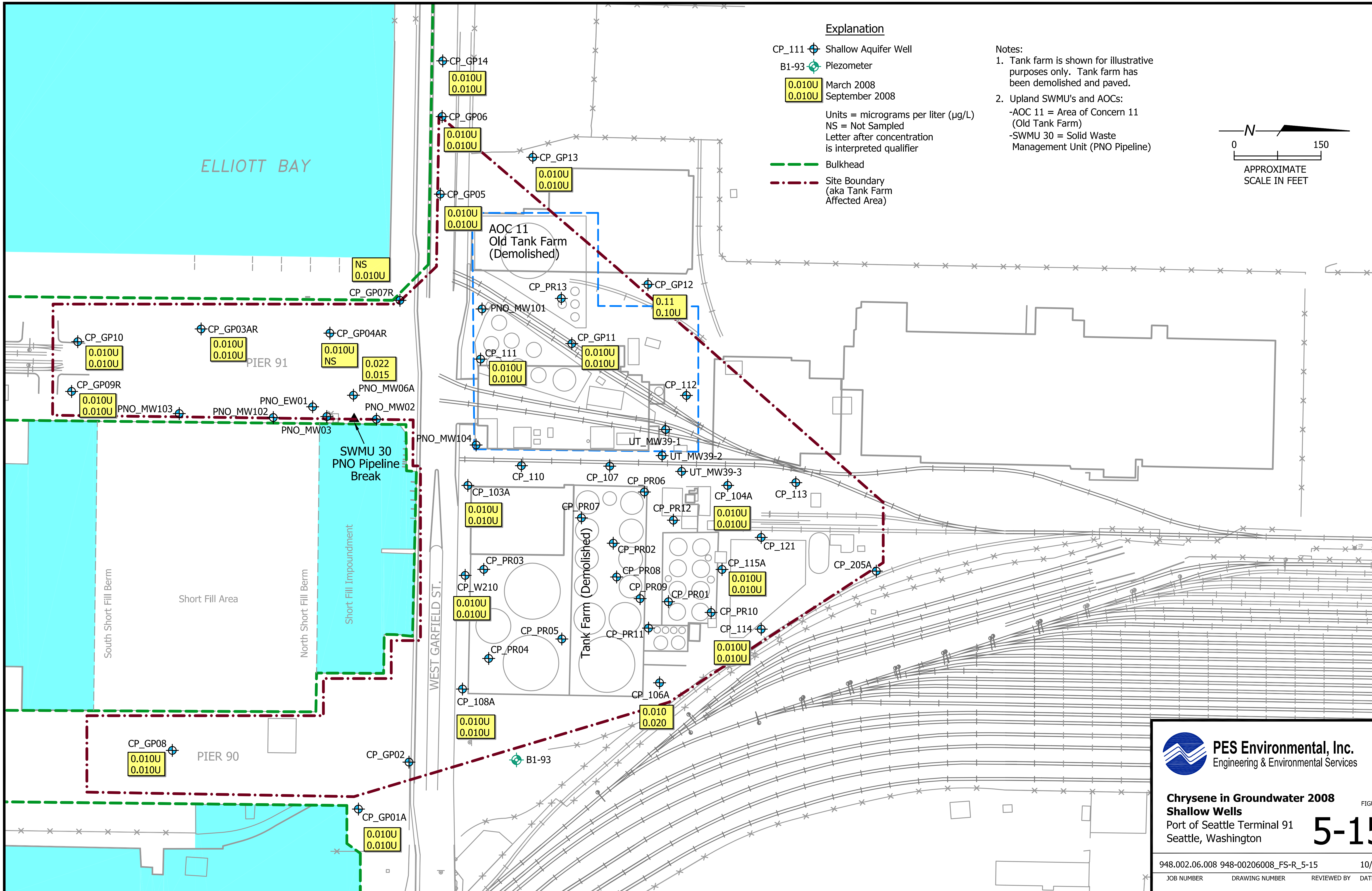
JOB NUMBER	DRAWING NUMBER	REVIEWED BY	DATE
948.002.06.008	948-00206008_FS-R_5-12		10/09



Explanation
CP_111 Shallow Aquifer Well
B1-93 Piezometer
250U 250U March 2008 September 2008
Units = micrograms per liter (µg/L)
NS = Not Sampled
Letter after concentration is interpreted qualifier
Bulkhead
Site Boundary (aka Tank Farm Affected Area)
Notes:
1. Tank farm is shown for illustrative purposes only. Tank farm has been demolished and paved.
2. Upland SWMU's and AOCs:
-AOC 11 = Area of Concern 11 (Old Tank Farm)
-SWMU 30 = Solid Waste Management Unit (PNO Pipeline)
N
0
150
APPROXIMATE SCALE IN FEET
ELLIOTT BAY
AOC 11 Old Tank Farm (Demolished)
PIER 91
PIER 90
SWMU 30 PNO Pipeline Break
South Short Fill Berm
Short Fill Area
North Short Fill Berm
Short Fill Impoundment
WEST GARFIELD ST.
Tank Farm (Demolished)
CP_GP14 250U 250U
CP_GP06 250U 250U
CP_GP13 250U 250U
CP_GP05 250U 250U
CP_GP12 250U 250U
CP_GP07R NS 250U
CP_PR13
PNO_MW101
CP_GP10 250U 250U
CP_GP03AR 250U 250U
CP_GP04AR 250U 250U
580 300
CP_GP11 250U 250U
CP_111 250U 250U
CP_112
CP_GP09R 250U 250U
PNO_MW06A
PNO_EW01
PNO_MW103
PNO_MW102
PNO_MW02
PNO_MW03
PNO_MW104
UT_MW39-1
UT_MW39-2
UT_MW39-3
CP_110
CP_107
CP_PR06
CP_104A 250U 250U
CP_113
CP_103A 250U 250U
CP_PR07
CP_PR12
CP_PR02
CP_121
CP_PR03
CP_PR08
CP_115A 250U 250U
CP_205A
CP_W210 430 460
CP_PR09
CP_PR01
CP_PR10
CP_PR05
CP_PR11
CP_114 250U 250U
CP_PR04
CP_108A 250U 250U
CP_106A 250U 250U
CP_GP08 250U 250U
CP_GP02
B1-93
CP_GP01A 250U 250U
PES Environmental, Inc.
Engineering & Environmental Services
Diesel-Range Hydrocarbons in Groundwater 2008
Shallow Wells
Port of Seattle Terminal 91
Seattle, Washington
FIGURE
5-13
948.002.06.008 948-00206008_FS-R_5-13 10/09
JOB NUMBER DRAWING NUMBER REVIEWED BY DATE



Explanation
CP_111 Shallow Aquifer Well
B1-93 Piezometer
0.010U 0.010U March 2007 September 2007
Units = micrograms per liter (µg/L)
NS = Not Sampled
Letter after concentration is interpreted qualifier
Bulkhead
Site Boundary (aka Tank Farm Affected Area)
Notes:
1. Tank farm is shown for illustrative purposes only. Tank farm has been demolished and paved.
2. Upland SWMU's and AOCs:
-AOC 11 = Area of Concern 11 (Old Tank Farm)
-SWMU 30 = Solid Waste Management Unit (PNO Pipeline)
N
0
150
APPROXIMATE SCALE IN FEET
ELLIOTT BAY
PIER 91
PIER 90
Short Fill Area
South Short Fill Berm
North Short Fill Berm
Short Fill Impoundment
WEST GARFIELD ST.
AOC 11
Old Tank Farm
(Demolished)
Tank Farm (Demolished)
SWMU 30
PNO Pipeline
Break
CP_GP14
0.010U
0.010U
CP_GP06
0.010U
0.010U
CP_GP13
0.010U
0.010U
CP_GP05
0.010U
0.010U
CP_GP12
0.11
0.24
CP_GP07R
0.010U
0.010U
CP_GP10
0.010U
0.010U
CP_GP03AR
0.010U
0.010U
CP_GP04AR
0.010U
0.010U
0.037J
0.013
CP_GP09R
0.010U
0.010U
CP_PR13
PNO_MW101
CP_GP11
0.010U
0.010U
CP_111
0.010U
0.010U
CP_112
PNO_MW06A
PNO_EW01
PNO_MW02
PNO_MW103
PNO_MW102
PNO_MW03
PNO_MW104
UT_MW39-1
UT_MW39-2
UT_MW39-3
CP_110
CP_107
CP_PR06
CP_104A
0.010U
0.010U
CP_113
CP_103A
0.010U
0.010U
CP_PR07
CP_PR12
CP_121
CP_PR02
CP_PR03
CP_115A
0.010U
0.010U
CP_205A
CP_W210
0.010U
0.010U
CP_PR08
CP_PR09
CP_PR01
CP_PR10
CP_PR05
CP_PR11
CP_114
0.010U
0.010U
CP_PR04
CP_108A
0.010U
0.010U
CP_106A
0.010
0.010U
CP_GP08
0.010U
0.010U
CP_GP02
B1-93
CP_GP01A
0.010U
0.010U
PES Environmental, Inc.
Engineering & Environmental Services
Chrysene in Groundwater 2007
Shallow Wells
Port of Seattle Terminal 91
Seattle, Washington
FIGURE
5-14
948.002.06.008
948-00206008_FS-R_5-14
10/09
JOB NUMBER
DRAWING NUMBER
REVIEWED BY
DATE

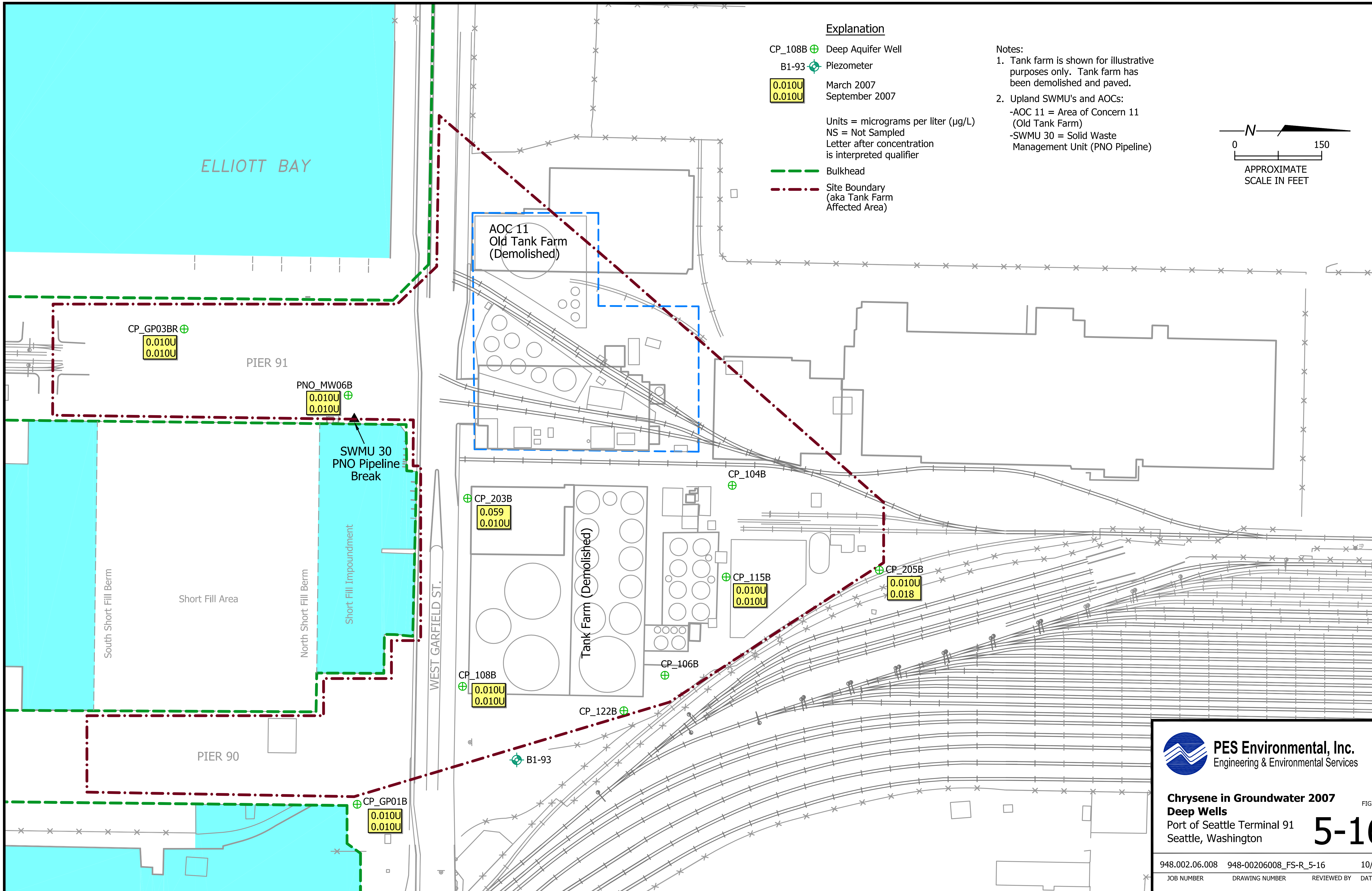


PES Environmental, Inc.
Engineering & Environmental Services

Chrysene in Groundwater 2008
Shallow Wells
Port of Seattle Terminal 91
Seattle, Washington

FIGURE **5-15**

JOB NUMBER	DRAWING NUMBER	REVIEWED BY	DATE
948.002.06.008	948-00206008_FS-R_5-15		10/09

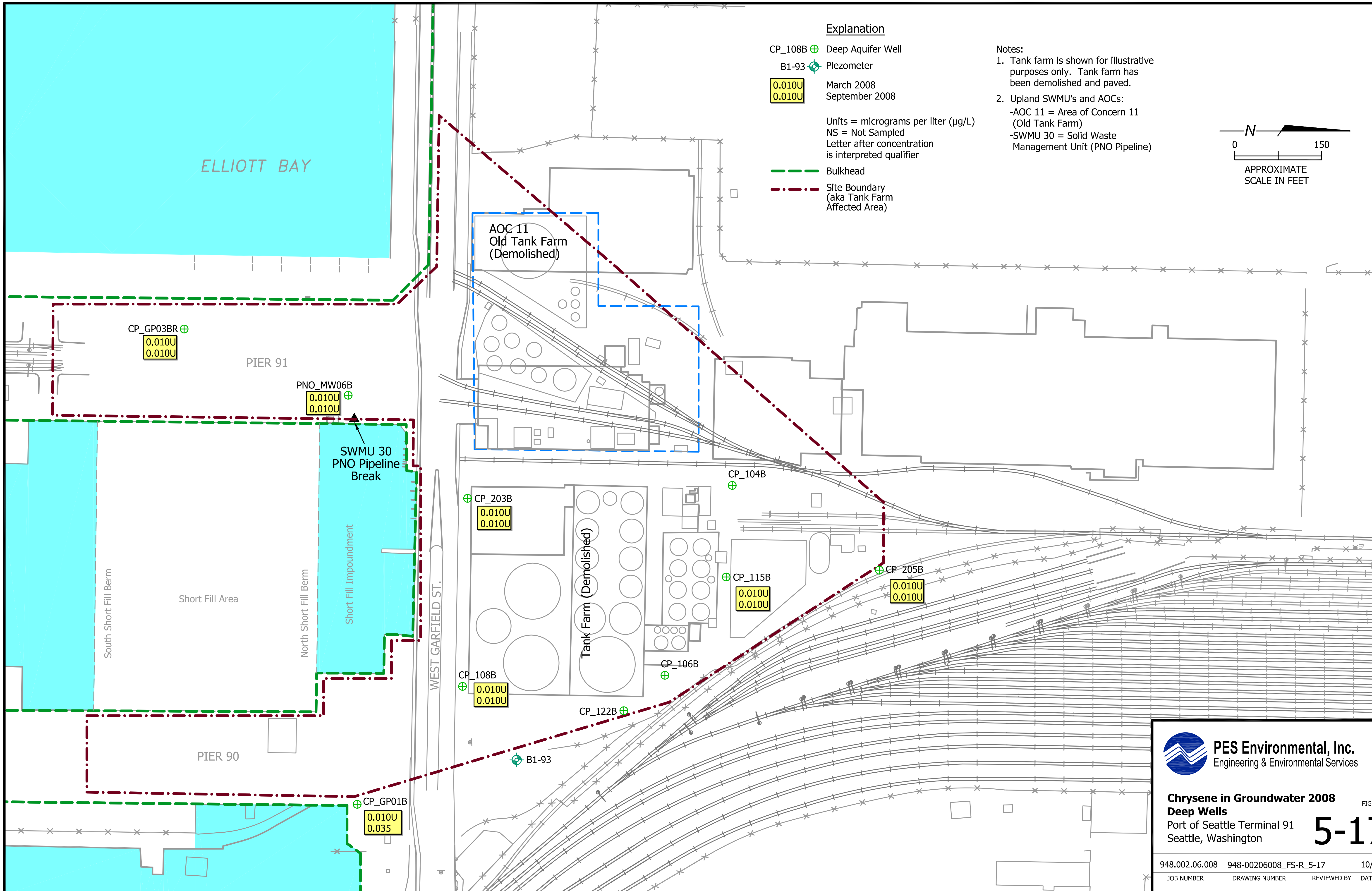


PES Environmental, Inc.
Engineering & Environmental Services

Chrysene in Groundwater 2007
Deep Wells
Port of Seattle Terminal 91
Seattle, Washington

FIGURE
5-16

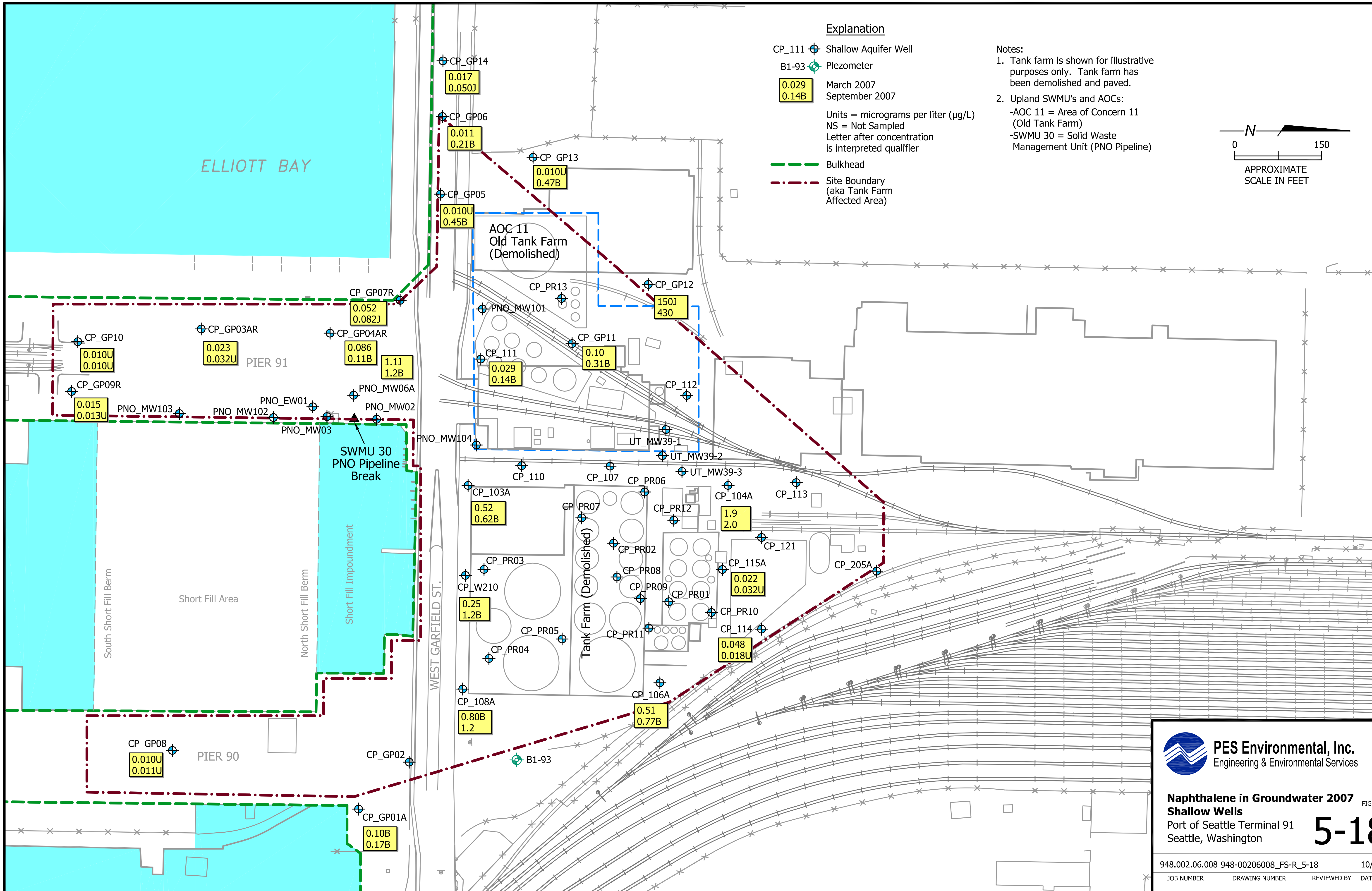
948.002.06.008	948-00206008_FS-R_5-16		10/09
JOB NUMBER	DRAWING NUMBER	REVIEWED BY	DATE



Chrysene in Groundwater 2008
Deep Wells
Port of Seattle Terminal 91
Seattle, Washington

FIGURE 5-17

JOB NUMBER	DRAWING NUMBER	REVIEWED BY	DATE
948.002.06.008	948-00206008_FS-R_5-17		10/09

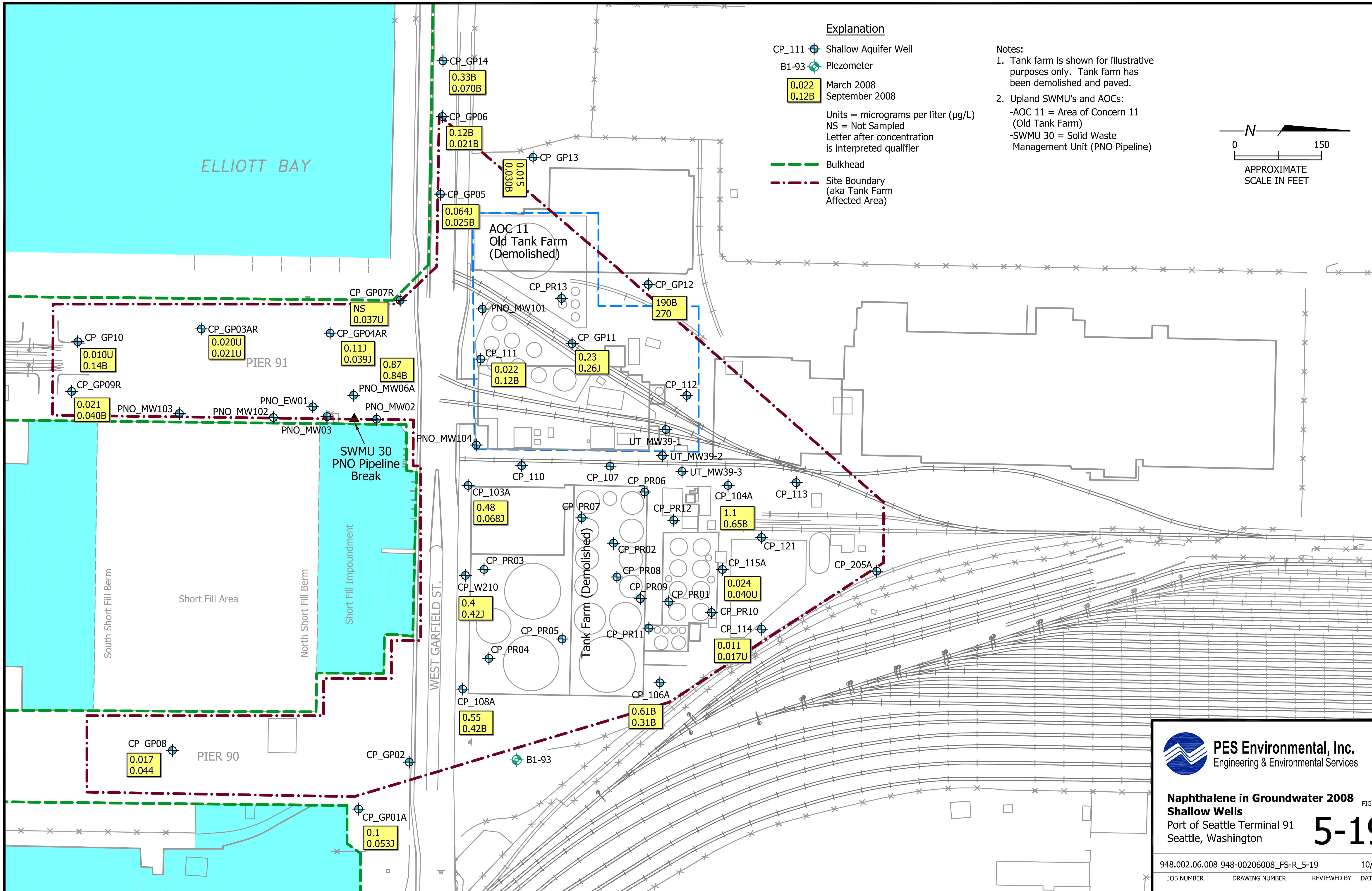


PES Environmental, Inc.
Engineering & Environmental Services

Naphthalene in Groundwater 2007
Shallow Wells
Port of Seattle Terminal 91
Seattle, Washington

FIGURE
5-18

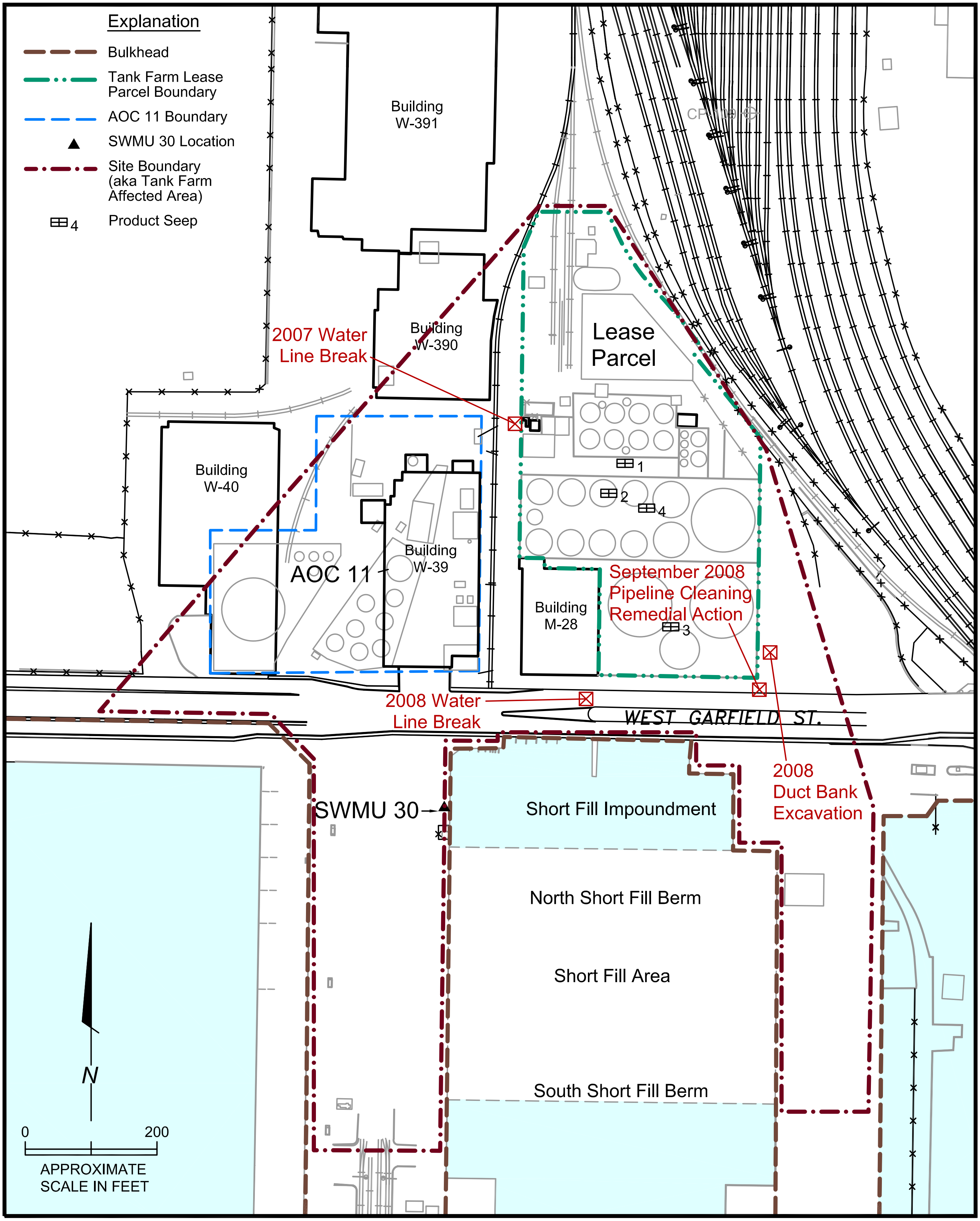
JOB NUMBER	DRAWING NUMBER	REVIEWED BY	DATE
948.002.06.008	948-00206008_FS-R_5-18		10/09



Naphthalene in Groundwater 2008
Shallow Wells
Port of Seattle Terminal 91
Seattle, Washington

FIGURE 5-19

JOB NUMBER	DRAWING NUMBER	REVIEWED BY	DATE
948.002.06.008	948-00206008_FS-R_5-19		10/09

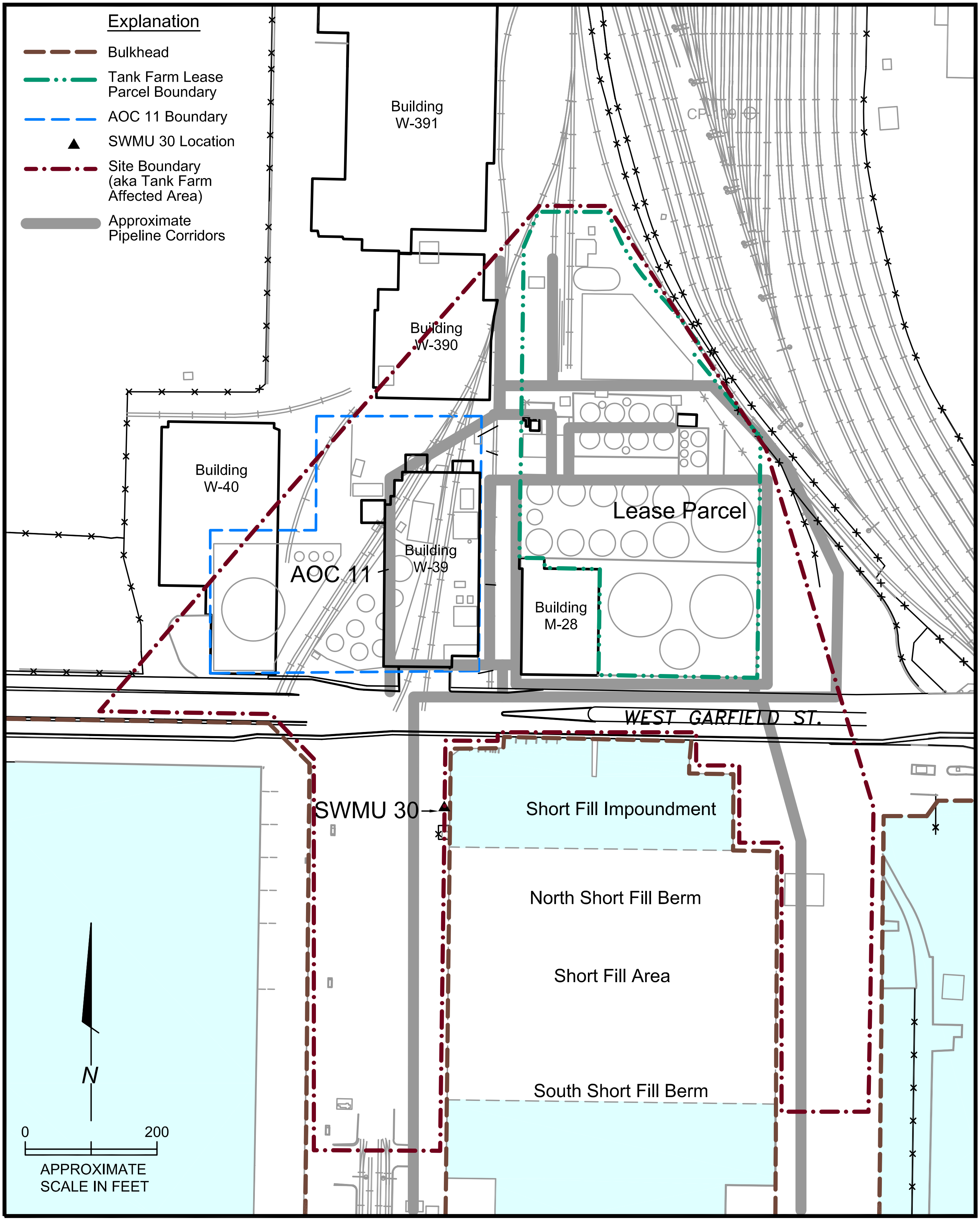


PES Environmental, Inc.
Engineering & Environmental Services

Location of Interim Remedial Actions
Port of Seattle Terminal 91 Tank Farm Site
Seattle, Washington

FIGURE
6-1

948.002.06.008	948-00206008_FS-R_6-1		10/09
JOB NUMBER	DRAWING NUMBER	REVIEWED BY	DATE

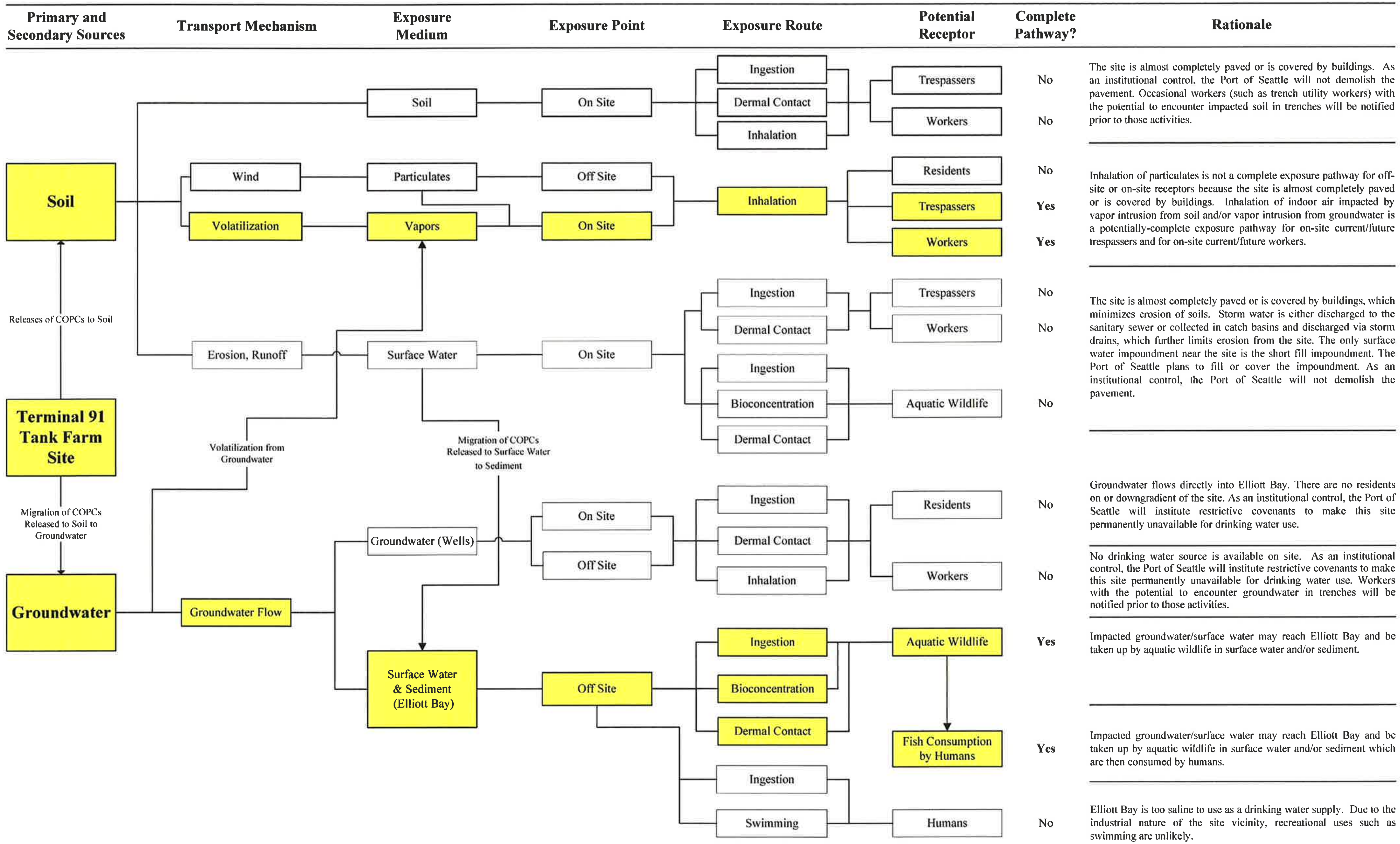


PES Environmental, Inc.
Engineering & Environmental Services

Pipeline Corridors
Port of Seattle Terminal 91
Seattle, Washington

FIGURE
6-2

JOB NUMBER	DRAWING NUMBER	REVIEWED BY	DATE
948.002.06.008	948-00206008_FS-R_2-4 6-2		10/09



Source - "Conceptual Site Model, Terminal 91 Tank Farm Site," Pioneer Technologies Corporation

PES Environmental, Inc.
Engineering & Environmental Services

Conceptual Site Model
Port of Seattle Terminal 91 Tank Farm Site
Seattle, Washington

PLATE
7-1

JOB NUMBER	DRAWING NUMBER	REVIEWED BY	DATE
948.002.06.008	948-00206008_FS_CSM		1/09

Legend

- Shallow Standard Point of Compliance Well
- Shallow Standard and Conditional Point of Compliance Well
- Deep Standard Point of Compliance Well
- Deep Standard and Conditional Point of Compliance Well
- Background Well Locations
- SWMU 30 Location
- AOC 11 Boundary
- Upland Monitoring Well Used in Background Evaluation

Notes:

Model Toxic Control Act (MTCA)

Standard Point of Compliance as defined in MTCA WAC 173-340-720(8)(b)

Conditional Point of Compliance as defined in MTCA WAC 173-340-720(8)(c)

Shallow wells are screened at a maximum depth of 21 feet below ground surface.

Deep wells are screened at a maximum depth of 60 feet below ground surface.

Solid Waste Managment Unit (SWMU)

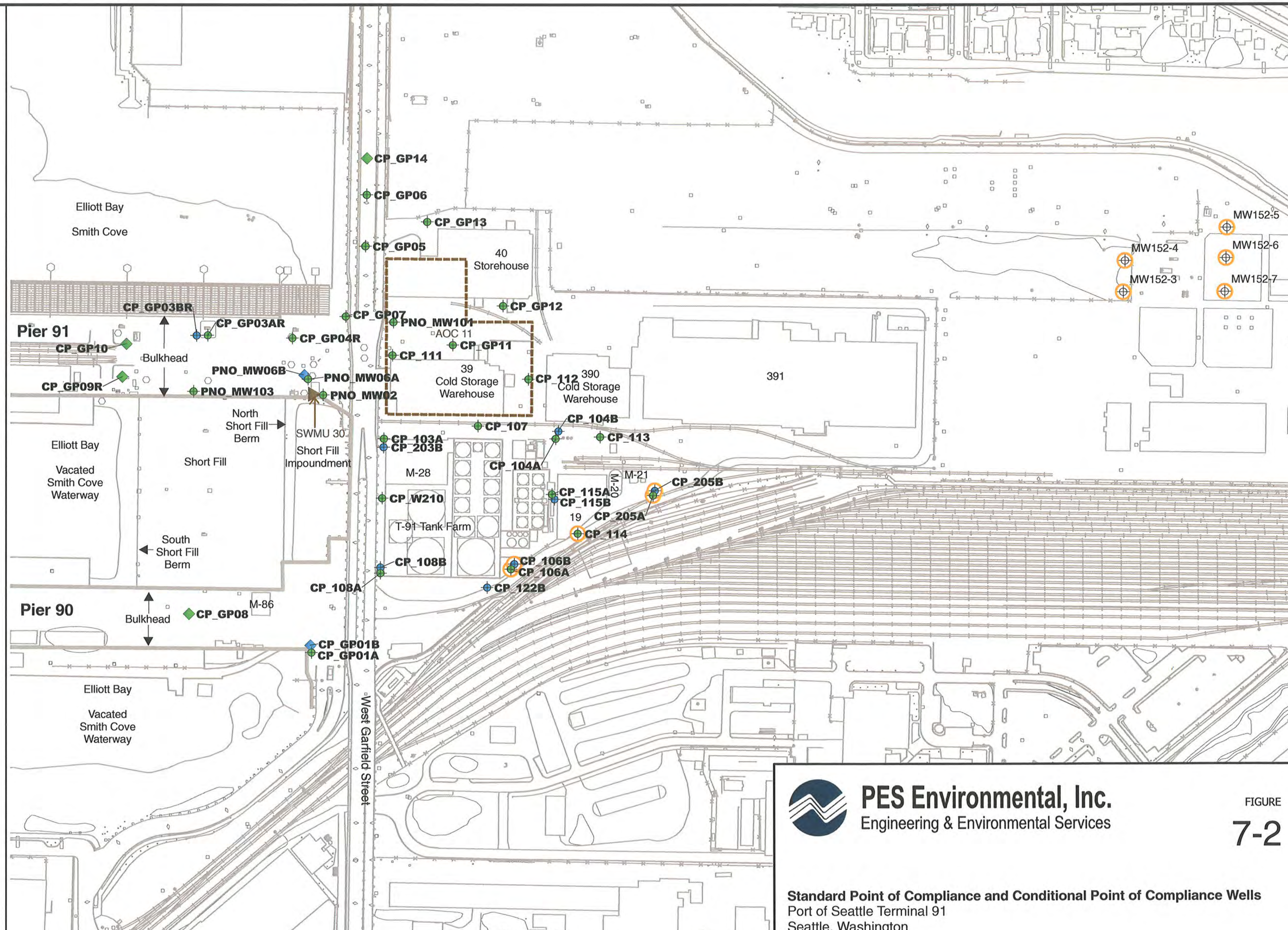
Area of Concern (AOC)

The tank farm is shown for illustrative purposes only. The above-ground portions of the tank farm were demolished and paved in 2005.

N

0 100 200 400 Feet

Map Reference: PIONEER Technologies Corporation, August 2008.



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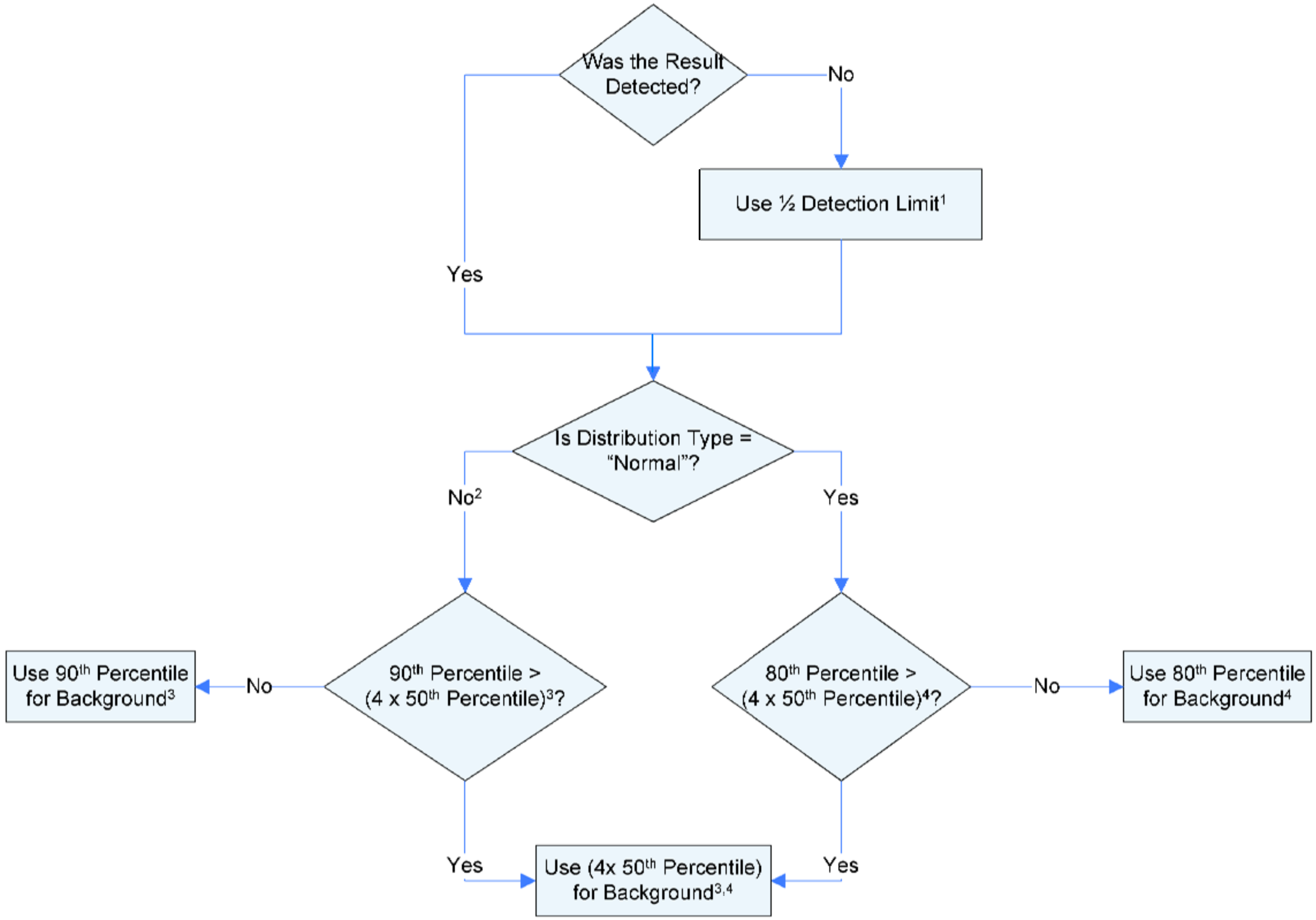
Engineering & Environmental Services

FIGURE
7-2

Standard Point of Compliance and Conditional Point of Compliance Wells
Port of Seattle Terminal 91
Seattle, Washington

JOB NUMBER	DRAWING NUMBER	REVIEWED BY	DATE
948.002.06.008	948-00206008_FS-R_7-2		10/09

Source - Pioneer Technologies Corporation



Note:
[1]Per WAC 173-340-709(5)(a)
[2]Assume that data is lognormally distributed per WAC 173-370-709(3)(b)
[3]Per WAC 173-340-709(3)(c)
[4]Per WAC 173-340-709(3)(d)

PES Environmental, Inc.
Engineering & Environmental Services

Background Calculations
Port of Seattle Terminal 91 Tank Farm Site
Seattle, Washington

FIGURE
7-3

948.002.06.008	948-00206008_FS-R_CSM		11/09
JOB NUMBER	DRAWING NUMBER	REVIEWED BY	DATE

Legend

- (red symbol) Shallow SPOC Well With At Least One Exceedance of Final FS CUL
- (green symbol) Shallow Well Without Exceedances of Final FS CULs
- (triangle) SWMU 30 Location
- (dashed box) AOC 11 Boundary

Notes:

Feasibility Study (FS)

Cleanup Level (CUL)

See Table 7-3 for a list of Final FS CULs.

Model Toxic Control Act (MTCA)

Standard Point of Compliance (SPOC) as defined in MTCA WAC 173-340-720(8)(b)

Shallow wells are screened at a maximum depth of 21 feet below ground surface.

Solid Waste Managment Unit (SWMU)

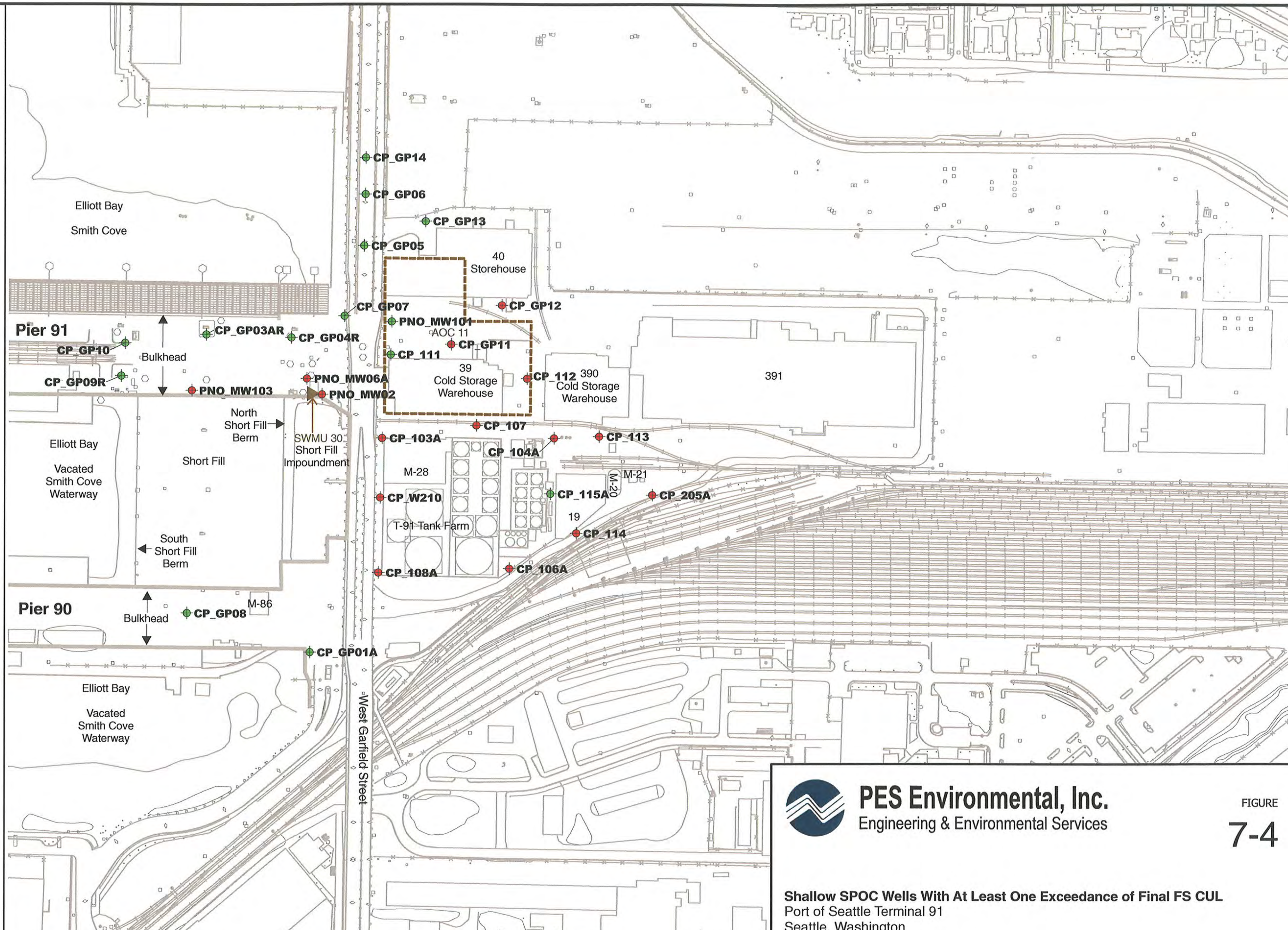
Area of Concern (AOC)

The tank farm is shown for illustrative purposes only. The above-ground portions of the tank farm were demolished and paved in 2005.

N

0 125 250 500 Feet

Map Reference: PIONEER Technologies Corporation, August 2008.



PES Environmental, Inc.
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FIGURE
7-4

Shallow SPOC Wells With At Least One Exceedance of Final FS CUL
Port of Seattle Terminal 91
Seattle, Washington

JOB NUMBER	DRAWING NUMBER	REVIEWED BY	DATE
948.002.06.008	948-00206008_FS-R_7-4		10/09

Legend

- Shallow SPOC Well With PAH Concentrations Exceeding Final FS CULs
- Shallow SPOC Well Without PAH Concentrations Exceeding Final FS CULs
- Background Well Locations
- SWMU 30 Location
- AOC 11 Boundary

Notes:

Feasibility Study (FS)

Cleanup Level (CUL)

See Table 7-3 for a list of Final FS CULs.

Model Toxic Control Act (MTCA)

Standard Point of Compliance (SPOC) as defined in MTCA WAC 173-340-720(8)(b)

Shallow wells are screened at a maximum depth of 21 feet below ground surface.

Polycyclic Aromatic Hydrocarbons (PAH)

Solid Waste Managment Unit (SWMU)

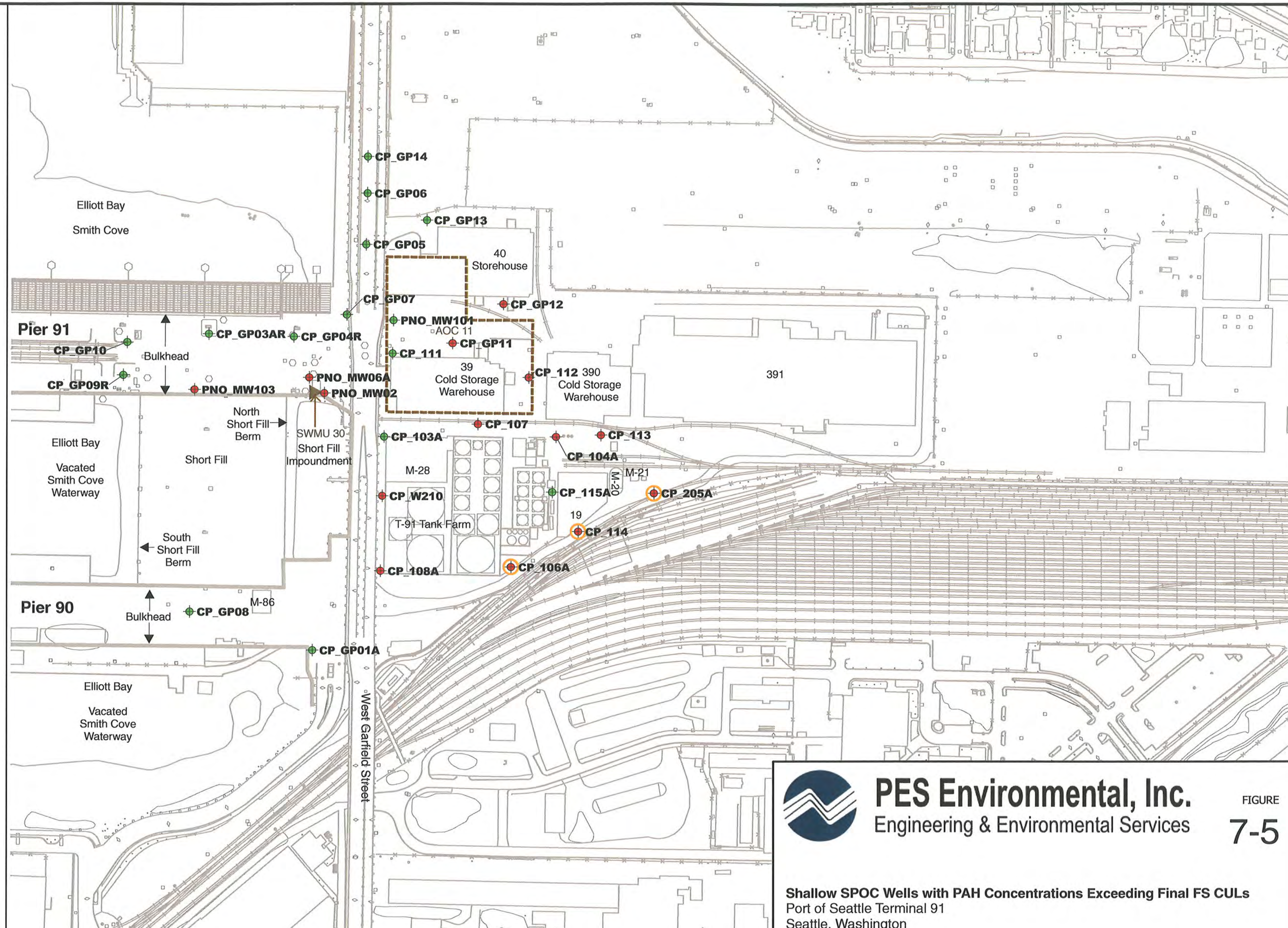
Area of Concern (AOC)

The tank farm is shown for illustrative purposes only. The above-ground portions of the tank farm were demolished and paved in 2005.

N

0 125 250 500 Feet

Map Reference: PIONEER Technologies Corporation, August 2008.



PES Environmental, Inc.
Engineering & Environmental Services

FIGURE 7-5

Shallow SPOC Wells with PAH Concentrations Exceeding Final FS CULs
Port of Seattle Terminal 91
Seattle, Washington

JOB NUMBER	DRAWING NUMBER	REVIEWED BY	DATE
948.002.06.008	948-00206008_FS-R_7-5C		10/09

Legend

- Shallow SPOC Well With Diesel Or Gasoline Concentrations Exceeding Final FS CULs
- Shallow SPOC Well Without Gasoline or Diesel Concentrations Exceeding Final FS CULs
- Background Well Locations
- SWMU 30 Location
- AOC 11 Boundary

Notes:

Feasibility Study (FS)

Cleanup Level (CUL)

See Table 7-3 for a list of Final FS CULs.

Model Toxic Control Act (MTCA)

Standard Point of Compliance (SPOC) as defined in MTCA WAC 173-340-720(8)(b)

Shallow wells are screened at a maximum depth of 21 feet below ground surface.

Solid Waste Managment Unit (SWMU)

Area of Concern (AOC)

The tank farm is shown for illustrative purposes only. The above-ground portions of the tank farm were demolished and paved in 2005.

N

0 125 250 500 Feet

Map Reference: PIONEER Technologies Corporation, August 2008.

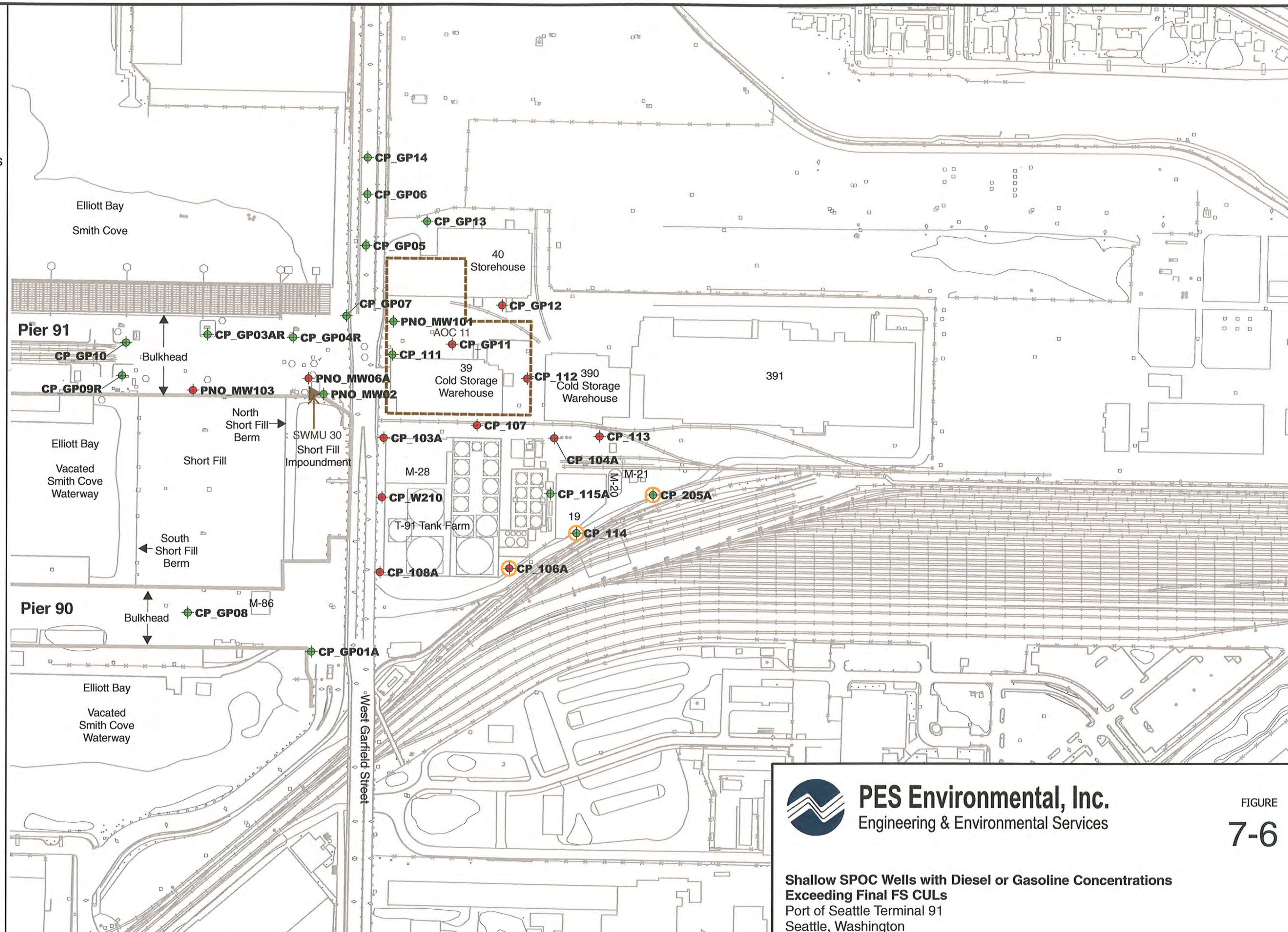


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FIGURE
7-6

Shallow SPOC Wells with Diesel or Gasoline Concentrations Exceeding Final FS CULs
Port of Seattle Terminal 91
Seattle, Washington

JOB NUMBER	DRAWING NUMBER	REVIEWED BY	DATE
948.002.06.008	948-00206008_FS-R_7-6C		10/09

Legend

- Deep SPOC Well With At Least One Exceedance of Final FS CUL
- Deep Well Without Exceedances of Final FS CULs
- Background Well Locations
- SWMU 30 Location
- AOC 11 Boundary

Notes:

Feasibility Study (FS)

Cleanup Level (CUL)

See Table 7-4 for a list of Final FS CULs.

Model Toxic Control Act (MTCA)

Standard Point of Compliance (SPOC) as defined in MTCA WAC 173-340-720(8)(b)

Deep wells are screened at a maximum depth of 60 feet below ground surface.

Solid Waste Managment Unit (SWMU)

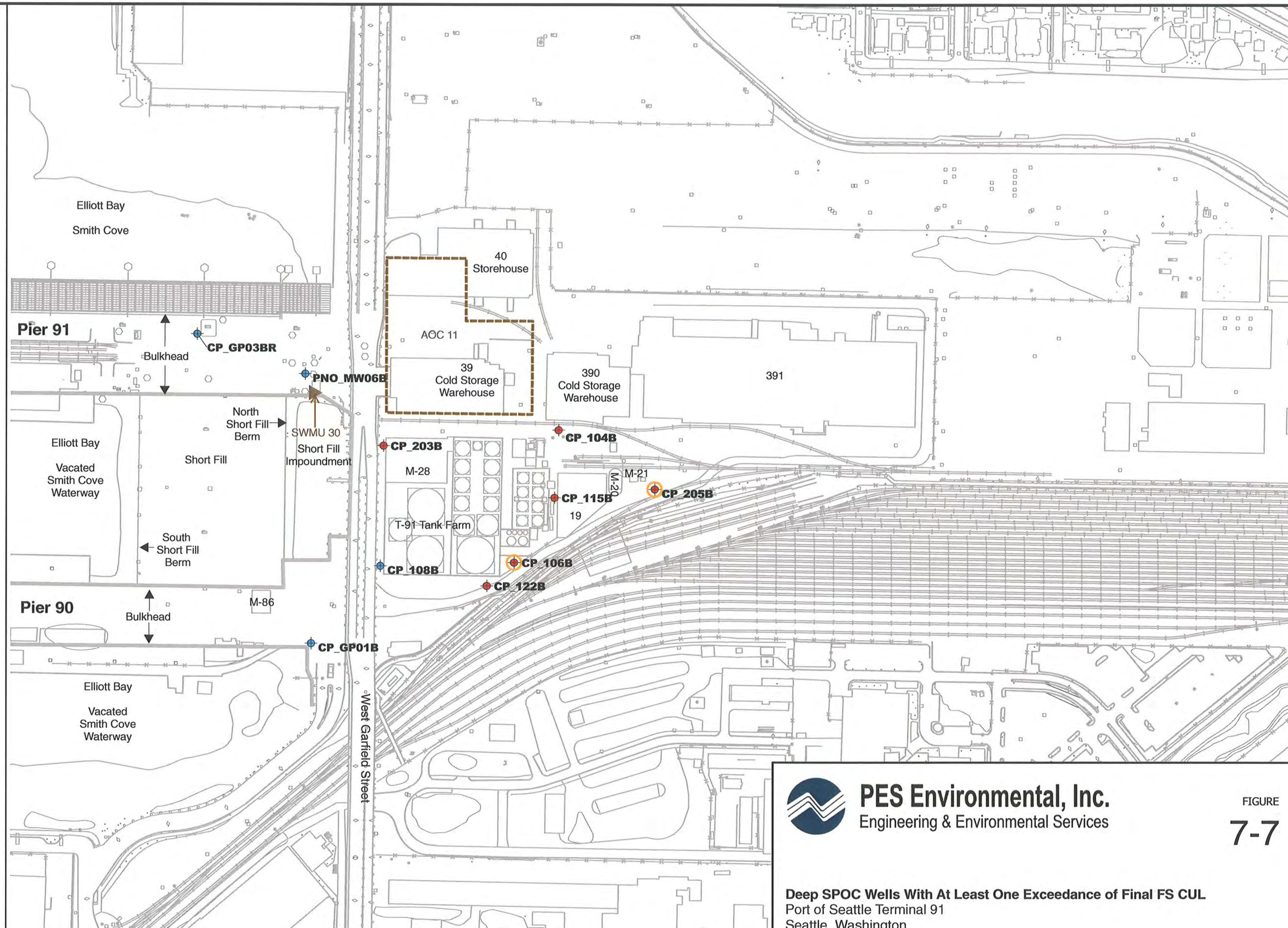
Area of Concern (AOC)

The tank farm is shown for illustrative purposes only. The above-ground portions of the tank farm were demolished and paved in 2005.

N

0 125 250 500 Feet

Map Reference: PIONEER Technologies Corporation, August 2008.



PES Environmental, Inc.
Engineering & Environmental Services

FIGURE
7-7

Deep SPOC Wells With At Least One Exceedance of Final FS CUL
Port of Seattle Terminal 91
Seattle, Washington

JOB NUMBER	DRAWING NUMBER	REVIEWED BY	DATE
948.002.06.008	948-00206008_FS-R_7-7C		1/09

Legend

- Deep SPOC Well With PAH Concentrations Exceeding Final FS CULs
- Deep SPOC Well Without PAH Concentrations Exceeding Final FS CULs
- Background Well Locations
- SWMU 30 Location
- AOC 11 Boundary

Notes:

Feasibility Study (FS)

Cleanup Level (CUL)

See Table 7-4 for a list of Final FS CULs.

Model Toxic Control Act (MTCA)

Standard Point of Compliance (SPOC) as defined in MTCA WAC 173-340-720(8)(b)

Deep wells are screened at a maximum depth of 60 feet below ground surface.

Polycyclic Aromatic Hydrocarbons (PAH)

Solid Waste Managment Unit (SWMU)

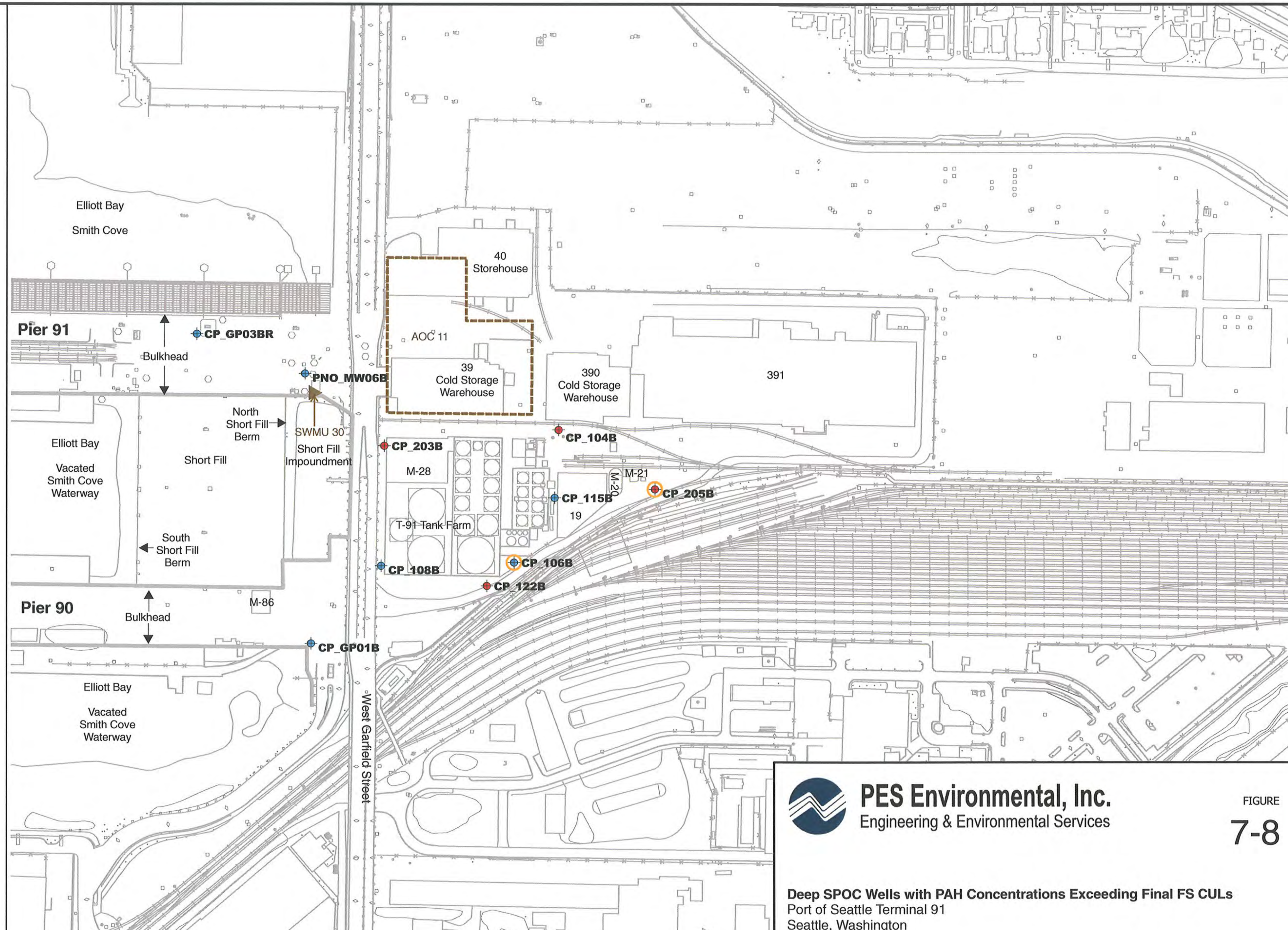
Area of Concern (AOC)

The tank farm is shown for illustrative purposes only. The above-ground portions of the tank farm were demolished and paved in 2005.

N

0 125 250 500 Feet

Map Reference: PIONEER Technologies Corporation, August 2008.



PES Environmental, Inc.
Engineering & Environmental Services

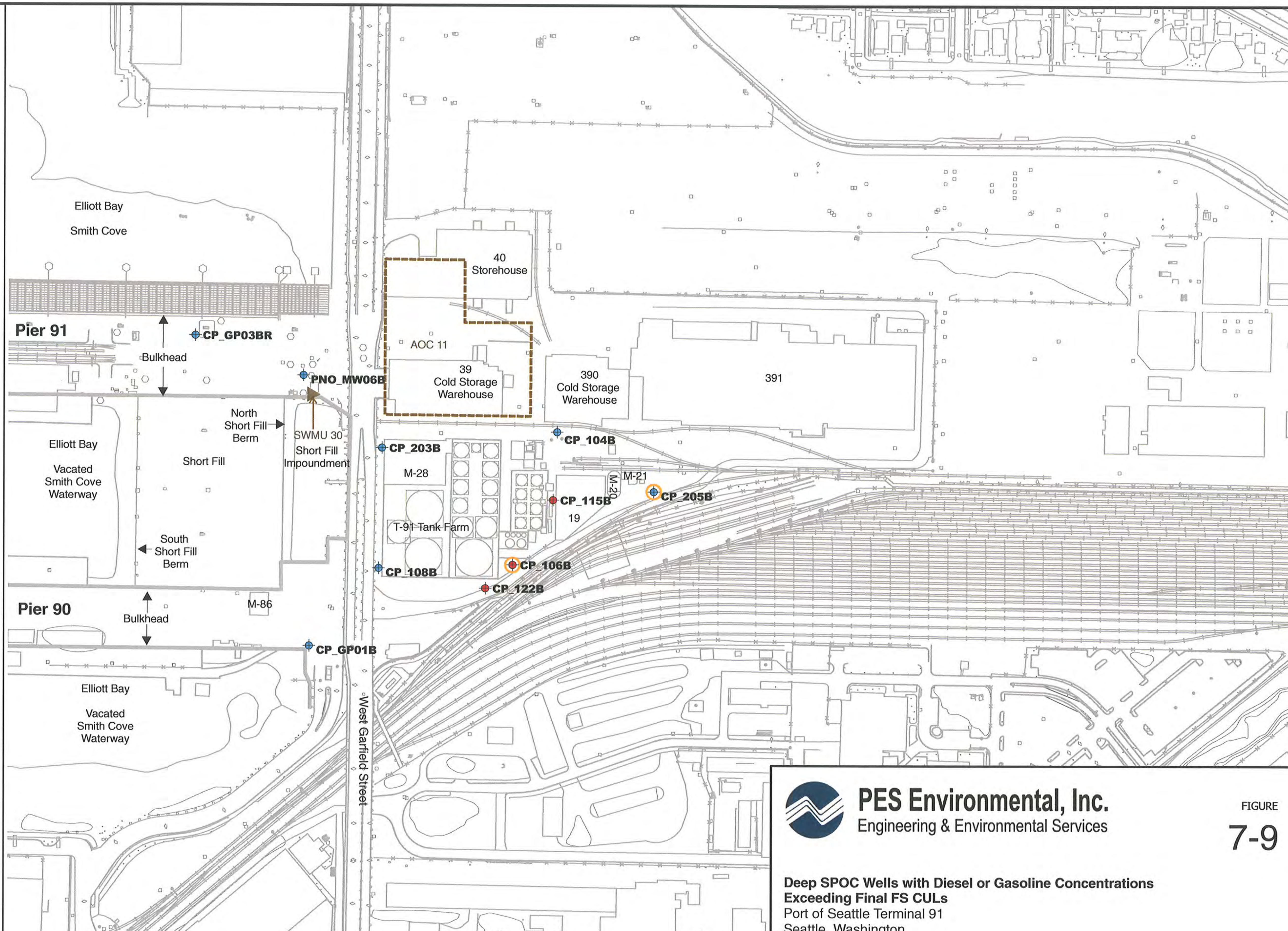
FIGURE 7-8

Deep SPOC Wells with PAH Concentrations Exceeding Final FS CULs
Port of Seattle Terminal 91
Seattle, Washington

JOB NUMBER	DRAWING NUMBER	REVIEWED BY	DATE
948.002.06.008	948-00206008_FS-R_7-8C		1/09

Legend

- Deep SPOC Well With Diesel Or Gasoline Concentrations Exceeding Final FS CULs
- Deep SPOC Well Without Gasoline or Diesel Concetrations Exceeding Final FS CULs
- Background Well Locations
- SWMU 30 Location
- AOC 11 Boundary



N

0 125 250 500 Feet

Notes:

Feasibility Study (FS)

Cleanup Level (CUL)

See Table 7-4 for a list of Final FS CULs.

Model Toxic Control Act (MTCA)

Standard Point of Compliance (SPOC) as defined in MTCA WAC 173-340-720(8)(b)

Deep wells are screened at a maximum depth of 60 feet below ground surface.

Solid Waste Managment Unit (SWMU)

Area of Concern (AOC)

The tank farm is shown for illustrative purposes only. The above-ground portions of the tank farm were demolished and paved in 2005.

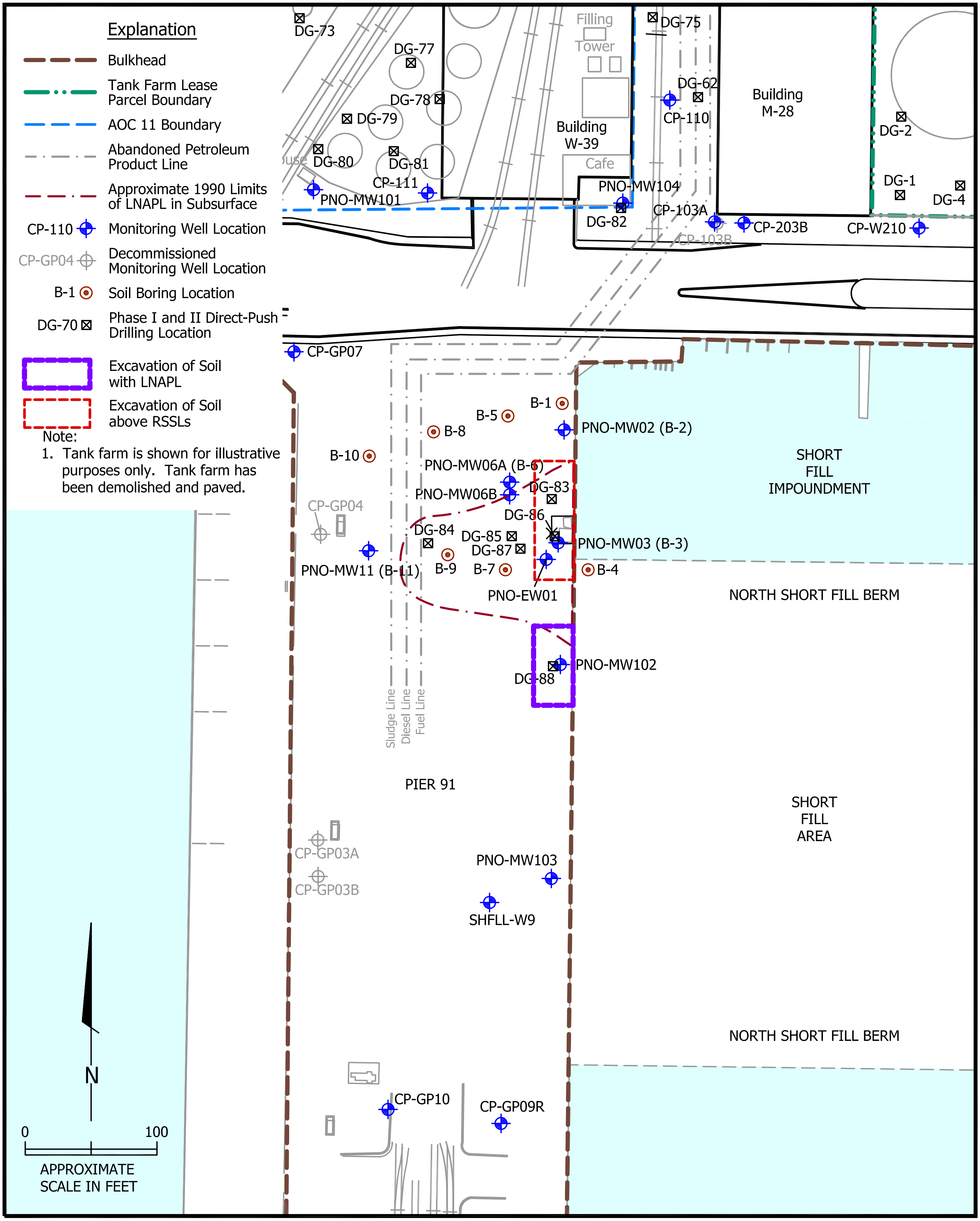
Map Reference: PIONEER Technologies Corporation, August 2008.

PES Environmental, Inc.
Engineering & Environmental Services

FIGURE
7-9

Deep SPOC Wells with Diesel or Gasoline Concentrations Exceeding Final FS CULs
Port of Seattle Terminal 91
Seattle, Washington

JOB NUMBER	DRAWING NUMBER	REVIEWED BY	DATE
948.002.06.008	948-00206008_FS-R_7-9C		1/09

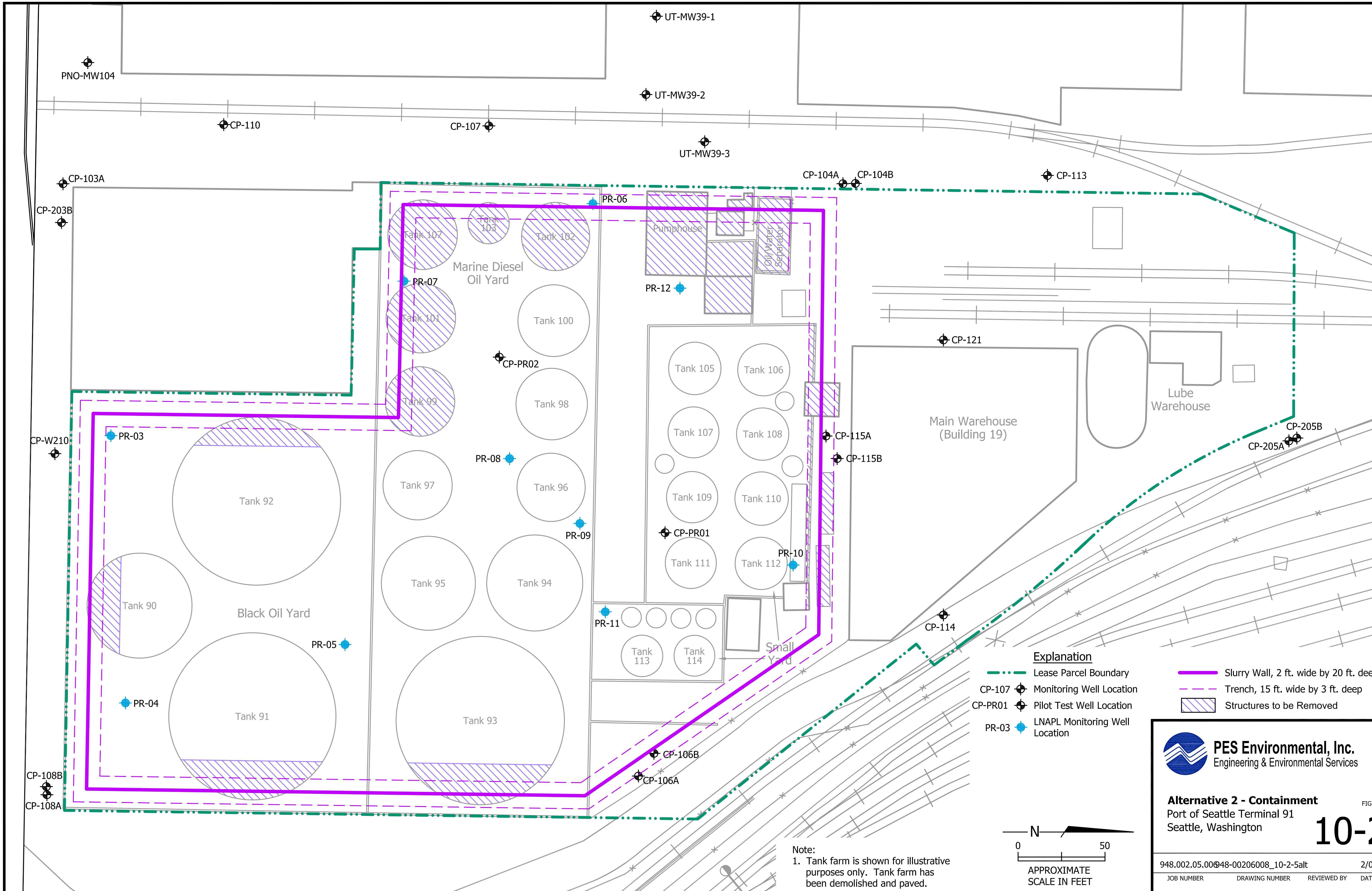


PES Environmental, Inc.
Engineering & Environmental Services

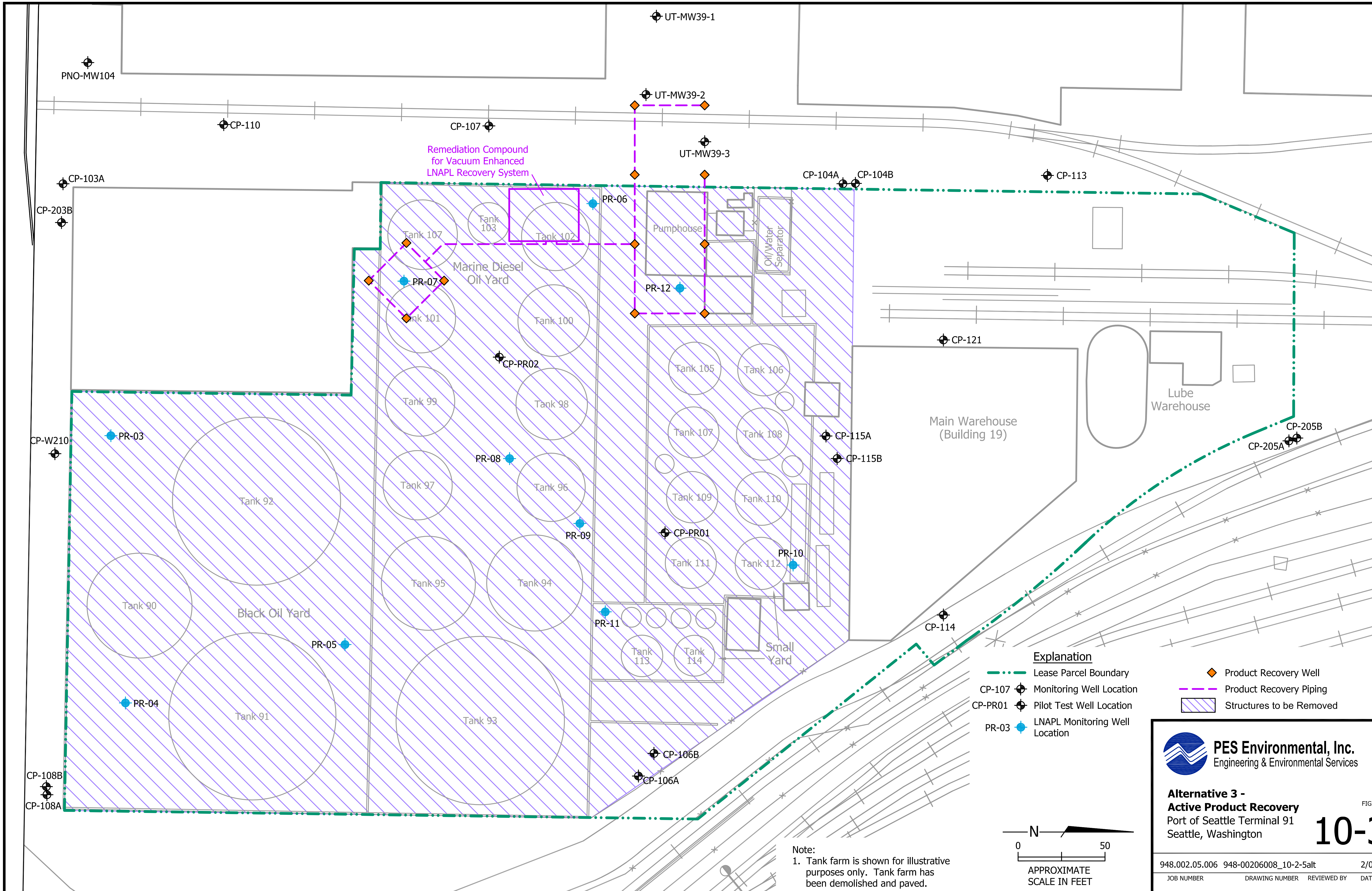
SWMU 30 - Limited Excavation
Port of Seattle Terminal 91
Seattle, Washington

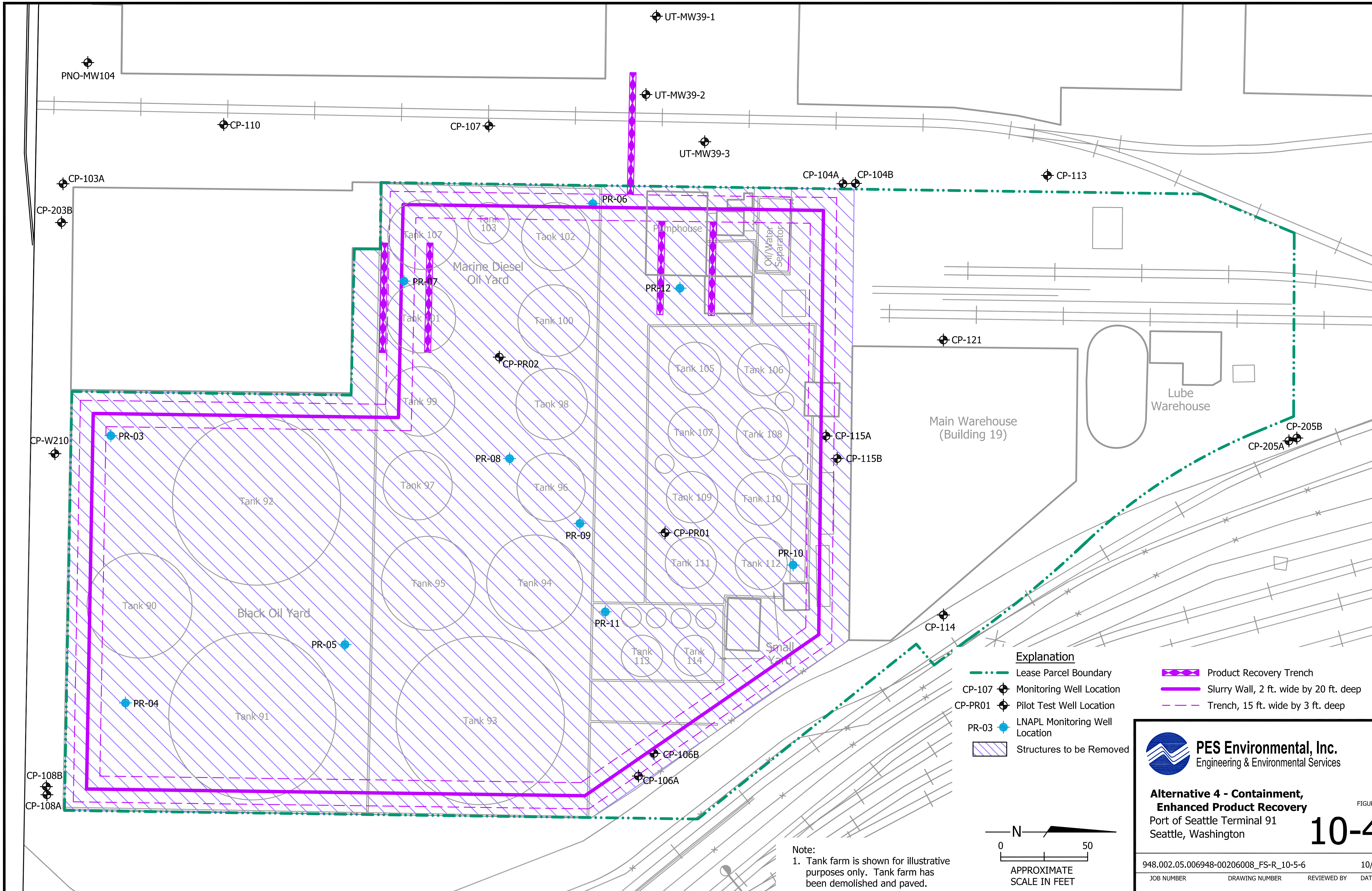
FIGURE
10-1

948.002.06.008	948-00206008_FS-R_10-1		10/09
JOB NUMBER	DRAWING NUMBER	REVIEWED BY	DATE



UT-MW39-1
PNO-MW104
UT-MW39-2
CP-110
CP-107
UT-MW39-3
CP-103A
CP-203B
CP-104A
CP-104B
CP-113
PR-06
Tank 107
Tank 103
Tank 102
Pumphouse
Oil/Water Separator
Marine Diesel Oil Yard
PR-07
PR-12
Tank 101
Tank 100
CP-121
CP-PR02
Tank 105
Tank 106
Tank 99
Tank 98
Lube Warehouse
Main Warehouse (Building 19)
CP-W210
PR-03
Tank 107
Tank 108
CP-115A
CP-205B
CP-205A
PR-08
CP-115B
Tank 92
Tank 97
Tank 96
Tank 109
Tank 110
PR-09
CP-PR01
PR-10
Tank 90
Tank 95
Tank 94
Tank 111
Tank 112
Black Oil Yard
PR-11
CP-114
PR-05
Tank 113
Tank 114
Small Yard
PR-04
Tank 91
Tank 93
CP-106B
CP-106A
CP-108B
CP-108A
Explanation
Lease Parcel Boundary
CP-107 Monitoring Well Location
CP-PR01 Pilot Test Well Location
PR-03 LNAPL Monitoring Well Location
Slurry Wall, 2 ft. wide by 20 ft. deep
Trench, 15 ft. wide by 3 ft. deep
Structures to be Removed
Note:
1. Tank farm is shown for illustrative purposes only. Tank farm has been demolished and paved.
N
0
50
APPROXIMATE SCALE IN FEET
PES Environmental, Inc.
Engineering & Environmental Services
Alternative 2 - Containment
Port of Seattle Terminal 91
Seattle, Washington
FIGURE
10-2
948.002.05.006
948-00206008_10-2-5alt
2/09
JOB NUMBER
DRAWING NUMBER
REVIEWED BY
DATE


UT-MW39-1
PNO-MW104
UT-MW39-2
CP-110
CP-107
UT-MW39-3
Remediation Compound
for Vacuum Enhanced
LNAPL Recovery System
CP-103A
CP-104A
CP-104B
CP-113
CP-203B
PR-06
Tank 107
Tank 103
Tank 102
Pumphouse
Oil/Water Separator
Marine Diesel
Oil Yard
PR-07
Tank 101
Tank 100
PR-12
CP-121
CP-PR02
Tank 105
Tank 106
Tank 99
Tank 98
Lube Warehouse
Main Warehouse
(Building 19)
CP-205B
CP-205A
CP-W210
PR-03
CP-115A
CP-115B
Tank 107
Tank 108
PR-08
Tank 92
Tank 97
Tank 96
Tank 109
Tank 110
PR-09
CP-PR01
Tank 90
Tank 95
Tank 94
Tank 111
Tank 112
PR-10
Black Oil Yard
PR-11
CP-114
PR-05
Tank 113
Tank 114
Small Yard
PR-04
Tank 91
Tank 93
CP-106B
CP-106A
CP-108B
CP-108A
Explanation
Lease Parcel Boundary
CP-107 Monitoring Well Location
CP-PR01 Pilot Test Well Location
PR-03 LNAPL Monitoring Well Location
Product Recovery Well
Product Recovery Piping
Structures to be Removed
N
0
50
APPROXIMATE
SCALE IN FEET
Note:
1. Tank farm is shown for illustrative purposes only. Tank farm has been demolished and paved.
PES Environmental, Inc.
Engineering & Environmental Services
Alternative 3 -
Active Product Recovery
Port of Seattle Terminal 91
Seattle, Washington
FIGURE
10-3
948.002.05.006
948-00206008_10-2-5alt
2/09
JOB NUMBER
DRAWING NUMBER
REVIEWED BY
DATE

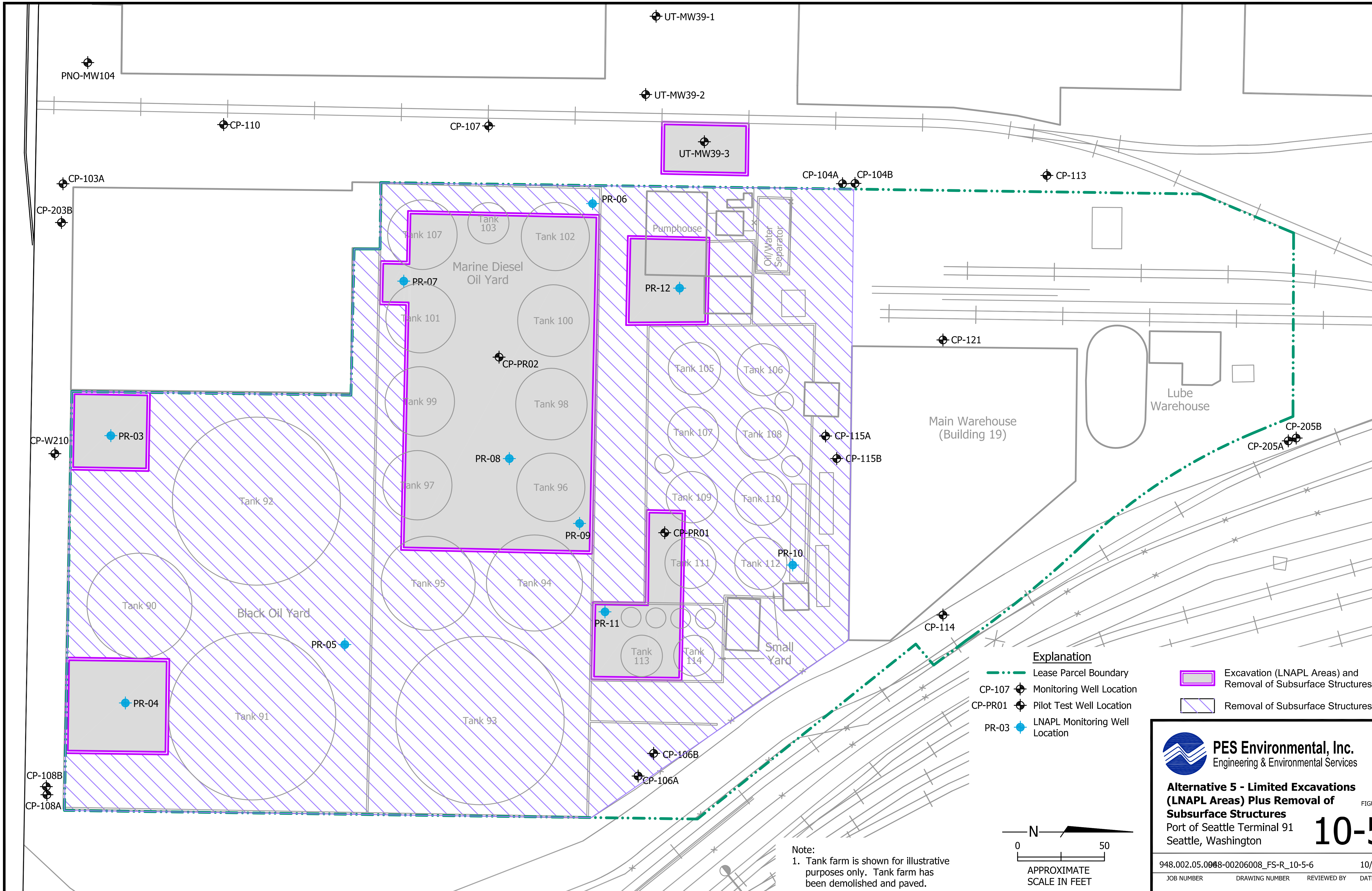


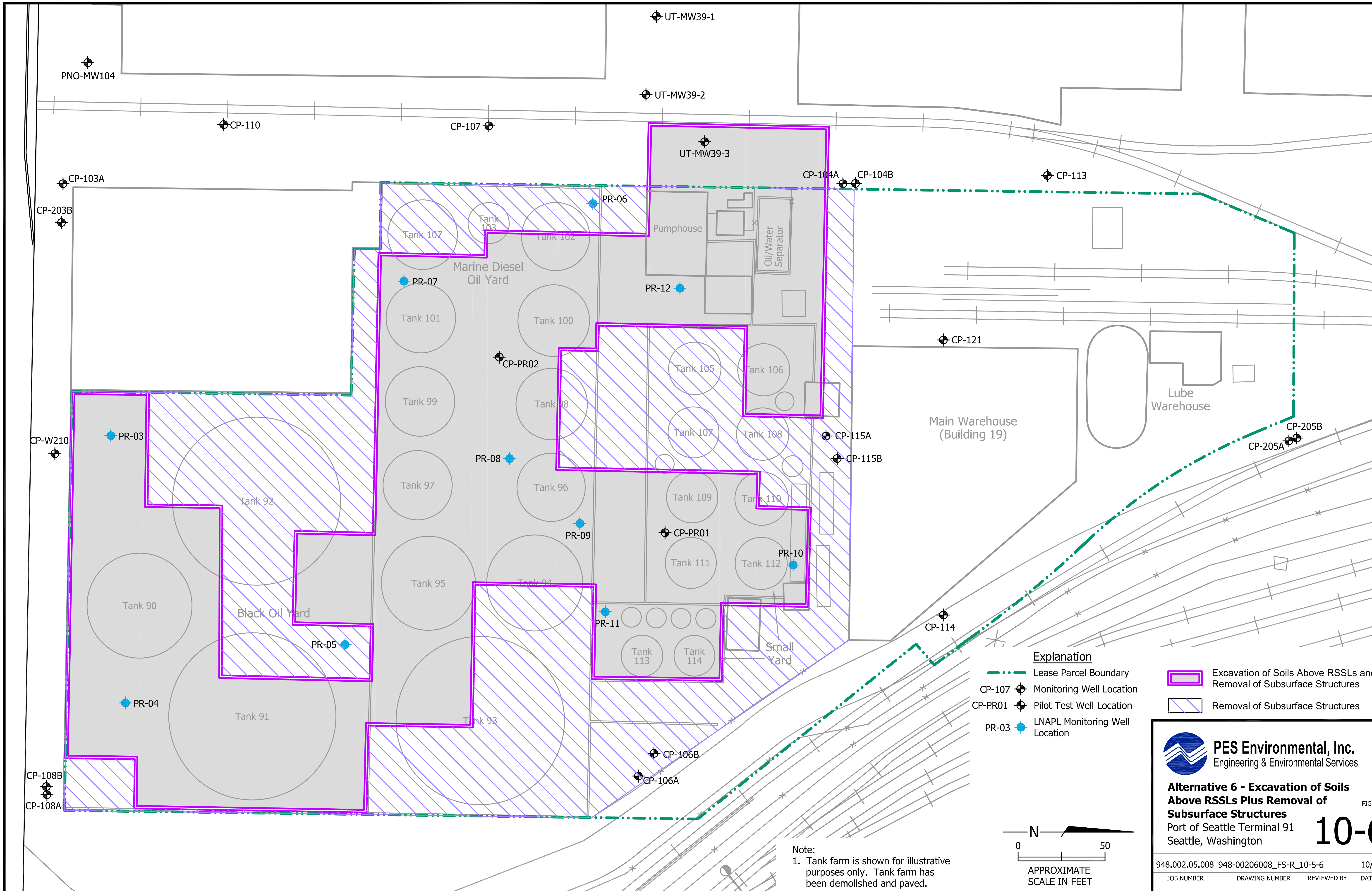
PES Environmental, Inc.
Engineering & Environmental Services

Alternative 4 - Containment, Enhanced Product Recovery
Port of Seattle Terminal 91
Seattle, Washington

FIGURE
10-4

JOB NUMBER	DRAWING NUMBER	REVIEWED BY	DATE
948.002.05.006948-00206008_FS-R_10-5-6			10/09


UT-MW39-1
PNO-MW104
UT-MW39-2
CP-110
CP-107
UT-MW39-3
CP-104A
CP-104B
CP-113
CP-103A
CP-203B
PR-06
Tank 107
Tank 103
Tank 102
Pumphouse
Oil/Water Separator
Marine Diesel Oil Yard
PR-07
PR-12
Tank 101
Tank 100
CP-PR02
CP-121
Tank 105
Tank 106
Tank 99
Tank 98
Lube Warehouse
Main Warehouse (Building 19)
PR-03
CP-W210
Tank 107
Tank 108
CP-115A
CP-205B
CP-205A
PR-08
CP-115B
Tank 97
Tank 96
Tank 109
Tank 110
Tank 92
PR-09
CP-PR01
PR-10
Tank 111
Tank 112
Tank 95
Tank 94
Tank 90
Black Oil Yard
PR-11
CP-114
PR-05
Tank 113
Tank 114
Small Yard
PR-04
Tank 91
Tank 93
CP-106B
CP-106A
CP-108B
CP-108A
Explanation
Lease Parcel Boundary
CP-107 Monitoring Well Location
CP-PR01 Pilot Test Well Location
PR-03 LNAPL Monitoring Well Location
Excavation (LNAPL Areas) and Removal of Subsurface Structures
Removal of Subsurface Structures
Note:
1. Tank farm is shown for illustrative purposes only. Tank farm has been demolished and paved.
N
0
50
APPROXIMATE SCALE IN FEET
PES Environmental, Inc.
Engineering & Environmental Services
Alternative 5 - Limited Excavations (LNAPL Areas) Plus Removal of Subsurface Structures
Port of Seattle Terminal 91
Seattle, Washington
FIGURE
10-5
948.002.05.004
948-00206008_FS-R_10-5-6
10/09
JOB NUMBER
DRAWING NUMBER
REVIEWED BY
DATE



PES Environmental, Inc.
Engineering & Environmental Services

Alternative 6 - Excavation of Soils Above RSSLs Plus Removal of Subsurface Structures
Port of Seattle Terminal 91
Seattle, Washington

FIGURE **10-6**

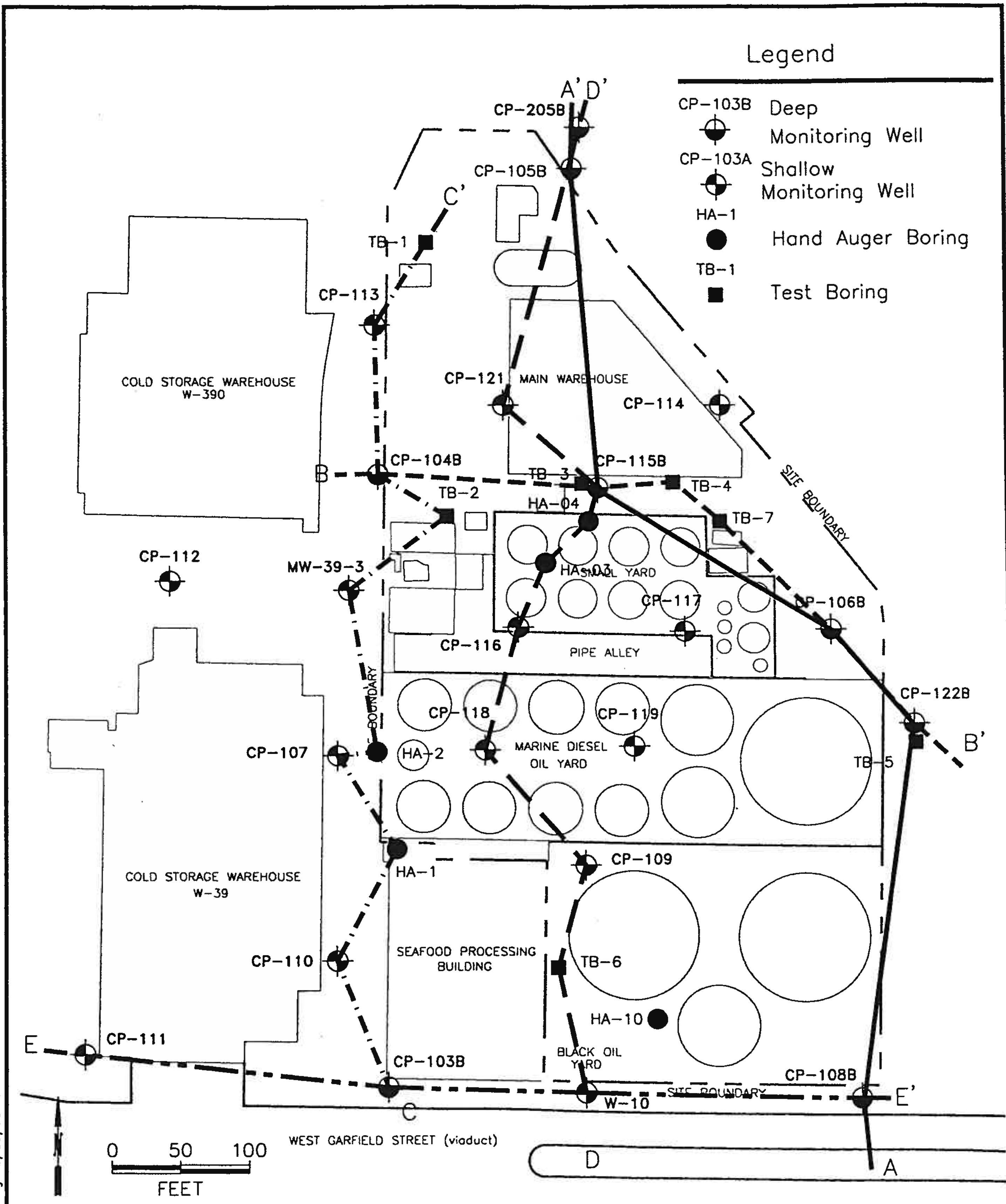
JOB NUMBER	DRAWING NUMBER	REVIEWED BY	DATE
948.002.05.008	948-00206008_FS-R_10-5-6		10/09

APPENDIX A

SELECT TABLES AND FIGURES FROM PREVIOUS INVESTIGATION REPORTS

APPENDIX A1

SELECT TABLES AND FIGURES FROM
REMEDIAL INVESTIGATION/DATA EVALULATION REPORT
PSC, 1999



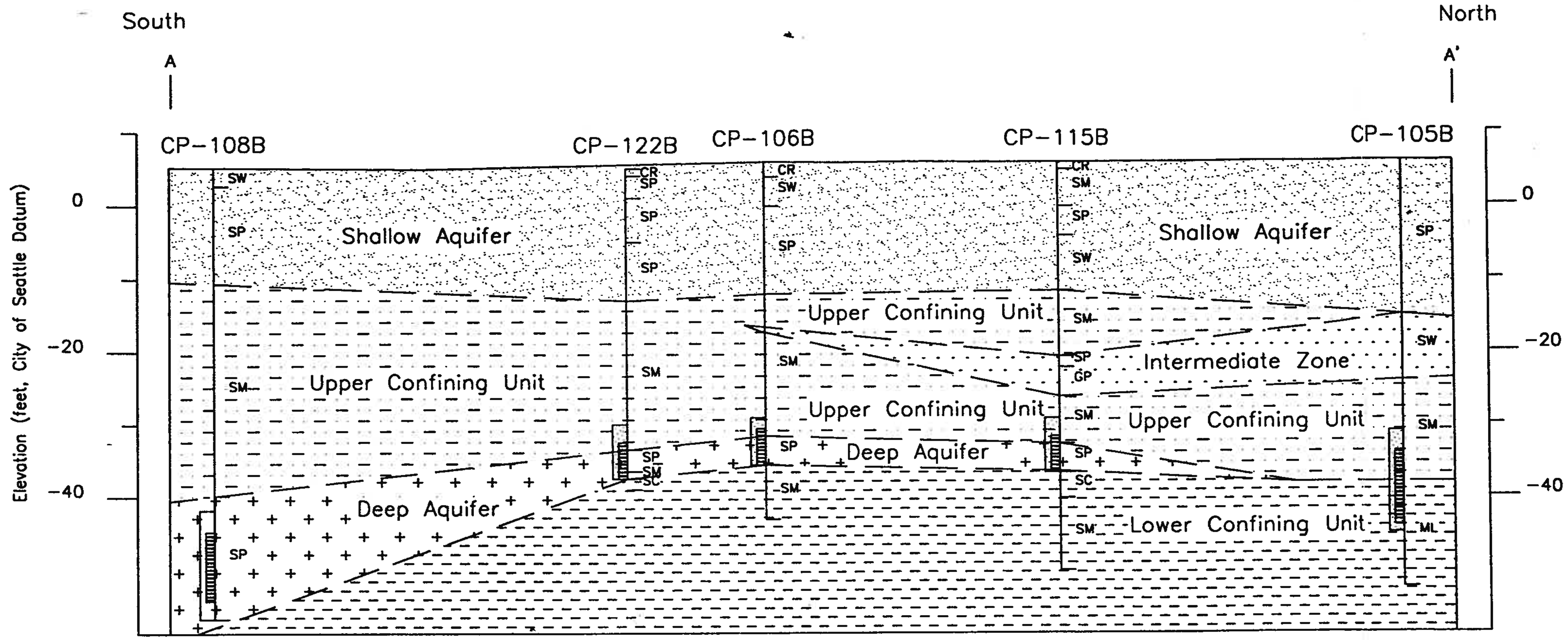
BV98014A-09.dwg areis base.dwg 12/23/98 1:1

Geologic Cross-Section Index Map

Terminal 91 Tank Farm Site

DWN.: BB	DES.: DP	FIGURE NUMBER
CHKD.:	APPD.:	**4-1**
DATE: 12/23/98	REV.: –	

Prepared by: PSC PHILIP SERVICES CORP. • AESI ASSOCIATED EARTH SCIENCES, INC • Roth Consulting



Note: This profile was developed by interpolation between widely spaced borings and monitoring wells. It should be considered as an approximation of geologic conditions to the degree implied by notes on the boring or well logs presented in this report.

Legend

MW-22S Monitoring well or boring designation
SM USCS Soil Classification (see text)
Monitoring well sand pack
Monitoring well screened interval
Total depth of monitoring well or boring

Stratigraphic Unit	Hydrostratigraphic Unit
Shallow Sand Unit	Shallow Aquifer
Silty Sand Unit	Upper Confining Unit
Silty Sandy Gravel Zone	Intermediate Zone of Upper Confining Unit
Deep Sand Unit	Deep Aquifer
Silty Clayey Sand and Silty Sand Unit	Lower Confining Unit

Horizontal Scale
0 50 100
FEET

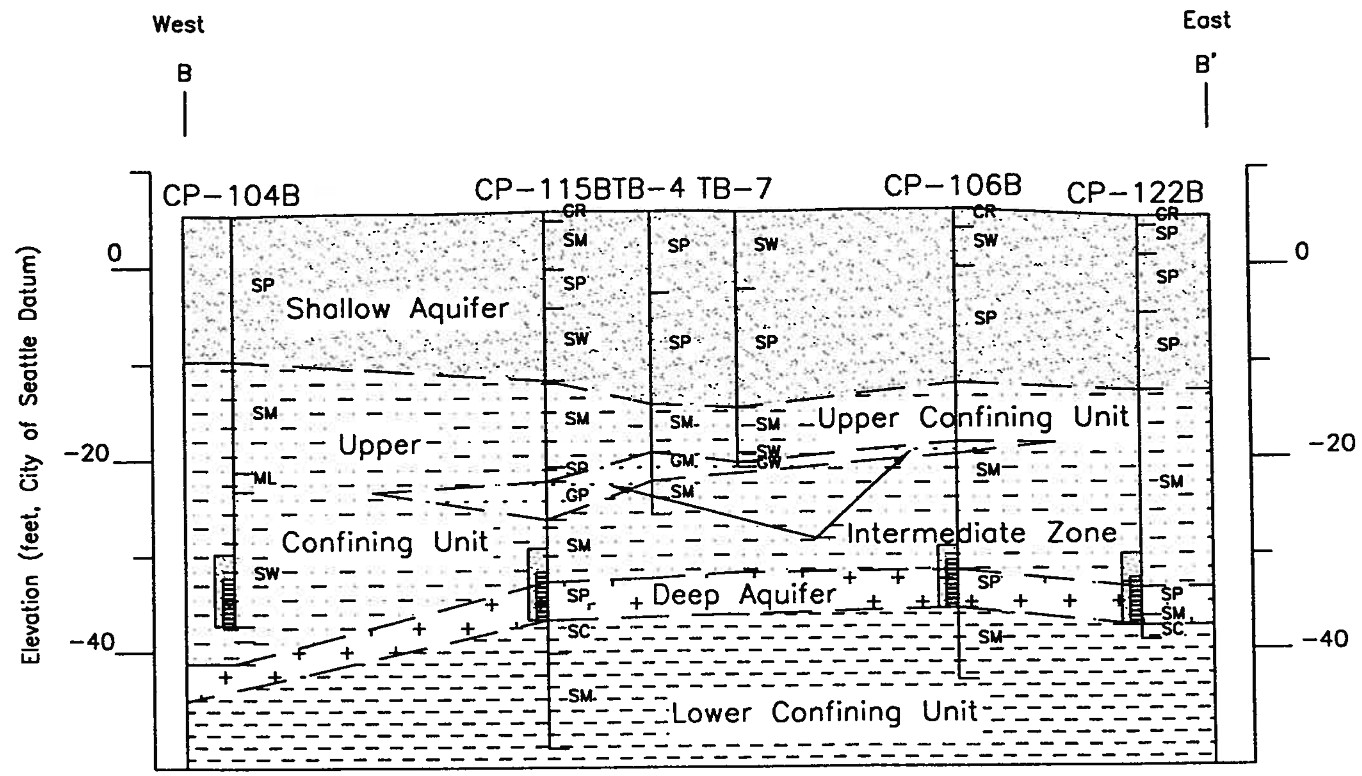
Vertical Exaggeration = 5

Geologic Cross Section A-A'
Terminal 91 Tank Farm Site

DWN.: DP	DES.: DP	FIGURE NUMBER
CHKD.:	APPD.:	4-2
DATE: 12/23/98	REV.:	

Prepared by: PHILIP SERVICES CORP • ASSOCIATED EARTH SCIENCES, INC • Roth Consulting

BY98014A-07.dwg tilemoded 12/23/98 1:1



Note: This profile was developed by interpolation between widely spaced borings and monitoring wells. It should be considered as an approximation of geologic conditions to the degree implied by notes on the boring or well logs presented in this report.

Legend

MW−22S — Monitoring well or boring designation
SM — USCS Soil Classification (see text)
Monitoring well sand pack
Monitoring well screened interval
Total depth of monitoring well or boring

Stratigraphic Unit	Hydrostratigraphic Unit
Shallow Sand Unit	Shallow Aquifer
Silty Sand Unit	Upper Confining Unit
Silty Sandy Gravel Zone	Intermediate Zone of Upper Confining Unit
Deep Sand Unit	Deep Aquifer
Silty Clayey Sand and Silty Sand Unit	Lower Confining Unit

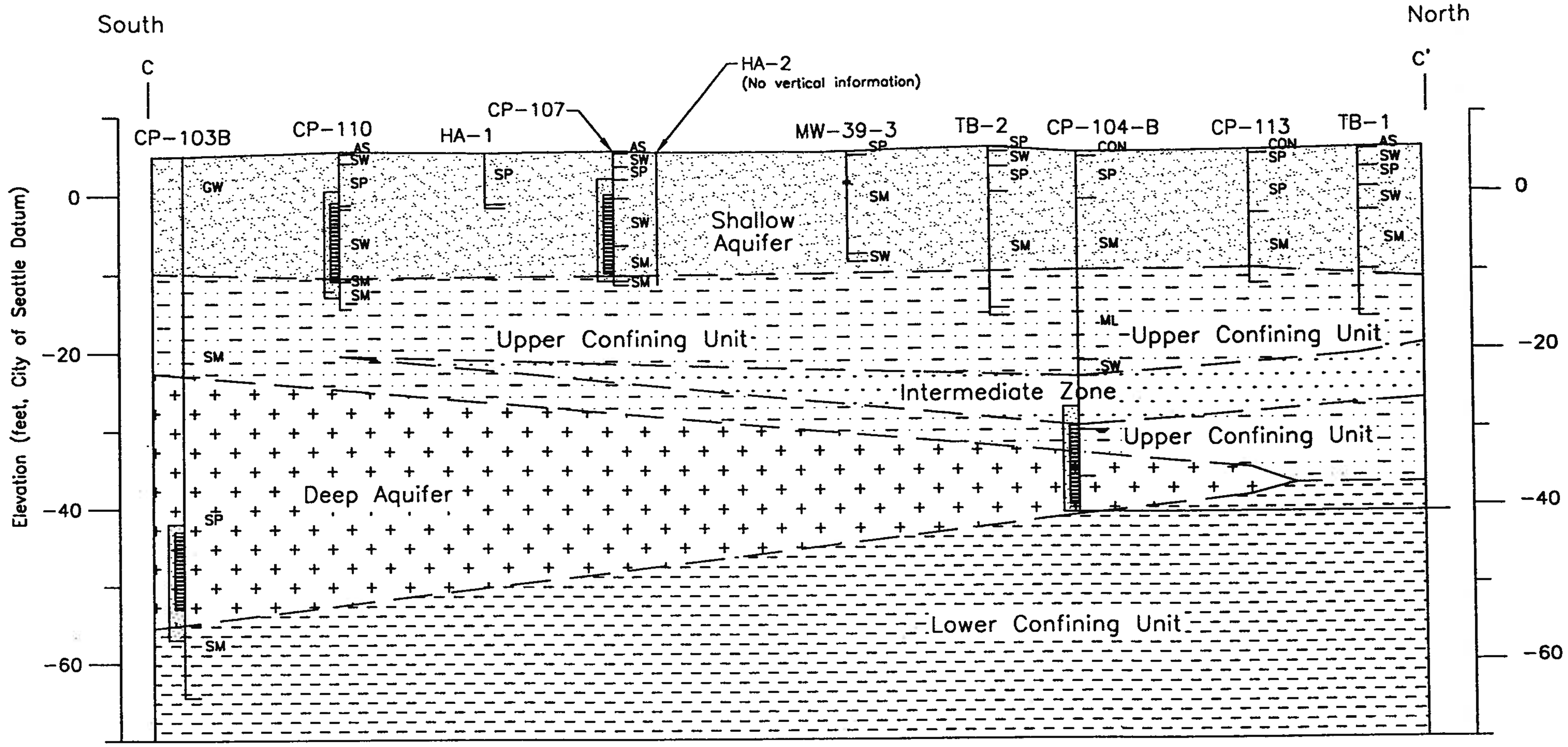
Horizontal Scale
0 50 100
FEET
Vertical Exaggeration = 5

Geologic Cross Section B-B'
Terminal 91 Tank Farm Site

DWN.: DP	DES.: DP	FIGURE NUMBER
CHKD.:	APPD.:	4-3
DATE: 12/23/98	REV.:	

Prepared by: PHILIP SERVICES CORP. • ASSOCIATED EARTH SCIENCES, INC • Roth Consulting

BV99014A-08.dwg filemoded 12/23/98 1:1



Note: This profile was developed by interpolation between widely spaced borings and monitoring wells. It should be considered as an approximation of geologic conditions to the degree implied by notes on the boring or well logs presented in this report.

Legend	Stratigraphic Unit	Hydrostratigraphic Unit
MW-22S Monitoring well or boring designation	Shallow Sand Unit	Shallow Aquifer
SM USCS Soil Classification (see text)	Silty Sand Unit	Upper Confining Unit
Monitoring well sand pack	Silty Sandy Gravel Zone	Intermediate Zone of Upper Confining Unit
Monitoring well screened interval	Deep Sand Unit	Deep Aquifer
Total depth of monitoring well or boring	Silty Clayey Sand and Silty Sand Unit	Lower Confining Unit

Horizontal Scale

0 50 100

FEET

Vertical Exaggeration = 5

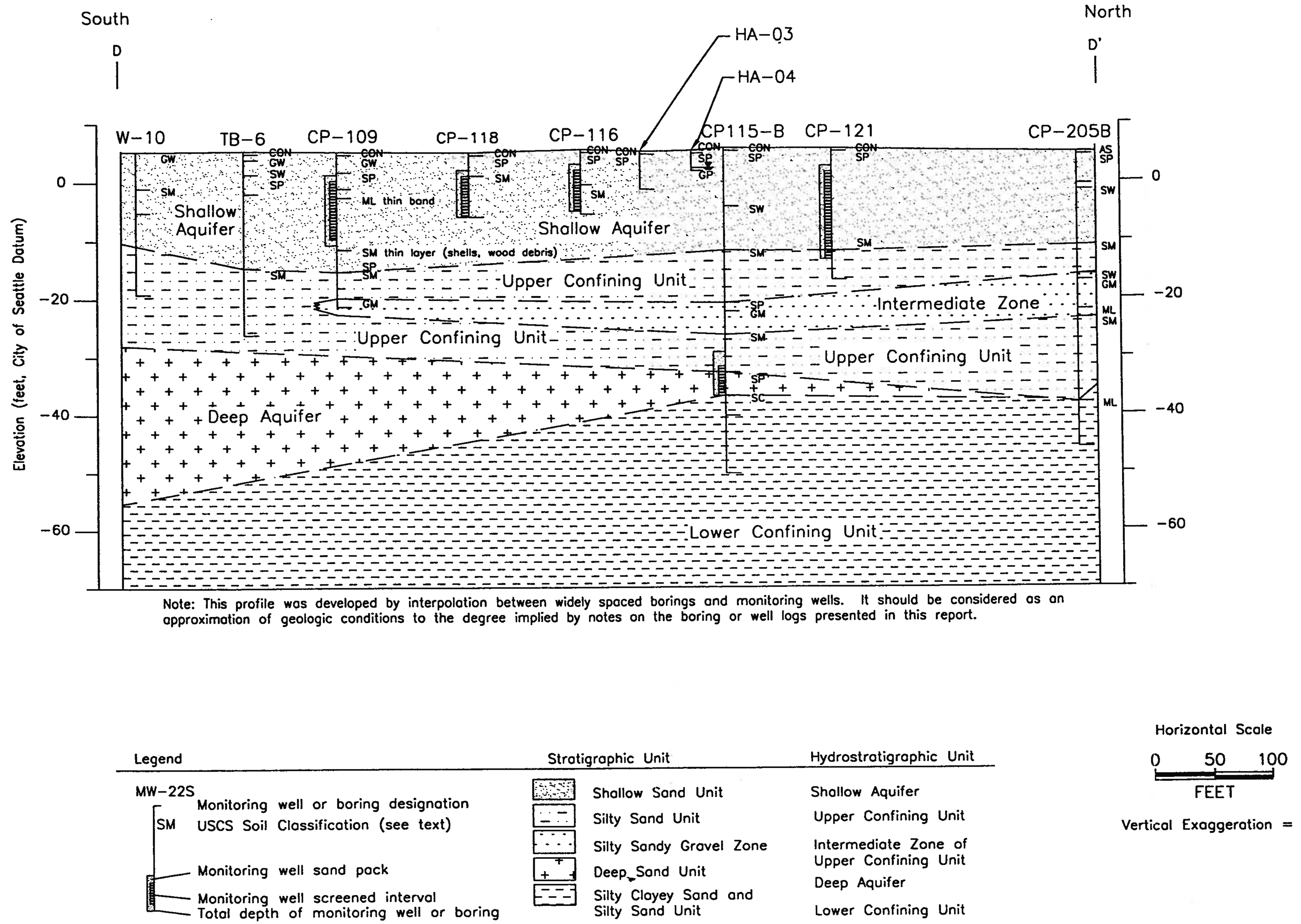
Geologic Cross Section C-C'

Terminal 91 Tank Farm Site

DWN.: BB	DES.: DP	FIGURE NUMBER
CHKD.:	APPD.:	**4-4**
DATE: 01/05/98	REV.:	

Prepared by: PHILIP SERVICES CORP • ASSOCIATED EARTH SCIENCES, INC • Roth Consulting

BV99014A-65.dwg tilemoded 12/23/98 1:1

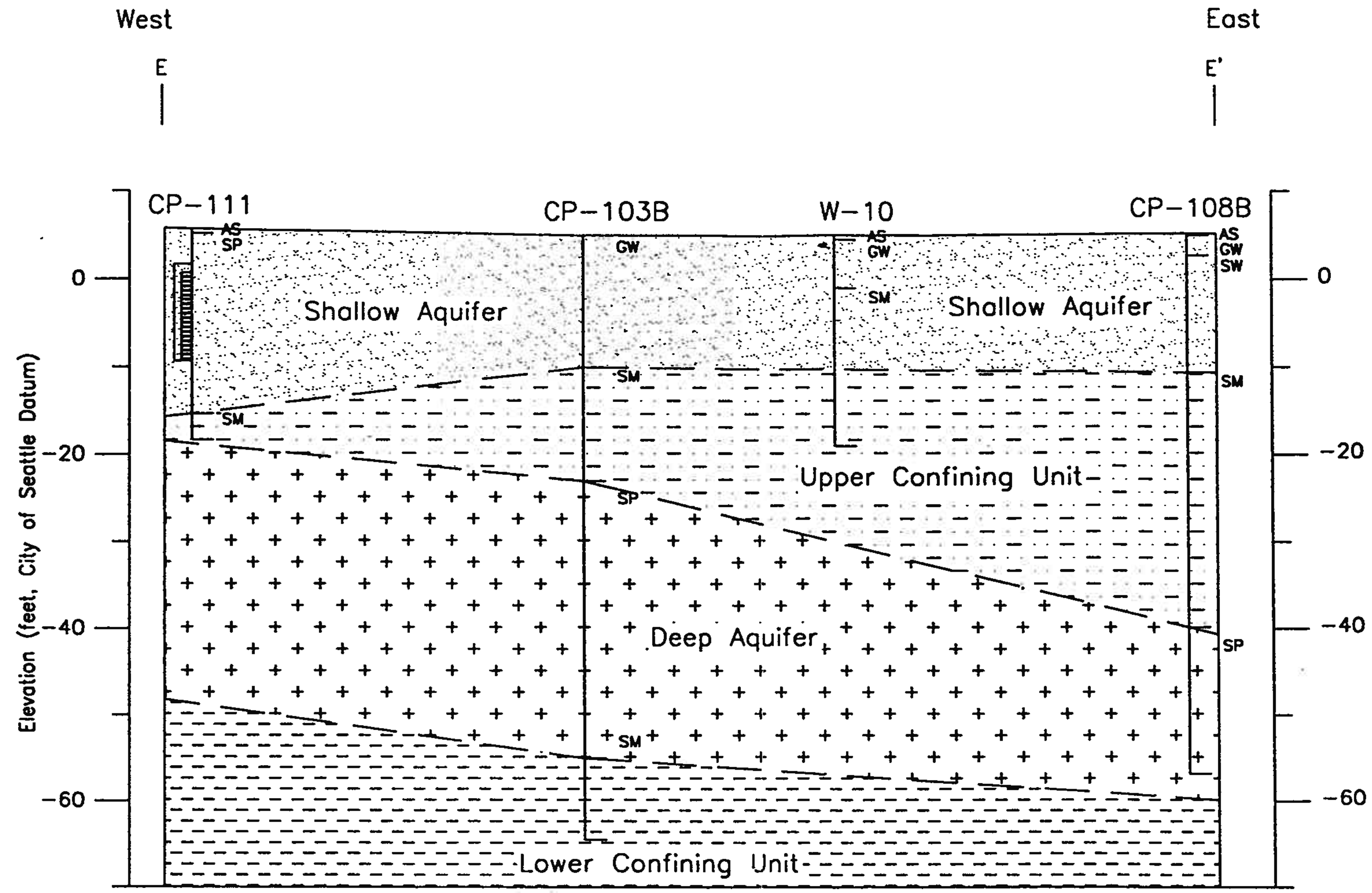


Geologic Cross Section D-D'
Terminal 91 Tank Farm Site

DWN.: BB	DES.: DP	FIGURE NUMBER
CHKD.:	APPD.:	4-5
DATE: 12/23/98	REV.:	

Prepared by: PHILIP SERVICES CORP • ASSOCIATED EARTH SCIENCES, INC • Roth Consulting

BV99014A-6... filemoded 12/23/98 1:1



Note: This profile was developed by interpolation between widely spaced borings and monitoring wells. It should be considered as an approximation of geologic conditions to the degree implied by notes on the boring or well logs presented in this report.

Legend

MW-22S Monitoring well or boring designation

SM USCS Soil Classification (see text)

Monitoring well sand pack

Monitoring well screened interval

Total depth of monitoring well or boring

Stratigraphic Unit	Hydrostratigraphic Unit
Shallow Sand Unit	Shallow Aquifer
Silty Sand Unit	Upper Confining Unit
Silty Sandy Gravel Zone	Intermediate Zone of Upper Confining Unit
Deep Sand Unit	Deep Aquifer
Silty Clayey Sand and Silty Sand Unit	Lower Confining Unit

Horizontal Scale

0 50 100 FEET

Vertical Exaggeration = 5

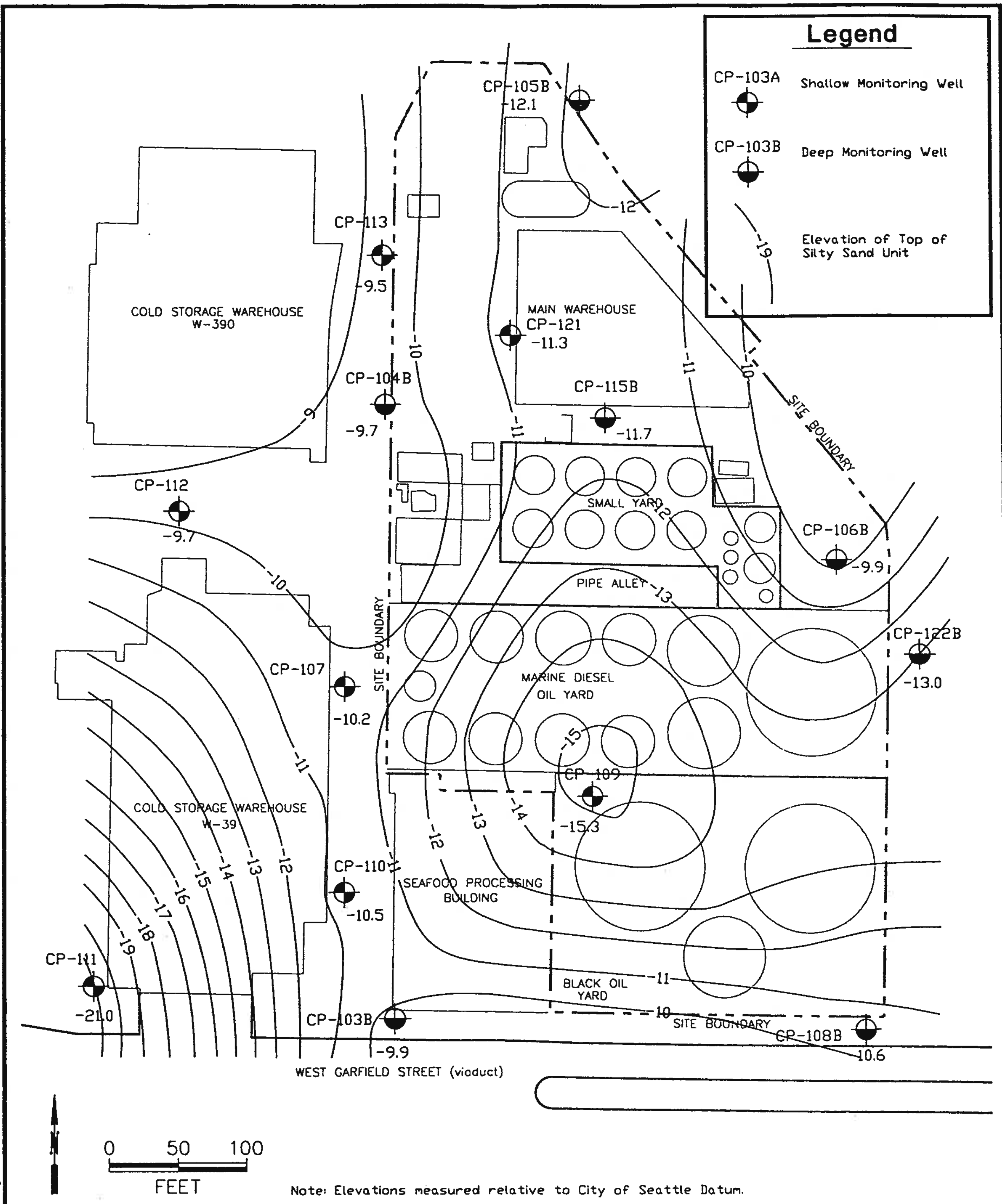
Geologic Cross Section E-E'

Terminal 91 Tank Farm Site

DWN.: BB	DES.: DP	FIGURE NUMI
CHKD.:	APPD.:	4-6
DATE: 12/23/98	REV.:	

Prepared by: PHILIP SERVICES CORP. • ASSOCIATED EARTH SCIENCES, INC • Roth Consulting

BV99014A-67.dwg tilemoded 12/23/98 1:1



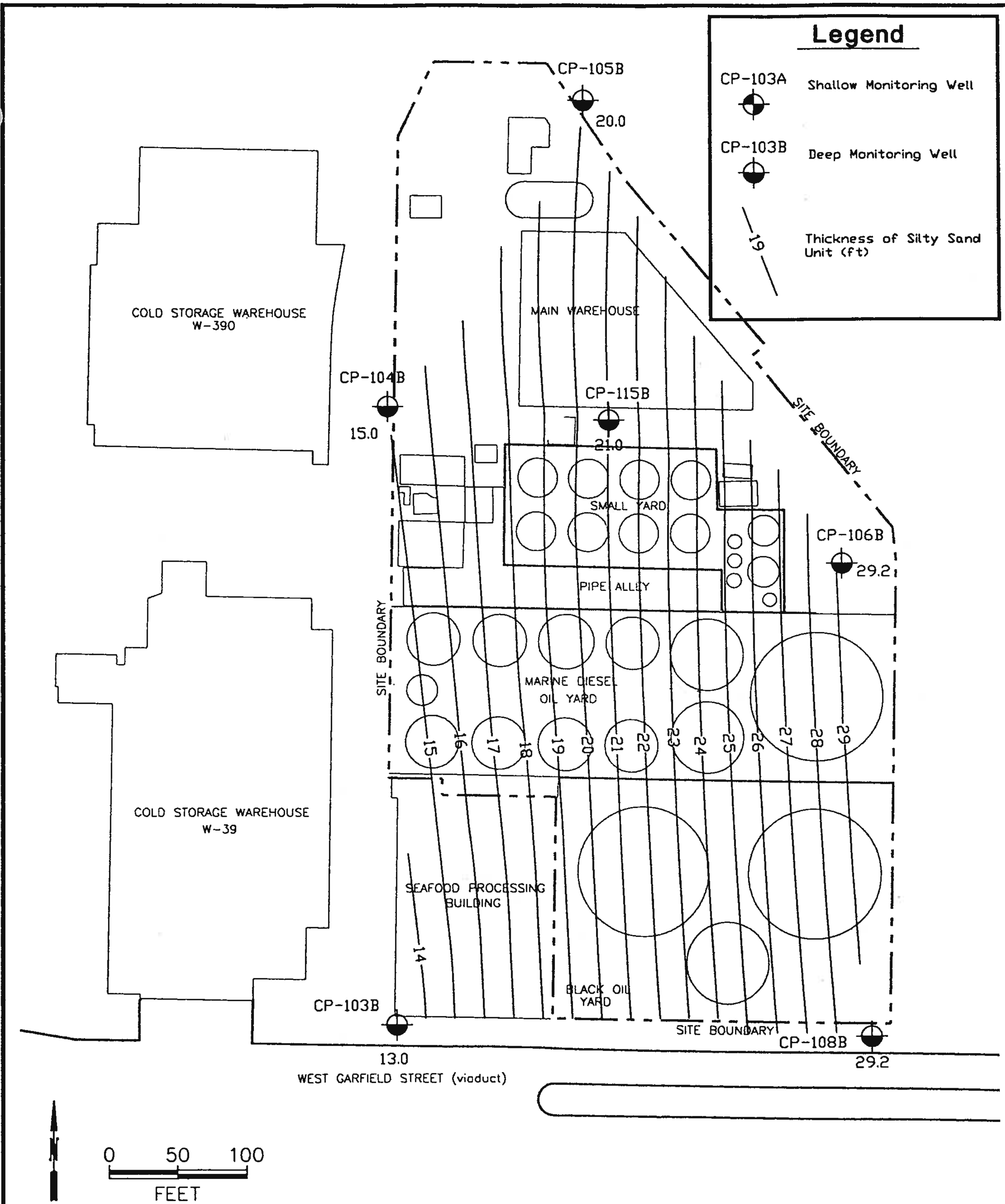
Elevation of the Top of the Silty Sand Unit (Upper Confining Unit)

Terminal 91 Tank Farm Site

DWN.: PB	DES.: DP	FIGURE NUMBER
CHKD.:	APPD.:	4-7
DATE: 12/23/98	REV.: -	

Prepared by: PHILIP SERVICES CORP. • ASSOCIATED EARTH SCIENCES, INC • Roth Consulting

BV98014A-50.dwg ...efs base.dwg 1:1



Thickness of Silty Sand Unit (Upper Confining Unit)

Terminal 91 Tank Farm Site

DWN.: PB	DES.: DP	FIGURE NUMBER
CHKD.:	APPD.:	4-8
DATE: 12/23/98	REV.: –	

Prepared by: PHILIP SERVICES CORP • ASSOCIATED EARTH SCIENCES, INC • Roth Consulting

BV98014A-51.dwg ...s base.dwg 1:1

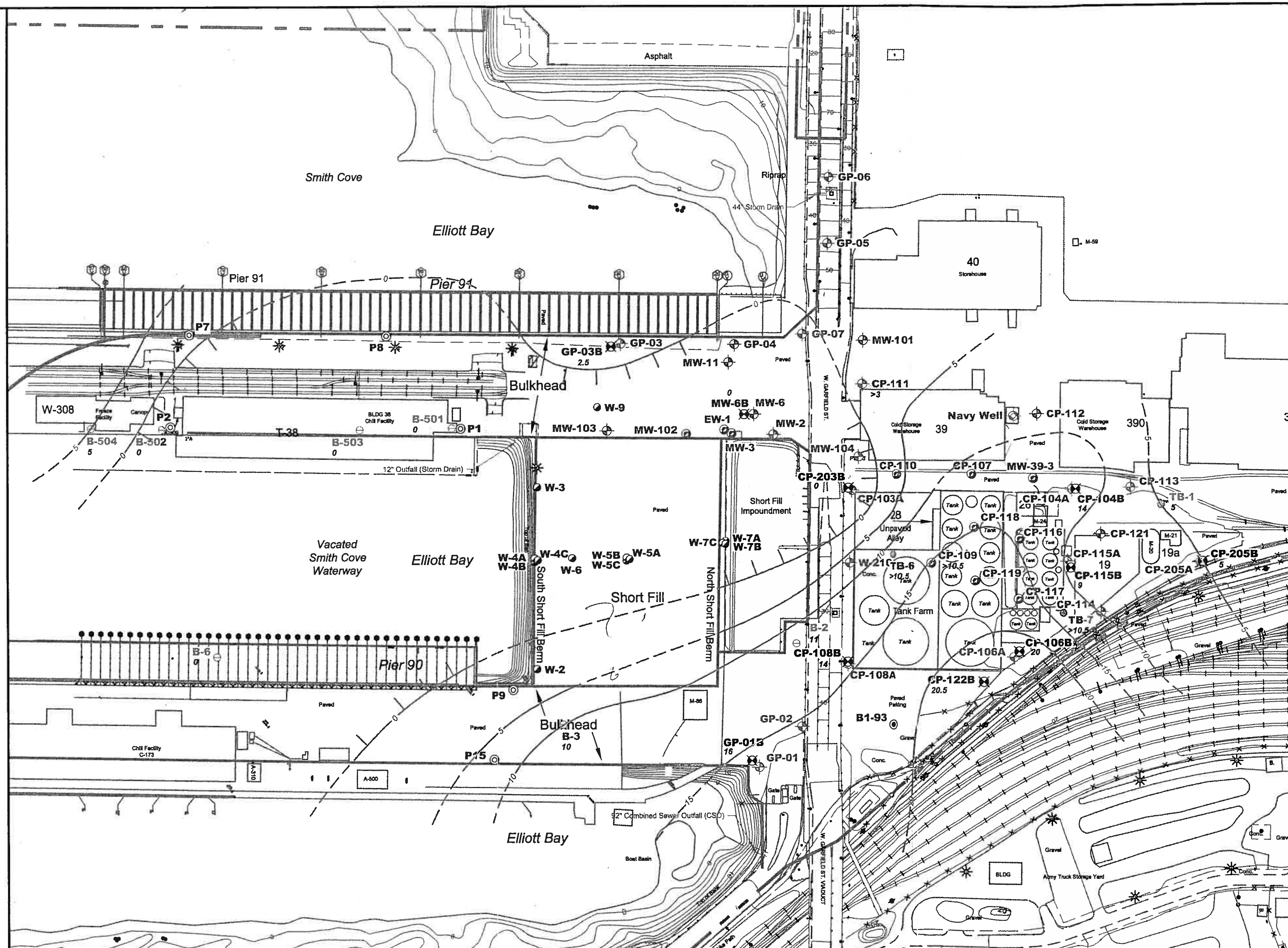
APPENDIX A2

SELECT TABLES AND FIGURES FROM BRIDGE DOCUMENT REPORT 3 ASPECT CONSULTING, MAY, 2004

Legend

Wells with Tidal Data

- Shallow Aquifer Monitoring Well
- Deep Confined Aquifer Monitoring Well
- LNAPL Monitoring/Recovery Wells
- Short Fill Monitoring Well
- Navy Well
- Piezometer
- Temporary Piezometer (Abandoned)
- TB Series Boring
- Geotech Borings (Hart Crowser)
- 10.5 UCU ~~Unit~~ Thickness in Feet
- 5 Isopach Contour, Inferred
- 10 Isopach Contour, Uncertain



N

0 200 400

Feet

Wells MW-103, MW-102, EW-1, MW-3, MW-104 surveyed by Pacific Northern Oil.
TB series and geotech boring locations are approximated based on historic report figures.
All other wells surveyed by POS. Structures shown on the southern half of piers 90 & 91 are approximated based on additional basemap drawings.

DRAFT

Roth Consulting

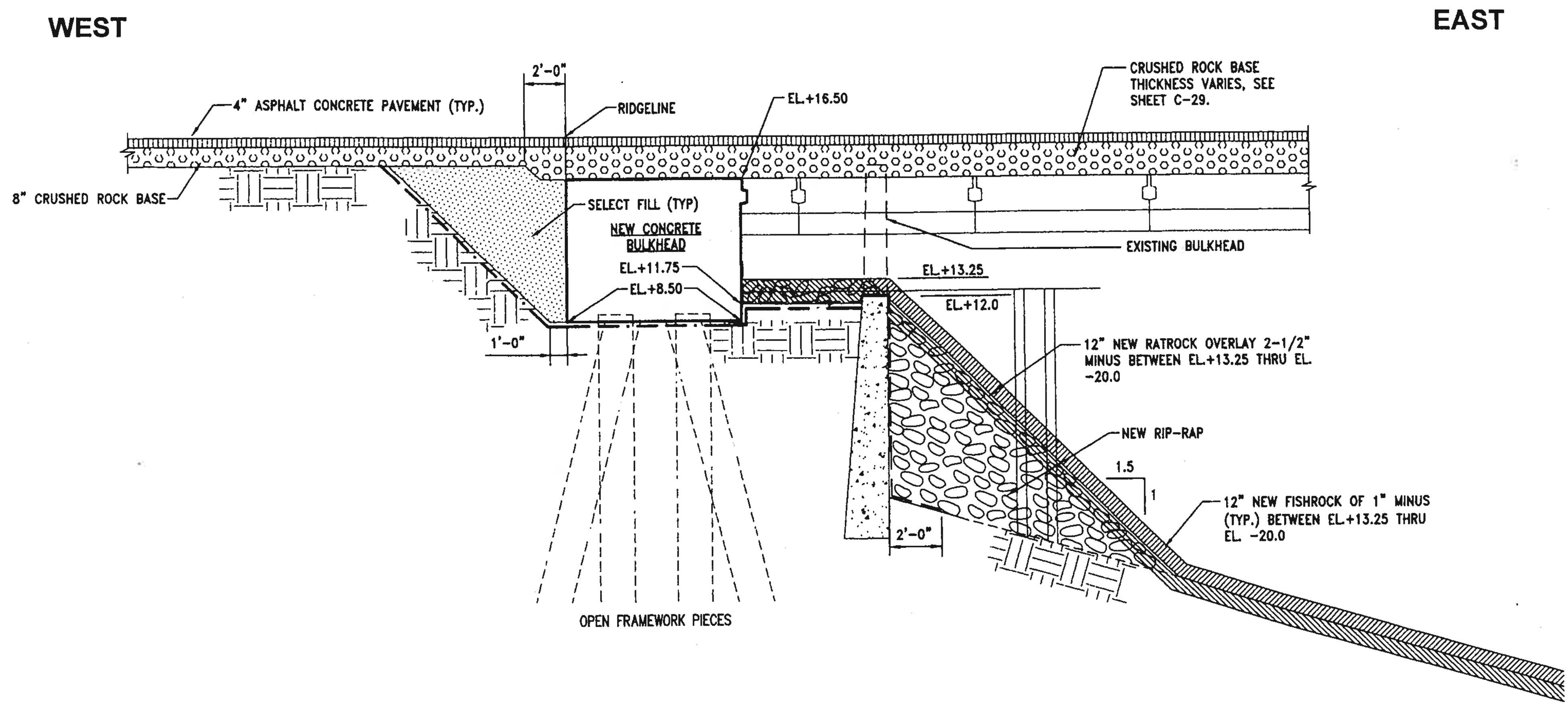
Aspect consulting
IN-DEPTH PERSPECTIVE

179 Madrone Lane North, Bainbridge Island, WA 98110, (206) 780-9370
811 First Avenue #480, Seattle, WA 98104, (206)-328-7443

Silty Sand/Upper Confining Unit Isopach Map

Bridge Document Report 3 - Terminal 91 Tank Farm Site
Seattle, Washington

DATE:	May 2004
DESIGNED BY:	WVG
DRAWN BY:	SDM/PMB
REVISED BY:	
PROJECT NO.	980014
FIGURE NO.	4.1



Drawing by KPPF Consulting Engineers, dated 12/27/02

DRAFT

Aspect consulting
IN-DEPTH PERSPECTIVE

179 Madrone Lane North
Bainbridge Island, WA 98110
(206) 780-9370

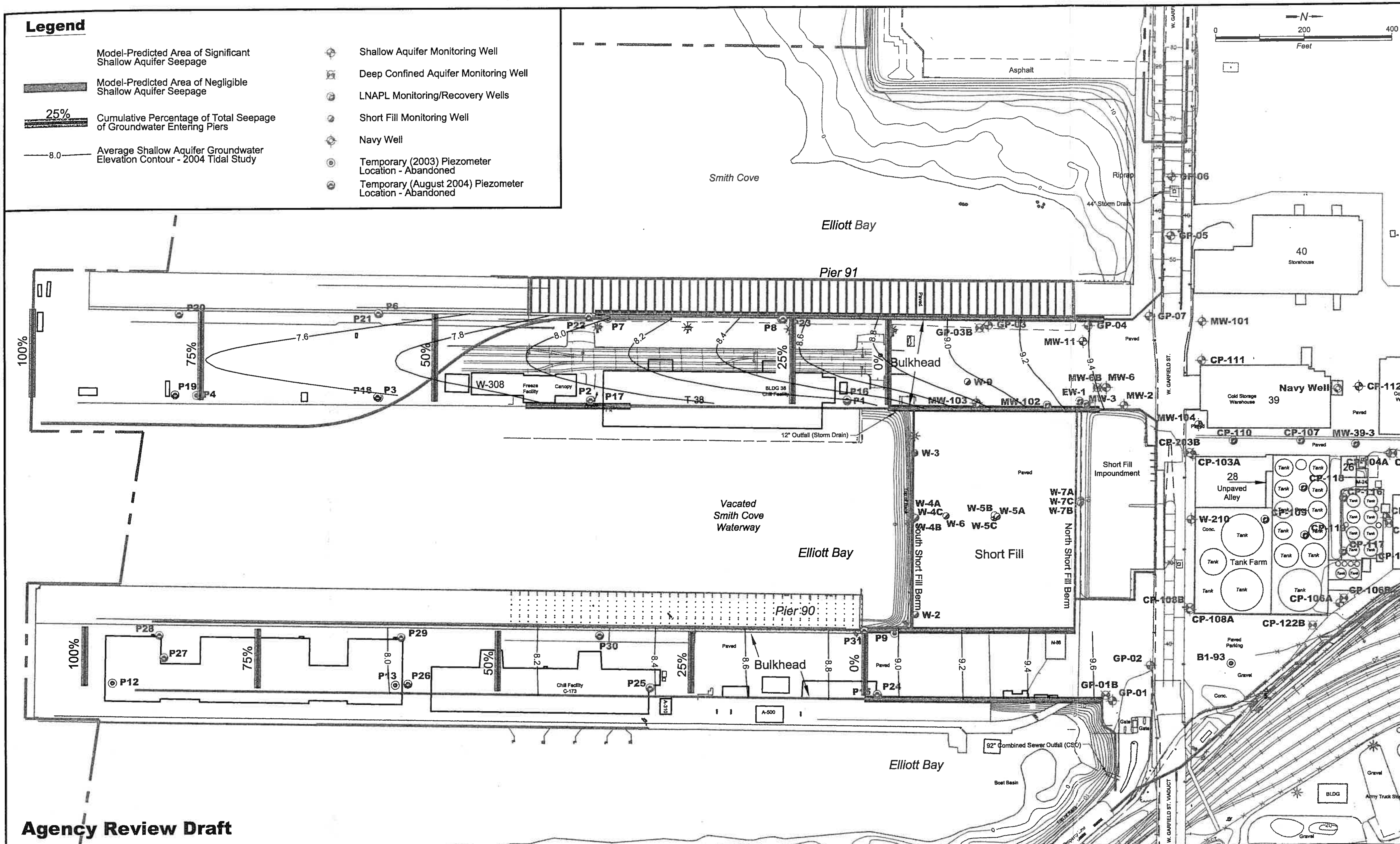
811 First Avenue #480
Seattle, WA 98104
(206)-328-7443

Typical Concrete Bulkhead Profile
Inner East Side of Pier 91
Bridge Document Report 3 - Terminal 91 Tank Farm Site
Seattle, Washington

DATE	May 2004
DESIGNED BY	RRH
DRAWN BY	PMB
REVISED BY	-
PROJECT NO.	980014
FIGURE NO.	3.8

APPENDIX A3

SELECT TABLES AND FIGURES FROM GROUNDWATER SEEPAGE EVALUATION REPORT ASPECT CONSULTING, NOVEMBER, 2004



Wells MW-103, MW-102, EW-1, MW-3, MW-104 surveyed by Pacific Northern Oil.
All other wells surveyed by POS.

Structures shown on the southern half of piers 90 & 91 are approximated based on additional basemap drawings.

Roth Consulting

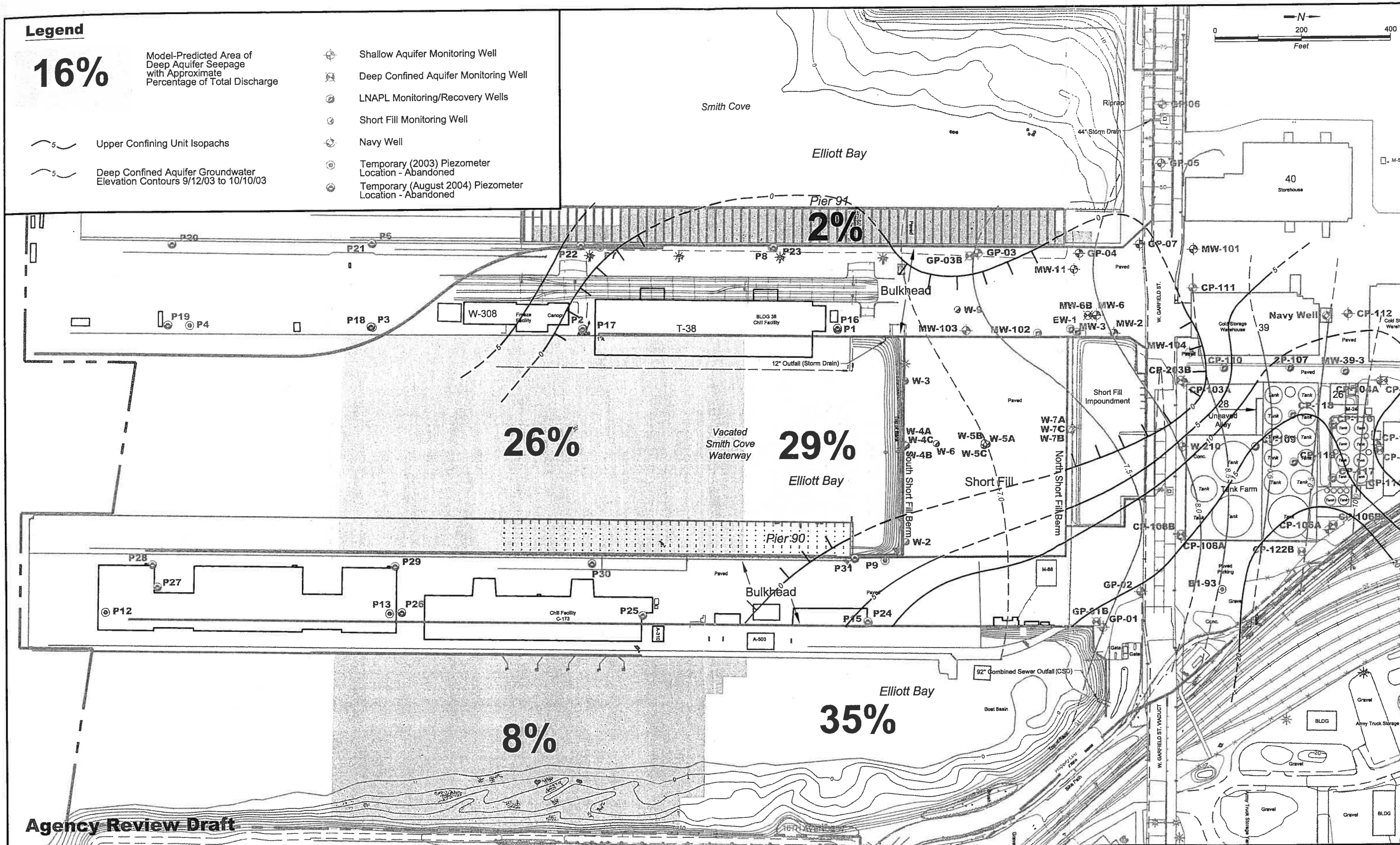
Aspect consulting
IN-DEPTH PERSPECTIVE

179 Madrone Lane North, Bainbridge Island, WA 98110, (206) 780-9370
811 First Avenue #480, Seattle, WA 98104, (206)-328-7443

Model-Predicted Shallow Aquifer Discharge Areas

Terminal 91 Tank Farm Site
Seattle, Washington

DATE:	Nov 2004	PROJECT NO.	980014A
DESIGNED BY:	WVG		
DRAWN BY:	PMB	FIGURE NO.	3.6
REVISED BY:			



Wells MW-103, MW-102, EW-1, MW-3, MW-104 surveyed by Pacific Northern Oil.
All other wells surveyed by POS.

Structures shown on the southern half of piers 90 & 91 are approximated based on additional basemap drawings.

Roth Consulting

Aspect consulting
IN-DEPTH PERSPECTIVE
179 Madrone Lane North Bainbridge Island, WA 98110 (206) 780-9370
811 First Avenue #480 Seattle, WA 98104 (206) 328-7443

Model-Predicted Deep Confined Aquifer Discharge Areas

Terminal 91 Tank Farm Site
Seattle, Washington

DATE:	Nov 2004
DESIGNED BY:	WVG
DRAWN BY:	PMB
REVISED BY:	
PROJECT NO.	980014A
FIGURE NO.	3.7

Q:\POS\980014_T-91 Tank Farm\2004-11 ARD\980014-03.dwg

APPENDIX A4

LNAPL/DNAPL CHECK TABLE
(PREVIOUSLY UNPUBLISHED)

T-91, ChemPro Pump LNAPL/DNAPL Check

Well ID	Pump Check		Well Check			Total Depth	Comments
	Type	Depth to Intake	Depth to :				
			LNAPL	Water	DNAPL		
CP-103A	Grundfos	11.45	ND	7.02	ND	14.69	Hard TD
CP-103B	Grundfos	55.40	ND	8.53	ND	58.85	Soft TD
CP-104A	Grundfos	11.55	ND	6.40	ND	14.10	Soft TD
CP-104B	Grundfos	40.35	ND	6.48	ND	44.70	Hard TD
CP-106A	Grundfos	11.45	ND	7.13	ND	12.15	Hard TD
CP-106B	Grundfos	39.35	ND	10.10	ND	41.90	Hard TD
CP-108A	Grundfos	12.45	ND	6.44	ND	13.90	TPH Odor
CP-108B	Grundfos	55.45	ND	9.72	ND	59.70	Soft TD
CP-111	Grundfos	12.45	ND	8.00	ND	14.45	Black oxide stain
CP-112	Grundfos	11.45	ND	6.42	ND	12.75	Soft TD
CP-113	Grundfos	11.35	ND	6.30	ND	16.40	Hard TD
CP-114	Grundfos	11.45	ND	6.82	ND	12.85	Hard TD
CP-115A	Grundfos	16.45	ND	6.71	ND	19.65	Black oxide stain
CP-115B	Grundfos	40.45	ND	8.75	ND	42.60	Foamy
CP-121	Grundfos	16.45	ND	6.56	ND	19.70	Hard TD
CP-122B	Grundfos	37.40	ND	6.35	ND	40.40	Hard TD
CP-205A	Grundfos	11.35	ND	6.53	ND	14.15	Soft TD
CP-205B	Grundfos	37.35	ND	7.20	ND	44.45	Hard TD
W-10	QED	22.75	ND	9.18	ND	23.33	TPH odor
GP-01	QED	13.60	ND	9.10	ND	19.10	New
GP-02	QED	13.90	ND	8.30	ND	20.00	New
GP-03	QED	15.20	ND	10.10	ND	20.20	New
GP-04	QED	15.10	ND	8.85	ND	20.20	New
GP-05	None	NA	ND	8.43	ND	9.95	New
GP-06	QED	13.60	ND	8.54	ND	17.50	New
GP-07	QED	14.10	ND	8.20	ND	20.10	New
CP-107	None	NA	6.67	6.68	ND	15.10	First FP ?
CP-109	None	NA	7.85	8.33	ND	16.25	FP recovery
CP-110	None	NA	7.30	7.52	ND	15.40	FP recovery
CP-116	None	NA	7.05	7.08	ND	10.80	First FP in 24 mo's.
CP-117	None	NA	7.35	8.35	ND	10.75	FP recovery
CP-118	None	NA	6.72	6.92	ND	10.45	FP recovery
CP-119	None	NA	6.05	6.38	ND	10.82	FP recovery
MW39-3	None	NA	6.55	7.48	ND	13.65	FP recovery

Notes:

ND - Not Detected with Interface probe (0.01')

TD - Total Depth

NA - Not Applicable (no pump in well)

FP- Free Product (LNAPL)

APPENDIX B

GUIDANCE FOR WASTE DESIGNATION PROCEDURES AT TERMINAL 91

1.0 BACKGROUND AND REGULATORY FRAMEWORK

A RCRA dangerous waste treatment and storage facility ("TSD") formerly was operated by former tenants of a 4-acre portion [known as the Tank Farm Lease Parcel ("TFLP")] within the Port of Seattle's 216-acre Terminal 91 property. Corrective action at the entire Terminal 91 property is required under a RCRA Part B permit because EPA's definition of "facility" for the purposes of corrective action includes all contiguous property under control of the owner or operator. This document provides a basis and rationale for an approach to characterization of cleanup media as dangerous or non-dangerous waste. It is intended for use in cleanups conducted within all areas subject to the 1998 Agreed Order and the 2009 Agreed Order (in progress).

2.0 RATIONALE FOR DETERMINATION IF WASTE MEDIA IS DANGEROUS OR NON-DANGEROUS

2.1 GENERAL PRINCIPLES

Contaminated media (e.g., soil or ground water) is not dangerous waste unless it exhibits a dangerous waste characteristic, state-only criteria or is contaminated with concentrations of hazardous constituents from listed dangerous waste. Note that a "contained-out" determination may be granted by Ecology for environmental media that contains concentrations of listed wastes that are below health-based levels (typically MTCA Method B cleanup levels). Characteristic and state only wastes are determined by means of generator knowledge and standard testing methods and are based upon the properties of the waste. By contrast, determination that a contaminated media contains constituents from a listed dangerous waste requires knowledge that a listed waste was released to and came into actual contact with the media in question. If a facility owner or operator makes a good faith effort to determine if a material is a listed waste but cannot make such a determination because documentation regarding a source of contamination, contaminant or waste is unavailable or inconclusive, the generator of the waste may assume the source, contaminant, or waste is not listed waste and, therefore, provided the material in question does not exhibit a characteristic of dangerous waste or state only criteria, RCRA requirements do not apply (EPA 1998).

2.1.1 Potential for Characteristic and State Only Criteria Wastes at Terminal 91

As with any cleanup site, contaminated media that constitutes characteristic dangerous waste could potentially be encountered wherever cleanup occurs at the Terminal. Therefore, the Port will apply standard waste classifications considerations to determine whether particular wastes might exhibit dangerous waste characteristics of toxicity, ignitability, etc. and does not exhibit a state only criteria.

2.1.2 Potential for Listed Wastes Mixed with Cleanup Media at Terminal 91

Media may be dangerous based on their contact with listed dangerous wastes. They could be encountered wherever listed wastes were released or where such releases have migrated. Characterization of wastes as mixed with listed dangerous wastes may be difficult at Terminal 91, because there is little information regarding historic releases of listed wastes, and because the chemical constituents now found in the media are consistent with various materials known to have been handled at the Terminal, some of which were listed dangerous wastes but the vast majority of which were not. Because many of the chemical constituents likely to be found in media at Terminal 91 could be attributed to either listed dangerous wastes or other wastes (solid wastes or characteristic dangerous wastes), care should be taken to avoid "false positive" identification of media as having been mixed with listed dangerous wastes. Therefore, the Port would characterize media by accounting for professional judgment and other factors in addition to media's chemical constituents. Because undocumented releases of listed dangerous wastes may have occurred, the use of professional judgment in determining the likelihood that environmental media could be contaminated with listed dangerous wastes is required. Some but not all possible examples: soils contaminated with listed constituents, located below or near areas where listed dangerous wastes were managed or located; groundwater contaminated with listed constituents located below, near and downgradient of areas where listed dangerous wastes were managed or located.

The use of professional judgment and other factors relate to the possibility that the media in question could have been contaminated by exposure to releases of listed dangerous waste, and they include:

- knowledge of listed wastes that were and were not handled at the TSD, as well as knowledge of other fuels and wastes historically handled at the Terminal that have constituents in common with the listed wastes handled at the TSD;
- knowledge of where wastes were released (although no releases of listed wastes are specifically known to have occurred);
- undocumented releases of listed dangerous wastes[1];
- knowledge of locations where listed wastes were or were not handled; and
- consideration of whether media could have been contaminated by releases of

constituents other than listed waste, based on knowledge of historic releases of such materials as, for example, fuel oil or bunker oil. Factors relevant under this category include where such releases occurred and concentrations or patterns of the constituents involved.

2.2 FACTORS AFFECTING WASTE DESIGNATION AT TERMINAL 91

2.2.1 Listed Wastes Known to Have Been Handled and Their Locations

The RI/DE Report identified wastes known to have been handled at the Tank Farm Lease Parcel during its operation as a RCRA DW treatment and storage facility [see attached Tables 2.3 (Wastes historically managed at the TSD) and 2.4 (Wastes managed at the time of closure) from the RI/DE Report (PSC 1999), which was incorporated by reference into the final RI Summary Report (Roth Consulting 2007) for the T91 Tank Farm Site]. The wastes historically handled at the facility fell into six categories, five of which were either solid wastes or characteristic dangerous wastes. One of the six categories included some low-level listed wastes. These listed wastes consist of low levels of F001 – F005 waste. Outside of the TFLP, there are no locations of the Terminal where listed dangerous wastes are known to have been handled. However, it is possible that listed dangerous wastes that may have been released from within the TFLP may have migrated with groundwater to portions of the site "outside" the TFLP. This is based on cleanup documents prepared under the 1998 Agreed Order [for example the T91 Baseline Report (Kennedy/Jenks Consultants 1997)] and under EPA's jurisdiction prior to the 1998 Agreed Order [such as the Remedial Facility Assessment (EPA 1994)].

2.2.2 Listed Waste Releases

Media to be removed from any areas where listed dangerous wastes were released would need to be evaluated for possible classification as dangerous wastes. Based on information provided by the former facility operator, PSC, in the RI/DE Report (PSC 1999), however, there were no known releases of listed or other dangerous wastes at the Tank Farm Lease Parcel[1]. PSC did report releases of large quantities of non-dangerous waste or product at the Tank Farm Lease Parcel, including bunker oil, asphalt, fuel oil, and oily water (PSC 1999). There are no reported releases of listed dangerous wastes at the Terminal outside the Tank Farm Lease Parcel. [1]

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[1] Although there are no reported and documented releases of listed wastes from the TFLP, the Port will need to assume the possibility of unreported releases of listed dangerous wastes in evaluating contaminated environmental media near areas where listed wastes were managed or located. In the case of contaminated saturated soils and groundwater, the Port will need to evaluate site sample data and use professional judgment in considering the likelihood that nearby soils and downgradient contaminated saturated soils and groundwater are contaminated from an unreported and undocumented release of an upgradient listed dangerous waste. The Port may also use other criteria including but not limited to, concentration of contaminants, the relatively small or large volumes of listed wastes managed (and locations) compared to volumes and locations of non-listed dangerous wastes (with similar chemical constituents) in specific areas to evaluate the likelihood that environmental media is contaminated with a listed dangerous waste. The Port should document its designation justifications and contact the Ecology NWRO if they have questions.

3.0 WASTE CHARACTERIZATION PRINCIPLES FOR TERMINAL 91

3.1 MEDIA REMOVED FROM AREAS OUTSIDE THE TANK FARM AFFECTED AREA

Cleanup media to be generated as wastes in connection with cleanup activities outside the Tank Farm Affected Area ("TFAA") will be classified using professional judgment and site-specific knowledge, including knowledge of contaminants known to have been or potentially released in the area and contaminants detected in analysis of the media. Petroleum and fuel-related materials were released outside of the Tank Farm, but as noted above, no releases of listed wastes are known to have occurred anywhere at Terminal 91, and listed dangerous wastes are not believed to have been managed outside the TFAA[1]. Therefore, as cleanup media are generated as wastes outside the TFAA, the Port will conduct routine sampling as necessary for waste screening and disposal purposes. Unless such analyses and professional judgment indicate the likelihood of dangerous waste characteristics, state-only criteria, or listed waste contamination, media from outside the TFAA will be managed as solid waste. Note: "Tank Farm Affected Area" includes areas where constituents (hazardous substances) from the Tank Farm Lease Parcel have come to be located. It is possible that media could be removed from strata overlying saturated zones affected by such migration. If such media are not believed to have come into contact with the migrated constituents because, for example, they are always above the saturated zone, they would not be considered to be from the TFAA, and would not be subject toany presumptions relating to the TFAA, such as increased potential for contact with listed dangerous wastes[1].

3.2 MEDIA FROM THE TANK FARM AFFECTED AREA FOUND NOT TO CONTAIN RELEVANT LISTED WASTE

Media removed from the TFAA will be sampled and analyzed to determine whether it contains constituents associated with listed wastes known to have been handled at the TSD. Those appear to have been limited to the listed wastes F001 - F005. Results from these analyses will be used to designate cleanup media wastes according to the following principles:

- Media found not to contain such F001 – F005 constituents will be managed in the same manner as section 3.1, i.e., as solid wastes (unless they exhibit a dangerous waste characteristic).
- Media found to contain only BTEX constituents will be managed as in section 3.1. This is because there is no information indicating releases[1] of listed dangerous wastes containing BTEX constituents in the TFAA. On the other hand, multiple relatively large-volumes of non-dangerous TPH materials were reportedly released.
- Other media found to contain constituents associated with listed wastes known to have been managed at the TSD (other than BTEX constituents) will be evaluated in light of historic waste handling and release information[1] to determine whether there is evidence that it contains a listed dangerous waste..
- Media found to contain such listed constituents, but at levels (below MTCA Method B), may, with Ecology's approval, be managed as solid wastes in accordance with Ecology's written approval and required management of contained-out environmental media.
- Media found to contain constituents as a result of mixture with listed dangerous wastes will be managed as listed dangerous wastes, unless Ecology approves a contained-out determination.

TABLE 2.3

WASTES HISTORICALLY MANAGED AT THE SITE BY BEI
TERMINAL 91 TANK FARM SITE RI/DE REPORT

WASTE DESCRIPTION	POTENTIAL CONTAMINANTS
Waste Oils[2]	
Crankcase oils, bunker fuels, diesel and tank cleaning residuals, and waste boiler fuel (fuel oil #6)	1. Metals including cadmium, chromium, lead 2. Other constituents silicon, and phenol (less than 1,000 ppm) 3. Sulfur; and 4. Iron scale
Coolant Oils	
Metal machining waste	1. Metals including aluminum, arsenic, chromium (III), iron, and zinc; 2. Exotic metals including magnesium and titanium; and 3. Chlorinated paraffins (non-hazardous waste)
Oily Industrial Wastewaters	
Tank cleaning waste, bilge waters, etc.	1. Low-level oil contamination; 2. Metals including trivalent chromium, hexavalent chromium, lead, and zinc; 3. Waste oil constituents including cadmium, copper, iron, lead, phenols and silicon; 4. Surfactants including soaps, and defoamers (non-hazardous wastes)
Industrial Wastewaters Without Oil	
Automobile manufacturing waste	1. Low levels of hexavalent chromium (VI) 2. Aluminum
Industrial Wastewaters With Solvents	
Rinsewater from cleaning and stripping of airplanes	1. Low levels of F001-F005 Waste 2. Phenol 3. Low-level (approximately 1000-4000 ppm) methylene chloride
Waste Sludges	
Oily sludges from cleaning of sumps	1. Metals including cadmium, chromium, lead 2. Other constituents silicon, and phenol (less than 1,000 ppm) 3. Sulfur 4. Iron scale

[1]Information obtained from BEI files.
[2]Note: All waste oils have the possibility of low-level PCB contamination and levels of BTEX compounds.

TABLE 2.4

WASTE AND PRODUCTS HANDLED BY BEI[1]
AT THE TIME OF ABOVEGROUND CLOSURE
TERMINAL 91 TANK FARM SITE RI/DE REPORT

WASTE DESCRIPTION	WASTE CODES	DW/EHW
Bunker-C and water	WT02	DW
Cleaners-mixed alkaline, glycol <10%, oil, water	WT02	DW
Crankcase oil	WT02	DW
Cutting fluid/tramp oil: chlorinated paraffins, diethylene	WP02	DW
Dewatered oil tank sludge	WT02	DW
Dewatered tank bottom solids potentially containing arsenic, cadmium, chromium, lead, or mercury	D004, D006, D007, D008, D009	DW
Diesel fuel - with benzene	D018, WT02	DW
Emulsified oil-coolant/water/detergent	WT02	DW
Ethylene glycol/water-antifreeze <12% concentration	WT02	DW
Jet/A-fuel and water	WT02	DW
Machine coolant (Trim-sol)	WT02	DW
Mineral oil	WT02	DW
Mineral oil	D001	DW
Mixed oils	WT02	DW
Non-RCRA waste liquid	WT02	DW
Oil tank bottom solids	WT02	DW
Oil, Bunker C	WT02	DW
Oil, water with trace metals	WT02	DW
Oil/kerosene	WT02	DW
Oily absorbent pads/debris/solids	WT02	DW
Oily floc from water treatment	WT02	DW
Oily floc/water: lead & benzene	D008, D018, WT02	DW
Oily sump sludge	WT02	DW
Paint booth rinsings containing chrome	D007, WT02	DW
Petroleum distillate, dye penetrant/water treatability	WT02	DW
Petroleum oil sludge	WT02	DW
Phenolic water	WT02	DW
Phosphate ester-based hydraulic fluid	WT02	DW
Process water	WT02, D018	DW
Sodium hydroxide (alkaline/phenolic)	WT02	DW

[1]Information obtained from BEI files.

Notes:

Waste Codes	-	As designated by Ecology and/or EPA.
DW/EHW	-	Dangerous Waste/Extremely Hazardous Waste
NA	-	Not Applicable

TABLE 2.4 (Continued)

WASTE AND PRODUCTS HANDLED BY BEI[1]
AT THE TIME OF ABOVEGROUND CLOSURE
TERMINAL 91 TANK FARM SITE RI/DE REPORT

Waste Description	Waste Codes	DW/EHW
Toluene/paint	F005	DW
Tramp oil from machine coolant oil	WT02	DW
Used engine oil	WT02	DW
Waste combustible liquid, n.o.s. (diesel)	WT02, D018	DW
Waste oil	WT02	DW
Water & oil from oil-water separators	WT02	DW
Water with lead <500 ppm	D008, WT02	DW
Water with phenol, coolant, metal chips & debris	WT02	DW
Water, methanol, hydrochloric acid, hexane, sediment	WT02	DW
Water, oil with lead	D008, WC02	DW
Water, oil, coolant	WT02	DW
Water, oil, coolant	WP02	DW
Water, oil, coolant (ethylene glycol)	WT02	DW
Water, oil, sludge	WT02	DW
Water, oil, soap	WT02	DW
Water, oil, soap, grease, contaminated	WT02	DW
Water, synthetic hydraulic fluid, oil	WT02	DW
Water/MEK, acetone, perchloroethylene	F001, F002, F003, F005, D035, D039	DW
Water/oil/hydraulic fluid/antifreeze – auto maintenance	WT02	DW
Water/oil/jet fuel	WT02	DW
Water: phenol < 500 ppm; acetone, toluene, 111-Tri	F001, F002, F003, F005	DW
Well drilling debris: barium, cadmium, chromium, lead	D005, D006, D007, D008	DW
Aqueous wastes containing phenol	non-regulated	NA
Boron wastewater	non-regulated	NA
Bunker C fuel oil	non-regulated	NA
Combustible oily water	non-regulated	NA
Concentrated salt brine with water, iron, nickel, hydroxide	non-regulated	NA
Coolant	non-regulated	NA
Coolant slops	non-regulated	NA
Diesel/water	non-regulated	NA

[1]Information obtained from BEI files.

Notes:
Waste Codes - As designated by Ecology and/or EPA.
DW/EHW - Dangerous Waste/Extremely Hazardous Waste
NA - Not Applicable

TABLE 2.4 (Continued)

WASTE AND PRODUCTS HANDLED BY BEI[1]
AT THE TIME OF ABOVEGROUND CLOSURE
TERMINAL 91 TANK FARM SITE RI/DE REPORT

Waste Description	Waste Codes	DW/EHW
Flash Point >100°F	non-regulated	NA
Gasoline/water	non-regulated	NA
Heavy metal aqueous waste	non-regulated	NA
Hydraulic oil	non-regulated	NA
Hydraulic oil/fuel oil, waste	non-regulated	NA
Lube Oil	non-regulated	NA
Mixed oil > 85% BSW therm chem treat	non-regulated	NA
Mixed oil BSW 0% to 12%	non-regulated	NA
Motor oil	non-regulated	NA
Oil sludge & water	non-regulated	NA
Oil/water BSW 13% to 30%	non-regulated	NA
Oil/water BSW 31% to 50%	non-regulated	NA
P.S. 400 - heavy fuel oil	non-regulated	NA
Transformer oil, if recyclable	non-regulated	NA
Treatable aqueous wastes	non-regulated	NA
Turbine oil, if recyclable	non-regulated	NA
Water containing asphalt emulsion/petroleum distills.	non-regulated	NA
Water, oil	non-regulated	NA
Water, oil, coolant	non-regulated	NA
Water/fuel	non-regulated	NA
Weak alkaline non-corrosive	non-regulated	NA

[1]Information obtained from BEI files.

Notes:

Waste Codes	-	As designated by Ecology and/or EPA.
DW/EHW	-	Dangerous Waste/Extremely Hazardous Waste
NA	-	Not Applicable

Management of the Port of Seattle's T-91 Facility's
Tank Farm Site Subsurface Debris

December 18, 2008

***<u>Issue submitted via email from the Port on November 10, 2008</u>*:**

T91 Tank Farm Site Subsurface Debris:
"The purpose of this email is to follow up on the subsurface debris issue that we discussed on our meeting on October 29, 2008. The primary purpose of that meeting was to discuss the status of the Port of Seattle's ("POS's") Feasibility Study preparation for the Terminal 91 Tank Farm Site ("Tank Farm Site"). During that meeting, we discussed several possible remedial action alternatives for the Tank Farm Site, some of which would likely involve removal and possible offsite disposal/recycling of concrete and other existing subsurface structures (including metal tank bases). We discussed some possible options for handling the subsurface structures, and agreed that further discussion would be necessary to come to agreement on how the subsurface debris would be handled during the final remedial action. Such a determination will be necessary in order to provide accurate cost estimates for the remedial action alternatives that involve handling of contaminated debris.

As you know, portions of the Tank Farm Lease Parcel ("Lease Parcel") historically were operated by former POS tenants as a dangerous waste treatment and storage facility ("TSD"). The aboveground portions of the TSD were "clean-closed" by Philip Services Corporation prior to and during 1995, and Ecology approved the final aboveground closure in a letter dated October 1, 2003. In that letter, Ecology stated 'the below-ground contamination is deferred to the on-going corrective action at the facility and Ecology is not certifying the Pier-91 facility as "clean-closed" at this time'.

During implementation of remedial action at the Tank Farm Site, it is probable that remaining in-place concrete and steel structures will be encountered. The in-place structures are what remain of the former tank farm after the 2005 demolition of the aboveground portions of the tank farm as part of an interim remedial action. During the 2005 demolition, some of the tank bases were left in place because it was considered possible that the space between the two tank bases (where present) could contain oily sand or pea gravel containing potential dangerous waste. If the final cleanup action selected by Ecology requires that the existing subsurface structures be removed, steel formerly in contact with dangerous waste will be decontaminated and recycled offsite using procedures described in Ecology's closure guidance.

Concrete structures known to remain at the Lease Parcel include the pavement that surrounds (and possibly lies beneath) some or all of the tank bases, and concrete footings at the locations of the former secondary containment walls. As part of typical demolition activities, the concrete will be removed from the ground by breaking it up into manageable pieces. For concrete not in contact with dangerous waste, standard construction methods will be performed.

The upper (aboveground) surfaces of the concrete pavement were clean-closed during past closure activities. The lower surface of these concrete pieces will likely have soil adhered to them. Once the concrete is broken up and removed, there are three general options for how it can be managed:

- *Recycle and reuse offsite. This is the typical method of handling at most construction sites. This option may require some level of decontamination and/or sampling of the lower concrete surfaces prior to offsite reuse.*

- *Recycle and reuse onsite as structural fill. This method may or may not require decontamination and/or sampling at the time of emplacement, but future decontamination and/or sampling might be required for this material if disturbed during future construction activities.*

· *Dispose of offsite as either a solid or hazardous waste. If disposed of as solid waste, this could involve collection of random representative chip samples of the bottom surfaces of the concrete to see if they meet a numerical cleanup standard. If presumed hazardous waste, sampling might not be required.*

The regulatory status of the concrete debris that is in contact with dangerous waste will be critical to how this waste will be managed and what the associated costs are. Please let us know at your earliest convenience when you will be able to meet to discuss these options further."

Susan Roth, LHG
Roth Consulting

The Department of Ecology's response to the Port of Seattle question on the management of contaminated debris at Terminal 91 Tank Farm site *(submitted via email on November 10, 2008).*

Ecology is working with the Port of Seattle (POS) to address issues associated with the management of contaminated debris, and in particular concrete, at the Terminal 91 Tank Farm site. Given the scale of the affected area and volume of contaminated debris involved, Ecology is offering guidance to maximize environmental benefit yet be feasible and attainable in the field. This guidance is based on information Ecology has to date and is offered as a courtesy to help expedite the development of the feasibility study (FS). Ecology may revise this guidance response if new information indicates that such revisions are needed to be in compliance with MTCA, RCRA and other ARARs.

Ecology suggests the POS look to the recently finalized document: '***Guidance for Waste Designation Procedures at Terminal 91***' (***GWDP)*** to provide a framework and consistency for the concrete debris determinations for disposal options.

When assessing contaminated debris, consider the following:

- Identify those portions of the tank farm site that are affected by TPH from areas that may also be potentially affected by listed wastes.
    a. As per the EPA publication ***Management of Remediation Waste Under RCRA (EPA530-F-98-026, October 1998)*** do not classify remediation waste as listed waste unless there is data available to serve as the basis for that listing or if there is reasonable likelihood that listed dangerous waste is the source of the contamination. This may include the presence of PCBs and chlorinated compounds, as well as other wastes not typically associated with TPH.
    b. Criteria to be used to delineate such areas should follow the same guidance decisions established in the final GWDP.

- For debris affected only by TPH-Oil contamination
    a. Debris will not need to be sampled for designation purposes (per WAC 173-303-071).
    b. Standard demolition, removal, and disposal practices may be used

   c. Ecology will look favorably upon disposal practices that incorporate reuse and recycling. Such practices will be qualitatively evaluated on an environmental net benefit basis.
   d. MTCA encourages permanent solutions to the maximum extent practicable. Ecology will also look favorably upon remedial actions that remove concrete in order to access and remove highly contaminated soils.

- For debris subject to dangerous waste designation requirements, develop a sampling and analysis plan to be reviewed and approved by Ecology.
   a. For debris that does not designate as dangerous waste[1]: Use best professional judgment for disposal.
      i. Consider what contaminants and concentrations are present to guide reuse or re-emplacement scenarios.
      ii. Consider current and potential exposure pathways and endpoints.
      iii. Consider potential future land use.
      iv. Ecology will not allow the placement of contaminated debris back on the land where such action leads to exceedances or potential exceedances of cleanup levels.
   b. If determined to be a dangerous waste, dispose in accordance with Chapter 173-303. In general, the options are:
      i. Send to a dangerous waste landfill and is subject to Land Disposal Restrictions (LDRs);
      ii. Decontaminate the dangerous waste debris per the Debris LDR treatment methods. Depending on the LDR debris treatment method, the post-treated debris may no longer be regulated as a DW;
      iii. Onsite or offsite recycling will need to meet the requirements of WAC 173-303

[1] Through sampling/analysis or generator knowledge