ENGINEERING DESIGN REPORT
TERMINAL 91 TANK FARM CLEANUP

PORT OF SEATTLE
SEATTLE, WASHINGTON

JULY 11, 2013

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LIST OF ACRONYMS AND ABBREVIATIONS

1998 AO	Agreed Order No. DE 98HW-N108
2010 AO	Agreed Order No. DE-7321
ACM	Asbestos-Containing Materials
AO	Agreed Order No. DE 8938
AOC	Area of Concern (used to describe AOC 11 area)
AOC	Area of Contamination (used in Section 11)
ARAR	Applicable or Relevant and Appropriate Requirement
BD	Bridge Document
bgs	Below Ground Surface
BMPs	Best Management Practices
BNSF	Burlington Northern Santa Fe
CAO	Cleanup Action Objective
CAP	Cleanup Action Plan
Chempro	Chemical Processors, Inc.
CMP	Compliance Monitoring Plan
CCWP	Contamination Contingency Work Plan
CPOC	Conditional Point of Compliance
CQA	Construction Quality Assurance
CQC	Construction Quality Control
CSM	Conceptual Site Model
CSWGP	Construction Stormwater General Permit
CULs	Cleanup Levels
cy	Cubic Yard
DBM	Design Basis Memorandum
DGI	Data Gaps Investigation
DGIWP	Data Gaps Investigation Work Plan
Ecology	Washington State Department of Ecology
EDR	Engineering Design Report
ESCP	Erosion and Sediment Control Plan
FS	Feasibility Study
ft	Feet / Foot
gpm	Gallons Per Minute
HASP	Health and Safety Plan
IHS	Indicator Hazardous Substance
in.	Inch / Inches
KCIW	King County Industrial Waste Program
Lease Parcel	Terminal 91Tank Farm Lease Parcel
LNAPL	Light Non-Aqueous Phase Liquid
MLLW	Mean Low Low Water
MNA	Monitored Natural Attenuation
MTCA	Model Toxics Control Act
O&M	Operations and Maintenance
OPT	One Pass Trencher / One Pass Trenching
OSHA	Occupational Safety and Health Act
OWS	Oil-Water Separator

LIST OF ACRONYMS AND ABBREVIATIONS (CONTINUED)

PES	PES Environmental, Inc.
PNO	Pacific Northern Oil Corporation
PPP	Public Participation Plan
pcf	Pounds Per Cubic Foot
psf	Pounds Per Square Foot
PVC	Polyvinyl Chloride
Port	The Port of Seattle
RCRA	Resource Conservation and Recovery Act
RCW	Revised Code of Washington
RFA	Terminal 91 RCRA Facility Assessment
RI	Remedial Investigation
SB	Soil-Bentonite
SCB	Soil-Cement-Bentonite
SEPA	State Environmental Policy Act
sf	Square Feet
SWMU	Solid Waste Management Unit
SWPPP	Stormwater Pollution Prevention Plan
T-91	Terminal 91
TESC	Temporary Erosion and Sediment Control
TFA	Tank Farm Area
TFAA	Tank Farm Affected Area
UCS	Unconfined Compressive Strength
USACE	United States Army Corps of Engineers
TFLP	Tank Farm Lease Parcel
WAC	Washington Administrative Code
WQ	Water Quality

1.0 INTRODUCTION

1.1 Purpose

PES Environmental, Inc. (PES) has prepared this Engineering Design Report (EDR) for a cleanup action at the Terminal 91 Tank Farm Affected Area (TFAA), a portion of the Port of Seattle's (Port's) Terminal 91 Complex (T-91) in Seattle, Washington (Figure 1). This EDR has been developed pursuant to Agreed Order No. DE-8938 (AO) between the Port and the Washington Department of Ecology (Ecology). This EDR has been prepared in accordance with the Model Toxics Control Act (MTCA) under Chapter 70.105D of the Revised Code of Washington (RCW) and Chapter 173-340 of the Washington Administrative Code (WAC).

The engineering design requirements are outlined in Section VII.A.4 of the AO, which stipulates the engineering design shall be performed consistent with the cleanup actions outlined in the Cleanup Action Plan (CAP) and the requirements of WAC 173-340-400(4), and in the following three stages:

(1) A Design Basis Memorandum (DBM) (PES 2012b);

(2) A draft EDR (90 percent design); and

(3) A final EDR (100 percent design).

The DBM was submitted to Ecology on August 10, 2012 and represented the design at approximately the 30 percent completion stage. The DBM utilized the information collected during the Data Gap Investigation (DGI, PES, 2012a) to present the general engineering concepts and criteria used for design of the cleanup action and lists of the anticipated construction plans and Technical Specifications to be included in the draft EDR. Ecology provided comments on the DBM on September 4, 2012, and PES provided a response to the comments in a letter dated October 23, 2012.

The purpose of the EDR is to build on the contents of the DBM to document the engineering concepts and design criteria and to provide sufficient information for the development and review of the construction plans and specifications.

1.2 Report Organization

Section 1 – Introduction: Provides background and purpose of the EDR report and the organization of the report.

Section 2 – Background Information: Provides a brief site description and history, a summary of subsurface conditions, and summarizes the Conceptual Site Model (CSM), including the cleanup action objectives.

Section 3 – Cleanup Action Summary: Provides a brief description of the cleanup action.

Sections 4 through 10 – Design Criteria for Major Work Elements: These seven sections present the design criteria and assumptions for the main components of the cleanup.

Section 11 – Management Framework for Environmental Media and Debris: Provides overview of the approach for managing environmental media, debris, and waste materials generated during the performance of the cleanup action.

Section 12 – Cleanup Action Implementation: Provides information on required permits and approvals, health and safety, construction quality assurance/construction quality control (CQA/CQC), Operations and Maintenance (O&M), and compliance monitoring.

Section 13 – Other Requirements: Provides a brief summary of other cleanup action requirements, including institutional controls, an implementation schedule, public participation plan, and financial assurance.

Section 14 – Reporting and Schedule: Provides a description of the reporting requirements and the schedule for implementing the cleanup action.

Section 15 – References: Lists the sources of information referenced in the document.

The following information is attached to the EDR:

Appendix A – Calculations and Design Data: Includes calculations and data that support the design.

Appendix B – Drawings: Includes drawings which, in combination with the Technical Specifications, detail the cleanup action. The drawings, which are provided under separate cover, include documentation of existing site conditions, identified regulated materials, references to existing historical structures, and construction plans, sections, and details.

Appendix C – Technical Specifications: Includes technical specifications which, in combination with the Drawings, detail the cleanup action. The technical specifications, which are provided under separate cover, include select Division 1 specifications and all of the Division 2 and 3 specifications required to perform the cleanup action. A complete project manual, including all Division 0 and Division 1 specifications, will be prepared at a later date as part of the bidding package.

Appendix D – Construction Quality Assurance Plan: Provides guidance for construction quality assurance procedures to be employed during construction to ensure that the cleanup action is implemented as designed. This document is provided under separate cover.

Appendix E – Regulated Materials Report: Provides documentation of regulated materials identified during a survey conducted in 2012.

Appendix F – Compliance Monitoring Plan: Provides procedures for monitoring groundwater conditions after construction is completed. This document is provided under separate cover.

Appendix G – Operations and Maintenance Plan: Provides procedures for operating, maintaining, monitoring, and inspecting specific components of the cleanup action after construction is completed. This document is provided under separate cover.

Appendix H – Draft Environmental Covenant: Provides a draft of the Environmental Covenant for the project that will address specific exposure pathways and ensure that the integrity of the cleanup action is maintained over time.

Appendix I – Schedule: Includes a schedule for implementing the elements of the cleanup action and post-EDR deliverables.

2.0 BACKGROUND INFORMATION

The background and history of the TFAA is described extensively in other documents, including:

- *Remedial Investigation Summary Report for the Terminal 91 Tank Farm Site in Seattle, Washington* (RI Summary Report; Roth Consulting, 2007);
- *Final Draft Feasibility Study Report, Terminal 91 Site, Seattle, Washington* (FS Report; PES et al., 2009);
- *Agreed Oder No. DE 8938* (AO; Ecology, 2010)
- *Final Cleanup Action Plan* (CAP; Ecology, 2010);
- *Final Data Gaps Investigation Work Plan, Terminal 91 Tank Farm Affected Area Cleanup, Port of Seattle, Seattle, Washington* (DGIWP; Appendix A2; PES et al., 2011);
- *Data Gaps Investigation Technical Memorandum, Terminal 91 Tank Farm Affected Area Cleanup, Port of Seattle, Seattle, Washington* (DGI Technical Memorandum; PES et al., 2012a); and
- Documents referenced in the above reports.

For ease of reference, the brief site description and history, summary of the subsurface conditions, and a summary of the conceptual site model (CSM) and goals of the cleanup action are presented below. A summary of the selected cleanup action is provided in Section 3.

2.1 Site Description and History

T-91 is located at 2001 West Garfield Street, Seattle, Washington and encompasses approximately 216 acres (Figure 1). The TFAA is located in the central portion of T-91, and comprises approximately 17 acres, including the Tank Farm Lease Parcel (TFLP), which is a contiguous parcel approximately four acres in size located immediately north of the Magnolia Bridge.[1] Figure 2 is a 2002 aerial photograph of the Terminal 91 Site showing the approximate boundaries of T-91, the TFAA, the TFLP, and other portions of T-91, including the Upland Area, Short Fill Area, and Submerged Lands Area.

The TFAA is flat and paved or covered with buildings. The TFAA generally is bounded to the south by Piers 90 and 91 and the Short Fill Area and Lake Jacobs (Short Fill Impoundment) located between the two piers, to the east by the Burlington Northern Santa Fe (BNSF) Rail Yard and the Washington Army National Guard facility, and to the north and west by the T-91 Upland Area.

The TFLP is located at the north end of the TFAA. The primary historical feature of the TFLP is the bulk petroleum tank farm present from the 1920s through 2005, and the dangerous waste treatment and storage operations that were conducted in the TFLP from 1980 through 1995. The

[1] The AO (Ecology 2010a) defines the TFAA as "*the Tank Farm Lease Parcel and any areas where Hazardous Substances originating from the Tank Farm Lease Parcel have come to be located*," and the TFLP as, "*the site of a tank farm, demolished in 2005, which had for a time operated as a Dangerous Waste Facility.*"

aboveground portion of the tank farm, including the tanks, containment walls, and other aboveground piping and equipment, was demolished and removed in 2005 as part of an interim remedial action (Roth Consulting, 2005). The TFLP consisted of three tank yards and associated buildings, divided into the following areas (Figure 3):

- **The Black Oil Yard** located at the south end of the TFLP. This yard contained three large tanks (Tanks 90 to 92) 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 contained 12 tanks (Tanks 93 to 104) 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** located at the north end of the tank farm. This yard contained 10 primary tanks (Tanks 105 to 114) and a number of smaller tanks that were used to store a variety of petroleum products including gasoline and diesel, wastewater, and a variety of other waste materials (all the tank bases in this yard were removed during the remedial action in 2005);

- **The main warehouse** (i.e., Building 19) located just north of the three tank yards. This building still exists in the TFLP; and

- **Additional areas** including the pipe alley between the Small Yard and the Marine Diesel Oil Yard, the decommissioned former oil-water separator (OWS) and pump house west of the Small Yard, and the foam mixing area at the north end of the TFLP.

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 3-ft high. All three tank yards were fully paved with concrete; the Small Yard was paved in 1982, and the Marine Diesel Oil and Black Oil Yards were paved in 1986. Aboveground and subsurface piping systems were used to transfer product within the tank yards. Underground fuel pipelines have been used throughout much of T-91’s history, connecting the tank yards with the piers (Piers 90 and 91) to the south.

As described in the FS Report (PES et al., 2009), dangerous waste treatment and storage operations were conducted in the TFLP from 1980 through 1995. No dangerous waste operations requiring a permit (other than corrective action) have been conducted at the TFLP since September 1995, and all regulated waste units at the TFLP have undergone closure.

Another tank farm, identified as the Old Tank Farm (referenced as Area of Concern (AOC) 11 in the Terminal 91 Resource Conservation and Recovery Act (RCRA) Facility Assessment (RFA) (EPA, 1994)), was located in the area west of the TFLP, as shown on Figure 4. This former tank farm was reportedly active between 1927 and 1942. The United States Department of the Navy took possession of T-91 in December 1942, and the tank farm was reportedly demolished subsequently, sometime between 1942 and 1946 (Pinnacle, 2006).

Other areas of interest in the TFAA include Solid Waste Management Unit (SWMU) 30, which is the location of a pipeline break that occurred in 1989 near the north end of Pier 91 (Figure 4), and former fuel transfer pipelines that ran in and around the TFLP and to Piers 90 and 91.

2.2 Subsurface Conditions

Numerous investigations have been conducted at T-91 since 1988 to characterize the geology, hydrogeology, and nature and extent of contamination. The results of these investigations are detailed in the RI Summary Report (Roth Consulting, 2007) and the FS Report (PES et al., 2009) and more generally in the CAP (Ecology, 2010). The following is a brief summary of the geology and hydrostratigraphy at the Site.

2.2.1 Geology

As described in detail in the RI and FS Reports, four mappable lithologic units have been identified beneath the TFLP and adjacent areas. These four units in order of increasing depth include:

- 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 moderately to poorly sorted, fine- to medium-grained, unconsolidated sand, with laminations of silty sand and gravel lenses occurring locally. The Shallow Sand Unit extends vertically from just below the paved ground surface to between 15 and 20 ft below ground surface (ft bgs).

- 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 TFLP 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 TFLP, to 5-ft thick or less in the southwest corner of the TFLP. A **Gravel Layer** was found within the Silty Sand Unit in some locations and consists of moderately to poorly sorted, silty sandy gravel.

- The **Deep Sand Unit** directly underlies the Silty Sand Unit and is composed primarily of poorly to moderately sorted, medium- to coarse-grained sand and gravelly sand, with only isolated occurrences of silt. However, beneath the northern portion of the TFLP, 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. The depth to the top of the Deep Sand Unit varies from approximately 25 ft bgs at the center of the TFLP to as much as 45 ft beneath the north end of Pier 90.

- The **Silty Clayey Sand Unit** underlies the Deep Sand Unit and is composed of soft to stiff fine-grained sediments, primarily silty clay and clayey silt, with lesser amounts of silt and silty clayey sand. The top of the Silty Clayey Sand Unit is shallowest beneath the eastern portion of the TFLP, where it occurs as shallow as 42 ft bgs, in boring CP_106B.

The first two of these units have the potential to be encountered during construction of the cleanup action. Generalized geologic cross-sections prepared for the *Remedial Investigation/Data Evaluation (RI/DE) Report* (Philip Environmental Services Corp., et al, 1999) are included in Appendix A1.

2.2.2 Hydrostratigraphy

Shallow Aquifer. The Shallow Aquifer is generally present in the Shallow Sand Unit and is separated from the Deep Confined Aquifer by the Silty Sand Unit which acts as an upper confining unit. Water level data collected during routine monitoring of monitoring wells show that the dominant unconfined groundwater flow direction is generally towards the south beneath the TFLP, TFAA, and piers, with flow locally to the southwest beneath AOC 11. Water levels in the monitoring wells typically range between 3 and 7 ft bgs and generally correspond to seasonal variations in precipitation rates, with the highest water levels observed during the wetter winter months. The typical horizontal gradient beneath the TFLP is approximately 0.001 ft/ft.

Downward vertical gradients between the Shallow Aquifer and Deep Confined Aquifer have been noted throughout the TFAA. Vertical gradients typically range from approximately 0.018 to 0.040 ft/ft, 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 TFAA is considered unlikely due to the low measured vertical permeability in the upper confining unit (Silty Sand Unit).

Tidal influence on Shallow Aquifer groundwater levels under the piers (reflected in higher tidal efficiency and lower time lag) is generally highest near the southern ends of the piers, decreasing progressively inland towards the east-west trending, shore-parallel bulkheads. Tidal efficiencies were notably higher on Pier 91 than Pier 90 and in areas without bulkheads or significant silt accumulations. Little tidal influence was evident in Shallow Aquifer wells at the south end of the TFLP.

Deep Confined Aquifer. The deep confined aquifer is present in the Deep Sand Unit. The tidally-averaged groundwater flow direction in the Deep Confined Aquifer beneath and shoreward (i.e., south) of the TFLP 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/ft beneath the TFAA.

Tidal influence on Deep Aquifer groundwater levels under the piers is similar to the Shallow Aquifer, with a higher influence near the southern ends of the piers. Time lags were generally shorter in the Deep Aquifer under the piers than in the Shallow Aquifer. Tidal influence was evident in Deep Aquifer wells in the TFLP, except east of the Small Yard and Marine Diesel Oil Yard; the shortest time lags were along the southern boundary of the TFLP, and the longest time lags were north of the Small Yard.

2.3 Conceptual Site Model

The results of the previous investigations were used to create a CSM that summarizes the sources of contamination, potential routes of exposure, and potential receptors. The CSM (presented in both the FS Report and CAP) is based on the current and future industrial land use, the soil and groundwater sampling results, and the active and potentially active fate and transport mechanisms.

2.3.1 Contaminant Sources

Tank Farm Lease Parcel. The primary source of contamination in the TFAA is the former tank farm and associated operations. A number of documented releases have occurred, including two large releases of petroleum hydrocarbons in 1978 (420,000 gallons of Bunker C) and 1980 (up to 113,000 gallons of oil). In both of these cases, the oil was contained within the tank farm by the concrete retaining walls and the oil and impacted soil removed to the extent practicable. A number of smaller releases of petroleum products and/or oily water have been documented, ranging in size from several hundred gallons to 20,000 gallons. In all cases, these documented releases were reported to have been cleaned up.

No releases were documented at the TFLP prior to 1971, although historical releases are suspected and periodic releases of oily liquids have reportedly occurred at the TFLP since the 1930s. The main activities conducted by Chemical Processors, Inc. (Chempro) after they began operations in 1971, and by Chempro's successors, were waste oil recovery and wastewater treatment. Chempro applied for and was granted interim status under RCRA and began dangerous waste management activities at the TFLP, which continued through 1995.

Secondary Source Areas. There are three other potential sources of contamination from sources outside the TFLP, including:

- **SWMU 30 –** An estimated 340 to 1,370 gallons of product were released from a fuel pipeline. 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 –** There are no documented releases from the AOC 11 tank farm, although historical undocumented releases are suspected. According to the Brownfield Historical Research Overview (Pinnacle, 2006), the AOC 11 tank farm was constructed sometime between 1925 and 1936. It began as a vegetable oil storage facility and was later converted to petroleum oil storage. By 1936, the tank farm consisted of eight smaller tanks and one large tank, an oil shed, and a truck loading rack. The AOC 11 tank farm was demolished during the early years of Navy occupancy, probably in 1942 and certainly by 1946.
- **Former fuel transfer pipelines –** Over the history of T-91, petroleum and other materials were transferred between ships at Piers 90 and 91, the tank farms, and waste management areas, typically via above- and below-ground pipelines.

2.3.2 Exposure Pathways and Receptors

The CSM established the following potentially complete exposure pathways and the potential receptors for the TFAA for both soil and groundwater.

Soil. 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).

Groundwater. Two potentially complete exposure pathways related to groundwater were identified: (1) groundwater to indoor air; and (2) groundwater to surface water/sediment.

2.3.3 Cleanup Action Objectives

Cleanup action objectives (CAOs) form the basis for developing potential TFAA cleanup actions. CAOs are based on an evaluation of the data collected during previous investigations (summarized in the CSM) and on the cleanup levels (CULs) established for the TFAA. The focus of the CAOs is protection of human health and the environment. The CAOs for soil and groundwater, which focus on four primary exposure or migration pathways, are:

- Preventing exposure of future subsurface construction workers to indicator hazardous substances in soil, particulates, and soil vapors;
- Preventing exposure of future workers and trespassers to indicator hazardous substances (IHSs) in vapors originating from soil and/or groundwater via indoor air;
- Preventing discharge of groundwater containing IHSs at concentrations exceeding the applicable CULs to surface water and/or sediment and the subsequent potential for impacts on aquatic life or humans consuming fish; and
- Control, to the extent practicable, the migration of IHSs from soil to groundwater in quantities that would result in the accumulation of light non-aqueous phase liquids (LNAPL) on the groundwater.

2.3.4 Approach to Addressing CAOs

The CULs developed for the TFAA and the CAOs, combined with the current concentrations of contaminants in the soil and groundwater, indicate that there are no current exposures above risk-based criteria in the TFAA (PES et al., 2009). The first two of the above future exposure pathways (direct contact with soil and vapor migration to indoor air) will be addressed through the presumptive cleanup action of implementing engineering and institutional controls.

Similarly, because long-term groundwater monitoring has documented that concentrations of site-related contaminants 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., 2006) documents that naturally occurring attenuation mechanisms have resulted in stable plumes of petroleum-related compounds originating in the former tank farm and secondary source areas (e.g., SWMU 30), and CULs are likely to continue to be met in the future at the conditional point of compliance (CPOC). As a result, the groundwater to surface water/sediment pathway will be addressed by the presumptive cleanup action of implementing a monitored natural attenuation (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) was the primary focus of the cleanup actions for the TFLP and secondary source areas.

3.0 CLEANUP ACTION SUMMARY

As described above, the majority of the potential exposure pathways are addressed using presumptive response actions (i.e., engineering controls, institutional controls, and MNA). The remaining parts of the TFAA not addressed by these presumptive cleanup actions are the TFLP and other contaminant source areas (SWMU 30, AOC 11, and the former fuel transfer pipelines). As described in the FS Report and CAP, presumptive cleanup actions were identified for the secondary sources areas while the final cleanup action summarized below was selected for implementation at the TFLP.

3.1 Presumptive Cleanup Actions

For areas downgradient of the TFLP and the secondary source areas, the CAP identifies a series of presumptive cleanup actions, including:

- Institutional controls, such as health and safety requirements for site workers and addressing potential exposures when future land use changes are made (see Section 13.1).
- Cleaning and decommissioning underground fuel pipelines remaining in the TFAA (see Section 4).
- Excavating LNAPL source areas at SWMU 30 (see Section 5).
- Implementing an MNA groundwater sampling program. This program will confirm that natural attenuation processes continue to degrade chemicals in groundwater (see Section 6).

3.2 Final Cleanup Action for Tank Farm Lease Parcel

The CAP selects the implementation of Alternative 4 from the FS Report as the final cleanup action for implementation at the TFLP and adjacent areas. Alternative 4's primary objective is to prevent migration of LNAPL from the TFLP source area and to prevent future surface product seeps from occurring. This alternative includes the following components:

- Removing existing above ground structures and the existing asphalt paving; removing the remaining subsurface utilities, structures, and tank bases that appear to be the source of the current surface seeps; and removing highly contaminated soil encountered during the tank base removal process (see Section 7);
- Constructing a subsurface cutoff wall around the perimeter of the former tank farm (see Section 8);
- Installing an enhanced passive LNAPL recovery system (see Section 9); and
- Backfilling and grading the area, constructing a new asphalt cover over the area and constructing new stormwater drainage improvements (see Section 10).

After construction of the final cleanup action is complete, operations and maintenance (O&M) activities will be conducted including:

- Asphalt paving inspections and maintenance;
- LNAPL monitoring and passive recovery from LNAPL recovery trenches and existing LNAPL monitoring wells;
- Compliance monitoring, including MNA monitoring; and
- Reporting.

4.0 FORMER FUEL TRANSFER PIPELINES

This work element includes decommissioning underground former fuel transfer pipelines (pipelines) in the TFAA. The locations of these pipelines are shown on Drawings C001 through C003 and are based on:

- Historical construction and as-built drawings provided by the Port dating back to the 1940s, when the Site was occupied by the United States Navy (Navy);
- Various drawings associated with Port construction and demolition projects; and
- Recently developed as-built drawings prepared by the Port.

The historical drawings used by PES to establish pipeline locations are included in the Drawings as Reference Drawings R016 through R021.

The available information regarding the locations and conditions of former fuel pipelines is also discussed in the DGI Technical Memorandum (PES, 2012a), including uncertainties related to some of the remaining pipelines. Uncertainties include locations of pipeline terminations, pipeline diameters, number of pipes present in specific pipe runs or corridors, contents of pipes when last used, and whether or not certain pipes have been decommissioned.

Pipelines included in this work are: those that originate at the TFLP and terminate on Piers 90 and 91, pipelines that run north out of the TFLP, and pipelines that are located over or inside the proposed cutoff wall within the TFLP.

4.1 Objective

The objective of this work element is to use the available historical information to identify and locate pipelines that exist inside the TFAA and implement performance based procedures for their decommissioning. In general, pipelines within the TFAA but outside the former tank farm will be located, cleaned, grouted and capped in-place. In some cases, pipelines may extend outside the TFAA; these pipeline extensions will be also be decommissioned.

Pipelines located within the former tank farm will be removed after cleaning, decontaminated, and disposed of or recycled. The area where pipeline removal will be required is referred to on the Drawings as the Tank Farm Area (TFA). The TFA is that area that needs to be disturbed to perform the cleanup action for the TFLP, including the construction of the cutoff wall, final cover, and stormwater control system, as described in Sections 7 through 10. It is generally defined by the former tank farm footprint and the associated tank farm support areas (e.g., former Building 26 [Pump House] and OWS). It is mainly contained within the limits of the TFLP; however, in some sections the design limits of the TFA fall slightly outside the TFLP.

The primary objective of the pipeline cleaning process is to remove all free product and other materials (e.g., sludge) that remain in the pipelines to minimize or eliminate the potential of a future release to the subsurface. It is not the objective to remove any residual stains, film or residue adhering to the interior pipeline walls.

4.2 Location, Quantity and Contents of Existing Pipelines

Drawings C001 and C002 show the approximate plan locations of pipelines and Drawing C003 presents an inventory of these pipelines in a table format. Based on this inventory, approximately 30,000 linear ft of pipelines require decommissioning. The table lists information found on the historical drawings, where available, including:

- A description of the pipeline location (assumed starting point, route, and termination point of the pipeline);
- The pipeline diameter;
- The approximate pipeline length;
- Type of product conveyed through the pipeline; and
- The historical reference drawing number that shows the pipeline location.

No information is available concerning pipe depths or elevations. It is likely that the actual number and lengths of pipelines that are encountered during the work will vary from the inventory shown on the Drawings; however, the inventory provided represents the available information about these pipelines, many of which were installed over 60 years ago. Additionally, other documented and undocumented pipelines and utilities may be encountered, and may require decommissioning or protection. The construction contract will require the contractor to decommission or remove all pipelines discovered during the project.

The following products or materials are presumed to remain in the pipelines:

- Sludges and solids defined as undesirable materials that accumulate in fuel pipelines consisting of heavy petroleum products, or a mixture of hydrocarbons, residue, scale and water, that may be flammable, hazardous, and/or toxic;
- Residual fuels including gasoline, diesel, and oil products; and
- Water, some of which may be contaminated by fuel products.

4.3 Pipeline Decommissioning

Section 02224 of the Technical Specifications provides a series of performance based procedures for decommissioning pipelines, including:

- Field locating and exposing;
- Cleaning;
- Grouting;
- Capping;
- Checking sections of pipe to be cut and removed for presence of asbestos containing material;
- Cold cutting and removing cleaned pipelines;

- Decontaminating the exterior and interior (if practicable) of the cleaned pipelines that have been removed;
- Characterizing, disposing, and/or recycling products removed from pipelines;
- Disposing or recycling cleaned and decontaminated pipelines; and
- Backfill and asphalt repair.

Additional information for each of these steps is provided in the sections below. As described in Section 4.5 below, the contractor will be required to prepare a work plan for pipeline decommissioning that details the specific procedures (means and methods) to be used in meeting the performance standards.

4.3.1 Field Locating and Exposing Pipelines

Drawings C001 and C002 and the associated reference drawings listed on the inventory tables (RO13and RO14ZZ) will be used as the first step to locate pipelines. Since there is little if any survey information defining the horizontal and vertical position of the pipelines, the pipelines will be field located by:

- Scaling approximate locations from the drawings relative to a fixed location (e.g., buildings, roadways or other existing fixed objects);
- Establishing coordinates for those locations; and
- Indentifying that location on the ground surface by survey.

The entire pipeline length will not be located. Instead, only the location where pipelines will be exposed for cleaning, grouting and capping will be established by survey. Once an approximate location is determined by surveying, a utility locate will be completed to verify or refine the location, if possible.

The pipeline will then be physically located by removing pavement and base course, and then excavating until the pipeline is exposed. The pipeline alignment, including the terminal end and branch lines if possible, will then be established using standard utility locating techniques. Procedures for excavating soil to expose existing pipelines are defined in Sections 02331, 02332, and 02338 of the Technical Specifications. Soil removed during excavation will be stockpiled and profiled for either off-site disposal at an approved facility, or re-used as backfill as described in Sections 02224 and 02405 of the Technical Specifications and Section 11 of this report.

The pipelines will be exposed at two locations for each segment that is cleaned: one for accessing the pipeline to insert cleaning equipment and pump grout, and the second at the opposite end of the segment to observe that the cleaning equipment travels through the entire segment, and to observe that grout completely fills the segment. These locations will also be used for collecting remaining fuel product or other residual materials removed during the cleaning process.

Because some pipelines may be greater in length than the travel constraints of the cleaning and grouting equipment, some of the pipelines may have to be decommissioned in several segments.

4.3.2 Cleaning Pipelines

Performance based procedures for cleaning pipelines are provided in Section 02224 of the Specifications. The objective of the pipeline cleaning is to remove and collect remaining products and residuals so that the cleaned pipeline does not pose a threat for future product releases.

Where pipelines are cleaned prior to removal in the TFA, the cleaning objective is to remove products to the extent that the pipelines can be safely removed prior to decontamination and subsequent disposal or recycling.

4.3.3 Grouting Pipelines

Performance based procedures for grouting pipelines are provided in Section 02224 of the Technical Specifications, including grout mix product requirements, and filling cleaned pipes with the grout. The objective is to fill the entire cleaned pipe segment with a solid, void-free, waterproof plug of non-shrink grout. The volume of grout pumped into a section of pipeline will be compared to the calculated volume; significant discrepancies between the measured and calculated volumes may indicate incomplete grouting or breaks in the pipeline.

4.3.4 Capping Pipelines

Pipeline capping is required for all pipelines that have been cleaned and grouted, and will remain in place. Performance based procedures for capping pipelines are provided in Section 02224 of the Technical Specifications. The objective is to install a cap that prevents any liquid or solid from entering the cleaned and grouted pipeline segment. Cap types will include blind flanges, welded slip-on caps, or isolation valves all of which must be manufactured from products compatible with the pipeline.

If present, vertical stickups from underground pipelines that are at, or near the ground surface will be cut to approximately 18 to 24 inches (in.) below finished design grades and grouted and capped as described above.

4.3.5 Removing Cleaned Pipelines in the TFA

Removal of pipelines is limited to the TFA. Performance based procedures for removing pipelines are provided in Section 02224 of the Technical Specifications. Those procedures generally require removing the cleaned pipelines, and hauling them to a designated stockpile location where they can be decontaminated and processed for recycling or disposal.

Fuel pipelines with asbestos coatings were encountered during the 2005 Tank Farm Demolition work. Pipelines crossing the TFA boundary were cut, and the buried sections within the TFA were left in place. Prior to cutting the pipelines with asbestos coatings, asbestos abatement was performed by removing the asbestos in the vicinity of the cut. If pipelines suspected of having asbestos coatings are encountered, the Port or contractor will conduct any necessary abatement work prior to removal activities. When removing asbestos coated pipelines that have been previously abated and cut at the TFA boundary, it may be possible to remove the remainder of the buried pipeline without additional abatement as long as no additional pipe cuts are required.

4.3.6 Decontaminating Cleaned Pipelines That Require Removal

Performance based procedures for decontaminating pipelines removed from the TFA are provided in Section 02211 of the Technical Specifications. The objective is to remove residual products from the inside and outside portions of the pipeline that would preclude it from being recycled or landfilled as a solid waste. The decontamination procedure will likely include steam cleaning the inside and exterior of the pipelines. The Specifications also include options for using various equipment, detergents and procedures for meeting the objective.

4.3.7 Characterizing, Disposal, and Recycling of Products Recovered From Pipelines

Procedures for characterizing fuel liquids, sludges, solids, oil products, and impacted water removed from pipelines prior to disposal are defined in Section 02405 of the Technical Specifications. The objective of these procedures is to determine disposal requirements for the collected products.

Procedures for disposal or recycling of fuel liquids, sludges, solids, oil products, and water removed from pipelines are provided in Sections 02224 and 02405 of the Technical Specifications. Those procedures include a determination regarding whether the product can be recycled, or if it has to be taken to a permitted disposal facility. Procedures for stabilization of the products, if required, will be provided by the recycler or disposal facility and are summarized in Section 11 of this report.

4.3.8 Disposal or Recycling of Cleaned and Decontaminated Pipelines

Procedures for disposal or recycling of pipelines removed from the TFA are provided in Section 02405 of the Technical Specifications. Those procedures include a determination regarding whether the product can be recycled, or if it has to be taken to a permitted disposal facility.

4.3.9 Backfill and Asphalt Repair

Procedures for backfilling excavations made to expose pipelines and repair the asphalt are provided in Sections 02338, 02722, and 02743. The objective of these procedures is to return the paved areas to their original condition.

4.4 Contractor Construction Quality Control

Contractor CQC standards are established in the various Technical Specifications listed above. One of the critical requirements is to physically locate by surveying methods the capped ends of all cleaned and grouted pipelines to provide a retrievable record documenting the locations on CAD Drawings.

Another CQC requirement will be the periodic video inspection of the cleaned pipelines to verify that all free product has been removed in accordance with Section 02227. The general requirement is that a camera be inserted in cleaned segments totaling up to 10 percent of the total length of pipelines. The video inspections will be prioritized at the beginning of the work to verify that the contractor's means and methods meet the required objective, and provide the Port with assurance that all of the pipelines are being adequately cleaned.

4.5 Contractor Work Plan

The decommissioning procedures and objectives described above and in the Technical Specifications are performance based. It will be the responsibility of the contractor to submit a Work Plan with prescriptive procedures (means and methods) for pipeline decommissioning. That Work Plan is subject to approval by the Port prior to issuing a Notice to Proceed. The Work Plan must include details for:

- Worker safety (reference to HASP is acceptable);
- Procedures and equipment for:
  - Pipeline location;
  - Pipeline tracing;
  - Locating and protecting adjacent utilities and structures;
  - Excavation;
  - Pipeline cutting
  - Free product removal;
  - Pipeline cleaning;
  - Grouting and capping pipelines;
  - Backfilling excavations;
  - Repairing asphalt;
  - Decontaminating equipment and removed pipelines; and
  - Handling of decontamination water and oily water.
- Grout mix design;
- Procedures for characterizing and then disposing or recycling of products removed from pipelines;
- Procedures for disposing or recycling of cleaned, removed and decontaminated pipelines;
- Proposed disposal sites;
- Quality control methods for testing and inspection to ensure all specifications and performance standards are met;
- Surveying procedures; and
- Protection of the environment including but not limited to spill prevention, spill control and response and spill cleanup.

5.0 SWMU 30

This work element includes excavation and backfill in SMWU 30, located adjacent to the short-fill area on Pier 91, where LNAPL and elevated concentrations of residual petroleum hydrocarbons have been observed (Drawing G003). Cleanup will take place in two distinct areas, designated as the SWMU 30 – North and South Areas.

The purpose of the cleanup is to remove a potential long-term source of groundwater contamination from this area. Key design considerations include:

- Excavation sheeting, shoring and groundwater management to isolate the excavations, prevent lateral movements of soil and adjacent utilities, and to control soil heave and groundwater inflow;
- Supporting the Short Fill Impoundment seawall and associated bulkhead(s), tiebacks, and anchorages;
- Supporting and protecting utilities within and adjacent to the excavations; and
- Potential for rainfall and stormwater run-on to have contact with contaminated soil due to construction schedule restrictions.

5.1 Design Criteria and Assumptions

The initial extents of the excavations were developed in Alternative 4 of the CAP (PES, 2010) as follows:

- The eastern limit of both excavations was defined by the location of the existing concrete or wood and concrete bulkhead and Short Fill Impoundment seawall.
- The western, northern, and southern excavation limits were established based on available soil and groundwater data, including three monitoring wells containing LNAPL (PNO_MW102, PNO_MW03, and PNO_EW01) and two soil borings with elevated concentrations of residual petroleum hydrocarbons (DG-83 and DG-88).

The excavation limits were further refined in the DBM (PES, 2012b), as follows:

- The eastern excavation limit has been defined as the west side of the existing bulkheads, so these structures may be left in place.
- The western limit of the excavations was moved 4 ft east after mapping of subsurface utilities indicated the presence of an 8-in. diameter fire line and 6-in. diameter water line at, or directly adjacent to, the proposed limits of the excavation areas. As a result, the western excavation limits are defined on the Drawings as being 26 ft from the eastern limits, although the excavation width may be reduced further if the excavation conflicts a power line and the previously mentioned water lines.

Therefore, as shown on the Drawings:

- The South Area measures 60 ft by 26 ft (1,560 square feet (sq ft)) and encompasses monitoring well PNO_MW102 in which LNAPL has been detected; and
- The North Area measures 90 ft by 26 ft (2,340 sq ft) and encompassing two monitoring wells (PNO_MW03 and PNO_EW01) in which LNAPL was detected in February 2012, and two soil borings (DG-83 and DG-88), which had elevated concentrations of residual petroleum hydrocarbons.

The initial excavation depth described in the CAP included excavation 3 ft below the seasonal low water table in the South Area, and excavation to the top of the smear zone in the North Area. The South Area excavation depth remains unchanged in this design. The North Area excavation depth, however, was revised in the DBM to also extend 3 ft below the seasonal low groundwater elevation due to LNAPL occurrence in monitoring wells PNO_MW03 and PNO_EW01 since 2010.

The seasonal groundwater elevations were determined through review of historical groundwater monitoring data from 1993 through 2011 for three monitoring wells located within the limits of the excavations (PNO_MW102, PNO_MW03, and PNO_EW01), and three nearby monitoring wells (PNO_MW02, PNO_MW06A, and PNO_MW103); this data is summarized in Table 5-1.

TABLE 5-1 SWMU 30 SEASONAL GROUNDWATER ELEVATIONS

WELL REFERENCE	MAXIMUM ELEVATION (FT)	MINIMUM ELEVATION. (FT)
PNO_EW01	10.29	8.06
PNO_MW02	9.92	8.03
PNO_MW03	10.02	7.62
PNO_MW102	12.39	7.36
PNO_MW06A	10.50	8.80
PNO_MW103	8.97	7.83

Excavated soil in the vadose zone[2] is not expected to be highly contaminated with petroleum hydrocarbons and will be stockpiled for potential reuse as backfill material. Excavated soil in the smear zone[3] and saturated zone[4] may be highly contaminated, and will be presumptively managed as highly contaminated and will be stockpiled separately and profiled for off-site disposal at an approved facility.

[2] Vadose zone soil is defined as soil located above the seasonal high groundwater elevation.
[3] Smear zone soil is defined as soil located between the seasonal high and seasonal low groundwater elevations.
[4] Saturated zone soil is defined as soil located below the seasonal low groundwater elevation.

Additional design criteria and assumptions established for this work element include the following:

- Approximate ground surface elevation of 18.0 ft mean low-low water (MLLW)[5].
- Seasonal high groundwater elevation of 10.5 ft. The historical maximum groundwater elevations were between 9.52 and 10.29 ft for monitoring wells located within the excavations, and between 8.97 and 10.5 ft for the remaining wells. Note that in July 1997 a groundwater elevation of 12.39 ft was measured in monitoring well PNO-MW102. The measurement is assumed to be an anomaly since the water level is 2.8 ft higher than the next highest historical water level in this well, and approximately 3 ft higher than water elevations measured in other wells during the same time period.
- Seasonal low groundwater elevation of 7.4 ft. The historical minimum groundwater elevations were between 7.36 and 8.06 ft for monitoring wells located within the excavations, and between 7.62 and 8.80 ft for the remaining wells.
- Based on the seasonal low groundwater elevation, the excavation bottom elevation is 4.4 ft (i.e. 3 ft below the seasonal low groundwater elevation).
- The exact construction and conditions of the existing bulkheads, tiebacks, and anchorages will not be known until they are exposed and evaluated. According to the Terminal 91 Condition Survey Bulkhead Report (ABAM, 1991), the Pier 91 bulkhead was originally constructed using 3-in. thick wood wakefield walls with three layers of 3-in. thick wood sheet piles tied back with wood walers attached to bulkhead piles on 10 ft centers, two sets of metal tiebacks (at 5.5 and 9.5 ft below the original deck), and anchor piles on 10 ft centers connected with wood lagging and blocks on each tieback. Later, during the 1930s, the wood bulkhead was replaced with a reinforced concrete seawall using the wood as a form and leaving the tiebacks in place.
- Inspections of exposed bulkheads conducted for the Bulkhead Report indicate that top wood walers, top tiebacks, and half of the original wood wall were intact; and the lower wood walers and tiebacks were deteriorated, missing, or not visible. Potential configurations of the bulkhead assemblies are shown on Drawings S-3 through S-6. Note that the anchor pile locations are estimated at approximately 24 ft from the bulkhead piles based on a 1919 drawing included in the Bulkhead Report; although the same drawing indicates that the anchor piles could be as close as 15.5 ft from the bulkhead piles. It should be noted that other drawings in the Bulkhead Report indicate that the anchor piles are 20 ft east of the reinforced concrete bulkhead, or that the tieback rods are approximately 34 ft long.
- In the SWMU 30 – South Area, the bulkhead system is no longer acting as a retaining wall since fill was placed to create the Short Fill Area. Therefore, Drawings C005

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[5] All elevation references in this document are relative to MLLW, unless stated otherwise.

through C008 show the bulkhead being left in place, but the anchorage system (tie rods, and anchor pile system) being removed to simplify excavation and backfilling.

- In the SWMU 30 – North Area two conditions apply:
  - In the southern part, the bulkhead system has been filled similar to the South Area, and the Drawings show the bulkhead being left in place, but the anchorage system (tie rods, and anchor pile system) being removed to simplify excavation and backfilling; and
  - In the northern part, the bulkhead system adjacent to the Short Fill Impoundment continues to function as a retaining wall, and the Drawings C009 through C011 show that the anchorage system (tie rods and anchor pile system) will be maintained or replaced if their condition warrants.

5.2 Construction Sequencing

The sequence for the excavation will be refined with the contractor. In an effort to avoid potential impacts or conflicts with the busy cruise season (late April through September), the general construction schedule includes contractor mobilization as early as October so that the excavations can be conducted between October and early April, if possible. It is assumed that the contractor will perform the excavations sequentially to minimize the construction footprint. The following is the anticipated construction sequence:

- Establishing truck access routes from SWMU 30 to the stockpiling locations;
- Mobilization, setting up and securing work zones, stockpile, soil profile areas, and materials storage areas, establishing stormwater best management practices (BMPs);
- Decommissioning existing monitoring wells (PNO_MW102, PNO_MW03, and PNO_EW01);
- Constructing water collection, treatment, and disposal systems to manage stormwater run-on, groundwater, and LNAPL that may accumulate in the excavations;
- Removing existing asphalt and base course;
- Exposing, supporting and protecting encountered utilities including power, telephone, natural gas, water, and sanitary sewers;
- Providing and installing sheeting and shoring to isolate the areas being excavated and prevent lateral movements of soil;
- Bracing and supporting the existing bulkhead and seawall in the North Area, removing tiebacks, and assessing and removing anchorages as needed;
- Excavating, loading, and stockpiling soil that is not highly contaminated from above elevation 10.5 ft;
- Excavating, loading, hauling, profiling and disposing of all soil from below elevation 10.5 ft (assumed to be highly contaminated soil);

- Permanently removing all exposed tiebacks and anchorages in the South Area and the southern part of the North Area;
- Performing a condition assessment of the existing bulkheads, tieback and anchorages designated to remain in the northern part of the North Area;
- If necessary, replace tiebacks and anchorages in the North Area;
- Backfilling the excavation with gravel fill, and engineered fill (including those soils removed from above elevation 10.5 ft that are not highly contaminated);
- Removing temporary sheeting and shoring; and
- Furnishing and installing base course and asphalt concrete over the engineered fill backfill.

5.3 Monitoring Well Decommissioning

Prior to excavation, the three monitoring wells inside the South and North Areas (PNO_MW102, PNO_MW03, and PNO_EW01) will be decommissioned using over-drilling methods per Chapter 173-160 WAC. These three wells are not currently anticipated to be replaced following completion of the excavation activities. If significant LNAPL is observed along the western edge of the north excavation, which may migrate into the granular backfill after the excavation shoring is removed, a monitoring well may be installed in the backfill and integrated into the LNAPL monitoring program defined in the compliance monitoring plan (CMP).

5.4 Existing Pavement

The existing surface paving will be saw-cut, broken up and removed from the site for off-site disposal. The base course will be removed prior to excavating underlying soil and stockpiled for reuse as engineered fill/backfill at SWMU 30.

5.5 Utility Protection

Expose, support and protect utilities within and adjacent to the excavations.

- As shown on Drawing C005, the South Area includes several utilities that must be supported during the excavation including a 12-in. diameter sanitary sewer, a fiber optics cable, electrical conduits in a concrete duct bank, another electrical conduit, and a natural gas main.
- As shown on Drawing C009, the North Area includes only a 12-in. diameter sanitary sewer that must be supported during the excavation.
- The 8-in. fire line, 6-in. water line, and 4-in. electrical conduit located adjacent to the west side of both the South and North Areas will be located and protected during the work.

5.6 Excavation Quantities

The estimated volumes (cubic yards [cy]) of soil will be excavated from the two areas are presented in Table 5-2.

TABLE 5-2 SWMU 30 ESTIMATED EXCAVATION VOLUMES

SEGMENT	SOUTH AREA (CY)	NORTH AREA (CY)	TOTAL (CY)
ABOVE ELEVATION 10.5 FT	435	650	1,085
BELOW ELEVATION 10.5 FT	350	530	880
TOTAL (CY)	785	1,180	1,965

The limits of the excavation areas and the resulting soil volumes may change during construction as the locations of the bulkhead structures and utilities are field located and verified.

5.7 Shoring

Temporary sheeting and shoring will be required for excavation in SWMU 30 in order to protect adjacent utilities, protect the bulkhead and seawall in the northern excavation, prevent over-excavation, control base heave and manage groundwater during excavation and backfilling activities. The contractor will be required to prepare a sheeting and shoring plan for both the North and South Areas. The plans will be subject to Port review. See Appendix A4 for additional evaluation and discussion of excavation considerations in the SWMU 30 area.

5.8 Groundwater Control

Groundwater is expected to be encountered below 10.5 ft, although the actual elevation will be affected by the amount of precipitation and season. The contractor will determine groundwater management requirements and methods, and will be required to appropriately manage groundwater where excavations extend close to or below the groundwater elevation. The groundwater management strategy must provide a stable excavation bottom; however, the cleanup does not require that the excavation be performed in dry and dewatered conditions. Any groundwater removed will be pumped to collection tanks where the water will be treated, sampled, and discharged to sanitary sewer under a discharge permit as described in Section 12.

Floating LNAPL encountered in the excavations or in dewatering collection tanks will be removed and profiled for off-site disposal at an approved facility. A sheen may be visible on the surface of water in the excavation after LNAPL removal is complete. This will be an acceptable condition.

5.9 Backfilling, Grading and Paving

If the excavation is performed in the wet, with groundwater maintained above the bottom of the excavation for stability purposes, geotextile separator will be deployed in the bottom of the excavation and gravel fill (essentially self-compacting material) will be placed to a minimum of 1 foot above the groundwater surface. Compacted engineered fill will then be placed above the gravel fill.

If the excavation is performed in the dry, with groundwater maintained below the base of the excavation, engineered fill may be placed over the full depth of the excavation without geotextile separator and gravel fill.

The engineered fill will be covered with subbase course granular material, base course granular material, and Class B asphalt concrete pavement to match existing grades, in accordance with Section 02743.

5.10 Stormwater Management

Stormwater runoff generated during construction activities will be managed consistent with the requirements of a Construction Stormwater General Permit (CSWGP) to be obtained by the contractor (see Section 12.1 for details). The CSWGP will require preparation of an Erosion and Sediment Control Plan that describes the best management practices and, as necessary, treatment procedures for managing stormwater during construction.

5.11 Temporary Facilities and Controls

Typical temporary facilities and controls include worker facilities, a decontamination area, and work area access controls. Potable water, portable toilets, and a job site trailer(s) will be provided. Water will be provided using existing water supplies at T-91. Portable toilets will be placed on-site for use by project personnel in accordance with the WISHA guidelines in WAC 296-155-140.

A decontamination area will be established near the SMWU 30 work area for vehicle, shoring, equipment, and personnel decontamination. All vehicles, shoring, equipment, and personnel that contact impacted materials will be decontaminated prior to exiting any exclusion zones. Contamination reduction zones will be installed adjacent to each active excavation area and stockpile area (exclusion zones).

Work area access controls will be installed for security and to prevent access by the general public. In addition to the existing T-91 chain link fence, temporary security fencing or barricades and caution tape will be installed around the limits of work. Existing access gates will be used for ingress/egress of the site. Other interior access controls to be established include work zone perimeters for worker health and safety and for decontamination. These include secure zones, exclusion zones, and contamination reduction zones. A traffic control plan will be prepared by the contractor to manage traffic flow around the works areas including appropriate signage to be placed to inform the public about truck traffic and to restrict access to the site.

6.0 MONITORED NATURAL ATTENUATION

The existing MNA program includes 16 wells along the following three flow paths (see Figure 5):

- **Tank Farm/AOC 11.** The MNA wells included CP_104A (source); CP_GP11, PNO_MW101, and CP_GP05 (plume); and CP_GP14 (sentinel). Two of the plume wells (CP_GP11 and PNO_MW101) are located near a potential secondary source (AOC 11).

- **Tank Farm (Pier 90).** The MNA wells included CP_108A (source); CP_GP02 and CP_GP01A (plume); and CP_GP08 (sentinel).

- **Tank Farm/SWMU 30 (Pier 91).** The MNA wells included CP_103A (source); PNO_MW02, PNO_MW06A, PNO_MW103, and CP_GP03A (plume); and CP_GP09 and CP_GP10 (sentinel). Two of the plume wells (PNO_MW02 and PNO_MW06A) are located in a secondary source area (SWMU 30).

The existing monitoring network appears to be adequate, and none of these MNA wells will be decommissioned during implementation of the cleanup action plan. If post construction monitoring indicates significant changes to groundwater flow and/or chemistry, the need for new monitoring wells and/or adjustments to the MNA program and related CMP (see Section 12.4) will be considered.

6.1 Monitoring and Analysis

Based on the previous MNA plan (PES, 2006a), 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 TFAA 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 or equivalent);
- Ferrous iron (field kit, Hach Method 8146 or equivalent); and

- Alkalinity (field kit, Hach Method AL AP MG-L or equivalent).

The following parameters that are contained in the current groundwater monitoring plan were not included in the CMP:

- two volatile organic compounds (VOCs): 1-4 dichlorobenzene and vinyl chloride;
- three semivolatile organic compounds (SVOCs): carbazole, dibenzofuran, and 1-methylnaphthalene;
- low level polynuclear aromatic hydrocarbons (PAHs); and
- two total metals: arsenic and zinc.

These parameters were not included in the CMP because recent groundwater monitoring results (2009 through 2011) have either not detected these constituents in any shallow monitoring wells (e.g., VOCs, total zinc), were not detected above the method reporting limit (carbazole and dibenzofuran), were detected only once in source area wells and not at all in CPOC wells (1-methylnaphthalene), or were detected in upgradient/background wells at a higher frequency and at higher concentrations than source area of CPOC wells (PAHs). Although arsenic has been detected above its cleanup level of 4.7 ug/L in several of the source area and downgradient wells, these detections have been intermittent and low level, with a maximum detection of 11.0 ug/L in well CP_GP10 in 2011.

6.2 Reporting and Evaluation

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, are presented in the MNA section of the CMP.

7.0 TANK FARM AREA SITE PREPARATION

In 2005, the Port demolished the aboveground portions of the former tank farm as an independent interim remedial action (Roth Consulting, 2005), leaving the majority of the subsurface structures in place. The interim action included the demolition of aboveground fuel storage tanks, concrete containment walls, buildings, gangways and catwalks, aboveground fuel pipelines, and other structures. It also included purging three underground fuel transmission lines that run from the tank farm to the fuel riser station on Pier 90 and cleaning of underground fuel piping in the tank farm. The interim action left the tank bases in place (with the exception of those in the Small Oil Yard) and the below ground portions of the tank or concrete containment wall foundations and pipe alleys. Other activities included removal and disposal of asbestos-containing materials (ACM), and removal and disposal of petroleum-impacted soil from pipe chases. Following the demolition activities, areas were backfilled and paved.

The subsurface structures remaining after the 2005 interim action are a significant obstruction to the installation of the cutoff wall that is a key component of the cleanup action. The work to be performed under this element of the cleanup action, therefore, includes removing the subsurface structures and other site preparation activities required to construct the cutoff wall around the former tank farm.

7.1 Overall Approach to Site Preparation

The limits of the site preparation area are referred to on the Drawings as the TFA. As noted in Section 4.1, the TFA is that area that needs to be disturbed to perform the cleanup action for the TFLP, including the construction of the cutoff wall, final cover, and stormwater control system. The anticipated limits of the TFA are defined on Drawing C012.

As noted previously, the TFA is mainly contained within the limits of the TFLP; however, in some sections the design limits of the TFA fall slightly outside the TFLP, as shown on Drawing G003.

The TFA is currently paved with asphalt (and relatively small areas of concrete), enclosed with temporary fencing, and used as a material storage area by the Port. In addition, stormwater management structures and pipes, electrical Substation 11, a few small buildings (requiring the removal of hazardous materials) and above-ground structures associated with the former tank farm, and some temporary structures are present.

Prior to the start of site preparation activities, a new electrical substation will be constructed by the Port, existing Substation 11 will be de-energized, and regulated materials identified during recent survey (Appendix E) will be abated in accordance with Drawings HA001 and HA002, and Sections 02075 (Lead Controls in Construction and Demolition), 02082 (Fluorescent Light Tubes), 02083 (Fugitive and Silica Dust Procedures), and 02085 (Asbestos Abatement) of the Technical Specifications.

The consequent expected TFA site preparation activities have been broken down into the following seven stages, based on the anticipated sequence of construction:

- Stage 1 – Establish site controls and temporary erosion and sediment controls (TESC);

- Stage 2 – Demolish existing above ground features;
- Stage 3 – Remove existing asphalt (and concrete) pavement;
- Stage 4 – Remove soil and demolish utilities and pipelines above tank bases;
- Stage 5 – Demolish remaining tank bases;
- Stage 6 – Demolish concrete structures; and
- Stage 7 - Excavate an exploratory trench along the cutoff wall alignment and backfill the TFA to elevations required to construct the cutoff wall.

Although the site preparation activities are shown on Drawings C012 to C020 in these seven stages for the TFA as a whole, the contractor will be required (Section 02222 of the Technical Specifications) to prepare a Project Work Plan to divide the TFA into a number of smaller areas and complete the activities in one area before moving to the next. The goals of subdividing the work into smaller areas include:

- Minimizing the area of contaminated materials (i.e. tank bases, and contaminated soil) exposed at any time to reduce the potential for odors, airborne exposures, and the generation of contaminated stormwater during precipitation;
- Maintaining accessibility and paved access throughout most of the preparation timeline;
- Maintaining portions of the existing stormwater control system throughout most of the preparation timeline; and
- Managing areas that may be used for staging or stockpiling during the work.

Materials that will be excavated, demolished, or removed during the TFA cleanup actions described below include environmental media (soil, groundwater, and stormwater), debris (e.g., concrete, steel), and waste generated during cleanup activities (e.g., LNAPL, decontamination water). The overall approach for managing these materials is described in detail in Section 11. A critical aspect of this management approach is that potentially contaminated materials generated from within the TFA that are intended for reuse as backfill (e.g., crushed concrete, soil not determined to be highly contaminated) must remain in a defined area in and immediately surrounding the TFA.

The major assumptions and description of each of the six stages are provided below.

7.2 Stage 1 – Establish Site Controls and TESCs

Drawing C012 shows the limits of the TFA and Drawing C013 shows the preliminary TESC measures to be implemented. Other TESC measures may be developed by the contractor as part of implementing the CSWGP that will be required for this project and in accordance with Section 02270 of the Technical Specifications. Specific site controls will include:

- Establishing a fenced secured zone around the TFA to restrict access to the construction area, while permitting Port and tenant access to neighboring buildings and facilities, including Buildings M-19, M-19A, M-28, W-39 and W-390, Coontz Avenue and West Garfield Street, and minimizing impacts and disruptions to ongoing operations; and

- Establishing temporary erosion control in stormwater catch basins and pump stations, and maintaining the erosion control measures until the structures are decommissioned.

7.3 Stage 2 - Demolish Above Ground Structures

Drawing C014 shows the primary surface features that will be managed during Stage 2, as follows:

- Demolish permanent fencing within the secured zone, near the former OWS in the northwest corner of the TFA;
- Demolish Substation 11 after the Port has constructed a replacement electrical substation and Substation 11 has been de-energized[6];
- Demolish above-ground components of Buildings 25 and 27, and recycle materials, such as wood and metal, that can be repurposed;
- Demolish the concrete loading ramp on the east side of Building 27;
- Demolish piping from surface vault on east side of Building 27 and demolish any above-ground components of vault;
- Abandon 12 monitoring wells and 6 vapor monitoring points within the cutoff wall alignment (CP_PR-01 through CP_PR-12, and VP-1 throughVP-6) and 1 monitoring well (UT_MW39-2) located outside of the cutoff wall alignment. The abandonment will be performed in accordance with Chapter 173-160 WAC by overdrilling with a hollow-stem auger while the casing is pulled. The overdrilled boreholes will be filled with bentonite to within 1 ft of the ground surface, and the upper 1 ft of UT_MW39-2 will be filled with concrete to match the existing pavement;
- Decommission the power to the 4 stormwater vaults, remove the pumps from within the vaults, and the concrete blocks from around the vaults;
- Remove above-ground storm water pipes (including, if necessary, the management of any pipe gaskets that contain asbestos), and any connections to existing stormwater and/or sanitary sewer systems; and
- Remove foam hydrants (on east and south sides of TFA), and any remaining above-ground foam system components.

7.4 Stage 3 – Remove Existing Asphalt Pavement

Drawing C015 shows the primary materials that will be managed during Stage 3, as follows:

- Saw cut asphalt (and concrete) pavement around perimeter of TFA;
- Clean any free product from pavement surface;

[6] Substation 11 currently provides power for Building 19, Building 19A, Building 309 (Shanty) and the pumps in the TFA stormwater vaults. The electrical service from Substation 11 will be rerouted outside of the TFA and cutoff wall alignment. However, temporary service may need to be established in the TFA to maintain the operation of the stormwater pumps until they have been demolished.

- Break up and remove asphalt (and concrete) pavement from TFA for recycling or disposal; and
- Remove and stockpile base course and subbase from beneath the existing paving.

7.5 Stage 4 - Remove Soil and Demolish Pipelines and Utilities Above Tank Bases

Drawing C016 shows the areas where soil and utilities above the tank bases and concrete slabs present throughout the tank farm will be removed and demolished. In addition, Drawing C002 shows the pipelines that may be encountered, if they were not decommissioned during the work in 2005. These activities will proceed after the asphalt pavement has been removed in Stage 3. Specific activities include:

- Remove soil fill, which was historically placed below existing asphalt and over existing concrete slabs, footings, and tank bases and which is not classified as highly contaminated, for reuse as engineered fill. Soil thicknesses at select locations based on information from the first phase of the Data Gaps Investigations (PES, 2007) are shown on Drawing C016; the average thickness of this fill is expected to be approximately 1.25 ft;
- Remove and stockpile separately any soil classified as highly contaminated so that it can be characterized and profiled prior to disposal, or haul directly to an approved disposal treatment facility if already profiled. See Section 11 for additional details on the approach for managing environmental media and debris;
- Based on the available sampling results, the majority of the soil fill is not expected to be highly contaminated;
- Clean, remove and decontaminate all subsurface pipelines and utilities inside the TFA. These may include fuel and product lines, steam lines, foam lines, and storm drains. Pipelines are to be cut at the limits of the TFA and the portions remaining outside the TFA are to be cleaned, grouted and capped as described in Section 4;
- Unknown active utilities which are encountered will either be rerouted around the TFA or removed, with the other pipelines and utilities, and replaced; and
- Remove vault structures (includes stormwater vaults, a gravel-filled vault adjacent to Building M-28, a gravel-filled pit adjacent to west end of Small Oil Yard, and other previously filled pits around the perimeter of the tank farm) to depths necessary to expose the remaining tank bases and concrete slabs that formed the “floor” of the former tank farm.

7.6 Stage 5 – Demolish Remaining Tank Bases

Drawing C017 shows the tank bases in the Black Oil Yard and the Marine Diesel Oil Yard that will be demolished. These activities will follow after the soil and utilities have been removed as described in Stage 4, and will include:

- Clean, dismantle, and remove for recycling steel components of tank bases. The specific procedures and methods for decontamination and dismantling of the steel tank bases will be described in a contractor-prepared Project Work Plan; and
- Remove oil-sand layers that may be present beneath tank bases, in accordance with a contractor-prepared Project Work Plan, and stockpile, or haul directly to an approved disposal treatment facility. Oil-sand layers, if present, will be assumed to be highly contaminated soil.

7.7 Stage 6 – Demolish Concrete Structures

Drawing C018 shows the below grade concrete structures to be demolished after the tank bases have been removed in Stage 5, The work will include:

- Decontaminate any free product observed on the concrete structures before demolishing;
- Saw-cut containment wall footing at north and south ends of the east side of Building M-28 to preserve the 15-ft high concrete retaining wall and foundation that forms the approximately 165-ft long east wall of Building M-28;
- Demolish the 12-ft wide containment wall footings around the Black Oil Yard and Marine Diesel Oil Yard;
- Demolish the footing for Firewall A, which formed the north and east sides of the Small Oil Yard;
- Demolish the footing for Firewall B, which formed the south and west sides of the Small Oil Yard adjacent to the former Pipe Alley;
- Demolish miscellaneous other retaining walls with unknown footing configurations that are in or adjacent to the Small Oil Yard;
- Demolish the concrete slabs, ring beams, individual footings, and pits associated with former tank bases;
- Demolish the concrete slab, and concrete pipe/equipment supports located between the former tank bases present throughout the three oil yards;
- Demolish: (i) the six stormwater vaults inside and outside the three oil yards, (ii) the approximately 9-ft deep sump and base located close to the north wall of Building M-28, which was filled with gravel during the 2005 mitigation, and (iii) pit approximately 3-ft below grade, west of the Small Oil Yard, that was backfilled during 2005 tank farm demolition project;
- Demolish foundations associated with former Buildings 16, 17, 24, 26, and 30, Buildings 25 and 27, and Substation 11;
- Excavate, and stockpile for reuse as engineered fill, soil placed, as a component of the 2005 mitigation, inside the former OWS and demolish the walls and base of the former OWS, which was approximately 45-ft long, 20-ft wide and 8-ft deep. Groundwater data from proximate monitoring well CP_PR-12 (where historical groundwater elevations have ranged from 9.3 to 13 ft) indicates the bottom of the OWS may be up to 2.5 ft below the groundwater surface;

- Remove any highly contaminated soil observed beneath demolished concrete structures in order to minimize the potential for these soils to act as a source of future seeps. Excavation of highly contaminated soil will continue downward vertically until non-highly contaminated soil or the water table is encountered, whichever is first. Excavation of highly contaminated soil will extend horizontally until non-highly contaminated soil or the edge of the TFA is encountered, whichever is first;
- Break up for recycling all the demolished concrete;
- Install temporary sheeting and shoring required to: remove some of the structures, protect adjacent structures and utilities, prevent over-excavation, and reduce inflow of groundwater during excavation below the water table. The contractor will be required to prepare for Port review a Sheeting and Shoring Plan that references each location where it will be employed. The structures that are anticipated to require temporary sheeting and shoring are:
    - The former OWS in the northwest corner of the TFA. This OWS needs to be removed to construct the cutoff wall. Historical drawings indicate the base of the OWS is approximately 7.5-ft below existing grades, and as noted above, the base may be up to 2.5 ft below the groundwater surface. In addition, the King County sanitary sewer (27-in. internal diameter and 55-in. outside diameter) is present below and slightly to the north of the OWS. At the northwest corner of the OWS it is estimated that the centerline of the sanitary sewer alignment is within 3 ft of the OWS and the crown of the sanitary sewer is approximately 7-ft below the base of the OWS. Therefore, caution will need to be exercised if installing sheeting in this area.
    - The approximately 9-ft deep, 4-ft diameter sump located approximately 10-ft north of Building M-28. This sump was filled with gravel as part of the tank farm decommissioning work in 2005.
    - The stormwater sumps in the three oil yards. These sumps are estimated to be approximately 8-ft deep. Since these structures are not located near to other structures, it may be feasible to safely remove these structures without shoring by sloping the excavation. However, sheeting may help control groundwater and reduce the volume of excavation and backfill, which may be a factor if highly contaminated soils are encountered.
    - The OWS, former steam vault, and existing manhole present outside the southeast corner of the Black Oil Yard. These structures are shown on Drawing C013, and Reference Drawings R002 and R007. The OWS is a conventional multi chamber structure measuring 11-ft long, 3.5-ft wide and 9-ft deep, which currently provides water quality treatment of stormwater on the east side of the TFA. The former steam vault consists of two chambers, which overall measure approximately 10-ft long, 8-ft wide and 8-ft deep. This structure is not thought to perform any function at this time. The two structures need to be removed to construct a replacement OWS and a Storm Filter treatment system to provide improved treatment of future runoff from the regraded TFA and ongoing treatment of the area to the east of the TFA. Both the removal of the structures and construction of replacement structures will require excavations approximately

10-ft deep. Due to the proximity of the location to roads, utilities and the cutoff wall alignment, sheeting and shoring will be required to control groundwater, ground movements and excavation limits.

- Stormwater runoff generated during construction activities will be managed consistent with the requirements of a Construction Stormwater General Permit (CSWGP) to be obtained by the contractor (see Section 12.1 for details). The CSWGP will require preparation of an Erosion and Sediment Control Plan that describes the best management practices and, as necessary, treatment procedures for managing stormwater during construction.

- Groundwater is expected to be encountered at an elevation below 13 ft, although the actual elevation will be affected by the amount of precipitation and season. The contractor will determine groundwater dewatering requirements and methods, and will be required to appropriately manage groundwater where excavations extend close to or below the water table. As with SWMU 30, the excavation may performed "in the wet", with groundwater maintained above the bottom of the excavation for stability purposes. The dewatering systems will be designed to reduce groundwater inflow as necessary to provide a stable excavation bottom and provide a reasonably dry base of excavation. Removed groundwater will be managed as described in Section 11.2 and in accordance with Section 02405 of the Technical Specifications. In general, groundwater removed from excavations in the TFA will be treated as necessary prior to discharge to the sanitary sewer under a permit with KCIW; and

- Remove and profile for off-site disposal at an approved facility any floating LNAPL encountered in the excavations or in dewatering collection tanks. A sheen may be visible on the water in the excavation after LNAPL removal is complete.

7.8 Stage 7 – Excavate Exploratory Trench and Perform Interim Site Grading

Following the removal of all below-grade concrete, excavate a 1-ft wide (minimum) exploratory trench along the alignment of the cutoff wall to explore for any man-made objects (e.g. structures, pipelines and utilities) that have not been encountered by the prior work, and that could affect the construction of the cutoff wall. The exploratory trench is shown on Drawing C019 and will include the following:

- Excavate the trench to an elevation of 11 ft or less (approximately 7 ft below surrounding grades); however, if the excavation associated with the concrete removal has reached this elevation, it will not be necessary to excavate the exploratory trench in the associated location;

- Remove soil that is classified as highly contaminated, profile and stockpile, or haul directly to an approved disposal treatment facility;

- Notify the Port immediately if any man-made objects are encountered in the exploratory trench and document the location; and

- To maintain consistency with the mix-design testing (PES, 2012a) for the construction of the cutoff wall, backfill the exploratory trench with soil removed from the exploratory trench, supplemented if necessary with material from close to the alignment of the exploratory trench;

- Following the completion of the exploratory trench, backfill the TFA with engineered fill, (using stockpiled soil that is not highly contaminated, recycled asphalt and concrete). The backfill will be placed and compacted in layers to the grades necessary to construct the cutoff wall. If excavation is conducted "in the wet," a geotextile separator will be deployed in the bottom of the excavation and gravel fill (essentially self-compacting material) will be placed to a minimum of 1 foot above the groundwater surface. Compacted engineered fill will then be placed above the gravel fill.

8.0 CUTOFF WALL

This section describes the design of the cutoff wall to be constructed around the perimeter of the former tank farm. The objectives of the cutoff wall are to:

1. Prevent migration of LNAPL from the TFLP;
2. Prevent groundwater from flowing through the former tank farm source area; and
3. Be compatible with the final cover system.

To meet these requirements, the cutoff wall has been designed, as follows:

- A top elevation of 15.2 to 15.6 ft and a bottom elevation of -0.7 ft (i.e. a height that varies from 15.9 to 16.3 ft);
- The upper 2 ft section made from soil-cement-bentonite with a minimum width of 6 ft; and
- The lower section made from soil-bentonite with a minimum width of 2 ft, and a hydraulic conductivity of 10^{-7} cm/sec or less.

The cutoff wall details are shown on Drawings C021 to C025 and C038 to C040, and Specification 02469.

In selecting this design, the following cutoff wall design issues were considered and are discussed below:

- Cutoff wall depth and subsurface conditions;
- Alignment relative to tank farm perimeter, buildings, utilities and structures;
- Structural integrity;
- Mix design; and
- Construction sequencing and construction method.

8.1 Subsurface Conditions and Cutoff Wall Top and Bottom Elevations

As discussed in Section 2.2, the subsurface conditions in the TFA consist of relatively permeable sandy soils with minor quantities of gravel and silt to a depth of over 40 ft, and silty clayey sand below this depth. Since the contaminants (LNAPL) are less dense than water, a “hanging wall” concept was selected as the preferred remedy in the CAP. With a hanging wall, it is not necessary to key the bottom of the cutoff wall into a low permeability zone to achieve the objectives (see above) as long as the bottom of the wall extends deep enough to be below the LNAPL fluctuation zone (essentially the groundwater surface). The CAP establishes 10 ft as the minimum depth the cutoff wall must extend below the low groundwater elevation.

Figure 5 shows the locations of current and abandoned monitoring wells in and around the TFA, and Table 8-1 summarizes the maximum and minimum shallow groundwater elevations recorded at each monitoring well located within or close to the cutoff wall alignment.

TABLE 8-1 – TFA GROUNDWATER ELEVATION SUMMARY

WELL	MAX WATER LEVEL (FT)	MIN WATER LEVEL (FT)	WELL	MAX WATER LEVEL (FT)	MIN WATER LEVEL (FT)
CP_PR-01	12.71	10.84	CP_103A	11.96	10.08
CP_PR-02	12.56	10.70	CP_104A	13.14	10.47
CP_PR-03	12.85	9.80	CP_106A	13.59	10.66
CP_PR-04	12.15	9.90	CP_108A	13.22	9.80
CP_PR-05	12.31	10.41	*CP_109*	*13.64*	*10.36*
CP_PR-06	12.64	10.77	CP_115A	13.61	10.73
CP_PR-07	12.50	9.84	*CP_116*	*13.93*	*9.91*
CP_PR-08	12.50	10.67	*CP_117*	*14.32*	*10.42*
CP_PR-09	12.56	10.73	*CP_118*	*14.19*	*10.04*
CP_PR-10	13.06	10.95	*CP-119*	*14.17*	*10.52*
CP_PR-11	12.43	10.74	CP_121	13.50	10.70
CP_PR-12	12.96	9.31	CP_W210	11.66	9.57
The maximum groundwater elevation adjacent to cutoff wall alignment = 13.6 ft at CP_106A, and CP_115A.					
Minimum groundwater elevation within, or close to, the cutoff wall alignment = 9.3 ft at CP_PR-12.					
Maximum groundwater range = 4.2 ft at CP_118.					
Wells in italics abandoned prior to 2005 tank farm demolition project.					

The lowest recorded groundwater elevation within or close to the cutoff wall alignment is 9.3 ft. This elevation was recorded in monitoring well CP-PR-12 in the northwest portion of the TFA. Therefore, based on this elevation and consistent with the CAP requirement that the bottom of the cutoff wall be approximately 10 ft below the low groundwater elevation, the design elevation of the bottom of cutoff wall is established at -0.7 ft.

The highest recorded groundwater elevation within or close to the cutoff wall alignment is approximately 13.6 ft on the north and northeast sides of the TFA (upgradient side of the TFA). This elevation was recorded in monitoring wells CP_106A and CP_115A. The highest recorded groundwater elevation on the south side of the TFA is 13.2 ft. This elevation was recorded in monitoring well CP_108A at the south east corner of the TFA (the other monitoring wells on the south side, CP_W210, CP_PR-03 and CP_PR-04 indicate maximum elevations up to 1.5 ft lower than in CP_108A). Additional groundwater elevation information is included in Appendix A3.

Evaluation of the historical groundwater flow across the former tank farm indicates that flow has generally been in the south to south-southwest direction with a gradient of roughly 0.001 to 0.003 ft/ft. Based on this very flat gradient, the potential for localized groundwater mounding on the upgradient side of the cutoff wall is expected to be on the order of several inches or less. Therefore, to be conservative, the top of the cutoff wall has been designed to be 2 ft above these maximum recorded elevations, and the design elevation of the top of the cutoff wall varies from an elevation of 15.6 ft in north portion of the TFA to 15.2 ft on the south side. These elevations will result in total cutoff wall heights ranging from 16.3 to 15.9 ft, and at least 2 ft between the top of the cutoff wall and the top of the final cover.

Consistent with this design concept, additional field investigation activities were conducted in the TFA as part of the Data Gaps Investigation (PES 2012a) to confirm the stratigraphic conditions and to collect soil, groundwater and LNAPL samples for the design of the cutoff wall. The DGI, which included drilling 7 borings to a maximum depth of 30 ft, confirmed the soils are:

- Relatively consistent along the cutoff wall alignment:
- Predominantly sandy with lesser quantities of gravel (size less than 1.5 in.) and fines;
- Generally coarser grained at shallow depth (less than 10 ft) and finer grained at greater depth (below 20 ft); and
- Non-plastic.

The generalized geologic cross-sections from the RI/DE report (Philip Environmental Services Corp., et al, 1999) included in Appendix A1 show these conditions along the majority of the cutoff wall alignment.

8.2 <u>Structural Integrity</u>

The most common type of cutoff walls for preventing pollution migration are made from soil-bentonite (SB), which has essentially no strength. However, SB cutoff walls usually only need to consider structural integrity with respect to the differential hydrostatic head across the wall. In situations where additional external loads are applied and potential ground deformations may be a concern (e.g. close to foundations or structures), or to provide flexibility relative to future development, cutoff walls made from soil-cement-bentonite (SCB) are a common choice to provide increased strength.

As detailed below, no conditions have been identified that necessitate the use of SCB for the cutoff wall as a whole. Therefore, as noted in Section 8.0, the greater part of the cutoff wall has been designed to be constructed using SB. However, because groundwater elevations require the top of the cutoff wall to be close to the final cover, the top of the wall has been designed with SCB (and overlying geogrid materials) to enable the final cover to bridge the cutoff wall.

8.2.1 Differential Hydrostatic Head

Typical construction practice is for SB cutoff walls to be constructed with a minimum nominal width of 2 ft. Case (1982) recommends that SB cutoff walls be designed with a width of 0.5 to

0.75 ft per 10 ft of hydrostatic head on the wall. On this basis the proposed 2-ft wide cutoff wall would be rated for approximately 27 to 40 ft of hydrostatic head. This will be more than adequate, since in this application hydrostatic heads are expected to be nominal, for the following reasons:

- The cutoff wall is a hanging wall, which is not keyed into an aquiclude. Therefore, groundwater will be able to pass under the wall, and hydrostatic elevations should equalize across the cutoff wall; and
- Even if the hydrostatic heads do not equalize, the maximum recorded groundwater elevation range at any monitoring well is approximately 4.2 ft, as documented in Table 8-1.

8.2.2 Additional External Loads

Future development. At this time, the Port is considering future development options for the TFA, but specific uses have not been determined. Given this uncertainty, the Port has decided that the cutoff wall and other components of the cleanup should be designed based on activities similar to those currently being conducted in the TFA (general materials storage and related traffic) and not based on potential future development options. Therefore, no external loads need be considered for future development.

Building M-28 East Side. The east side of Building M-28 consists of a 15-ft high monolithic reinforced concrete retaining wall that formed a portion of the containment wall around the Black Oil Yard. This wall has a 12-ft wide footing that likely imposes a relatively uniform vertical net load of less than 250 pounds per square foot (psf) due to the incremental dead load of the concrete. This will result in negligible stresses on the cutoff wall, which will be located approximately 10 ft from the edge of the retaining wall foundation. Stress calculations are included in Appendix A5.

Building M-28 North Side. The foundations supporting the north side of Building M-28 were explored by excavating shallow test pits at two locations (TP-3 and TP-4) during the DGI (PES 2011 and PES 2012a). As reported in the DGI:

> *TP-3 was located 12 ft from the northeast corner of Building M-28 where the building has a wooden siding exterior. An 8-inch thick concrete strip foundation was encountered at the location. The top of the foundation is located approximately 30 inches below grade and the foundation extends 4-in outside the building wall.*
>
> *TP-4 was located 22 ft from the northwest corner of Building M-28 where the building has a brick exterior. TP-4 met refusal on concrete at a depth of 19 inches below grade. This concrete surface extends out at least 6 ft from the building at this location and appeared to be consistent with concrete exposed at the northwest corner of the building and in the side of a service manhole located approximately 3.5 ft from the building corner. The concrete slab in the side of the service manhole was observed to be about 10-inches thick. The existing ground surface on the north side of M-28 has been filled over this slab and paved. The concrete layer was not penetrated by the test pit and the building foundation could not be accessed; however,*

based on the finding of TP-3 and the height of the building it is likely that this part of the building is also supported on a strip foundation.

Although the width of the foundation was not determined at TP-3, it should also be relatively lightly loaded (single story building with wood or brick walls), with a likely net foundation pressure of 1,000 psf or less (assuming a 3-ft wide foundation and a 15-ft high wall with a loading of 200 lb per foot height). This will result in negligible stresses on the cutoff wall, which will be located approximately 15 ft from the edge of the retaining wall foundation. Stress calculations are included in Appendix A5.

King County Sanitary Sewer. The King County sanitary sewer is a pressure system that was constructed in 1966. Details of the sewer adjacent to the north side of the TFA are contained on the following Reference Drawings:

- R012 - Drawing P205 Sheet 23 (Metropolitan Engineers for Municipality of Metropolitan Seattle, Feb 1966);
- R013 - Drawing P205 Sheet 24 (Metropolitan Engineers for Municipality of Metropolitan Seattle, Feb 1966);
- R014 - Drawing P205 Sheet 6 (Metropolitan Engineers for Municipality of Metropolitan Seattle, Feb 1966); and
- R015 - Drawing P205 Sheet 7 (Metropolitan Engineers for Municipality of Metropolitan Seattle, Feb 1966).

These drawings cover the section adjacent to the north side of the TFA and document the sanitary sewer:

- Was constructed by jacking a steel pipe from the manhole locations, pushing a reinforced concrete pipe on centering skids inside the steel pipe, and grouting the annulus between the concrete and steel pipes to create a composite pipe section with internal and external diameters of 27 and 55 in., respectively;
- Has invert elevations that slope at 0.1 percent from -0.72 ft at Manhole W10-91 near the northwest corner of the TFA, to -0.84 at Manhole W10-92 near the northwest corner of the Small Oil Yard, to -0.99 ft at Manhole W10-93 near the northeast corner of the TFA[7].

King County has a permanent 5-ft wide easement on either side of the sanitary sewer alignment. Accommodating the storm drainage improvements (to manage runoff from the final cover) will require approximately 5 ft outside the easement, and these stormwater improvements must be constructed outside of the geogrid that bridges the top of the cutoff wall and extends 10 ft outside the center line of the cutoff wall. As a result of these restrictions, the cutoff wall will be constructed approximately 15 ft from the edge of the easement (i.e. 20 ft from the center line of the sanitary sewer). Therefore, given the horizontal separation between the cutoff wall and the

[7] The elevations shown on the referenced sanitary sewer record drawings are relative to the King County and Metro datum, which is 94.08 ft above the MLLW datum.

sanitary sewer, and the similarity in elevation of the sanitary sewer and the bottom of the cutoff wall, the sewer will not impose any external stresses on the cutoff wall.

8.2.3 Final Cover

Along most of the alignment of the cutoff wall, the top of the cutoff wall will be approximately 2 ft below the top of the final cover. If the cutoff wall were constructed entirely of SB, this dimension would not be sufficient for the overlying materials (engineered fill and final cover) to span the cutoff wall alignment without risk of cover failure, because SB has a very low shear strength (typically 100 to 300 psf) and provides minimal resistance to deformation when loaded (nor would the 2-ft dimension be sufficient to enable the cutoff wall to be spanned using only the geosynthetic components proposed below). Therefore, the top of the cutoff wall below the final cover section has been modified, as shown on Drawing C040, as follows:

- The uppermost 2 ft of the cutoff wall will be widened to a minimum width of 6 ft (2 ft beyond both sides of the cutoff wall);

- The widened section will be constructed from SCB to provide a material with higher shear strength than the SB in the rest of the cutoff wall. SCB laboratory testing (Section 8.4.2; PES, 2012a) indicates that a SCB material with an unconfined compressive strength of at least 70 psi(10,000 psf; equivalent to a hard clay [Lambe and Whitman, 1969, p77.]) should be attainable with the proposed SB materials mixed with Portland cement;

- The widened SCB section will be overlain with a soil-geogrid composite system, consisting of, from bottom to top:

    - A uniaxial geogrid laid across the widened SBC section and secured in anchor trenches located 7 feet from the center line of the cutoff wall. The purpose of this layer is to develop tension if the underlying material starts to settle and thereby reduce the vertical load applied to the cutoff wall;

    - Select granular backfill, which will interlock with the geogrid and that can be placed over the underlying uniaxial geogrid without the use of heavy compaction equipment; and

    - A triaxial geogrid that extends out a minimum of 8 feet on both sides of the cutoff wall alignment. This geogrid will interlock with the underlying select granular backfill and the overlying final cover subbase, to increase the dissipation of applied pavement and reduce the stresses at the top of the cutoff wall.

Stress calculations for the uniaxial geogrid are included in Appendix A-4.

8.3 <u>Cutoff Wall Alignment</u>

The overall alignment of the cutoff wall is shown on Drawings C019 and C021 and summarized below.

- Station 0+00 to 1+03. In this section the alignment will be located 17 ft from the north side of Building M-28 and will also follow the alignment of the foundation of the former Marine Diesel Oil Yard containment wall.

- Station 1+03 to 1+50. In this section the cutoff wall alignment changes direction along a 30-ft radius curve.

- Station 1+50 to 3+15. In this section the alignment runs parallel to, but offset approximately 10 ft from, the west side of the TFLP. This section will approximately follow the alignment of the foundation of the former Marine Diesel Oil Yard containment wall foundation to approximately station 2+50. Extensive utilities located in Coontz Avenue just west of the tank farm prevent moving this portion of the cutoff wall further west.

- Station 3+15 to 3+55. In this section the cutoff wall alignment changes direction along a 30-ft radius curve, and passes through the footprint of the former OWS.

- Station 3+55 to 5+40. In this section the alignment runs along the north side of the TFA and includes a minor change of direction, which it is assumed can be constructed without the need for a radius curve. In this section the alignment will be parallel to, and offset 20 ft from, the center line of the King County sanitary sewer alignment, as discussed in Section 8.2.2 above. Additionally, the alignment follows the alignment of the former Small Oil Yard fire wall footing from approximately Station 4+10 to Station 5+40.

- Station 5+40 to 5+64. In this section the alignment changes direction along a 30-ft radius curve.

- Station 5+64 to 7+30. In this section the alignment runs along the northeast side of the TFA and will continue to be parallel to, and offset 20 ft from, the center line of the King County sanitary sewer alignment.

- Station 7+30 to 7+52. In this section the alignment changes direction along a 30-ft radius curve.

- Station 7+52 to 9+70. In this section the alignment runs along the east side of the TFA generally parallel to the inside edge of the former Marine Diesel Oil Yard and Black Oil Yard containment wall foundation.

- Station 9+70 to10+17. In this section the alignment changes direction along a 30-ft radius curve.

- Station 10+17 to 11+70. In this section the alignment runs along the south side of the TFA. In this section, in order to construct stormwater controls between the cutoff wall and the nearby gas line, the alignment has been set to run in line with the inside edge of the former Black Oil Yard containment wall foundation.

- Station 11+70 to12+17. In this section the alignment changes direction along a 30-ft radius curve.

- Station 12+17 to 13+53. In this section the alignment runs parallel to the east side of Building M-28. The alignment has been offset 12 ft from the inside edge of the former Black Oil Yard containment wall foundation (i.e. the foundation of the east wall of Building M-28).

- At Station 0+00/13+53 the north-south and east-west sections of the cutoff wall will be extended at full depth a minimum of 5 ft to ensure continuity of the cutoff wall at the cross over.

8.4 Design Mix

A comprehensive laboratory testing program was performed as part of the DGI (PES, 2011; 2012a) to develop design mixes for the cutoff wall. The DGI was implemented, and the laboratory testing program performed, before the decision about future site development and usage had been finalized, and information concerning the cutoff wall alignment relative to existing facilities (buildings and King County sanitary sewer) was available. Therefore, the laboratory program was tailored to provide flexibility in the final choice of cutoff wall type by considering design mixes for both SB and soil-cement-bentonite SCB.

With the decisions about future development and additional information about existing facilities, it has been determined (with the exception of the top of the cutoff wall, as discussed in Section 8.2.3) that the site conditions are compatible with an SB cutoff wall. The rest of the mix design discussion in this section considers the SB and SCB aspects relevant to the selected cutoff wall configuration. Full details of the laboratory testing performed to develop both the SB and SBC mix designs are contained in the DGI (PES 2012a).

8.4.1 Soil-Bentonite (SB) Design Mix

The SB design mix was developed to:

- Incorporate the soil that will be excavated along the cutoff wall alignment;

- Be chemically compatible with the contaminated groundwater and LNAPL; and

- Achieve a long-term saturated laboratory hydraulic conductivity of 5 x 10^{-8} cm/sec. or less to prevent the migration of LNAPL from the TFA. Because laboratory procedures are more controlled than in the field, this is the value recommended by the US Army Corps of Engineers ([USACE];1996) to achieve an in-place field value of 1 x 10^{-7} cm/sec. or less.

8.4.1.1 SB Design Mix Constituents

The final SB design mix contains the constituents that are shown in Table 8-2.

TABLE 8-2 SB DESIGN MIX CONSTITUENTS

CONSTITUENT	SOURCE
Soil	1. On-site soil samples obtained from the upper 20 ft from 7 borings located close to the alignment of the cutoff wall; and 2. Off-site, fine-grained soil, from Quality Aggregates, Maple Valley, Washington.
Bentonite	Hydrogel®, a commercially available bentonite from Wyoming Bentonite (Wyo-Ben) of Billings, Montana.
Water	Seattle City water available at T-91.

Prior to the start of the laboratory program, as discussed in the DGIWP (PES, 2011), it was recognized that the site soils are generally sandy, and that an off-site source of low-permeability soil (silt/clay) would be required to blend with the site soils to achieve an acceptable mix design. USACE (1996) provides the typical gradation criteria, contained in Table 8-3 below, for SB backfill soils to achieve a low permeability of $1x10^{-7}$ cm/sec or less:

TABLE 8-3 USACE (1996) GRADATION CRITERIA

SIEVE SIZE OR NUMBER (U.S. STANDARD)	PERCENT PASSING BY DRY WEIGHT
3 in.	100
No. 4 (0.187 in. / 4.75 mm)	40 – 80
No. 40 (0.167 in. / 0.425 mm)	25 - 60
Fines - No. 200 (0.0029 in. / 0.075 mm)	20 - 40

The laboratory testing of on-site soil samples, obtained from the upper 20 ft from 7 borings located close to the alignment of the cutoff wall, established the average gradations shown in Table 8-4.

TABLE 8-4 GRADATION OF ON-SITE SOIL

SIEVE SIZE	AVERAGE PERCENT PASSING BY WEIGHT (0 TO 20 FT)
3 in.	100.0
No. 4 (0.187 in. / 4.75 mm)	87.4
No. 40 (0.167 in. / 0.425 mm)	67.2
No. 200 (0.0029 in. / 0.075 mm)	9.6

As shown, the average fines content over the design depth of the cutoff wall is approximately 10 percent, which is outside the USACE's 20 to 40 percent recommended range. Therefore, several potential sources of fine grained soil were considered, and a soil sample from Quality Aggregates, Maple Valley, Washington was selected to develop the design mix. This soil source was selected because the sample:

- Contained over 98 percent fines (the high fines content will minimize the volume that will be needed to blend with the site soils); and
- Quality Aggregates indicated the same source would be available over the scheduled timeline of the cutoff wall construction activities.

8.4.1.2 SB Laboratory Testing Approach

To meet the SB design mix goals, a testing program consisting of the following four phases was implemented:

- **Phase 1 – Soil Index Testing** to evaluate physical characteristics of the subsurface soil and borrow soil samples.
- **Phase 2 – Compatibility Testing** to evaluate the potential for incompatibility between bentonite and City water, site groundwater and LNAPL.
- **Phase 3 – Workability Testing** to verify that the design mix is workable using typical construction techniques;
- **Phase 4 – Hydraulic Conductivity Testing** to evaluate the saturated hydraulic conductivity of the design mix and to assess the potential for long-term degradation of the design mix when permeated with site groundwater[8] and LNAPL.

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[8] The groundwater sample used for testing was obtained from monitoring well CP_PR-03, located near the southeast corner of Building M-28. Groundwater from this monitoring well is expected to be representative of groundwater chemistry along the slurry wall alignment based on review of 2001 and 2003 salinity data included in the Bridge Document Report 3 (Aspect Consulting, 2004), and recent field specific conductance (SC) data included in the 2010 annual report (Kennedy/Jenks Consultants, 2011) and 2011 annual report (Kennedy/Jenks Consultants, 2012). The 2001 and 2003 salinity data was collected from shallow monitoring wells along the southern edge of the former tank farm; the 2010 and 2011 field SC

8.4.1.3 Selected SB Design Mix and Properties

The selected SB design mix consists of:

- A blended mixture of on-site soil and off-site soil from Quality Aggregates, with a combined 30 percent fines content, by weight. Based on the laboratory measured properties of the soils, the combined 30 percent fines content will require the soil mix proportions shown in Table 8-5. Therefore, based on a 16-ft deep, 1,360-ft long cutoff wall, with a 2-ft nominal width (assumed constructed width of 2.5 ft), approximately 500 cy of off-site soil will be required.

TABLE 8-5 SOIL MIX PROPORTIONS

% ON-SITE SOIL		% OFF-SITE SOIL		% FINES BY DRY WT
BY WET WT	BY DRY WT	BY WET WT	BY DRY WT	
74	77	26	23	30

- Hydrogel bentonite at a minimum concentration of 5 percent by dry unit weight of soil; and
- City water added to provide a SB water content of approximately 30 percent.

Based on the laboratory testing the selected mix design will be expected to have the following properties:

- Slump – 4 to 6 in.;
- Unit weight – 115 pcf;
- Long-term saturated hydraulic conductivity of less than 1 x 10^{-7} cm/sec., and no long-term adverse reaction to permeation by groundwater or LNAPL.

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measurements were collected from shallow monitoring wells around the perimeter of the former tank farm. The SC measurements were converted to total dissolved solids (TDS), or salinity, using the approximation that TDS is 65 percent of SC (Hem, 1985, p. 67). The range of shallow groundwater salinity measurements along the southern edge of the former tank in 2001 and 2003 was between 400 and 600 mg/L, and the range of estimated salinity around the perimeter of the former tank farm in 2010 and 2011 was roughly between 100 and 400 mg/L.

Monitoring wells near the perimeter of the former tank farm are either screened in the shallow aquifer (well depths of between 12 and 15 ft deep), or in the deep confined aquifer (well depths of between 44 to 60 ft deep). Salinity data and field specific conductance data from deep monitoring wells indicate a relatively broad range of salinities: 300 to 6,300 mg/L, and it appears that the groundwater becomes more saline somewhere between the shallow and deep aquifers. Since none of the wells are screened across the silty sand confining layer, the transition from relatively fresh water to moderately saline water is not known. However, since the approximate 16 ft deep cutoff wall will be largely mixed using groundwater from the shallow aquifer (12 to 15 ft deep) and from city water, effects of groundwater from the silty sand confining layer are expected to be minimal.

8.4.2 Soil-Cement -Bentonite (SCB) Design Mix

Similar to the SB laboratory testing, The SBC design mix was developed to:

- Incorporate the soil that will be excavated along the cutoff wall alignment;
- Be chemically compatible with the contaminated groundwater and LNAPL;
- Achieve a long-term saturated laboratory hydraulic conductivity of 5 x 10^{-7} cm/sec. or less to prevent the migration of LNAPL from the TFA. Because laboratory procedures are more controlled than in the field, this is the value recommended by the USACE (1996) to achieve an in-place field value of 1 x 10^{-6} cm/sec. or less; and
- Determine unconfined compressive strength (UCS) relationships based on different cement contents.

8.4.2.1 SCB Design Mix Constituents

The SCB design mix testing was performed using SB mixtures (Section 8.4.1.1) plus commercially available Type I-II Portland cement.

8.4.2.2 SCB Laboratory Testing Approach

The SCB testing was performed using same four phases as the SB testing (Section 8.4.1.2), with the exception that Phase 3 included strength testing.

8.4.2.3 Selected SCB Design Mix and Properties

The SCB hydraulic conductivity testing showed that the final SB samples (which attained the required laboratory conductivity values when subject to long term testing using groundwater and LNAPL as permeants), when mixed with 6 percent cement attained the desired long-term laboratory hydraulic conductivity of less than 5 x 10^{-7} cm/sec.

The SCB strength testing indicated UCS increased with increasing cement content and mixes with more than 4.5 percent cement (by dry unit weight of soil) achieved a UCS of more than 8,000 psf at 28 days. The data also showed that strength increases were continuing after 28 days, and the strength data varied by 30 percent for similar batches made at different times.

The main design function of the SCB material will be to bridge the underlying CB material to allow the cover system to function without excessive deformation. The SCB will be used in the upper 2 ft of the cutoff wall, which is the zone above the highest recorded groundwater elevation in the TFA. Therefore, the selected SCB mix design consists of:

- The SB design mix (Section 8.4.1.3);
- Type I-II Portland cement at a minimum concentration of 8 percent (by dry unit weight of soil); and
- Additional City water to provide a water content of approximately 45 percent.

Based on the laboratory testing the selected mix design will be expected to have the following in-place field properties:

- Slump – 4 to 6 in.;
- Unit weight – 110 pcf;
- UCS at 28 days greater than 70 psi (10,000 psf);
- Long-term saturated hydraulic conductivity of less than 1 x 10^{-6} cm/sec., and no long-term adverse reaction to permeation by groundwater or LNAPL.

8.5 Construction Sequencing and Method

8.5.1 Construction Sequencing

The following general construction procedures are anticipated:

- Prepare the whole of the TFA as discussed in Section 7, including backfilling the area to grades required to construct the cutoff wall;
- If necessary, construct temporary berms, or a working trench, along the cutoff wall alignment to contain materials during the cutoff wall construction activities;
- Establish the necessary cutoff wall construction support equipment;
- Construct the cutoff wall from SB in accordance with the mix design (Section 8.4.1.3) and perform quality control and quality assurance tests during and after construction;
- Observe the top of the cutoff wall for 5 days and add additional SB if the surface of the wall settles following construction;
- Use excess soil-bentonite from the alignment, or mix additional soil bentonite, and mix with cement to construct the widened (6-ft minimum width), upper 2-ft section of the cutoff wall from SCB;
- Cover the SCB with plastic sheeting to prevent desiccation of the SCB;
- Construct the LNAPL trenches, as described in Section 9;
- All equipment involved in the construction of the cutoff wall will be decontaminated and removed from the TFLP; and
- The geosynthetics over the cutoff wall, final grading, final cover, and stormwater elements will be constructed, as described in Sections 10 and 11.

8.5.2 Construction Method

Construction of a traditional SB cutoff wall typically involves excavating the soils from the alignment of the cutoff wall with a backhoe to create a trench, temporarily filling the trench with bentonite slurry to maintain the stability of the trench, mixing the excavated soil with bentonite on the ground adjacent to the trench, and then pushing the soil-bentonite mixture into the trench with dozers to displace the bentonite slurry.

An alternate to the traditional method is the One-Pass Trenching (OPT) construction method. The OPT method employs a track-mounted vehicle equipped with a cutting boom that resembles a large chain saw. In this method the soil, bentonite (in powder and/or pre-hydrated slurry form), and, if necessary, water are mixed in situ without the need to excavate the soil and support an open trench with bentonite slurry, or manage and mix potentially contaminated soils on the ground adjacent to the alignment. This continuous and simultaneous trenching and mixing process reduces the potential for irregularities and discontinuities in the SB cutoff wall, and should result in a thoroughly mixed homogeneous soil-bentonite material.

It is recommended that the OPT method be used to construct the cutoff wall around the TFA for various reasons, including those presented in Table 8-6. Additionally, the OPT method may be suitable as a method to construct the LNAPL collection trenches within the cutoff wall alignment where no utilities are present (Section 9).

TABLE 8-6 OPT CONSTRUCTION METHOD CONSIDERATIONS

CONSTRUCTION CONSIDERATION	OPT RELEVANT CHARACTERISTIC
Alignment – the alignment includes a series of 8 changes of direction, with five of those changes requiring a 90 degree change in direction	The OPT can typically execute turns with a minimum radius of approximately 30 ft. Since the OPT only disturbs soil along the vertical chain the OPT will maintain a consistent trench width. In contrast, a backhoe has to sweep through the entire boom length and has less control through a turn as it makes sequential excavating sweeps.
Trench depth	The OPT boom depth can be set accurately and observed continuously as the cutoff wall is constructed. In contrast, with a backhoe, the depth has to be measured and there is greater potential for the bottom of the trench to heave and soil to fall from the sides of the trench.
On site soil	The OPT mixes soil in place. Only sufficient soil will need to be removed from the cutoff wall alignment to blend in the off-site soil and bentonite. This will minimize the need for potentially contaminated soil and groundwater/LNAPL to be managed. Construction with a backhoe will require all alignment soils to be excavated, exposed to the environment with greater potential health and safety and odor considerations.
Soil blending quantities	Soil blending should be able to be controlled accurately with OPT. The upper part of the cutoff wall alignment could be pre-excavated to a controlled depth and backfilled with an accurately controlled quantity of off-site soil. Blending soil on the ground using traditional construction methods will inherently be less controlled and subject to greater variability in the proportions of the mixed materials.

Soil blending effectiveness	The OPT is capable of breaking soil materials into small sizes and achieving a homogeneous product. The speed of the chain can be adjusted, and the machine speed can be changed to modify the mixing residency time and ensure a homogeneous product. Blending soil on the ground with construction equipment will inherently be unable to achieve the same degree of material dispersion and blending.
Cleanliness	Since the OPT method performs the mixing in situ, it is a relatively clean method. Material mixing on the ground surface results in bentonite slurry and soil-bentonite backfill materials being spread and tracked over a considerable area outside the cutoff wall alignment.

9.0 ENHANCED LNAPL RECOVERY SYSTEM

This work element includes installation of five passive LNAPL recovery trenches in areas most likely to contain recoverable LNAPL. Four of the trenches will be installed inside the cutoff wall alignment (see Section 8), and one trench will be installed in the former fuel line area directly west of the TFA. As described in the CAP (PES, 2010), the objective of the LNAPL recovery system is to remove recoverable LNAPL to the extent practicable using passive recovery techniques. Key design criteria include:

- Extend LNAPL recovery trenches above and below the seasonal water table to allow for potential year-round accumulation and recovery of LNAPL;
- Install granular trench backfill with higher permeability than surrounding sandy soil to promote LNAPL accumulation in the trench; and
- Locate trenches near monitoring wells with accumulations of recoverable LNAPL since 2010.

9.1 Design Basis

As described in the CAP and recent status report (Kennedy/Jenks Consultants, 2012b), the most likely areas for potential LNAPL recovery are in and around the western portion of the former tank farm. The following includes discussion of existing TFLP area monitoring wells that have had recoverable LNAPL in recent years (through February 2012), and provides the rationale for the location of the passive LNAPL recovery trenches in the Small Oil Yard, Marine Diesel Oil Yard, Black Oil Yard, and the former pipeline area.

- **Small Oil Yard.** Two of the four monitoring wells in the Small Oil Yard area (i.e., areas north of the Marine Diesel Oil Yard) have had recoverable LNAPL in recent history: CP_PR-01 and CP_PR-12. LNAPL monitoring in CP- PR-01 began in October 2005, and recoverable LNAPL developed in August 2008. Recoverable LNAPL has been infrequently present and a total 1.5 gallons of LNAPL has been recovered. Conversely, recoverable LNAPL has been consistently present in CP_PR-12 since monitoring began in November 2007, with weekly and monthly recovery yielding more than 107 gallons of LNAPL. Enhanced LNAPL recovery is recommended near CP_PR-12, and as shown on Drawing C026, trenches will be installed both upgradient and downgradient of the well location. Continued LNAPL recovery near the CP_PR-01 location is not necessary due to the interior location and limited LNAPL presence of recoverable LNAPL.

- **Marine Diesel Oil Yard.** Two of the four monitoring wells in the Marine Diesel Oil Yard have had recoverable LNAPL in recent history: CP_PR-02 and CP_PR-07. LNAPL monitoring in CP_PR-02 began in October 2005, and recoverable LNAPL developed in March 2008. Recoverable LNAPL has been intermittently present, and a total of 6.8 gallons of LNAPL has been recovered. Conversely, recoverable LNAPL has been consistently present in CP_PR-07 since monitoring began in November 2007, with monthly recovery yielding more than 8.1 gallons of LNAPL. Enhanced LNAPL recovery is recommended near CP_PR-07 to minimize the potential for LNAPL buildup on the upgradient edge of the nearby cutoff wall. As shown on Drawing C026, one trench will be installed between the cutoff wall and the monitoring well location, with both the cutoff wall and trench being located close to Building M-28. This LNAPL recovery trench should also serve the CP_PR-02 area should mobile LNAPL develop.

- **<u>Black Oil Yard.</u>** Two of the three monitoring wells in the Black Oil Yard have had recoverable LNAPL in recent history: CP_PR-03 and CP_PR-04. LNAPL monitoring began in both wells in November 2007. Recoverable LNAPL has been consistently present in CP_PR-03 since May 2009 and has resulted in a total of 3.6 gallons of LNAPL. LNAPL has declined in CP_PR-04 and recoverable LNAPL has been present on only one occasion since October 2010. Enhanced LNAPL recovery is recommended near CP_PR-03, but not near CP_PR-04. As shown on Drawing C026, one trench will be installed between the cutoff wall and the monitoring well location.

- **<u>Former Fuel Pipeline Area.</u>** Three of the five monitoring wells in the former fuel pipeline area have had recoverable LNAPL in recent history: UT_MW39-2, UT_MW39-3, and PNO_MW104. UT-MW39-2 was incorporated into the LNAPL monitoring program in August 2008 due to presence of recoverable LNAPL, and a total of 4.2 gallons of LNAPL has been recovered in the last four-plus years. LNAPL has been consistently present in UT_MW39-3 since monitoring began in March 2000, and a total of 13 gallons of LNAPL has been recovered. PNO_MW104 was incorporated into the LNAPL monitoring network in March 2008, with intermittent presence of recoverable LNAPL and a total of 1.4 gallons of LNAPL recovered. Enhanced LNAPL recovery is recommended near UT_MW39-2 and UT_MW39-3 since these wells are located outside of the cutoff wall, and one trench will be installed south of UT_MW39-2 as shown on Drawing C026. The exact location of the trench will be determined in the field based on setbacks from buildings required for contractor trenching equipment, several buried utilities, and a rail-spur. Enhanced LNAPL recovery is not necessary near PNO_MW104, although this well should remain in the LNAPL monitoring program.

Some excavated LNAPL trench soil is expected to be considered highly contaminated. This contaminated soil will be stockpiled separately and profiled for off-site disposal at an approved facility as described in Section 11. However, soil that is not highly contaminated will be stockpiled for potential reuse as backfill material.

Trenches will be constructed with a granular filter pack that extends at least 1.5 ft into the vadose zone[9], across the smear zone[10], and approximately 3 ft into the saturated zone[11]. The seasonal groundwater and LNAPL elevations were determined through review of historical groundwater monitoring data from 1993 through 2011 (See Appendix A3) for monitoring wells located within the cutoff wall alignment, monitoring wells located around the perimeter of the cutoff wall, and monitoring wells with historical LNAPL located in the former fuel pipeline area, including the following:

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[9] Vadose zone soil is defined as soil located above the seasonal high groundwater or LNAPL elevation.
[10] smear zone soil is defined as soil located between the seasonal high groundwater or LNAPL elevation and the seasonal low groundwater elevation.
[11] saturated zone soil is defined as soil located below the seasonal low groundwater elevation.

- Monitoring wells within the cutoff wall alignment include existing wells CP_PR-01 through CP_PR-12, and abandoned monitoring wells CP_109, and CP-116 through CP-119.
- Monitoring wells outside of the cutoff wall alignment include CP_103A, CP_104A, CP_106A, CP_108A, CP_114, CP_115A, CP_121, and CP_W210.
- Monitoring wells in the former fuel pipeline area include CP_107, CP_110, UT_MW39-2, and UT_MW39-3.

The LNAPL collection trenches are designed to extend at least 1.5 feet above the historical maximum groundwater elevation, which is as far above the elevation of high groundwater level as practicable given the final cover design and other site constraints, and are designed to accommodate the roughly 2 to 3 ft seasonal groundwater level variation that has been observed at the Site. Historical groundwater flow across the former tank farm has generally been in the south to south-southwest direction with a gradient of roughly 0.001 to 0.003 ft/ft. The potential for localized groundwater mounding on the upgradient side of the cutoff wall is not expected to exceed a few inches. Therefore, any localized mounding is expected to be well within the vertical freeboard of the cutoff wall and granular portion of the LNAPL trenches, and is expected to have relatively little effect on the potential for localized LNAPL migration. In addition, the LNAPL monitoring data generally indicate that the greatest potential for LNAPL accumulation in groundwater and in LNAPL collection trenches will occur when groundwater elevations are low, in which case slight mounding should have relatively little effect.

9.2 Design Criteria and Assumptions

The following design criteria and assumptions have been established for the LNAPL trenches:

- A minimum ground surface elevation of 18 ft in areas of the LNAPL recovery trenches within the cutoff wall alignment (LNAPL Trenches 1 to 4).
- Approximate ground surface elevation of 17.5 ft in the area of the LNAPL recovery trench located adjacent to Building W-39 to the west of the cutoff wall in the former fuel pipeline area (LNAPL Trench 5).
- Seasonal high groundwater or LNAPL elevations of 14.3 ft. The historical maximum elevations were between 12.15 and 14.32 ft for current and abandoned monitoring wells located within the cutoff wall alignment, between 11.66 and 13.68 ft for the monitoring wells located around the perimeter of former tank farm, and between 12.60 and 13.64 ft for wells in the former fuel pipeline area.
- Seasonal low groundwater elevation of 9.3 ft. The historical minimum groundwater elevations were between 9.31 and 10.84 ft for current and abandoned monitoring wells located within the cutoff wall alignment, between 9.57 and 10.79 ft for the monitoring wells located around the perimeter of the cutoff wall alignment, and between 9.36 and 11.39 ft for wells in the former fuel pipeline area.
- Typically LNAPL recovery has been greater when the water table is low. Therefore, set the springline (centerline) of the horizontal LNAPL collection pipes at the average annual low groundwater elevation as determined using the last 5 years of water level

monitoring data from monitoring wells around the perimeter of the former tank farm and in Coontz Avenue. Interpolate the estimated horizontal collection pipe elevation for each trench.

- The annual low groundwater elevations have varied from year to year in each of the monitoring wells. The average annual variance across all of the nearby wells is 0.8 ft, with a range of 0.5 ft to 1.1 ft between the individual monitoring wells. Size the horizontal LNAPL collection pipes to 12-in. nominal diameter to account for the range of annual low water levels.
- LNAPL trench bottom elevation of 6.3 ft.
- Existing soil in the area of LNAPL trenches is predominantly coarse- to fine-grained sand as shown in the DGI (PES, 2012a).

9.3 Construction Sequencing

The sequence for the LNAPL trench construction will be refined after the contractor is selected. The general construction sequence assumes that the LNAPL trenches will be installed after the cutoff wall has been constructed, but prior to completing the site grading for the final cover. The anticipated construction sequence for the LNAPL trenches inside the cutoff wall alignment (LNAPL Trenches 1 to 4) will differ from the construction sequence for the LNAPL trench outside the cutoff wall alignment (LNAPL Trench 5).

9.3.1 LNAPL Trenches 1 through 4

LNAPL trenches 1 through 4 are located within the cutoff wall alignment. The work zones, stockpile and soil profile areas, materials storage areas, truck routes, groundwater treatment and disposal systems, stormwater BMPs which were established for the TFA site preparation and cutoff wall construction will be maintained. The following is the anticipated construction sequence:

- Providing, installing and maintaining trench safety systems;
- Constructing and operating water collection systems to manage stormwater run-on, groundwater, and LNAPL that may accumulate in the trenches;
- Excavating, loading, hauling, and stockpiling soil excavated from the trenches;
- Excavating, loading, hauling, and stockpiling highly contaminated soil from the trenches; and
- Constructing the trenches as discussed in Section 9.4.

9.3.2 LNAPL Trench 5

LNAPL trench 5 is located outside of the cutoff wall alignment in the former fuel pipeline area.

The following is the anticipated construction sequence:

- Adjusting work zones, truck routes, groundwater controls, and stormwater BMPs to include LNAPL trench construction in the former fuel pipeline area. Maintain stockpile and soil profile areas, materials storage areas, and groundwater treatment and disposal systems established for the TFLP site preparation and cutoff wall construction;
- Removing existing asphalt and base course in the former fuel pipeline area. Any soil or potential contaminant adhering to the demolished surface materials that is to be recycled or reused will be removed. Reusable asphalt will be crushed and screened for use as engineered fill. Materials that cannot be recycled or reused will be stockpiled on-site, profiled, and disposed at an appropriate facility.
- Exposing, supporting and protecting, or temporarily rerouting, encountered utilities including natural gas, water, and storm sewers. Utility locations are shown on Drawing C026;
- Supporting and protecting, or temporarily removing a section of the rail spur. Rail spur location is shown on Drawing C026;
- Constructing and operating water collection systems to manage stormwater run-on, groundwater, and LNAPL that may accumulate in the trenches;
- Exposing, cutting, cleaning, and capping the former fuel pipelines that cross the LNAPL trench as described in Section 4;
- Providing, installing and maintaining trench safety systems;
- Excavating, loading, hauling, and stockpiling soil excavated from the trench;
- Excavating, loading, hauling, and stockpiling highly contaminated soil from the trench; and
- Constructing the trench as discussed in Section 9.4

9.3.3 Water Management

The contractor will be required to manage groundwater and stormwater runoff that accumulates in the subgrade work areas.

Stormwater runoff generated during construction activities will be managed consistent with the requirements of a Construction Stormwater General Permit (CSWGP) to be obtained by the contractor (see Section 12.1 for details). The CSWGP will require preparation of an Erosion and Sediment Control Plan that describes the best management practices and, as necessary, treatment procedures for managing stormwater during construction.

Removed groundwater will be managed as described in Section 11.2 and in accordance with Section 02405 of the Technical Specifications. In general, groundwater removed from excavations in the TFA will be treated as necessary prior to discharge to the sanitary sewer under a permit with KCIW.

9.4 LNAPL Trench Construction

As described above, the five LNAPL recovery trenches will be installed in areas proximate to monitoring wells in which LNAPL has been observed. Trench locations are shown on Drawing C026, and trench details and sections are show on Drawing C027. LNAPL Trenches 1 through 4 will be 78-ft long, and Trench 5 will be 58 ft long. The trenches will be 3 ft wide, and constructed to a bottom elevation of 6.3 ft. The trenches will be backfilled with select gravel to at least elevations of 15.1 ft (Trench 5) and 15.7 ft (Trenches 1 to 4) so that the select gravel extends at least 1.5 ft above the historical high groundwater or LNAPL elevation. The trenches will include slotted 12-in. diameter horizontal collection piping, vertical collection piping sump and risers at each end, and access vaults at each riser. Collection piping lengths and depths are shown on tables included on drawings C026 and C027.

- **LNAPL Collection Pipe.** The horizontal LNAPL collection pipes within the trenches will be nominally 70 ft long in Trenches 1 through 4, and 50 ft long in Trench 5. Collection piping includes a factory-slotted 12-in. diameter PVC well screen set at the average annual low groundwater elevation for each location. Well screen, piping, and fittings will be constructed of Schedule 40 PVC with the exception of the horizontal well screen in Trench 5 which will be Schedule 80 PVC due to the anticipated additional loading from the rail spur. Note that the pipe schedule (wall thickness) for the horizontal PVC well screen was developed using technical guidance from a PVC pipe manufacturer (JM Eagle, 2009). The guidance includes a simplified and conservative version of the Modified Iowa Equation and lookup tables for determining diametric pipe deflection under a range of burial depths, and utilizes project specific information including live load, backfill type (gravel), and compaction (loose). Trenches 1 – 4 assume a live load based on American Association of State Highway and Transportation Officials (AASHTO) H-20 (or HS-20) truck traffic load which simulates a 20-ton truck traffic load (with impact); and Trench 5 assumes a live load based on Cooper E-80 railroad loads which simulates an 80,000 lb/ft railway load (with impact).

- **Collection Sump.** A 12-in. diameter collection sump will be installed at each end of the trench connected to the slotted horizontal collection pipe. The sump pipe will be constructed of factory slotted Schedule 40 PVC well screen within the select gravel zone, and Schedule 40 PVC blank pipe above the gravel. The blank pipe will daylight in an access vault and be capped.

- **Slotted Pipe.** Slotted collection pipes will include 0.125-inch wide slots spaced 0.15-inches apart with at least 15% open area per ft of screen.

- **Access Vault.** Traffic-rated vaults and lids rated for H20 traffic (i.e., highway loading), will be installed to access the collection sump and cleanout pipes. The collection sump vaults are sized to accommodate LNAPL skimming equipment if automated LNAPL collection is required in the future.

- **Gravel.** Engineered gravel fill will be placed in each of the trenches per Sections 02338, 02339, and 02621 of the Technical Specifications. The LNAPL trench gravel is designed to be at least as permeable as the formation, provide stability to prevent the formation from piping into the trench, and to be held back by the slotted LNAPL collection pipes. Geotextile separation layer will be installed above the gravel. Engineered fill design information is included in Appendix A6.

- Compacted backfill will be installed above the select gravel to the bottom of pavement elevation.
- Final backfilling, grading, and paving will be performed as described in Section 10.

LNAPL trenches located inside of the cutoff wall alignment are not expected to encounter subsurface obstructions because, as described in Section 7.0, all subsurface structures, pipelines, and utilities will be removed from inside the cutoff wall alignment.

10.0 FINAL COVER AND STORMWATER MANAGEMENT SYSTEM

This section describes the final cover system to be constructed over the TFA and the associated stormwater management system components that will be integrated to manage runoff from the TFA.

10.1 Final Cover

10.1.1 Existing Final Cover

The existing cover system, which was constructed after the aboveground portion of the tank farm was decommissioned in 2005, consists of fill soils and asphalt pavement. The current topography (Drawing C013) shows that most of the area slopes inwards to a network of storm water collection structures that were part of the former tank farm storm water management system, and which are pumped into the T-91 storm water system near the southeast corner of Building M-28, for discharge at the north end of the Submerged Area on the east side of Pier 90.

As part of the cleanup preparation activities to construct the cutoff wall, the materials used to construct the existing cover (asphalt and base course) will be recovered and stockpiled for recycling as described in Section 7.0. The general fill will be reused as engineered fill in the TFA and the asphalt will either be ground and reused as fill or hauled off-site for recycling. Boring records in the area report a typical asphalt thickness of 3 in., as shown on Drawing C015. Therefore, based on the TFA outline (Drawing C012), which encloses an area of approximately 3.4 acres, approximately 1,375 cy of asphalt will be generated.

10.1.2 New Final Cover

The new cover will be constructed after the cutoff wall and LNAPL trenches have been constructed. The final cover, as depicted on Drawings C028 to C033, is based on the following design assumptions:

- This final cover is intended to minimize infiltration of precipitation and prevent direct contact with residual contaminants;
- As noted in Section 8.2, the Port has decided that the final cover and other components of the cleanup should be designed based on activities similar to those currently being conducted in the TFA (general materials storage and related traffic) and not based on potential future development options;
- The cover will generally be graded at a minimum slope of 2 percent to promote storm water runoff, and a maximum slope of 5 percent, to ensure site usability;
- The cover grades will match existing grades to the extent practicable to minimize over-paving and to reduce restrictions to future vehicular access;
- On the east side of Building M-28, the cover will be sloped at 5 percent away from the building to prevent ponding and flow along the building edge;

- On the north side of Building M-28, a 5-ft wide walkway will be provided to maintain access to a doorway near the northeast corner of the building. A gravity block retaining wall (Ultrablock or equivalent) will be constructed to provide grade separation between the final cover and the walkway. A maximum of fill height of 5 ft is anticipated adjacent to the retaining wall (See Appendix A5);
- The final cover grades attempt to balance anticipated cleanup material volumes with the volume of fill required below the final cover, while allowing for non-reusable debris and highly contaminated soil to be removed from the Site. However, the material balance is based on assumptions about the quantity of material that will be available for reuse (i.e., recycled concrete, recycled asphalt, and soil that is not classified as highly contaminated). If the actual quantities differ from the assumed quantities, final grades will be managed in one of the following ways: (i) the final grades may be adjusted at the time of construction, within the 5 percent maximum and 2 percent minimum design slope constraints, based on actual quantities available; (ii) excess material may be removed from the site; or (iii) additional borrow soil may be imported;
- The grading provides a minimum grade separation of 2-ft between the top of the cutoff wall and final grade to enable the pavement to bridge the slurry wall. This bridging will be enhanced by constructing the top of the cutoff wall from soil-cement-bentonite and placing geogrid layers across the top of the cutoff wall. Select granular fill will be placed above the geogrid layers to ensure interaction between the soil and geogrid;
- All engineered fill will be placed and compacted in controlled lifts;
- Consistent with the Port's standards for trafficked areas, the final cover section above the fill will consist of:
  - A 4-in. thick layer of compacted Class B hot mix asphalt;
  - A 4-in. thick layer of ¾-in. minus crushed rock base course; and
  - A 4 -in. thick layer of 1½-in. minus crushed rock subbase.
- An asphalt permeability standard will not be required since the groundwater surface will be able to fluctuate within the alignment of the "hanging" cutoff wall (Section 8).
- The cover will drain all storm water to outside the cutoff wall alignment (unlike the present cover, storm water will not be collected within the TFA);
- The cover has been divided into five distinct drainage area as discussed in Section 10-2. The portion that drains west will be integrated with the existing storm water management system in Coontz Avenue. The remaining portions of the cover, on the north, east and south sides, drain to shallow (0.1 to 0.6-ft deep) 10-ft wide collection swales built into the final cover outside the cutoff wall alignment. The swales have been designed with longitudinal slopes of 1 percent, and discharge into collection basins and manholes at the low points to enable the runoff to be captured and treated to meet water quality objectives; and
- Consistent with the requirements of the Stormwater Code Interagency Agreement between the Port and the City of Seattle, "the Port shall comply with all substantive requirements of the City Stormwater Code for all its facilities, whether or not they

discharge to City drainage control systems or public combined sewers, but the Port shall not be required to obtain permits required by the Stormwater, Grading and Drainage Control Code where the project site does not discharge to a City drainage control system or public combined sewer and the project will not undercut or otherwise endanger adjacent property." The Port's "Project Design Guidance Manual" will be used during the final design of the stormwater management components of the final cover.

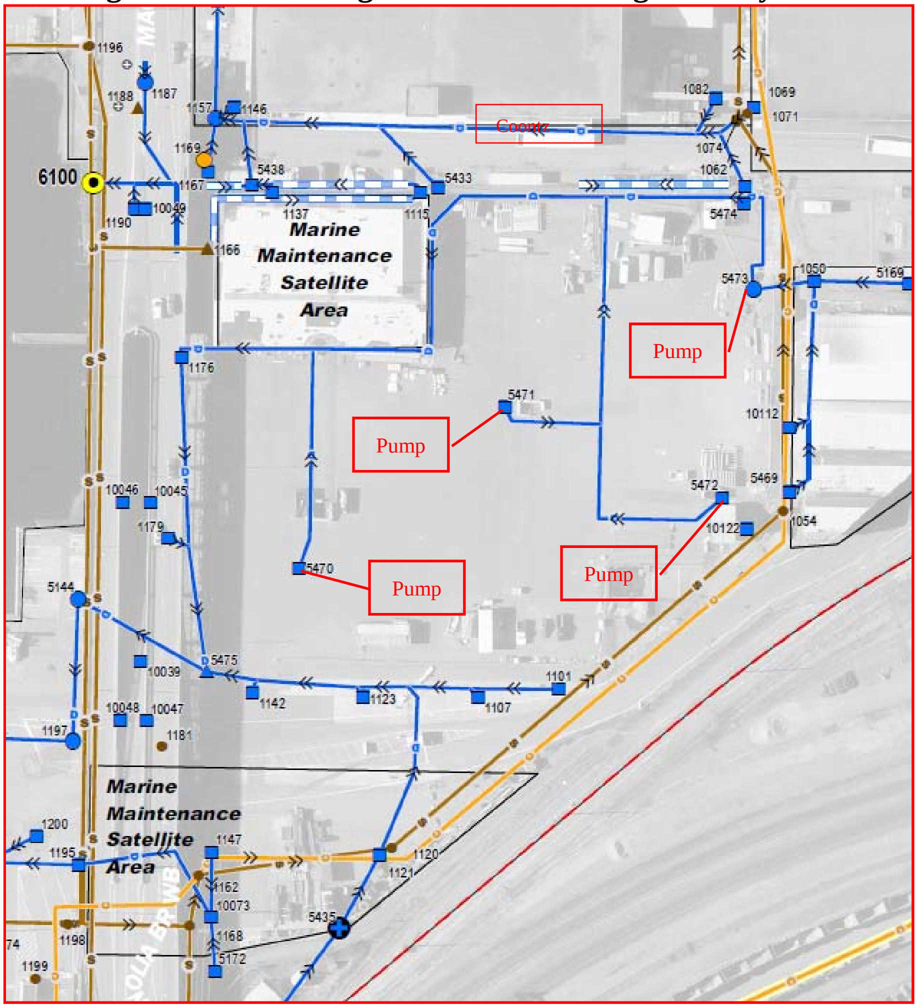
10.2 Stormwater Management

10.2.1 Existing System

The existing stormwater management system in the TFA consists of a series of catch basins and four small pumping stations, referenced as Structures 5470 to 5473 on the Seaport Stormwater Map, a portion of which is shown below. The force mains from these pumps are installed on the ground surface and discharge to gravity storm drains.

Structure 5473, which collects stormwater from the TFA and catch basins to the west of Building M-19, may discharge to the drain system in Coontz Avenue, or may combine with the discharges from the other three pumping stations and discharge to Structure 1176, near the southeast corner of Building M-28, which flows under gravity to Structure 5475 (an OWS) at the southeast corner of the TFA. Flow at Structure 5475 is combined with stormwater collected on the east side of the TFA and passes through an existing OWS before discharging. Figure 10-1 shows the existing stormwater management system.

Figure 10-1 - Existing Stormwater Management System



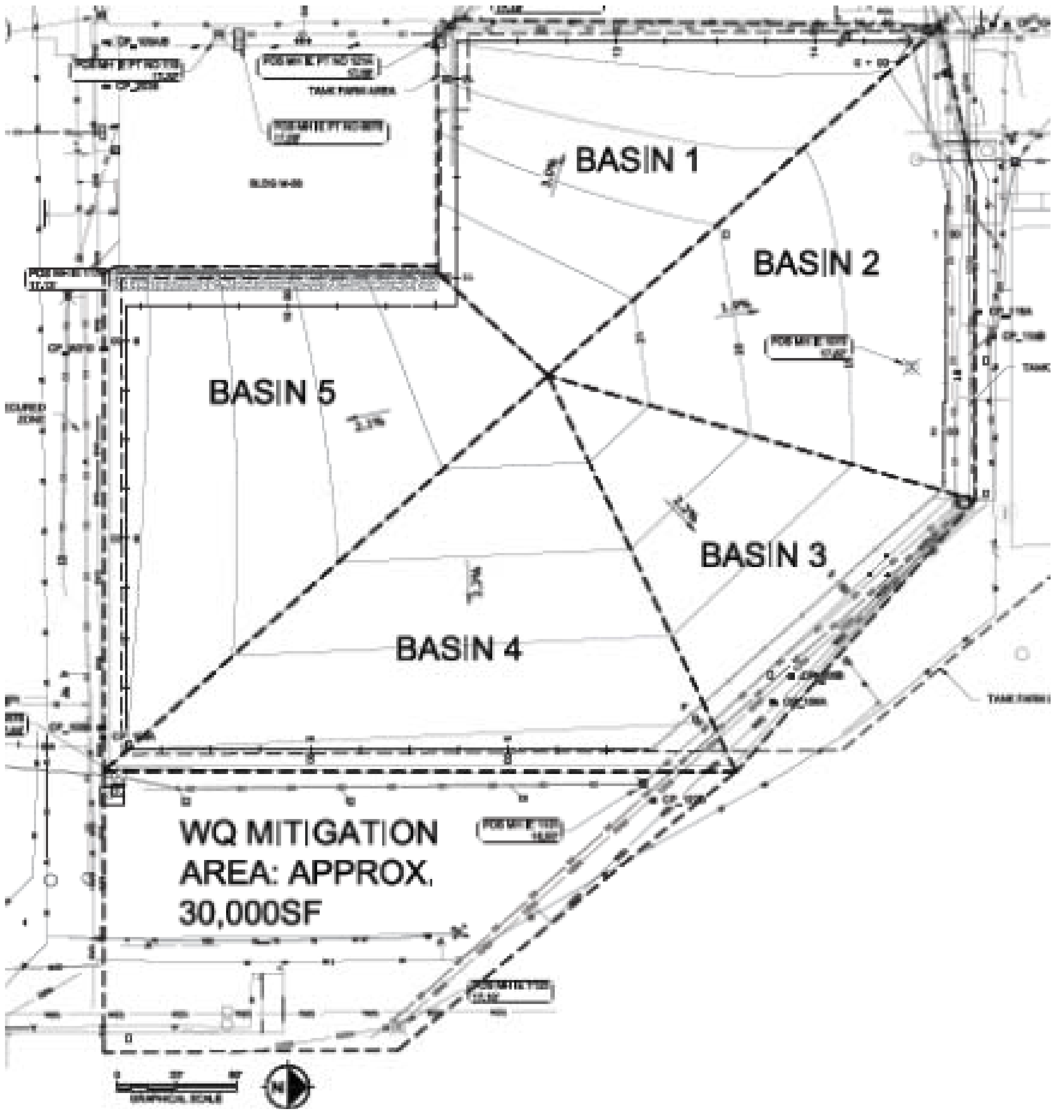
10.2.2 Hydrology and Hydraulic Analysis

HydroCAD was used to model the stormwater runoff from the final cover. The model used the SCS Method with a Type 1A storm to simulate runoff from the site. The entire area was modeled as pavement and runoff rates were determined for 10-yr and 100-yr 24 hour events. The model was also used to evaluate the hydraulic analysis and verify the selection of pipe sizes. The modeling results are shown in Appendix A7.

Although the outlet of the site drainage system will be surcharged by high tides, the Ecology WWHM3 model was used to calculate the water quality (WQ) design flow for the project. The WQ flow is based on the area of replaced pavement in the remediation area plus the area of replaced pavement from SWMU 30 (approximately 4,000 square feet [sf]). The results of the WQ modeling are shown in Appendix A7.

Figure 10-2 shows the drainage basins for the design final cover.

Figure 10-2 – Final Cover Drainage Basins



The following table summarizes these drainage areas:

TABLE 10-1 FINAL COVER DRAINAGE AREAS

BASIN NUMBER	AREA (SF)	AREA (ACRE)
1	26,462	0.61
2	26,827	0.62
3	18,692	0.43
4	32,059	0.74
5	33,317	0.76
Subtotal	*137,357*	*3.153*
ADDITIONAL AREAS		
SWMU 30 North Area	1,560	0.04
SWMU 30 South Area	2,340	0.05
Subtotal	*3,900*	*0.090*
TOTAL AREA	**141,257**	**3.24**

10.2.3 Conveyance

Conveyance piping was designed using the flows calculated in the hydrologic analysis described above. Pipes were sized for the 10-year event and assume gravity flow. The system capacity was also checked for the 100-year runoff. The purpose of the new system is to collect runoff from the Site and provide water quality treatment consistent with City of Seattle requirements.

The new system must also integrate with the existing drainage system that serves the surrounding areas. In order to accomplish this, drainage from north of the project site (Building M-19) will be diverted to the existing storm drain system in Coontz Avenue. Runoff from Building M-28 is to be diverted south to the storm drain in West Garfield Street. Due to flat grades and limited fall on the pipes, the west portion of the site (Basin 1) will be drained to the system in Coontz Avenue.

In order to compensate for the diversion of Basin 1, to provide the required extent of water quality treatment, runoff from an area east of the project, equivalent in size to Basin 1, will be captured and routed through the treatment facilities. These areas are indicated on the figure above.

The outlet elevation at the southeast corner of the Site is controlled by the invert elevation of 11.75 ft of the outlet of the existing OWS, Structure 5475, at the southeast corner of the Site. The existing OWS vault will be removed and the new conveyance will be connected to the existing pipe with a new storm drain manhole.

As a result of the flat grades on the Site, the pipe grades are between 0.3 percent and 0.6 percent. The pipe sizes have been selected to provide the required capacity at these grades; however, the relatively flat slopes may require additional cleaning to prevent accumulation of sediment. The flat grades and outfall control elevation also results in shallow cover for the proposed conveyance piping. To address this, ductile iron pipe is shown where the depth of cover is less than 18 in.. A minimum of 12 in. of cover is provided on the ductile iron pipe.

Due to the potential for tidal influence, a Tideflex Checkmate Inline Check (or equivalent) will be installed on the outlet pipe at the new manhole at Station –(0+25.23) as shown on Drawing C029, downstream of the WQ system components.

10.2.4 Flow Control

Since the Site discharges directly to Puget Sound (Elliott Bay) through a private storm drain system, flow control is not required.

10.2.5 Water Quality Treatment

In accordance with City of Seattle requirements, basic water quality treatment is proposed for all new and replaced impervious surfaces that are subject to vehicular traffic. Basic water quality treatment will be provided using Stormfilter cartridge type filters (or equivalent) sized in accordance with Department of Ecology design requirements. The design flow was calculated using WWHM3 for the areas (3.24 acres) listed above. In addition to the replaced pavement the remediation site, SWMU 30 results in another 4,000 sf of replaced pavement. This 4,000 sf area is included in the 30,000 sf "Mitigation Area" shown on the site plan.

Due to the shallow grades, low head (1.8 ft) type cartridges are proposed for the project. Standard cartridges have a capacity of 7.5 gallons per minute (gpm), but the low head version is only rated for 5 gpm. As a result, a 50 cartridge filter is required for the design flow. The following table summarizes the calculations of the number of cartridges required for the project.

TABLE 10-2 WATER QUALITY TREATMENT

Water Quality Design Flow.	0.5539 cubic feet per second (248 gpm)
Cartridge Loading	5 gpm
Number of Cartridges	50

In addition to water quality treatment, due to the potential for heavy traffic and other industrial activity, an OWS is required. A coalescing plate type OWS was selected to reduce the size of the vault required for the design flow of 248 gpm. The unit selected (Appendix A7) has a treatment capacity of 280 gpm and a hydraulic capacity of over 1,400 gpm. A high flow bypass is proposed for the treatment facility to prevent the system from being overloaded.

11.0 MANAGEMENT FRAMEWORK FOR ENVIRONMENTAL MEDIA AND DEBRIS

This section provides the general framework for managing the materials that will be excavated, demolished, or removed during the cleanup actions described in Sections 4 through 10. These materials include environmental media (soil, groundwater, and stormwater), debris[12] (e.g., concrete, steel), and waste generated during cleanup activities (e.g., LNAPL, decontamination water). Management activities may include one or more of the following depending on the specific material: stockpiling, processing (e.g., crushing of asphalt), decontamination, re-use, recycling, and disposal.

The general approach and principles for waste designation at Terminal 91 are provided in the *Guidance for Waste Designation Procedures at Terminal 91*, which is included as Appendix B to the *Contamination Contingency Work Plan* (Exhibit E of 2012 AO; Ecology 2012). Appendix C to the *Contamination Contingency Work Plan* provides additional guidance related to management of contaminated debris associated with the tank farm. These project-specific documents follow Ecology's *Guidance for Clean Closure of Dangerous Waste Units and Facilities* (May 2005).

The specific actions and requirements for these materials during the implementation of the cleanup are detailed in the specifications. An overview of the overall management framework is described below and shown in Figures 6 and 7.

11.1 Soil and Debris

11.1.1 SMWU 30 and Pipeline Decommissioning outside of TFA

Soil and debris that is excavated and removed will be managed consistent with Contamination Contingency Work Plan with the provision that soils determined to be highly contaminated will be stockpiled separately and profiled for off-site disposal at an approved facility. Specific areas outside the TFA include the SWMU 30 excavation and excavations associated with decommissioning of pipelines outside of the TFA.

For SMWU 30, asphalt from these relatively small excavations will be recycled or disposed of off-site. Excavated soil in the vadose zone is not expected to be highly contaminated with petroleum hydrocarbons and will be stockpiled for potential reuse as backfill material. Soil in the smear and saturated zones may be highly contaminated, and will be presumptively managed as highly contaminated and will be stockpiled separately. Debris (e.g. wood piles, steel tie rods) will be stockpiled and decontaminated as necessary prior to recycling or disposal. See Section 02333 of the specifications for specific SWMU excavation requirements.

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[12] "Debris" is used to mean any residue from excavation other than soil, and includes concrete, piping, tank bases, asphalt, and/ or other man-made material.

For the excavations associated with pipeline decommissioning, asphalt from these relatively small excavations will be recycled or disposed of off-site. Soil not considered to be highly contaminated will be reused as backfill while highly contaminated soil will be stockpiled separately and profiled for off-site disposal. Debris (e.g., pipeline components) will be stockpiled and decontaminated as necessary prior to recycling or disposal. See Section 02224 of the specifications for specific pipeline decommissioning requirements

11.1.2 Tank Farm Area

Appendix C to the Contamination Contingency Work Plan emphasizes productive re-use of media and debris to fill and stabilize the excavation areas that will result from the cleanup at the TFLP. Due to the variety and volume of materials that will be removed during the construction of the selected remedy for the former tank farm, the Port has developed the following management framework to guide in the construction planning and implementation.

This framework includes the use of an “area of contamination” (AOC) which would be established by Ecology consistent with its 1991 inter-program policy. Features of the AOC include:

- AOCs can be designated as areas in which contamination from dangerous waste units or other sources is continuously present;
- The AOC permits movement of materials within Ecology-supervised cleanups without materials being labeled “generated” as wastes;
- Any materials to be considered not generated must not leave the AOC.

The AOC policy’s requirement of considering applicable or relevant and appropriate requirement (ARARs) has been met at this Site through the remedy selection process used to develop the CAP (Ecology 2012), which included reuse of media and debris as fill with capping and long-term monitoring.

The AOC for this project would include the TFLP and adjacent areas included in the remedy construction as shown in Figure 8 and on Drawing C012. Debris and media excavated from within the AOC as part of implementing the cleanup action will be managed as follows:

1. Highly contaminated soil. This material, which is defined in Section 8.2 of the CAP as soil that is, “visibly and highly contaminated with petroleum” (i.e., product-saturated soil), will be excavated, stockpiled (inside or outside of AOC – see below), tested to characterize under the above-referenced documents, and disposed of off-site. This could include sand or pea gravel between the bases of former tanks with multiple bases.

2. Debris not suitable for reuse on-site. This material includes pipes, tank bases and other non-concrete debris. This material will be stockpiled (inside or outside of AOC) and then managed as follows:
    - Debris known to have come from units in which dangerous waste was managed, or that has come into contact with listed dangerous waste, will be decontaminated

consistent with the *Guidance for Clean Closure of Dangerous Waste Units and Facilities* to meet Land Disposal Restrictions and disposed of or recycled.

- Debris that has not come from units in which listed dangerous waste was managed, and that did not come into contact with listed dangerous waste, will be decontaminated and tested as necessary to meet receiving facility requirements, and recycled or disposed of.

3. Media and debris potentially suitable for reuse on-site including soil, asphalt, and concrete (excluding highly contaminated soil). This material will be separated into two general categories as follows:
   - Soil or debris from units not known to have managed or come into contact with listed dangerous waste. This category includes the existing asphalt cover and the underlying gravel and fill brought in after the 2005 tank farm demolition, with the possible exception of gravel and fill associated with the two product seeps being contained in utility vaults. This material will be stockpiled (inside or outside of AOC), processed as necessary to be suitable for reuse (e.g., crushing asphalt), and then used on-site as fill. If there is an excess of material associated with the project, this material could be disposed of or recycled off-site.
   - Soil or debris known to have managed or potentially come in contact with listed dangerous waste or listed dangerous waste constituents. This includes concrete (slabs beneath tank bases, containment wall footings, sumps, paving between tanks) and soil beneath the former tank farm. This material will be managed entirely within the AOC. Soil would be stockpiled and reused as fill to bring the site up to its final grade. Concrete would have gross contamination (adhered soil, product) removed and then be crushed, stockpiled, and finally reused as fill.

See specification sections 02222 (TFA Preparation), 02228 (asphalt and concrete crushing, screening, and stockpiling), 02332 (TFA soil excavation and management), and 02405 (waste collection, storage, profiling, and disposal) for specific requirements related to the TFA work.

11.2 Groundwater (Dewatering)

Groundwater removed from excavations during dewatering activities would be treated and discharged to the King County sanitary sewer system under the terms of a discharge permit. See Section 02405 of the specifications for specific requirements related to groundwater management.

11.3 Stormwater Runoff

Stormwater runoff generated during construction activities will be managed consistent with the requirements of a CSWGP to be obtained by the contractor. The CSWGP will require preparation and implementation of a Stormwater Pollution Prevention Plan that describes the best management practices and, as necessary, treatment procedures for managing stormwater during construction; see Section 02270 for details on the required erosion and sediment control practices.

Runoff that has potentially been impacted by site contamination, such as may be generated from exposed areas of the TFA during demolition and excavation activities, will require treatment prior to discharge. This treatment will generally include oil/water separation, sediment removal, and carbon adsorption, and potentially pH and/or dissolved oxygen control in order to meet discharge. See Section 02245 of the specifications for specific requirements for stormwater treatment and discharge.

11.4 Waste Materials

A number of waste materials will be generated during the implementation of the cleanup action including:

- LNAPL recovered from excavations;
- Fuels removed from decommissioned pipelines;
- Sludges, sediment, and water removed from decommissioned pipelines;
- Decontamination fluids and solids; and
- General solid waste (e.g., trash) associated with construction.

These materials will be collected in the appropriate containers, profiled, and recycled or disposed of consistent with the applicable regulations. See Section 02405 for specific requirements for these materials.

12.0 CLEANUP ACTION IMPLEMENTATION

This section discusses implementation of the final cleanup action, including permits and approvals needed prior to implementation, health and safety, CQA/CQC, O&M, and compliance monitoring.

12.1 Permits and Approvals

Consistent with Section VIII.P of the Agreed Order, although the Port must comply with substantive requirements of state and local permits and approvals in its implementation of the cleanup action plan, it is exempt from their procedural requirements. The following is a list of permits and approvals which have been identified for the major work elements identified in this EDR.

- The Port prepared an environmental analysis and review of the Draft CAP (PES, 2010) and prepared a SEPA Checklist in 2010. Per the Port (Port, 2010), the environmental evaluation included review of pertinent environmental information following the provisions of SEPA under Chapter 43.21C RCW, Chapter 197-11, WAC, and Port Commission Resolutions 3028, 3211, and 3539, and Port of Seattle SEPA Policies and Procedures. As the lead agency, the Port determined that the proposed work would not have a probable significant adverse impact on the environment, and a determination of non-significance was granted by Ecology.
- Because the construction of the cleanup action will disturb more than 1 acre of land, the contractor will be required to apply for coverage under Ecology's CSWGP. The CSWGP will require that a SWPPP be prepared and implemented. The SWPPP includes various BMPs to control runoff from the Property, minimize the transport of sediment and other contaminants to the stormwater conveyance system and receiving waters, and, as necessary, treatment procedures for managing stormwater during construction.
- Consistent with the requirements of the Stormwater Code Interagency Agreement between the Port and the City of Seattle, "the Port shall comply with all substantive requirements of the City Stormwater Code for all its facilities, whether or not they discharge to City drainage control systems or public combined sewers, but the Port shall not be required to obtain permits required by the Stormwater, Grading and Drainage Control Code where the project site does not discharge to a City drainage control system or public combined sewer and the project will not undercut or otherwise endanger adjacent property." The Port's "Project Design Guidance Manual" was used during the design of the stormwater management components of the final cover described in Section 10. A copy of the technical memorandum will be kept on file at the Port that documents that the stormwater management components constructed as part of this project comply with the applicable City of Seattle code.
- As described in Section 11, groundwater and/or wastewater generated during implementation of the cleanup action will be managed appropriately including potential discharge to the sanitary sewer via underground piping via temporary discharge authorization through the King County Industrial Waste Program (KCIW); and/or off-site disposal at an approved facility.

- Well decommissioning and well installation, if needed, will comply with the Minimum Standards for Construction and Maintenance of Wells (WAC 173-160).
- Throughout the design process, the Port and PES will determine whether additional state, federal, or local permits or approvals are required for the cleanup action components or work elements. As required by Section VIII.P of the AO, if additional permits or approvals are identified, the Port will notify Ecology and determine the applicable substantive and/or procedural requirements that may apply.

12.2 Health and Safety

A HASP will be prepared consistent with the requirements outlined in the Worker Health and Safety guidelines (WAC 173-340-810) and the Occupational Safety and Health Act (OSHA, 29 CFR 1900). The HASP will incorporate the Port's Construction Safety and Health Manual (Port, 2009) by reference. All workers associated with the cleanup action will be required to read the HASP prior to starting work at the Property; however, only PES personnel will be responsible for signing the HASP associated with the cleanup action. The HASP will be prepared prior to initiating construction once the roles of the various project personnel and organizations are better defined.

Subcontractors and or other non-PES personnel will be responsible for preparing, providing, and signing their own project specific HASP, which also incorporates the Ports safety and health policies. Health and safety meetings associated with the cleanup action will be conducted with all contractors, subcontractors, construction personal, and all other applicable personnel prior to the commencement of cleanup action activities at the Site.

12.3 Construction Quality Assurance/Quality Control

CQA/CQC will be conducted to ensure that the cleanup action is implemented as designed.

12.3.1 Construction Quality Assurance

CQA represents a planned and systematic pattern of procedures and documentation designed to provide confidence that items of work or services meet the requirements of the contract documents. A third-party consultant independent of the Owner and contractor must perform CQA. A CQA Manual has been prepared that outlines specific monitoring, testing, construction, and documentation procedures that will be implemented to ensure that the remedial action objectives of the project are met. The CQA Manual is included as Appendix D of this EDR and includes the following information:

- The CQA organization, roles, and responsibilities;
- General requirements for notifications, meetings, control of project records and documentation, and correction of nonconforming work;
- Monitoring and documentation requirements including daily record keeping, daily test reports and installation reports, nonconformance reports (as necessary), progress reports,

drawing and specification revisions, requests for information, test data summaries and a Final Construction Report; and

- Delineation of the detailed CQA requirements for specific work elements in the form of checklists.

The CQA activities are separate from the construction quality control (CQC) activities identified in the Drawings and Technical Specifications that the contractor must perform.

12.3.2 Construction Quality Control

CQC activities provide a means to measure and regulate the characteristics of an item or service to comply with the requirements of the contract documents. CQC activities will be conducted by the contractor, subcontractors, and equipment and materials suppliers. In general, the contractor is responsible for coordinating the activities of its own forces and subcontractors, scheduling and performing the work within the timeframe and budget agreed to in the contract, performing the work in accordance with the Drawings and Technical Specifications, and implementing QC procedures to document construction complies with the Technical Specifications. The contractor is expected to cooperate with the Owner and its CQA representative in performing CQA activities to achieve a quality product.

12.4 Compliance Monitoring

A draft CMP has been be prepared outlining the procedures to be used to monitor the cleanup action after construction is completed and included as Appendix F of this EDR. The CMP is based on and generally follows the procedures outlined in the existing Groundwater Monitoring Plan for T91 TFAA (Kennedy/Jenks Consultants 2010a) and the associated Quality Assurance Project Plan for T91 TFAA (Kennedy/Jenks Consultants 2010b). These plans were approved by Ecology on October 14, 2010. The CMP also incorporates the components of the existing MNA Plan (PES, 2006).

The draft CMP has been prepared consistent with WAC and describing monitoring to be performed during operation and maintenance, a sampling and analysis plan meeting the requirements of WAC 173-340-820, data evaluation procedures, and reporting of the compliance monitoring data. Compliance monitoring includes protection monitoring, performance monitoring, and confirmational monitoring (WAC 173-340-410).

12.5 Operations and Maintenance

A draft O&M plan has been prepared per WAC 173-340-400(4)(c) and is included as Appendix G of this EDR. The draft O&M plan includes:

- Startup procedures and testing;
- General operating procedures, including startup, normal operations, and contingency procedures;
- A discussion of the detailed operation of individual components of the cleanup action, including a description of recommended operating parameters; and

- Procedures and sample forms for collection and management of operating and maintenance records.

13.0 OTHER REQUIREMENTS

13.1 Institutional Controls

Institutional controls are to be incorporated in the cleanup action, since contaminants exceeding the cleanup levels described in the CAP (Ecology, 2010) will remain within the TFAA. Institutional controls will consist of filing an environmental covenant developed consistent with Ecology's Model Restrictive (Environmental) Covenant[13] in the real property records to notify potential purchasers of the Property of this cleanup action. A draft of the environmental covenant is included in Appendix H of this EDR.

The environmental covenant will limit activities that may create a new exposure pathway (e.g., direct contact with soil and vapor migration to indoor air), result in release of hazardous substances, or interfere with the integrity of the cleanup action without Ecology's written approval. As described below, future development in the portion of the T91 facility covered by the environmental covenant will have to consider the indoor air pathway and incorporate engineering controls (e.g., vapor barriers) as appropriate, or conduct a development-specific evaluation of the soil/groundwater to indoor air pathway to control potential exposures.

13.1.1 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 addresses this potential exposure by implementing 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.

13.1.2 Indoor Air Pathway

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 is to implement land use restrictions that include the following institutional controls:

- Placing a notice in the public land records identifying the potential presence of contaminated soil and/or groundwater;

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[13] 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

- 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.

13.2 Implementation Schedule

A schedule that outlines the current schedule for implementing the cleanup actions described in this EDR is included in Appendix I. The timing of certain aspects of the cleanup is uncertain and will depend in part on the timing of Ecology's final approval of the design, the Port's bidding process, and coordination of construction with active Port operations at the T91 facility. For example, the SMWU 30 excavation will need to be coordinated with the Port's Cruise Ship Terminal operations and as such will likely be conducted in the "off season" for the cruise ships (generally October through March).

13.3 Closure and Post-Closure Standards: Substitution of CAP and Detailed Cleanup Documents

Because it housed a former dangerous waste storage and treatment facility, the Terminal 91 Facility remains subject to certain dangerous waste regulations, Ch. 173-303 WAC. The Port proposes that Ecology approve the CAP, and all subsequent submittals made by the Port under the CAP (including this EDR), to substitute for the generic closure and post-closure standards set forth in WAC 173-303-610 (except the closure performance standards of WAC 173-303-610(2)(a)), and for the unit specific requirements referenced in WAC 173-303-610(2)(b).

Dangerous waste operations (excluding corrective action) ceased at the Terminal 91 treatment and storage facility in 1995. The facility operator at the time completed closure of all above-ground facility components in 1997, and Ecology approved that closure in 2003. Since 1997, the TFLP has had no dangerous waste operations other than corrective action. In 2005, the Port demolished most of the remaining above-ground components of the former storage and treatment facility through an interim remedial action reported to Ecology in October 2005.

Ecology implements corrective action requirements through authority provided by the Model Toxics Control Act. It imposes corrective action at Terminal 91 through a dangerous waste permit (under WAC 173-303) ("DW Permit") and through the Agreed Order. The DW Permit is a corrective action-only permit, and contains no terms regarding operation, closure or post-closure. It does, however, require the Port to provide financial assurance pursuant to WAC 173-303-620 and to meet the general conditions for permit holders specified in WAC 173-303-810.

It also specifically incorporates the Agreed Order to specify the remedial actions the Port must implement to achieve corrective action.

An over-arching requirement of MTCA is that cleanup actions taken must protect human health and the environment. The CAP, implemented through the EDR and other detailed design documents (further references to the "CAP" in this Section 13.3 include all submittals under the Order that require Ecology's approval) details a suite of cleanup actions developed specifically to address conditions at Terminal 91. Based on many years of investigation, the CAP requires (among other things): removal of contaminated soil to address LNAPL, installation of a slurry wall around the former tank farm, installation of a asphalt cover over the same area, installation and operation of LNAPL recovery trenches, long-term groundwater monitoring to confirm natural attenuation, and imposition of institutional controls to protect the integrity of the remedy and to prevent exposures to hazardous substances that remain at the Site. At Terminal 91, the CAP addresses all functions served by "closure plans" and "post-closure plans" at operating dangerous waste facilities.

Ecology may impose alternative closure and post-closure requirements when it determines that:

(i) A dangerous waste unit is situated among other solid waste management units or areas of concern, a release has occurred, and both the dangerous waste unit and one or more of the solid waste management units or areas of concern are likely to have contributed to the release; and

(ii) It is not necessary to apply the requirements of this section (or the unit-specific requirements referenced in subsection (2)(b) of this section because the alternative requirements will protect human health and the environment.

<u>WAC 173-303-610(1)(e).</u> Condition (i) is met by Terminal 91, where releases occurred from various solid waste management units and areas of concern within the TFLP. With respect to condition (ii), the CAP adequately protects human health and the environment, and would substitute for the following closure and post-closure sections as described below.

<u>Unit-specific requirements referenced in WAC 173-303-610(2)(b)</u>. No further units requiring unit-specific management remain at the Site, other than underground remnants of closed units that are addressed by the CAP.

<u>Closure plan; amendment of plan (WAC 173-303-610(3))</u>. The CAP has already been functionally substituted for the former facility closure plan (Philip, 1996), which was limited to above-ground closure and which was the basis of Ecology's determination to address below-ground contamination through the corrective action process. As noted above, the Agreed Order (and therefore the CAP, which is imposed as a requirement under the Order) is Ecology's corrective action mechanism for Terminal 91.

<u>Closure; time allowed for closure (WAC 173-303-610(4))</u>. The requirements imposed under this subsection were addressed by Philip's closure activities, as approved by Ecology in 2003.

<u>Disposal or decontamination of equipment, structures and soils (WAC 173-303-610(5))</u>. Limited remnants of the former tank farm remain after above-ground closure was completed, and disposal and decontamination of those remnants are addressed with specificity by the EDR.

Certification of closure (WAC 173-303-610(6)). This requirement pertains to closure of intact units. With completion of above-ground closure in 1997 and demolition of the remaining above-ground permitted structures in 2005, the generic certification requirements are no longer necessary. Ecology's oversight of the cleanup as specified by the CAP is adequate to confirm completion of the required measures. Requirements to termination of financial assurance for closure are moot; only corrective action remains to be performed at Terminal 91, and financial assurance for corrective action remains in place according to Section I.1 of the DW Permit and WAC 173-303-646(1) and 173-303-620.

Post-closure care and use of property (WAC 173-303-610(7)). The groundwater monitoring, remedy protection and exposure restriction functions in this subsection are fully addressed by parallel provisions in the CAP, as necessary to protect human health and the environment.

Post-closure plan; amendment of plan (WAC 173-303-610(8)). The CAP's long-term provisions for remedy protection will adequately address issues across the post-closure period.

Notice to local land authority (WAC 173-303-610(9)). The restrictive covenants called for by the CAP will better serve to protect the remedial actions and to inform/restrict future land uses at the Terminal 91 Facility.

Notice in deed to property (WAC 173-303-610(10)). Likewise, the restrictive covenants required by the CAP satisfy the purposes of this requirement.

Certification of completion of post-closure care (WAC 173-303-610(11)). Ecology's oversight over the Port's performance of the CAP will be provided for adequately by the CAP itself and the Agreed Order's requirements for Ecology to approve submittals required by the Order.

13.4 Public Participation Plan

Consistent with the requirements of Section H of the AO, a Public Participation Plan (PPP) is required for this Property. Ecology updated the PPP in December 2011, and it is incorporated into the AO as Exhibit D. Ecology shall review the PPP periodically to determine its continued appropriateness and whether it requires amendment. The Port will assist Ecology in developing and implementing the PPP as requested by Ecology. This assistance may include the preparation of mailing lists, fact sheets, and public notices.

13.5 Financial Assurance

The Port provided a cost estimate for purposes of establishing financial assurance for the completion of the CAP, which includes Ecology's selection of a final remedy, post-cleanup monitoring at the Site, and completion of remedial action at the Site, to Ecology on January 4, 2011. The cost estimate was approved by Ecology. Consistent with the requirements of the AO, annual updates the cost estimate were prepared and transmitted to Ecology on May 17, 2012 and May 22, 2013.

14.0 REPORTING AND SCHEDULE

Project reporting will include preparation of this revised engineering design report (100 percent), a construction report, and continued preparation of quarterly progress reports.

14.1 Construction Report

A construction or implementation report (or reports) will be prepared in accordance with WAC 173-340-400(6)(b) and submitted to Ecology after completion of construction to document how the cleanup action was implemented, the CQA procedures used, the test data supporting compliance with the design, and as-built drawings.

14.2 Quarterly Progress Reports

Progress reports will be submitted to Ecology on a quarterly basis. Each report will include a list of activities that have taken place during the quarter, summaries of significant findings, and/or changes, monitoring data collected for the CMP, information collected for the O&M plan, new releases (if any), occurrence of any problems or deviations, how problems were rectified, and a list of projected work and deliverables in the upcoming quarter.

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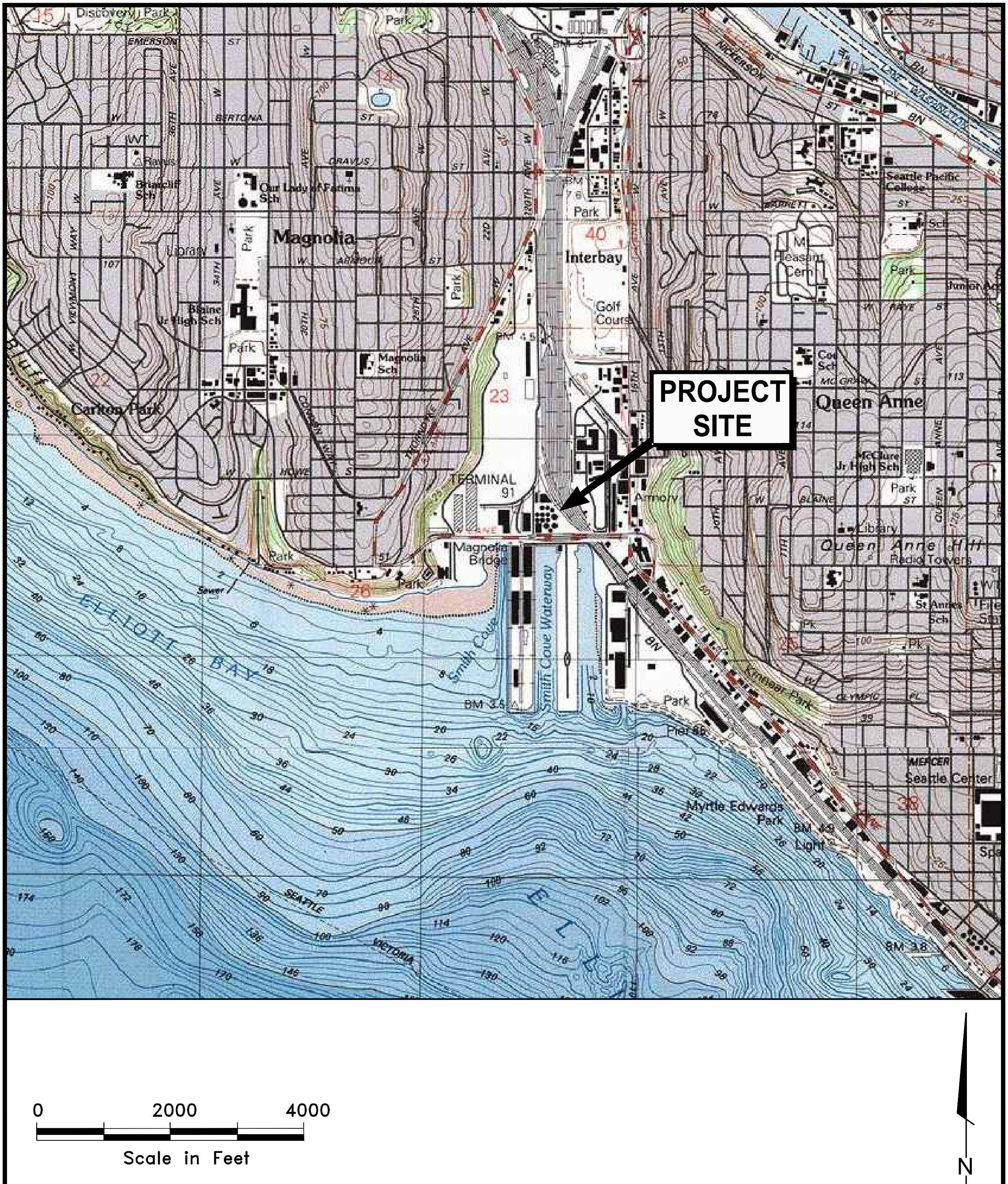
ILLUSTRATIONS



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
1

JOB NUMBER	DRAWING NUMBER	REVIEWED BY	DATE
948.007.04.006	94800704006_EDR_1	BLO	7/13

94800704006_EDR_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

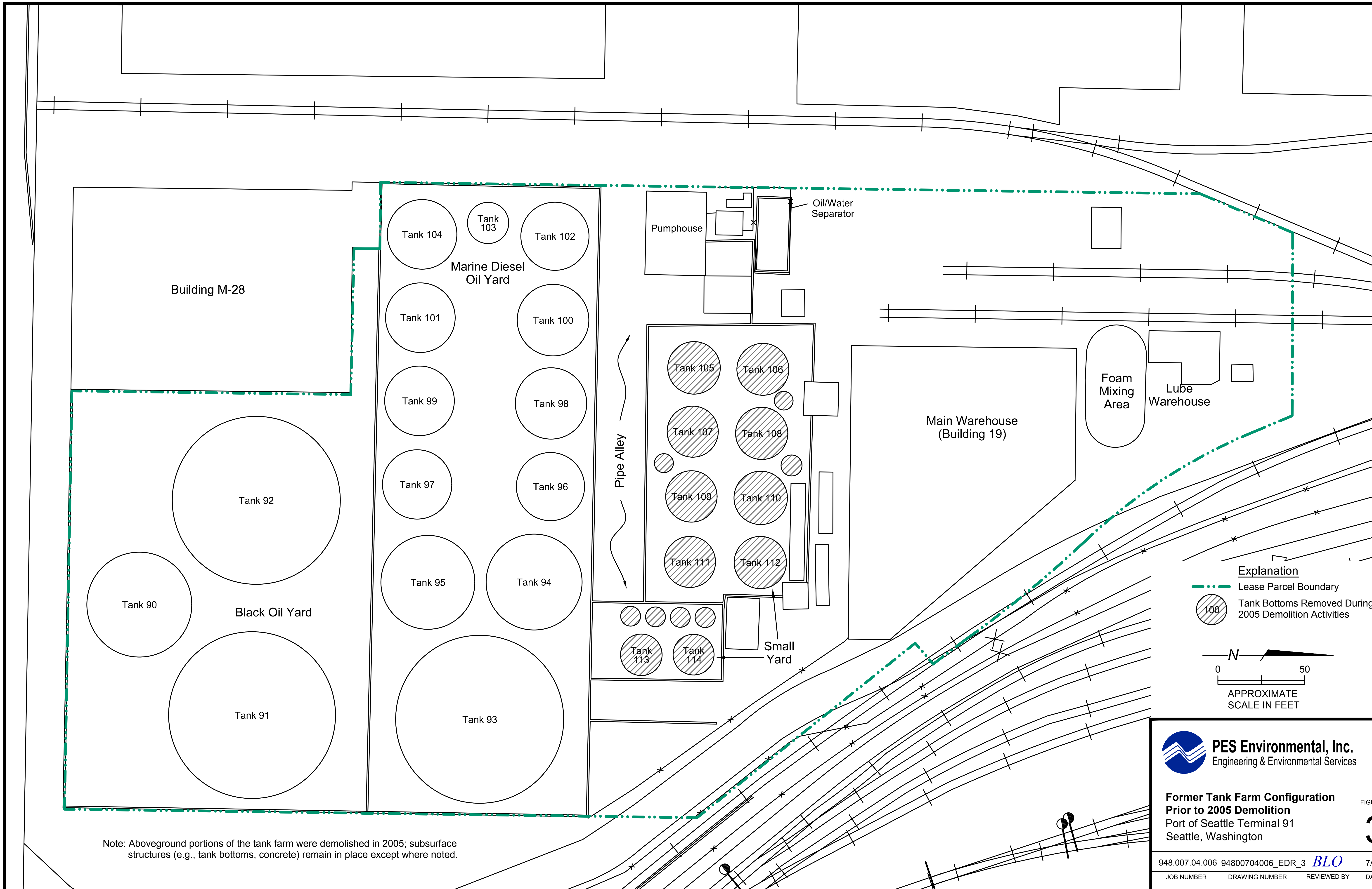
- Port of Seattle Property Limits
- Tank Farm Lease Parcel
- Tank Farm Affected Area
- Submerged Land

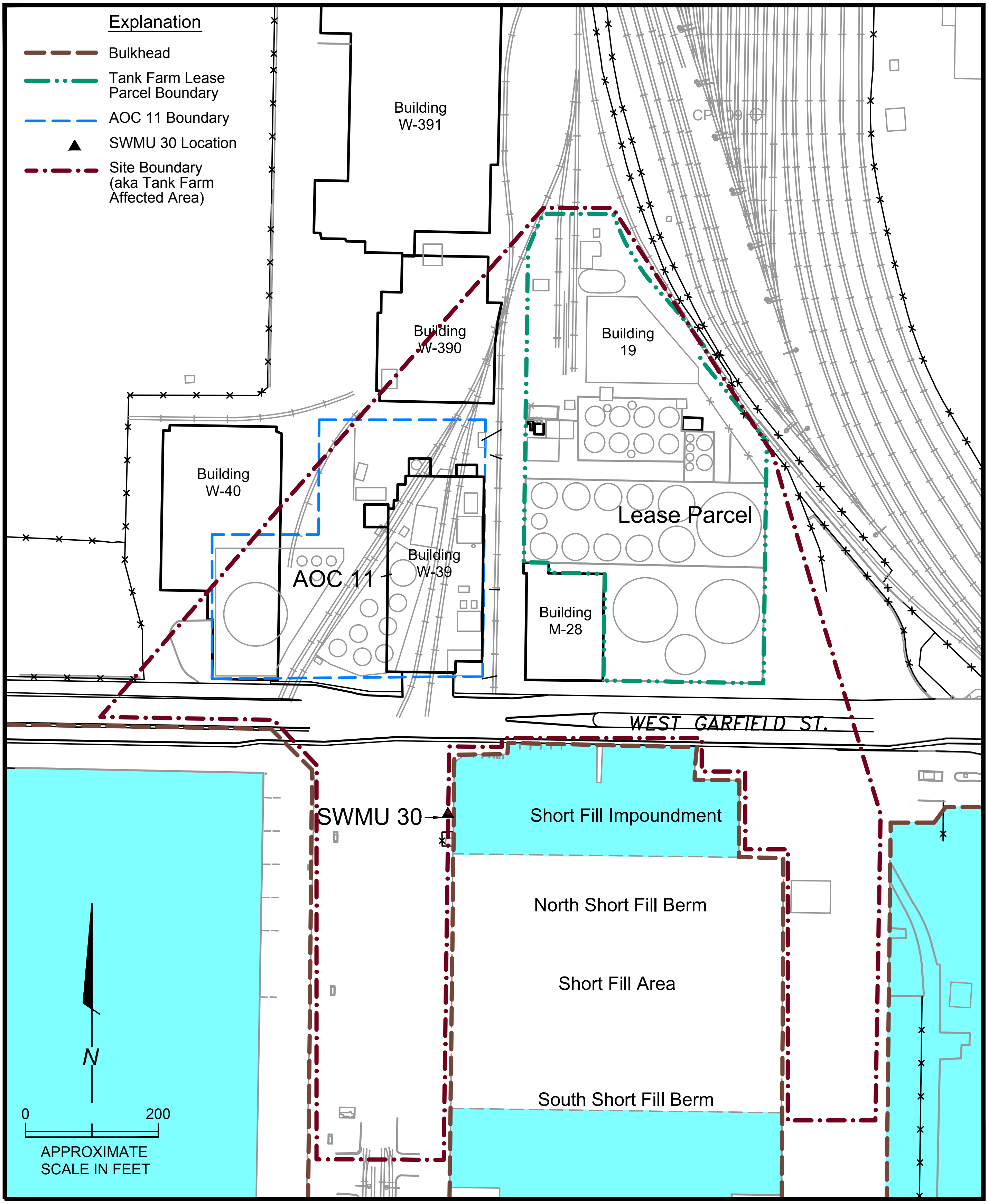
PES Environmental, Inc.
Engineering & Environmental Services

FIGURE 2

Port of Seattle Terminal 91 Facility and Tank Farm Lease Parcel
Port of Seattle Terminal 91
Seattle, Washington

948.007.04.006	94800704006_EDR_2	BLO	7/13
JOB NUMBER	DRAWING NUMBER	REVIEWED BY	DATE


Building M-28
Marine Diesel Oil Yard
Tank 104
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
Black Oil Yard
Pipe Alley
Pumphouse
Oil/Water Separator
Tank 105
Tank 106
Tank 107
Tank 108
Tank 109
Tank 110
Tank 111
Tank 112
Tank 113
Tank 114
Small Yard
Main Warehouse (Building 19)
Foam Mixing Area
Lube Warehouse
Explanation
Lease Parcel Boundary
100
Tank Bottoms Removed During 2005 Demolition Activities
N
0
50
APPROXIMATE SCALE IN FEET
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
3
948.007.04.006
94800704006_EDR_3
BLO
7/13
JOB NUMBER
DRAWING NUMBER
REVIEWED BY
DATE



PES Environmental, Inc.
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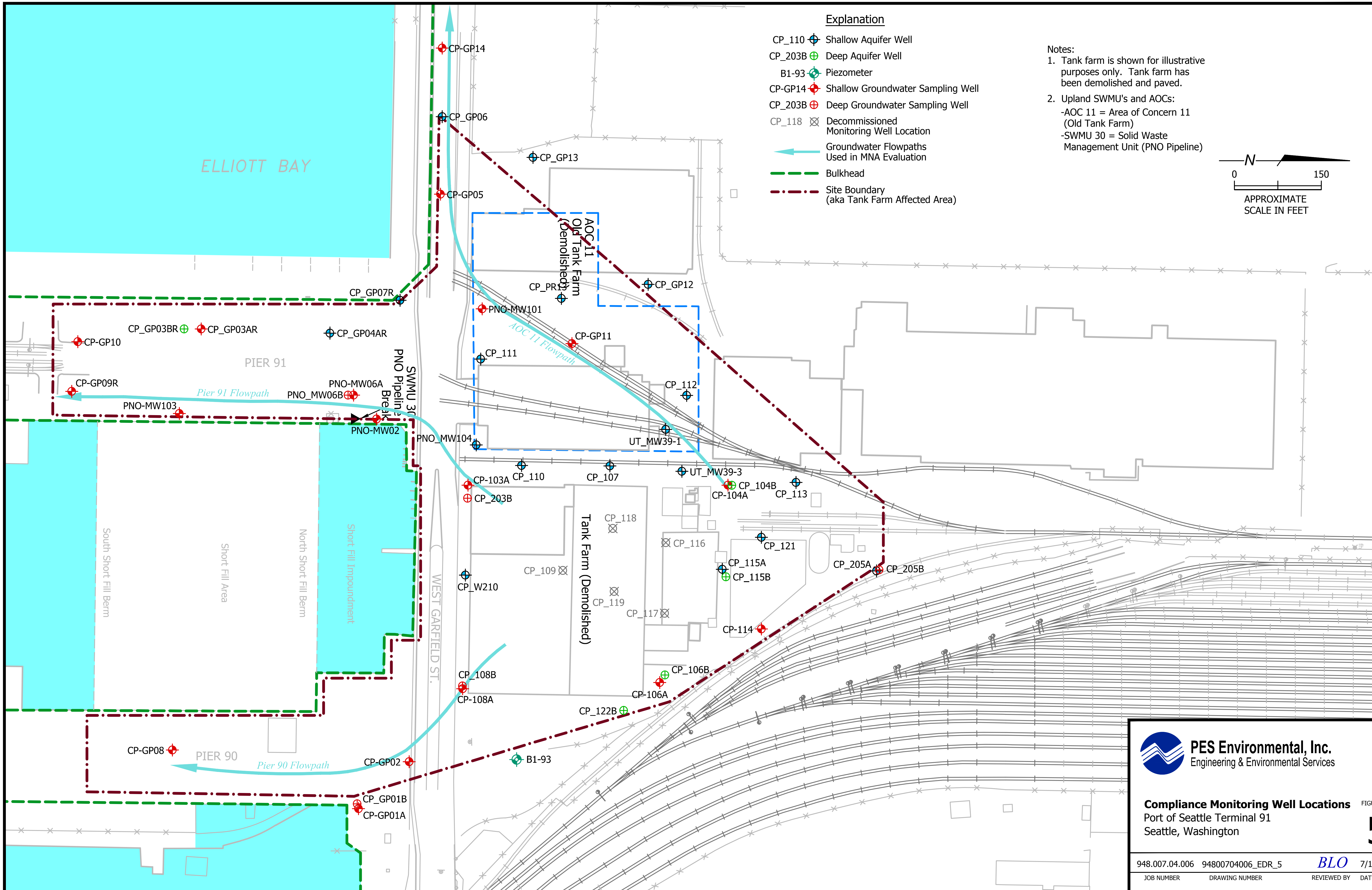
Site Plan
Port of Seattle Terminal 91
Seattle, Washington

FIGURE
4

948.007.04.006	94800704006_EDR_4	BLO	7/13
JOB NUMBER	DRAWING NUMBER	REVIEWED BY	DATE

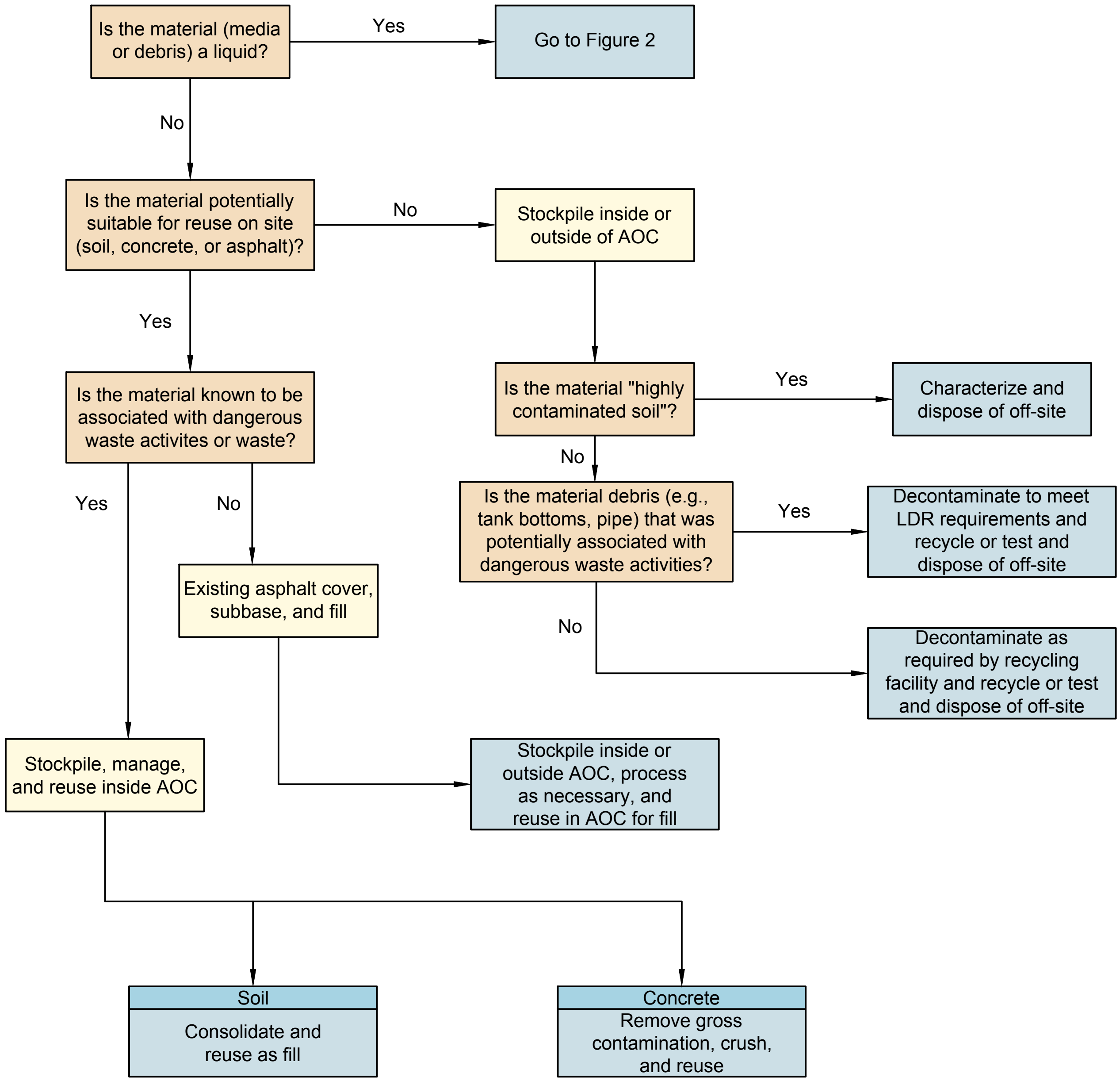


PES Environmental, Inc.
Engineering & Environmental Services

Compliance Monitoring Well Locations
Port of Seattle Terminal 91
Seattle, Washington

FIGURE 5

JOB NUMBER	DRAWING NUMBER	REVIEWED BY	DATE
948.007.04.006	94800704006_EDR_5	BLO	7/13

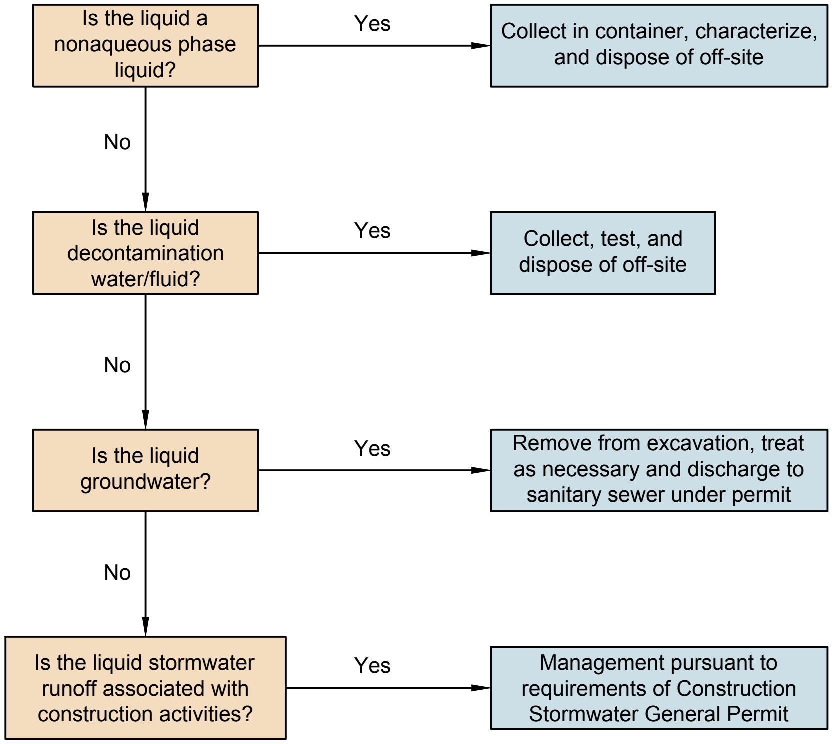


PES Environmental, Inc.
Engineering & Environmental Services

Environmental Media and Debris Management Approach
Port of Seattle Terminal 91
Seattle, Washington

FIGURE
6

948.007.04.006	94800704006_EDR_6-7	BLO	7/13
JOB NUMBER	DRAWING NUMBER	REVIEWED BY	DATE



PES Environmental, Inc.
Engineering & Environmental Services

Water and Liquid Waste Management Approach
Port of Seattle Terminal 91
Seattle, Washington

FIGURE
7

JOB NUMBER	DRAWING NUMBER	REVIEWED BY	DATE
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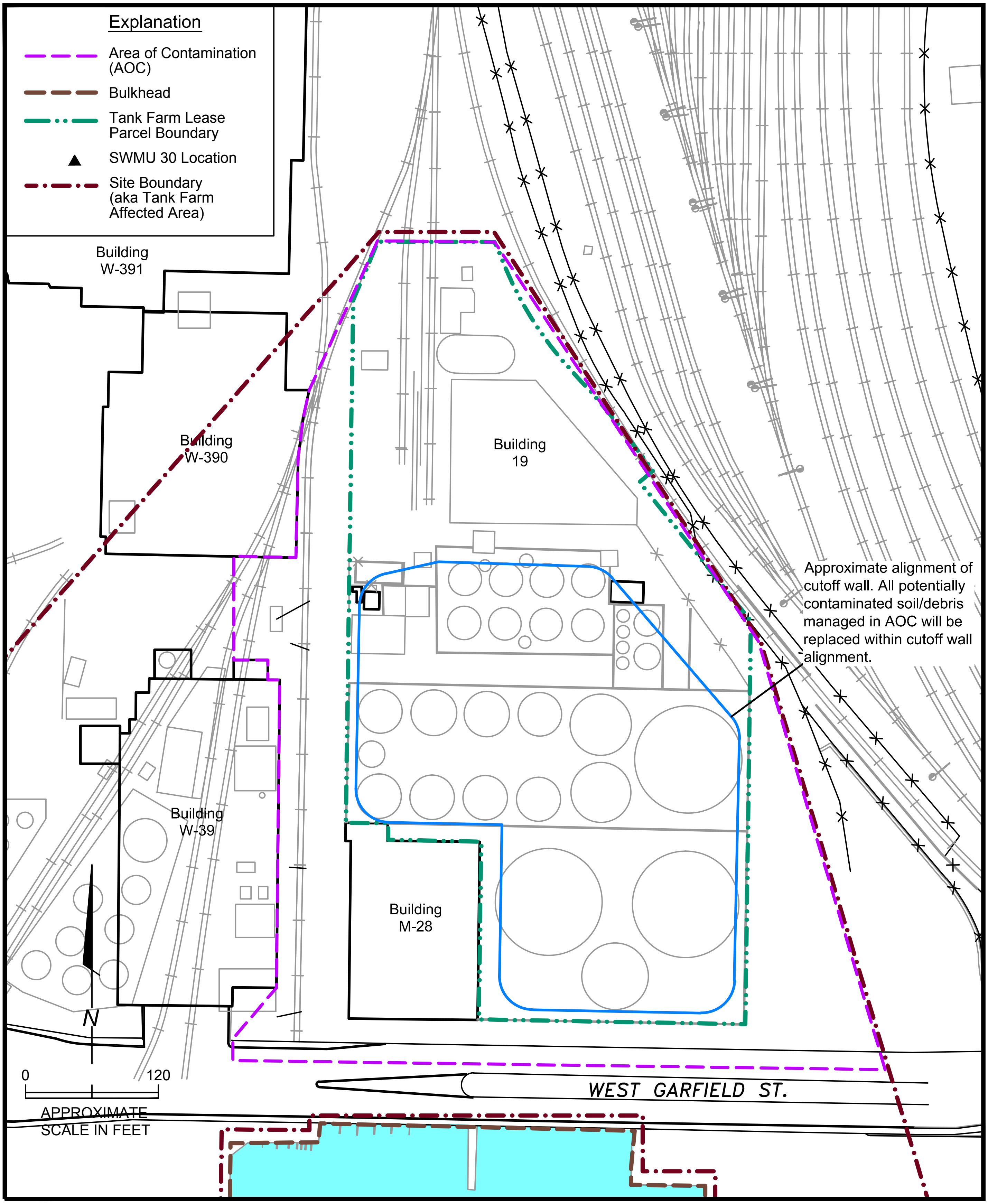


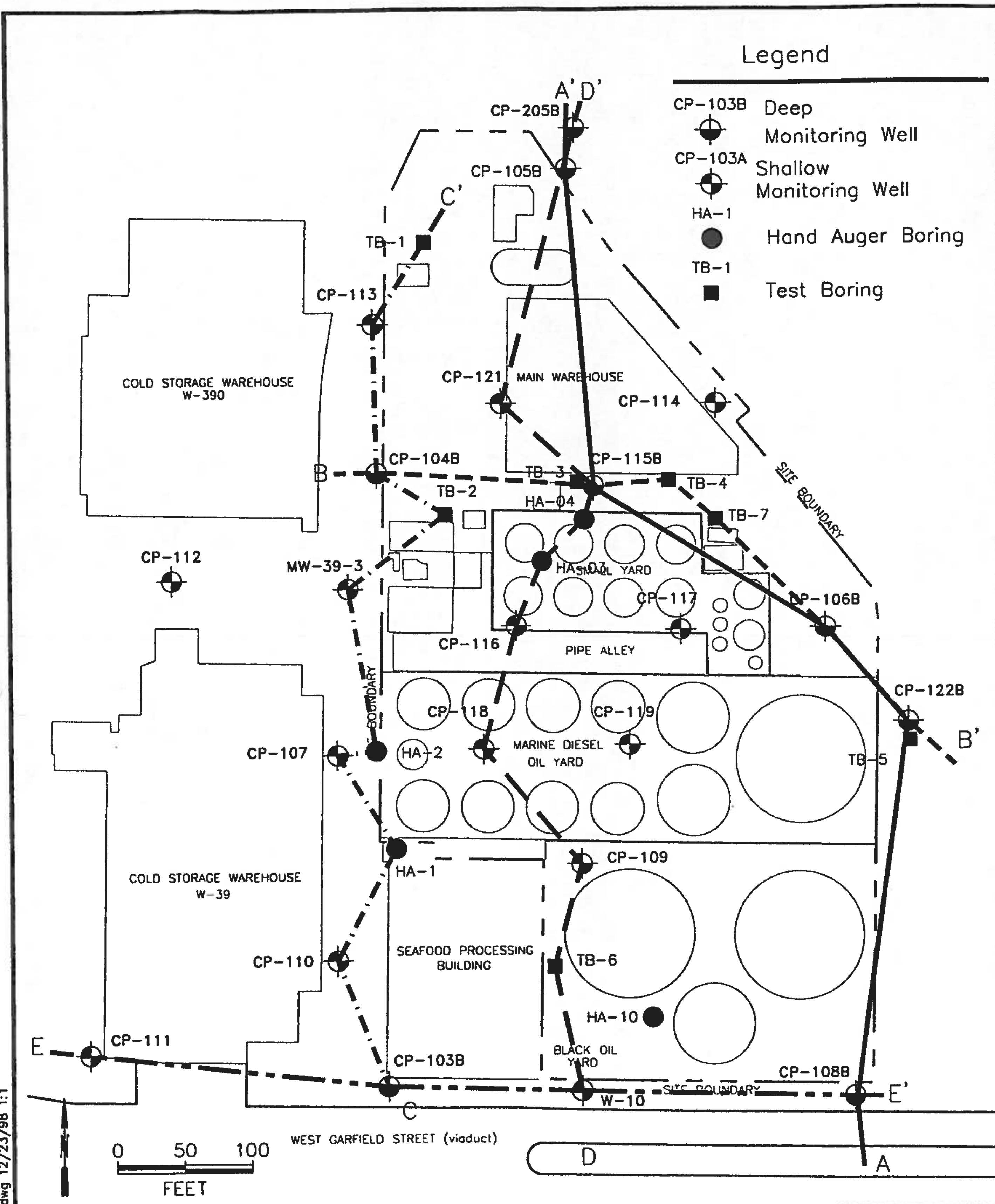
PES Environmental, Inc.
Engineering & Environmental Services

Area of Contamination
Port of Seattle Terminal 91
Seattle, Washington

FIGURE
8

948.007.04.006	94800704006_EDR_8	BLO	7/13
JOB NUMBER	DRAWING NUMBER	REVIEWED BY	DATE

APPENDIX A1
Generalized Geologic Cross Sections



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

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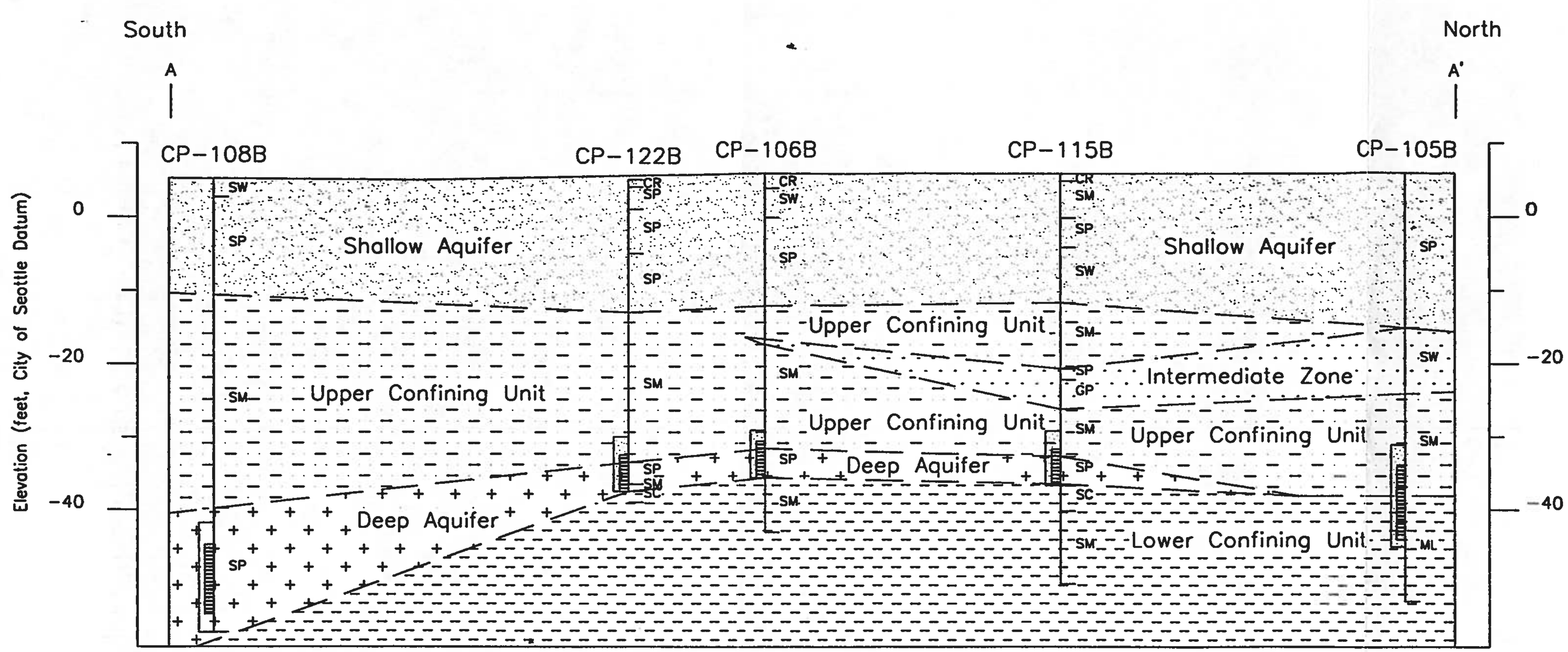

Note: This profile was developed by interpolation between widely spaced borings and monitoring wells. It should be considered as an approximation of geologic conditions to the degree implied by notes on the boring or well logs presented in this report.

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

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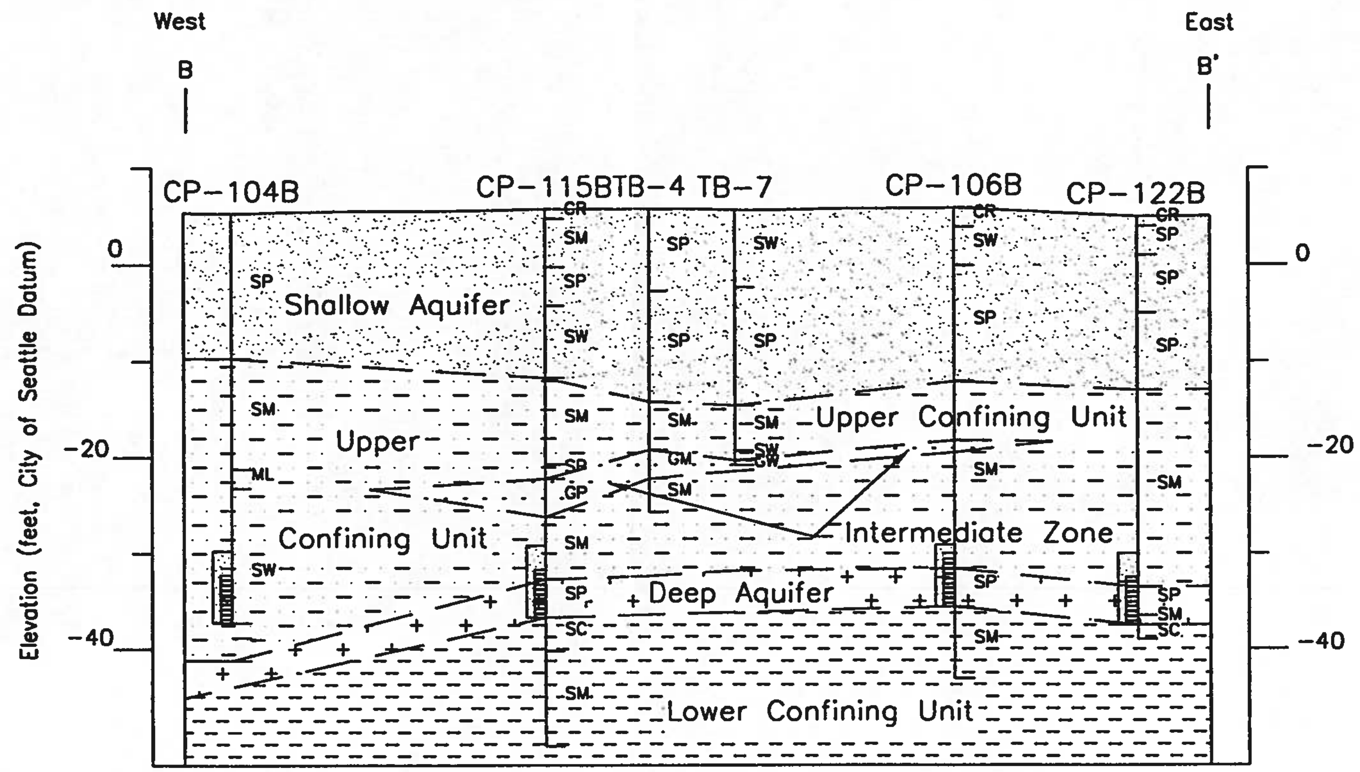
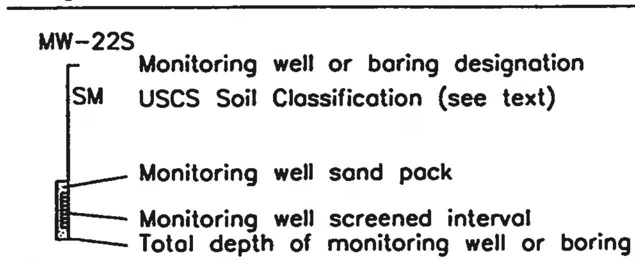


Note: This profile was developed by interpolation between widely spaced borings and monitoring wells. It should be considered as an approximation of geologic conditions to the degree implied by notes on the boring or well logs presented in this report.



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

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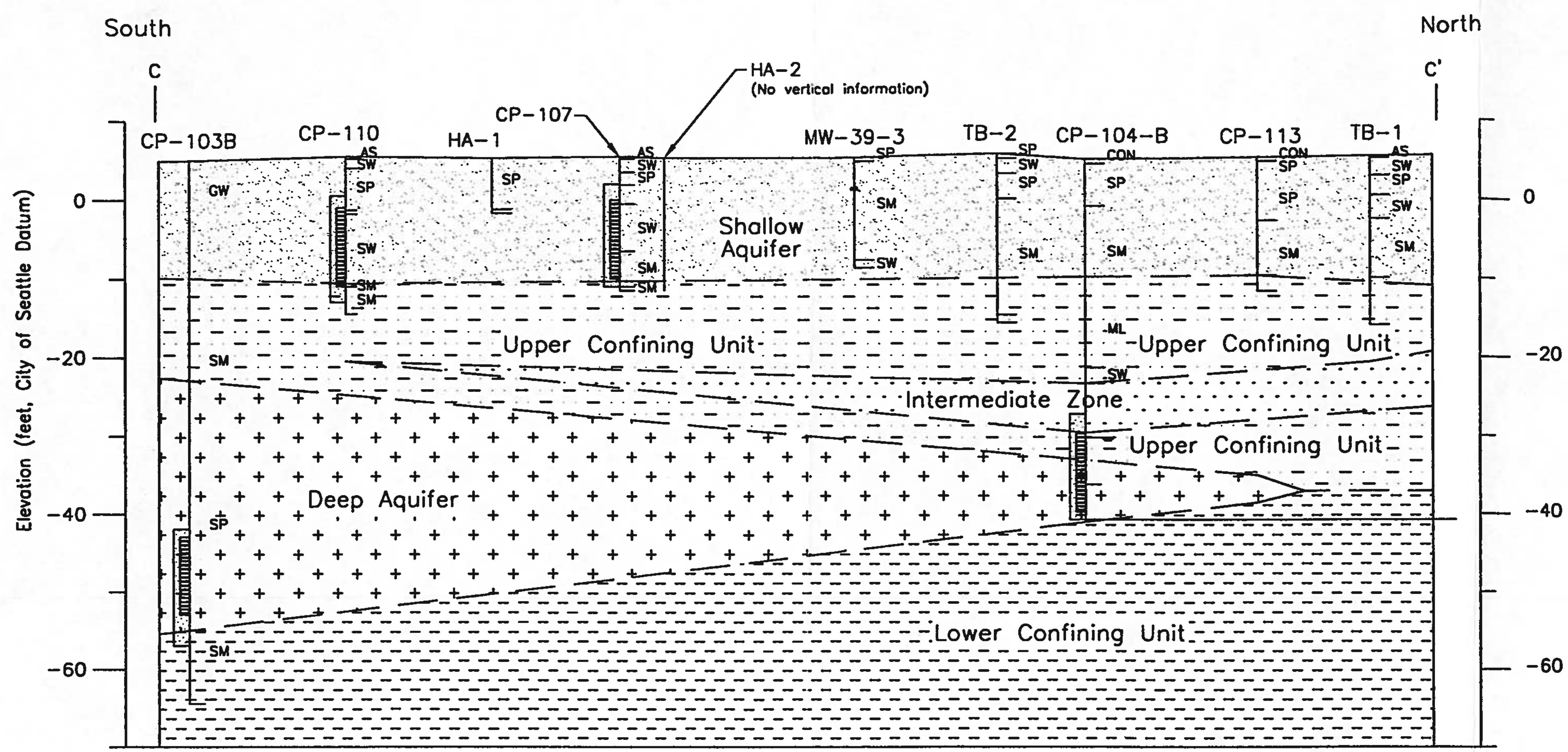

Note: This profile was developed by interpolation between widely spaced borings and monitoring wells. It should be considered as an approximation of geologic conditions to the degree implied by notes on the boring or well logs presented in this report.

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 C-C'

Terminal 91 Tank Farm Site

DWN.: BB	DES.: DP
CHKD.:	APPD.:
DATE: 01/05/98	REV.:

FIGURE NUMBER **4-4**

Prepared by: PSC PHILIP SERVICES CORP. • AESI ASSOCIATED EARTH SCIENCES, INC • Roth Consulting

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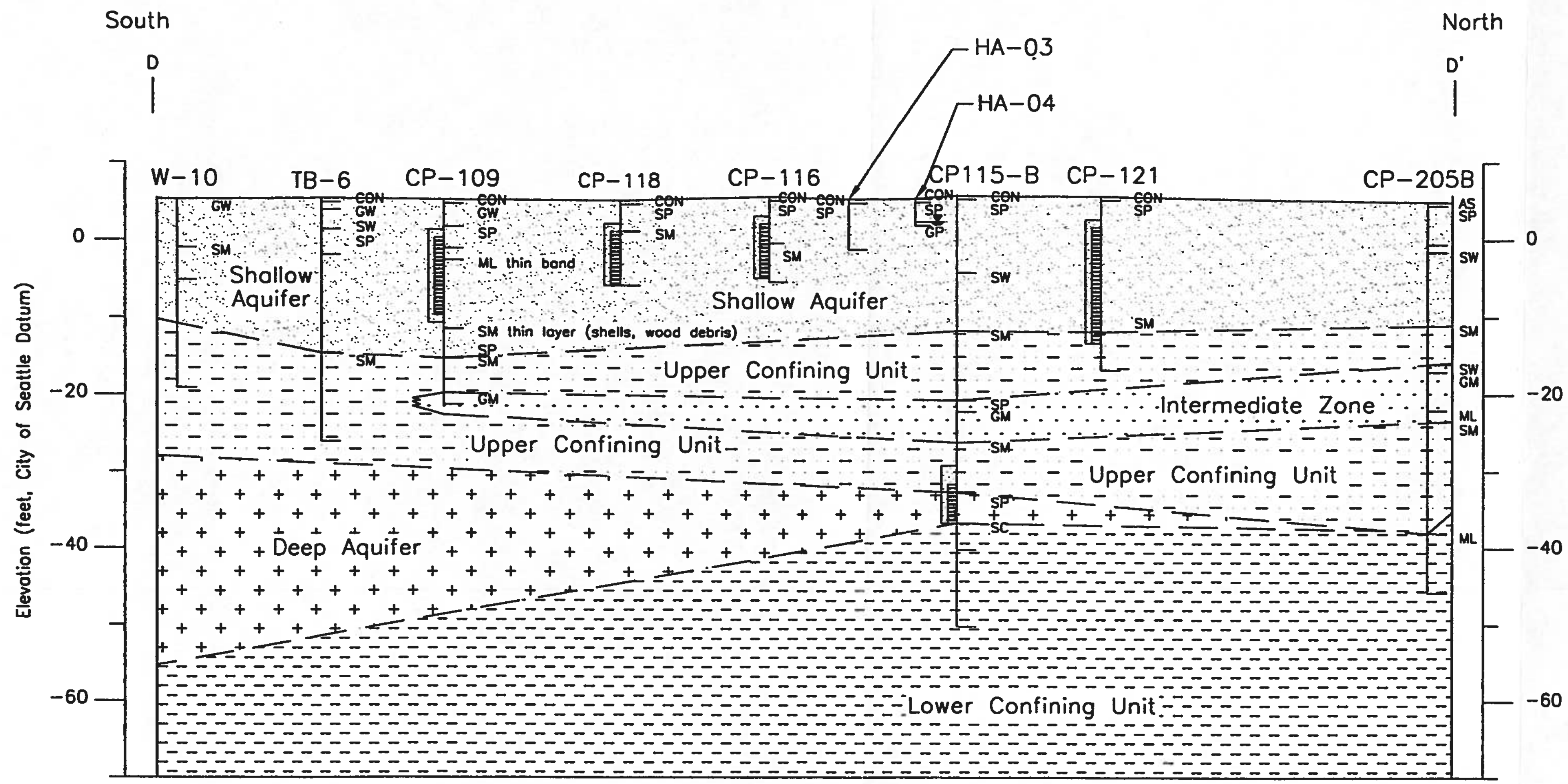


Note: This profile was developed by interpolation between widely spaced borings and monitoring wells. It should be considered as an approximation of geologic conditions to the degree implied by notes on the boring or well logs presented in this report.

Horizontal Scale

0 50 100

FEET

Vertical Exaggeration = 5

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

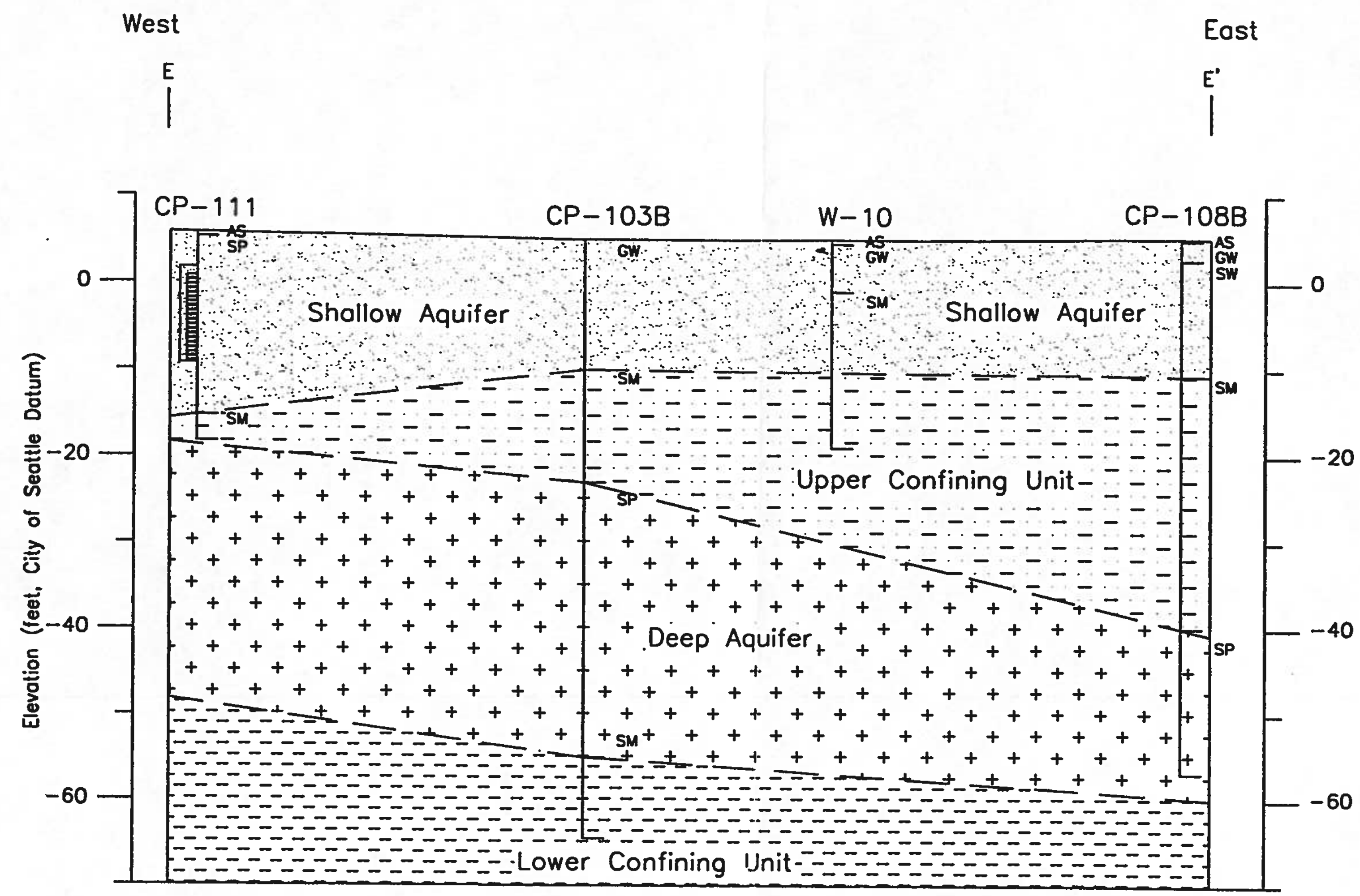
Stratigraphic Unit	Hydrostratigraphic Unit
Shallow Sand Unit	Shallow Aquifer
Silty Sand Unit	Upper Confining Unit
Silty Sandy Gravel Zone	Intermediate Zone of Upper Confining Unit
Deep Sand Unit	Deep Aquifer
Silty Clayey Sand and Silty Sand Unit	Lower Confining Unit

Geologic Cross Section D-D'
Terminal 91 Tank Farm Site

DWN.: BB | DES.: DP | CHKD.: | APPD.: | DATE: 12/23/98 | REV.:

FIGURE NUMBER 4-5

Prepared by: PHILIP SERVICES CORP. • 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 E-E'

Terminal 91 Tank Farm Site

DWN.: BB	DES.: DP	FIGURE NUMBER
CHKD.:	APPD.:	4-6
DATE: 12/23/98	REV.:	

Prepared by: PHILIP SERVICES CORP. • ASSOCIATED EARTH SCIENCES, INC • Roth Consulting

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APPENDIX A2
Data Gaps Investigation Technical Memorandum

PES Environmental, Inc.
Engineering & Environmental Services

DATA GAPS INVESTIGATION TECHNICAL MEMORANDUM
TERMINAL 91 TANK FARM AFFECTED AREA CLEANUP

PORT OF SEATTLE
SEATTLE, WASHINGTON

JULY 2012

Excerpt from Report
Section 5 - Laboratory Testing Program

Appendix C - Materials Lab Report and SB and SCB Lab Mix Design Testing

Appendix D - Materials Lab Report, Betonite Slurry Compatibility Evaluation

Prepared for:

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Seattle, WA 98111

Prepared by:

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Seattle, Washington 98161

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4132 SW Barbur Boulevard
Portland, Oregon 97239

948.007.02

5.0 LABORATORY TESTING PROGRAM

5.1 Introduction

This section summarizes the results of the laboratory testing program implemented to develop a design mix for the cutoff wall that is to be constructed around the former tank farm as part of the final cleanup action. The scope of the laboratory testing program is described in detail the DGIWP. As presented in the DGIWP, the laboratory testing has been performed in conjunction with:

- A pipeline and utility identification program to determine the location and status of existing utilities, subsurface structures and pipelines (see Section 3); and
- A soils and geotechnical investigation (see Section 4).

The overall goal is to select a type of cutoff wall that is appropriate for the site conditions, including:

- The required hydraulic conductivity to prevent the migration of LNAPL from the tank farm area;
- The site subsurface soils that will be excavated along the cutoff wall alignment;
- The properties of the contaminated groundwater and LNAPL;
- Subsurface conditions;
- Adjacent structures; and
- Proposed future development of the property.

The DGIWP was implemented, and the laboratory testing program performed, before some of the decisions about future site development and usage had been finalized. Therefore, the laboratory program was tailored to provide flexibility in the final choice of cutoff wall type by considering design mixes for both soil-bentonite (SB) and soil-cement-bentonite (SCB) cutoff walls. Additionally, as discussed in the DGIWP, it was recognized that the site soils are generally sandy, and that an off-site source of low-permeability soil (silt/clay) may be required to mix with the site soils to achieve acceptable design mixes.

5.2 Laboratory Testing Objectives

The purpose of the laboratory testing program was to develop SB and SCB mixes that satisfy the following conditions:

- **Workability.** The design mix should have a consistency suitable for field construction with a slump of 4 to 6 inches (in.);
- **Chemical Compatibility.** The bentonite, as well as the design mixes, must be compatible with the site LNAPL and groundwater;
- **Permeability.** SB and SCB design mixes should have long-term saturated coefficients of hydraulic conductivity, as measured in the laboratory, of less than 5×10^{-8} and 5×10^{-7} cm/sec, respectively. It is assumed that the target permeabilities for the

laboratory design mixes will be approximately half of the target field permeability of 1×10^{-7} cm/sec and $1\text{x}10^{-6}$ cm/sec for the SB and SCB materials, respectively; and

- **Unconfined Compressive Strength** – The SCB should develop a minimum 28-day unconfined compressive strength that will be determined for the project, but typically at least 15 pounds per square inch (psi; 1,080 pounds per square foot [psf]).

In performing the work, it was assumed that the cutoff wall will be constructed using:

- Subsurface soils from the alignment of the cutoff wall;
- Fine soil (e.g. silt/clay) from an off-site borrow source;
- A commercially-available bentonite for both SB and SCB cutoff walls;
- A commercially-available cement for an SCB wall; and
- The City of Seattle water (City water) available at the site.

5.3 Laboratory Testing Approach

To accomplish the laboratory testing goals, a testing program consisting of the following four phases was implemented:

- **Phase I - Soil Index Testing** to evaluate physical characteristics of the subsurface soil and borrow soil samples.
- **Phase 2 - Compatibility Testing** to evaluate the potential for incompatibility between bentonite and City water, site groundwater and LNAPL.
- **Phase 3 - Workability and Strength Testing** to verify that the design mix is workable using typical construction techniques, and that the SCB mix will develop adequate strength.
- **Phase 4 - Hydraulic Conductivity Testing** to evaluate the saturated hydraulic conductivity of the soil, SB and SCB mixes and to assess the potential for long-term degradation of the SB and SCB mixes when permeated with site groundwater and LNAPL.

All the laboratory testing was performed by HWA Geosciences, Inc. (HWA) at its soil and environmental laboratory in Bellevue, Washington, and is described in the report entitled *Materials Laboratory Report, SB and SCB Laboratory Mix Design Testing, Terminal 91 Tank Farm Affected Cleanup Project, Seattle, Washington* (HWA, 2012a) and included in Appendix C.

5.4 Materials Tested

The following materials were used in the laboratory testing program:

- Subsurface soil from the site;
- An off-site low permeability soil;
- Commercially-available bentonite;
- Commercially-available Portland cement;

- Seattle City water;
- Site groundwater; and
- LNAPL from the Site.

The material sources are described below.

5.4.1 Subsurface Soil

Twenty geoprobe subsurface soil samples were obtained from seven borings at various depths ranging from 4 to 30 ft as a part of a subsurface investigation conducted at the Site. Table 4-1 summarizes the direct-push sample collection data, including sample identification, sample depths, estimated volume, and the associated field screening results. The samples were placed in buckets and delivered to HWA's laboratory on November 8, 2011. Upon receipt, the samples were weighed, to determine the individual and total sample masses, and visually classified.

5.4.2 Off-Site Borrow

Two fine grained soil samples were obtained and sent to HWA for testing. An initial sample of approximately 13-gallons (by volume) of soil was obtained on February 16, 2012 from Lakeside Industries in Issaquah Washington. A second sample of approximately 15-gallons (by volume) was collected on February 29, 2012 from Quality Aggregates in Maple Valley, Washington.

5.4.3 Bentonite

Two commercially-available bentonites were sourced by Vista and sent directly to HWA by the suppliers:

- Hydrogel® supplied by Wyoming Bentonite (Wyo-Ben) of Billings, Montana; and
- Sorbond UP supplied by CETCO of Arlington Heights, Illinois.

5.4.4 Cement

A sample of commercially-available Type I-II Portland cement manufactured by Lehigh Cement Company was obtained by HWA.

5.4.5 City Water

PES provided HWA with approximately 5-gallons of City water, obtained on November 22, 2012 from a faucet in Building M-28 Terminal 91.

5.4.6 Groundwater

A sample of site groundwater was obtained by PES from monitoring well (PR-03) on November 22, 2011 and delivered to HWA. The groundwater sample was collected in a 5-gallon bucket with a peristaltic pump using low-flow procedures to minimize drawdown during sample collection. The sample was kept in relatively air-tight containers for the duration of the laboratory testing program.

5.4.7 LNAPL Sample

Two LNAPL samples were collected by PES and submitted to HWA. The samples were collected from product recovery wells since there was no existing LNAPL satellite accumulation drum on-site. An initial LNAPL sample (approximately 2-liters) was collected and composited from two product recovery wells (CP_PR-02 and CP_PR-03) on November 30, 2011. A second sample (approximately 2-liters) was collected from product recovery well PR-12 on May 29, 2012. The LNAPL samples were kept in relatively air-tight containers for the duration of the laboratory testing.

5.5 Phase 1 - Soil Index Testing

Soil index testing of the twenty site subsurface soil samples and the off-site borrow soil included:

- **Moisture content**. The moisture content of each sample was determined in general accordance with American Society of Testing Materials (ASTM) D2216, Standard Test Methods for Laboratory Determination of Water (Moisture) Content of Soil and Rock by Mass.
- **Particle size distribution.** The particle size distribution of each sample was determined in accordance with ASTM D422, Standard Test Method for Particle-Size Analysis of Soils.
- **Atterberg Limits.** The Atterberg limits of samples that the laboratory personnel determined could be tested were determined in accordance with ASTM D4318, Standard Test Method for Liquid Limit, Plastic Limit, and Plasticity Index of Soils.
- **Material classification.** Each sample was classified in general accordance with ASTM D2487, Standard Test Method for Classification of Soils for Engineering Purposes and ASTM D2488, Standard Practice for Description and Identification of Soils (Visual- Manual Procedure).

The results of the soil index testing are presented in Appendix C, including Figures 1 to 14 (HWA, 2012a).

5.5.1 Site Subsurface Soil

The site soils are predominantly sandy with lesser quantities of gravel and fines. The relative percentage of the different grain sizes are summarized by depth in Table 5-1, by boring in Table 5-2, and by sieve size in Table 5-3.

The data shows that the site soils:

- Are non-plastic;
- Are generally coarser grained at shallow depth (less than 10 feet) and finer grained at greater depth (below 20 feet);
- Are relatively consistent between borings;
- The overall average fines content is less than 13 percent (individual borings range from 5.4 to 20.2 percent);
- Typically have grain sizes less than 1.5 in.;

- Have moisture contents at shallow depth (1 to 10 ft) that are less than those below 10 ft, which is likely consistent with the location of the groundwater surface.

5.5.2 Off-Site Borrow Soil

Samples were obtained from two off-site sources:

- Lakeside Industries, Issaquah, Washington; and
- Quality Aggregates, Maple Valley Washington.

The index testing data is presented in Appendix A-2 and shows:

- The Lakeside sample contained over 40 percent sand size material; and
- The Quality Aggregates sampled contained over 98 percent fines and classified as a low-plasticity clay, with a moisture content of 37 percent.

On this basis of the testing the Lakeside material was considered too coarse and the Quality Aggregates material was selected for all further testing.

5.5.3 Soil Selection For Additional Testing

USCOE (1996) provides the gradation criteria guidelines contained in Table 5-4 for backfill soils to achieve a low permeability of $1x10^{-7}$ cm/sec or less.

As can be seen from Table 5-4, the on-site soils are outside the USCOE guidelines, especially with respect to the fines content. In particular, the fines content in the upper 20 ft (the pre-design target depth of the cutoff wall) is only half the USCOE minimum guideline value (individual borings range from 5.4 to 14.1 percent);

Based on the above, it was considered unlikely that the on-site soils would generate a low-permeability soil-bentonite mix without the addition of supplemental fine-grained soil, as typically 20 to 40 percent fines are required prior to the addition of bentonite.

Therefore, the following soil mixtures were selected for the Phase 3 testing:

- **Soil Mix 1 – Composite Baseline Sample**. On-site subsurface soils, without the addition of any off-site borrow soil. Approximately equal weights of soil from all the individual soil samples above 20 ft (the sample from B-5 between 14 and 21 ft was also included) were composited to provide a baseline sample with a resulting fines content of approximately 10 percent.
- **Soil Mix 2 – 25 Percent Fines**. On-site surface soil (Soil Mix 1, composite baseline sample) was mixed with off-site borrow (from Quality Aggregates) at a ratio of 1 to 0.25 (wet weight on-site soil to wet weight off-site soil) to create a soil mixture with a target fines content of approximately 25 percent (by dry unit weight).
- **Soil Mix 3 – 35 Percent Fines**. On-site surface soil (Soil Mix 1, composite baseline sample) was mixed with off-site borrow (from Quality Aggregates) at a ratio of 1 to 0.48 (wet weight on-site soil to wet weight off-site soil) to create a soil mixture with a target fines content of approximately 35 percent (by dry unit weight).

- **Soil Mix 4 – 30 Percent Fines.** Later in the testing program, Soil Mix 4 with 30 percent fines (by dry unit weight) was developed after testing of Soil Mixes 2 and 3 with 3 percent bentonite resulted in a lower than desired hydraulic conductivity values, and an intermediate mix between Soil Mixes 2 and 3 was preferred to avoid an overly conservative soil-bentonite design based on Soil Mix 3. To make Soil Mix 4, on-site soil (Soil Mix 1, composite baseline sample) was mixed with off-site borrow (from Quality Aggregates) at a ratio of 1 to 0.35 (wet weight on-site soil to wet weight off-site soil).

Index tests were performed on all four mixes. The data is presented in Appendix C, Figures 10, 11, and 13 (HWA, 2012a) and shows:

- The fines contents of Mixes 2, 3 and 4 were very close to the target ratios based on calculated mix proportions;
- Soil Mix 2 (25 percent fines) and Soil Mix 4 (30 percent fines) were non-plastic; and
- Mix 3 (35 percent fines) represents a low plasticity silt/clay.

Table 5-5 summarizes the soil proportions in each of the mixes and Table 5-6 compares the gradations of the resulting soil mixes to the USCOE guidelines and

5.6 <u>Phase 2 - Compatibility Testing</u>

Laboratory tests were conducted to evaluate potential incompatibilities between the two bentonite samples and:

- City of Seattle water (City water);
- Site groundwater; and
- Free floating product (LNAPL).

The following procedure was used to perform this evaluation:

- A sample of each of the two bentonites (Hydrogel and Sorbond UP) was mixed with City water to form hydrated slurries with bentonite contents of 10 percent by weight;
- The two slurries were then diluted to an equivalent 5 percent bentonite content by weight, to simulate representative and potential worst case site conditions where the site groundwater and/or free-product are introduced to the SB slurry after the initial hydration of the bentonite has taken place, to produce six slurries, by adding either:
    - Additional City water (Slurry Mixes 1 and 2, for Hydrogel and Sorbond UP, respectively); or
    - Site groundwater (Slurry Mixes 3 and 6 for Hydrogel and Sorbond UP, respectively); or
    - LNAPL (Slurry Mixes 7 and 8 for Hydrogel and Sorbond UP, respectively);
- Additionally, to simulate a potential worst case incompatibility condition, samples of each bentonite product were mixed directly with the site groundwater to prepare two slurries with 5 percent bentonite contents by weight (Slurry Mixes 5 and 4 for Hydrogel and Sorbond UP, respectively).

- The eight slurry mixes (2 initial slurries with 3 diluting liquids, plus 2 site groundwater and bentonite slurries) were allowed to age for seven days in relatively air-tight containers;
- After the seven day curing period, the following tests were performed on each slurry mix:
    - Unit weight (American Petroleum Institute [API] Recommended Practice [RP] 13B-1, Recommended Practice for Field Testing Water-based Drilling Fluids);
    - Atterberg limits (ASTM D4318);
    - Marsh viscosity (API RP 13B-1);
    - Bentonite filtrate loss (ASTM D5891);
    - pH (API RP 13B-1); and
    - Dispersive characteristics (ASTM D4221, Standard Test Method for Dispersive Characteristics of Clay Soil by Double Hydrometer).

5.6.1 Compatibility Testing Results

The results of the soil index testing are presented in the HWA report entitled *Materials Laboratory Report, Bentonite Slurry Compatibility Evaluation, Terminal 91 Tank Farm Affected Area Cleanup Project, Seattle, Washington* (HWA, 2012b) attached in Appendix D and summarized in Table 5-6. The bentonite compatibility test data indicates:

- **Unit weight and specific gravity.** The unit weight and specific gravity values for both bentonites are similar.
- **Marsh viscosity.** The Marsh viscosity times (sec) were 60 or above for the Hydrogel based slurries. In addition, the times for the Hydrogel Slurry Mixes 3, 5 and 7, containing LNAPL and/or groundwater, were all greater than the time for Slurry Mix-1, the control made only with City water. This indicates additional beneficial swelling of the bentonite in the presence of groundwater and LNAPL. The greatest Marsh viscosity time was for Slurry Mix-5, which was made to simulate a potential worst case compatibility situation and contained no City water.

  The Marsh viscosity times (sec) were 46 or below for the Sorbond based slurries. In addition, the times for the Sorbond Slurry Mixes 6, 8 and 4, containing LNAPL or groundwater, were all less than the time for Slurry Mix-2, the control made only with City water. This indicates some reduction in swelling of the bentonite in the presence of groundwater and LNAPL. The biggest decrease was for Mix-4, which was made to simulate a potential worst case compatibility situation and contained no City water.
- **Filtrate loss.** A greater filtrate loss indicates the bentonite is more effective at sealing and therefore less permeable. The results for both bentonites are similar with the Hydrogel exhibiting marginally higher values than the Sorbond UP for corresponding mixtures.
- **pH.** The pH values for both bentonites are similar for corresponding mixtures, with the highest values being for the control slurries mixed with City water. Additionally, the pH values of the slurry mixes are approximately 0.7 to 1.5 higher than the corresponding liquids.

- **Dispersion.** ASTM D4221, compares the measured percentage of particles smaller than 5μm (0.005 mm) in a sample that has been artificially dispersed to a companion sample that has not been treated with a dispersing agent. All the slurry mixes exhibited highly dispersive properties, as expected for material composed of sodium montmorillonite, with only relatively small gradation changes resulting from the addition of dispersing agents[1]. The Sorbond UP exhibited the greatest dispersion (100 percent) in City water alone (Slurry Mix-2), and the Hydrogel exhibited the greatest dispersion (97 percent) with City water and LNAPL (Slurry Mix-7). The same dispersion (92 percent) was reported for both bentonites with groundwater alone (Slurry Mix-4 and Slurry Mix-5).
- **Atterberg limits.** The Atterberg limits values were similar for all corresponding slurry mixes, except for Slurry Mix-4 and Slurry Mix-5, bentonite with groundwater alone, for which the Hydrogel exhibited higher (more plastic) values than the Sorbond. This may be associated with the Marsh viscosity test for which the Hydrogel exhibited increased viscosity.

5.6.2 Bentonite Selection For Additional Testing

Typically required (e.g. UFGS, 2010) hydrated bentonite-slurry properties for SB cutoff wall applications are:

- Minimum Marsh Viscosity of 40 sec;
- Minimum unit weight of approximately 64 pcf;
- pH in the range of 6.5 to 10; and
- Filtrate loss of less than 20 ml in 30 minutes.

Both the Wyo-Ben Hydrogel and the CETCO Sorbond UP bentonites met these typical requirements. In addition, none of the mixtures appeared to exhibit any adverse reactions compared to the baseline mixtures made with City water. However, the Hydrogel was selected for use in the Phase 3 and Phase 4 testing based on the greater Marsh viscosity times.

5.7 Phase 3 – Workability and Strength Testing

The purpose of this phase of testing was to identify economical mixes of on-site soil, off-site soil, bentonite, cement (for SCB mixes) and water, for testing to achieve laboratory hydraulic conductivities of 5×10^{-8} cm/sec (SB) and 5×10^{-7} cm/sec (SCB). The section describes the testing performed to select potential design mixes for hydraulic conductivity testing (Phase 4 testing) based on:

- Workability for both soil-bentonite (SB) and soil-cement-bentonite (SCB) mixtures; and
- Strength for only SCB mixtures.

As noted in Section 5.5.3, and presented in Appendix C, four soil mixes were developed for this phase of the laboratory testing program, as follows:

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[1] The dispersion value is calculated by dividing the percentage of untreated soil finer than 5μm (by weight) by the percentage of artificially dispersed soil finer that 5μm (by weight).

- **Soil Mix 1** – Baseline sample consisting of composite sample of all on-site individual samples from upper 20 feet (upper 21 feet from boring B-5);
- **Soil Mix 2** – Baseline sample mixed with off-site borrow to provide a soil mix with approximately 25 percent fines (by dry unit weight);
- **Soil Mix 3** – Baseline sample mixed with off-site borrow to provide a soil mix with approximately 35 percent fines (by dry unit weight); and
- **Soil Mix 4 –** Baseline sample mixed off-site borrow to provide a soil mix with approximately 30 percent fines (by dry unit weight).

5.7.1 SB and SCB Workability

To produce a low-permeability durable mix, the SB, or SCB, mix must contain an adequate concentration of fines (silt/clay), a minimal amount of large diameter particles, and suitable concentrations of bentonite, cement (for SCB mixes) and water. The bentonite contributes to the low permeability of the mix and with the water creates a material that should have sufficient workability to flow and backfill the entire profile of the excavated trench. To fulfill the workability requirement, without introducing excessive quantities of water, it is typically recommended that an SB (or SCB) mix have a slump of 4 to 6 inches (USEPA, 1984). Therefore, for all the testing performed for this project a target slump of 5 inches was selected.

The four soil mixes were mixed with different concentrations of bentonite (SB mixes) and for each bentonite content the slump was measured at a series of increasing water contents in accordance with ASTM C172 (*Standard Practice for Sampling Freshly Mixed Concrete*). In this manner a family of curves was developed for each SB mix.

Based on the SB workability testing the following samples were selected for strength testing with cement addition:

- Mix 1B (5 percent bentonite);
- Mix 2B (3 percent bentonite);
- Mix 3B (3 percent bentonite);
- Mix 4A (4.5 percent bentonite); and
- Mix 4 (soil only, no bentonite).

As cement was added to the above referenced SB mixes, the water content was determined for SCB slumps of approximately 5 inches.

The workability data is presented in Appendix C, including Tables 1, 2, 3 and Figures 15 to 19, (HWA, 2012a) and summarized in Table 5-8.

The workability test data indicates:

- The required moisture content for a given slump (e.g. 5-in. slump) increases as the fines content increases at a constant bentonite ratio (e.g., at 3 percent bentonite, the required moisture content of Mix 3B [30% moisture content] > Mix 2B [26.5% moisture content] > Mix 1A [18.5% moisture content]);

- The required moisture content for a given slump (e.g. 5-in slump) increases as the bentonite content increases and additional water is required to hydrate the bentonite (see trends within each mix group);
- The required moisture content for a given slump (e.g. 5-in slump) increases as the cement content increases and additional water is required to hydrate the cement (see trend within each SCB mix group);
- Each SB mix group resulted in a consistent family of workability curves from which interpolations could be made for different fines, bentonite and cement contents; and
- The unit weight decreases with increasing bentonite content and general, but to a lesser extent, with increasing cement content.

5.7.2 SCB Strength Testing

Based on the workability test data, the SCB samples (and one soil-cement [SC] sample tested to provide baseline data without the influence of bentonite) tested are shown in Table 5-8. As shown, soil samples made with 0, 3, 4.5 and 5 percent bentonite were mixed with different concentrations of commercially available cement (Type I-II Portland Cement), cast into cylinders approximately 6-in high and 3-in diameter (at least three of each sample), and tested at different ages in accordance with ASTM D2166 (*Standard Test Method for Unconfined Compressive Strength of Cohesive Soil*). The unconfined compressive strength (UCS) testing data is presented in Appendix C, Tables 3 and 4 and Figures 20 to 27 (HWA, 2012a) and summarized in Table 5-9.

The SCB strength testing data indicates:

- Each mix group resulted in a general consistent family of curves from which interpolations can be made for different cement contents;
- UCS increases with increasing cement content;
- UCS values of soil Mix 1 (10 percent fines) were less than the other mixes at similar cement contents;
- UCS values were generally similar at the same cement content for soil Mixes 2, 3 and 4 (25 to 35 percent fines). The UCS for the 35 percent fines sample was slightly higher at 7 percent cement content, and slightly lower at 3 percent cement content than the 25 percent fines sample, indicating that the fines content was of minor importance over the tested range. Furthermore, form Mixes 2, 3 and 4, cement contents in excess of 4.5 percent achieved UCS values greater than 8,000 psf (55.5 psi), which is equivalent to clay with a hard consistency and a standard penetration resistance of more than 30 (Lambe & Whitman, 1969, p. 77);
- Based on the shapes of the curves, UCS values likely continue to increase beyond 28 days;
- A comparison of the sample made without bentonite, indicates that the addition of 4.5 percent bentonite reduced the UCS approximately 40 to 50 percent; and
- The two versions of SCB Mix 4A-4.5 (4.5 percent bentonite and 4.5 percent cement) made 19-days apart, resulted in 28-day strength values that vary by 30 psi. This indicates

that even materials made under laboratory conditions may be subject to significant variations and the results should be used conservatively.

5.8 Phase 4 – Hydraulic Conductivity Testing

As noted in the DGIWP, the intent of the soil index testing, chemical compatibility testing and workability testing (and UCS testing for SCB specimens) was to narrow possible mix designs to a few options. Hydraulic conductivity testing would then be performed in two stages to confirm potential SB and SCB design mixes:

- Perform routine hydraulic conductivity testing, of selected mix designs and control soil samples prepared without bentonite, using City water as a permeant; and
- Based on these results select final design mixes for potential breakthrough (compatibility) hydraulic testing using site groundwater and LNAPL as the permeant.

5.8.1 Soil and SB Mix Design Selection

The following soil and SB mixes (see Tables 5-5 and 5-8) were initially selected for the Phase 4 routine hydraulic conductivity testing using City water as the permeant:

- Soil Mix 1 – On-site soil, without bentonite (as a control to determine the property of the site soil and to allow the effect of bentonite addition to be determined);
- SB Mix 1B – Soil Mix 1 plus 5 percent bentonite;
- Soil Mix 2 – On-site and off-site soil with 25 percent fines, without bentonite (to compare the effect of fines addition to Mix 1, and as a control to allow the effect of bentonite addition to be determined);
- SB Mix 2B – Soil Mix 2 plus 3 percent bentonite;
- Soil Mix 3 – On-site and off-site soil with 35 percent fines, without bentonite (to compare the effect of fines addition relative to Mixes 1 and 2, and as a control to allow the effect of bentonite addition to be determined); and
- SB Mix 3B – Soil Mix 3 plus 3 percent bentonite.

The hydraulic conductivity values of SB Mixes 2B and 3B were determined to be lower than the target value of $5x10^{-8}$ cm/sec; therefore, the following additional SB mixes were also selected:

- SB Mix 4A – Soil Mix 4 plus 4.5 percent bentonite; and
- SB Mix 4B – Soil Mix 4 plus 6 percent bentonite (to enable the effect of varying the bentonite content to be assessed).

5.8.2 SCB Mix Design Selection

SCB Mix 4A-6 (SB Mix 4A plus 6 percent cement) was selected for the hydraulic conductivity testing using City water as the permeant (6 percent cement was selected conservatively rather than the 4.5 percent cement content used for some of the workability specimens since hydraulic conductivity tends to decrease with increasing cement content, and 6 percent cement was considered the upper limit that would be considered based on the UCS test data).

5.8.3 Routine Hydraulic Conductivity Testing

The procedures used and the results of the hydraulic conductivity testing using City water as the permeant are detailed in Appendix C. including Table 5 and Figures 28 to 39 (HWA, 2012a). The results are also summarized in Table 5-10.

The hydraulic conductivity test results indicate:

- The composite site soils (Soil Mix 1) have a hydraulic conductivity of approximately 4×10^{-4} cm/sec;
- Adding 5 percent bentonite to the site soils (Soil Mix 1B) reduced the hydraulic conductivity by four orders of magnitude to approximately 6×10^{-8} cm/sec (values of 6.8 and 2.6×10^{-8} cm/sec reported), a value close to the target laboratory value of 5×10^{-8} cm/sec for an SB mix;
- Increasing the fines content to 25 percent (Soil Mix 2) and 35 percent (Soil Mix 3) reduced the hydraulic conductivity values by over three orders of magnitude to 3.6×10^{-7} cm/sec and 1.6×10^{-7} cm/sec, respectively.
- SB Mix 2B and SB Mix 3B with 3 percent bentonite indicate only minor decreases in hydraulic conductivity compared to Soil Mix 2 and Soil Mix 3, respectively, with neither result meeting the target laboratory value of 5×10^{-8} cm/sec for and SB mix;
- It may be that with the addition of fines, the surface area of the particles in Soil Mixes 2 and 3 increased to such an extent that the bentonite was unable to coat the particles sufficiently to make a significant effect;
- With the increase in bentonite content to 4.5 (SB Mix 4A) and 6 percent (SB Mix 4B) the reported hydraulic conductivity values decreased to 5.7×10^{-8} cm/sec and 2.9×10^{-8} cm/sec, respectively. These values are essentially at or below the target laboratory value of 5×10^{-8} cm/sec for an SB mix; and
- The hydraulic conductivity value of 1.9×10^{-7} cm/sec for SCB Mix 4A-6 is less than the target laboratory value of 5×10^{-7} cm/sec for an SCB mix (Section 5.2).

5.8.4 Breakthrough (Compatibility) Hydraulic Conductivity Testing

Based on the results of the routine hydraulic conductivity testing (Section 5.8.3**)** the following SB and SCB mixes (and comparative soil samples) were selected for the compatibility hydraulic testing using groundwater and LNAPL as permeants under a high hydraulic gradient:

- Soil Mix 4 – On-site and off-site soil with 30 percent fines, without bentonite (as a control to allow the effect of the permeants on the soil matrix itself to be determined);
- SB Mix 4A – Soil Mix 4 plus 4.5 percent bentonite;
- SC Mix 4 – Soil Mix 4 plus 4.5 percent cement (as a control to allow the effect of the permeants on the cement to be determined in conjunction with the results of Soil Mix 4); and

- SBC Mix 4A-4.5 – SB Mix 4 plus 4.5 percent cement.

Two specimens were made of each mix, with one specimen permeated with site groundwater and the other specimen permeated with LNAPL. The procedures used and the results of the hydraulic conductivity testing are detailed in Appendix C, including Table 6 and Figures 40 to 44 (HWA, 2012a)[2]. The results are also summarized in Table 5-11.

The hydraulic conductivity test results indicate:

- Difficulty was experienced in working with the LNAPL because of its tendency to react with latex membranes, and the resulting tendency for sidewall leakage to develop;
- No indication of adverse groundwater or LNAPL interaction with the specimens was noted based on the hydraulic conductivity data;
- All the test results appear consistent with data obtained using City water.

5.8.5 Summary

The final selection of a mix design for the cutoff wall will be made in conjunction with the detailed design for the site; however, the following summary comments can be made:

- Wyo-Ben Hydrogel, which appeared to perform slightly better in this application than CETCO Sorbond UP, was selected for use in all workability, strength, and permeability testing. Therefore, this product should be specified for use in the project unless the selected contractor repeats the design mix testing for another product;
- The laboratory testing has demonstrated that mixes meeting the target laboratory hydraulic conductivities of 5×10^{-8} cm/sec (SB) and 5×10^{-7} cm/sec (SCB) with desirable workability characteristics (and UCS for SCB mixes);
- None of the materials tested (on-site soil, off-site soil, bentonite and cement) appear to be detrimentally affected by constituents in site groundwater or LNAPL;
- The gradation of the on-site soils (particularly the fine grained fraction) is outside the typically recommended range of values; however, a bentonite content of 5 percent indicated that a hydraulic conductivity of 10^{-7} cm/sec may be achieved based on the use of the composite subsurface sample. However, the subsurface data indicates locations exist (e.g., boring B-4) where the soils are coarser (less fines content) than the composite sample used for the testing. Therefore, it is recommended that the mix design be based on adding imported fines.

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[2] This testing is still in progress. This report will be updated when the final results are available.

APPENDIX C

MATERIALS LABORATORY REPORT, SB AND SCB LABORATORY MIX DESIGN TESTING TERMINAL 91 TANK FARM AFFECTED CLEANUP PROJECT SEATTLE, WASHINGTON JULY 2012

HWA GEOSCIENCES INC.
Geotechnical & Pavement Engineering • Hydrogeology • Geoenvironmental • Planning & Permitting • Inspection & Testing

July 20, 2012
HWA Project No. 2011-121-23

PES Environmental, Inc.
1215 Fourth Avenue, Suite 1350
Seattle, Washington 98161

Attention: Mr. Brian O'Neal, PE

Subject: **MATERIALS LABORATORY REPORT**
SB & SCB LABORATORY MIX DESIGN TESTING
Terminal 91 Tank Farm Affected Area Cleanup Project
Seattle, Washington

Dear Mr. O'Neal:

As requested, HWA GeoSciences Inc. (HWA) performed laboratory testing for the design of Soil-Bentonite (SB) and Soil-Cement-Bentonite (SCB) Slurry materials for use on the subject project. Herein we present the results of our laboratory analyses, which are summarized on the attached Figures. The laboratory testing program was performed in general accordance with the instructions of Mr. Roger North, PE. (Engineer-Vista Consultants LLC.) and appropriate ASTM Standards and procedures as outlined below.

TESTING PROGRAM

This mix design program consisted of four main phases:

- **Site and Imported Soil Characterization:** Testing consisted of moisture content, particle size analysis (wet sieve or wet sieve and hydrometer), and atterberg limits for samples obtained in the field by the Client.

- **SB & SCB Slurry Workability:** Using the selected blend of site soils, imported fines, bentonite, and cement, four potential SB mixes were prepared having a 4 to 6 inch slump. Cement was added to these mixes at a range of concentrations to determine an SCB mix design with desired strength and workability characteristics.

- **SCB Compressive Strength Testing:** SCB material batches prepared during the workability assessment described above were used to cast unconfined compressive strength specimens that were tested at 3, 7, 14, 28 and 56 days.

- **Hydraulic Conductivity Testing:** Hydraulic conductivity determinations were made for baseline materials (without bentonite amendment), SB and

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SCB materials at standard gradients, and at high gradients (100) with site groundwater and free product as permeants to assess the potential for breakthrough.

MATERIALS UTILIZED: The following materials were provided to our laboratory for use in this testing program:

Site Soil Composite. Fourteen individual site soil samples were combined as directed by the Engineer to produce a composite soil mixture used as a base for all other testing in this program.

Bentonite. Based on the results of our previously completed slurry compatibility testing program (see HWA report dated January 4th, 2012) WYO-BEN Hydrogel was utilized in all testing conducted for the mix design program.

Portland Cement. Type I-II Portland cement manufactured by Lehigh Cement Co. provided by Salmon Bay Concrete of Seattle, Washington was used in this testing program.

City Water. Seattle City Water obtained from a hydrant near the T-91 site was provided by PES personnel to HWA for use in this testing program.

Site Groundwater. Site groundwater from on-site wells was provided by PES personnel to HWA for use in this testing program.

LNAPL. LNAPL free product obtained from on-site wells was provided by PES personnel to HWA for use in this testing program. LNAPL was sampled on site twice for this project.

SOIL CHARACTERIZATION

Twenty soil samples obtained during exploration drilling were delivered to our laboratory by PES personnel on November 8, 2011 for use in this evaluation. The samples were contained in sealed five-gallon buckets. Upon receipt, each individual sample was thoroughly mixed and split to obtain a sample for moisture content and particle-size determinations. Atterberg limits determinations were conducted on selected samples that contained appreciable fine-grained material. The site soil samples received were designated as follows:

Boring	Depth Interval	Soil Classification
B-1	**4'-10'**	**SP**
B-1	**10'-20'**	**SP-SM**
B-1	20'-30'	SM
B-2	**4.5'-10'**	**SP**
B-2	**10'-20'**	**SM**
B-2	20'-28.5'	SP-SM

Boring	Depth Interval	Soil Classification
B-3	**3.5'-10'**	**SP**
B-3	**10'-20'**	**SP-SM**
B-3	20'-30'	SM
B-4	**4'-10'**	**SP**
B-4	**10'-26'**	**SP-SM**
B-5	**4.5'-14'**	**SP**
B-5	**14'-21'**	**SM**
B-5	22'-30'	SM
B-6	**3'-10'**	**SP-SM**
B-6	**10'-20'**	**SM**
B-6	20'-29'	SM
B-8	**4'-10'**	**SP-SM**
B-8	**10-20'**	**SP-SM**
B-8	20'-30'	SM

Note: Samples in BOLD were used in the SB and SCB Mix design

In addition, two samples of imported soil material from Lakeside Industries and Quality Aggregates intended for use as amendment to increase the fines content of the mix were delivered to our laboratory on February 17 and March 3, 2012, respectively, for evaluation. These samples were designated as follows:

Sample Designation	Source	Soil Classification
Lakeside Wash Pit	Lakeside Industries, Issaquah	ML
QA Fines	**Quality Aggregate, Maple Valley**	**CL**

Note: The material from Quality Aggregates was selected for use in the Mix design

MOISTURE CONTENT OF SOIL: The moisture content of selected soil samples (percent by dry mass) was determined in general accordance with ASTM D 2216. The results are shown on the Summary of Material Properties Table on Figures 1 and 2 and on other test report sheets as appropriate.

PARTICLE SIZE ANALYSIS OF SOILS: Selected samples were tested to determine the particle distribution of material in general accordance with ASTM D422 (wet sieve or wet sieve and hydrometer). The results are summarized on the attached Particle-Size Analysis of Soils Reports shown on Figures 3 through 11 which also provide information regarding the classification of the sample and the moisture content at the time of testing.

LIQUID LIMIT, PLASTIC LIMIT, AND PLASTICITY INDEX OF SOILS (ATTERBERG LIMITS): Selected samples were tested using method ASTM D 4318, multi-point method. The results are reported on the attached Liquid Limit, Plastic Limit, and Plasticity Index reports shown on Figures 12 through 14.

SC & SCB WORKABILITY

The first phase of workability testing consisted of the preparation of twelve soil blends composed of site soils, imported fines and bentonite at various ratios to develop a mix design that has desirable characteristics such as a slump between 4 to 6 inches, a high clay content with only a moderate bentonite content and a low water content. Initially, materials were blended into three 45 to 60 pound batches composed according to the following blends specified by the Engineer.

Mix Designation	Fines Content	Bentonite Content
Mix 1	None added	3%, 5%, 7%, 9%
Mix 2	25%	2%, 3%, 4%, 5%
Mix 3	35%	2%, 3%, 4%, 5%

Base Mix 1 consisted of a composite of site soils only without the addition of imported fines. Base Mixes 2 and 3 were prepared by mixing the appropriate amounts of site soils and imported fines (QA fines) in accordance with blending calculations provided by the Engineer. The blend calculations utilized moisture and fines content data previously determined for the blend constituents during the previously described soil characterization. In order to represent the conditions expected during construction, the bentonite was added in dry powder form and was not introduced as pre-hydrated slurry. Batches were thoroughly mixed with hand tools or directly by hand then allowed to "rest' for a period of 20 minutes. After that time, the sample was quickly re-mixed and a sample was obtained for moisture content, particle size and Atterberg limits to verify the blend characteristics. These tests were conducted in accordance with procedures outlined in the soil characterization section described previously. The results of the index testing conducted on the three mixes, are depicted on Figures 13 and 14.

Workability testing consisted of measuring the effect that water added in measured increments had on the slump of the mix. Typically each blend was too dry to slump initially and water was added in increments approximately equal to 1 to 2% (by dry weight) until the blend exhibited a measurable slump. At that point, water in smaller increments ranging from about 0.5 to 1% (by dry weight) was added between slump tests until the mix exhibited a slump ranging between 4 and 6 inches. Upon reaching the target consistency, the bulk density of each mix was determined utilizing a 1/10 of cubic foot yield bucket, and a moisture content sample was obtained. The data obtained during this exercise are briefly summarized in Table 1 below and depicted graphically on Figures 15 through 17.

Table 1 - Summary of Initial Workability Assessment

Base Mix	Bentonite Content	Final Slump	Moisture Content	Bulk Unit Weight (pcf)
SB Mix 1A	3%	6.75"	19.7%	117.6
SB Mix 1B	5%	7.0"	24.1%	114.8
SB Mix 1C	7%	5.75"	30.8%	113.8
SB Mix 1D	9%	5.0"	36.3%	112.8
SB Mix 2A	2%	5.5"	24.5%	118.5
SB Mix 2B	3%	5.25"	26.8%	118.3
SB Mix 2C	4%	5.0"	28.0%	117.8
SB Mix 2D	5%	5.75"	31.5%	115.9
SB Mix 3A	2%	5.25"	29.9%	118.4
SB Mix 3B	3%	5.0"	30.3%	116.6
SB Mix 3C	4%	4.75"	31.5%	115.0
SB Mix 3D	5%	5.25"	34.0%	113.4

After review of initial baseline permeability data, it was determined that a SB mix containing 30% fines would be the most efficient blend. This new material blend was designated Mix 4 and was blended as specified by the Engineer. Testing was limited to four Mix 4 blends in which either the bentonite, or cement (for SCB mix design) content, was varied.

Mix Designation	Fines Content	Bentonite Content	Cement Content
Mix 4	30%	4.5% or 6.0%	0%, 4.5% or 6.0%

The mixing was conducted utilizing the same methods used during the preliminary workability assessment. The particle size distribution for un-amended (no Bentonite or cement) Mix 4 material is shown on Figure 11.

Workability testing consisted of measuring the effect that water added in measured increments had on the slump of the mix as was done previously for Mixes 1 through 3. The data obtained for Mix 4 during this design phase are briefly summarized in Table 2 below and depicted graphically on Figures 18 and 19.

Table 2 - Summary of Mix 4 Workability Assessment

Base Mix	Bentonite Content	Cement Content	Final Slump	Moisture Content	Bulk Unit Weight (pcf)
SCB Mix 4A	4.5%	0%	5.0"	30.5%	116.4
SCB Mix 4B	6.0%	0%	5.25"	32.0%	113.0
SCB Mix 4C	4.5%	4.5%	4.25"	39.0%	112.5
SCB Mix 4D	4.5%	6.0%	4.25"	42.0%	110.8

SCB COMPRESSIVE STRENGTH TESTING

Synchronously with the preliminary workability assessment, batches of Soil Cement Bentonite slurry (SCB) were prepared by amending SB material comprised of Mix 1, Mix 2, and Mix 3 containing the same bentonite content (3% by dry weight) with three different amounts of Portland cement. Six 3-inch by 6-inch long cylindrical specimens were cast for each batch to provide 3 pairs of specimens which after curing in the mold for 7, 14 and 28 days were loaded to failure in general accordance with ASTM D 2166 to determine the materials unconfined compressive strength (See photo 1). During portion of the project a total of six (6) specimens were cast for each mix of the nine (9) mixes specified by the Engineer, resulting in 54 test specimens. The results for the average of each pair of specimens is summarized in Table 3 below and tabulated and graphed on Figures 20 through 22, and 24 through 26.

Table 3 - Summary of SCB Strength Testing

Mix No.	Cement Content (%)	Moisture Content (%)	Unit Weight (pcf)	Age (days)	UCS (psi)
1B3a-b	3.0	29.5	115.4	7	23
1B3c-d	3.0	30.8	114.6	14	26
IB3e-f	3.0	31.1	113.0	28	43
1B5a-b	5.0	32.9	111.7	7	30
1B5c-d	5.0	32.6	112.3	14	40
1B5e-f	5.0	31.3	113.0	28	49.5
1B7a-b	7.0	33.2	113.4	7	46.5
1B7c-d	7.0	28.8	115.6	14	61.5
1B7e-f	7.0	30.9	115.5	28	76.5

Table 3 - Summary of SCB Strength Testing (Continued)

Mix No.	Cement Content (%)	Moisture Content (%)	Unit Weight (pcf)	Age (days)	UCS (psi)
2B3a-b	3.0	32.1	115.2	7	38
2B3c-d	3.0	31.2	115.4	14	46.5
2B3e-f	3.0	31.4	114.6	28	51.5
2B5a-b	5.0	33.4	115.5	7	55
2B5c-d	5.0	32.6	114.8	14	74
2B5e-f	5.0	33.5	114.4	28	80
2B7a-b	7.0	36.4	112.0	7	70.5
2B7c-d	7.0	34.4	114.1	14	96
2B7e-f	7.0	34.3	113.9	28	104.5
3B3a-b	3.0	35.7	110.8	7	31
3B3c-d	3.0	34.1	114.9	14	31
3B3e-f	3.0	34.3	114.6	28	35
3B5a-b	5.0	36.7	111.9	7	65
3B5c-d	5.0	37.4	110.8	14	73
3B5e-f	5.0	36.5	112.3	28	77
3B7a-b	7.0	38.5	111.7	7	85
3B7c-d	7.0	40.7	110.2	14	102.5
3B7e-f	7.0	40.8	109.0	28	114.5

Once the focus of the evaluation had been shifted to Mix 4, twelve (12) additional specimens were cast comprised of Mix 4 soils with 4.5% bentonite and 4.5% cement (6 specimens- comprised of two different batches), Mix 4 soils and 4.5% bentonite and 6.0% cement (3 specimens), and Mix 4 soils with 4.5% cement without bentonite (3 specimens). Water content was adjusted to match blends made during the workability trials. Batch moisture contents were adjusted to match previously determined values for each blend within the desired slump range during the workability testing. The results for each specimen is summarized in Table 4 below and tabulated on Figure 23 and graphed on Figure 27.

Table 4 - Summary of Mix 4 SCB & SC Strength Testing

Mix No.	Cement Content (%)	Moisture Content (%)	Unit Weight (pcf)	Age (days)	UCS (psi)
SB4-4.5A	4.5	35.9	111.9	3	34
SB4-4.5B	4.5	36.8	110.8	7	50
SB4-4.5C	4.5	38.5	111.8	28	60
SB4-4.5D	4.5	37.7	111.6	3	48
SB4-4.5E	4.5	35.3	112.5	7	60
SB4-4.5F	4.5	33.1	113.9	54	91
SB4-6.0A	6.0	42.9	108.0	3	37
SB4-6.0B	6.0	39.8	110.5	7	60
SB4-6.0C	6.0	35.2	112.2	28	88
S-4.5CA	4.5	26.5	120.5	3	65
S-4.5CB	4.5	25.0	120.6	7	88
S-4.5CC	4.5	24.2	120.3	54	143

HYDRAULIC CONDUCTIVITY TESTING

Initially, hydraulic conductivity testing (per ASTM D 5084) was conducted on remolded specimens of selected SB and SCB design mixes. In addition, baseline hydraulic conductivity tests were conducted on similar specimens prepared without the addition bentonite. The testing for this phase was conducted in general accordance with the methodology described below.

HYDRAULIC CONDUCTIVITY OF SOIL (FLEXIBLE-WALL TRIAXIAL CHAMBER METHOD) : The hydraulic conductivity (also commonly referred to as coefficient of permeability) of selected samples was measured in general accordance with method ASTM D-5084. SB samples were prepared by spooning the material into a 3-inch diameter steel tube lined with a tubular latex membrane. A circular porous stone placed in the bottom of the tube provided a base for the sample. The material was spooned into the membrane in 3 lifts and lightly tamped with a 3/8-inch diameter rod and tapped on the sides of the tube to consolidate and reduce air voids. When the target length is reached a porous stone is placed on the top of the specimen and it is removed from the steel tube. This method resulted in cylindrical test specimens with initial dimensions ranging from 2.8 to 2.9-inches in diameter and 3.1 to 3.6 inches in length.

SCB samples were cast in 3-inch diameter by 6-inch long cylindrical plastic mold and allowed to cure for at least 7 days prior to testing. Selected test specimens were de-molded, weighed, and measured prior to encapsulation with a latex membrane and loading into a triaxial pressure chamber.

In turn, each specimen was loaded into a triaxial pressure chamber and saturation was induced by subjecting the test specimens to an effective stress of 3 psi and a flow gradient of about 17-20 generated by a back-pressure differential of 2 psi within a triaxial pressure chamber. Testing was conducted until inflow was approximately equal to outflow and the hydraulic conductivity was essentially steady. The results of these tests are summarized on Figures 28 through 39 and Table 5 below.

Table 5 - Summary of Hydraulic Conductivity Testing for SB Mix Evaluation

Mix Designation	Soil	Fines %	Bentonite %	Cement %	Permeability cm/sec.
Soil 1	Only	0	0	0	3.9×10^{-4}
SB 1B	X	0	5	0	6.3×10^{-8}
SB 1B*	X	0	5	0	2.6×10^{-8}
Soil 2	X	25	0	0	3.6×10^{-7}
SB 2B	X	25	3	0	1.1×10^{-7}
SB 2B*	X	25	3	0	1.2×10^{-7}
Soil 3	X	35	0	0	1.6×10^{-7}
SB 3B	X	35	3	0	9.9×10^{-8}
SB 3B*	X	35	3	0	8.2×10^{-8}
SB 4A	X	30	4.5	0	5.7×10^{-8}
SB 4B	X	30	6	0	2.9×10^{-8}
SCB 4A-6	X	30	4.5	6	1.9×10^{-7}

Note: Samples designated with an * (i.e. SB 1B*) were conducted for internal QA purposes.

Based on the results of the mix evaluation testing, Mix 4 was selected for further testing as the proposed design SB mix. In order to assess the effects of chemical compatibility and hydraulic gradient on the proposed mix, four specimens of SB and SCB were prepared. Each specimen was prepared as described previously and initially permeated with lab water at the same pressures as were used during the mix evaluations until flow rates were relatively steady and consolidation was apparently complete. Subsequently, each pair of specimens was switched to either site groundwater or LNAPL as a permeant and the flow gradient was increased to approximately 100. Testing is conducted for a maximum of 4 weeks, or until a minimum of 3 pore volumes of permeant has passed through the sample, or until free product breakthrough (i.e. a significant increase in the measured permeability rate when compared to the rate measured for lab water.

Permeability testing using free product was conducted utilizing a pair of bladder-accumulators for each test set-up to minimize equipment and technician exposure to the free product (see Photo 2). Except for the testing of the un-amended SB sample, considerable difficulty was experienced during testing using the LNAPL free product because of its tendency to react with the latex membrane resulting in visible deformation of the membrane creating interconnected vertical and horizontal wrinkles that likely facilitate sidewall leakage. Time was spent, re-wrapping the specimens with "solvent resistant" membranes and ultimately wrapping each specimen with 0.03-mm Teflon sheeting and silicone grease prior to re-encapsulation with a membrane. In addition, permission was given by the Engineer to increase the gradient on the SCB samples to 200 in order to increase the permeant flow rate.

The results for test-in progress and completed tests are summarized in Table 6 below. Individual reports for completed tests are shown on Figures 40 through 44.

Table 6 - Summary of Hydraulic Conductivity Testing For Breakthrough Assessment

Mix Designation	Soil	Fines %	Bentonite %	Cement %	Permeant Type	Permeability (cm/sec.)
Soil 4	X	30	0	0	GW	**3.3×10^{-7}**
Soil 4	X	30	0	0	LNAPL	**3.2×10^{-7}**
SB 4A	X	30	4.5	0	GW	**4.3×10^{-8}**
SB 4A	X	30	4.5	0	LNAPL	3.6×10^{-8}
SC 4	X	30	0	4.5	GW	**1.8×10^{-7}**
SC 4	X	30	0	4.5	LNAPL	In-progress
SCB 4A-4.5	X	30	4.5	4.5	GW	**2.0×10^{-7}**
SCB 4A-4.5	X	30	4.5	4.5	LNAPL	9.0×10^{-8}

Notes: Test results in **BOLD** are final results. All others are pending and will be reported under separate cover when complete. GW-site groundwater. LNAPL-free product.

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CLOSURE: Experience has shown that laboratory test values for soil and other natural materials vary with each representative sample. As such, HWA has no knowledge as to the extent and quantity of material the tested sample may represent. HWA also makes no warranty as to how representative either the sample tested or the test results obtained are to actual field conditions. It is a well established fact that sampling methods present varying degrees of disturbance or variance that affect sample representativeness.

No copy should be made of this report except in its entirety.

We appreciate the opportunity to provide laboratory testing services on this project. Should you have any questions or comments, or if we may be of further service, please call.

Sincerely,

HWA GEOSCIENCES INC.

Steven E. Greene, L.G., L.E.G.
Senior Engineering Geologist
Vice-President

A. Ashley Crane
Laboratory Supervisor

George Minassian P.E., PhD
Geotechnical Engineer

SEG:ac:gm;seg

Attachments:

Figures 1-2	Material Summary
Figures 3 – 11	Particle-Size Analysis of Soils (per ASTM D 422)
Figures 12 – 14	Liquid Limit, Plastic Limit, and Plasticity Index of Soils
Figures 15 – 19	Slump vs Moisture Content of SB and SCB mixes
Figures 20 – 23	Tabulations of SCB Compressive Strength Data
Figures 24 – 27	SCB Compressive Strength vs Age Plots
Figures 28 – 39	Hydraulic Conductivity Test Reports (Baseline Data)
Figures 40 – 44	Hydraulic Conductivity Test Reports (Breakthrough)
Photo 1	Unconfined Compressive Strength Testing of an SCB cylinder
Photo 2	Permeability Testing with LNAPL Permeant using Bladder-Accumulators

EXPLORATION DESIGNATION	SAMPLE NUMBER	TOP DEPTH (feet)	BOTTOM DEPTH (feet)	fracture face RESISTANCE (blows/6")	DRY DENSITY (pcf)	MOISTURE CONTENT (%)	ATTERBERG LIMITS (%)			% GRAVEL	% SAND	% FINES	PROCTOR MAXIMUM DRY DENSITY (pcf)	OPTIMUM WATER CONTENT (%)	ASTM SOIL CLASSIFICATION	SAMPLE DESCRIPTION
							LL	PL	PI							
B-1		4.0	10.0			11				16.9	80.8	2.2			SP	Dark gray, poorly graded SAND with gravel and shell fragments
B-1		10.0	20.0			22				3.7	86.9	9.4			SP-SM	Dark gray, poorly graded SAND with silt and shell fragments
B-1		20.0	30.0			26	NP	NP	NP	1.6	68.2	30.3			SM	Gray, silty SAND
B-2		4.5	10.0			12				10.9	86.8	2.4			SP	Gray, poorly graded SAND with shell fragments
B-2		10.0	20.0			25				0.3	84.7	15.1			SM	Dark Gray, silty SAND
B-2		20.0	28.5			18				24.5	63.5	12.0			SP-SM	Gray, poorly graded SAND with silt and gravel
B-3		3.5	10.0			12				13.5	82.8	3.7			SP	Gray, poorly graded SAND wtih shell fragments
B-3		10.0	20.0			23				0.9	90.8	8.3			SP-SM	Dark gray, poorly graded SAND with silt and shell fragments
B-3		20.0	30.0			20	NP	NP	NP	18.5	65.8	15.7			SM	Dark gray, silty SAND with gravel and shell fragments
B-4		4.0	10.0			7				31.2	66.6	2.2			SP	Dark gray, poorly graded SAND with gravel
B-4		10.0	26.0			11	NP	NP	NP	34.4	56.9	8.6			SP-SM	Dark gray, poorly graded SAND wtih silt and gravel
B-5		4.5	14.0			8				34.2	62.8	3.0			SP	Dark gray, poorly graded SAND with gravel
B-5		14.0	21.0			22	NP	NP	NP	0.8	74.0	25.2			SM	Dark gray, silty SAND
B-5		22.0	30.0			20	NP	NP	NP	29.1	51.7	19.2			SM	Dark gray, silty SAND with gravel and shell fragments
B-6		3.0	10.0			18				12.2	76.6	11.2			SP-SM	Dark brownish gray, poorly graded SAND with silt
B-6		10.0	20.0			18	NP	NP	NP	19.9	66.2	13.9			SM	Dark gray, silty SAND with gravel
B-6		20.0	29.0			25	NP	NP	NP	10.4	54.1	35.5			SM	Gray, silty SAND
B-8		4.0	10.0			10				18.1	75.2	6.7			SP-SM	Dark gray, poorly graded SAND with silt and gravel and shell fragments
B-8		10.0	20.0			23				0.7	87.5	11.9			SP-SM	Dark gray, poorly graded SAND with silt
B-8		20.0	30.0			25	NP	NP	NP	2.3	74.0	23.8			SM	Dark gray, silty SAND

Notes:
1. This table summarizes information presented elsewhere in the report and should be used in conjunction with the report text, other graphs and tables, and the exploration logs.
2. "Penetration Resistance" may represent the results of standard (SPT) or non-standard penetration tests. See exploration logs.

HWA GEOSCIENCES INC.

Terminal 91 Tank Farm Affected Area Cleanup Project
Lab testing for PES Environmental, Inc.
SB & SCB Mix Design

SUMMARY OF MATERIAL PROPERTIES

PROJECT NO.: 2011-121 FIGURE: 1

EXPLORATION DESIGNATION	SAMPLE NUMBER	TOP DEPTH (feet)	BOTTOM DEPTH (feet)	fracture face RESISTANCE (blows/6")	DRY DENSITY (pcf)	MOISTURE CONTENT (%)	ATTERBERG LIMITS (%)			% GRAVEL	% SAND	% FINES	PROCTOR MAXIMUM DRY DENSITY (pcf)	OPTIMUM WATER CONTENT (%)	ASTM SOIL CLASSIFICATION	SAMPLE DESCRIPTION
							LL	PL	PI							
Lakeside Washpit						57	NP	NP	NP		42.9	57.1			ML	Light brown, sandy SILT
Mix 1						15				13.0	77.2	9.7			SP-SM	Brown, poorly graded SAND with silt (Composited Site Soils)
Mix 2						19	NP	NP	NP	10.3	65.4	24.3			SC	Dark brown, clayey SAND (Site soils with imported fines) Not Plastic
Mix 3						22	23	18	5	9.3	54.6	36.1			SC	Dark brown, silty, clayey SAND (Site soils with imported fines)
Mix 4						19	NP	NP	NP	14.6	56.9	28.5			SM	Dark brown, clayey SAND (site soils with imported fines) Non Plastic
QA Fines						37	47	26	21		1.6	98.4			CL	Olive brown, lean CLAY (Quality Aggregate Wash pit)

Notes:
1. This table summarizes information presented elsewhere in the report and should be used in conjunction with the report text, other graphs and tables, and the exploration logs.
2. "Penetration Resistance" may represent the results of standard (SPT) or non-standard penetration tests. See exploration logs.

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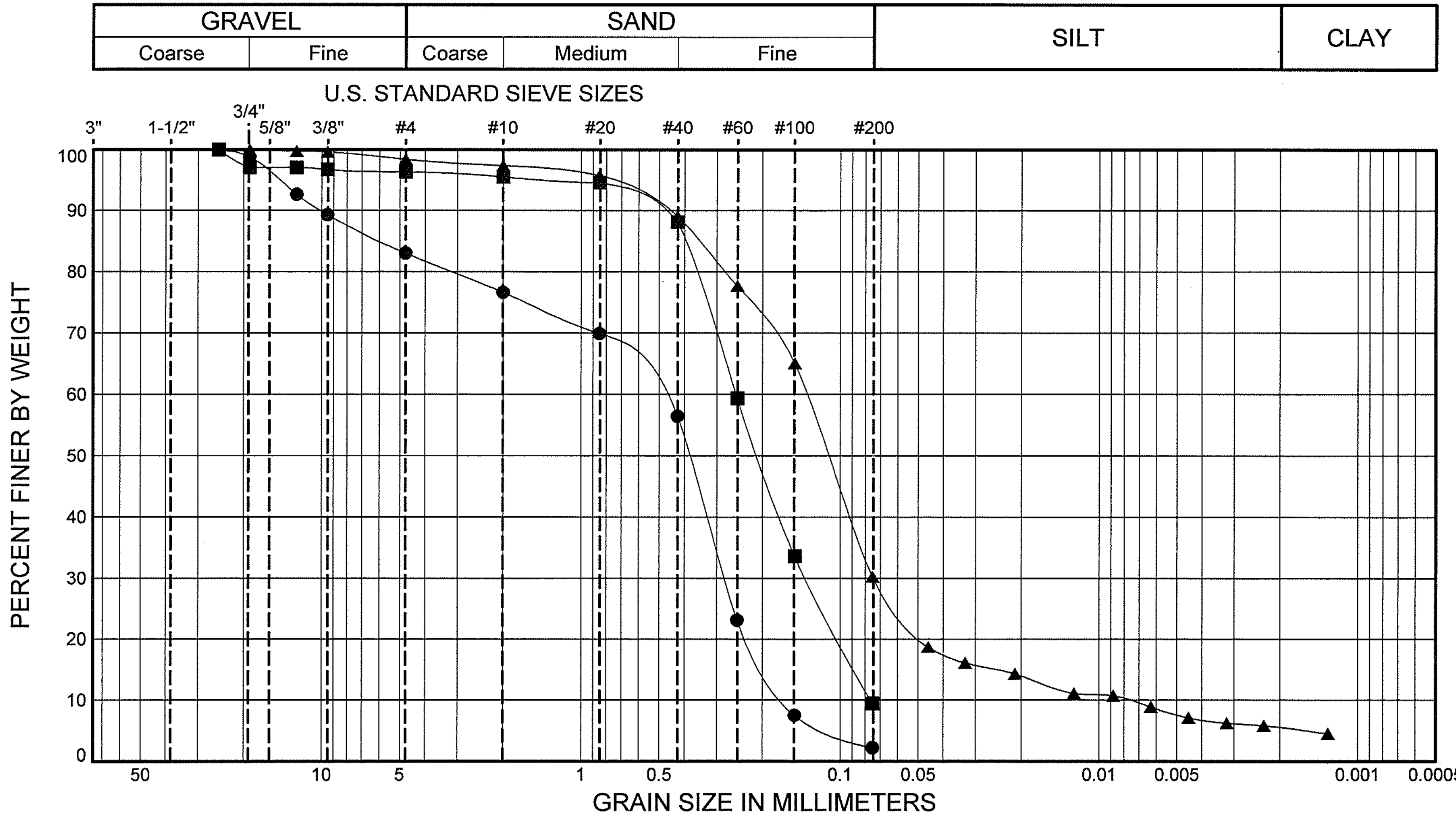
Terminal 91 Tank Farm Affected Area Cleanup Project
Lab testing for PES Environmental, Inc.
SB & SCB Mix Design

SUMMARY OF MATERIAL PROPERTIES



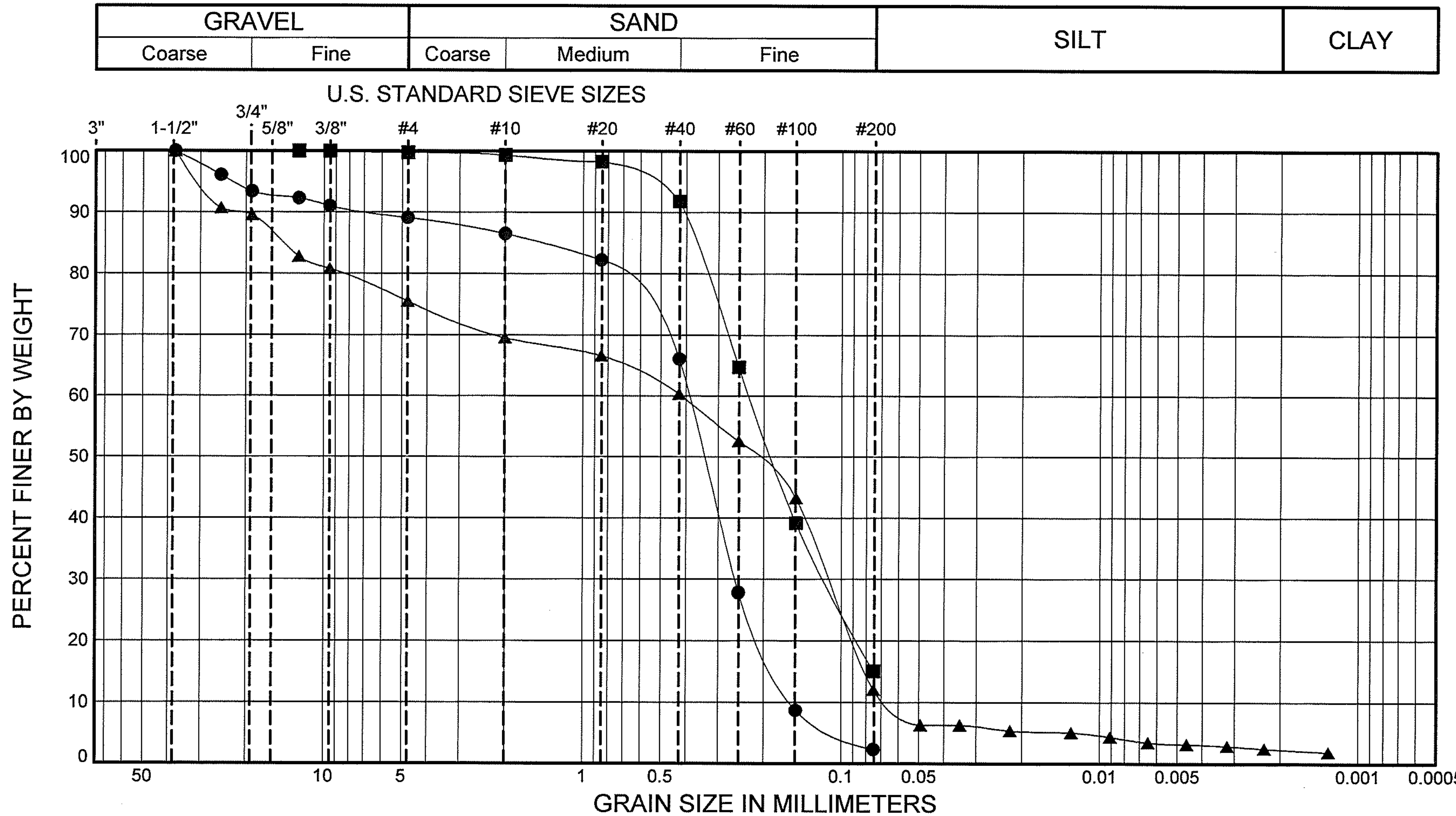
SYMBOL	SAMPLE		DEPTH (ft)	CLASSIFICATION OF SOIL- ASTM D2487 Group Symbol and Name	% MC	LL	PL	PI	Gravel %	Sand %	Fines %
●	B-1		4.0 - 10.0	(SP) Dark gray, poorly graded SAND with gravel and shell fragments	11				16.9	80.8	2.2
■	B-1		10.0 - 20.0	(SP-SM) Dark gray, poorly graded SAND with silt and shell fragments	22				3.7	86.9	9.4
▲	B-1		20.0 - 30.0	(SM) Gray, silty SAND	26	NP	NP	NP	1.6	68.2	30.3

HWA GEOSCIENCES INC.

Terminal 91 Tank Farm Affected Area Cleanup Project
Lab testing for PES Environmental, Inc.
SB & SCB Mix Design

PARTICLE-SIZE ANALYSIS OF SOILS METHOD ASTM D422

PROJECT NO.: 2011-121 FIGURE: 3



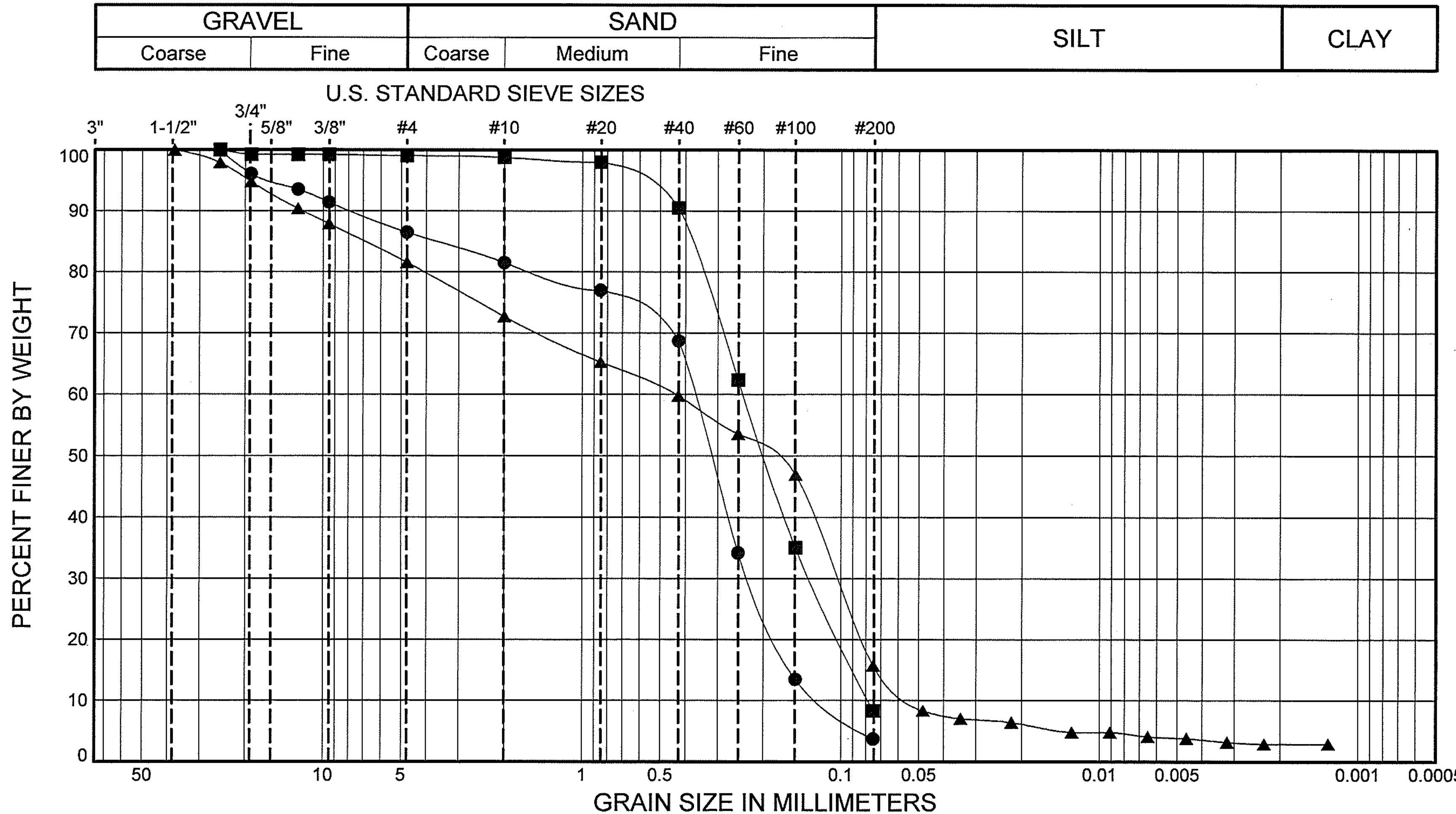
SYMBOL	SAMPLE		DEPTH (ft)	CLASSIFICATION OF SOIL- ASTM D2487 Group Symbol and Name	% MC	LL	PL	PI	Gravel %	Sand %	Fines %
●	B-2		4.5 - 10.0	(SP) Gray, poorly graded SAND with shell fragments	12				10.9	86.8	2.4
■	B-2		10.0 - 20.0	(SM) Dark Gray, silty SAND	25				0.3	84.7	15.1
▲	B-2		20.0 - 28.5	(SP-SM) Gray, poorly graded SAND with silt and gravel	18	NP	NP	NP	24.5	63.5	12.0

HWA GEOSCIENCES INC.

Terminal 91 Tank Farm Affected Area Cleanup Project
Lab testing for PES Environmental, Inc.
SB & SCB Mix Design

PARTICLE-SIZE ANALYSIS OF SOILS METHOD ASTM D422

PROJECT NO.: 2011-121 FIGURE: 4



SYMBOL	SAMPLE		DEPTH (ft)	CLASSIFICATION OF SOIL- ASTM D2487 Group Symbol and Name	% MC	LL	PL	PI	Gravel %	Sand %	Fines %
●	B-3		3.5 - 10.0	(SP) Gray, poorly graded SAND wtih shell fragments	12				13.5	82.8	3.7
■	B-3		10.0 - 20.0	(SP-SM) Dark gray, poorly graded SAND with silt and shell fragments	23				0.9	90.8	8.3
▲	B-3		20.0 - 30.0	(SM) Dark gray, silty SAND with gravel and shell fragments	20	NP	NP	NP	18.5	65.8	15.7

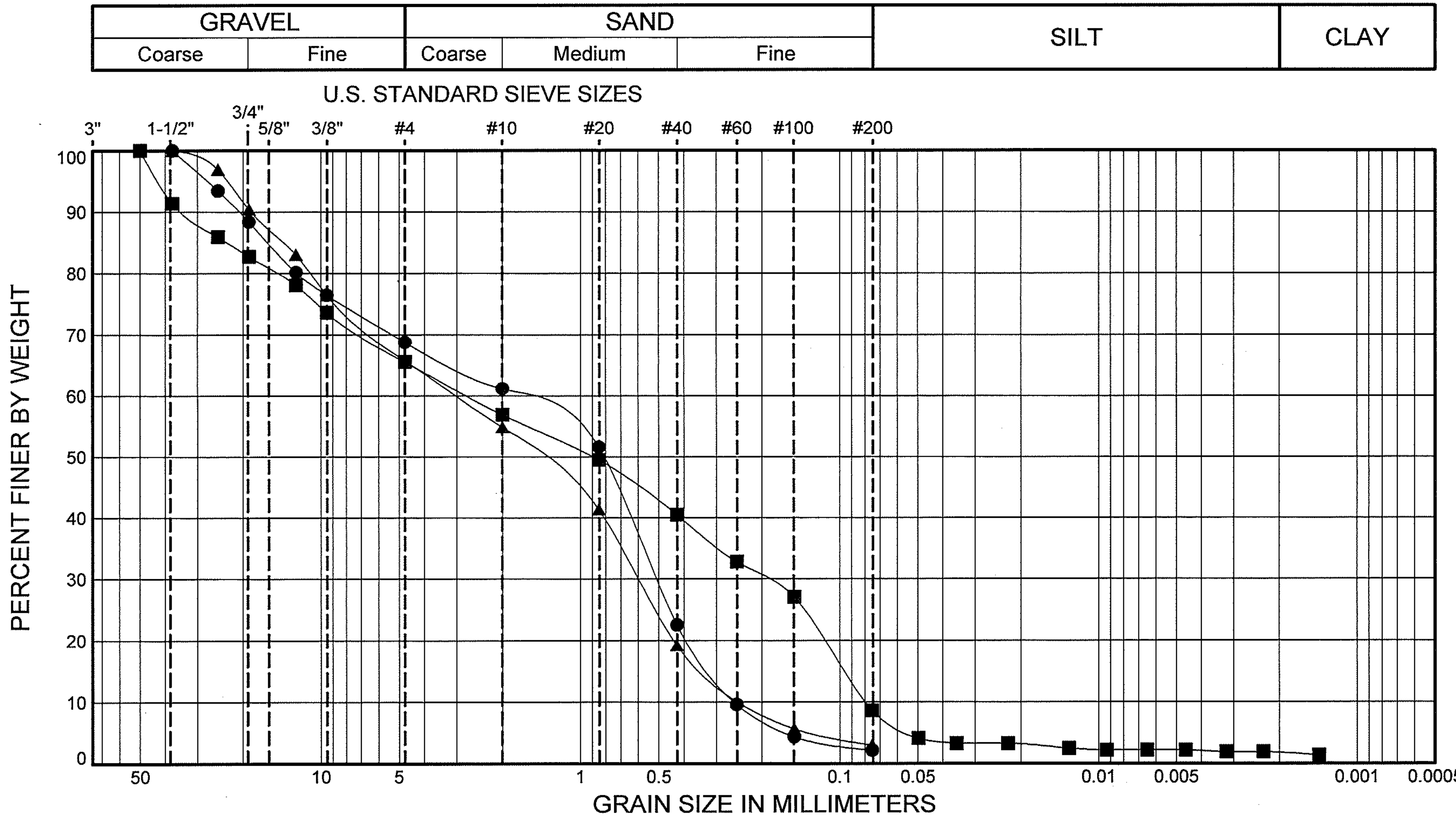
HWA GEOSCIENCES INC.

Terminal 91 Tank Farm Affected Area Cleanup Project
Lab testing for PES Environmental, Inc.
SB & SCB Mix Design

PARTICLE-SIZE ANALYSIS OF SOILS METHOD ASTM D422

PROJECT NO.: 2011-121

FIGURE: 5



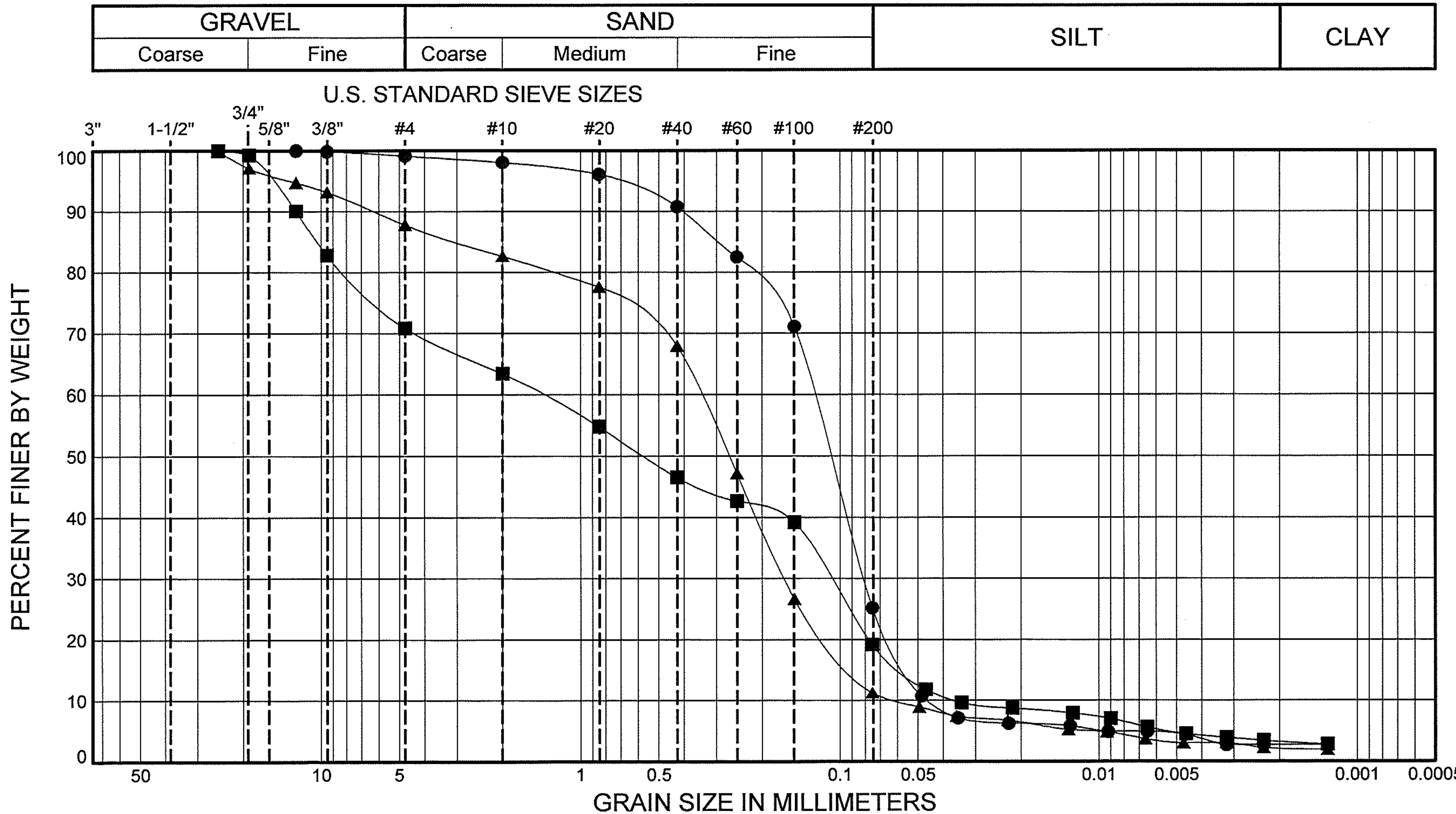
SYMBOL	SAMPLE		DEPTH (ft)	CLASSIFICATION OF SOIL- ASTM D2487 Group Symbol and Name	% MC	LL	PL	PI	Gravel %	Sand %	Fines %
●	B-4		4.0 - 10.0	(SP) Dark gray, poorly graded SAND with gravel	7				31.2	66.6	2.2
■	B-4		10.0 - 26.0	(SP-SM) Dark gray, poorly graded SAND wtih silt and gravel	11	NP	NP	NP	34.4	56.9	8.6
▲	B-5		4.5 - 14.0	(SP) Dark gray, poorly graded SAND with gravel	8				34.2	62.8	3.0

HWA GEOSCIENCES INC.

Terminal 91 Tank Farm Affected Area Cleanup Project
Lab testing for PES Environmental, Inc.
SB & SCB Mix Design

PARTICLE-SIZE ANALYSIS OF SOILS METHOD ASTM D422

PROJECT NO.: 2011-121 FIGURE: 6



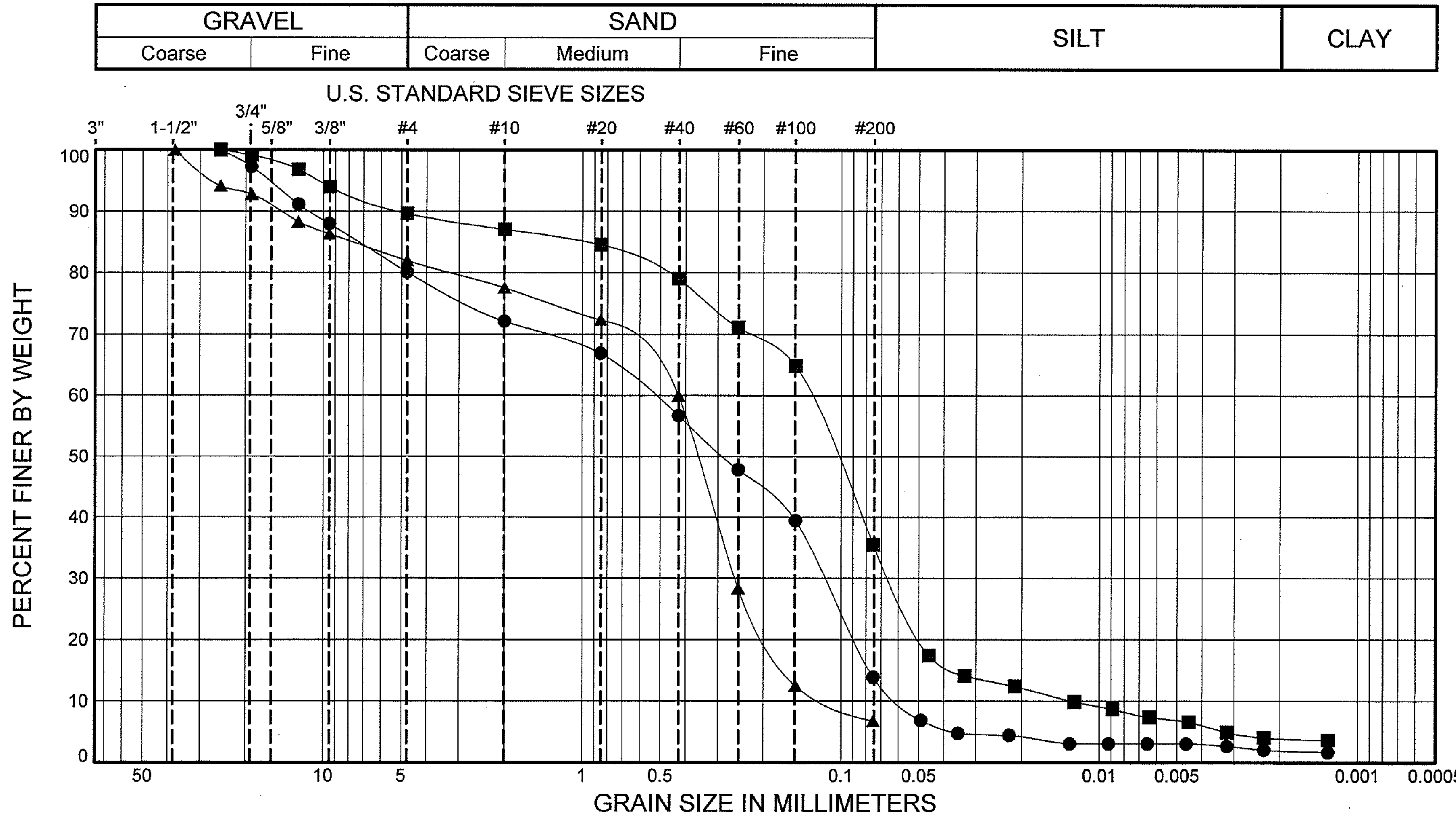
SYMBOL	SAMPLE		DEPTH (ft)	CLASSIFICATION OF SOIL- ASTM D2487 Group Symbol and Name	% MC	LL	PL	PI	Gravel %	Sand %	Fines %
●	B-5		14.0 - 21.0	(SM) Dark gray, silty SAND	22	NP	NP	NP	0.8	74.0	25.2
■	B-5		22.0 - 30.0	(SM) Dark gray, silty SAND with gravel and shell fragments	20	NP	NP	NP	29.1	51.7	19.2
▲	B-6		3.0 - 10.0	(SP-SM) Dark brownish gray, poorly graded SAND with silt	18	NP	NP	NP	12.2	76.6	11.2

HWA GEOSCIENCES INC.

Terminal 91 Tank Farm Affected Area Cleanup Project
Lab testing for PES Environmental, Inc.
SB & SCB Mix Design

PARTICLE-SIZE ANALYSIS
OF SOILS
METHOD ASTM D422

PROJECT NO.: 2011-121 FIGURE: 7



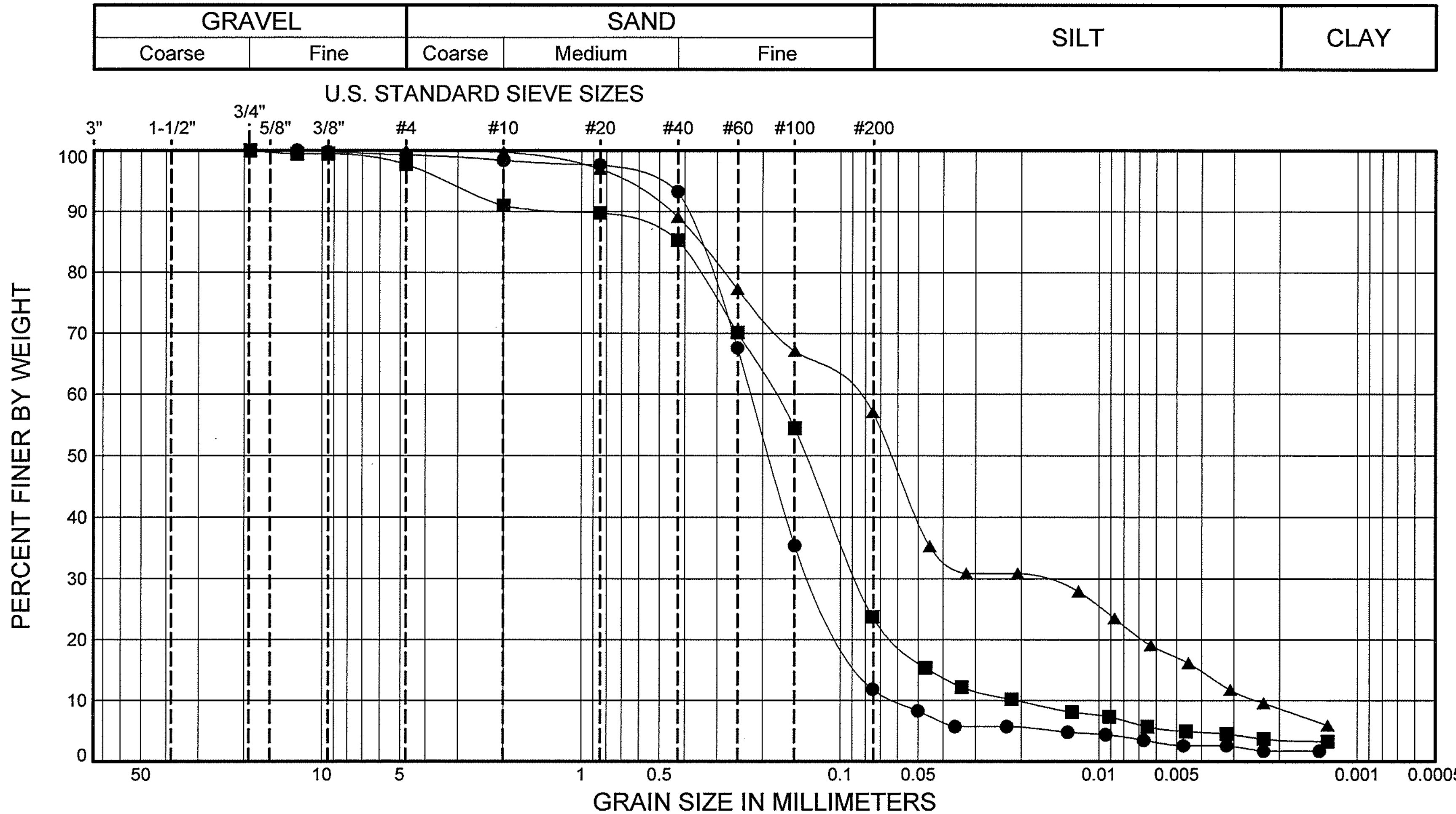
SYMBOL	SAMPLE		DEPTH (ft)	CLASSIFICATION OF SOIL- ASTM D2487 Group Symbol and Name	% MC	LL	PL	PI	Gravel %	Sand %	Fines %
●	B-6		10.0 - 20.0	(SM) Dark gray, silty SAND with gravel	18	NP	NP	NP	19.9	66.2	13.9
■	B-6		20.0 - 29.0	(SM) Gray, silty SAND	25	NP	NP	NP	10.4	54.1	35.5
▲	B-8		4.0 - 10.0	(SP-SM) Dark gray, poorly graded SAND with silt and gravel and shell fragments	10				18.1	75.2	6.7

HWA GEOSCIENCES INC.

Terminal 91 Tank Farm Affected Area Cleanup Project
Lab testing for PES Environmental, Inc.
SB & SCB Mix Design

PARTICLE-SIZE ANALYSIS OF SOILS METHOD ASTM D422

PROJECT NO.: 2011-121 FIGURE: 8



SYMBOL	SAMPLE	DEPTH (ft)	CLASSIFICATION OF SOIL- ASTM D2487 Group Symbol and Name	% MC	LL	PL	PI	Gravel %	Sand %	Fines %
●	B-8	10.0 - 20.0	(SP-SM) Dark gray, poorly graded SAND with silt	23	NP	NP	NP	0.7	87.5	11.9
■	B-8	20.0 - 30.0	(SM) Dark gray, silty SAND	25	NP	NP	NP	2.3	74.0	23.8
▲	Lakeside Washpit		(ML) Light brown, sandy SILT	57	NP	NP	NP	0.0	42.9	57.1

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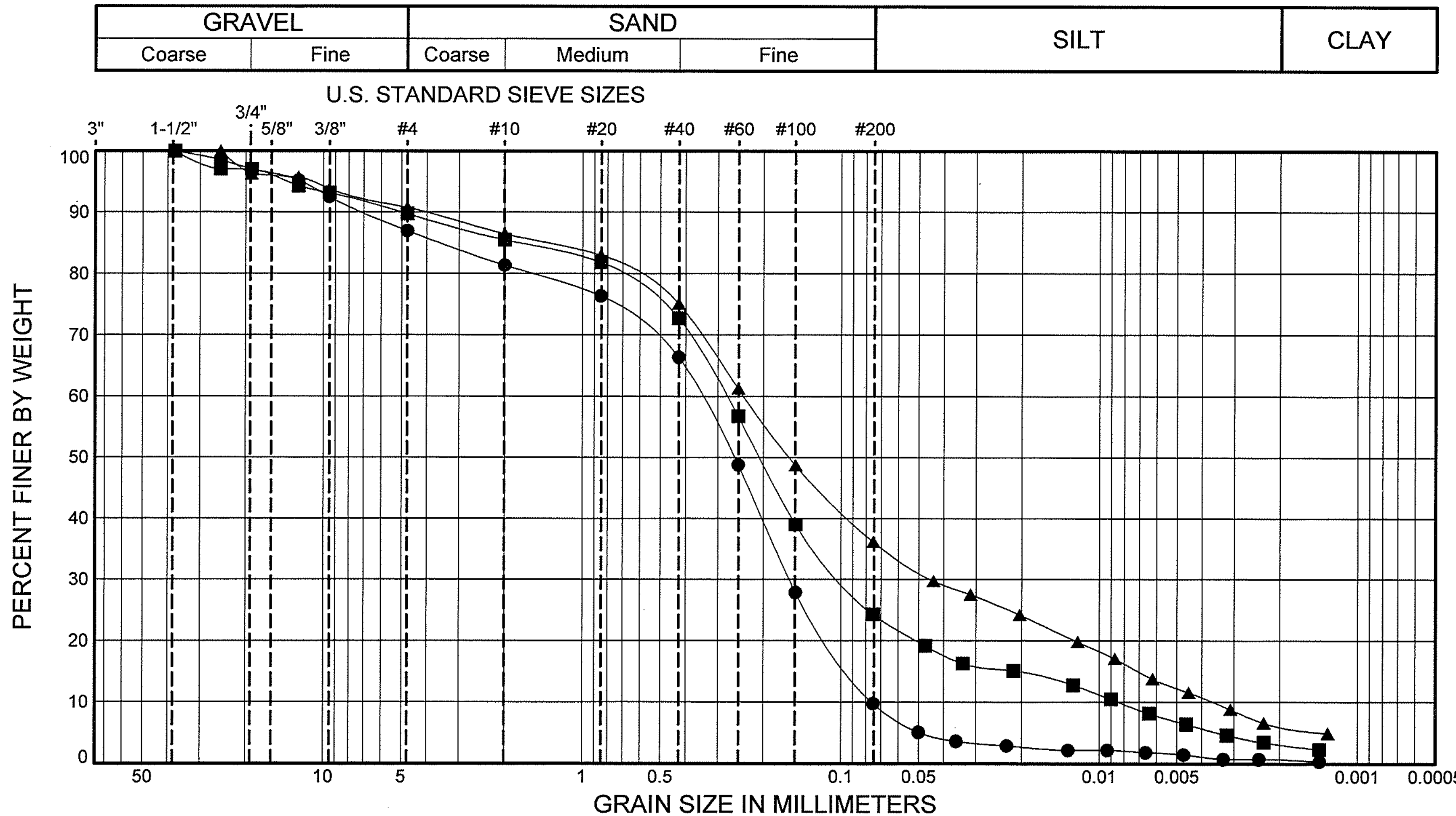
Terminal 91 Tank Farm Affected Area Cleanup Project
Lab testing for PES Environmental, Inc.
SB & SCB Mix Design

PARTICLE-SIZE ANALYSIS OF SOILS
METHOD ASTM D422

PROJECT NO.: 2011-121 FIGURE: 9



SYMBOL	SAMPLE		DEPTH (ft)	CLASSIFICATION OF SOIL- ASTM D2487 Group Symbol and Name	% MC	LL	PL	PI	Gravel %	Sand %	Fines %
●	Mix 1			(SP-SM) Brown, poorly graded SAND with silt (Composited Site Soils)	15				13.0	77.2	9.7
■	Mix 2			(SC) Dark brown, clayey SAND (Site soils with imported fines) Not Plastic	19	NP	NP	NP	10.3	65.4	24.3
▲	Mix 3			(SC) Dark brown, silty, clayey SAND (Site soils with imported fines)	22	23	18	5	9.3	54.6	36.1

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Lab testing for PES Environmental, Inc.
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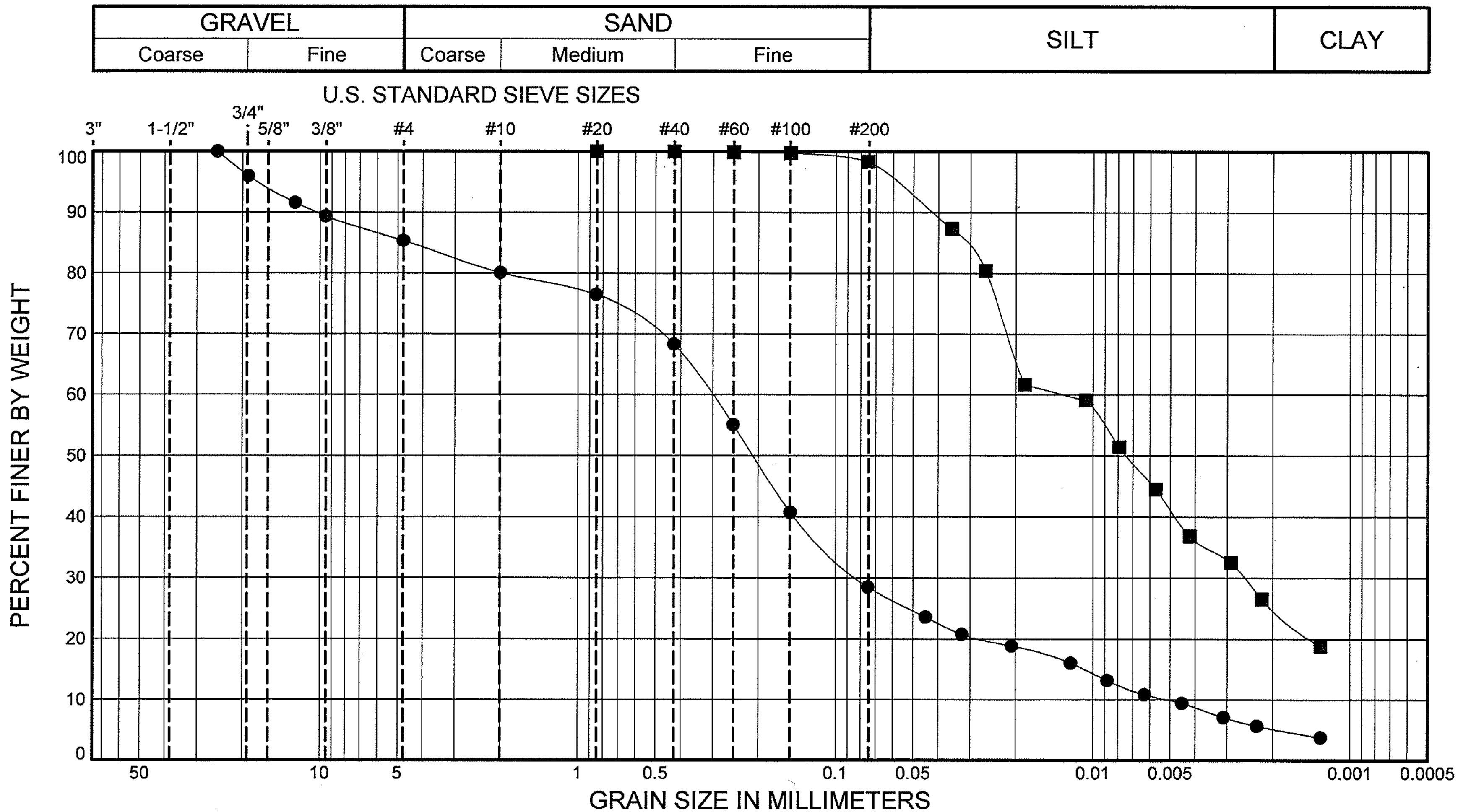
PARTICLE-SIZE ANALYSIS OF SOILS METHOD ASTM D422

PROJECT NO.: 2011-121 FIGURE: 10



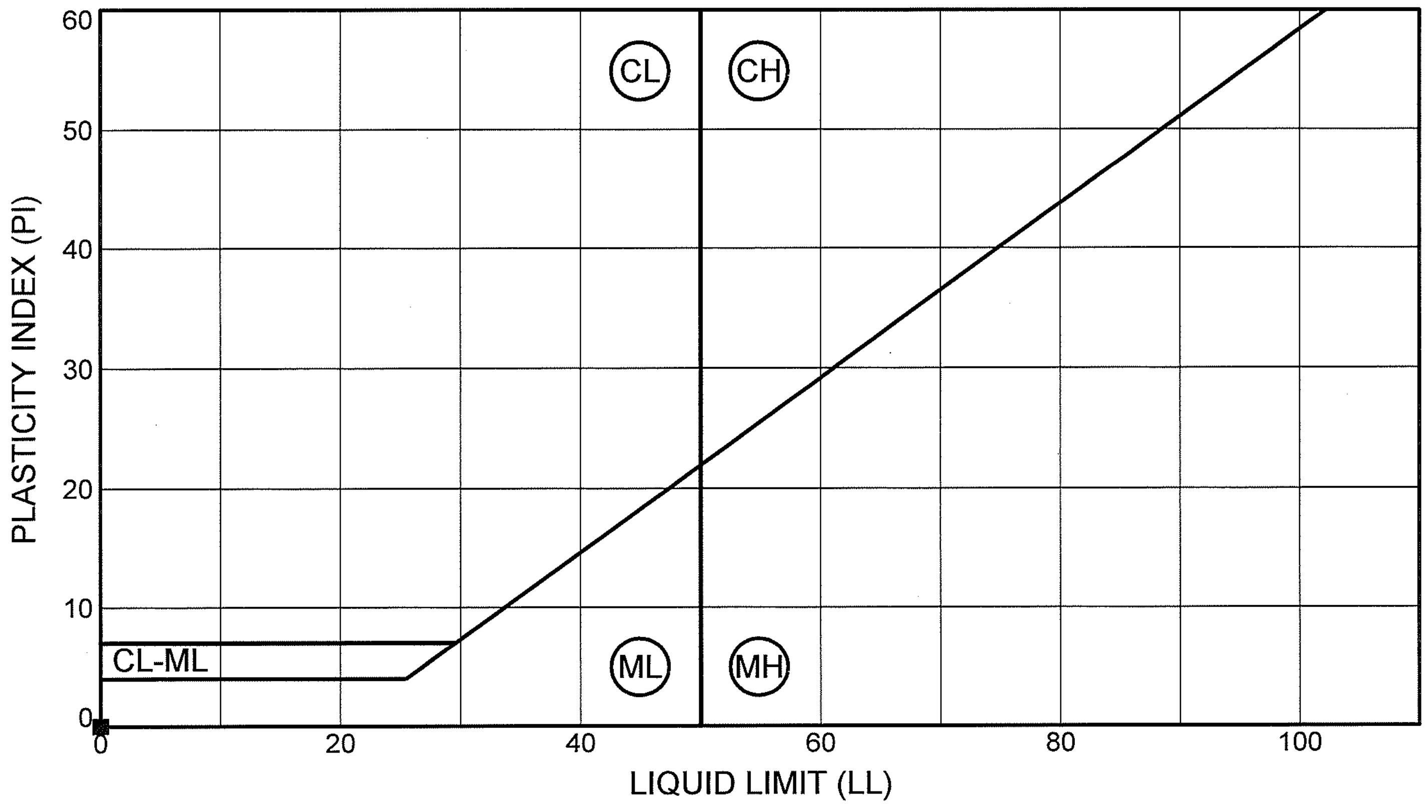
SYMBOL	SAMPLE		DEPTH (ft)	CLASSIFICATION OF SOIL- ASTM D2487 Group Symbol and Name	% MC	LL	PL	PI	Gravel %	Sand %	Fines %
●	Mix 4			(SM) Dark brown, clayey SAND (site soils with imported fines) Non Plastic	19	NP	NP	NP	14.6	56.9	28.5
■	QA Fines			(CL) Olive brown, lean CLAY (Quality Aggregate Wash pit)	37	47	26	21	0.0	1.6	98.4

HWA GEOSCIENCES INC.

Terminal 91 Tank Farm Affected Area Cleanup Project
Lab testing for PES Environmental, Inc.
SB & SCB Mix Design

PARTICLE-SIZE ANALYSIS OF SOILS METHOD ASTM D422

PROJECT NO.: 2011-121 FIGURE: 11



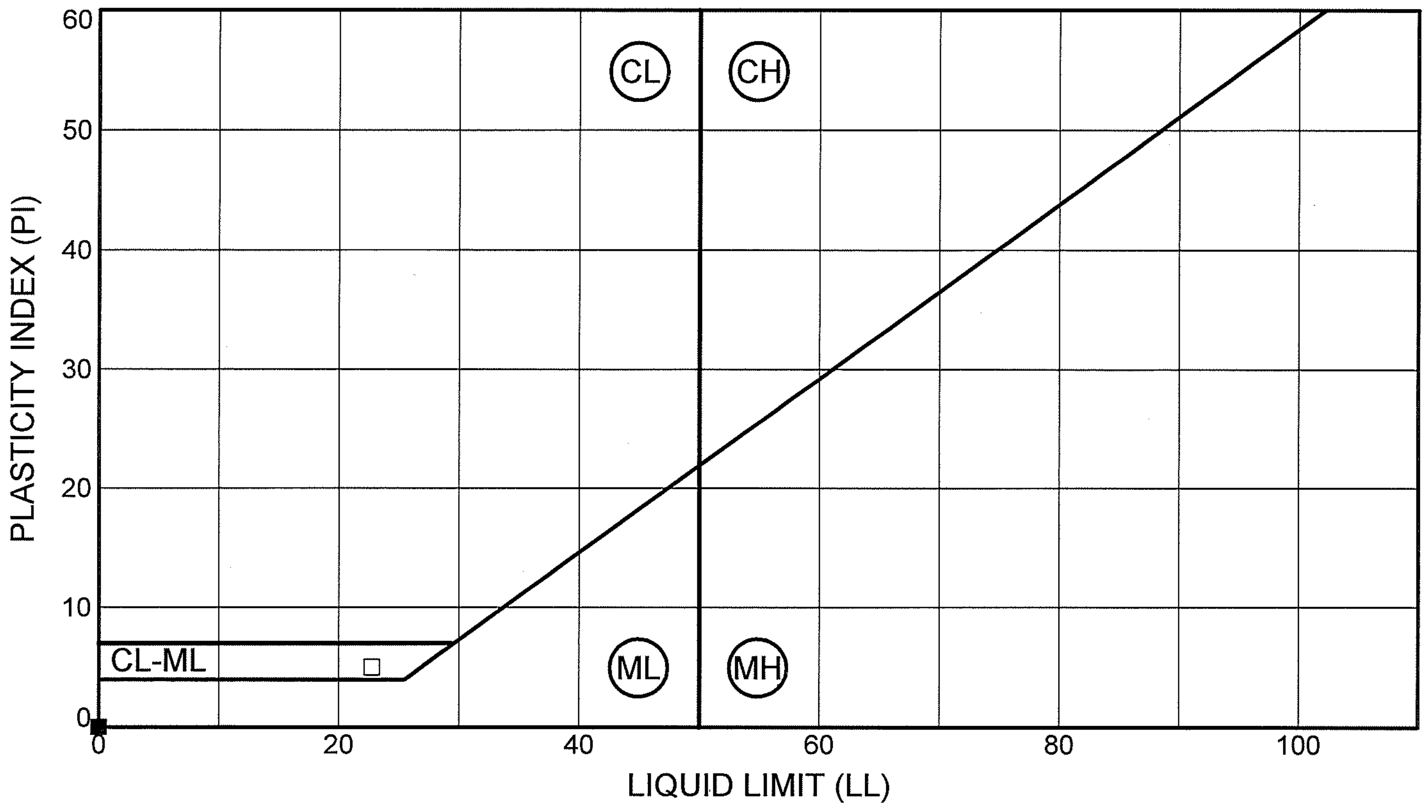
SYMBOL	SAMPLE	DEPTH (ft)	CLASSIFICATION	% MC	LL	PL	PI	% Fines
●	B-1	20.0 - 30.0	(SM) Gray, silty SAND	26	NP	NP	NP	30.3
■	B-3	20.0 - 30.0	(SM) Dark gray, silty SAND with gravel and shell fragments	20	NP	NP	NP	15.7
▲	B-4	10.0 - 26.0	(SP-SM) Dark gray, poorly graded SAND wtih silt and gravel	11	NP	NP	NP	8.6
○	B-5	14.0 - 21.0	(SM) Dark gray, silty SAND	22	NP	NP	NP	25.2
□	B-5	22.0 - 30.0	(SM) Dark gray, silty SAND with gravel and shell fragments	20	NP	NP	NP	19.2
△	B-6	10.0 - 20.0	(SM) Dark gray, silty SAND with gravel	18	NP	NP	NP	13.9

HWA GEOSCIENCES INC.

Terminal 91 Tank Farm Affected Area Cleanup Project
Lab testing for PES Environmental, Inc.
SB & SCB Mix Design

LIQUID LIMIT, PLASTIC LIMIT AND PLASTICITY INDEX OF SOILS METHOD ASTM D4318

PROJECT NO.: 2011-121 FIGURE: 12



SYMBOL	SAMPLE	DEPTH (ft)	CLASSIFICATION	% MC	LL	PL	PI	% Fines
●	B-6	20.0 - 29.0	(SM) Gray, silty SAND	25	NP	NP	NP	35.5
■	B-8	20.0 - 30.0	(SM) Dark gray, silty SAND	25	NP	NP	NP	23.8
▲	Lakeside Washpit		(ML) Light brown, sandy SILT	57	NP	NP	NP	57.1
○	Mix 2		(SC) Dark brown, clayey SAND (Site soils with imported fines) Not Plastic	19	NP	NP	NP	24.3
□	Mix 3		(SC) Dark brown, silty, clayey SAND (Site soils with imported fines)	22	23	18	5	36.1
△	Mix 4		(SM) Dark brown, clayey SAND (site soils with imported fines) Non Plastic	19	NP	NP	NP	28.5

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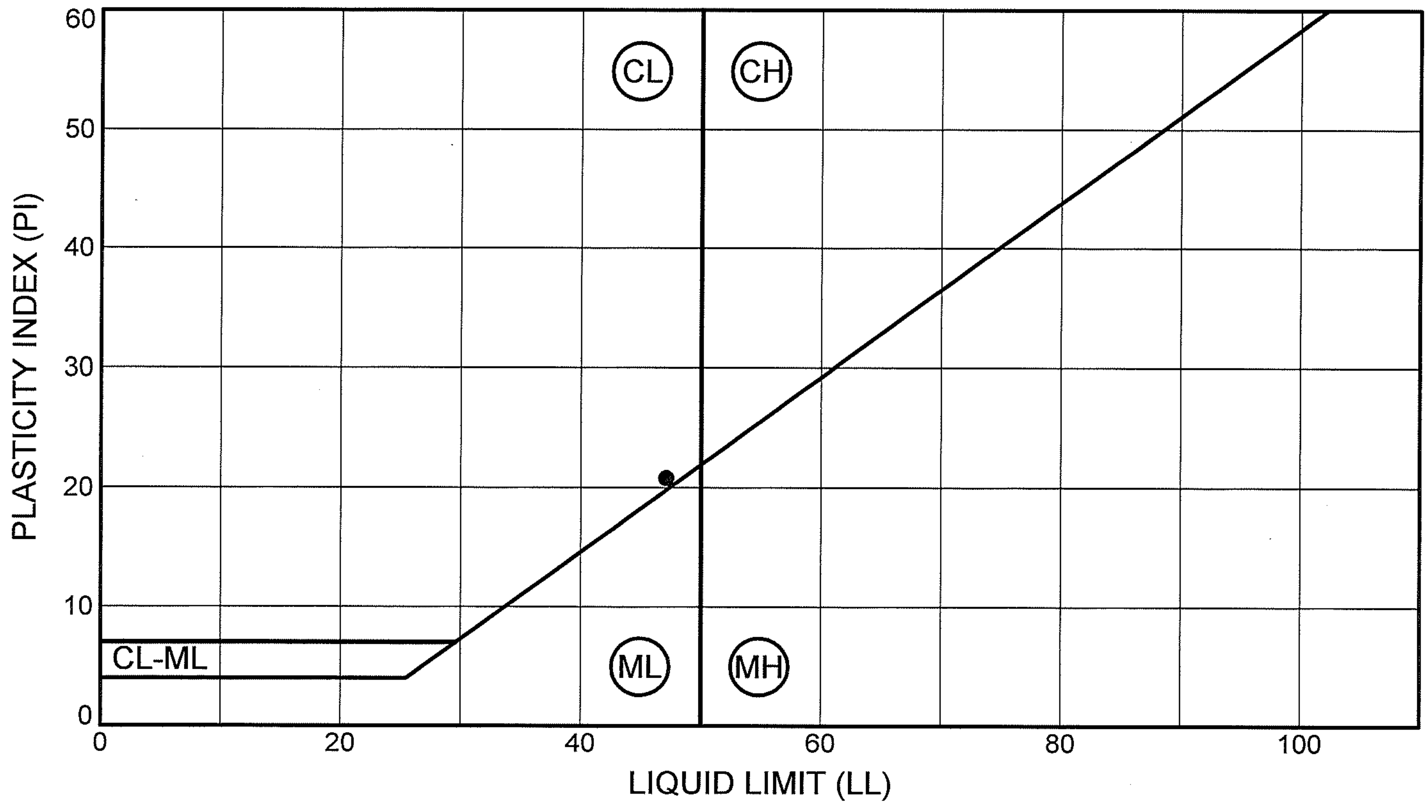
Terminal 91 Tank Farm Affected Area Cleanup Project
Lab testing for PES Environmental, Inc.
SB & SCB Mix Design

LIQUID LIMIT, PLASTIC LIMIT AND PLASTICITY INDEX OF SOILS METHOD ASTM D4318

PROJECT NO.: 2011-121 FIGURE: 13



SYMBOL	SAMPLE		DEPTH (ft)	CLASSIFICATION	% MC	LL	PL	PI	% Fines
●	QA Fines			(CL) Olive brown, lean CLAY (Quality Aggregate Wash pit)	37	47	26	21	98.4

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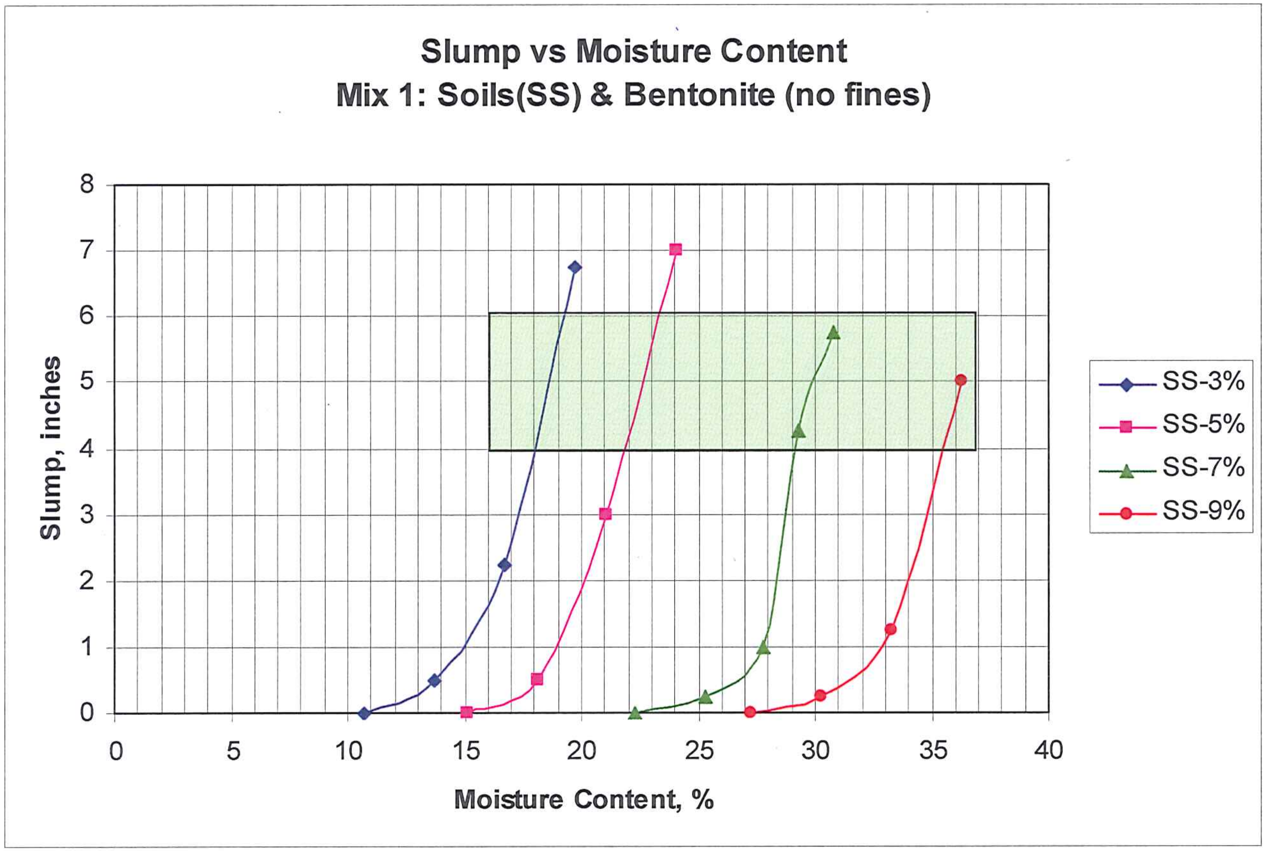
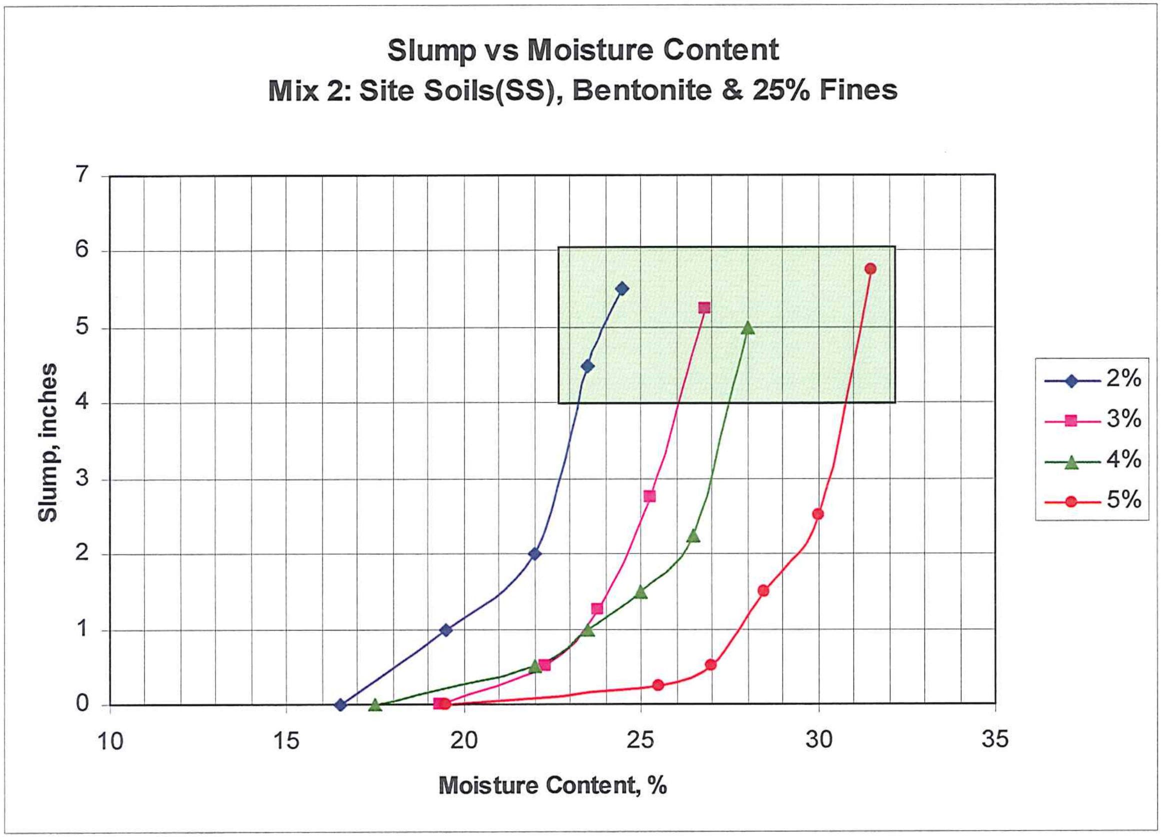
LIQUID LIMIT, PLASTIC LIMIT AND PLASTICITY INDEX OF SOILS METHOD ASTM D4318

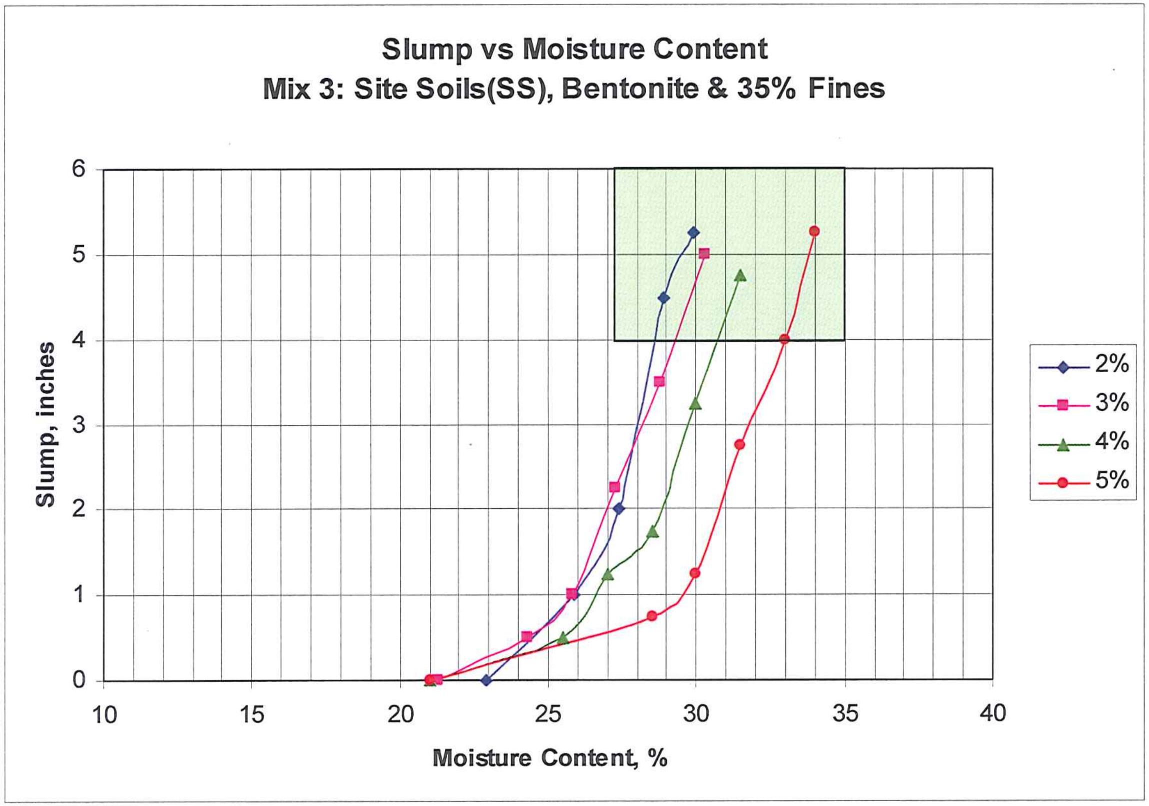
PROJECT NO.: 2011-121 FIGURE: 14



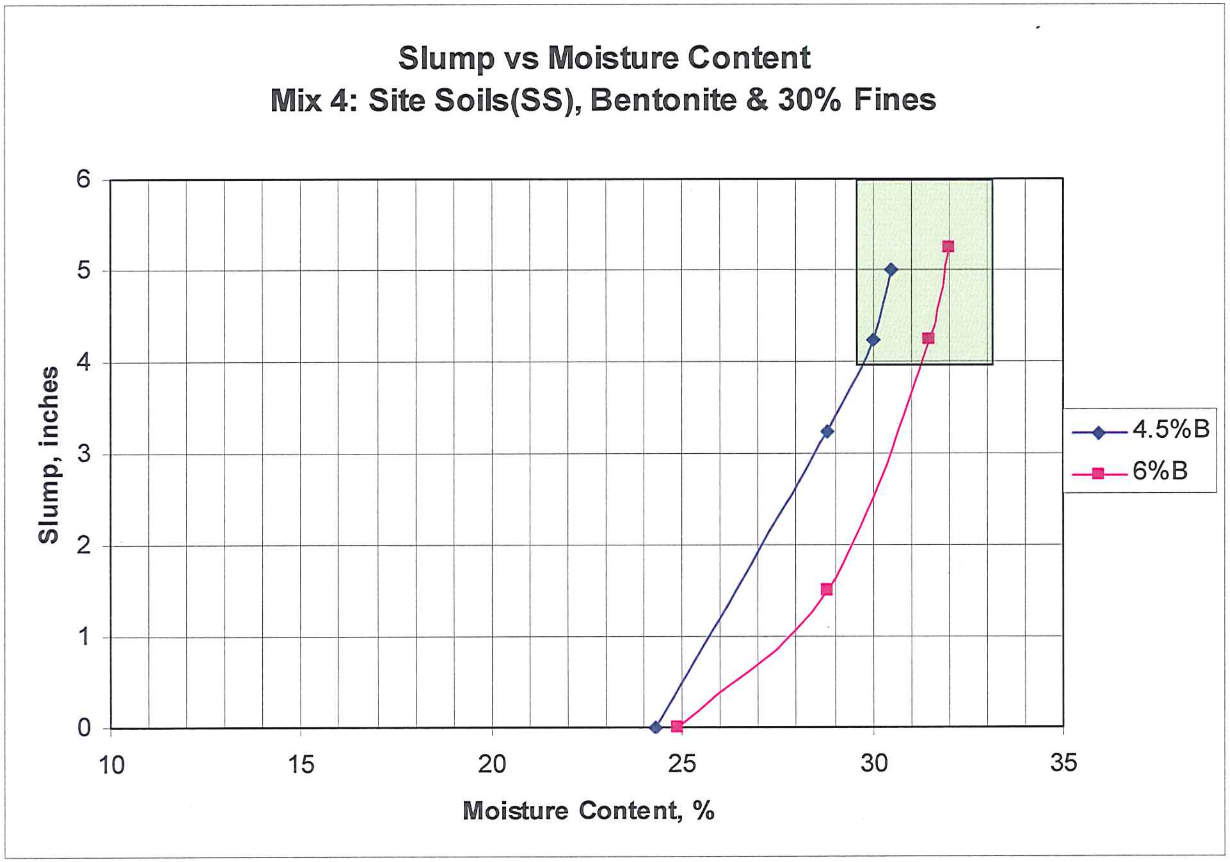
Bentonite (%)	Final Slump (inches)	Moisture Content	Bulk Unit Weight (pcf)
3%	6.75	19.7%	117.6
5%	7	24.1%	114.8
7%	5.75	30.8%	113.8
9%	5.0	36.3%	112.8



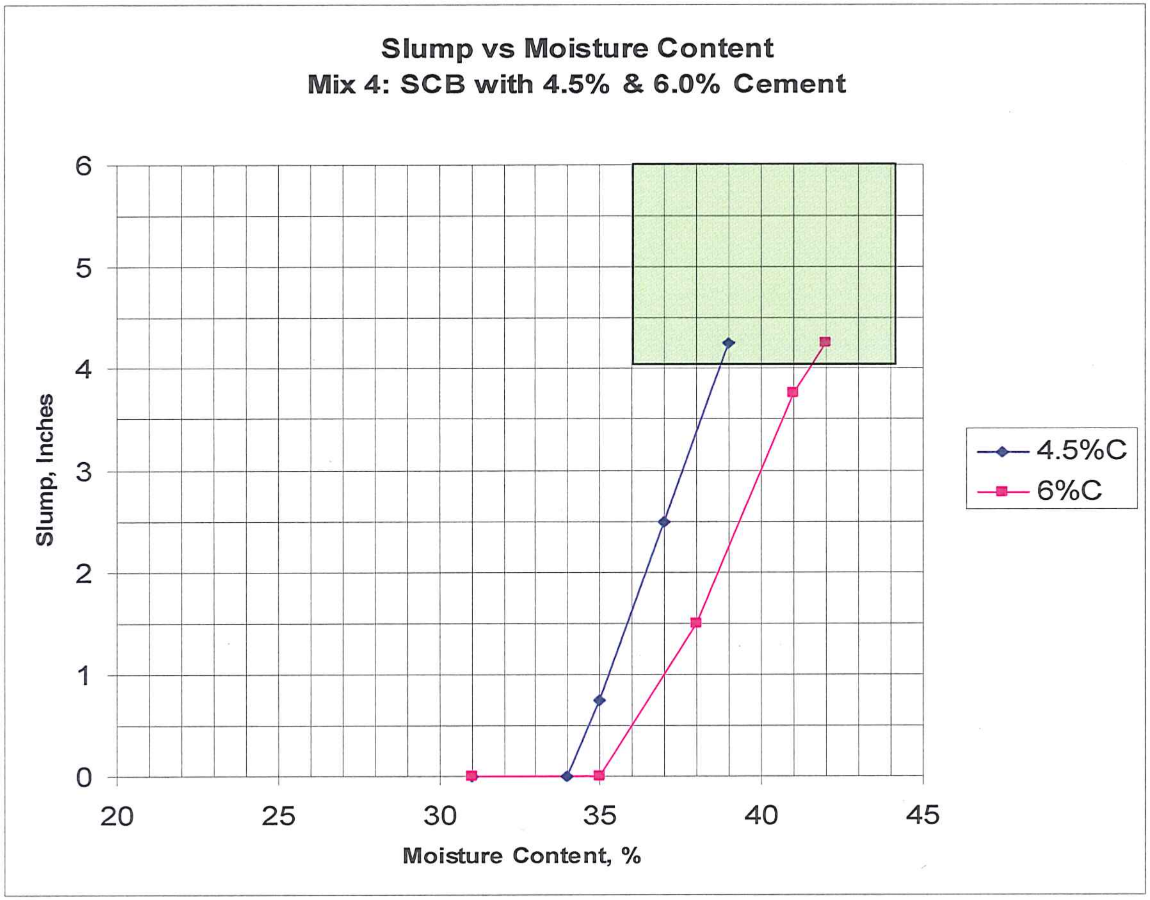
Bentonite (%)	Final Slump (inches)	Moisture Content	Bulk Unit Weight (pcf)
2%	5.5	24.5%	118.5
3%	5.25	26.8%	118.3
4%	5	28.0%	117.8
5%	5.75	31.5%	115.9



Bentonite (%)	Final Slump (inches)	Moisture Content	Bulk Unit Weight (pcf)
2%	5.25	29.9%	118.4
3%	5	30.3%	116.6
4%	4.75	31.5%	115.0
5%	5.25	34.0%	113.4



Bentonite (%)	Final Slump (inches)	Moisture Content	Bulk Unit Weight (pcf)
4.5%	5.0	30.5%	116.4
6.0%	5.25	32.0%	113.0



Bentonite (%)	Cement %	Final Slump (inches)	Moisture Content	Bulk Unit Weight (pcf)
4.5%	4.5	4.25	39.0%	112.5
4.5%	6.0	4.25	42.0%	110.8

T-91 Tank Farm Affected Area Cleanup Project
SCB Compressive Strength Data

Mix 1	Age (days)	Break Date	Weight (gms)	Length (In)	Diameter (in)	Area (in^2)	Volume (Ft^3)	Unit Weight (pcf)	Load (Lbs)	UCS (psi)	Tare ID	Tare Wt.	Wet + Tare	Dry+ Tare	MC
1B3a	7	4/25/12	1258.9	5.922	3.004	7.084	0.02428	114.3	17	23	V	192.1	1450.8	1158.1	30.3%
1B3b	7	4/25/12	1282	5.914	3.005	7.089	0.02426	116.5	17	23	M	177.7	1455.1	1170.2	28.7%
1B3c	14	5/2/12	1252.4	5.906	3.007	7.098	0.02426	113.8	18	24	G	177.2	1428	1126.8	31.7%
1B3d	14	5/2/12	1267.1	5.891	3.009	7.107	0.02423	115.3	21	28	K	181.7	1446.3	1155.7	29.8%
1B3e	28	5/16/12	1249.9	5.939	3.004	7.084	0.02435	113.2	30.5	41	C	176.7	1424.4	1133.2	30.4%
1B3f	28	5/16/12	1235.7	5.903	3.001	7.07	0.02415	112.8	32	44	E	178.9	1412.2	1115.2	31.7%
1B5a	7	4/25/12	1203.6	5.925	2.998	7.056	0.02419	109.7	23	31	F	175.6	1374	1071.2	33.8%
1B5b	7	4/25/12	1244	5.93	2.994	7.037	0.02415	113.6	21	29	H	178.6	1417.3	1117.3	32.0%
1B5c	14	5/2/12	1244.6	5.92	3.01	7.112	0.02437	112.6	29	39	P	174.9	1416.3	1114.7	32.1%
1B5d	14	5/2/12	1227.8	5.927	2.996	7.046	0.02417	112.0	30	41	S	184.3	1408.4	1104.6	33.0%
1B5e	28	5/16/12	1237.9	5.921	2.99	7.018	0.02405	113.5	37	51	P	174.5	1409.9	1118.2	30.9%
1B5f	28	5/16/12	1231.7	5.923	2.995	7.041	0.02414	112.5	35	48	T	181	1408.9	1113	31.7%
1B7a	7	4/25/12	1238.6	5.926	2.994	7.037	0.02413	113.2	35	48	Q	177.3	1409.8	1101.9	33.3%
1B7b	7	4/25/12	1241.6	5.926	2.993	7.032	0.02412	113.5	33	45	J	179.3	1414.8	1107.4	33.1%
1B7c	14	5/2/12	1285	5.928	3.004	7.084	0.0243	116.6	44	60	A	183.5	1465.2	1191	27.2%
1B7d	14	5/2/12	1252.5	5.931	2.992	7.027	0.02412	114.5	46	63	E	179.2	1428.6	1137.7	30.4%
1B7e	28	5/16/12	1265.1	5.934	2.985	6.995	0.02402	116.1	54.5	75	A	181.5	1443.2	1154.8	29.6%
1B7f	28	5/16/12	1246.6	5.918	2.985	6.995	0.02395	114.8	55	76	V	193.4	1436.1	1134.4	32.1%

T-91 Tank Farm Affected Area Cleanup Project
SCB Compressive Strength Data

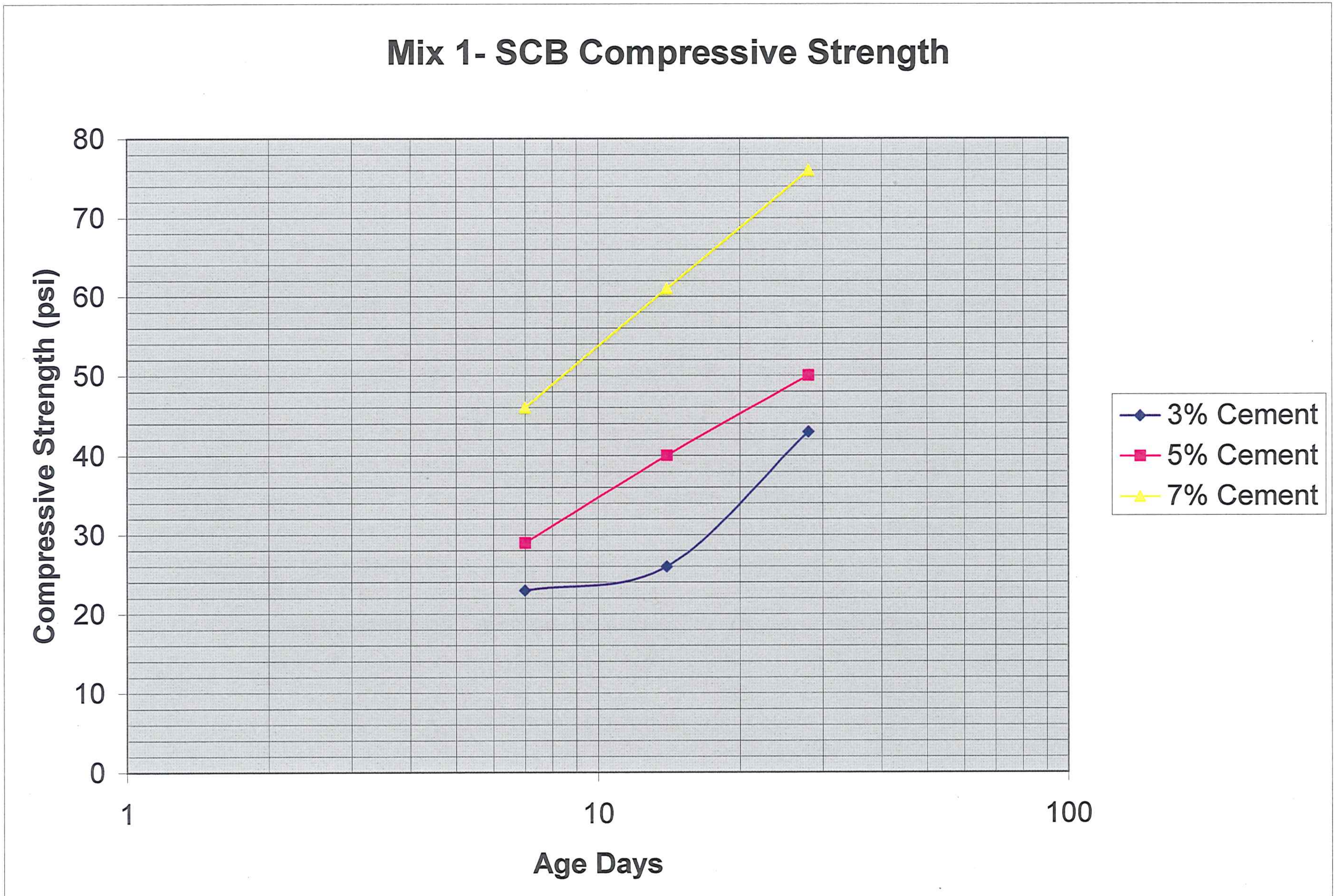
Mix 2	Age (days)	Break Date	Weight (gms)	Length (In)	Diameter (in)	Area (in^2)	Volume (Ft^3)	Unit Weight (pcf)	Load (Lbs)	UCS (psi)	Tare ID	Tare Wt.	Wet + Tare	Dry+ Tare	MC
2B3a	7	4/18/12	1269.8	5.973	2.99	7.018	0.02426	115.4	269	38	H	181.7	1448.9	1145.2	31.5%
2B3b	7	4/18/12	1260.7	5.947	2.992	7.027	0.02419	114.9	264	38	G	187.7	1435.9	1129.3	32.6%
2B3c	14	4/25/12	1271	5.935	2.993	7.032	0.02415	116.0	317	45	R	175.5	1441.4	1142.4	30.9%
2B3d	14	4/25/12	1261.4	5.956	2.992	7.027	0.02422	114.8	336	48	I	185.3	1438.0	1138.2	31.5%
2B3e	28	5/9/12	1263.61	5.96	2.995	7.041	0.02429	114.7	351	50	N	177.9	1437.9	1140.2	30.9%
2B3f	28	5/9/12	1257.36	5.956	2.993	7.032	0.02424	114.4	370	53	A	182.7	1436.5	1134.2	31.8%
2B5a	7	4/18/12	1269.4	5.951	2.988	7.009	0.02414	116.0	404	58	T	181.6	1446.8	1133.1	33.0%
2B5b	7	4/18/12	1264.4	5.941	2.998	7.056	0.02426	114.9	365	52	R	175.7	1435.6	1118	33.7%
2B5c	14	4/25/12	1260.7	5.951	2.989	7.013	0.02415	115.1	538	77	C	177.1	1430.9	1123.2	32.5%
2B5d	14	4/25/12	1257.6	5.963	2.991	7.023	0.02423	114.4	500	71	T	181.5	1432.4	1124.3	32.7%
2B5e	28	5/9/12	1260.03	5.946	2.994	7.037	0.02421	114.7	548	78	P	174.8	1431.0	1119	33.1%
2B5f	28	5/9/12	1249.24	5.958	2.987	7.004	0.02415	114.1	577	82	E	179	1424.1	1108.5	33.9%
2B7a	7	4/18/12	1236.2	5.947	2.993	7.032	0.0242	112.6	519	74	U	184.6	1412.6	1094	35.0%
2B7b	7	4/18/12	1225.5	5.947	2.996	7.046	0.02425	111.4	471	67	I	185.6	1406.0	1071.1	37.8%
2B7c	14	4/25/12	1245.7	5.934	2.992	7.027	0.02413	113.8	654	93	N	178.2	1419.0	1096.5	35.1%
2B7d	14	4/25/12	1248.5	5.939	2.987	7.004	0.02407	114.4	692	99	E	179	1422.0	1109.2	33.6%
2B7e	28	5/9/12	1248.71	5.967	2.982	6.98	0.0241	114.2	764	109	S	184.1	1425.5	1114.3	33.5%
2B7f	28	5/9/12	1246.89	5.951	2.994	7.037	0.02423	113.5	707	100	G	177.1	1419.6	1097.7	35.0%

T-91 Tank Farm Affected Area Cleanup Project
SCB Compressive Strength Data

Mix 3	Age (days)	Break Date	Weight (gms)	Length (In)	Diameter (in)	Area (in^2)	Volume (Ft^3)	Unit Weight (pcf)	Load (Lbs)	UCS (psi)	Tare ID	Tare Wt.	Wet + Tare	Dry+ Tare	MC
3B3a	7	4/23/12	1234.18	5.924	3.047	7.288	0.02499	108.9	218	30	M	178.1	1406.1	1081	36.0%
3B3b	7	4/23/12	1237.04	5.932	2.997	7.051	0.0242	112.7	227	32	F	176.1	1407.1	1086.1	35.3%
3B3c	14	4/30/12	1246.3	5.927	2.989	7.013	0.02406	114.2	227	32	O	183.1	1426.5	1099.5	35.7%
3B3d	14	4/30/12	1267.69	5.932	2.996	7.046	0.02419	115.6	208	30	L	187.4	1451.5	1141.9	32.4%
3B3e	28	5/14/12	1261.6	5.942	3.002	7.074	0.02433	114.4	246	35	I	184.6	1443.0	1125.1	33.8%
3B3f	28	5/14/12	1253.7	5.94	2.987	7.004	0.02408	114.8	246	35	B	173.1	1423.9	1101.3	34.8%
3B5a	7	4/23/12	1222.35	5.945	3.002	7.074	0.02434	110.7	445	63	H	179.6	1418.8	1093.3	35.6%
3B5b	7	4/23/12	1245.53	5.942	3	7.065	0.02429	113.1	473	67	J	180.5	1394.7	1062.3	37.7%
3B5c	14	4/30/12	1227.31	5.964	3.003	7.079	0.02443	110.8	525	74	D	178.1	1401.4	1069.5	37.2%
3B5d	14	4/30/12	1224.43	5.963	3	7.065	0.02438	110.7	511	72	B	172.5	1390.3	1057.7	37.6%
3B5e	28	5/14/12	1231	5.934	2.993	7.032	0.02415	112.4	558	79	K	181.7	1409.8	1088.6	35.4%
3B5f	28	5/14/12	1234.3	5.94	3	7.065	0.02429	112.1	520	74	V	193.8	1424.2	1088.8	37.5%
3B7a	7	4/23/12	1216.76	5.94	2.995	7.041	0.02421	110.8	615	87	V	199.3	1407.1	1064.2	39.6%
3B7b	7	4/23/12	1237.36	5.957	2.994	7.037	0.02426	112.5	587	83	Q	177.6	1406.7	1072.2	37.4%
3B7c	14	4/30/12	1213.8	5.931	2.986	6.999	0.02402	111.4	710	101	M	177.6	1387.0	1043	39.7%
3B7d	14	4/30/12	1197.2	5.922	3	7.065	0.02421	109.0	738	104	U	183.5	1373.9	1023.4	41.7%
3B7e	28	5/14/12	1198.5	5.951	3.001	7.07	0.02435	108.5	785	111	N	177.8	1372.7	1025.2	41.0%
3B7f	28	5/14/12	1199.2	5.936	2.992	7.027	0.02414	109.5	833	118	A	181.7	1375.8	1031.5	40.5%

SCB Compressive Strength Data

Mix 4	Age (days)	Break Date	Weight (gms)	Length (In)	Diameter (in)	Area (in^2)	Volume (Ft^3)	Unit Weight (pcf)	Load (Lbs)	UCS (psi)	Tare ID	Tare Wt.	Wet + Tare	Dry+ Tare	MC
S-4.5C	3	5/26/12	1341.6	5.937	3.017	7.145	0.02455	120.5	464	65	V	339.3	1676.0	1396.4	26.5%
S-4.5C	7	5/30/12	1334.8	5.959	3.003	7.079	0.02441	120.6	624	88	A	176.6	1509.7	1243.4	25.0%
S-4.5C	56	7/18/12	1327.77	5.957	2.999	7.06	0.02434	120.3	1012	143	K	180.6	1505.9	1248	24.2%
SB4-4.5A	3	5/7/12	1238.98	5.935	3.009	7.107	0.02441	111.9	241	34	R	175.3	1411.3	1085.1	35.9%
SB4-4.5B	7	5/11/12	1219.82	5.934	3.001	7.07	0.02428	110.8	355	50	N	177.8	1392.5	1065.6	36.8%
SB4-4.5C	28	6/1/12	1227.91	5.933	2.997	7.051	0.02421	111.8	426	60	T	174.0	1396.2	1056.2	38.5%
SB4-4.5D	3	5/26/12	1226.98	5.931	2.999	7.06	0.02423	111.6	341	48	R	344.2	1566.9	1232.2	37.7%
SB4-4.5E	7	5/30/12	1242.27	5.935	3.005	7.089	0.02435	112.5	426	60	N	174.0	1415.0	1091	35.3%
SB4-4.5F	56	7/18/12	1239.49	5.927	2.985	6.995	0.02399	113.9	634	91	F	175.9	1413.2	1105.4	33.1%
SB4-6.0A	3	5/7/12	1188.42	5.937	3	7.065	0.02427	108.0	265	37	V	194.0	1379.4	1023.3	42.9%
SB4-6.0B	7	5/11/12	1221.13	5.949	3.003	7.079	0.02437	110.5	426	60	A	182.1	1399.3	1052.5	39.8%
SB4-6.0C	28	6/1/12	1232.83	5.929	2.999	7.06	0.02422	112.2	624	88	T	180.7	1411.6	1091.4	35.2%


Mix 1- SCB Compressive Strength
Compressive Strength (psi)
80
70
60
50
40
30
20
10
0
1
10
100
Age Days
3% Cement
5% Cement
7% Cement


Mix 2-SCB Compressive Strength
Compressive Strength (psi)
120
100
80
60
40
20
0
1
10
100
Age Days
3% Cement
5% Cement
7% Cement


Mix 3-SCB Compressive Strength
Compressive Strength (psi)
120
100
80
60
40
20
0
1
10
100
Age Days
3% Cement
5% Cement
7% Cement

FIGURE 26


Mix 4-SCB Compressive Strength
Compressive Strength (psi)
0
20
40
60
80
100
120
140
160
1
10
100
Age Days
4.5% Cement
6% Cement
4.5%C No B

Hydraulic Conductivity (a.k.a. Permeability) Test Report

Method ASTM D 5084

HWA GEOSCIENCES INC.

Project	Terminal 91	Assumed Specific Gravity	2.65		
Client	PES Environmental	Initial Sample Area (cm2)	44.40	Final Sample Area (cm2)	42.25
Project number	2011-121	Initial Sample Length (cm)	7.84	Final Sample Length (cm)	7.72
Date	4/20/2012	Initial Sample Volume (cc)	347.9	Final Sample Volume (cc)	326.4
Technician	HB	Initial moisture (%)	13.8	Final moisture (%)	18.3
Sample point	Soil 1	Initial wet unit wt. (pcf)	113.4	Final wet unit weight (pcf)	125.7
Sample number	Composite	Initial dry unit wt. (pcf)	99.7	Final dry unit weight (pcf)	106.2
Sample depth	NA	Initial void ratio	0.659	Final void ratio	0.557
Sample description	Brown, poorly graded SAND with silt (SP-SM)	Initial porosity	0.397	Final porosity	0.358
		Initial saturation (%)	55.5	Final saturation (%)	87.1

Run No.	Hydraulic Conductivity (cm/s)	Running Average of 4 Readings (cm/s)	Maximum % Deviation from Average (should be less than 25%)	Flow Ratio (0.75 to 1.25 required)	Effective Confining Stress (psi)	Other Information
1	4.0E-04	n.a.		0.89	2.5	Maximum Gradient 10.1
2	4.0E-04	n.a.		1.04	2.5	
3	3.9E-04	n.a.		1.03	2.5	Minimum Gradient 6.3
4	3.9E-04	3.9E-04	1.5%	1.05	2.5	
5	4.0E-04	3.9E-04	2.1%	1.00	2.5	Max. Back Pressure (psi) 7.0
Final	3.8E-04	**3.9E-04**	3.0%	1.02	2.5	
						Min. Back Pressure (psi) 7.0

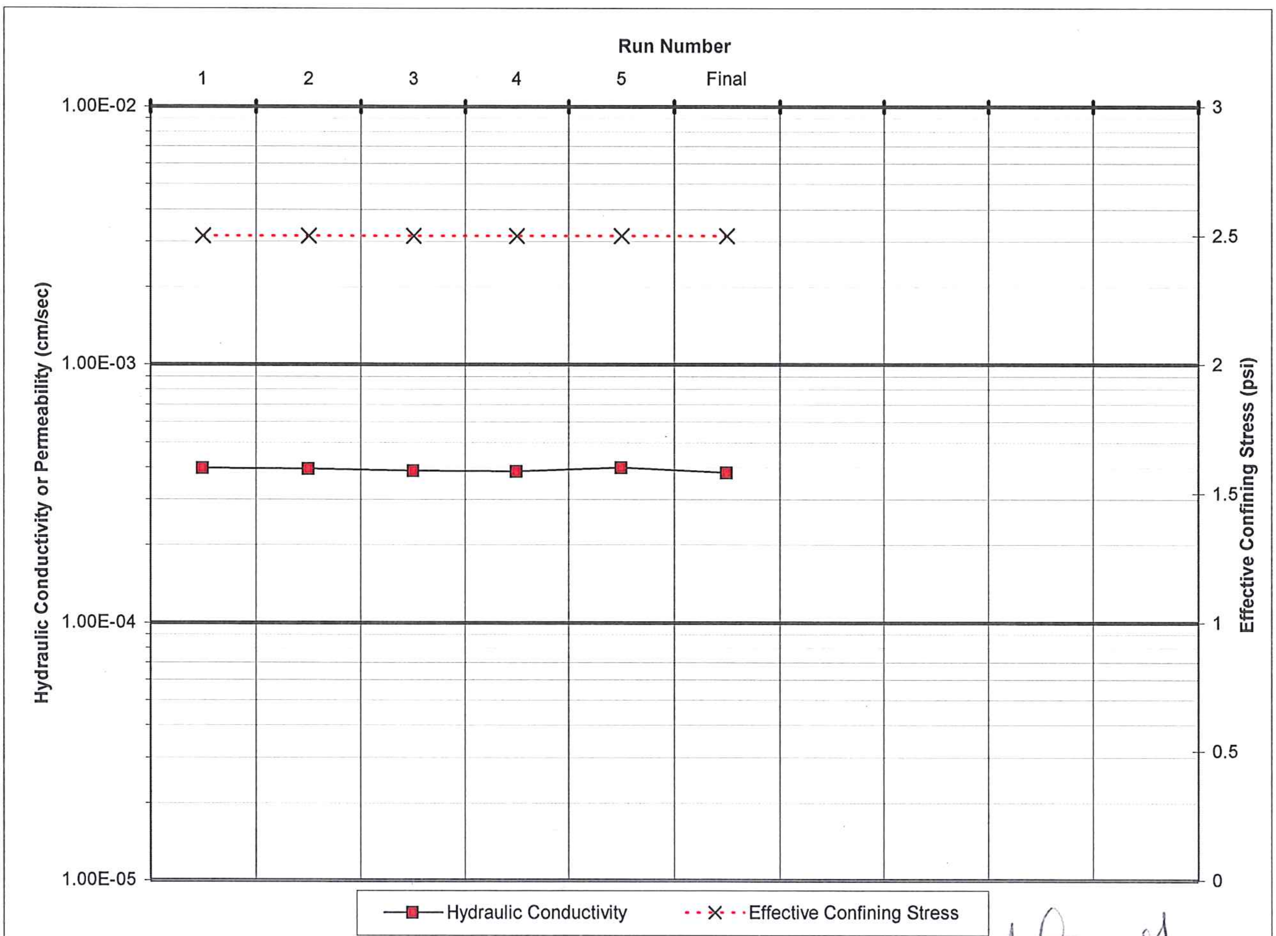


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FIGURE: 28

Hydraulic Conductivity (a.k.a. Permeability) Test Report

Method ASTM D 5084

HWA GEOSCIENCES INC.

Project	Terminal 91
Client	PES Environmental
Project number	2011-121
Date	3/29/2012
Technician	HB
Sample point	SB 1B
Sample number	NA
Sample depth	NA
Sample description	Site Soils + 5% Bentonite

Assumed Specific Gravity	2.60		
Initial Sample Area (cm2)	39.73	Final Sample Area (cm2)	36.29
Initial Sample Length (cm)	8.26	Final Sample Length (cm)	7.93
Initial Sample Volume (cc)	327.9	Final Sample Volume (cc)	287.8
Initial moisture (%)	28.7	Final moisture (%)	23.1
Initial wet unit wt. (pcf)	108.0	Final wet unit weight (pcf)	120.5
Initial dry unit wt. (pcf)	83.9	Final dry unit weight (pcf)	97.9
Initial void ratio	0.933	Final void ratio	0.656
Initial porosity	0.483	Final porosity	0.396
Initial saturation (%)	79.8	Final saturation (%)	91.4

Run No.	Hydraulic Conductivity (cm/s)	Running Average of 4 Readings (cm/s)	Maximum % Deviation from Average (should be less than 25%)	Flow Ratio (0.75 to 1.25 required)	Effective Confining Stress (psi)	Other Information
1	6.6E-08	n.a.		1.50	2.5	Maximum Gradient
2	6.7E-08	n.a.		0.69	2.5	9.9
3	6.6E-08	n.a.		0.65	2.5	Minimum Gradient
4	6.3E-08	6.5E-08	3.8%	0.50	2.5	4.6
5	6.5E-08	6.5E-08	3.4%	0.62	2.5	Max. Back Pressure (psi)
6	6.4E-08	6.4E-08	2.4%	0.71	2.5	7.0
7	6.2E-08	6.3E-08	2.0%	0.64	2.5	Min. Back Pressure (psi)
8	6.5E-08	6.4E-08	2.8%	0.67	2.5	7.0
Final	6.1E-08	**6.3E-08**	3.8%	0.61	2.5	

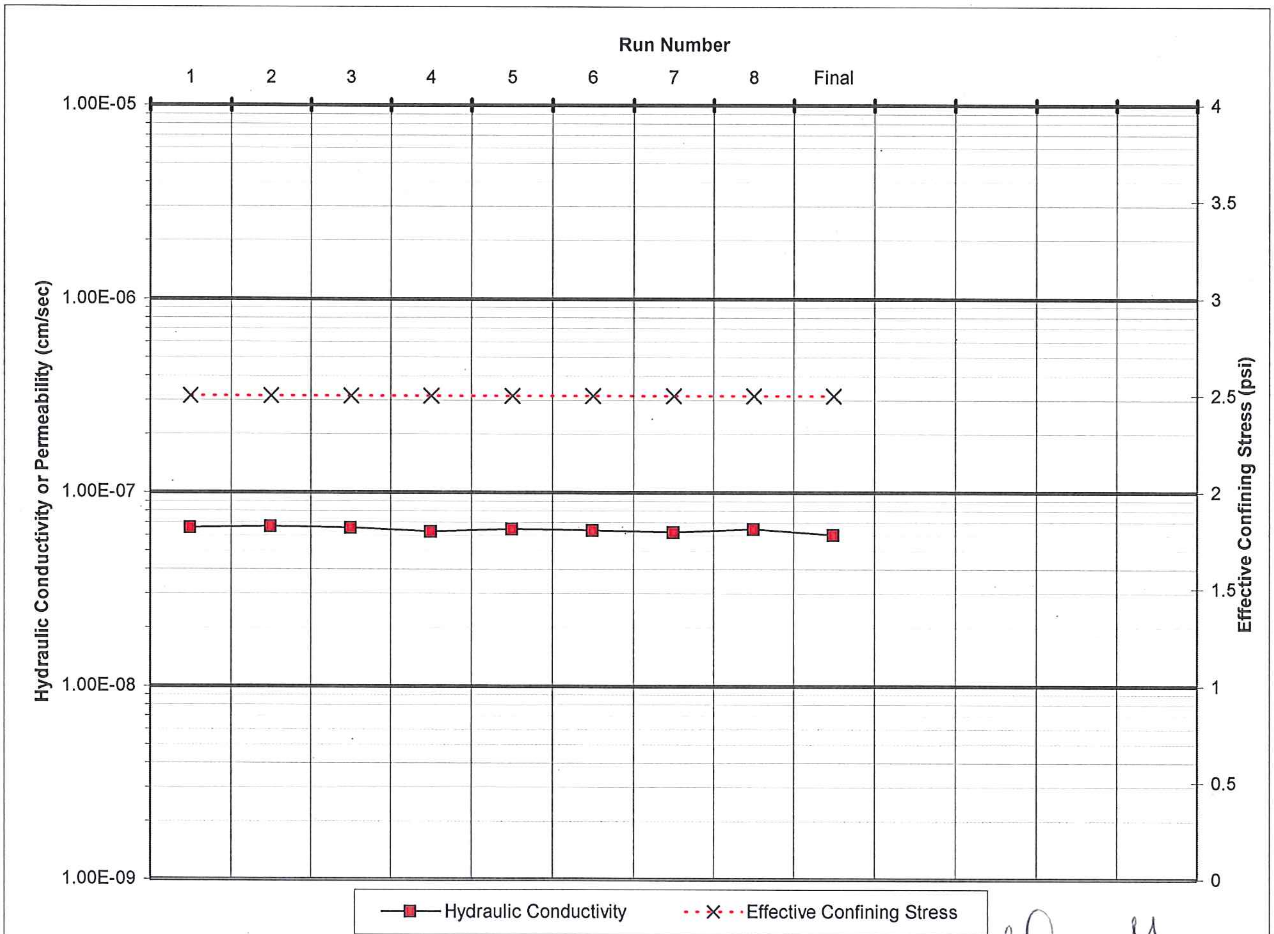

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FIGURE: 29

Hydraulic Conductivity (a.k.a. Permeability) Test Report

Method ASTM D 5084

HWA GEOSCIENCES INC.

Project	Terminal 91
Client	PES Environmental
Project number	2011-121
Date	4/20/2012
Technician	HB
Sample point	SB 1B*
Sample number	QA Check
Sample depth	NA
Sample description	Site Soils + 5% Bentonite

Assumed Specific Gravity	2.65		
Initial Sample Area (cm2)	41.16	Final Sample Area (cm2)	38.53
Initial Sample Length (cm)	8.10	Final Sample Length (cm)	7.91
Initial Sample Volume (cc)	333.5	Final Sample Volume (cc)	304.8
Initial moisture (%)	22.6	Final moisture (%)	20.4
Initial wet unit wt. (pcf)	120.7	Final wet unit weight (pcf)	128.5
Initial dry unit wt. (pcf)	98.4	Final dry unit weight (pcf)	106.7
Initial void ratio	0.680	Final void ratio	0.549
Initial porosity	0.405	Final porosity	0.355
Initial saturation (%)	88.1	Final saturation (%)	98.3

Run No.	Hydraulic Conductivity (cm/s)	Running Average of 4 Readings (cm/s)	Maximum % Deviation from Average (should be less than 25%)	Flow Ratio (0.75 to 1.25 required)	Effective Confining Stress (psi)	Other Information
1	2.4E-08	n.a.		0.78	3	Maximum Gradient
2	2.2E-08	n.a.		0.57	3	18.7
3	2.6E-08	n.a.		0.69	3	Minimum Gradient
4	2.5E-08	2.4E-08	9.9%	0.64	3	15.3
5	2.7E-08	2.5E-08	12.8%	0.73	3	Max. Back Pressure (psi)
6	2.7E-08	2.6E-08	4.3%	0.80	3	16.0
Final	2.7E-08	**2.6E-08**	5.0%	0.78	3	Min. Back Pressure (psi)
						16.0

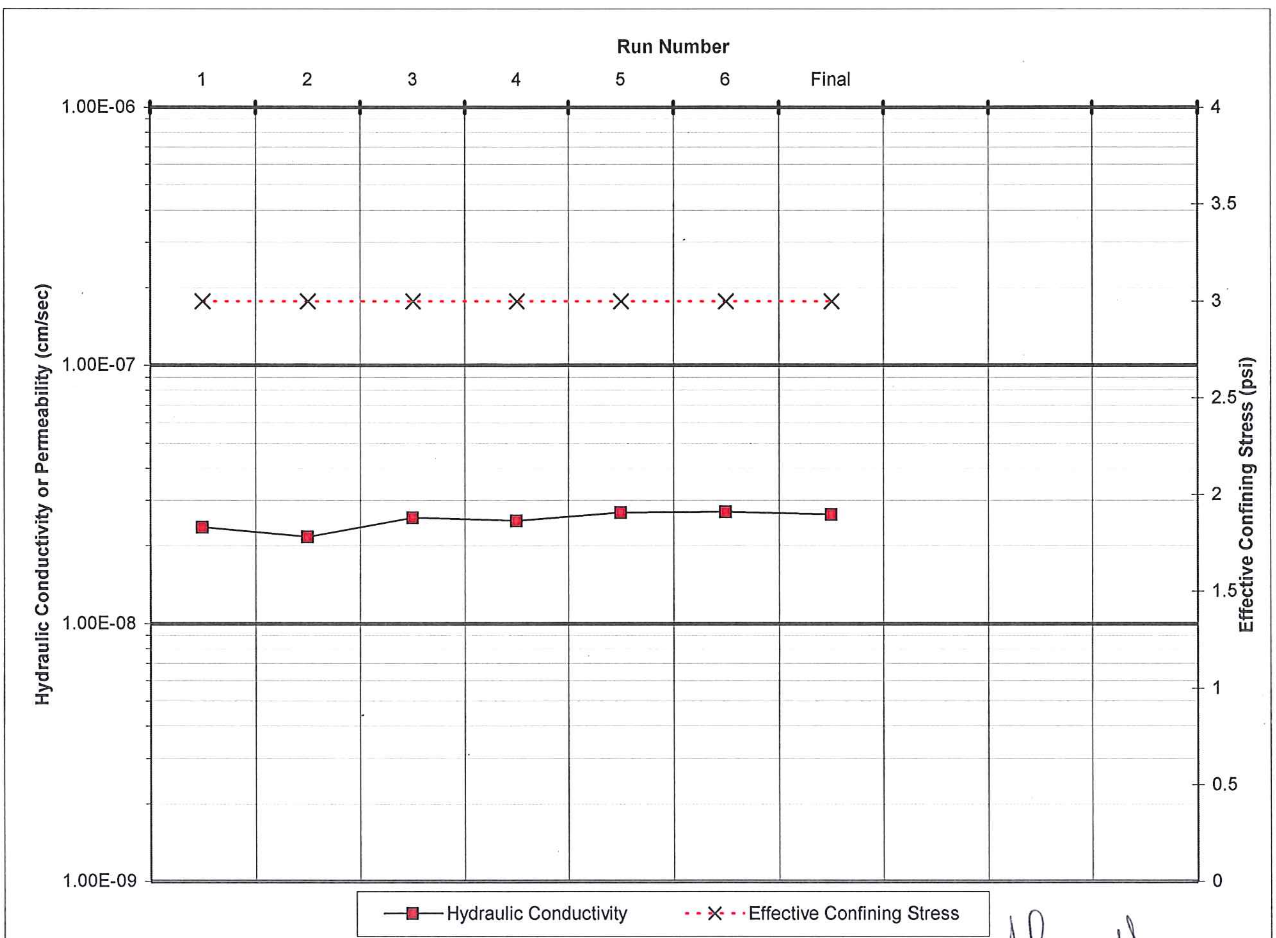

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FIGURE: 30

Hydraulic Conductivity (a.k.a. Permeability) Test Report

Method ASTM D 5084

HWA GEOSCIENCES INC.

Project	Terminal 91
Client	PES Environmental
Project number	2011-121
Date	4/20/2012
Technician	HB
Sample point	Soil 2
Sample number	NA
Sample depth	NA
Sample description	Site Soils + 25 % fines.

Assumed Specific Gravity	2.65
Initial Sample Area (cm2)	40.87
Initial Sample Length (cm)	6.68
Initial Sample Volume (cc)	273.0
Initial moisture (%)	18.8
Initial wet unit wt. (pcf)	128.0
Initial dry unit wt. (pcf)	107.7
Initial void ratio	0.535
Initial porosity	0.349
Initial saturation (%)	93.0

Final Sample Area (cm2)	39.86
Final Sample Length (cm)	6.37
Final Sample Volume (cc)	254.1
Final moisture (%)	16.2
Final wet unit weight (pcf)	132.6
Final dry unit weight (pcf)	114.1
Final void ratio	0.449
Final porosity	0.310
Final saturation (%)	95.7

Run No.	Hydraulic Conductivity (cm/s)	Running Average of 4 Readings (cm/s)	Maximum % Deviation from Average (should be less than 25%)	Flow Ratio (0.75 to 1.25 required)	Effective Confining Stress (psi)	Other Information
1	3.8E-07	n.a.		0.90	2.5	Maximum Gradient
2	3.7E-07	n.a.		0.92	2.5	11.8
3	3.8E-07	n.a.		1.00	2.5	Minimum Gradient
4	3.4E-07	3.6E-07	7.6%	0.87	2.5	4.9
5	3.6E-07	3.6E-07	6.7%	1.00	2.5	Max. Back Pressure (psi)
6	3.7E-07	3.6E-07	7.0%	1.00	2.5	7.0
Final	3.6E-07	**3.6E-07**	5.7%	0.96	2.5	Min. Back Pressure (psi)
						7.0

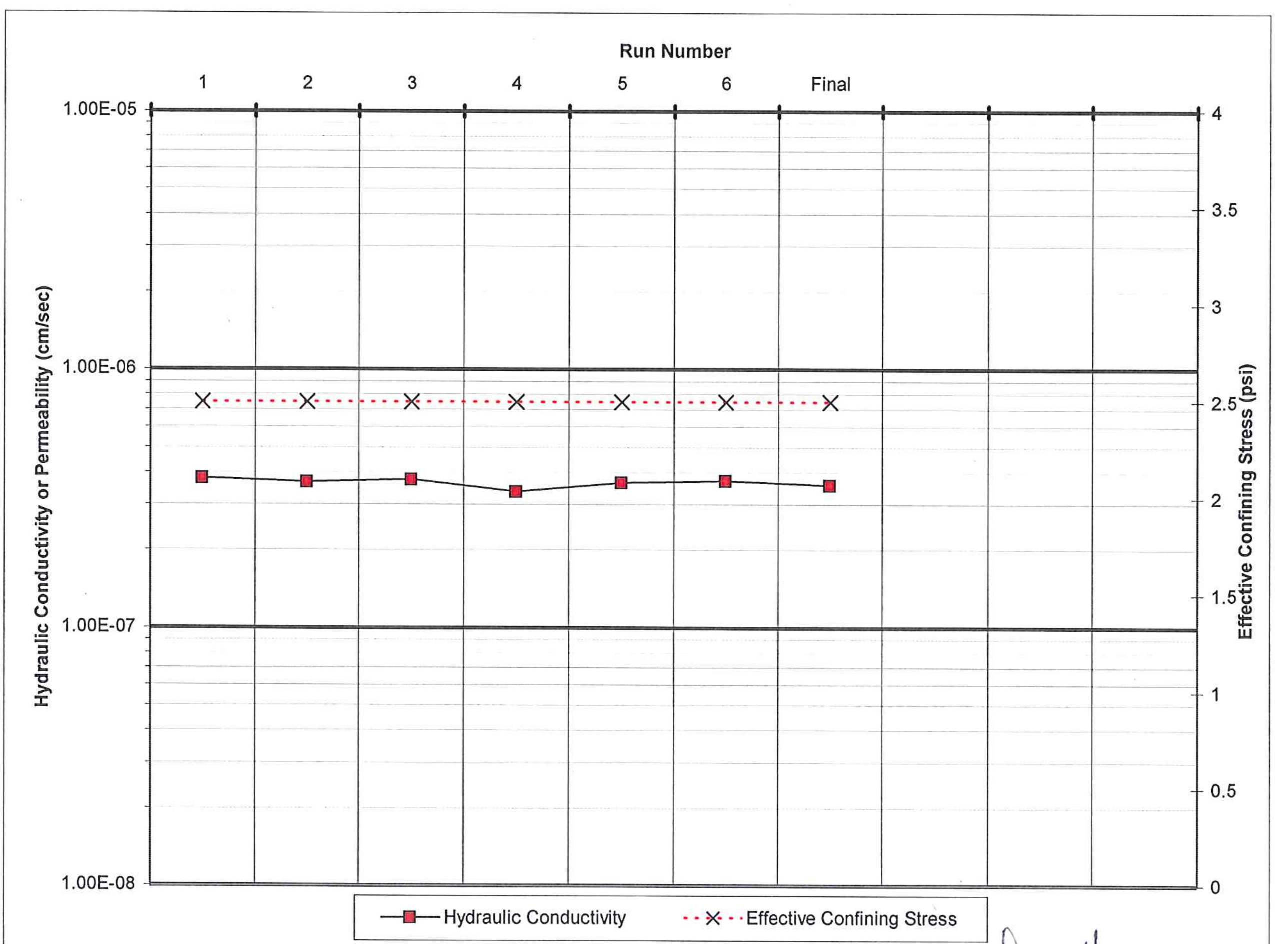

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FIGURE: 31

Hydraulic Conductivity (a.k.a. Permeability) Test Report

Method ASTM D 5084

HWA GEOSCIENCES INC.

Project	Terminal 91	Assumed Specific Gravity	2.70		
Client	PES Environmental	Initial Sample Area (cm2)	39.73	Final Sample Area (cm2)	36.02
Project number	2011-121	Initial Sample Length (cm)	8.89	Final Sample Length (cm)	8.16
Date	4/11/2021	Initial Sample Volume (cc)	353.2	Final Sample Volume (cc)	293.8
Technician	HB	Initial moisture (%)	26.8	Final moisture (%)	20.9
Sample point	SB 2B	Initial wet unit wt. (pcf)	115.5	Final wet unit weight (pcf)	135.4
Sample number	NA	Initial dry unit wt. (pcf)	91.1	Final dry unit weight (pcf)	112.0
Sample depth	NA	Initial void ratio	0.850	Final void ratio	0.504
Sample description	Site Soils + 25% Fines + 3% Bentonite.	Initial porosity	0.459	Final porosity	0.335
		Initial saturation (%)	85.1	Final saturation (%)	111.6

Run No.	Hydraulic Conductivity (cm/s)	Running Average of 4 Readings (cm/s)	Maximum % Deviation from Average (should be less than 25%)	Flow Ratio (0.75 to 1.25 required)	Effective Confining Stress (psi)	Other Information
1	9.9E-08	n.a.		1.14	2.5	Maximum Gradient
2	9.6E-08	n.a.		1.00	2.5	9.6
3	9.8E-08	n.a.		0.87	2.5	Minimum Gradient
4	9.9E-08	9.8E-08	1.8%	0.91	2.5	5.7
5	9.3E-08	9.7E-08	3.4%	0.92	2.5	Max. Back Pressure (psi)
6	8.5E-08	9.4E-08	9.4%	0.83	2.5	7.0
7	1.1E-07	9.6E-08	12.5%	1.13	2.5	Min. Back Pressure (psi)
8	1.1E-07	1.0E-07	15.2%	0.95	2.5	7.0
9	1.1E-07	1.0E-07	18.1%	0.90	2.5	
Final	1.1E-07	**1.1E-07**	3.2%	0.90	2.5	

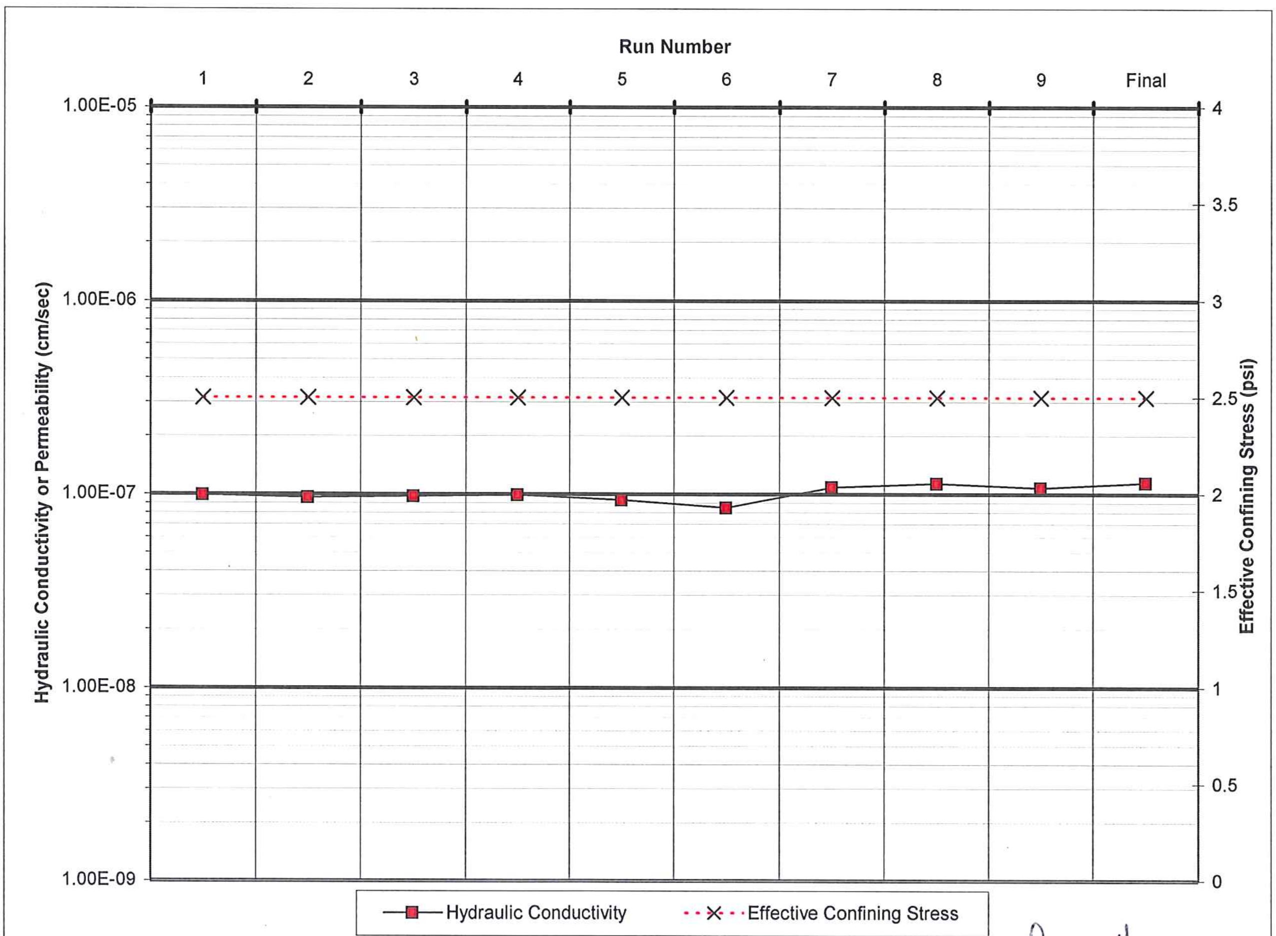

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FIGURE: 32

Hydraulic Conductivity (a.k.a. Permeability) Test Report

Method ASTM D 5084

HWA GEOSCIENCES INC.

Project	Terminal 91
Client	PES Environmental
Project number	2011-121
Date	4/20/2012
Technician	HB
Sample point	SB-2B*
Sample number	QA Check
Sample depth	NA
Sample description	Site soils + 25% Fines and 3% Bentonite.

Assumed Specific Gravity	2.65		
Initial Sample Area (cm2)	41.16	Final Sample Area (cm2)	38.23
Initial Sample Length (cm)	8.15	Final Sample Length (cm)	7.62
Initial Sample Volume (cc)	335.6	Final Sample Volume (cc)	291.3
Initial moisture (%)	26.3	Final moisture (%)	20.3
Initial wet unit wt. (pcf)	116.4	Final wet unit weight (pcf)	124.4
Initial dry unit wt. (pcf)	92.1	Final dry unit weight (pcf)	103.4
Initial void ratio	0.795	Final void ratio	0.599
Initial porosity	0.443	Final porosity	0.375
Initial saturation (%)	87.8	Final saturation (%)	89.8

Run No.	Hydraulic Conductivity (cm/s)	Running Average of 4 Readings (cm/s)	Maximum % Deviation from Average (should be less than 25%)	Flow Ratio (0.75 to 1.25 required)	Effective Confining Stress (psi)	Other Information
1	1.3E-07	n.a.		0.57	3	Maximum Gradient 19.5
2	1.5E-07	n.a.		1.00	3	
3	1.3E-07	n.a.		0.88	3	Minimum Gradient 12.5
4	1.1E-07	1.3E-07	13.5%	1.09	3	
5	1.3E-07	1.3E-07	13.5%	0.89	3	Max. Back Pressure (psi) 16.0
6	1.3E-07	1.3E-07	10.8%	0.88	3	
Final	1.1E-07	**1.2E-07**	7.6%	0.90	3	Min. Back Pressure (psi) 16.0

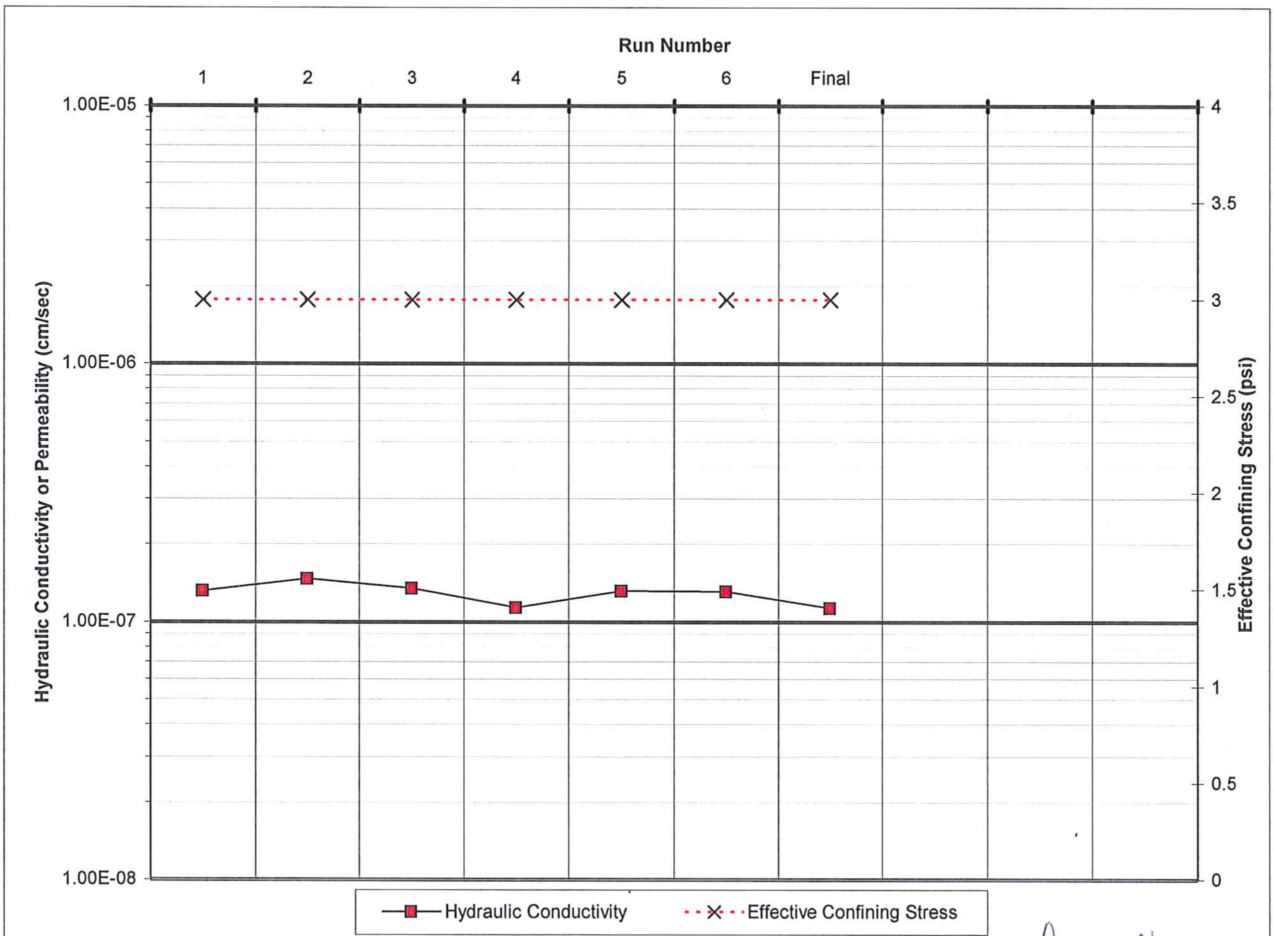

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FIGURE: 33

Hydraulic Conductivity (a.k.a. Permeability) Test Report

Method ASTM D 5084

HWA GEOSCIENCES INC.

Project	Terminal 91
Client	PES Environmental
Project number	2011-121
Date	4/20/2012
Technician	HB
Sample point	Soil 3
Sample number	NA
Sample depth	NA
Sample description	Site Soils + 35% Fines.

Assumed Specific Gravity	2.60		
Initial Sample Area (cm2)	39.73	Final Sample Area (cm2)	36.66
Initial Sample Length (cm)	7.65	Final Sample Length (cm)	6.25
Initial Sample Volume (cc)	303.7	Final Sample Volume (cc)	229.2
Initial moisture (%)	21.2	Final moisture (%)	18.1
Initial wet unit wt. (pcf)	106.6	Final wet unit weight (pcf)	137.2
Initial dry unit wt. (pcf)	88.0	Final dry unit weight (pcf)	116.2
Initial void ratio	0.844	Final void ratio	0.396
Initial porosity	0.458	Final porosity	0.284
Initial saturation (%)	65.3	Final saturation (%)	118.7

Run No.	Hydraulic Conductivity (cm/s)	Running Average of 4 Readings (cm/s)	Maximum % Deviation from Average (should be less than 25%)	Flow Ratio (0.75 to 1.25 required)	Effective Confining Stress (psi)
1	2.0E-07	n.a.		1.00	2.5
2	1.6E-07	n.a.		1.00	2.5
3	1.6E-07	n.a.		1.00	2.5
4	1.5E-07	1.7E-07	17.1%	0.96	2.5
5	1.7E-07	1.6E-07	6.4%	1.00	2.5
Final	1.6E-07	**1.6E-07**	6.4%	0.97	2.5

Other Information
Maximum Gradient 12.2
Minimum Gradient 8.4
Max. Back Pressure (psi) 7.0
Min. Back Pressure (psi) 7.0

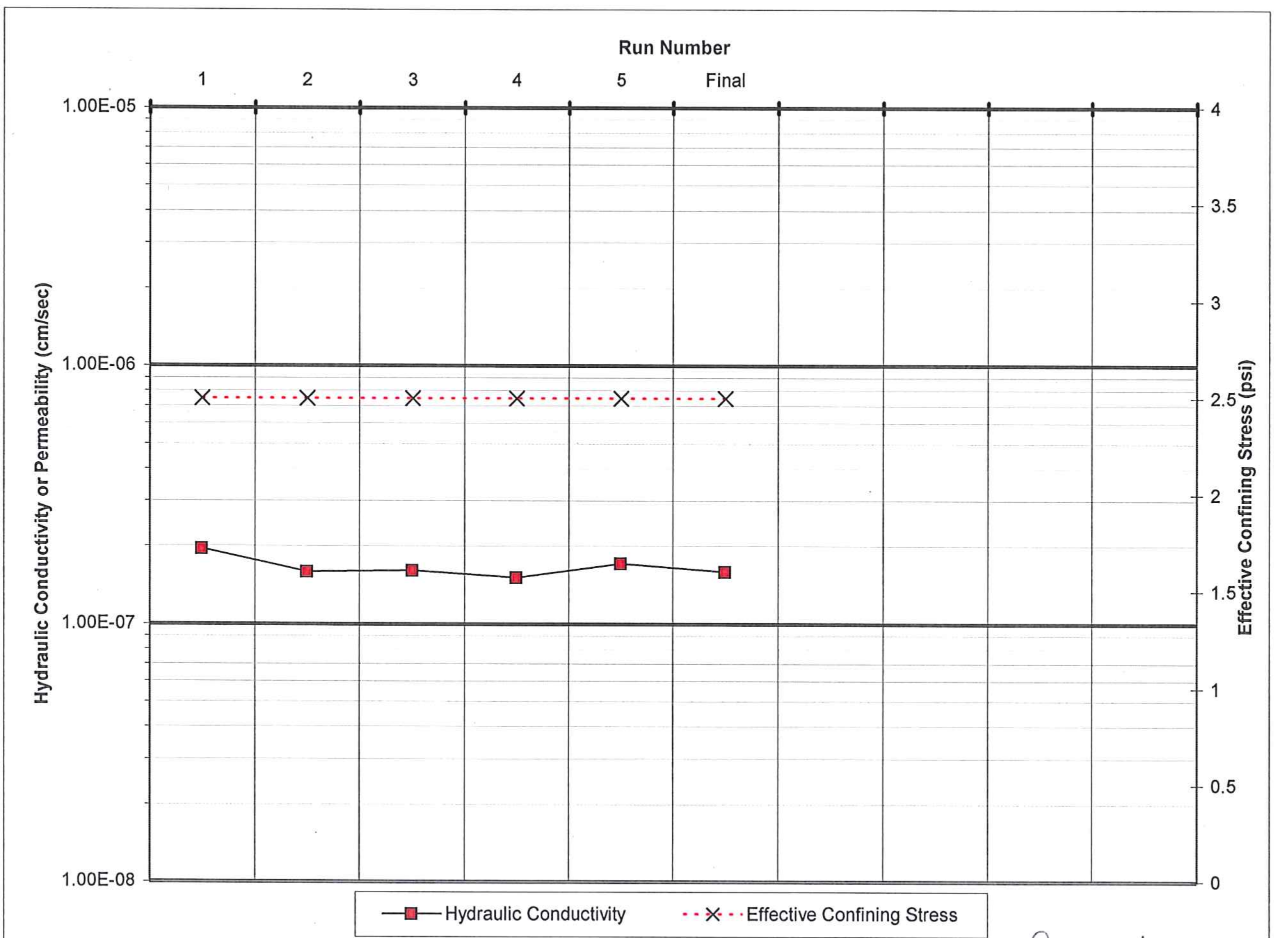

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FIGURE: 34

Hydraulic Conductivity (a.k.a. Permeability) Test Report

Method ASTM D 5084

HWA GEOSCIENCES INC.

Project	Terminal 91	Assumed Specific Gravity	2.70		
Client	PES Environmental	Initial Sample Area (cm2)	39.73	Final Sample Area (cm2)	34.49
Project number	2011-121	Initial Sample Length (cm)	8.89	Final Sample Length (cm)	8.19
Date	4/11/2021	Initial Sample Volume (cc)	353.2	Final Sample Volume (cc)	282.6
Technician	HB	Initial moisture (%)	33.8	Final moisture (%)	23.9
Sample point	Soil 3B	Initial wet unit wt. (pcf)	114.9	Final wet unit weight (pcf)	132.2
Sample number	NA	Initial dry unit wt. (pcf)	85.9	Final dry unit weight (pcf)	106.7
Sample depth	NA	Initial void ratio	0.961	Final void ratio	0.579
Sample description	Site Soils + 35% Fines + 3% Bentonite	Initial porosity	0.490	Final porosity	0.367
		Initial saturation (%)	94.9	Final saturation (%)	111.3

Run No.	Hydraulic Conductivity (cm/s)	Running Average of 4 Readings (cm/s)	Maximum % Deviation from Average (should be less than 25%)	Flow Ratio (0.75 to 1.25 required)	Effective Confining Stress (psi)
1	1.4E-07	.n.a.		3.50	2.5
2	1.3E-07	n.a.		1.50	2.5
3	1.0E-07	n.a.		1.11	2.5
4	1.0E-07	1.2E-07	18.4%	1.14	2.5
5	9.7E-08	1.1E-07	17.3%	0.90	2.5
Final	9.4E-08	**9.9E-08**	4.7%	0.89	2.5

Other Information
Maximum Gradient
9.5
Minimum Gradient
6.4
Max. Back Pressure (psi)
7.0
Min. Back Pressure (psi)
7.0

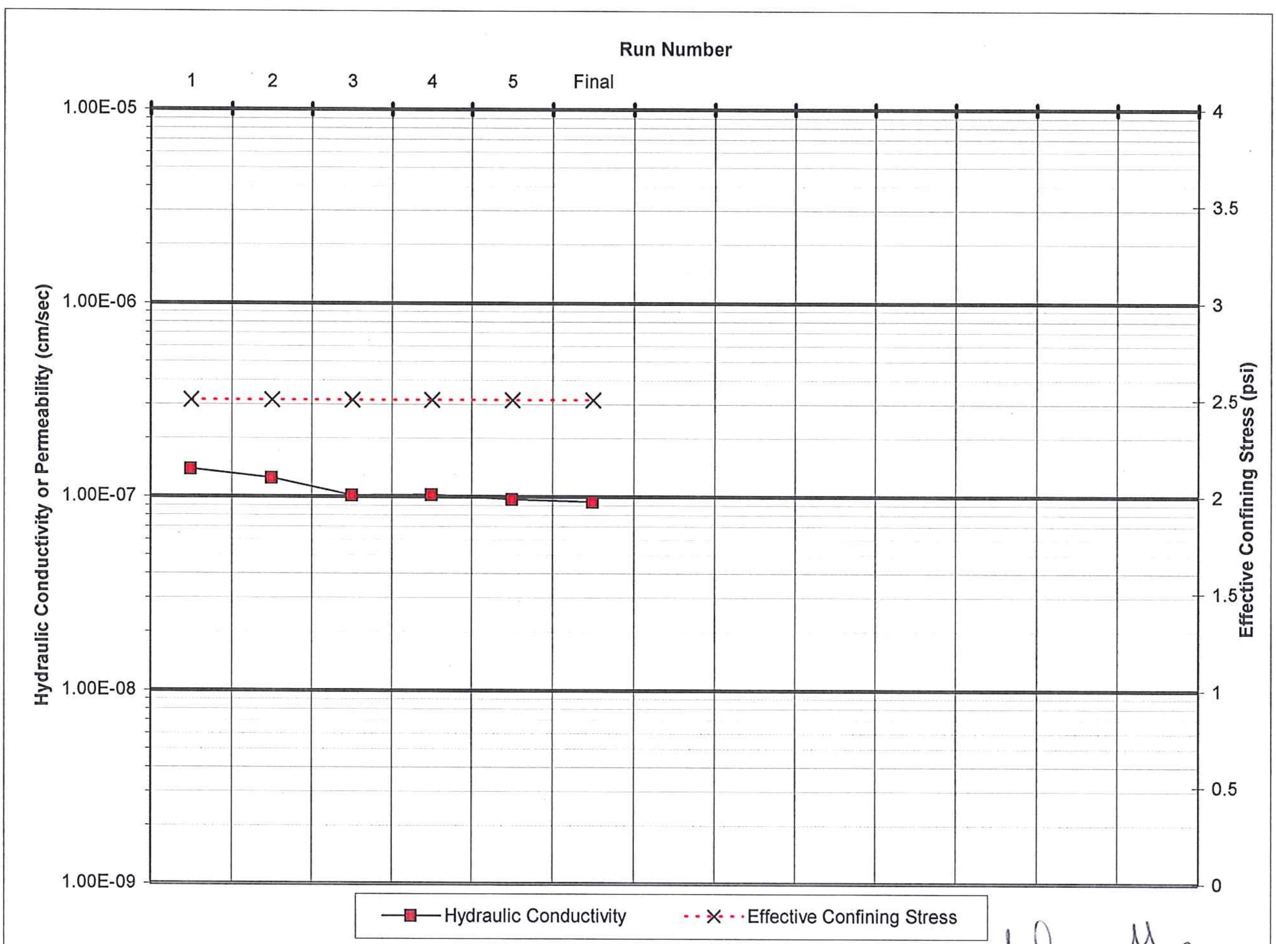

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FIGURE: 35

Hydraulic Conductivity (a.k.a. Permeability) Test Report

Method ASTM D 5084

HWA GEOSCIENCES INC.

Project	Terminal 91
Client	PES Environmental
Project number	2011-121
Date	4/20/2012
Technician	HB
Sample point	Soil 3B*
Sample number	QA Check
Sample depth	NA
Sample description	Soil Soils + 35% Fines and 3% Bentonite

Assumed Specific Gravity	2.65		
Initial Sample Area (cm2)	41.16	Final Sample Area (cm2)	38.23
Initial Sample Length (cm)	8.04	Final Sample Length (cm)	7.08
Initial Sample Volume (cc)	330.9	Final Sample Volume (cc)	270.6
Initial moisture (%)	29.6	Final moisture (%)	21.4
Initial wet unit wt. (pcf)	141.0	Final wet unit weight (pcf)	124.5
Initial dry unit wt. (pcf)	108.8	Final dry unit weight (pcf)	102.6
Initial void ratio	0.520	Final void ratio	0.612
Initial porosity	0.342	Final porosity	0.379
Initial saturation (%)	150.9	Final saturation (%)	92.5

Run No.	Hydraulic Conductivity (cm/s)	Running Average of 4 Readings (cm/s)	Maximum % Deviation from Average (should be less than 25%)	Flow Ratio (0.75 to 1.25 required)	Effective Confining Stress (psi)
1	8.4E-08	n.a.		1.22	3
2	8.3E-08	n.a.		1.02	3
3	8.2E-08	n.a.		0.98	3
4	8.2E-08	8.2E-08	1.4%	0.97	3
Final	8.2E-08	**8.2E-08**	1.2%	0.96	3

Other Information
Maximum Gradient
20.4
Minimum Gradient
15.4
Max. Back Pressure (psi)
16.0
Min. Back Pressure (psi)
16.0

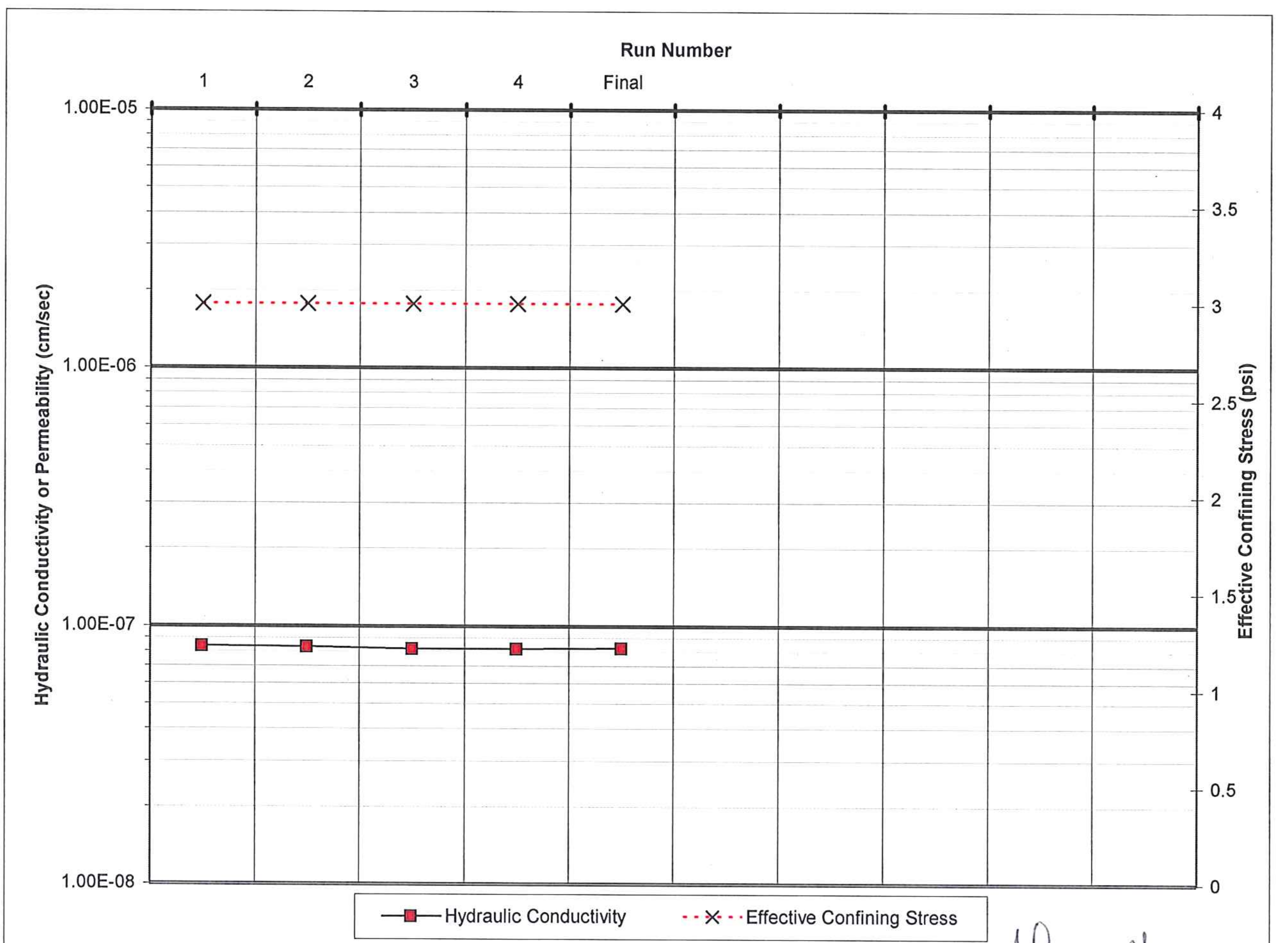

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FIGURE: 36

Hydraulic Conductivity (a.k.a. Permeability) Test Report

Method ASTM D 5084

HWA GEOSCIENCES INC.

Project	Terminal 91
Client	PES Environmental
Project number	2011-121
Date	4/20/2012
Technician	HB
Sample point	Soil 4A
Sample number	0
Sample depth	0
Sample description	Site Soils + 30% Fines + 4.5% Bentonite.

Assumed Specific Gravity	2.65		
Initial Sample Area (cm2)	41.16	Final Sample Area (cm2)	35.76
Initial Sample Length (cm)	7.91	Final Sample Length (cm)	7.27
Initial Sample Volume (cc)	325.6	Final Sample Volume (cc)	260.0
Initial moisture (%)	30.4	Final moisture (%)	21.7
Initial wet unit wt. (pcf)	107.4	Final wet unit weight (pcf)	125.6
Initial dry unit wt. (pcf)	82.4	Final dry unit weight (pcf)	103.2
Initial void ratio	1.007	Final void ratio	0.602
Initial porosity	0.502	Final porosity	0.376
Initial saturation (%)	80.0	Final saturation (%)	95.4

Run No.	Hydraulic Conductivity (cm/s)	Running Average of 4 Readings (cm/s)	Maximum % Deviation from Average (should be less than 25%)	Flow Ratio (0.75 to 1.25 required)	Effective Confining Stress (psi)
1	4.4E-08	n.a.		1.22	3
2	4.3E-08	n.a.		1.36	3
3	3.7E-08	n.a.		1.92	3
4	3.8E-08	4.1E-08	8.2%	2.11	3
5	4.1E-08	4.0E-08	8.4%	1.55	3
6	3.8E-08	3.9E-08	6.2%	1.76	3
7	3.5E-08	3.8E-08	7.4%	1.42	3
8	5.6E-08	4.3E-08	30.6%	1.16	3
9	5.5E-08	4.6E-08	22.9%	0.87	3
10	5.9E-08	5.1E-08	30.5%	0.93	3
Final	5.9E-08	**5.7E-08**	3.9%	0.92	3

Other Information
Maximum Gradient 21.3
Minimum Gradient 15.6
Max. Back Pressure (psi) 16.0
Min. Back Pressure (psi) 16.0

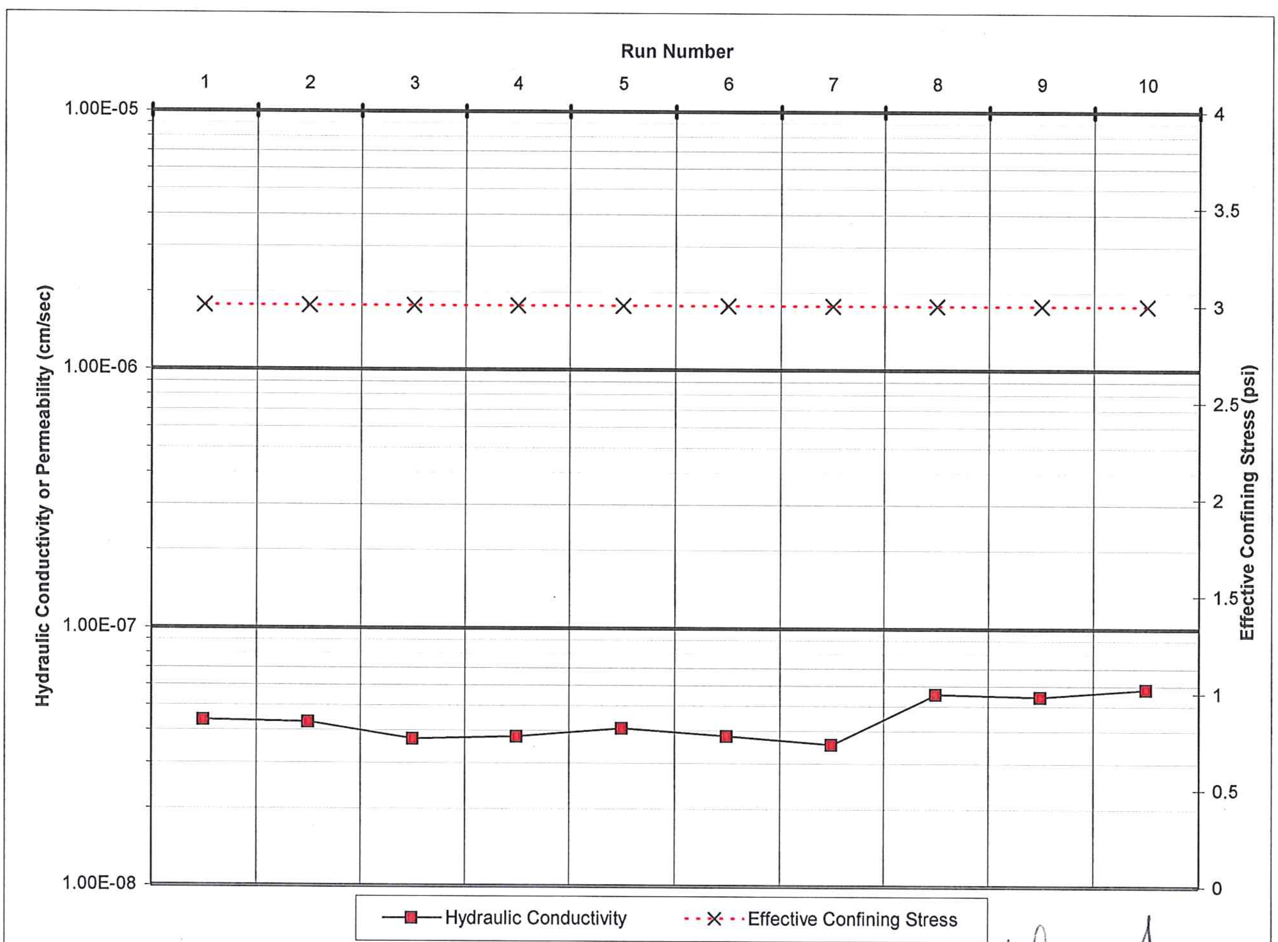

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FIGURE: 37

Hydraulic Conductivity (a.k.a. Permeability) Test Report

Method ASTM D 5084

HWA GEOSCIENCES INC.

Project	Terminal 91
Client	PES Environmental
Project number	2011-121
Date	4/20/2012
Technician	HB
Sample point	Soil 4B
Sample number	0
Sample depth	0
Sample description	Site Soils + 30% Fines + 6% Bentonite.

Assumed Specific Gravity	2.65		
Initial Sample Area (cm2)	40.58	Final Sample Area (cm2)	35.76
Initial Sample Length (cm)	8.28	Final Sample Length (cm)	7.73
Initial Sample Volume (cc)	336.0	Final Sample Volume (cc)	276.5
Initial moisture (%)	34.3	Final moisture (%)	26.6
Initial wet unit wt. (pcf)	105.7	Final wet unit weight (pcf)	120.8
Initial dry unit wt. (pcf)	78.7	Final dry unit weight (pcf)	95.4
Initial void ratio	1.100	Final void ratio	0.733
Initial porosity	0.524	Final porosity	0.423
Initial saturation (%)	82.6	Final saturation (%)	96.2

Run No.	Hydraulic Conductivity (cm/s)	Running Average of 4 Readings (cm/s)	Maximum % Deviation from Average (should be less than 25%)	Flow Ratio (0.75 to 1.25 required)	Effective Confining Stress (psi)
1	2.8E-08	n.a.		0.78	3
2	3.0E-08	n.a.		0.83	3
3	3.0E-08	n.a.		0.86	3
Final	3.0E-08	2.9E-08	3.8%	0.83	3

Other Information
Maximum Gradient 18.8
Minimum Gradient 14.0
Max. Back Pressure (psi) 16.0
Min. Back Pressure (psi) 16.0

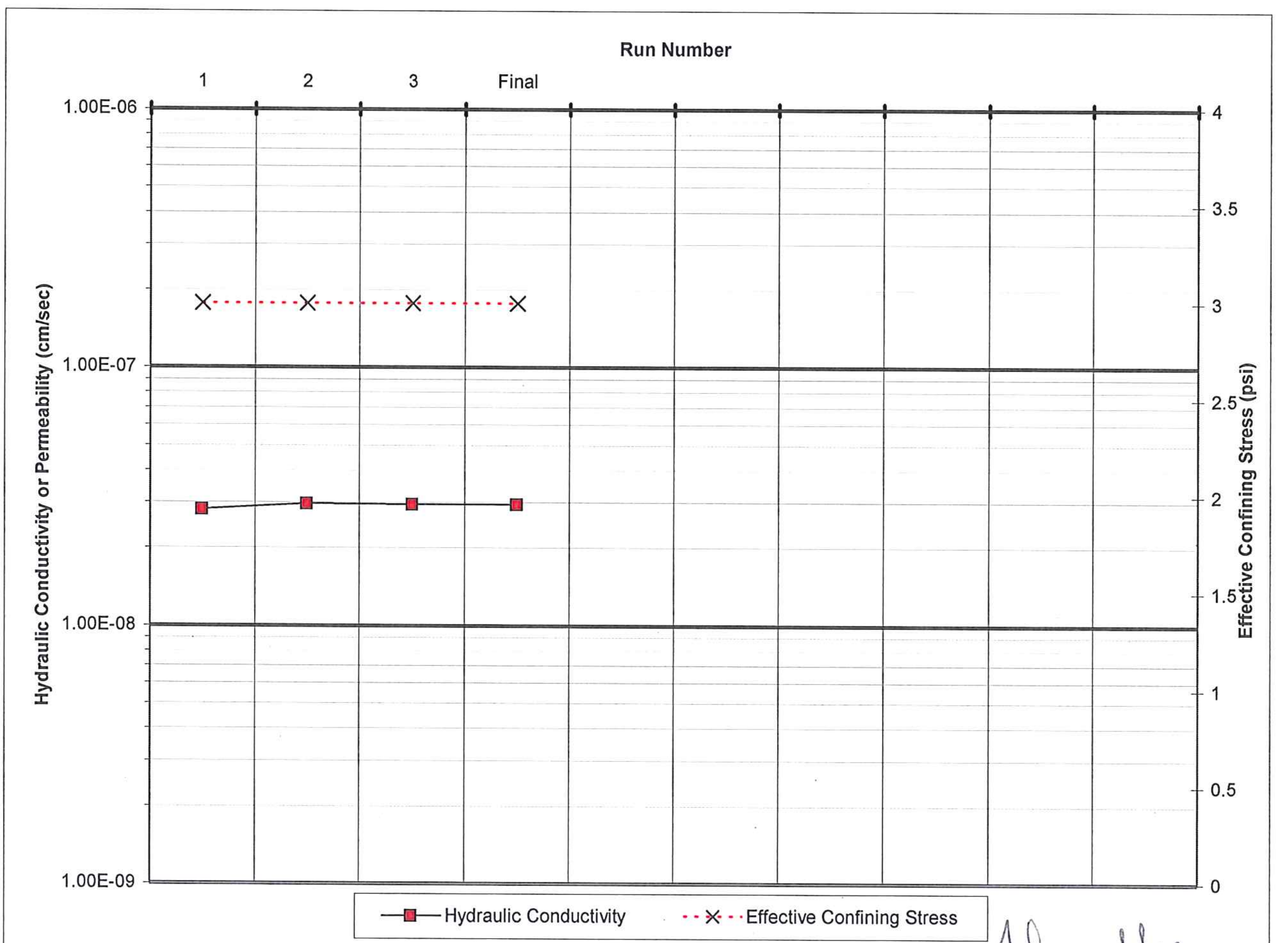

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FIGURE: 38

Hydraulic Conductivity (a.k.a. Permeability) Test Report

Method ASTM D 5084

HWA GEOSCIENCES INC.

Project	Terminal 91
Client	PES Environmental
Project number	2011-121
Date	4/20/2012
Technician	AC
Sample point	SCB 4A-6
Sample number	0
Sample depth	0
Sample description	SB 30% fines, 4.5% bentonite, 6% Cement

Assumed Specific Gravity	2.65		
Initial Sample Area (cm2)	45.31	Final Sample Area (cm2)	45.31
Initial Sample Length (cm)	15.10	Final Sample Length (cm)	15.10
Initial Sample Volume (cc)	684.4	Final Sample Volume (cc)	684.4
Initial moisture (%)	42.0	Final moisture (%)	44.0
Initial wet unit wt. (pcf)	109.8	Final wet unit weight (pcf)	111.3
Initial dry unit wt. (pcf)	77.3	Final dry unit weight (pcf)	77.3
Initial void ratio	1.139	Final void ratio	1.139
Initial porosity	0.533	Final porosity	0.533
Initial saturation (%)	97.7	Final saturation (%)	102.3

Run No.	Hydraulic Conductivity (cm/s)	Running Average of 4 Readings (cm/s)	Maximum % Deviation from Average (should be less than 25%)	Flow Ratio (0.75 to 1.25 required)	Effective Confining Stress (psi)
1	2.0E-07	n.a.		0.79	3
2	2.0E-07	n.a.		0.81	3
3	2.0E-07	n.a.		0.95	3
4	2.0E-07	2.0E-07	1.1%	0.85	3
5	1.9E-07	2.0E-07	2.9%	0.93	3
6	1.7E-07	1.9E-07	8.5%	0.90	3
7	2.0E-07	1.9E-07	8.4%	1.00	3
Final	2.0E-07	**1.9E-07**	9.2%	0.90	

Other Information
Maximum Gradient 10.3
Minimum Gradient 6.3
Max. Back Pressure (psi) 16.0
Min. Back Pressure (psi) 16.0

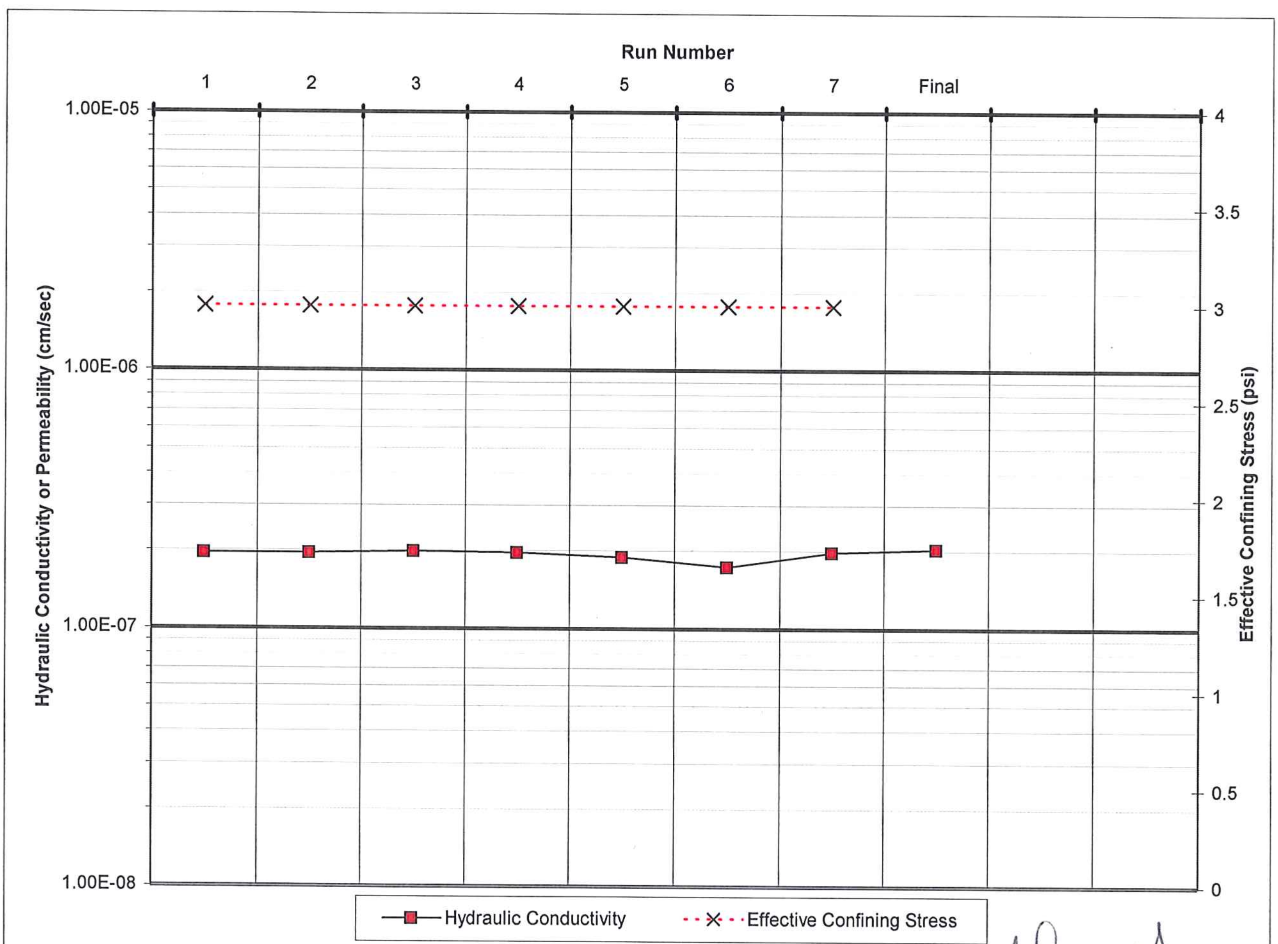

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FIGURE: 39

Hydraulic Conductivity (a.k.a. Permeability) Test Report

Method ASTM D 5084

HWA GEOSCIENCES INC.

Project	Terminal 91
Client	PES Environmental
Project number	2011-121
Date	4/20/2012
Technician	AC
Sample point	Soil 4
Sample number	0
Sample depth	0
Sample description	Ssite Soils + 30% Fines. Permeant :GW

Assumed Specific Gravity	2.65		
Initial Sample Area (cm2)	41.59	Final Sample Area (cm2)	35.40
Initial Sample Length (cm)	8.56	Final Sample Length (cm)	8.01
Initial Sample Volume (cc)	356.2	Final Sample Volume (cc)	283.4
Initial moisture (%)	23.9	Final moisture (%)	17.4
Initial wet unit wt. (pcf)	118.6	Final wet unit weight (pcf)	140.9
Initial dry unit wt. (pcf)	95.7	Final dry unit weight (pcf)	120.1
Initial void ratio	0.728	Final void ratio	0.377
Initial porosity	0.421	Final porosity	0.274
Initial saturation (%)	87.0	Final saturation (%)	122.1

Run No.	Hydraulic Conductivity (cm/s)	Running Average of 4 Readings (cm/s)	Maximum % Deviation from Average (should be less than 25%)	Flow Ratio (0.75 to 1.25 required)	Effective Confining Stress (psi)	Other Information
1	3.8E-07	n.a.		0.91	3	Maximum Gradient 97.6
2	3.8E-07	n.a.		1.14	3	
3	4.0E-07	n.a.		1.00	3	Minimum Gradient 16.3
4	3.8E-07	3.8E-07	4.7%	1.00	3	
5	3.5E-07	3.8E-07	7.1%	1.00	3	Max. Back Pressure (psi) 16.0
6	3.5E-07	3.7E-07	8.7%	1.18	7.5	
7	3.5E-07	3.6E-07	5.9%	1.01	7.5	Min. Back Pressure (psi) 16.0
8	3.4E-07	3.5E-07	2.3%	0.97	7.5	
9	3.4E-07	3.4E-07	2.1%	1.06	7.5	
10	3.4E-07	3.4E-07	2.0%	1.00	7.5	
11	3.1E-07	3.3E-07	5.1%	0.92	7.5	Total volume of permeant= 443 cc
12	3.3E-07	3.3E-07	4.5%	1.01	7.5	PV Initial =149.9 cc, Final= 77.7 cc
Final	3.3E-07	**3.3E-07**	3.9%	0.97	7.5	Total elapsed time 254. 8 hours

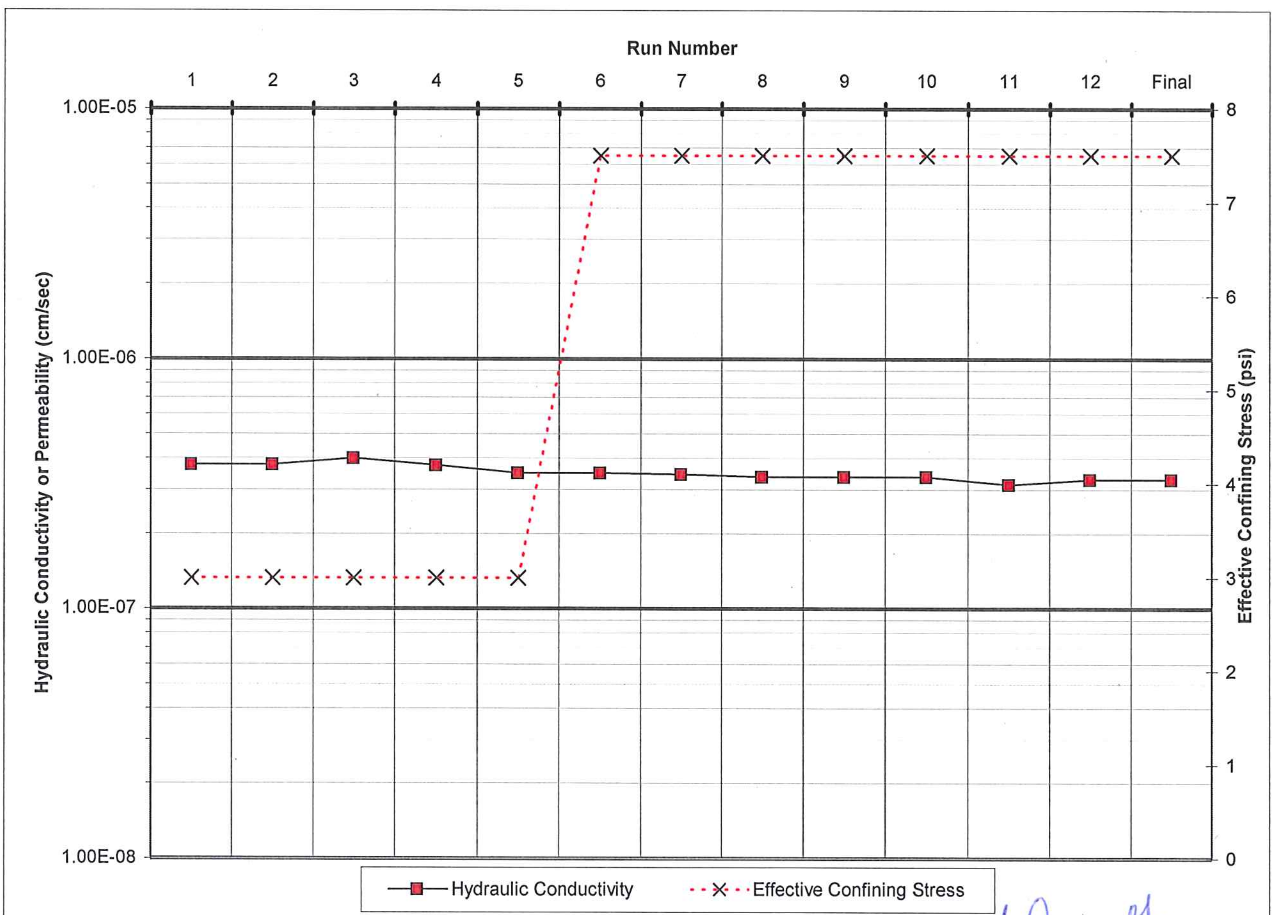

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FIGURE: 40

Hydraulic Conductivity (a.k.a. Permeability) Test Report

Method ASTM D 5084

HWA GEOSCIENCES INC.

Project	Terminal 91
Client	PES Environmental
Project number	2011-121
Date	4/20/2012
Technician	AC
Sample point	Soil 4
Sample number	0
Sample depth	0
Sample description	Site Soils + 30% Fines.

Assumed Specific Gravity	2.65		
Initial Sample Area (cm2)	40.60	Final Sample Area (cm2)	37.37
Initial Sample Length (cm)	8.49	Final Sample Length (cm)	7.49
Initial Sample Volume (cc)	344.7	Final Sample Volume (cc)	280.0
Initial moisture (%)	22.9	Final moisture (%)	15.0
Initial wet unit wt. (pcf)	117.5	Final wet unit weight (pcf)	135.2
Initial dry unit wt. (pcf)	95.6	Final dry unit weight (pcf)	117.5
Initial void ratio	0.729	Final void ratio	0.407
Initial porosity	0.422	Final porosity	0.289
Initial saturation (%)	83.1	Final saturation (%)	97.9

Run No.	Hydraulic Conductivity (cm/s)	Running Average of 4 Readings (cm/s)	Maximum % Deviation from Average (should be less than 25%)	Flow Ratio (0.75 to 1.25 required)	Effective Confining Stress (psi)	Other Information
1	2.1E-07	n.a.		1.02	3	Maximum Gradient 104.3
2	2.3E-07	n.a.		0.95	3	
3	2.2E-07	n.a.		0.97	3	Minimum Gradient 11.3
4	2.3E-07	2.2E-07	5.6%	1.04	3	
5	2.5E-07	2.3E-07	7.3%	0.98	3	Max. Back Pressure (psi) 16.0
6	2.4E-07	2.3E-07	6.3%	0.96	3	
7	2.2E-07	2.3E-07	6.6%	0.98	3	Min. Back Pressure (psi) 16.0
8	2.1E-07	2.3E-07	8.3%	0.95	3	
9	3.0E-07	2.4E-07	23.4%	1.00	7.5	
10	3.4E-07	2.7E-07	26.8%	0.99	7.5	Sample consolidated so much that piping
11	3.3E-07	3.0E-07	28.0%	0.97	7.5	developed between sample and membrane. Test
12	3.0E-07	3.2E-07	7.1%	1.02	7.5	terminated.. Volume of permeant 407 cc.
13	5.9E-07	3.9E-07	50.8%	0.93	7.5	Initial PV=145.5 cc, Final PV= 80.9 cc
Final	8.4E-07	5.1E-07	62.4%	0.98	7.5	Elapsed Time=246.1 hours
						151 hours at high gradient

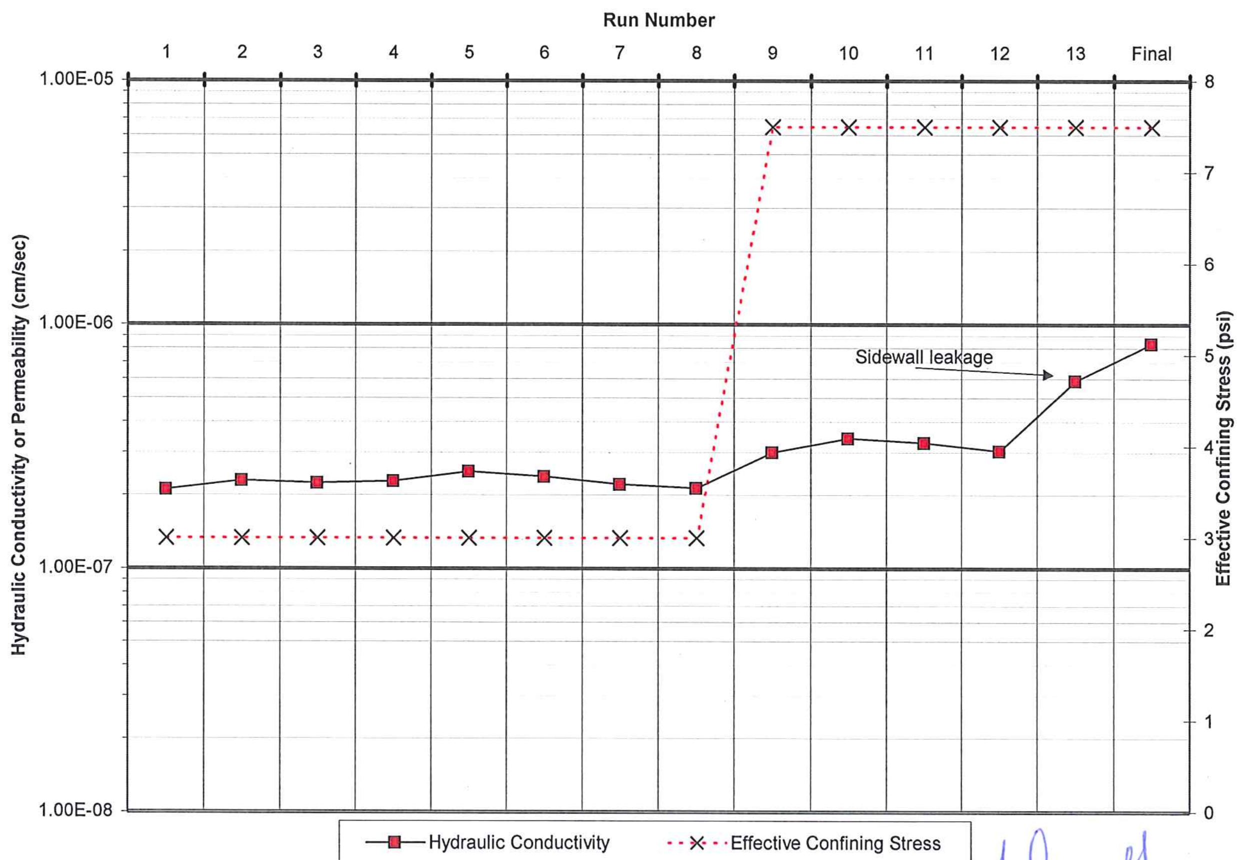

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FIGURE: 41

Hydraulic Conductivity (a.k.a. Permeability) Test Report

Method ASTM D 5084

HWA GEOSCIENCES INC.

Project	Terminal 91
Client	PES Environmental
Project number	2011-121
Date	4/20/2012
Technician	HB
Sample point	SB 4A
Sample number	0
Sample depth	0
Sample description	SB 30% fines, 4.5% bentonite

Assumed Specific Gravity	2.65		
Initial Sample Area (cm2)	42.00	Final Sample Area (cm2)	36.94
Initial Sample Length (cm)	8.51	Final Sample Length (cm)	7.87
Initial Sample Volume (cc)	357.6	Final Sample Volume (cc)	290.9
Initial moisture (%)	30.7	Final moisture (%)	19.8
Initial wet unit wt. (pcf)	117.5	Final wet unit weight (pcf)	131.7
Initial dry unit wt. (pcf)	90.0	Final dry unit weight (pcf)	109.9
Initial void ratio	0.838	Final void ratio	0.504
Initial porosity	0.456	Final porosity	0.335
Initial saturation (%)	96.9	Final saturation (%)	103.9

Run No.	Hydraulic Conductivity (cm/s)	Running Average of 4 Readings (cm/s)	Maximum % Deviation from Average (should be less than 25%)	Flow Ratio (0.75 to 1.25 required)	Effective Confining Stress (psi)
1	4.9E-08	n.a.		0.67	3
2	6.0E-08	n.a.		0.80	3
3	6.2E-08	n.a.		0.67	3
4	5.2E-08	5.6E-08	12.7%	0.86	7.5
5	4.4E-08	5.5E-08	18.9%	1.08	7.5
6	4.2E-08	5.0E-08	23.5%	1.06	7.5
7	3.9E-08	4.4E-08	17.4%	0.95	7.5
8	4.1E-08	4.2E-08	6.4%	1.00	7.5
9	3.8E-08	4.0E-08	4.8%	1.00	7.5
Final	5.5E-08	4.3E-08	26.2%	1.00	7.5

Other Information
Maximum Gradient 99.0
Minimum Gradient 18.4
Max. Back Pressure (psi) 16.0
Min. Back Pressure (psi) 16.0

Permeant Vol.= 499.8 cc
Initial PV= 163.1 cc, Final Pv= 97.5 cc
1030 hours total Elapsed Time
967 hours at high Gradient

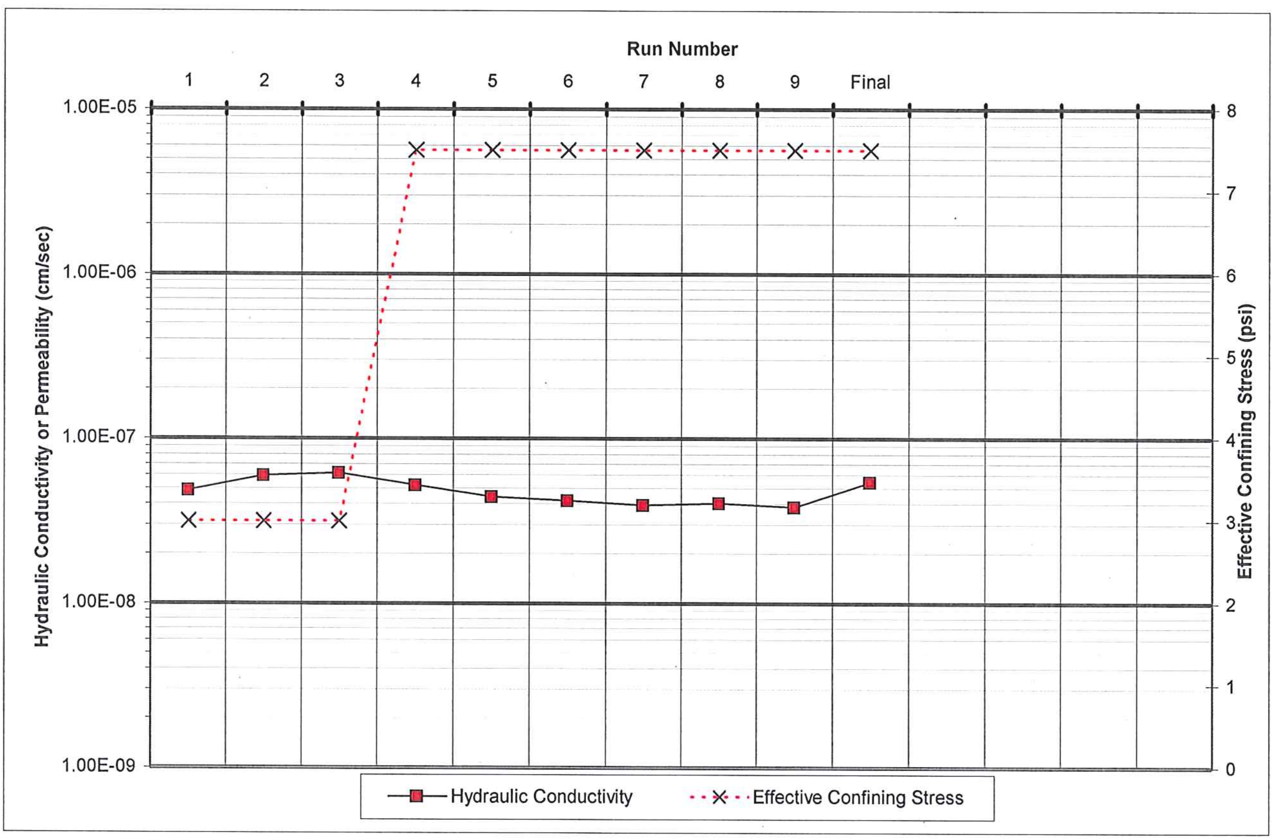

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FIGURE: 42

Hydraulic Conductivity (a.k.a. Permeability) Test Report

Method ASTM D 5084

HWA GEOSCIENCES INC.

Project	Terminal 91
Client	PES Environmental
Project number	2011-121
Date	4/20/2012
Technician	HB
Sample point	SC 4
Sample number	0
Sample depth	0
Sample description	SB 30% fines, 0% bentonite, 4.5% Cement

Assumed Specific Gravity	2.65		
Initial Sample Area (cm2)	46.05	Final Sample Area (cm2)	46.05
Initial Sample Length (cm)	15.24	Final Sample Length (cm)	15.24
Initial Sample Volume (cc)	701.9	Final Sample Volume (cc)	701.9
Initial moisture (%)	25.0	Final moisture (%)	27.5
Initial wet unit wt. (pcf)	119.0	Final wet unit weight (pcf)	120.9
Initial dry unit wt. (pcf)	95.2	Final dry unit weight (pcf)	94.8
Initial void ratio	0.737	Final void ratio	0.744
Initial porosity	0.424	Final porosity	0.427
Initial saturation (%)	89.8	Final saturation (%)	98.0

Run No.	Hydraulic Conductivity (cm/s)	Running Average of 4 Readings (cm/s)	Maximum % Deviation from Average (should be less than 25%)	Flow Ratio (0.75 to 1.25 required)	Effective Confining Stress (psi)
1	1.3E-07	n.a.		1.14	3
2	1.8E-07	n.a.		0.91	3
3	1.6E-07	n.a.		0.80	3
4	2.1E-07	1.7E-07	21.0%	1.00	3
5	2.0E-07	1.9E-07	14.2%	1.00	3
6	2.0E-07	1.9E-07	16.9%	0.96	12.75
7	2.0E-07	2.0E-07	2.1%	0.87	12.75
8	2.0E-07	2.0E-07	2.6%	0.92	12.75
9	1.9E-07	2.0E-07	3.4%	1.04	12.75
10	2.0E-07	2.0E-07	3.1%	0.85	12.75
11	2.0E-07	2.0E-07	3.4%	1.00	12.75
12	1.9E-07	2.0E-07	4.2%	0.90	12.75
13	1.9E-07	1.9E-07	5.0%	1.00	12.75
14	1.9E-07	1.9E-07	2.7%	0.95	12.75
15	1.9E-07	1.9E-07	2.4%	0.94	12.75
16	1.8E-07	1.9E-07	3.5%	1.04	12.75
17	1.8E-07	1.9E-07	3.3%	1.06	12.75
18	1.8E-07	1.8E-07	5.1%	1.07	12.75
19	1.8E-07	1.8E-07	1.0%	1.07	12.75
20	1.8E-07	1.8E-07	0.9%	0.94	12.75
Final	1.8E-07	1.8E-07	0.8%	0.94	12.75

Other Information
Maximum Gradient 100.5
Minimum Gradient 10.3
Max. Back Pressure (psi) 16.0
Min. Back Pressure (psi) 16.0

Permeant Vol. = 1042 cc
Initial PV= 297.6 cc, Final PV=299.7 cc
Total Elapsed Time 481 hours
360 hours at High Gradient

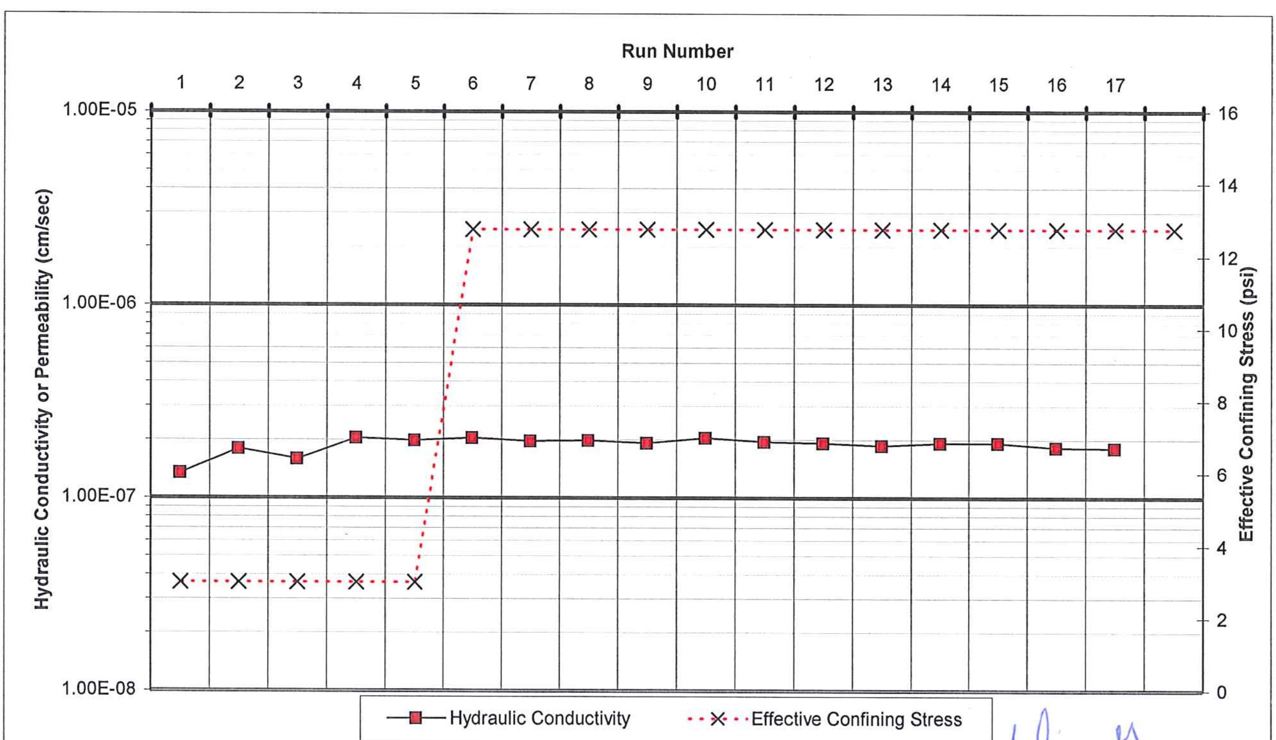

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FIGURE: 43

Hydraulic Conductivity (a.k.a. Permeability) Test Report

Method ASTM D 5084

HWA GEOSCIENCES INC.

Project	Terminal 91
Client	PES Environmental
Project number	2011-121
Date	4/20/2012
Technician	HB
Sample point	SCB 4A-4.5
Sample number	0
Sample depth	0
Sample description	SB 30% fines, 4.5% Bentonite, 4.5% Cement

Assumed Specific Gravity	2.65		
Initial Sample Area (cm2)	45.49	Final Sample Area (cm2)	45.83
Initial Sample Length (cm)	13.05	Final Sample Length (cm)	13.04
Initial Sample Volume (cc)	593.8	Final Sample Volume (cc)	597.6
Initial moisture (%)	30.0	Final moisture (%)	39.6
Initial wet unit wt. (pcf)	109.3	Final wet unit weight (pcf)	112.8
Initial dry unit wt. (pcf)	84.0	Final dry unit weight (pcf)	80.8
Initial void ratio	0.968	Final void ratio	1.048
Initial porosity	0.492	Final porosity	0.512
Initial saturation (%)	82.2	Final saturation (%)	100.3

Run No.	Hydraulic Conductivity (cm/s)	Running Average of 4 Readings (cm/s)	Maximum % Deviation from Average (should be less than 25%)	Flow Ratio (0.75 to 1.25 required)	Effective Confining Stress (psi)	Other Information
1	6.8E-07	n.a.		1.02	3	Maximum Gradient 102.5
2	6.4E-07	n.a.		1.00	3	
3	6.1E-07	n.a.		1.00	3	Minimum Gradient 9.3
4	6.0E-07	6.3E-07	7.6%	0.92	3	
5	5.6E-07	6.0E-07	7.5%	1.00	3	Max. Back Pressure (psi) 16.0
6	5.5E-07	5.8E-07	5.8%	1.00	11.5	
7	4.4E-07	5.4E-07	17.7%	1.01	11.5	Min. Back Pressure (psi) 16.0
8	4.5E-07	5.0E-07	11.8%	0.99	11.5	
9	3.6E-07	4.5E-07	22.6%	0.96	11.5	
10	1.8E-07	3.6E-07	49.0%	0.98	11.5	Total Vol. of Permeant 757 cc
11	2.1E-07	3.0E-07	50.0%	1.07	11.5	Initial PV=292.1 cc, Final PV= 305.9
12	2.0E-07	2.4E-07	51.2%	0.97	11.5	Total Elapsed Time= 266 hours
Final	2.0E-07	**2.0E-07**	7.7%	1.00	11.5	Time at High Gradient= 124 hours

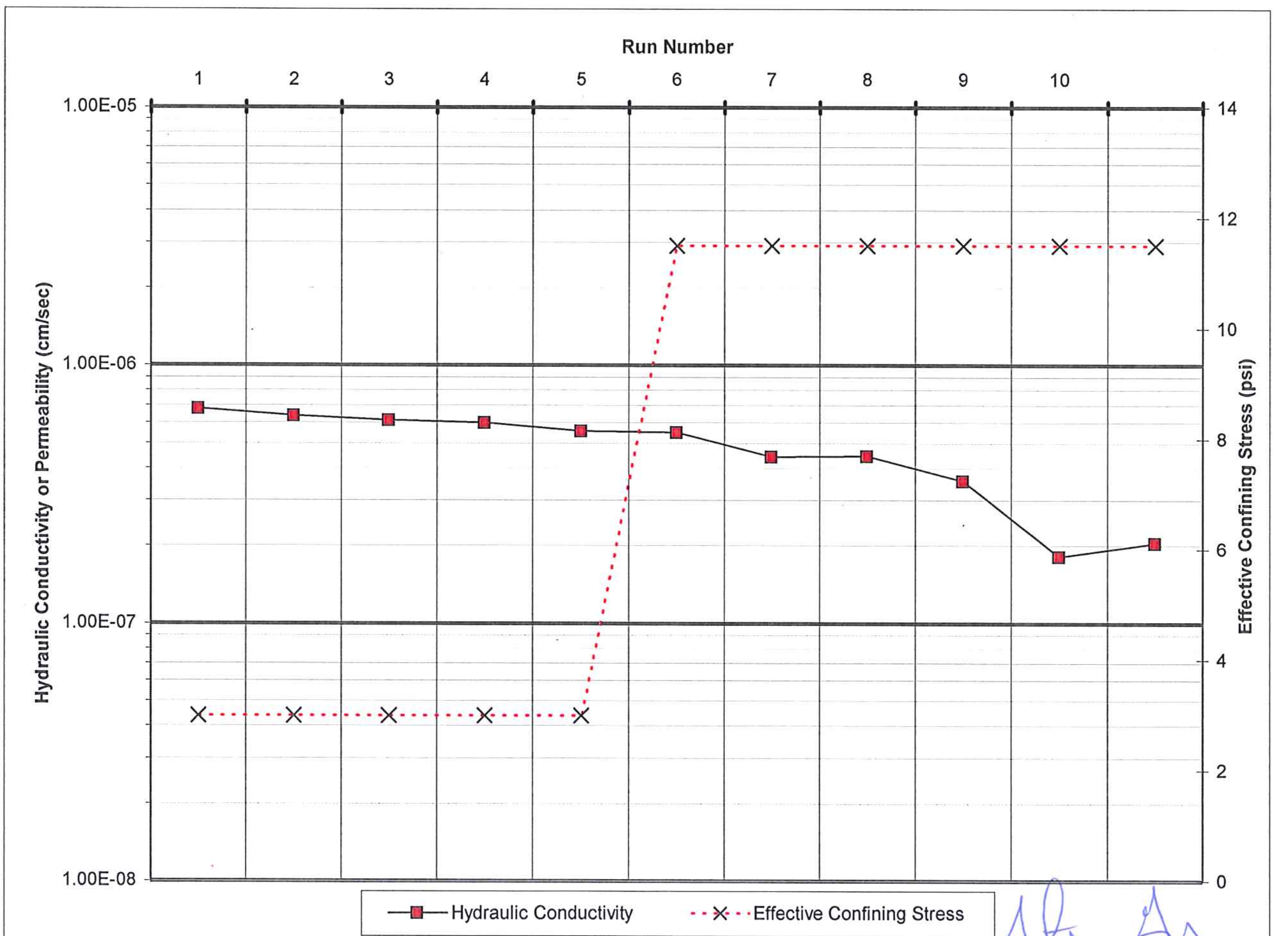

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FIGURE: 44

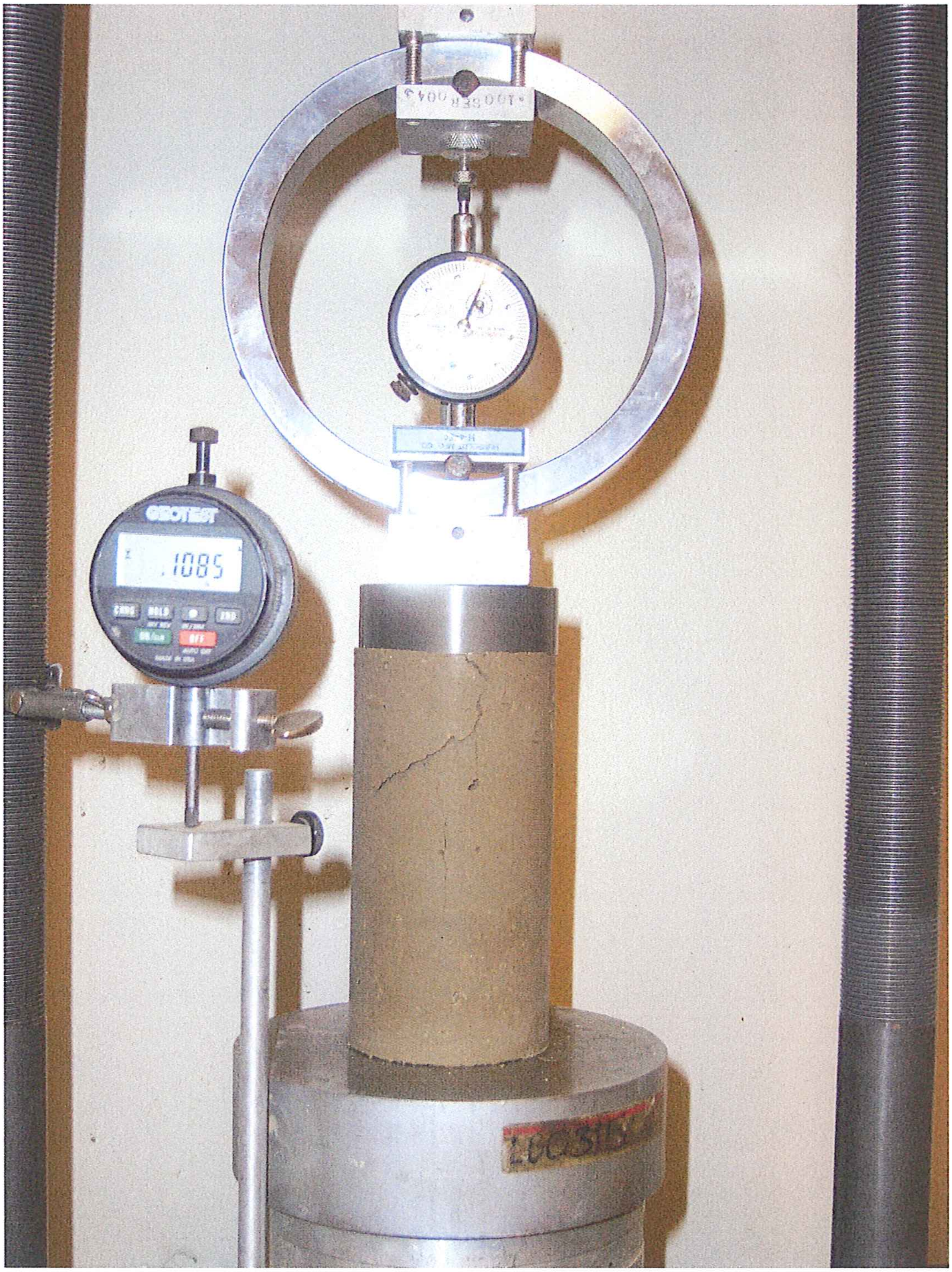

Photo 1. Unconfined compressive strength testing of SCB.

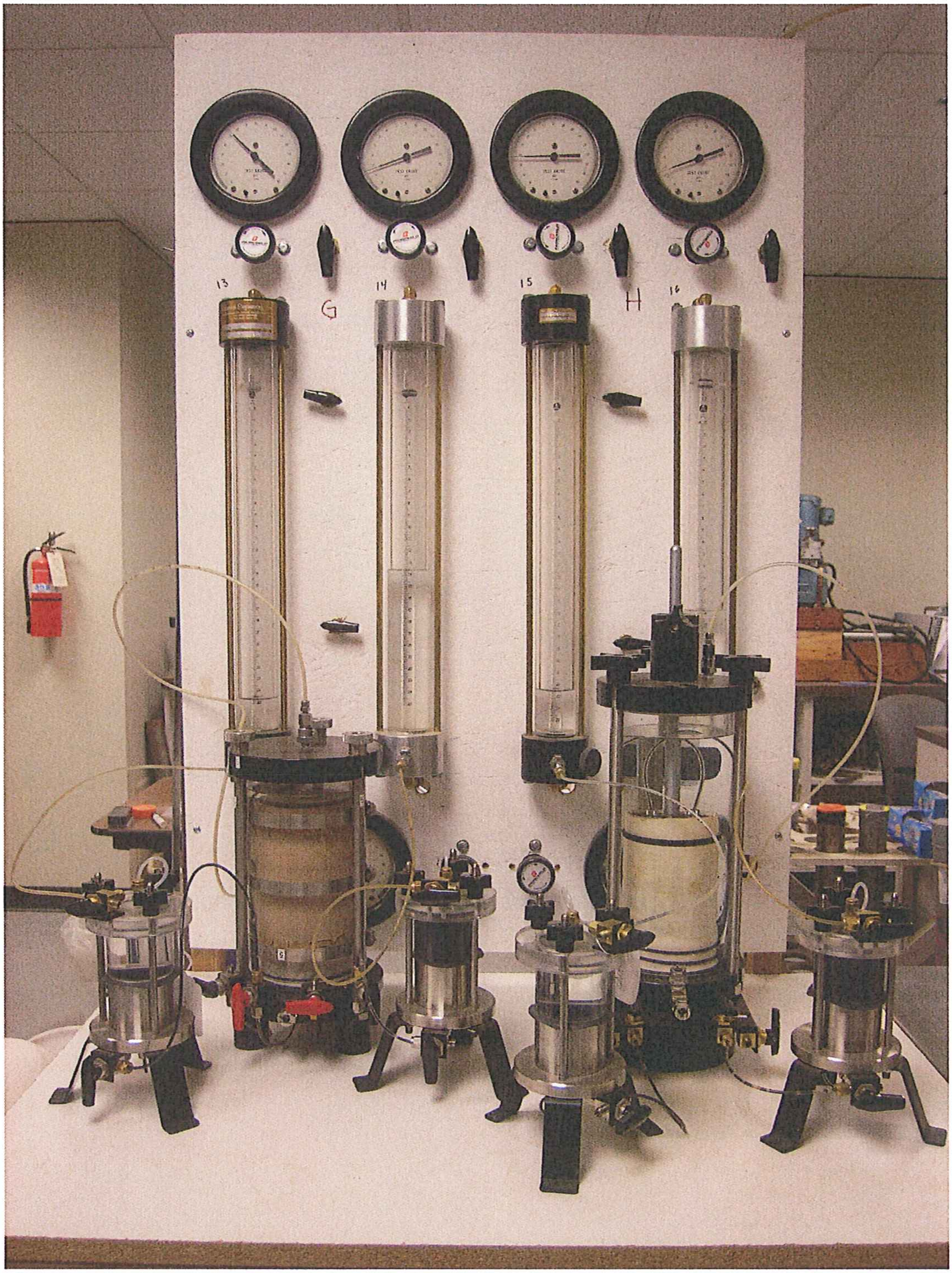

Photo 2. Permeability testing using bladder-accumulators for LNAPL permeant.

APPENDIX D

MATERIALS LABORATORY REPORT
BENTONITE SLURRY COMPATIBILITY EVALUATION
TERMINAL 91 TANK FARM AFFECTED AREA CLEANUP PROJECT
SEATTLE, WASHINGTON
JANUARY 2012

HWA GEOSCIENCES INC.
Geotechnical & Pavement Engineering • Hydrogeology • Geoenvironmental • Planning & Permitting • Inspection & Testing

January 4, 2012
HWA Project No. 2011-121-23

PES Environmental, Inc.
1215 Fourth Avenue, Suite 1350
Seattle, Washington 98161

Attention: Mr. Brian O'Neal, PE

Subject: **MATERIALS LABORATORY REPORT**
BENTONITE SLURRY COMPATIBILITY EVALUATION
Terminal 91 Tank Farm Affected Area Cleanup Project
Seattle, Washington

Dear Mr. O'Neal:

As requested, HWA GeoSciences Inc. (HWA) performed laboratory testing for the subject project task. Herein we present the results of our laboratory analyses, which are summarized on the attached Figures. The laboratory testing program was performed in general accordance with your instructions and appropriate ASTM Standards as outlined below.

TESTING PROGRAM: This compatibility testing program was conducted to initially assess the potential for incompatibility between proposed bentonite materials and:

LNAPL;

Site groundwater; and

City water.

At least two sources of commercially-available bentonite will be identified. A sample of each of the identified bentonite products was mixed separately with the City water to provide three hydrated slurry mixes with 10 percent bentonite content. To simulate representative and potential worst case site conditions where the site groundwater and/or free-product are introduced to the SB slurry after the initial hydration of the bentonite has taken place, each of the three 10 percent bentonite slurries will be diluted to an equivalent 5 percent bentonite content by adding either: additional City water; LNAPL; or site groundwater. In addition, to simulate a potential worst case incompatibility condition, a selected sample of each bentonite product will be initially hydrated with the Site groundwater and prepared at 5 percent bentonite content.

Following this protocol, a minimum of eight slurry specimens were prepared (i.e., 2 initial slurries with 3 diluting liquids, plus 2 site groundwater and bentonite slurries). The diluted mixtures were allowed to age for approximately seven days,

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to allow for potential incompatibility effects to be realized, prior to testing using the following methods:

- Bentonite slurry unit weight (API recommended practice 13B-1);
- Atterberg limits (ASTM D4318);
- Viscosity test (API Recommended Practice 13B-1);
- Bentonite filtrate loss (ASTM D 5891);
- pH test (API recommended practice 13B-1); and
- Dispersive characteristics of clay soil by the double hydrometer (ASTM D4221).

MATERIALS UTILIZED: The following materials were provided to our laboratory for use in this testing program:

Bentonite. Two commercially-available bentonite products were provided to HWA directly from the manufacturers and used in this testing program namely; WYO-BEN Hydrogel and CETCO Sorbond UP.

City Water. Seattle City Water obtained from a hydrant near the T-91 site was provided by PES personnel to HWA for use in this testing program.

Site Groundwater. Site groundwater from on-site wells was provided by PES personnel to HWA for use in this testing program.

LNAPL. LNAPL product obtained from on-site wells was provided by PES personnel to HWA for use in this testing program.

SLURRY PREPARATION: Eight samples of Bentonite slurry were prepared for use in this evaluation. Samples were prepared in small 500 ml batches that were composited together to create 2 liters of slurry prior to final dilution to 4 liters. After preparation was completed the slurries were stored in relatively airtight containers and allowed to “age” for 7 days prior to testing as directed by the Client.

The samples prepared were designated as follows:

Slurry Mix-1 10% WYO-BEN Hydrogel mixed and diluted with City water
Slurry Mix-2 10% CETCO Sorbond UP mixed and diluted with City water.
Slurry Mix-3 10% WYO-BEN Hydrogel mixed with City water and diluted with groundwater
Slurry Mix-4 5% CETCO Sorbond UP mixed directly with groundwater
Slurry Mix-5 5% WYO-BEN Hydrogel mixed directly with groundwater
Slurry Mix-6 10% CETCO Sorbond UP mixed with City water and diluted with groundwater
Slurry Mix-7 10% WYO-BEN Hydrogel mixed with City water and diluted with LNAPL
Slurry Mix-8 10% CETCO Sorbond UP mixed with City water and diluted with LNAPL

MOISTURE CONTENT OF BENTONITE: The "as-received" moisture content of each bentonite material (percent by dry mass) was determined in general accordance with ASTM D 2216. The results are summarized in Table 1 below:

TABLE 1 AS-RECEIVED MOISTURE CONTENT OF BENTONITE MATERIALS

MANUFACTURER	PRODUCT	MOISTURE CONTENT
WYO-BEN	HYDROGEL	7.9%
CETCO	SORBOND UP	9.9%

pH OF SLURRY: The pH of each slurry sample was determined utilizing a Mettler Toledo meter equipped with a LE407 probe. The results are summarized in Figure 1.

MARSH VISCOSITY: The viscosity of each slurry sample was determined using a marsh funnel per API recommended practice 13B-1, Section 6.2. The results are summarized in Figure 1.

SLURRY DENSITY-BULK UNIT WEIGHT: The bulk unit weight of each slurry sample was determined using a mud balance per API recommended practice 13B-1, Section 4. The results are summarized in Figure 1.

FILTRATE LOSS: The volume of filtrate loss for each slurry sample was determined in general accordance with ASTM D 5891. The results are summarized in Figure 1.

DISPERSIVE CHARACTERISTICS OF CLAY BY DOUBLE HYDROMETER: The slurry samples were tested to determine the dispersive characteristics of the two Bentonite materials with respect to four different mixing solutions in general accordance with ASTM D4221. The individual percent dispersion values are summarized on Figure 1. The dispersion is calculated by dividing the percent passing 5-µm determined for the sample that was not agitated and to which no dispersing agent was added by the percent passing the 5-µm for the sample conducted per ASTM D 422. The Particle Size distributions representing the mechanically dispersed and non-agitated samples of each slurry sample are presented on the attached Particle Size Analysis reports shown on Figures 2 through 9.

LIQUID LIMIT, PLASTIC LIMIT, AND PLASTICITY INDEX OF SOILS (ATTERBERG LIMITS): The slurry samples were tested using method ASTM D4318, multi-point method. Testing was conducted on a partially oven dried sample of each slurry. Drying was conducted at temperatures less than 60 degrees centigrade as is required for high clay content materials. The results are summarized on Figure 1, and plotted on the attached Liquid Limit, Plastic Limit, and Plasticity Index report on Figures 10 and 11.

CLOSURE: Experience has shown that laboratory test values for soil and other natural materials vary with each representative sample. As such, HWA has no knowledge as to the extent and quantity of material the tested sample may represent. HWA also makes no warranty as to how representative either the sample tested or the test results obtained are to actual field conditions. It is a well established fact that sampling methods present varying degrees of disturbance or variance that affect sample representativeness.

No copy should be made of this report except in its entirety.

We appreciate the opportunity to provide laboratory testing services on this project. Should you have any questions or comments, or if we may be of further service, please call.

Sincerely,

HWA GEOSCIENCES INC.

Steven E. Greene, L.G., L.E.G.
Senior Engineering Geologist
Vice-President

Ashley Crane
Laboratory Supervisor

SEG:ac;seg

Attachments:

Figure 1	Material Summary
Figures 2 – 9	Particle-Size Analysis of Soils (per ASTM D 422 and D4221)
Figures 10 & 11	Liquid Limit, Plastic Limit, and Plasticity Index of Soils

SAMPLE IDENTIFICATION	ATTERBERG LIMITS (%)			MUD BALANCE		% DISPERSION	MARSH FUNNEL (sec)	FILTRATE LOSS	PH	ASTM SOIL CLASSIFICATION	SAMPLE DESCRIPTION
	LL	PL	PI	BULK SPECIFIC GRAVITY	WET DENSITY (PCF)						
Slurry Mix-1,	484	28	456	1.025	64.0	81	60	14.8	8.9	CH	WyoBen and City Water
Slurry Mix-2,	500	28	472	1.025	64.0	100	46	13.6	9.0	CH	Sorbond and City Water
Slurry Mix-3,	528	26	502	1.030	64.2	85	67	13.6	8.5	CH	WyoBen, City Water and Groundwater
Slurry Mix-4,	504	27	477	1.030	64.2	92	42	14.4	8.4	CH	Sorbond and Groundwater
Slurry Mix-5,	576	31	545	1.029	64.1	92	79	15.6	8.3	CH	WyoBen and Groundwater
Slurry Mix-6,	513	30	483	1.028	64.0	95	43	12.8	8.3	CH	Sorbond, City Water and Groundwater
Slurry Mix-7,	532	25	507	1.029	64.1	97	66	13.2	8.0	CH	WyoBen, City Water and LNAPL
Slurry Mix-8,	532	24	508	1.025	64.0	93	45	12.8	8.1	CH	Sorbond, City Water and LNAPL

Notes: 1. This table summarizes information presented elsewhere in the report and should be used in conjunction with the report text, other graphs and tables.

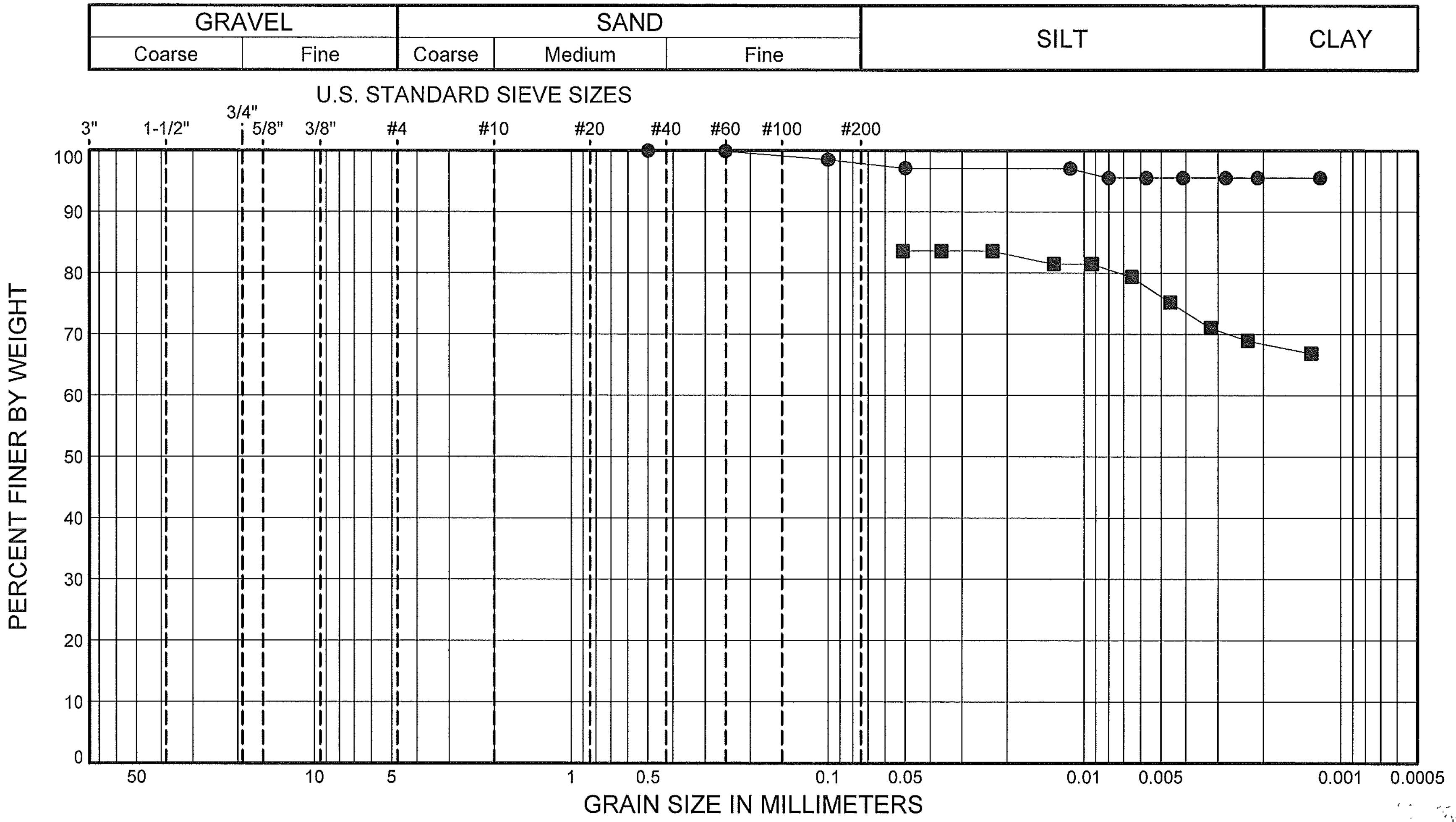
HWA GEOSCIENCES INC.

Terminal 91 Tank Farm Affected Area Cleanup Project
Lab testing for PES Environmental, Inc.

SUMMARY OF MATERIAL PROPERTIES

PAGE: 1 of 1

PROJECT NO.: 2011-121 FIGURE: 1



SYMBOL	SAMPLE	DEPTH (ft)	CLASSIFICATION OF SOIL- ASTM D2487 Group Symbol and Name	% MC	LL	PL	PI	Gravel %	Sand %	Fines %
●	Slurry Mix-1		(CH) WyoBen and City Water		484	28	456	0.0	2.0	98.0
■	Slurry Mix-1 B		(CH) WyoBen and City Water (Not Dispersed)							

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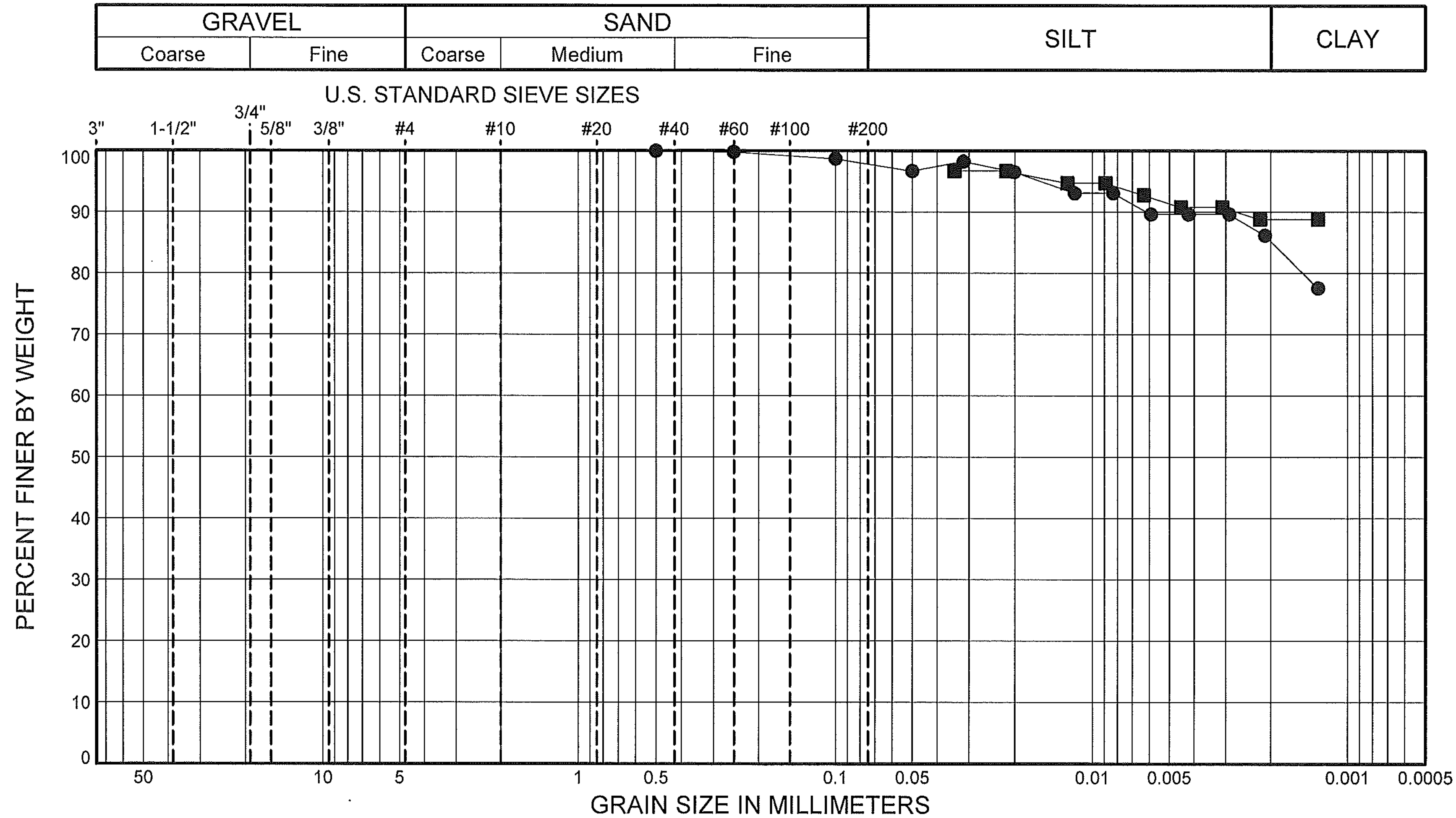
Terminal 91 Tank Farm Affected Area Cleanup Project
Lab testing for PES Environmental, Inc.

PARTICLE-SIZE ANALYSIS OF SOILS
METHOD ASTM D422

PROJECT NO.: 2011-121 FIGURE: 2



SYMBOL	SAMPLE	DEPTH (ft)	CLASSIFICATION OF SOIL- ASTM D2487 Group Symbol and Name	% MC	LL	PL	PI	Gravel %	Sand %	Fines %
●	Slurry Mix-2		(CH) Sorbond and City Water		500	28	472	0.0	2.1	97.9
■	Slurry Mix-2 B		(CH) Sorbond and City Water (Not Dispersed)							

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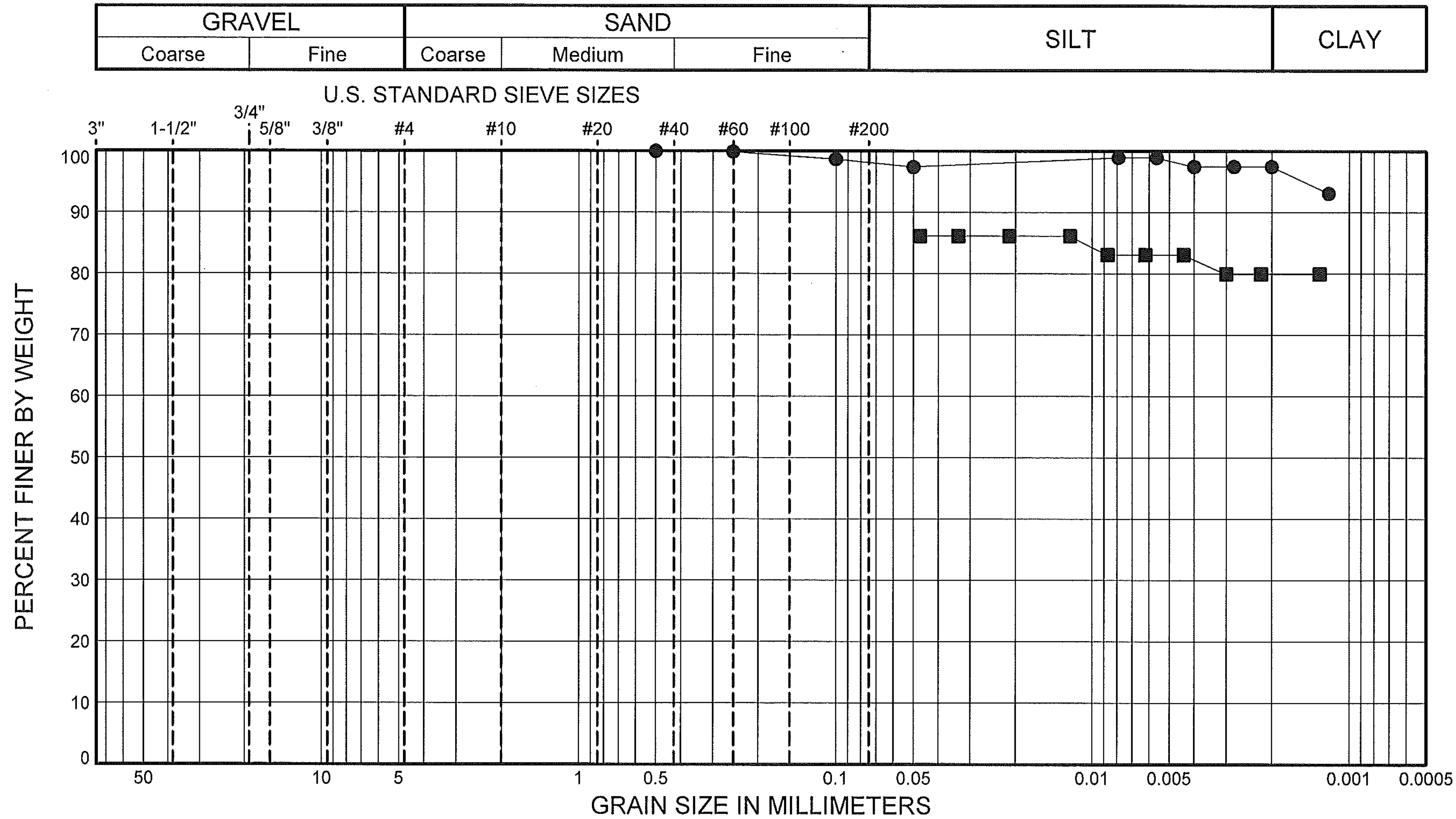
Terminal 91 Tank Farm Affected Area Cleanup Project
Lab testing for PES Environmental, Inc.

PARTICLE-SIZE ANALYSIS OF SOILS METHOD ASTM D422

PROJECT NO.: 2011-121 FIGURE: 3



SYMBOL	SAMPLE	DEPTH (ft)	CLASSIFICATION OF SOIL- ASTM D2487 Group Symbol and Name	% MC	LL	PL	PI	Gravel %	Sand %	Fines %
●	Slurry Mix-3		(CH) WyoBen, City Water and Groundwater		528	26	502	0.0	1.8	98.2
■	Slurry Mix-3 B		(CH) WyoBen, City Water and Groundwater (Not Dispersed)							

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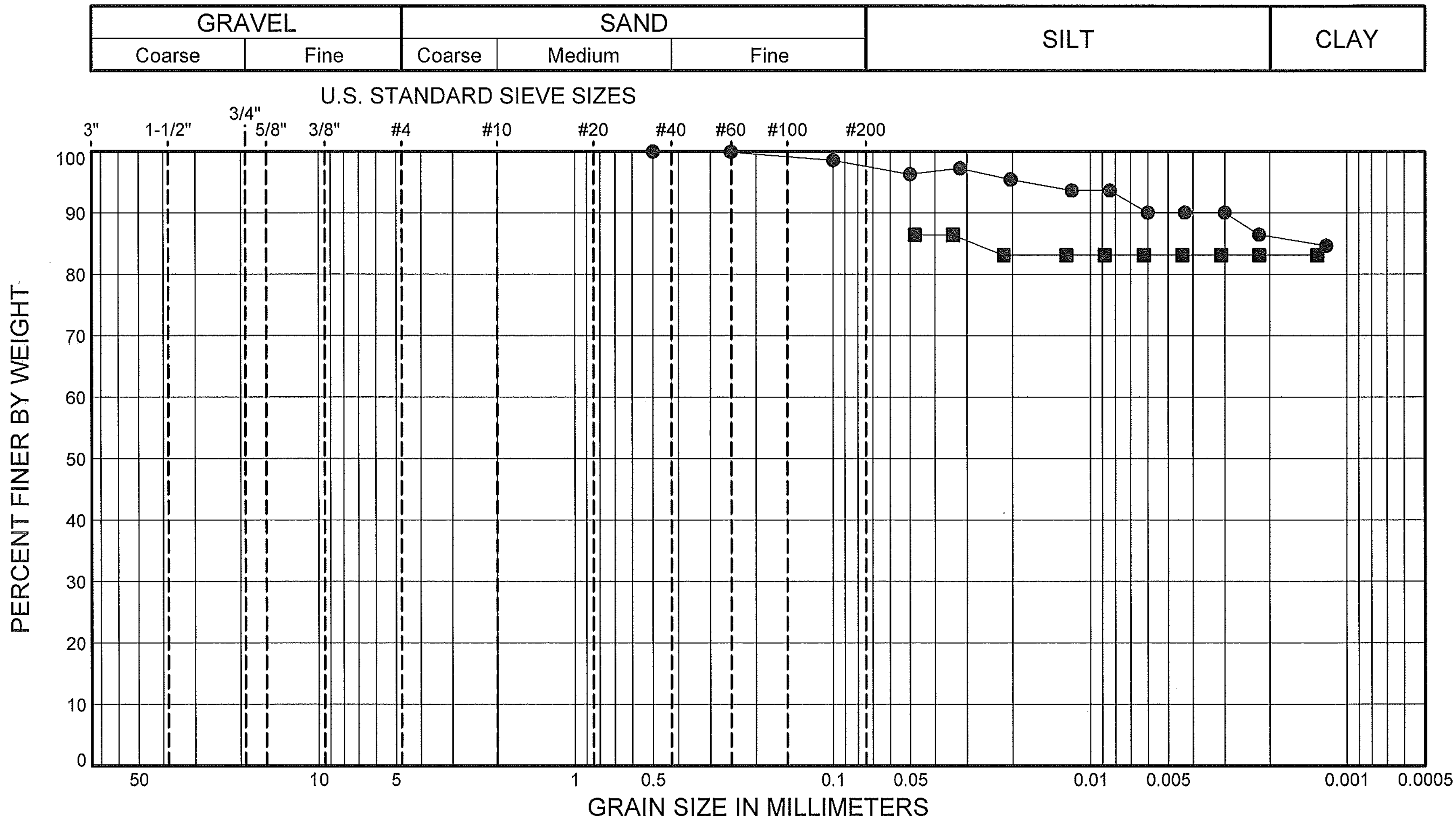
Terminal 91 Tank Farm Affected Area Cleanup Project
Lab testing for PES Environmental, Inc.

PARTICLE-SIZE ANALYSIS
OF SOILS
METHOD ASTM D422

PROJECT NO.: 2011-121 FIGURE: 4



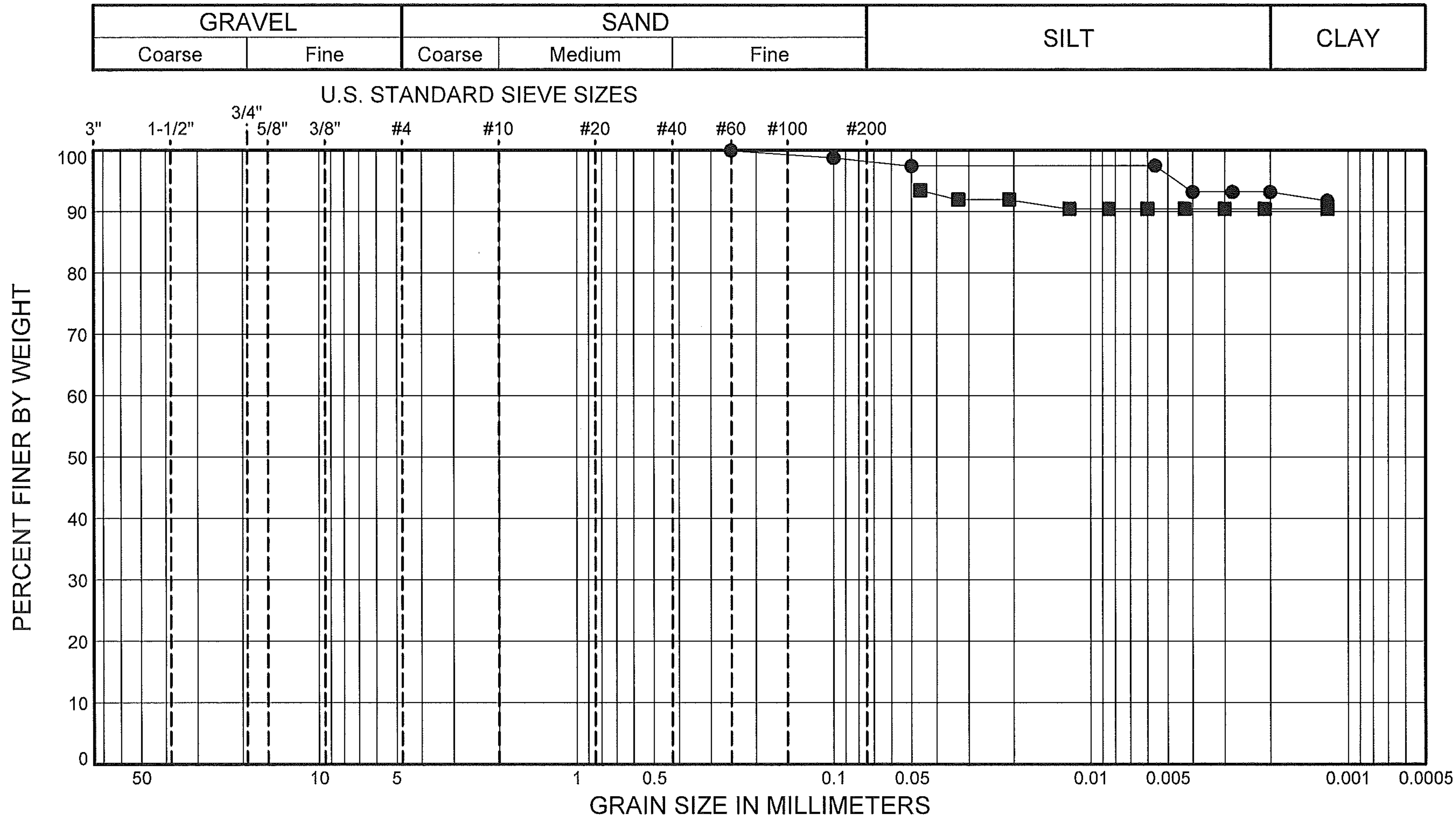
SYMBOL	SAMPLE	DEPTH (ft)	CLASSIFICATION OF SOIL- ASTM D2487 Group Symbol and Name	% MC	LL	PL	PI	Gravel %	Sand %	Fines %
●	Slurry Mix-4		(CH) Sorbond and Groundwater		504	27	477	0.0	2.3	97.7
■	Slurry Mix-4 B		(CH) Sorbond and Groundwater (Not Dispersed)							

HWA GEOSCIENCES INC.

Terminal 91 Tank Farm Affected Area Cleanup Project
Lab testing for PES Environmental, Inc.

PARTICLE-SIZE ANALYSIS OF SOILS METHOD ASTM D422

PROJECT NO.: 2011-121 FIGURE: 5



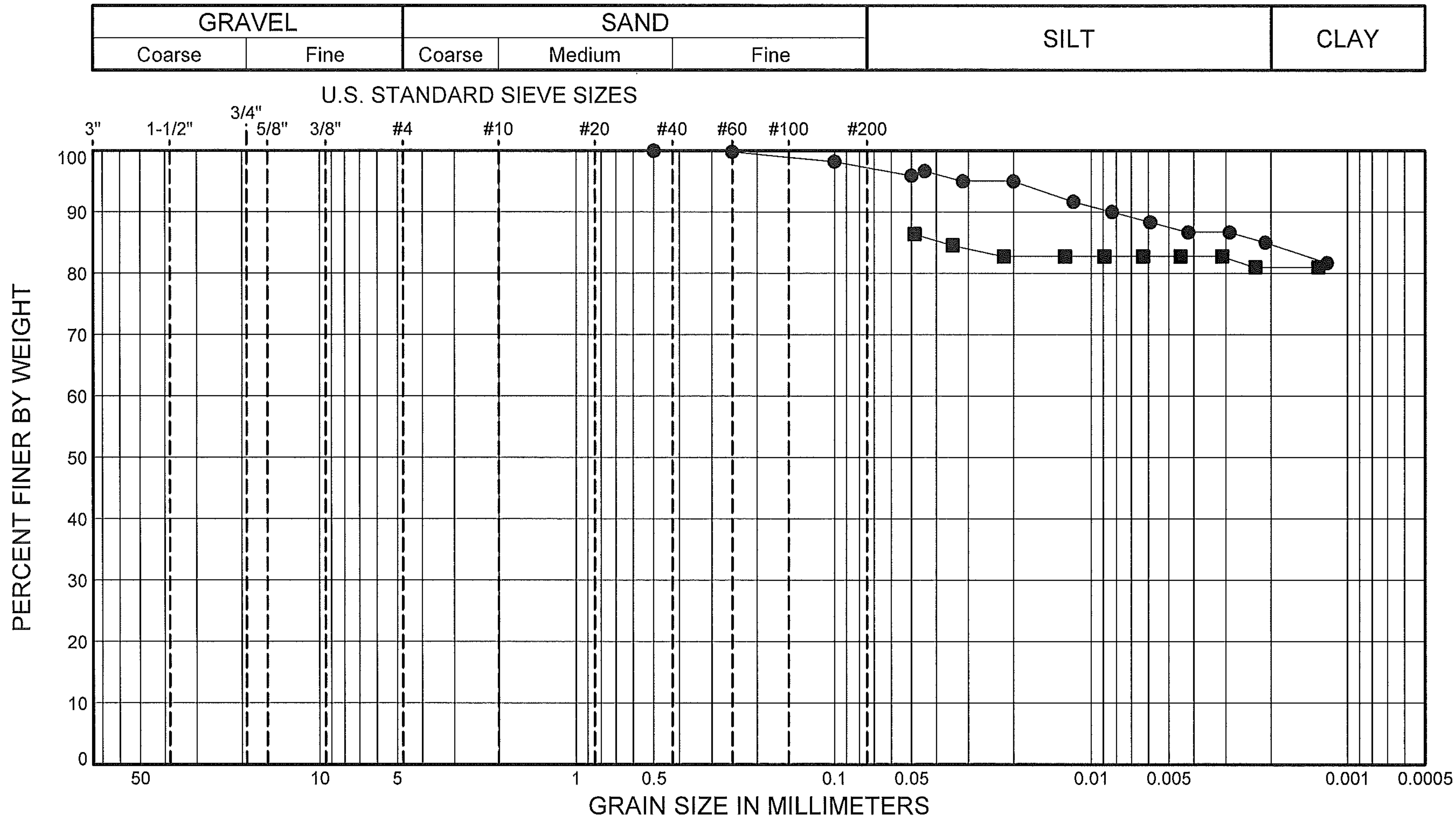
SYMBOL	SAMPLE	DEPTH (ft)	CLASSIFICATION OF SOIL- ASTM D2487 Group Symbol and Name	% MC	LL	PL	PI	Gravel %	Sand %	Fines %
●	Slurry Mix-5		(CH) WyoBen and Groundwater		576	31	545	0.0	1.8	98.2
■	Slurry Mix-5 B		(CH) WyoBen and Groundwater (Not Dispersed)							

HWA GEOSCIENCES INC.

Terminal 91 Tank Farm Affected Area Cleanup Project
Lab testing for PES Environmental, Inc.

PARTICLE-SIZE ANALYSIS OF SOILS METHOD ASTM D422

PROJECT NO.: 2011-121 FIGURE: 6



SYMBOL	SAMPLE	DEPTH (ft)	CLASSIFICATION OF SOIL- ASTM D2487 Group Symbol and Name	% MC	LL	PL	PI	Gravel %	Sand %	Fines %
●	Slurry Mix-6		(CH) Sorbond, City Water and Groundwater		513	30	483	0.0	2.7	97.3
■	Slurry Mix-6 B		(CH) Sorbond, City Water and Groundwater (Not Dispersed)							

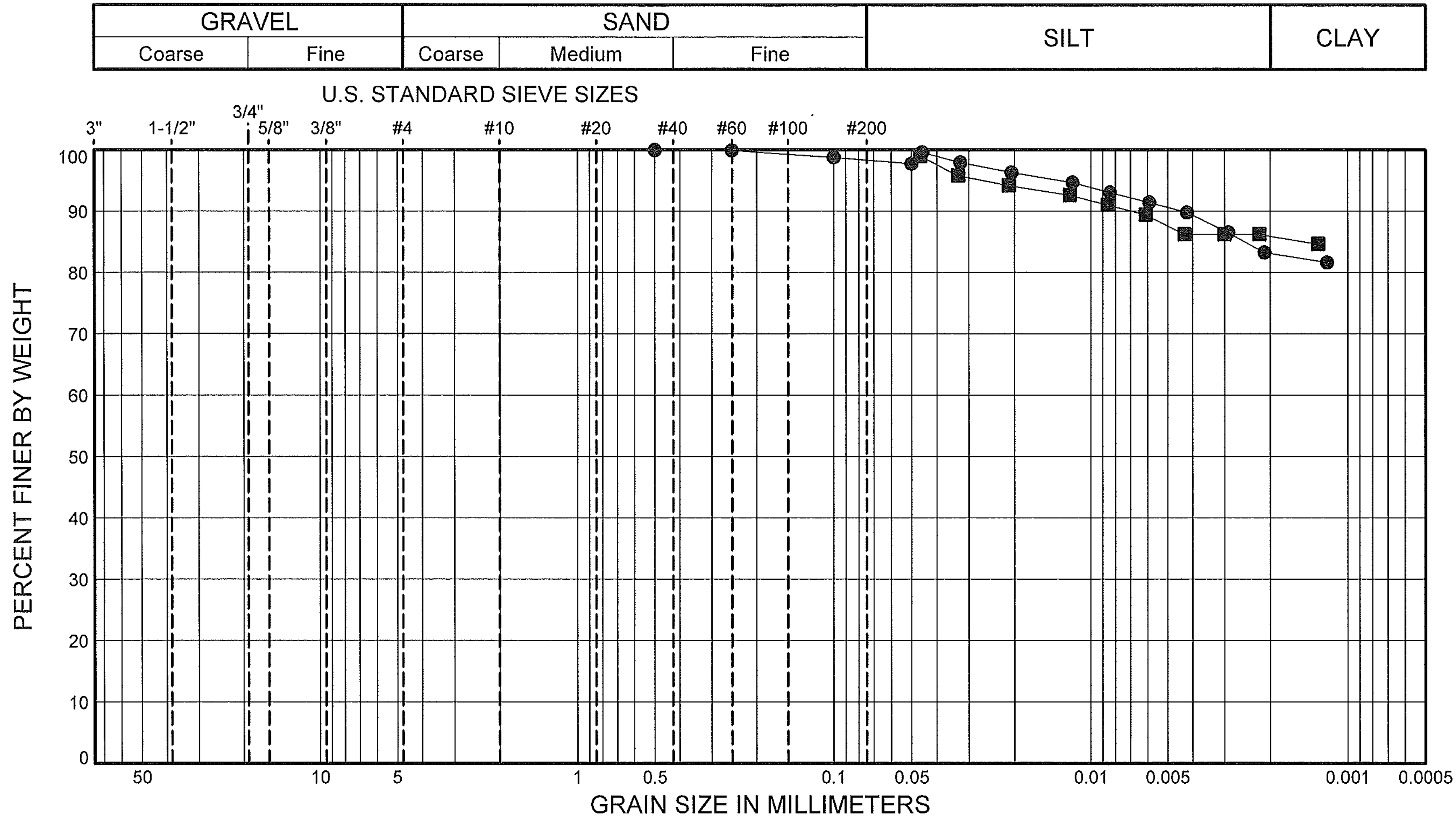
HWA GEOSCIENCES INC.

Terminal 91 Tank Farm Affected Area Cleanup Project
Lab testing for PES Environmental, Inc.

PARTICLE-SIZE ANALYSIS OF SOILS
METHOD ASTM D422

PROJECT NO.: 2011-121 FIGURE: 7

SPECIAL GS 2011-121.GPJ 12/30/11



SYMBOL	SAMPLE	DEPTH (ft)	CLASSIFICATION OF SOIL- ASTM D2487 Group Symbol and Name	% MC	LL	PL	PI	Gravel %	Sand %	Fines %
●	Slurry Mix-7		(CH) WyoBen, City Water and LNAPL		532	25	507	0.0	1.6	98.4
■	Slurry Mix-7 B		(CH) WyoBen, City Water and LNAPL (Not Dispersed)							

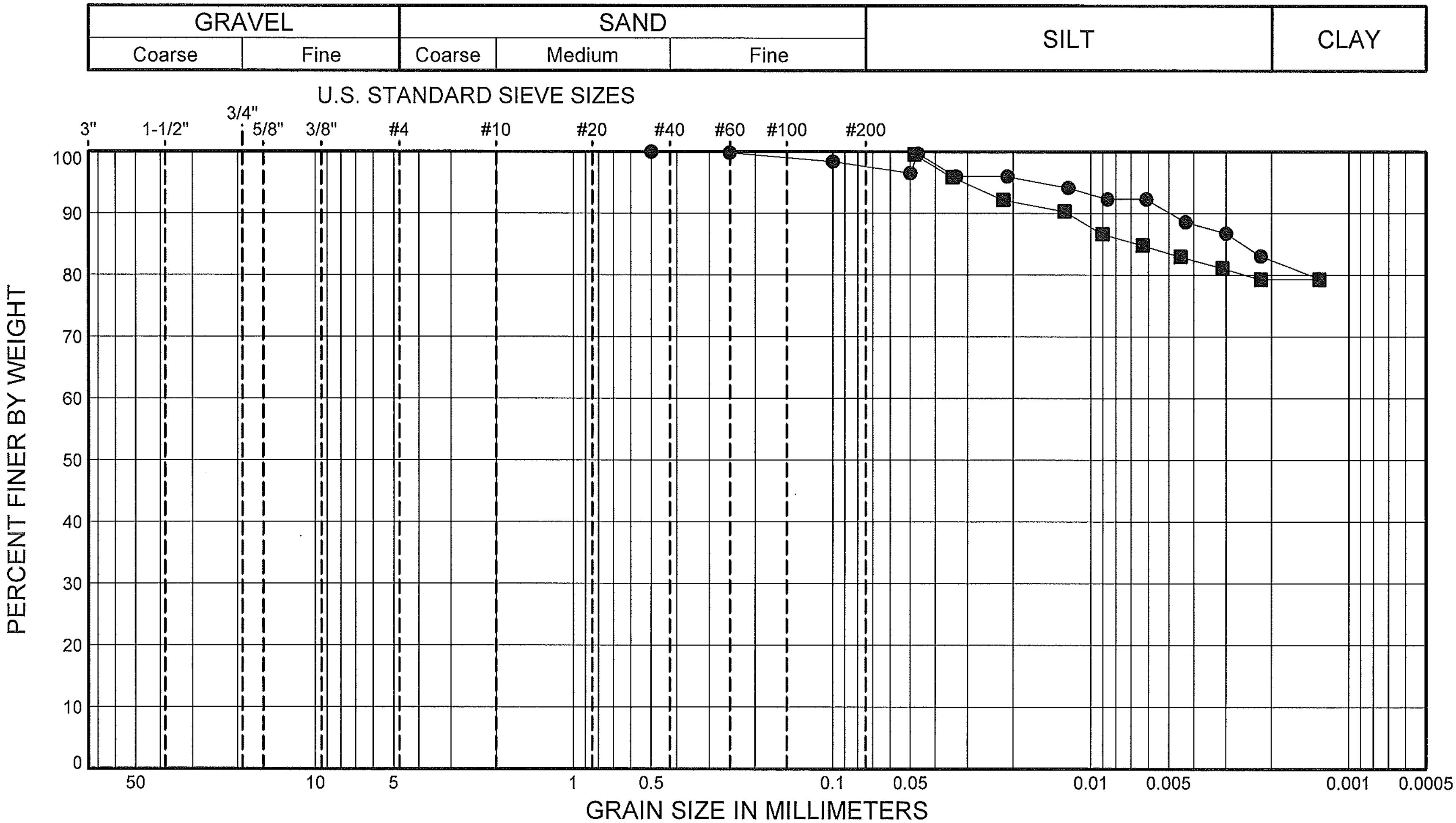
HWA GEOSCIENCES INC.

Terminal 91 Tank Farm Affected Area Cleanup Project
Lab testing for PES Environmental, Inc.

PARTICLE-SIZE ANALYSIS
OF SOILS
METHOD ASTM D422

PROJECT NO.: 2011-121 FIGURE: 8

SPECIAL GS 2011-121.GPJ 12/30/11



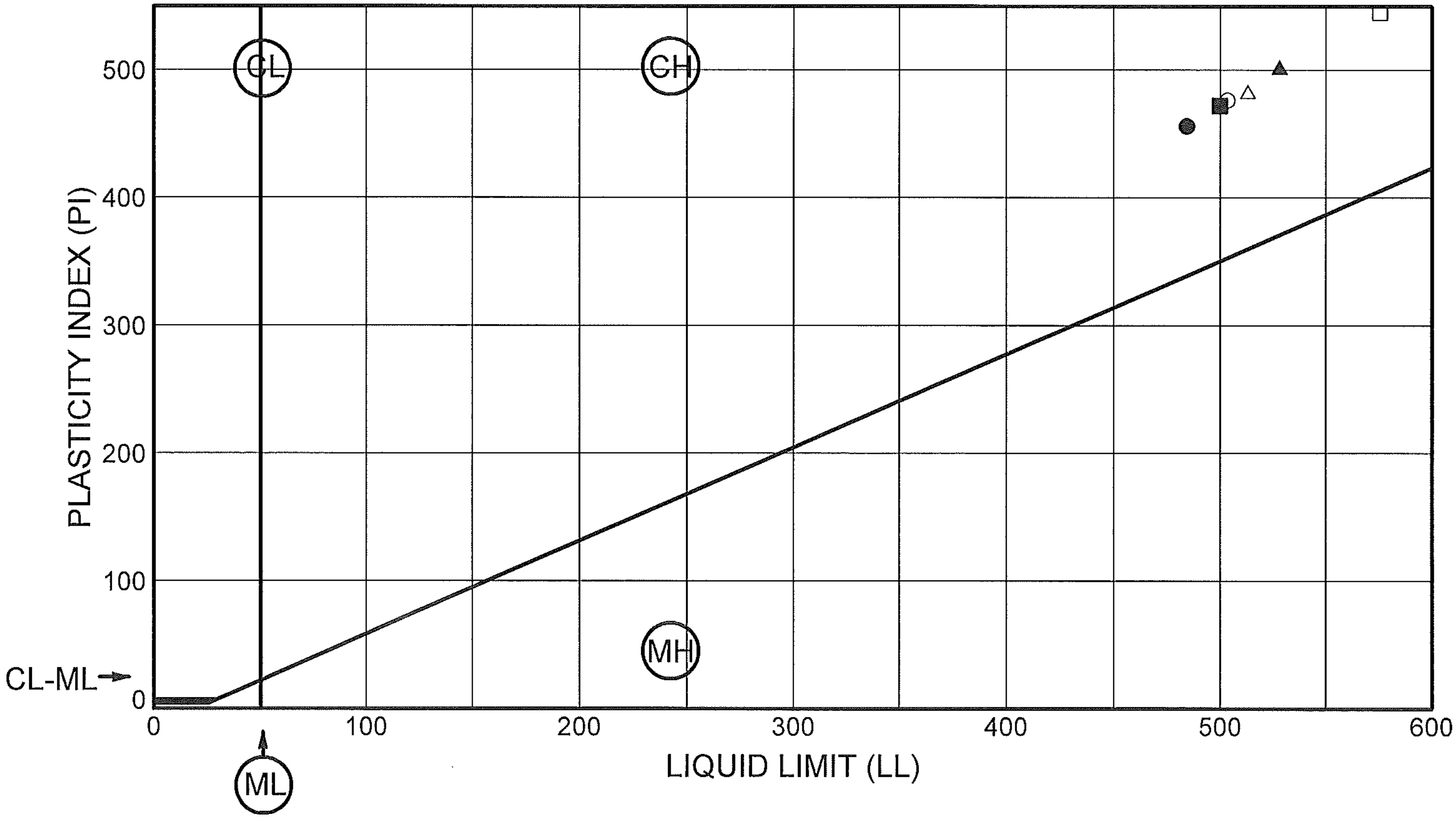
SYMBOL	SAMPLE	DEPTH (ft)	CLASSIFICATION OF SOIL- ASTM D2487 Group Symbol and Name	% MC	LL	PL	PI	Gravel %	Sand %	Fines %
●	Slurry Mix-8		(CH) Sorbond, City Water and LNAPL		532	24	508	0.0	2.4	97.6
■	Slurry Mix-8 B		(CH) Sorbond, City Water and LNAPL (Not Dispersed)							

HWA GEOSCIENCES INC.

Terminal 91 Tank Farm Affected Area Cleanup Project
Lab testing for PES Environmental, Inc.

PARTICLE-SIZE ANALYSIS OF SOILS METHOD ASTM D422

PROJECT NO.: 2011-121 FIGURE: 9



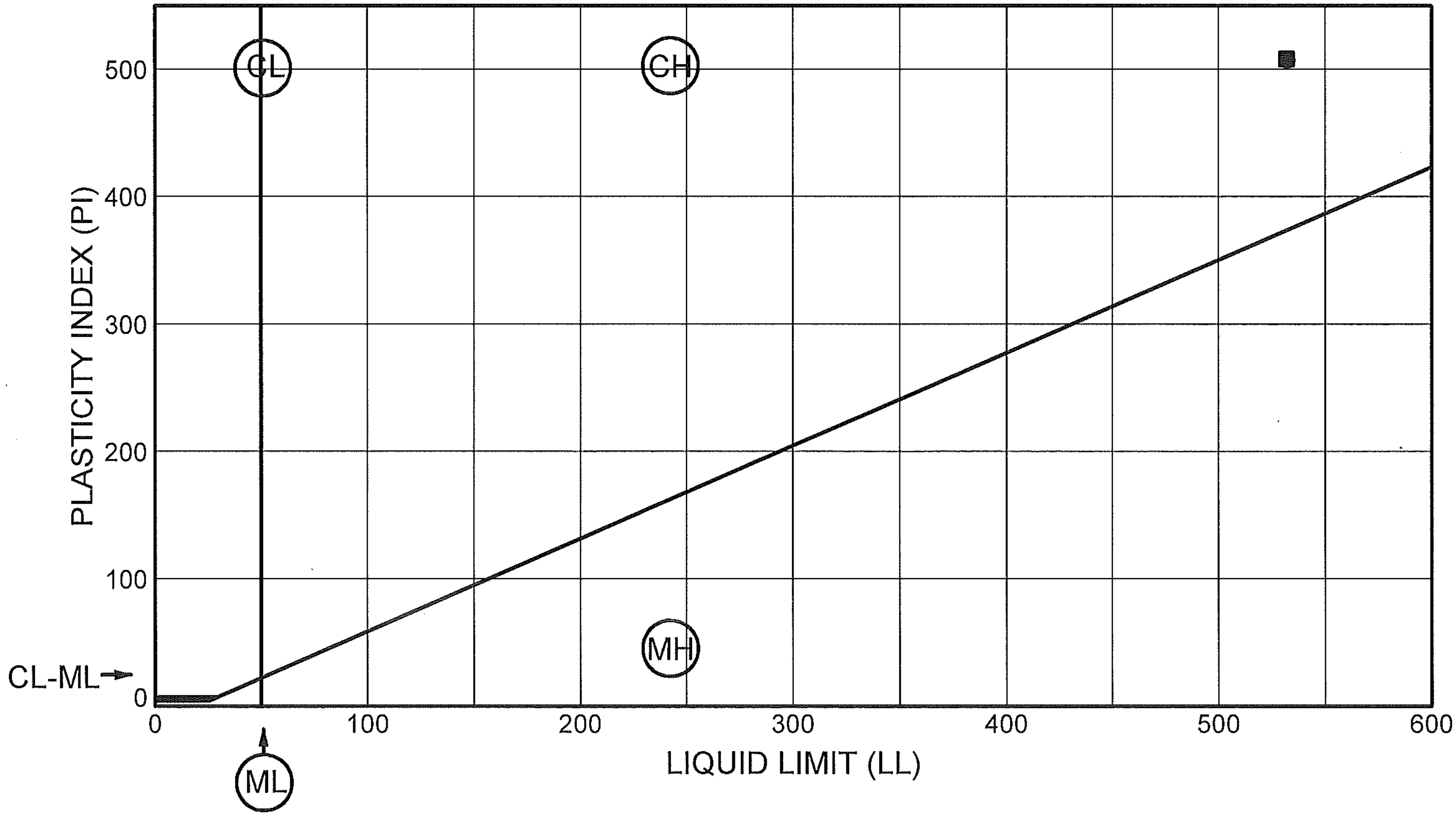
SYMBOL	SAMPLE	DEPTH (ft)	CLASSIFICATION	% MC	LL	PL	PI	% Fines
●	Slurry Mix-1		(CH) WyoBen and City Water		484	28	456	
■	Slurry Mix-2		(CH) Sorbond and City Water		500	28	472	
▲	Slurry Mix-3		(CH) WyoBen, City Water and Groundwater		528	26	502	
○	Slurry Mix-4		(CH) Sorbond and Groundwater		504	27	477	
□	Slurry Mix-5		(CH) WyoBen and Groundwater		576	31	545	
△	Slurry Mix-6		(CH) Sorbond, City Water and Groundwater		513	30	483	

HWA GEOSCIENCES INC.

Terminal 91 Tank Farm Affected Area Cleanup Project
Lab testing for PES Environmental, Inc.

LIQUID LIMIT, PLASTIC LIMIT AND PLASTICITY INDEX OF SOILS METHOD ASTM D4318

PROJECT NO.: 2011-121 FIGURE: 10



SYMBOL	SAMPLE	DEPTH (ft)	CLASSIFICATION	% MC	LL	PL	PI	% Fines
●	Slurry Mix-7		(CH) WyoBen, City Water and LNAPL		532	25	507	
■	Slurry Mix-8		(CH) Sorbond, City Water and LNAPL		532	24	508	

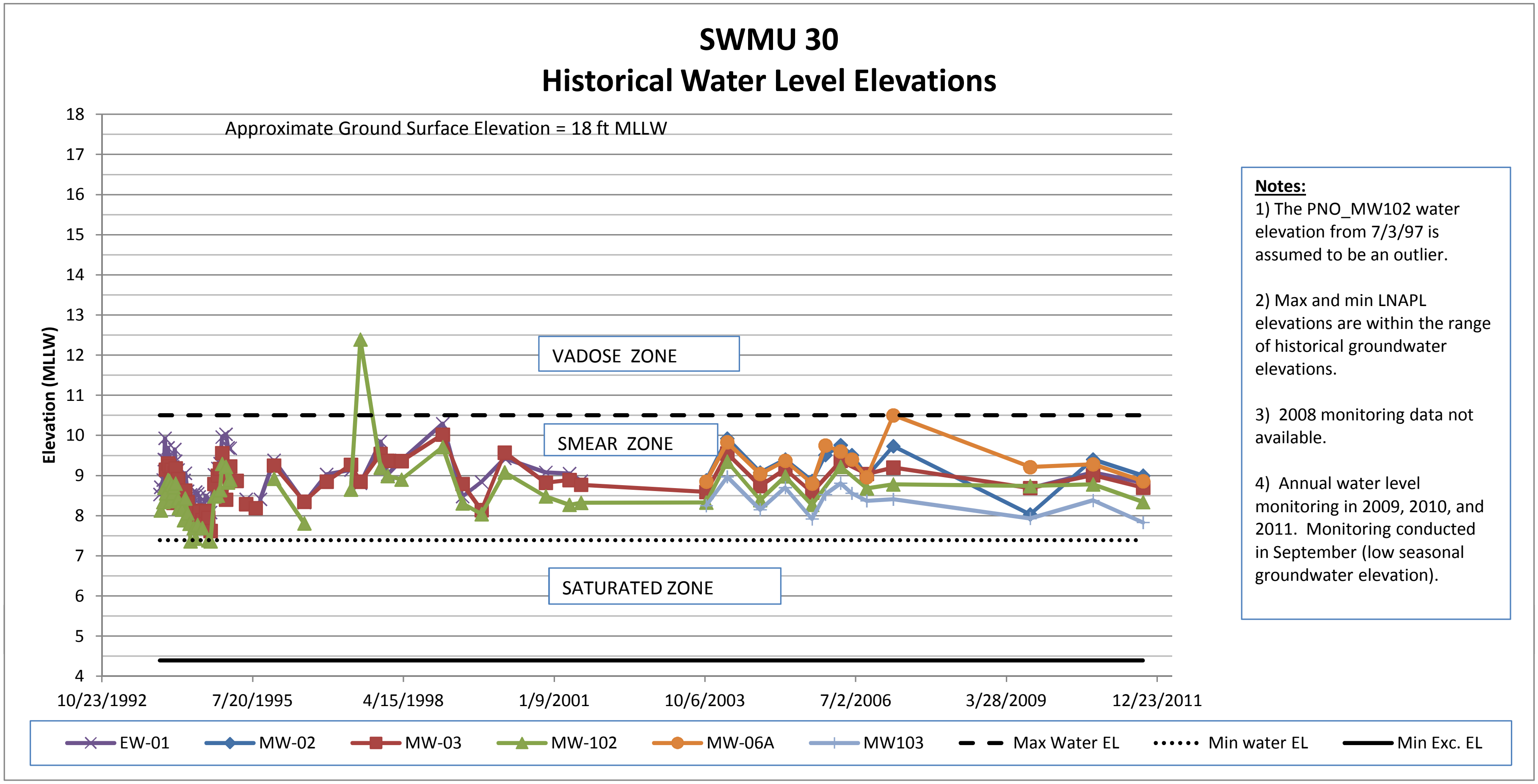
HWA GEOSCIENCES INC.

Terminal 91 Tank Farm Affected Area Cleanup Project
Lab testing for PES Environmental, Inc.

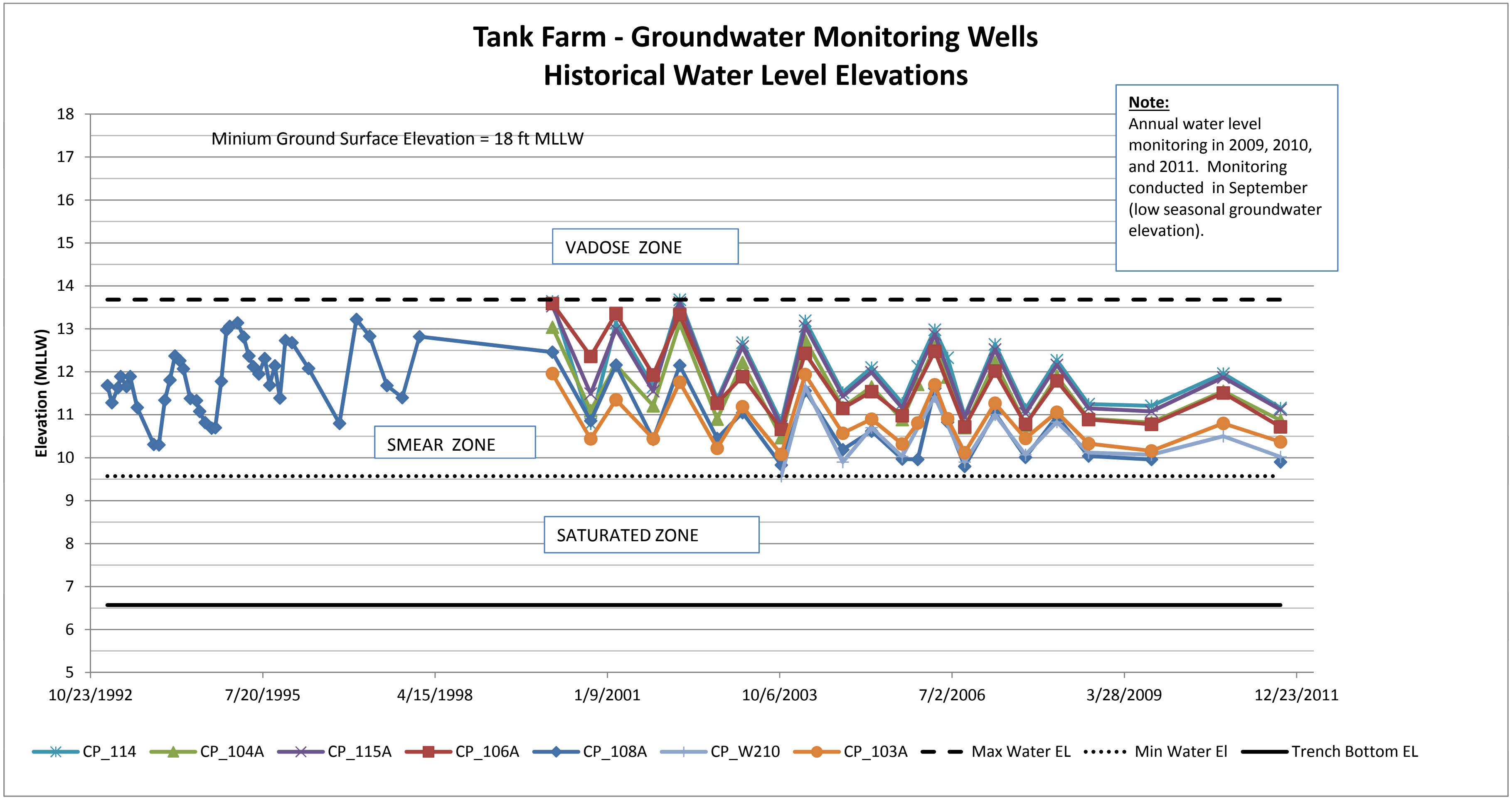
LIQUID LIMIT, PLASTIC LIMIT AND PLASTICITY INDEX OF SOILS METHOD ASTM D4318

PROJECT NO.: 2011-121 FIGURE: 11

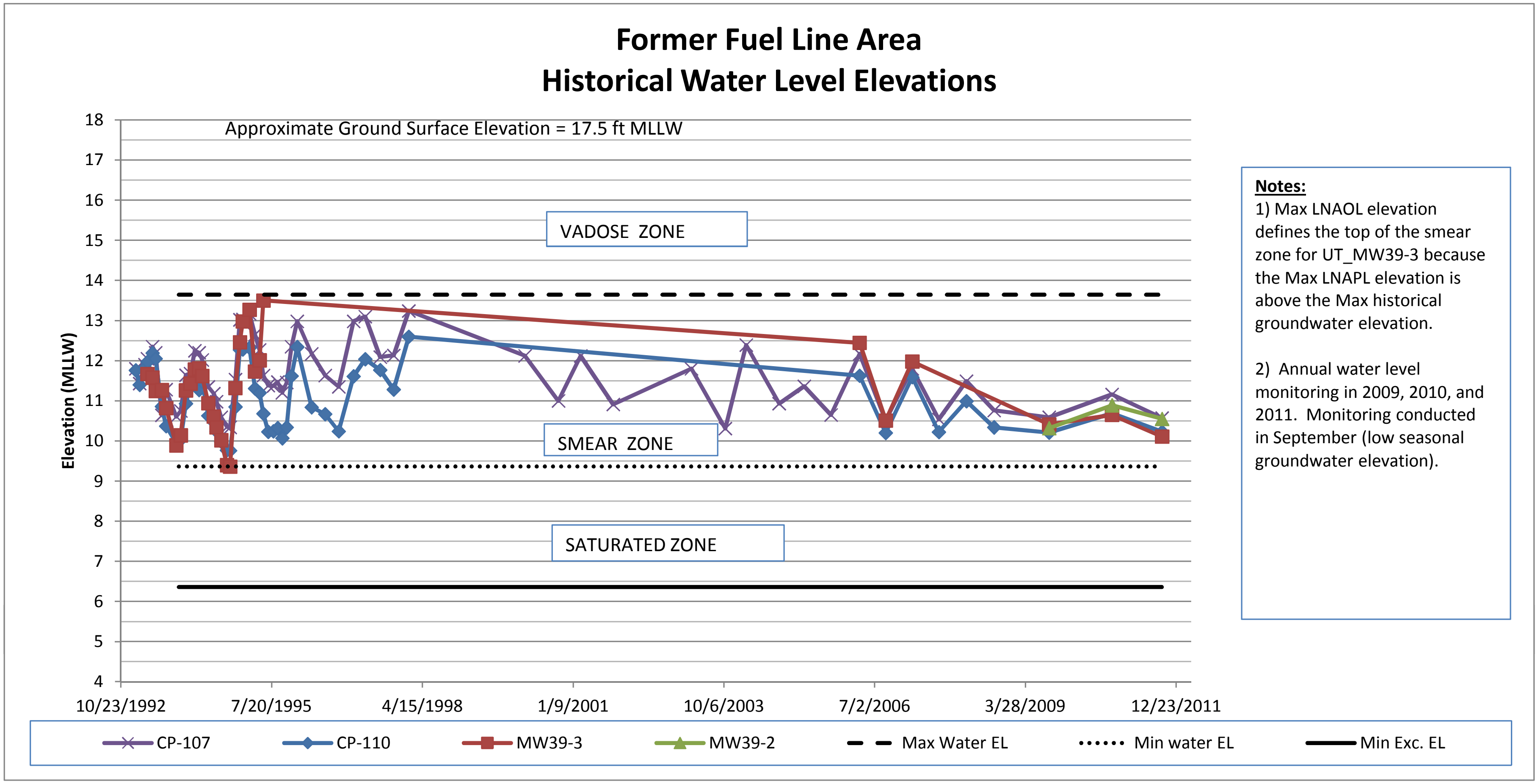
APPENDIX A3
Groundwater Elevations and LNAPL Data



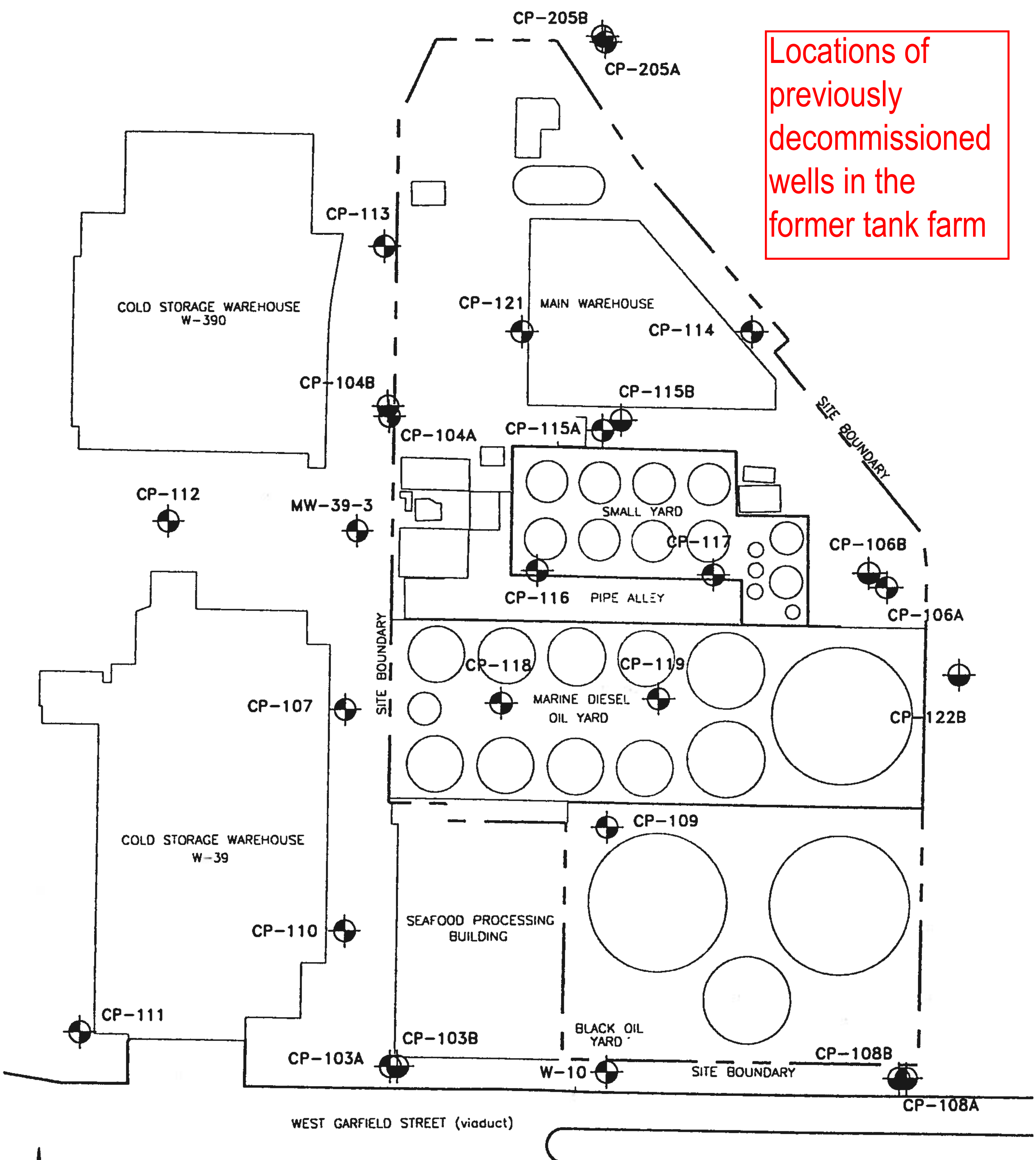
Well_id	Date Min	Date Max	Casing Elevation	EL Max	Date	EL Min	Date	Avg Max EL	Avg Min EL	Number of Monitoring events
PNO_EW01	11/11/1993	9/20/2011	17.73	10.29	12/31/1998	8.06	8/19/1994	9.62	8.76	59
PNO_MW02	10/14/2003	9/20/2011	17.71	9.92	3/1/2004	8.03	9/1/2009	9.69	9.00	13
PNO_MW03	11/17/1993	9/20/2011	17.70	10.02	12/31/1998	7.62	10/13/1994	9.43	8.71	66
PNO_MW102	11/11/1993	9/20/2011	17.69	12.39	7/3/1997	7.36	10/13/1994	9.38	8.34	57
PNO_MW06A	10/14/2003	9/20/2011	18.05	10.50	3/8/2007	8.80	9/15/2005	9.92	9.00	13
PNO_MW103	10/14/2003	9/20/2011	17.48	8.97	3/1/2004	7.83	9/20/2011	8.63	8.12	13

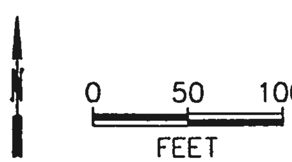


Well_id	Date Min	Date Max	Casing Elevation	EL Max	Min Depth	Date	EL Min	Date	Avg Max EL	Avg Min EL	Number of Monitoring events
CP_103A	2/24/2000	9/20/2011	17.11	11.96	5.15	2/24/2000	10.08	10/14/2003	11.46	10.36	23
CP_104A	2/24/2000	9/20/2011	17.13	13.14	3.99	3/4/2002	10.47	10/14/2003	12.41	10.95	23
CP_106A	2/24/2000	9/20/2011	18.00	13.59	4.41	2/24/2000	10.66	10/14/2003	12.49	11.15	21
CP_108A	1/29/1993	9/20/2011	16.58	13.22	3.36	1/13/1997	9.80	9/13/2006	11.90	9.99	63
CP_114	2/24/2000	9/20/2011	17.94	13.68	4.26	3/4/2002	10.79	10/3/2000	12.93	11.26	23
CP_115A	2/24/2000	9/20/2011	17.74	13.61	4.13	3/4/2002	10.73	10/14/2003	12.81	11.24	21
CP_121	2/24/2000	9/20/2011	17.61	13.50	4.11	2/24/2000	10.70	10/14/2003	12.78	11.21	21
CP_W210	10/14/2003	9/20/2011	17.11	11.66	5.45	3/1/2004	9.57	10/14/2003	11.23	10.46	21



Well_id	Date Min	Date Max	Casing Elevation	EL Max	Date	EL Min	Date	Avg Max EL	Avg Min EL	Number of Monitoring events
CP_107	1/29/1993	9/20/2011	17.15	13.24	1/14/1998	10.31	10/14/2003	12.37	10.86	62
CP_110	1/29/1993	9/20/2011	17.42	12.60	1/14/1998	9.76	10/17/1994	12.08	10.50	52
UT_MW39-3	1/29/1993	9/20/2011	17.33	13.64	2/23/1995	9.36	10/17/1994	12.85	10.86	31
UT_MW39-2	9/1/2009	9/20/2011	16.84	NA	7/3/1997	11.39	10/13/1994	NA	10.59	0





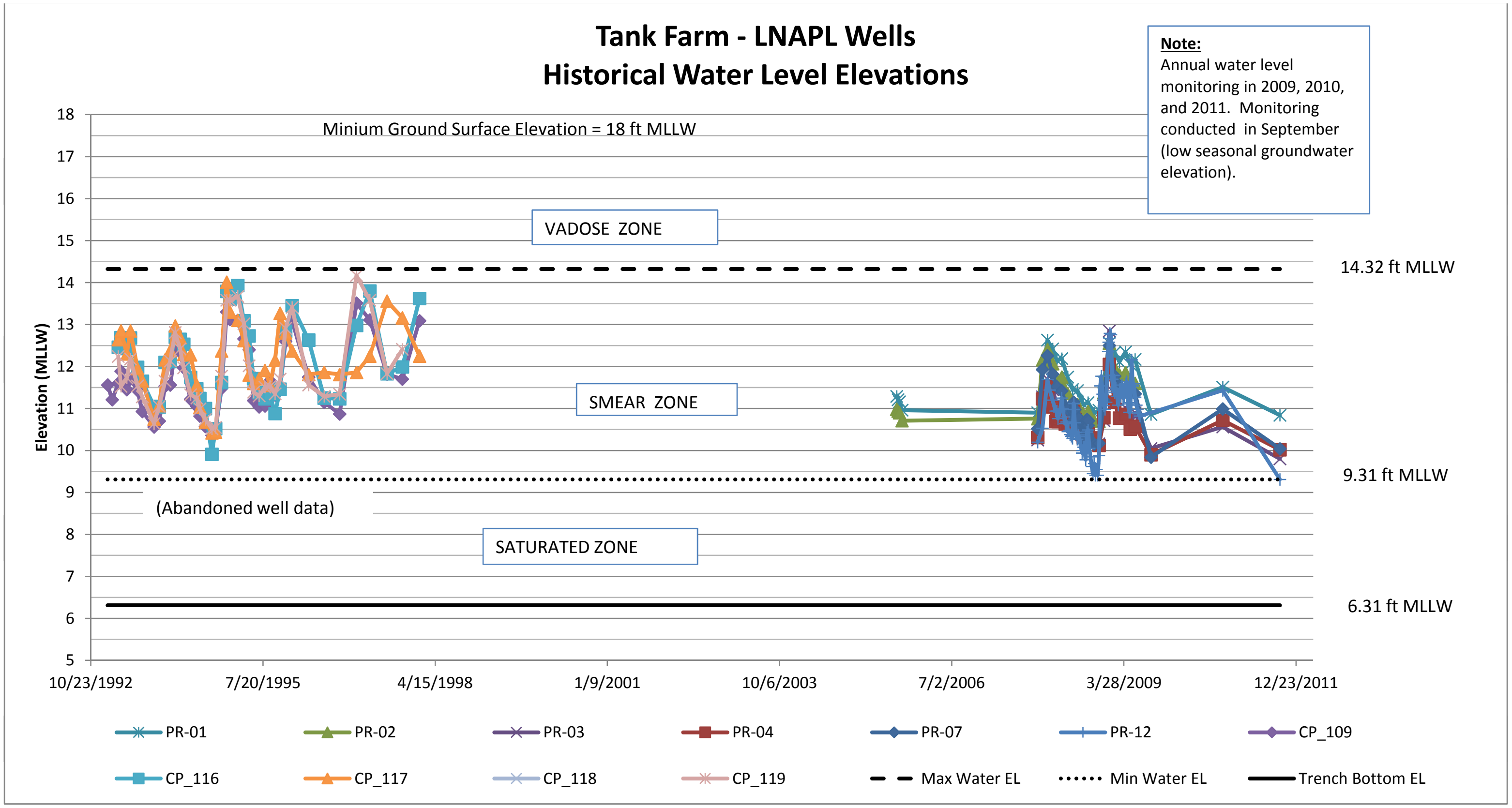
Source:
Philip Services Corporation, Associated Earth Sciences, Inc., and Roth Consulting. 1999. *Agency Draft Remedial Investigation/Data Evaluation Report, Terminal 91 Tank Farm Site, Seattle, Washington.* Prepared for The Terminal 91 Tank Farm PLP Group. January 6, 1999.

Groundwater Monitoring Well Locations
Terminal 91 Tank Farm Site

DWN.: PB	DES.: DP	FIGURE NUMBER
CHKD.:	APPD.:	3-1
DATE: 12/23/98	REV.: –	

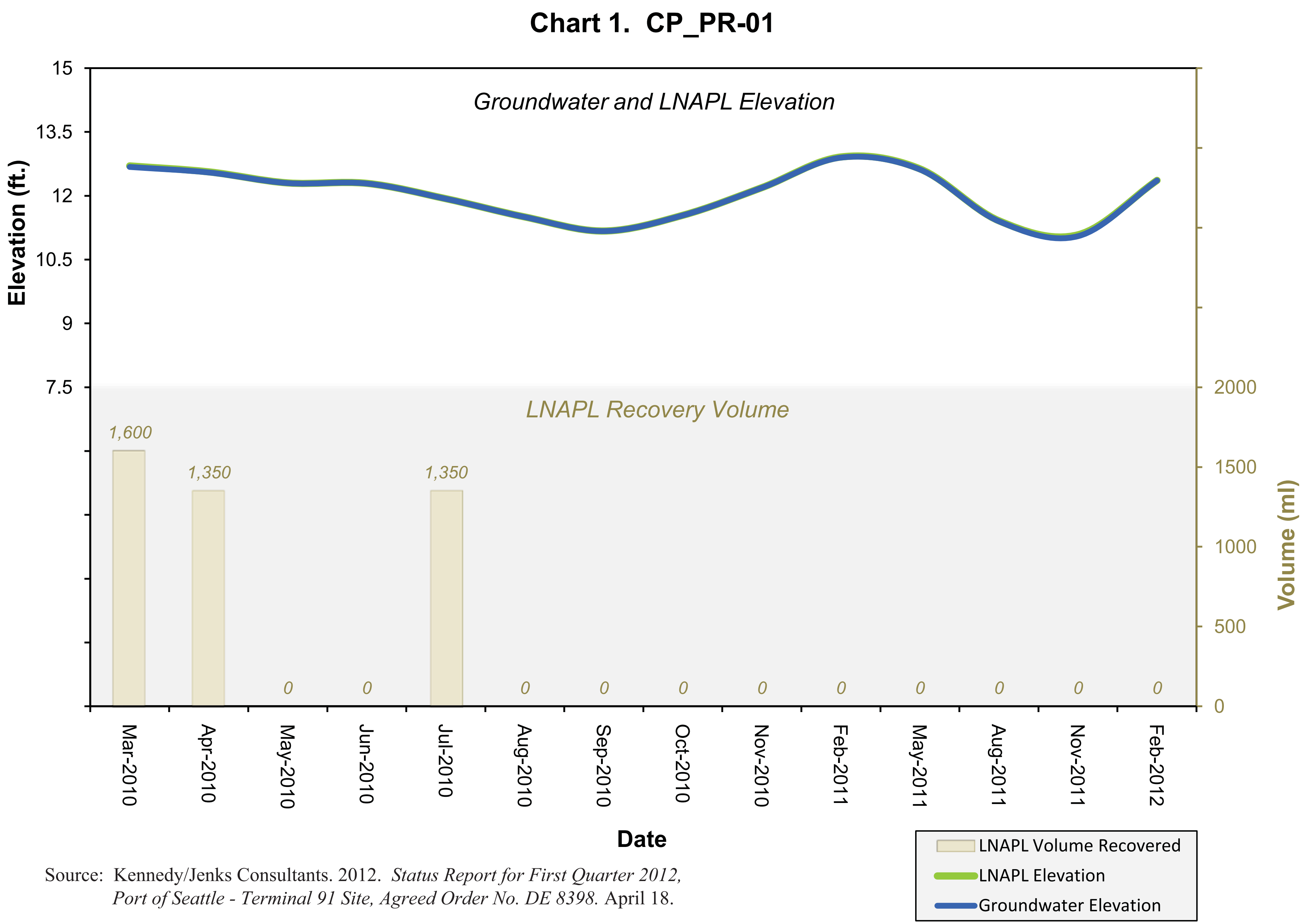
Prepared by: PHILIP SERVICES CORP. • ASSOCIATED EARTH SCIENCES, INC • Roth Consulting

BV98014A-64.dwg base.dwg 1:1

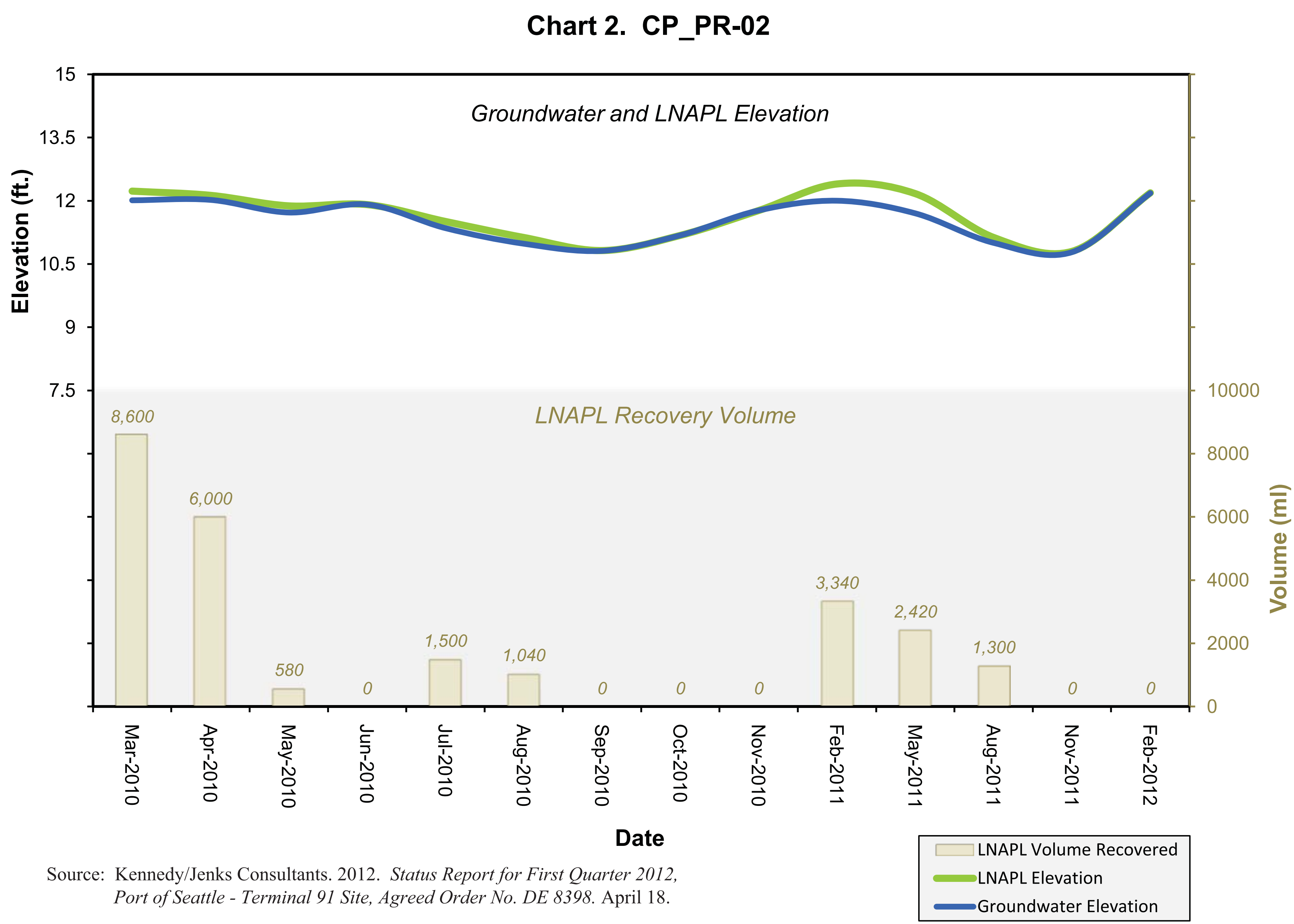


Well_id	Date Min	Date Max	Casing Elevation	EL Max	Min Depth	Date	EL Min	Date	Min LNAPL Thickness	Max LNAPL Thickness	Number of Monitoring events
PR-01	8/16/2005	9/20/2011	18.84	12.71	6.13	1/9/2008	10.84	9/20/2011	0.005	0.09	26
PR-02	8/16/2005	6/1/2009	17.89	12.56	5.33	1/2/2009	10.70	11/3/2008	0.005	0.19	24
PR-03	11/13/2007	9/20/2011	18.40	12.85	5.55	1/2/2009	9.80	9/20/2011	0.005	1.15	23
PR-04	11/13/2007	9/20/2011	18.17	12.15	6.02	1/2/2009	9.90	9/1/2009	0.01	0.68	46
PR-05	11/13/2007	9/20/2011	18.18	12.31	5.87	1/2/2009	10.41	9/20/2011	0.00	0.00	23
PR-06	11/13/2007	9/20/2011	18.45	12.64	5.81	1/9/2008	10.77	9/20/2011	0.00	0.00	23
PR-07	11/13/2007	9/20/2011	18.55	12.50	6.05	1/2/2009	9.84	9/1/2009	0.01	0.73	38
PR-08	11/13/2007	9/20/2011	17.18	12.50	4.68	1/2/2009	10.67	9/20/2011	0.00	0.00	23
PR-09	11/13/2007	9/20/2011	18.24	12.56	5.68	1/9/2008	10.73	9/20/2011	0.00	0.00	23
PR-10	11/13/2007	9/20/2011	18.37	13.06	5.31	1/9/2008	10.95	9/20/2011	0.00	0.00	23
PR-11	11/13/2007	9/20/2011	18.44	12.43	6.01	1/2/2009	10.74	9/20/2011	0.00	0.02	23
PR-12	3/17/2008	9/20/2011	18.36	12.96	5.40	1/12/2009	9.31	9/1/2009	0.01	1.72	74
CP_109	1/29/1993	1/14/1998	18.35	13.64	4.71	1/14/1998	10.36	9/26/1994	0.03	1.19	43
CP_116	3/31/1993	1/14/1998	17.79	13.93	3.86	2/23/1995	9.91	9/26/1994	0.01	0.94	41
CP_117	3/31/1993	1/14/1998	18.30	14.32	3.98	2/23/1995	10.42	9/26/1994	0.02	1.22	41
CP_118	3/31/1993	1/14/1998	17.22	14.19	3.03	1/13/1997	10.04	9/26/1994	0.09	1.86	41
CP_119	3/31/1993	10/6/1997	16.73	14.17	2.56	1/13/1997	10.52	9/26/1994	0.01	1.57	40

Note: Wells in italics were abandoned prior to the 2005 Tank Farm demo.

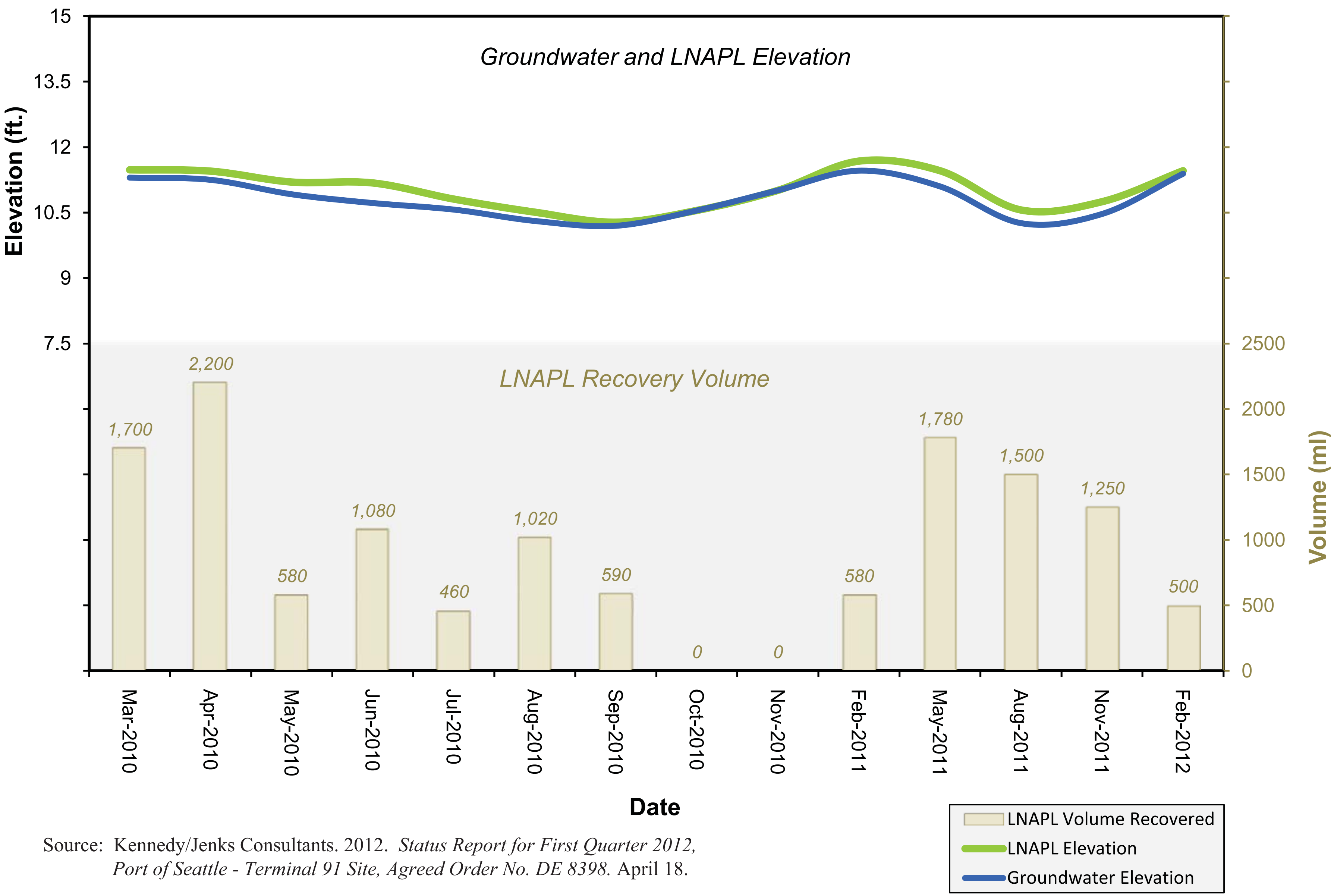


Source: Kennedy/Jenks Consultants. 2012. *Status Report for First Quarter 2012, Port of Seattle - Terminal 91 Site, Agreed Order No. DE 8398.* April 18.

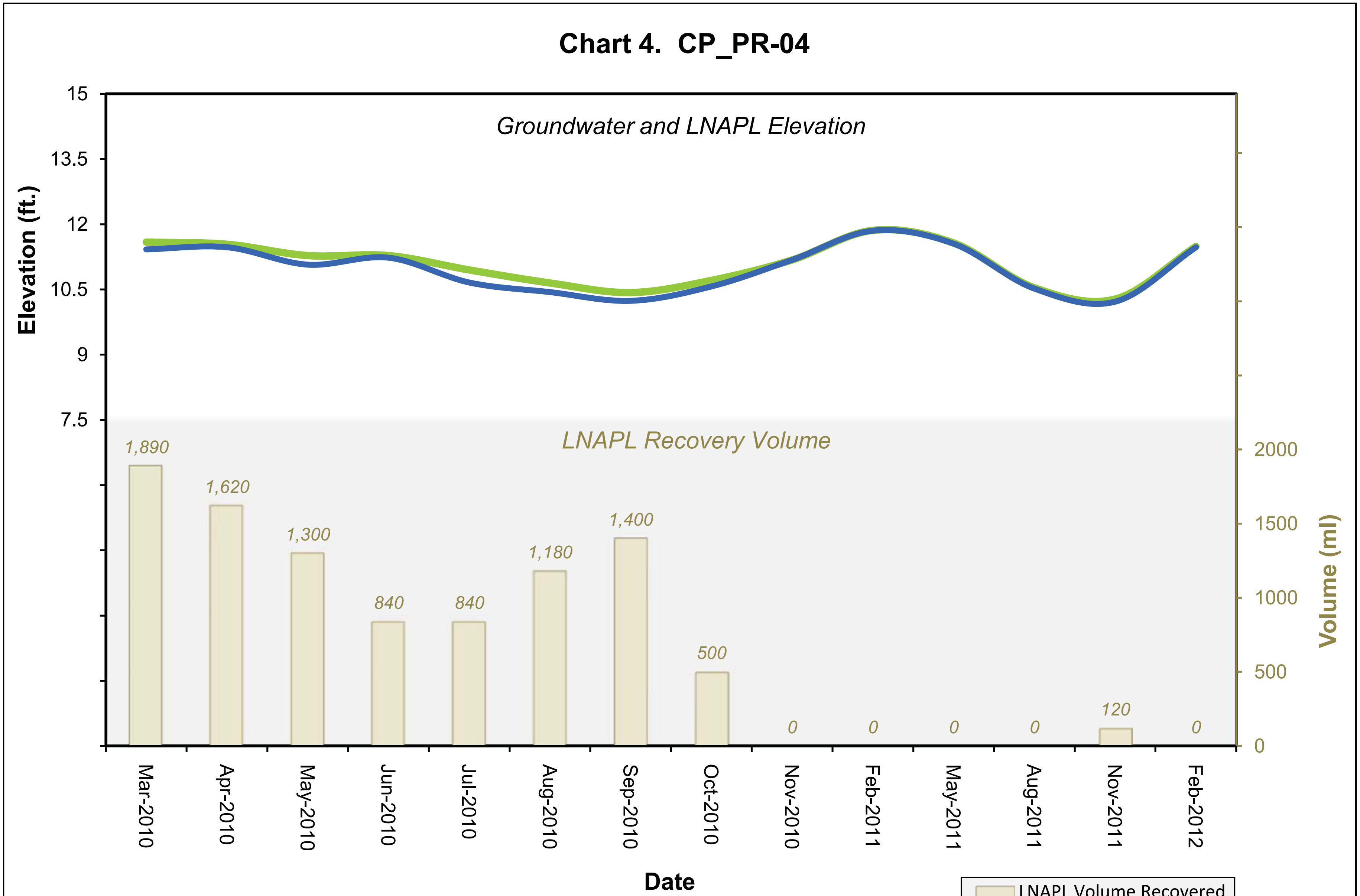


Source: Kennedy/Jenks Consultants. 2012. *Status Report for First Quarter 2012, Port of Seattle - Terminal 91 Site, Agreed Order No. DE 8398.* April 18.

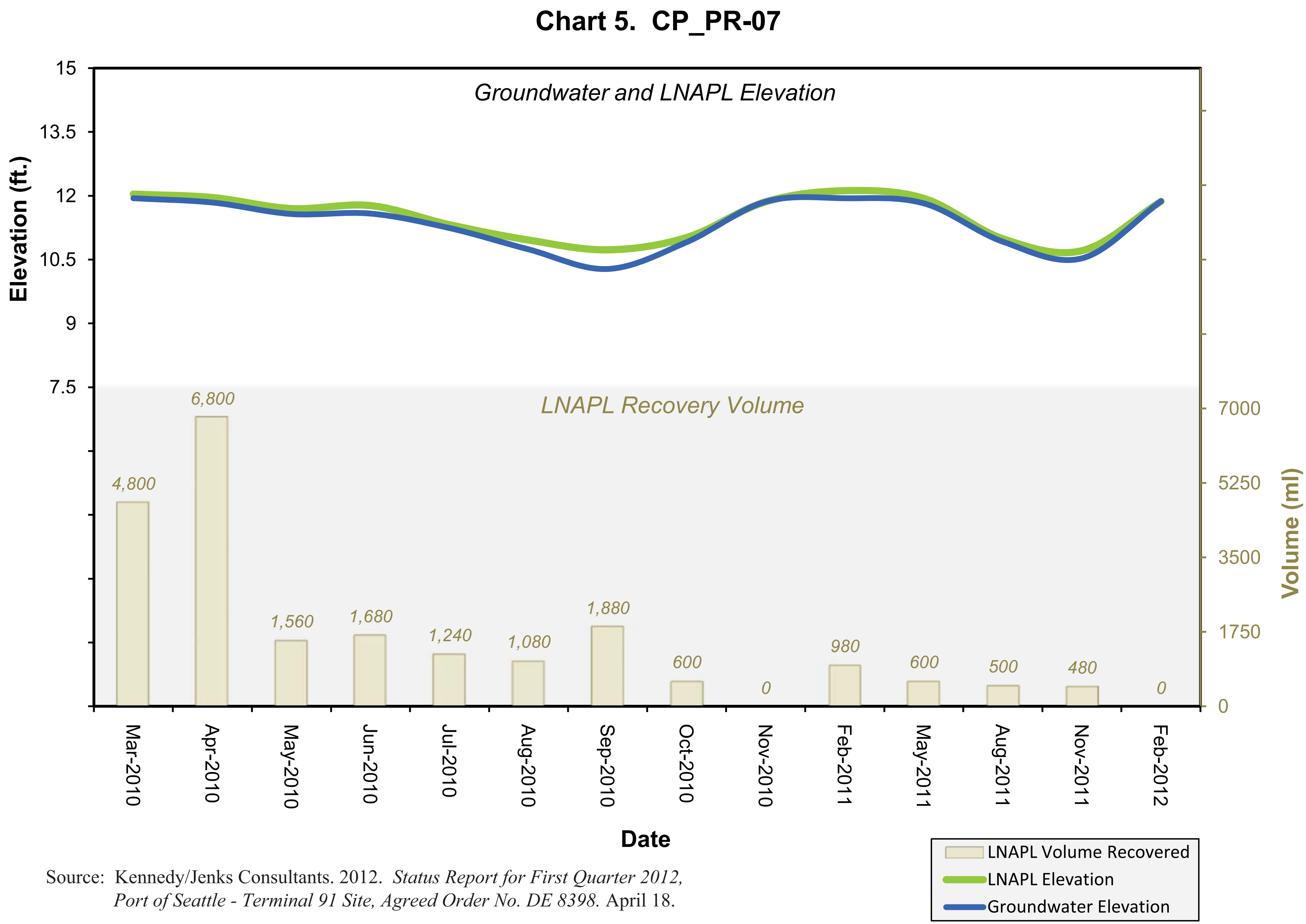
Chart 3. CP_PR-03



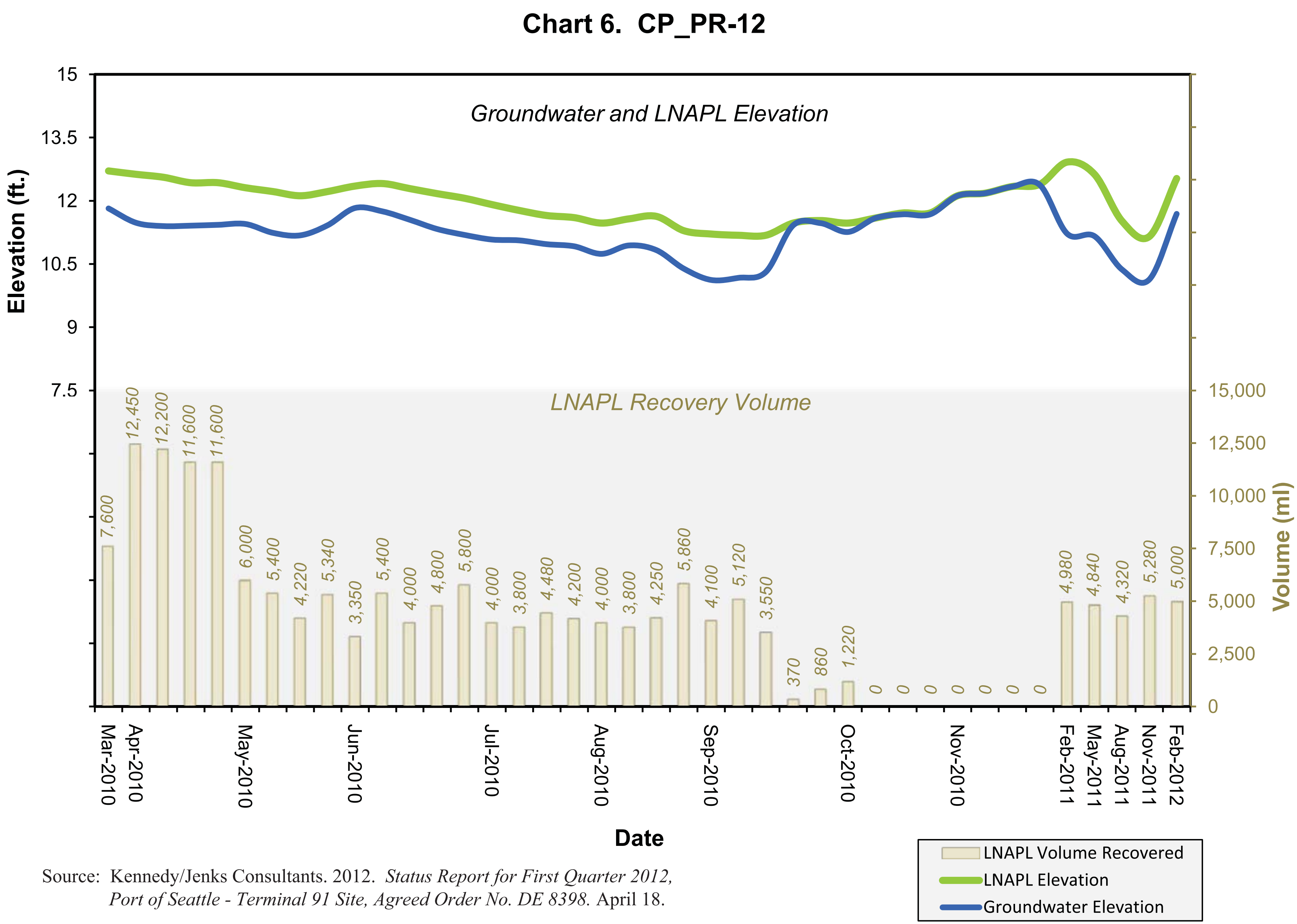
Source: Kennedy/Jenks Consultants. 2012. *Status Report for First Quarter 2012, Port of Seattle - Terminal 91 Site, Agreed Order No. DE 8398.* April 18.



Source: Kennedy/Jenks Consultants. 2012. *Status Report for First Quarter 2012, Port of Seattle - Terminal 91 Site, Agreed Order No. DE 8398.* April 18.

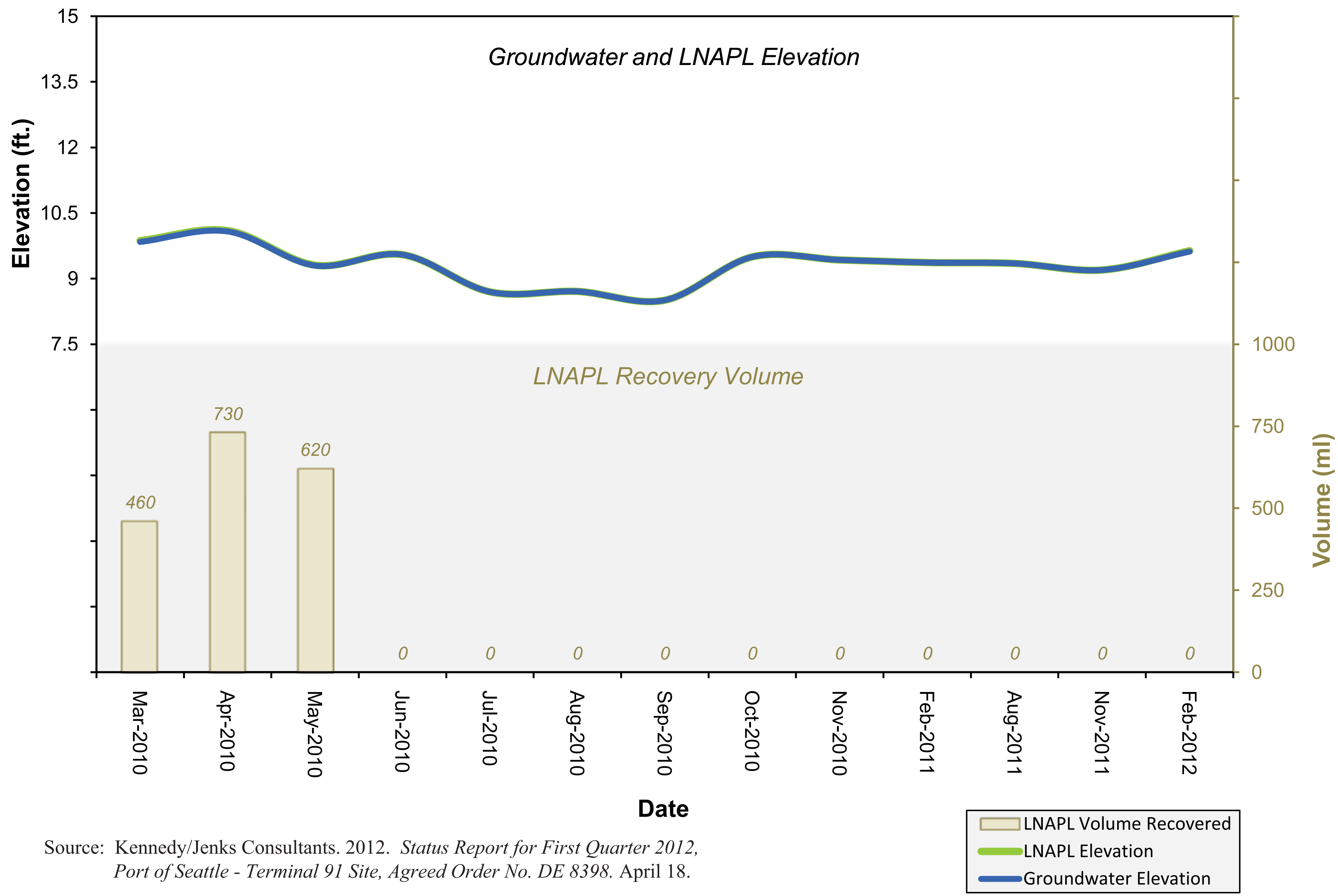


Source: Kennedy/Jenks Consultants. 2012. *Status Report for First Quarter 2012, Port of Seattle - Terminal 91 Site, Agreed Order No. DE 8398.* April 18.

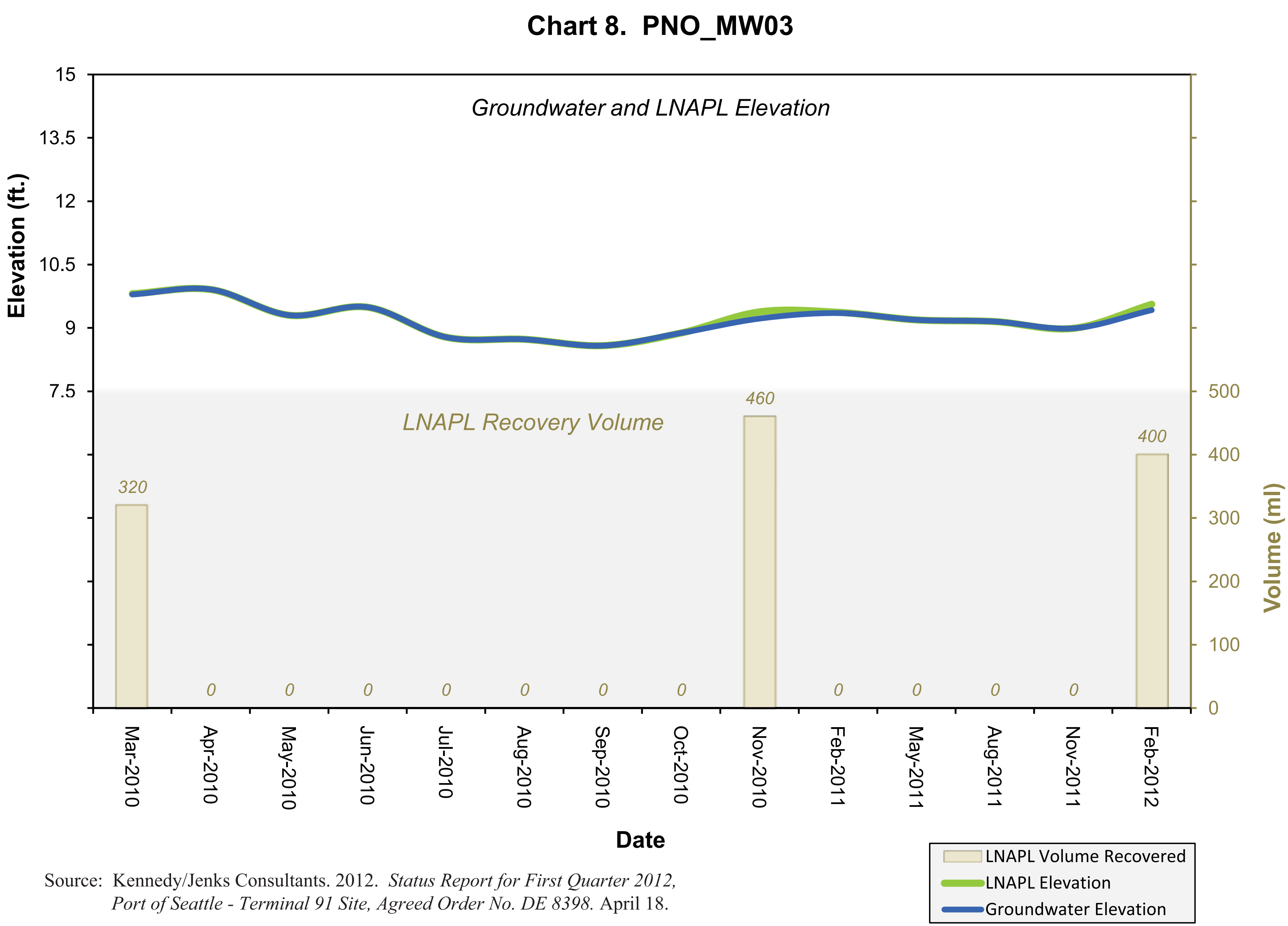


Source: Kennedy/Jenks Consultants. 2012. *Status Report for First Quarter 2012, Port of Seattle - Terminal 91 Site, Agreed Order No. DE 8398.* April 18.

Chart 7. PNO_EW01

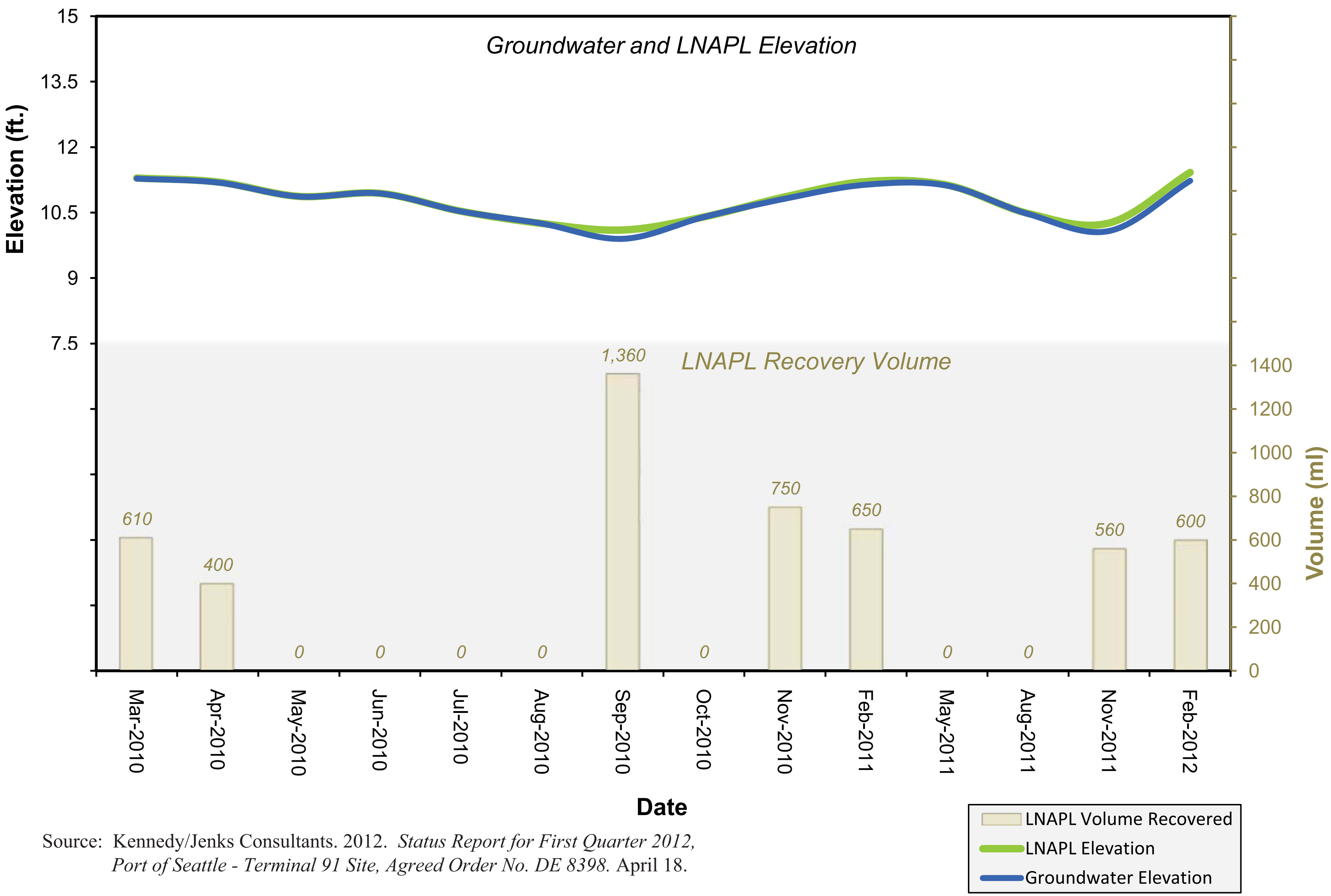


Source: Kennedy/Jenks Consultants. 2012. *Status Report for First Quarter 2012, Port of Seattle - Terminal 91 Site, Agreed Order No. DE 8398.* April 18.



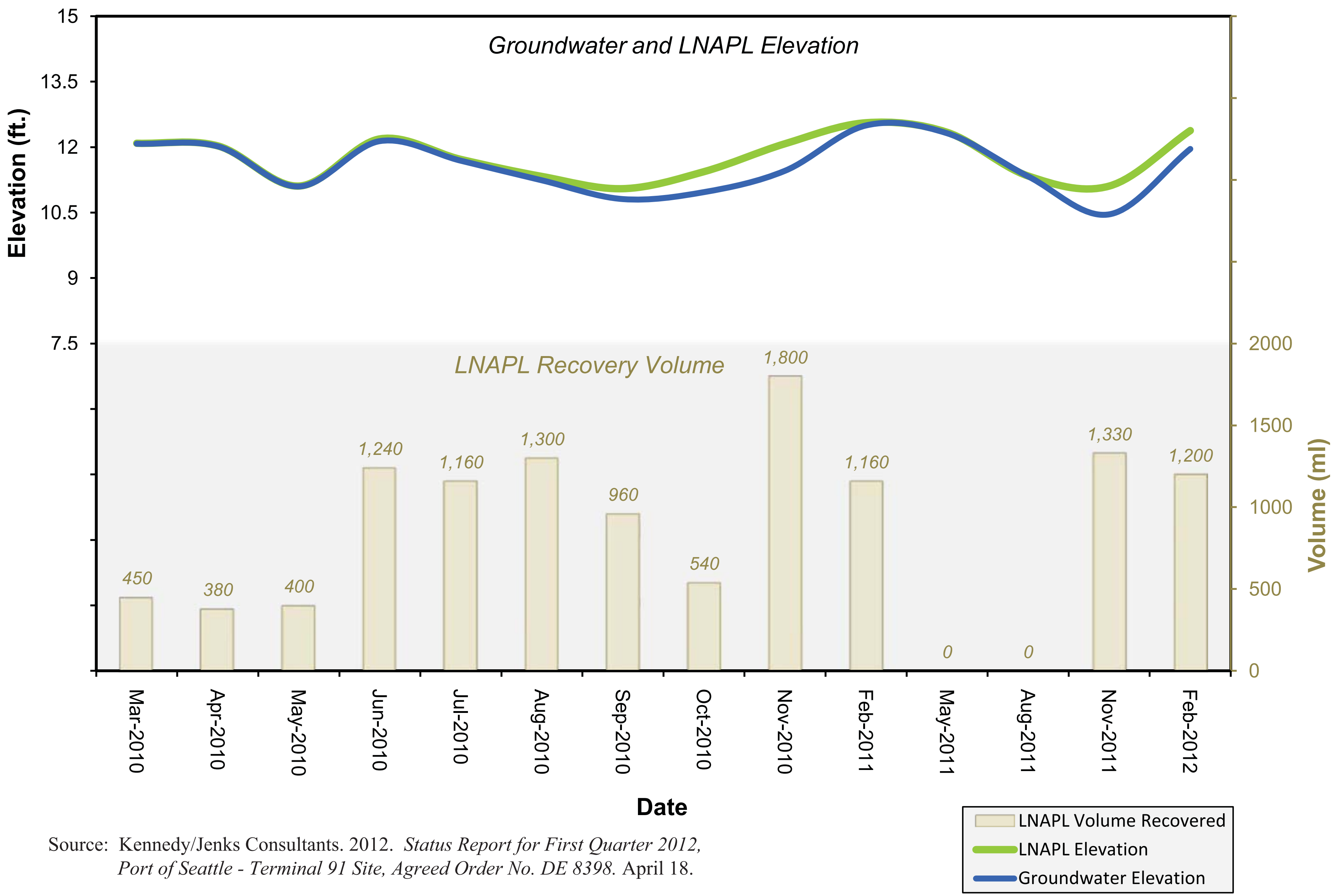
Source: Kennedy/Jenks Consultants. 2012. *Status Report for First Quarter 2012, Port of Seattle - Terminal 91 Site, Agreed Order No. DE 8398.* April 18.

Chart 9. PNO_MW104

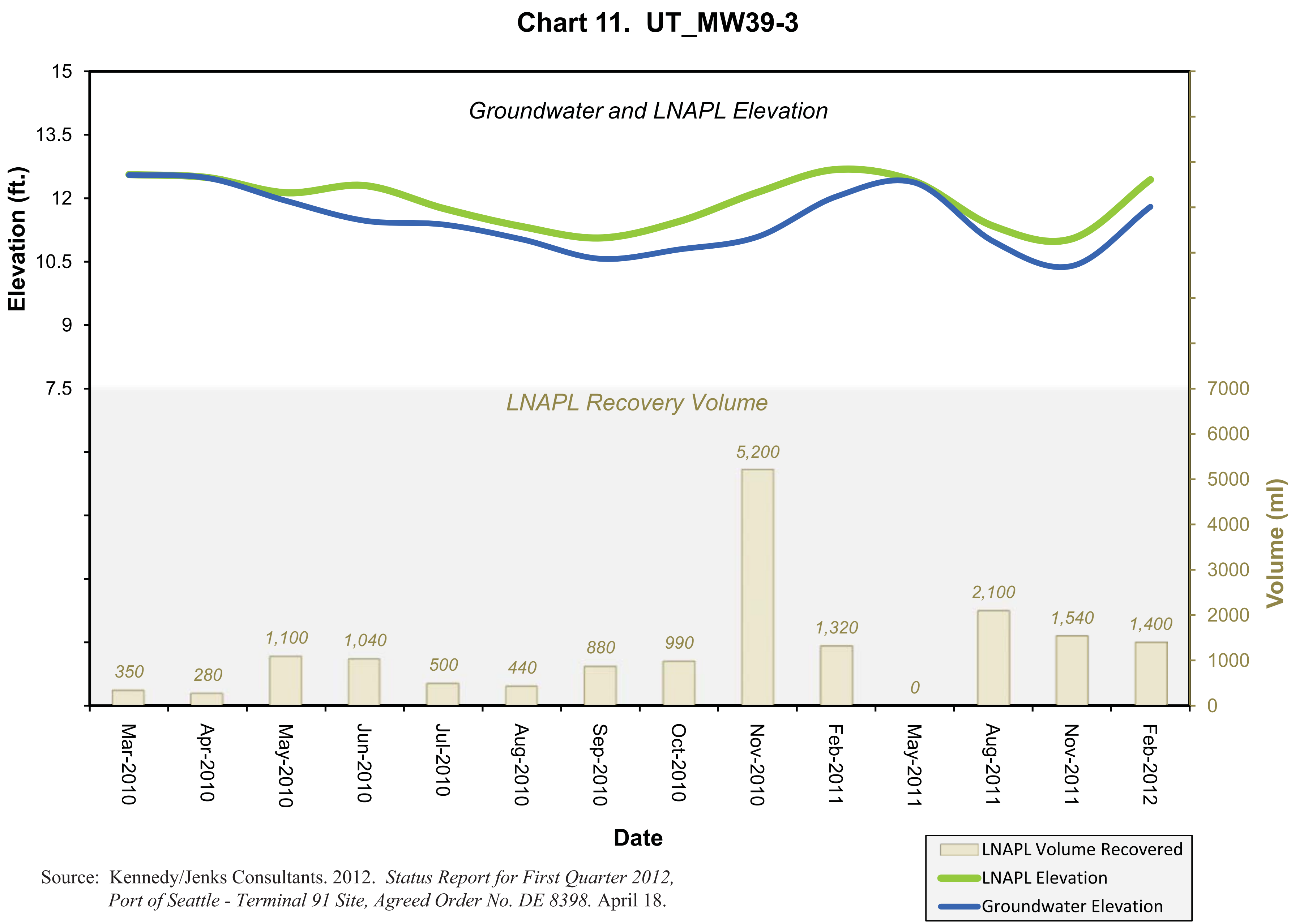


Source: Kennedy/Jenks Consultants. 2012. *Status Report for First Quarter 2012, Port of Seattle - Terminal 91 Site, Agreed Order No. DE 8398.* April 18.

Chart 10. UT_MW39-2



Source: Kennedy/Jenks Consultants. 2012. *Status Report for First Quarter 2012, Port of Seattle - Terminal 91 Site, Agreed Order No. DE 8398.* April 18.



Source: Kennedy/Jenks Consultants. 2012. *Status Report for First Quarter 2012, Port of Seattle - Terminal 91 Site, Agreed Order No. DE 8398.* April 18.

APPENDIX A4
SWMU 30 Excavation Considerations

4132 SW BARBUR BOULEVARD
PORTLAND, OREGON 97239
(503) 922 2522

VISTA CONSULTANTS

MEMORANDUM

To: File

From: Roger North

Date: March 4, 2013

Subject: SWMU 30 Excavation Considerations
Terminal 91 Tank Farm Affected Area Cleanup

The purpose of this memorandum is to discuss for the SWMU 30 area the site conditions, and the cleanup requirements, and ways in which the cleanup may be performed.

BACKGROUND

The SWMU 30 area consists of two subareas, referred to as SWMU 30 - North and South Areas, which are separated by about 27 feet. The South Area measures 60 ft (N-S) by 26 ft (E-W) and the North area 90 ft (N-S) by 26 ft (E-W). Cleanup is required in both areas due to contamination from prior fuel pipeline leaks.

The areas are paved and level and form part of Pier 91. The surface elevations is approximately 18 ft, and the agreed cleanup involves excavating and removing all soil to elevation 4.4 ft, a depth of approximately 13.6 ft. Historical groundwater elevations, obtained from groundwater monitoring wells located in and around the areas have ranged from 7.4 to 10.5 ft. Therefore, the required cleanup will likely require excavations between 3 and 6 feet below groundwater.

Both areas are bounded on the east side by a bulkhead structure that used to form the east side of Pier 91. This structure is tied back to an anchor wall that is located within the proposed excavation limits. In addition, both areas are traversed by utilities, which the Port has indicated need to remain in place and cannot be temporarily rerouted. These are as follows:

SWMU 30 – South Area

- 12-in sanitary sewer (N-S);
- Fiber optic line (E-W);
- Power – multiple lines in a duct bank and a separate power line (E-W); and
- Gas line (E-W).

SWMU 30 – North Area

- 12-in sanitary sewer (N-S).

The depths of the utilities (as well as the size and composition of some of the utilities; e.g. the duct bank) are unknown and the method that will be needed to support the utilities are unknown, but will likely include support from both above and below the individual utilities.

ASSESSMENT

The presence of the tie backs, tie-back anchor wall, and the utilities (with the need for the provision of supporting members) will prevent traditional sheeting from being installed uninterrupted around the entire excavation areas. Some other means of shoring will be needed at conflict locations. An option would be installing H-piles on both sides of each conflict and installing lagging between the piles as the excavation proceeds (this is not be as water tight as continuous interlocked sheet piling, but can be constructed incrementally as the excavation is advanced, but only to the depth of excavation). Other options would include techniques such as jet grouting, and ground freezing, but these would be more expensive to implement.

Regardless of the method used, the complications introduced by the utilities (particularly in the south area) and the bulkhead support elements, will limit the ability to construct a continuous groundwater cutoff zone below the base of the excavation, and therefore to perform the excavation in the dry with some form of groundwater dewatering[1]. Therefore, the sheeting/shoring complications will result in greater potential for:

- Groundwater inflow through the sides of the excavation;
- Soil piping through the sides of the excavation, and associated ground settlement outside the excavation;
- Groundwater inflow through the base of the excavation; and
- Ground heaving (piping) in the base of the excavation.

One possible approach to manage the excavation with a mixed shoring system would be to maintain a positive groundwater differential between the inside and the outside of the excavation (higher groundwater elevation inside than outside) to minimize the potential for groundwater flow and soil piping

[1] Given the sandy nature of the soils, even continuous sheet piles would likely have to be driven to significant depth below the planned bottom of the excavation to adequately control groundwater.

into the excavation, and to perform the portion of the excavation and subsequent backfilling, which is below the inside water elevation, underwater. This would have the additional benefit of not requiring groundwater to be pumped and treated (except when backfill gravel is added and groundwater is displaced), but should still enable any observed LNAPL to be skimmed from the groundwater surface.

One drawback to this approach would be the ability to expose and examine the anchor piles and lagging in the north area over the full depth of the excavation. Additionally, excavation and backfilling around this structure (where it needs to be preserved – approximately north of Northing 34,420) would have to be carefully controlled to avoid damage to the piles and lagging. In the south area and in the north area south of Northing 34,420, the structure could be removed and there would be no examination or damage concerns.

* * * * *

APPENDIX A5
Cut Off Wall Calculations

Vista Consultants

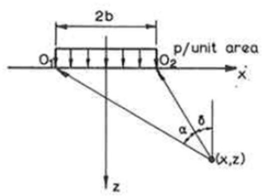
Client:	Port of Seattle	Date:	February 27, 2013
Project:	Terminal 91 - TFAA Cleanup	Proj. #:	12-33
Scenario:	Building M-28 East Wall		
Prepared by:	Roger B. North, P.E.	Page: 1	

Stresses From Distributed Load On Surface of Semi-Infinite Mass

Purpose:

Compute the stresses resulting from and uniform vertical strip loading on the surface of a semi-infinite mass, assuming elastic conditions, and the geometry and equations shown on the figure below (Poulos, H.G. and Davis E.H. [1974], Elastic Solutions for Soil and Rock Mechanics in Soil Mechanics, John Wiley & Sons, New York, pp. 36-38).

Imposed Loading Geometry



$\sigma z = p\ [\alpha + \sin\alpha.\cos(\alpha + 2\delta)]/\pi$

$\sigma x = p\ [\alpha - \sin\alpha.\cos(\alpha + 2\delta)]/\pi$

Initial Loads

γ = Unit weight of soil
k = Horizontal stress ratio (assumed in situ ratio of horizontal to vertical stresses)
z = Depth below surface

σz = γ.z
σx = k.γ.z

Problem Statement:

Assess the stresses at the cutoff wall due to the presence of the east wall of Building M-28, which is the 15 ft high former contianment wall with a 12 ft wide footing.

Assumptions

1. Assume conservatively the strip footing is located at the ground surface.

2. Width of footing is 12 ft. Footing is 2-ft thick. 15-ft high wall is 1 ft thick. (Total loading = 490 psf)
3. Assume soil weight of 115 pcf
4. Based on typical cutoff wall equipment, assume cutoff wall will be constructed 12 ft from edge of the footing and 18 ft from the center line of the footing.
5. Assume resulting footing load from concrete wall and additional building loads is building loads are modest and assume 1,000 psf.

INPUT VALUES (For Single Point Set x1 = x10 and z1 = z10)

γ =	115	(pcf) = Unit weight of soil
k =	0.5	= Horizontal stress ratio
p =	1000	(psf) = Imposed load per unit area
2b =	12	(ft) = Width of strip
x1 =	18	(ft) = Minimum distance from center line to consider
x10 =	18	(ft) = Maximum distance from center line to consider
z1 =	1	(ft) = Minimum depth from surface to consider
z10 =	16	(ft) = Maximum depth from surface to consider

CONCLUSION

See Page 2 for results. Resulting imposed loads on cutoff wall due to the existing structure are very small less than 150 psf for both vertical and horizontal stresses.
Acceptable for soil-bentonite wall.

Vista Consultants

Client:	Port of Seattle	Date:	February 27, 2013
Project:	Terminal 91 - TFAA Cleanup	Proj. #:	12-33
Scenario:	Building M-28 East Wall		
Prepared by:	Roger B. North, P.E.	Page: 2	

Stresses From Distributed Load On Surface of Semi-Infinite Mass

OUTPUT VALUES FOR CASE WHEN X1 = X10 (i.e. FIXED DISTANCE FROM APPLIED LOAD)

Initial Vertical and Horizontal Stresses Due to Unit Weight Soil (psf)

Depth Below Load (ft)		Initial Vert Stress	Initial Horiz Stress
z1	1.0	115	58
z2	2.7	307	153
z3	4.3	498	249
z4	6.0	690	345
z5	7.7	882	441
z6	9.3	1073	537
z7	11.0	1265	633
z8	12.7	1457	728
z9	14.3	1648	824
z10	16.0	1840	920

Change in Vertical Stress Due To Imposed Load (σz, psf)

Depth Below Load (ft)		x1
		18.0
z1	1.0	0
z2	2.7	2
z3	4.3	7
z4	6.0	17
z5	7.7	30
z6	9.3	46
z7	11.0	61
z8	12.7	76
z9	14.3	90
z10	16.0	102

Change in Vertical Stress As % of Initial Vertical Stress (%)

Depth Below Load (ft)		x1
		18.0
z1	1.0	0
z2	2.7	1
z3	4.3	1
z4	6.0	2
z5	7.7	3
z6	9.3	4
z7	11.0	5
z8	12.7	5
z9	14.3	5
z10	16.0	6

Total Vertical Stress Due To Imposed Load and Initial Stress

Depth Below Load (ft)		x1
		18.0
z1	1.0	115
z2	2.7	309
z3	4.3	506
z4	6.0	707
z5	7.7	912
z6	9.3	1119
z7	11.0	1326
z8	12.7	1533
z9	14.3	1739
z10	16.0	1942

Change in Horizontal Stress Due To Imposed Load (σx, psf)

Depth Below Load (ft)		x1
		18.0
z1	1.0	26
z2	2.7	67
z3	4.3	99
z4	6.0	122
z5	7.7	135
z6	9.3	139
z7	11.0	137
z8	12.7	132
z9	14.3	123
z10	16.0	114

Change in Horizontal Stress As % of Initial Horizontal Stress (%)

Depth Below Load (ft)		x1
		18.0
z1	1.0	46
z2	2.7	44
z3	4.3	40
z4	6.0	35
z5	7.7	31
z6	9.3	26
z7	11.0	22
z8	12.7	18
z9	14.3	15
z10	16.0	12

Total Horizontal Stress Due To Imposed Load and Initial Stress

Depth Below Load (ft)		x1
		18.0
z1	1.0	84
z2	2.7	220
z3	4.3	349
z4	6.0	467
z5	7.7	576
z6	9.3	676
z7	11.0	770
z8	12.7	860
z9	14.3	947
z10	16.0	1034

Vista Consultants

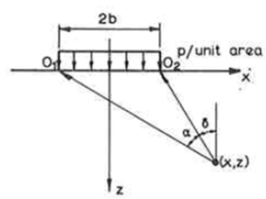
Client:	Port of Seattle	Date:	February 27, 2013
Project:	Terminal 91 - TFAA Cleanup	Proj. #:	12-33
Scenario:	Building M-28 North Wall		
Prepared by:	Roger B. North, P.E.	Page: 1	

Stresses From Distributed Load On Surface of Semi-Infinite Mass

Purpose:

Compute the stresses resulting from and uniform vertical strip loading on the surface of a semi-infinite mass, assuming elastic conditions, and the geometry and equations shown on the figure below (Poulos, H.G. and Davis E.H. [1974], Elastic Solutions for Soil and Rock Mechanics in Soil Mechanics, John Wiley & Sons, New York, pp. 36-38).

Imposed Loading Geometry



$\sigma z = p\,[\alpha + \sin\alpha.\cos(\alpha + 2\delta)]/\pi$

$\sigma x = p\,[\alpha - \sin\alpha.\cos(\alpha + 2\delta)]/\pi$

Initial Loads

γ = Unit weight of soil

k = Horizontal stress ratio (assumed in situ ratio of horizontal to vertical stresses)

z = Depth below surface

$\sigma z = \gamma.z$

$\sigma x = k.\gamma.z$

Problem Statement:

Assess the stresses at the cutoff wall due to the presence of the north wall of Building M-28, which is a single story building supported on a strip footing of unknown width. Assume 3 ft wide.

Assumptions

1. Assume conservatively the strip footing is located at the ground surface.

2. Width of footing is unknown. Assume it is 3-ft wide.
3. Assume soil weight of 115 pcf
4. Assume cutoff wall 18 ft from the center line of the footing.

5. Assume resulting footing load from concrete wall and additional building loads is building loads are modest and assume 1,500 psf.

INPUT VALUES (For Single Point Set x1 = x10 and z1 = z10)

γ =	115	(pcf) = Unit weight of soil
k =	0.5	= Horizontal stress ratio
p =	1500	(psf) = Imposed load per unit area
2b =	3	(ft) = Width of strip
x1 =	18	(ft) = Minimum distance from center line to consider
x10 =	18	(ft) = Maximum distance from center line to consider
z1 =	1	(ft) = Minimum depth from surface to consider
z10 =	16	(ft) = Maximum depth from surface to consider

CONCLUSION

See Page 2 for results. Resulting imposed loads on cutoff wall due to the existing structure are very small less than 60 psf for both vertical and horizontal stresses.
Acceptable for soil-bentonite wall.

Vista Consultants

Client:	Port of Seattle	Date:	February 27, 2013
Project:	Terminal 91 - TFAA Cleanup	Proj. #:	12-33
Scenario:	Building M-28 North Wall		
Prepared by:	Roger B. North, P.E.	Page: 2	

Stresses From Distributed Load On Surface of Semi-Infinite Mass

OUTPUT VALUES FOR CASE WHEN X1 = X10 (i.e. FIXED DISTANCE FROM APPLIED LOAD)

Initial Vertical and Horizontal Stresses Due to Unit Weight Soil (psf)

Depth Below Load (ft)		Initial Vert Stress	Initial Horiz Stress
z1	1.0	115	58
z2	2.7	307	153
z3	4.3	498	249
z4	6.0	690	345
z5	7.7	882	441
z6	9.3	1073	537
z7	11.0	1265	633
z8	12.7	1457	728
z9	14.3	1648	824
z10	16.0	1840	920

Change in Vertical Stress Due To Imposed Load (σz, psf)

Depth Below Load (ft)		x1
		18.0
z1	1.0	0
z2	2.7	1
z3	4.3	2
z4	6.0	5
z5	7.7	9
z6	9.3	14
z7	11.0	19
z8	12.7	25
z9	14.3	30
z10	16.0	35

Change in Vertical Stress As % of Initial Vertical Stress (%)

Depth Below Load (ft)		x1
		18.0
z1	1.0	0
z2	2.7	0
z3	4.3	0
z4	6.0	1
z5	7.7	1
z6	9.3	1
z7	11.0	2
z8	12.7	2
z9	14.3	2
z10	16.0	2

Total Vertical Stress Due To Imposed Load and Initial Stress

Depth Below Load (ft)		x1
		18.0
z1	1.0	115
z2	2.7	307
z3	4.3	500
z4	6.0	695
z5	7.7	891
z6	9.3	1087
z7	11.0	1284
z8	12.7	1482
z9	14.3	1679
z10	16.0	1875

Change in Horizontal Stress Due To Imposed Load (σx, psf)

Depth Below Load (ft)		x1
		18.0
z1	1.0	9
z2	2.7	23
z3	4.3	34
z4	6.0	43
z5	7.7	49
z6	9.3	51
z7	11.0	52
z8	12.7	50
z9	14.3	47
z10	16.0	44

Change in Horizontal Stress As % of Initial Horizontal Stress (%)

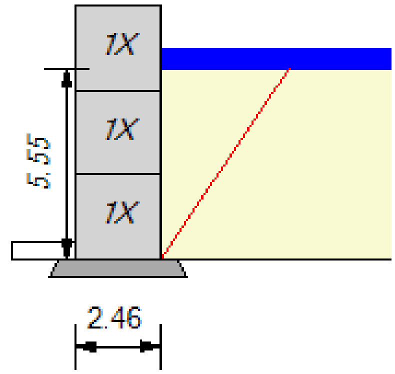
Depth Below Load (ft)		x1
		18.0
z1	1.0	15
z2	2.7	15
z3	4.3	14
z4	6.0	13
z5	7.7	11
z6	9.3	10
z7	11.0	8
z8	12.7	7
z9	14.3	6
z10	16.0	5

Total Horizontal Stress Due To Imposed Load and Initial Stress

Depth Below Load (ft)		x1
		18.0
z1	1.0	66
z2	2.7	176
z3	4.3	284
z4	6.0	388
z5	7.7	490
z6	9.3	588
z7	11.0	684
z8	12.7	778
z9	14.3	872
z10	16.0	964

Ultrablock, Inc

UltraWall version 3.1.13037



Project: Terminal 91 TFAA Cleanup
Location: TFA Adjacent to Building M-28
Designer: Roger North
Date: 3/1/2013
Section: Section 1
Design Method: NCMA_09_3rd_Ed
Design Unit: Ultrablock Full

Seismic Acc: 0.200

SOIL PARAMETERS	φ	coh	γ
Retained Soil:	30 deg	0 psf	120 pcf
Foundation Soil:	30 deg	0 psf	120 pcf

Leveling Pad: Crushed Stone

GEOMETRY

Design Height:	5.55 ft	Live Load:	100 psf
Wall Batter/Tilt:	0.00/ 0.00 deg	Live Load Offset:	0.00 ft
Embedment:	0.50 ft	Live Load Width:	100 ft
Leveling Pad Depth:	0.50 ft	Dead Load:	0 psf
Slope Angle:	0.0 deg	Dead Load Offset:	0.0 ft
Slope Length:	0.0 ft	Dead Load Width:	100 ft
Slope Toe Offset:	0.0 ft	Leveling Pad Width:	3.46 ft

Vertical δ on Single Depth

FACTORS OF SAFETY (Static / Seismic)

Sliding:	1.50 / 1.125	Overturning:	1.50 / 1.125
Bearing:	2.00 / 1.5		

RESULTS (Static / Seismic)

FoS Sliding:	2.54 (fnd) / 2.08	FoS Overturning:	2.25 / 1.44
Bearing:	1424.81 / 2105.28	FoS Bearing:	3.31 / 2.24

Name	Elev.	ka	kae	Pa	Pae	Pir	- PaC	FSsl	FoS OT	siesFSsl	FoS SeisOT
1X	4.92	0.297	0.369	7	9	87	0	100.00	100.00	100.00	29.70
1X	2.46	0.297	0.369	171	211	175	0	72.16	6.96	47.64	3.77
1X	0.00	0.297	0.369	549	681	262	0	2.62[2.54]	2.25	2.08[1.91]	1.44

Vista Consultants
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PORTLAND, OR 97239

Client:	Port of Seattle	Date:	March 2, 2013
Project:	Terminal 91 - TFAA Cleanup	Proj. #:	12-33
Scenario:	Geogrid Design To Span Cutoff Wall		
Prepared by:	Roger B. North, P.E.	Page:	1 of 3

Geogrid Design

Purpose:

Determine properties of appropriate geogrid to use to assist with spanning of the cutoff wall to prevent excessive deflection of the overlying final cover asphalt pavement.

References

1. Giroud, J.P. et. al. (1990). "Design of Soil Layer-Geosynthetic Systems Overlying Voids".
2. US Department of Transportation, Federal Highway Administration (2001). "Mechanically Stabilized EarthWalls and Reinforced Soil Slopes. Desig nadn Construction Guidelines." Publication Number FHWA-NHI-00-043.
3. Poulos H.G. and Davis E.H. (1974). Elastic Solutions for Soil and Rock Mechanics.
4. Tensar geogrid properties for determining allowable tensile loads at 5% strain
5. GRI Standard Paractice GG4(a). (2012). Determination of the Long-Term Design Strength of Stiff Geogrids.

Assumptions

1 Cutoff wall can be considered as an infinitely long inclusion, for use of Ref. 1.
2 Nominal width of cutoff wall = 2 ft. Material is SB with very low compressive and shear strenghs.
3 Proposed to mix 2 ft thick and 6 ft wide SCB zone at top of wall. Note the 6 ft with is ignored in these calculations, as it is assumed tha
4 Uniaxial geogrid witl span the cutoff wall
5 Backfill over geogrid will bea minimum of 1 ft of crushed rock, eg. Subbase 1.5 in. minus.

Computations

Using Reference 1, the following Notations and Values apply.

Notations, values and units for assumed values:

b	=	2	(ft)	Width of infinitely long void or depression
FS	=	1.25		Overall Factor of Safety for Design and Construction Uncertainties
H	=	2	(ft)	Thickness of soil layer
r	=	8	(in.)	Radius of applied wheel load on surface of final cover
RF_{DN}	=	1.1		Partial Reduction Factor for installation
RF_{CR}	=	2.0		Partial Reduction Factor for creep (2.0 selected since the deformation will be reduced by the SCB plug and deformations will be less than 5%.)
RF_{CD}	=	1.3		Partial Reduction Factor for chemical degradation (above water table, 1.3 selected to allow for LNAPL vapors)
RF_{BD}	=	1.1		Partial Reduction Factor for biological degradation (set in clean gravel, 1.1 selected per GRI typical allowance)
RF_{JCT}	=	1.0		Partial Reduction Factor for junction strength (No joints, grid only over trench)
RF_{JNT}	=	1.0		Partial Reduction Factor for joints - seams and connections.
γ	=	125	(pcf)	Density of soil above cutoffwall / geogrid

Notations and units for calculated values:

p	=	(psf) Pressure on the geosynthetic (vertical stresson bottom of soil layer) over the void.
p_b	=	(psf) Pressure transmitted to bottom of void when geogrid in contact with underlying material.
q	=	(psf) Live load at top of cutoff wall / geogrid
T_5	=	(lb/ft) Minimum product tensile strength required at 5% strain
T_{ULT}	=	(lb/ft) Ultimate tensile strength of geogrid
α	=	(lb/ft) Geogrid tension (force per unit width) corresponding to the geosynthetic strain ε
y	=	(ft) Depth void / deflection
ε	=	(Dimensionless) Strain
Ω	=	(dimensionless) Factor related to y and ε

Geogrid Design

Calculation approach

1. Assume applied live load die to a wheel load with tire pressure of 80 psi applied in a circular area of radius = 8 in.
   Ignore the effect of the triplanar geogrid - consider worst case loading.
   Calculate stress on top of cutoff wall at Depth = H below top of cover. (H = 2 (ft) * 12 (in.) = 24 in.)
   From Ref. 3, pg 44 - Fig. 3.14.
   - Depth in radius = H/r = 24/3 = 3
   - Offset = 0 (Computes load directly under applied load)
   - From Fig. 3.14, Stress = 15% of applied surface contact pressure (effect of overlying triplanar geogrid will be to increase distribution of load and reduce the stress below the applied load.)

   Resulting applied vertical stress at top geogrid / cutoff wall, **q =**
   q = 80 (psi) * 144 (sq in. per sq. ft) * 0.15 (% of applied pressure)
   q = 1,728 psf

2. Assume initially that only SB is present and the SB offers no resistance, then geogrid acts as though a void is present and geogrid has to withstand entire applied dead load (soil and cover) and live load.
   $p = 2\gamma b(1-e^{-0.5(H/b)}) + qe^{-0.5(H/b)}$ (Eqn 10 in Ref. 1)
   p = 197 + 1048 psf (i.e. pressure due to soil + pressure due to live load)
   p = 1245 psf

   Assume maximum 5% strain in geogrid (Typical working value quoted by manufacturer, e.g. Tensar - Ref. 4)
   Ω = 0.97 (Table 2 in Ref 1)
   y/b = 0.138 (Table 2 in Ref 1) (for 24-in. wide cutoff wall, this would imply a deflection of y = 0.128 * 24 = 3.3 in. This would represent excessive deformation under the final cover.

   Tension in geogrid $\alpha = pb\Omega$ (Eqn 15 in Ref 1)
   α = 1245 * 2 * 0.97
   α = 2415 lb/lf

   Per Ref 5. ,
   $\alpha < T_{ULT} /(FS * RF_{ID} * RF_{CR} * RF_{CD} * RF_{BD} * RF_{JCT} * RF_{JNT})$
   T_{ULT} >= α * (FS * RFID * RFCR * RFCD * RFBD * RFJCT * RFJNT)
   T_{ULT} >= 9497 lb/ft

   This will require a material such as UX1600HS (or equivalent), which has a manufacturere quoted ultimate tensile strength of 9.870 lb/ft and a tensile strength at 5% of 3,980 lb/ft.

3. Asses the effect of void not forming and geogrid being in contact with the underlying SCB, based on the following equation.
   $p_b = 2\gamma b(1-e^{-0.5(H/b)}) + qe^{-0.5(H/b)} - \alpha/(b\Omega)$ (Eqn 24 in Ref. 1)

   Assume a maximum deflection (y) of 1in. Then:
   y/b = 1/24
   y/b = 0.042
   And:
   ε = 0.47 % (Table 2 in Ref 1)
   Ω = 3.03 (Table 2 in Ref 1)

Geogrid Design

And:

Assuming Tensar UX1600HS with Tensile Strength at 5% strain = 3,980 lb/ft

α = 3980*0.47/5

α = 374 lb/ft

p_b = 1183 psf

4. Therefore the design can be summarized as follows:
   - A stress from a wheel load at 80 psi is applied to the final cover
   - As a result of load distribution (ignoring proosed triplanar geogrid below the subbase) 1245 psf (including soil layers) is transmitted to the top of the geogrid / top of cutoff wall.
   - The geogrid would support 2,414 lb/lf with free deformation into an SB wall.
   - With limited deflection, the geogrid supports 374 lb/lf
   - With limited deflection, the remainder, 1,183 psf is transmitted to the SCB material. Expected unconfined compressive strength of SCB is approximately 10,000 psf. Therefore it will be able to support this load. And shear strength across the 2 ft thick SCB will be approx 300 psf.

5. Consider resistance to pull out force in geogrid.

   Using:

   $P_F = F*\alpha*\sigma_v*L_e*C$ from Ref 2, Equ.1 pg 56

where:

P_F = (lb/ft) Pullout resistance per foot. Needs to exceed the geogrid tensile force

F = Tan Ø , where Ø is the friction angle for the soil. For angular gravel assume 37 degrees, conservatively.

α = 0.8 Scale correction factor - recommended value for geogrids

σv = γH = vertical effective stress on the geogrid (γ from above 125 pcf) and (H= 2 ft over 5 ft, then 3 ft for 2 ft - vertical portion of anchor trench, and 4 ft over the 2 ft width of anchor rtrench)

L_e = 9 (ft) Length of geogrid from edge of cut off wall.

C = 2 Reinforcement effective unit perimeter (2 for geogrids)

P_F = 3617 lb/ft

This resistance represents the following factors of safety:

- For resistance to pull out assuming contact with SCB and limited deflection

  FS = 3617 / 374

  FS = 9.7 >= 1.5 Acceptable

- For resistance to pull out assuming no contact with SCB and full tensile load developed in geogrid - very conservative.

  FS = 3617 / 2415

  FS = 1.5 >= 1.5 Acceptable

APPENDIX A6
Engineered Fill Selection

LNAPL TRENCH GRADATION

Available Grading Information of Native Soils from about upper 10 ft

Sample	Depth	D15 (mm)	D85 (mm)	D50 (mm)
B-1	4 -10 ft	0.2	6	0.4
B-2	4 -10 ft	0.19	1.2	0.33
B-3	3.5 -10 ft	0.16	3.5	0.31
B-4	4 - 10 ft	0.33	16	0.8
B-5	4.5 - 14 ft	0.34	12	1.2
B-6	3 - 10 ft	0.09	2	0.27
B-8	4 - 10 ft	0.17	7	0.35
	Avg	0.21	6.81	0.52
	Max	0.34	16	1.2
	Min	0.09	1.2	0.27

Reference: Seepage, Drainage, and Flow Nets (Harry R. Cedergreen, 1967. John Wiley & Sons, Inc., pg 174 to 179)

Gradation Criteria for Drainage Filter

Where:

(F) Filter

(S) Soil retained

Critical values for specification (shaded)

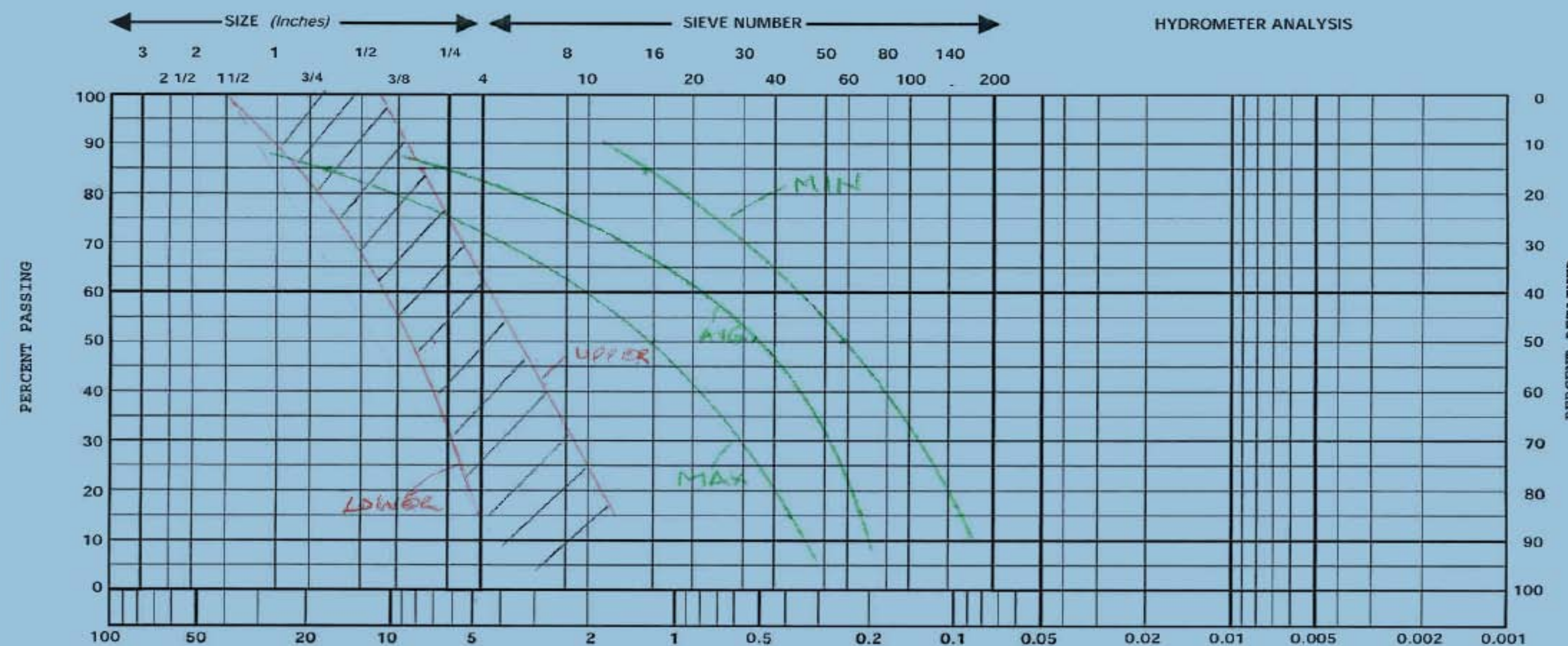
Filter Criteria for Stabily Against Piping	D15(F)	<= (4 to 5)*D85(S)	=	27.3	(mm) Based on D85(S) Avg. Value
	D15(F)	<= (4 to 5)*D85(S)	=	64.0	(mm) Based on D85(S) Max. Value
	D15(F)	<= (4 to 5)*D85(S)	=	4.8	(mm) Based on D85(S) Min. Value
Filter Criteria for Adequate Permeability	D15(F)	>= (4 to 5)*D15(S)	=	1.1	(mm) Based on D15(S) Avg. Value
	D15(F)	>= (4 to 5)*D15(S)	=	1.7	(mm) Based on D15(S) Max. Value
	D15(F)	>= (4 to 5)*D15(S)	=	0.5	(mm) Based on D15(S) Min. Value
Filter Criteria Based on Pipe Slot Size	D85(F)	>= 1.2* Slot Width	=	7.5	(mm) Based on 1/4-in. slot width
A secondary sometimes used Criteria for Stability Against Piping	D50(F)	<= 25*D50(S)	=	13.1	(mm) Based on D50(S) Avg. Value
	D50(F)	<= 25*D50(S)	=	30.0	(mm) Based on D50(S) Max. Value
	D50(F)	<= 25*D50(S)	=	6.8	(mm) Based on D50(S) Min. Value

GRAIN SIZE DISTRIBUTION GRAPH - AGGREGATE GRADATION CHART

1. PROJECT T91 TFAA CLEANUP - LNAPL TRENCH

2. DATE 2/6/13.

SIEVE ANALYSIS - US STANDARD SIEVE SIZES



GRAIN SIZE IN MILLIMETERS

EXCAVATION NUMBER	SAMPLE NUMBER	LL	PL	PI	Cu (D_{60}/D_{10})	Cc $(D_{30})^2/(D_{60} \times D_{10})$	SOIL DESCRIPTION/REMARKS	CLASSIFICATION (USCS)

3. TECHNICIAN *(Signature)*

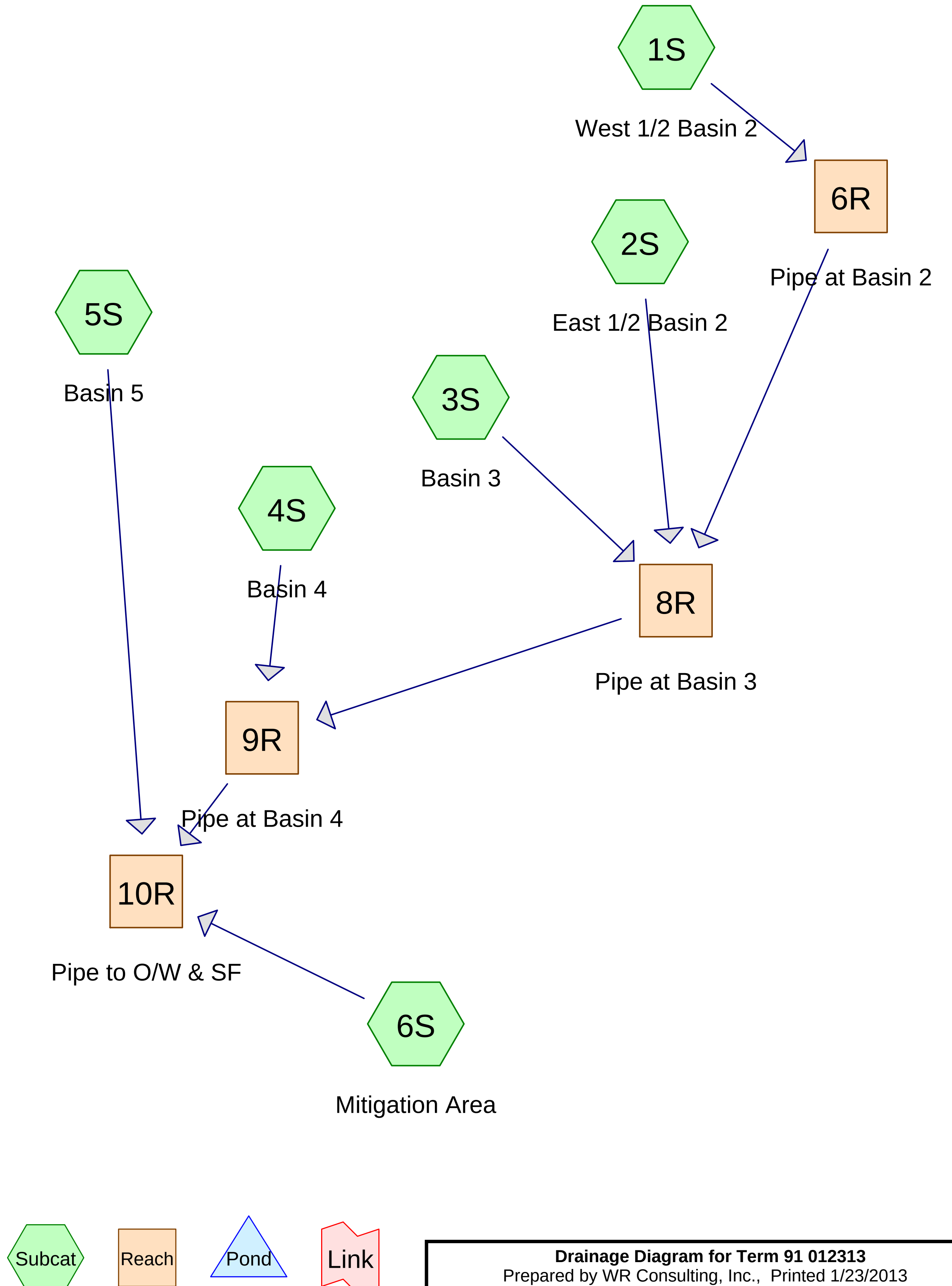
4. PLOTTED BY *(Signature)*

5. CHECKED BY *(Signature)*

APPENDIX A7
Stormwater Calculations

ATTACHMENT A

STORMWATER HYDROGRAPHS



Drainage Diagram for Term 91 012313
Prepared by WR Consulting, Inc., Printed 1/23/2013
HydroCAD® 8.50 s/n 005771 © 2007 HydroCAD Software Solutions LLC

Area Listing (all nodes)

Area (acres)	CN	Description (subcatchment-numbers)
2.470	98	Paved parking & roofs (1S,2S,3S,4S,6S)
0.765	98	Paved roads w/curbs & sewers (5S)
3.234		**TOTAL AREA**

Time span=0.00-30.00 hrs, dt=0.01 hrs, 3001 points
Runoff by SCS TR-20 method, UH=SCS
Reach routing by Stor-Ind+Trans method - Pond routing by Stor-Ind method

Subcatchment 1S: West 1/2 Basin 2 Runoff Area=13,413 sf 100.00% Impervious Runoff Depth=2.57"
Flow Length=150' Slope=0.0200 '/' Tc=2.3 min CN=98 Runoff=0.20 cfs 0.066 af

Subcatchment 2S: East 1/2 Basin 2 Runoff Area=13,413 sf 100.00% Impervious Runoff Depth=2.57"
Flow Length=200' Slope=0.0190 '/' Tc=3.0 min CN=98 Runoff=0.20 cfs 0.066 af

Subcatchment 3S: Basin 3 Runoff Area=18,692 sf 100.00% Impervious Runoff Depth=2.57"
Flow Length=170' Slope=0.0220 '/' Tc=2.5 min CN=98 Runoff=0.28 cfs 0.092 af

Subcatchment 4S: Basin 4 Runoff Area=32,059 sf 100.00% Impervious Runoff Depth=2.57"
Flow Length=200' Slope=0.0220 '/' Tc=2.8 min CN=98 Runoff=0.49 cfs 0.158 af

Subcatchment 5S: Basin 5 Runoff Area=33,317 sf 100.00% Impervious Runoff Depth=2.57"
Flow Length=215' Slope=0.0210 '/' Tc=3.0 min CN=98 Runoff=0.51 cfs 0.164 af

Subcatchment 6S: Mitigation Area Runoff Area=30,000 sf 100.00% Impervious Runoff Depth=2.57"
Flow Length=400' Slope=0.0100 '/' Tc=7.2 min CN=98 Runoff=0.45 cfs 0.147 af

Reach 6R: Pipe at Basin 2 Avg. Depth=0.25' Max Vel=1.67 fps Inflow=0.20 cfs 0.066 af
D=8.0" n=0.013 L=180.0' S=0.0030 '/' Capacity=0.66 cfs Outflow=0.20 cfs 0.066 af

Reach 8R: Pipe at Basin 3 Avg. Depth=0.41' Max Vel=2.27 fps Inflow=0.69 cfs 0.224 af
D=12.0" n=0.013 L=206.0' S=0.0030 '/' Capacity=1.95 cfs Outflow=0.69 cfs 0.224 af

Reach 9R: Pipe at Basin 4 Avg. Depth=0.56' Max Vel=2.60 fps Inflow=1.17 cfs 0.381 af
D=12.0" n=0.013 L=276.0' S=0.0030 '/' Capacity=1.95 cfs Outflow=1.17 cfs 0.381 af

Reach 10R: Pipe to O/W & SF Avg. Depth=0.73' Max Vel=3.45 fps Inflow=2.13 cfs 0.692 af
D=12.0" n=0.013 L=22.0' S=0.0045 '/' Capacity=2.40 cfs Outflow=2.13 cfs 0.692 af

Total Runoff Area = 3.234 ac Runoff Volume = 0.692 af Average Runoff Depth = 2.57"
0.00% Pervious = 0.000 ac 100.00% Impervious = 3.234 ac

Summary for Subcatchment 1S: West 1/2 Basin 2

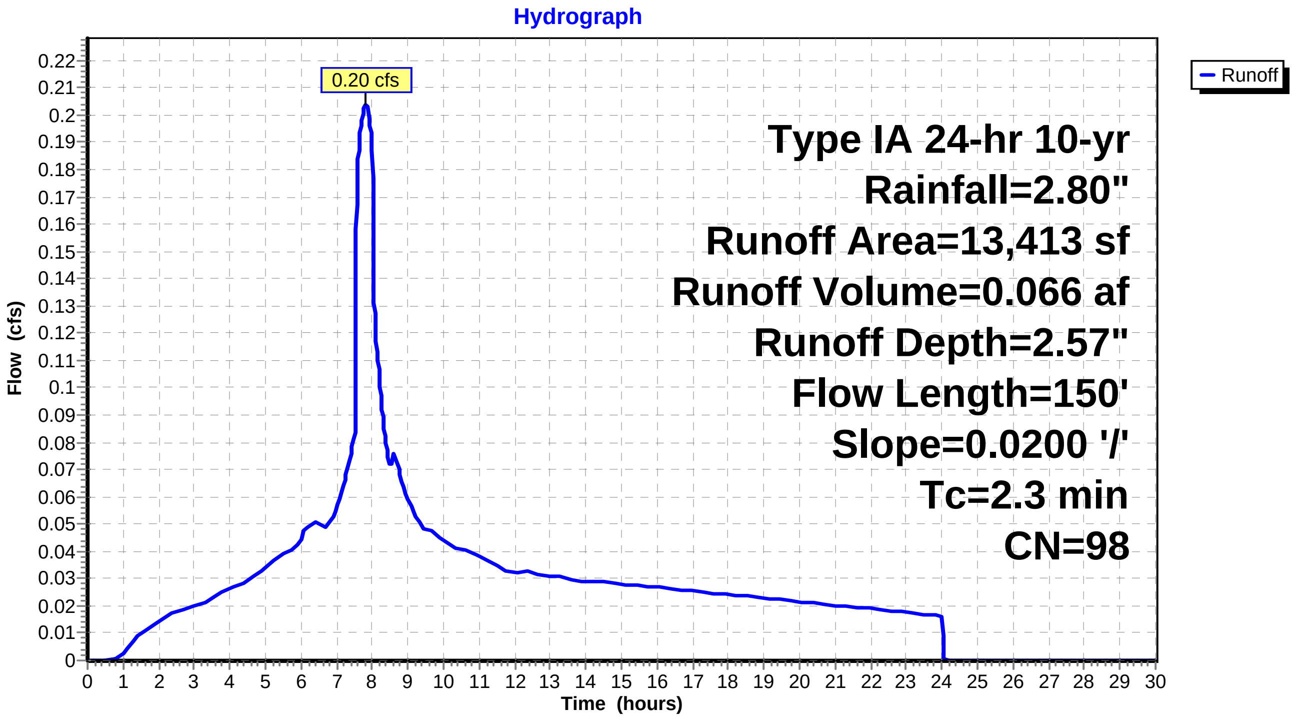
Runoff = 0.20 cfs @ 7.82 hrs, Volume= 0.066 af, Depth= 2.57"

Runoff by SCS TR-20 method, UH=SCS, Time Span= 0.00-30.00 hrs, dt= 0.01 hrs
Type IA 24-hr 10-yr Rainfall=2.80"

Area (sf)	CN	Description
13,413	98	Paved parking & roofs
13,413		Impervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
2.3	150	0.0200	1.07		**Lag/CN Method,**

Subcatchment 1S: West 1/2 Basin 2



Summary for Subcatchment 2S: East 1/2 Basin 2

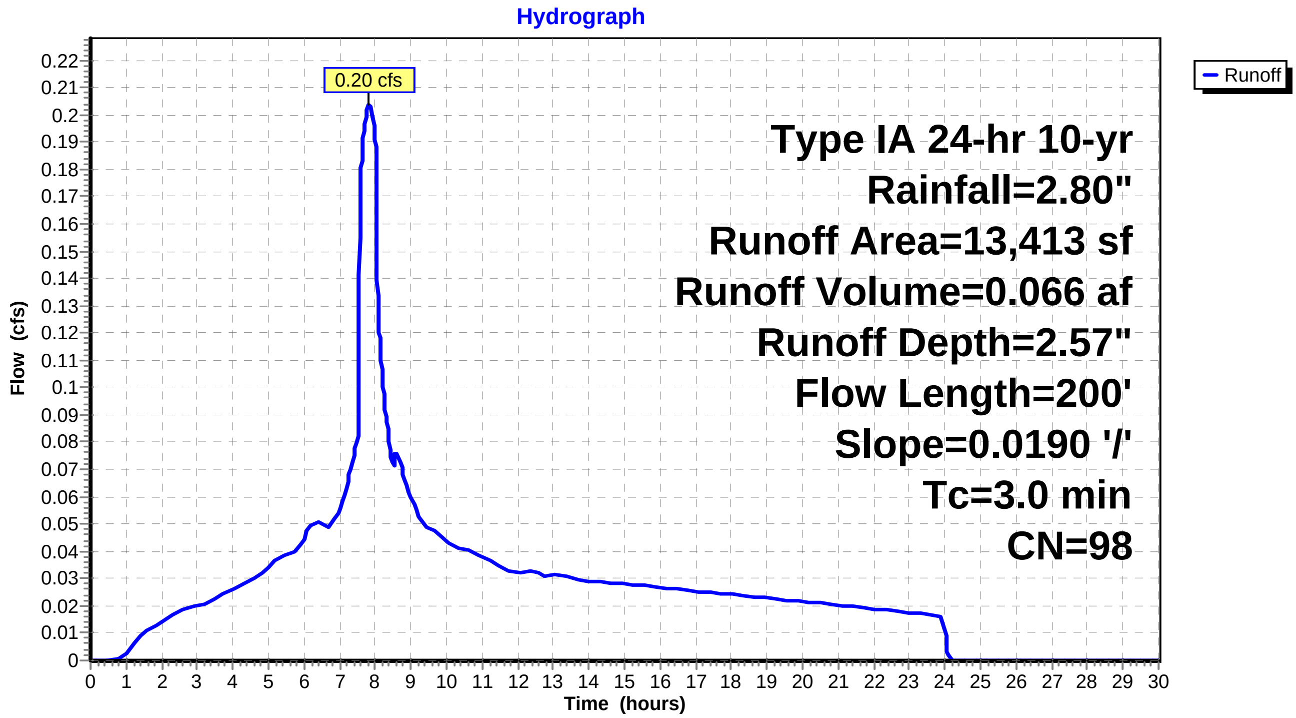
Runoff = 0.20 cfs @ 7.82 hrs, Volume= 0.066 af, Depth= 2.57"

Runoff by SCS TR-20 method, UH=SCS, Time Span= 0.00-30.00 hrs, dt= 0.01 hrs
Type IA 24-hr 10-yr Rainfall=2.80"

Area (sf)	CN	Description
13,413	98	Paved parking & roofs
13,413		Impervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
3.0	200	0.0190	1.11		**Lag/CN Method,**

Subcatchment 2S: East 1/2 Basin 2



Summary for Subcatchment 3S: Basin 3

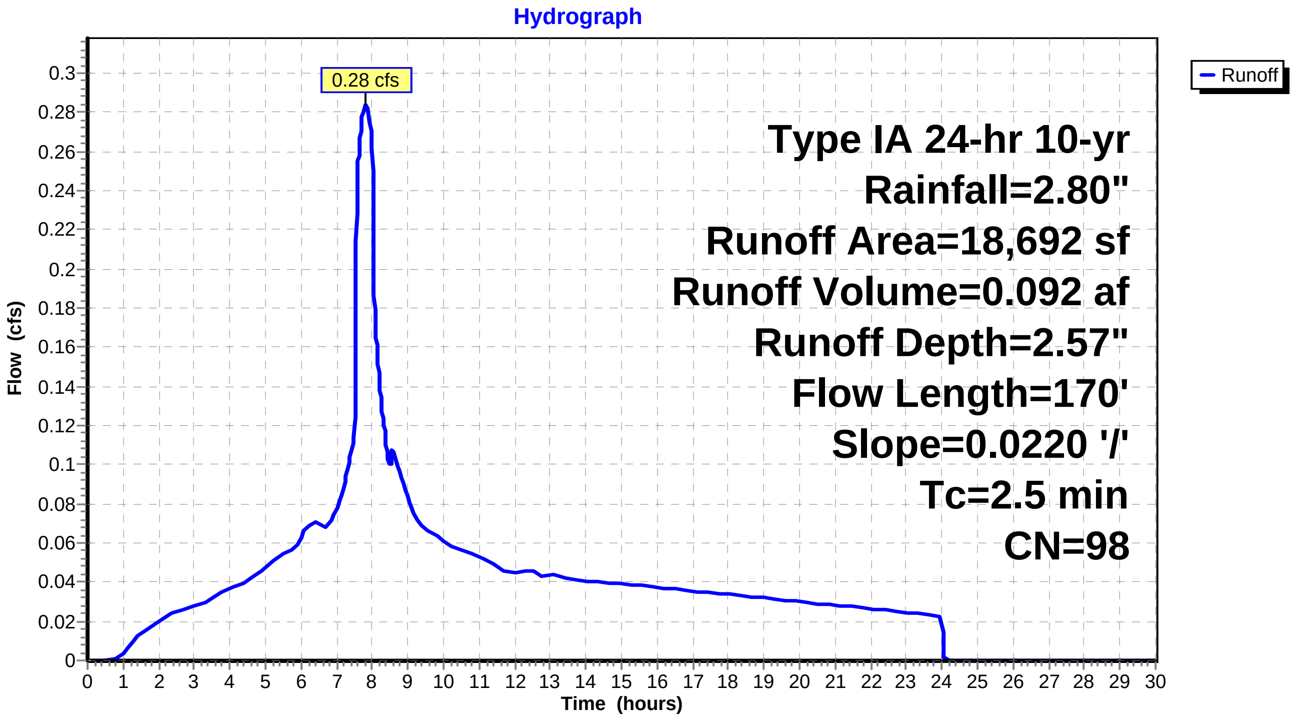
Runoff = 0.28 cfs @ 7.82 hrs, Volume= 0.092 af, Depth= 2.57"

Runoff by SCS TR-20 method, UH=SCS, Time Span= 0.00-30.00 hrs, dt= 0.01 hrs
Type IA 24-hr 10-yr Rainfall=2.80"

Area (sf)	CN	Description
18,692	98	Paved parking & roofs
18,692		Impervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
2.5	170	0.0220	1.15		**Lag/CN Method,**

Subcatchment 3S: Basin 3



Summary for Subcatchment 4S: Basin 4

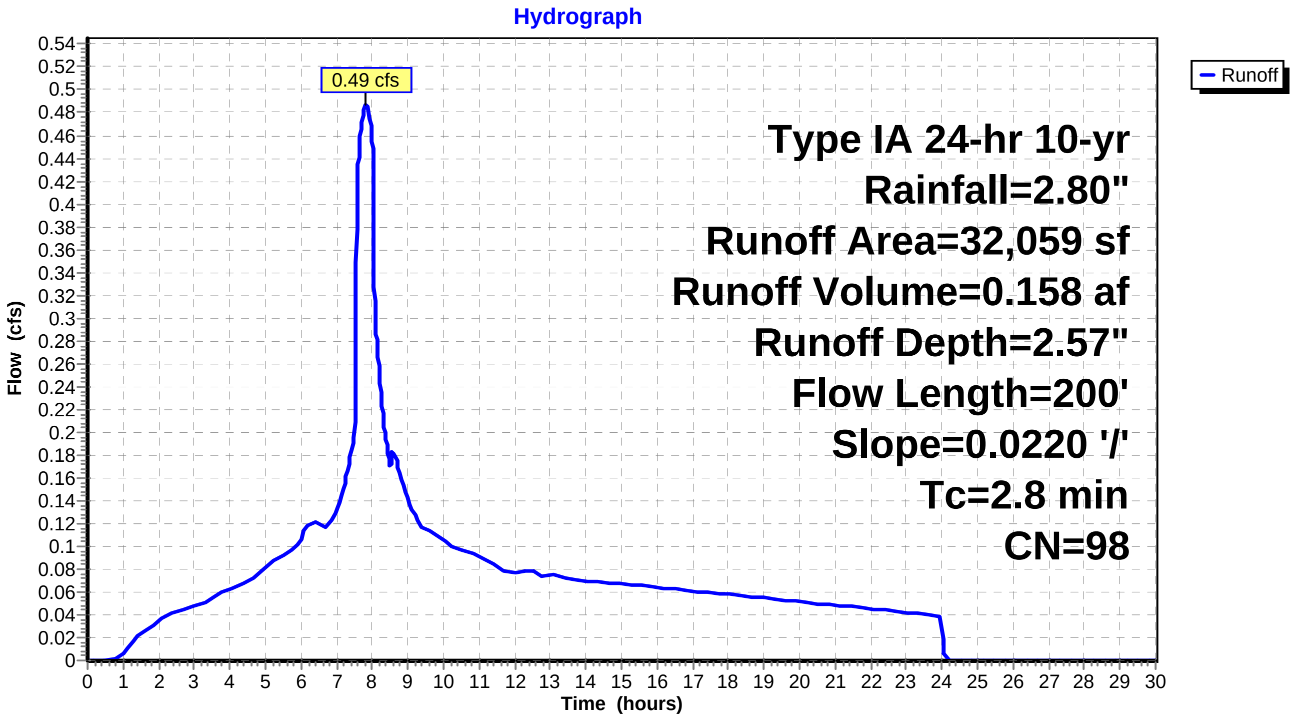
Runoff = 0.49 cfs @ 7.82 hrs, Volume= 0.158 af, Depth= 2.57"

Runoff by SCS TR-20 method, UH=SCS, Time Span= 0.00-30.00 hrs, dt= 0.01 hrs
Type IA 24-hr 10-yr Rainfall=2.80"

Area (sf)	CN	Description
32,059	98	Paved parking & roofs
32,059		Impervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
2.8	200	0.0220	1.19		**Lag/CN Method,**

Subcatchment 4S: Basin 4



Summary for Subcatchment 5S: Basin 5

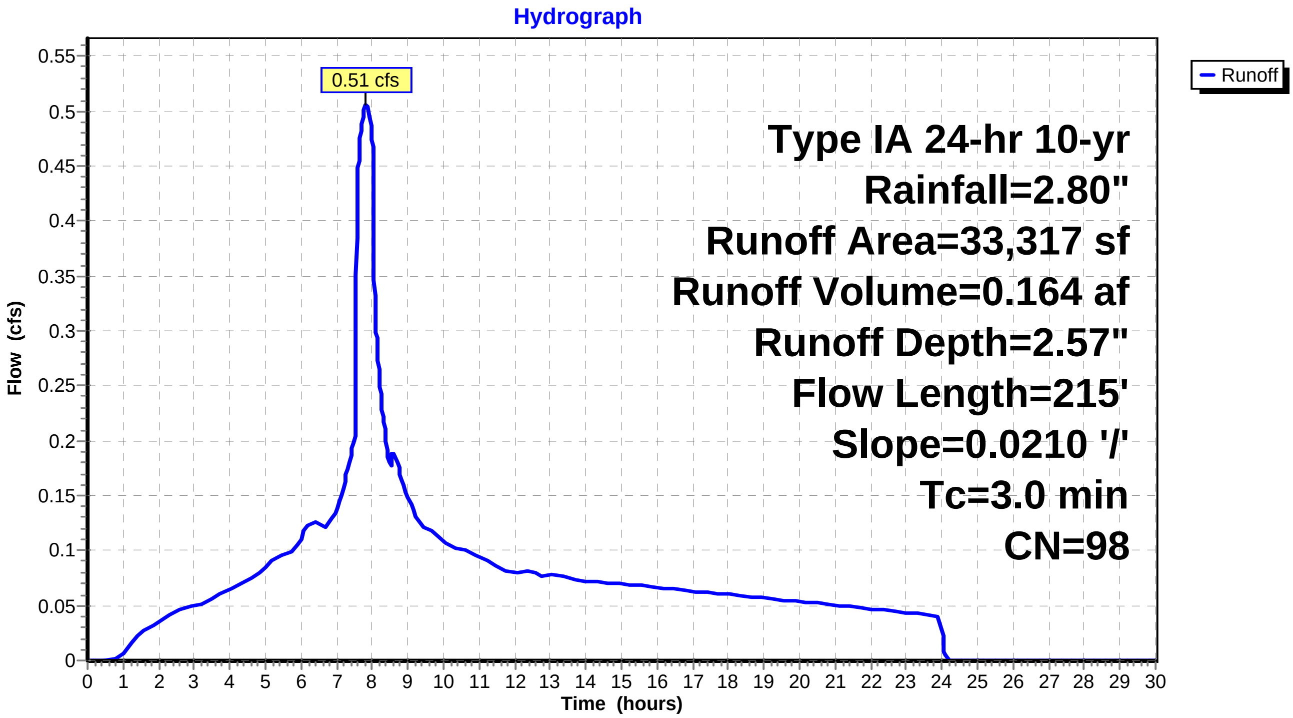
Runoff = 0.51 cfs @ 7.82 hrs, Volume= 0.164 af, Depth= 2.57"

Runoff by SCS TR-20 method, UH=SCS, Time Span= 0.00-30.00 hrs, dt= 0.01 hrs
Type IA 24-hr 10-yr Rainfall=2.80"

Area (sf)	CN	Description
33,317	98	Paved roads w/curbs & sewers
33,317		Impervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
3.0	215	0.0210	1.18		**Lag/CN Method,**

Subcatchment 5S: Basin 5



Summary for Subcatchment 6S: Mitigation Area

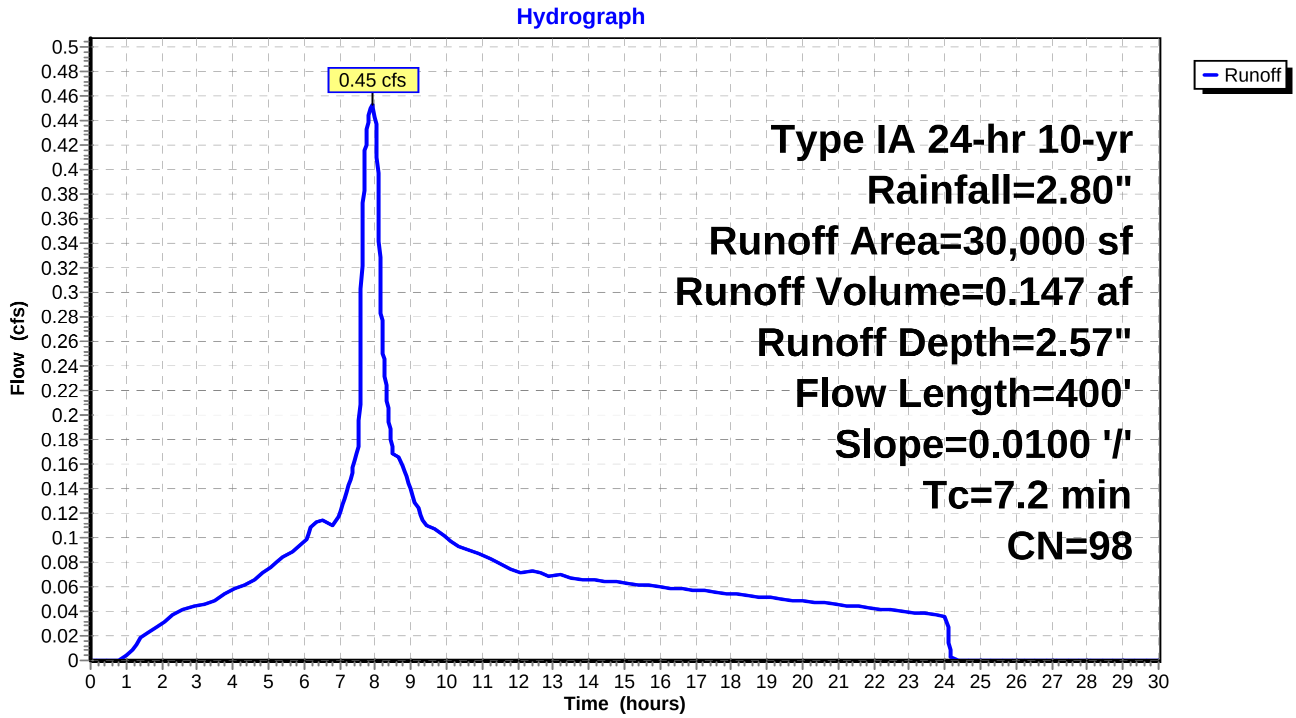
Runoff = 0.45 cfs @ 7.90 hrs, Volume= 0.147 af, Depth= 2.57"

Runoff by SCS TR-20 method, UH=SCS, Time Span= 0.00-30.00 hrs, dt= 0.01 hrs
Type IA 24-hr 10-yr Rainfall=2.80"

Area (sf)	CN	Description
30,000	98	Paved parking & roofs
30,000		Impervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
7.2	400	0.0100	0.92		**Lag/CN Method,**

Subcatchment 6S: Mitigation Area



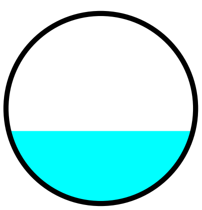
Summary for Reach 6R: Pipe at Basin 2

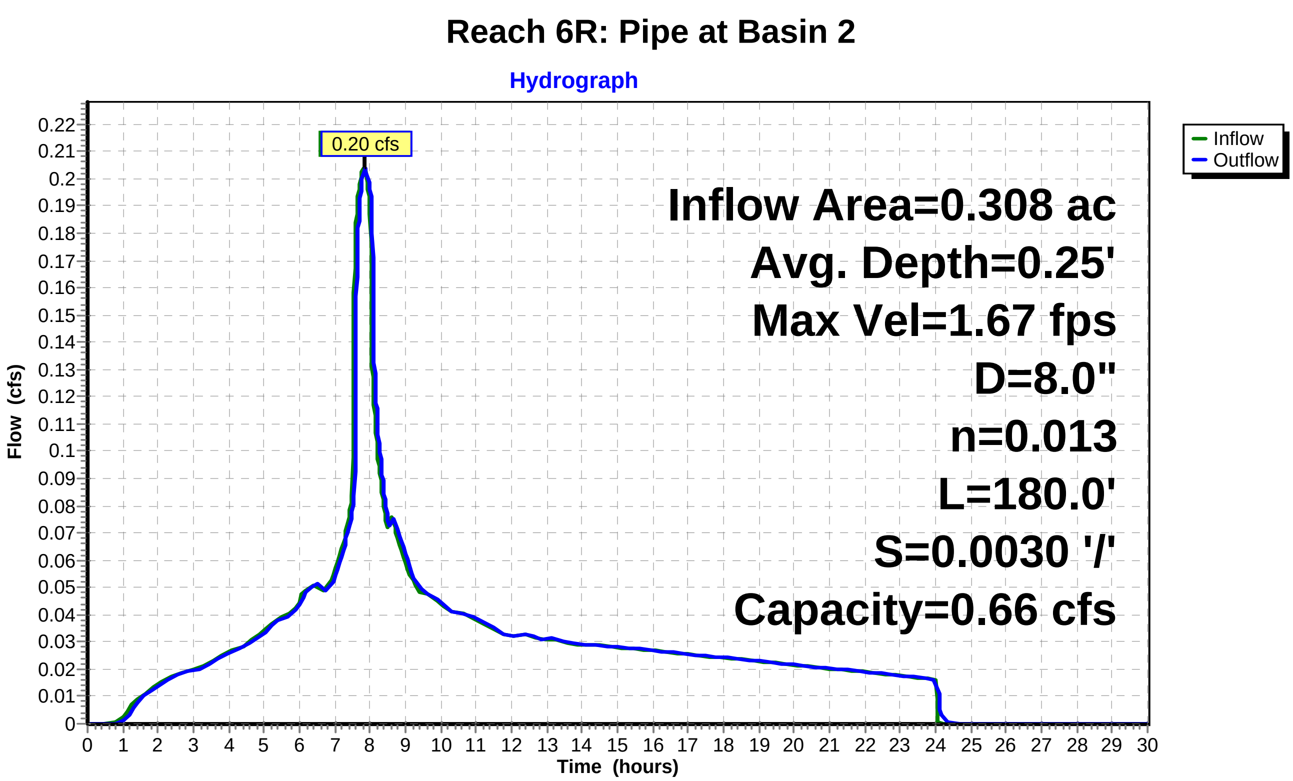
Inflow Area = 0.308 ac,100.00% Impervious, Inflow Depth = 2.57" for 10-yr event
Inflow = 0.20 cfs @ 7.82 hrs, Volume= 0.066 af
Outflow = 0.20 cfs @ 7.87 hrs, Volume= 0.066 af, Atten= 0%, Lag= 3.1 min

Routing by Stor-Ind+Trans method, Time Span= 0.00-30.00 hrs, dt= 0.01 hrs
Max. Velocity= 1.67 fps, Min. Travel Time= 1.8 min
Avg. Velocity = 0.92 fps, Avg. Travel Time= 3.2 min

Peak Storage= 22 cf @ 7.84 hrs, Average Depth at Peak Storage= 0.25'
Bank-Full Depth= 0.67', Capacity at Bank-Full= 0.66 cfs

8.0" Diameter Pipe, n= 0.013 Corrugated PE, smooth interior
Length= 180.0' Slope= 0.0030 '/'
Inlet Invert= 15.79', Outlet Invert= 15.25'





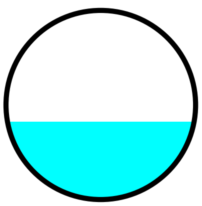
Summary for Reach 8R: Pipe at Basin 3

Inflow Area = 1.045 ac,100.00% Impervious, Inflow Depth = 2.57" for 10-yr event
Inflow = 0.69 cfs @ 7.84 hrs, Volume= 0.224 af
Outflow = 0.69 cfs @ 7.88 hrs, Volume= 0.224 af, Atten= 0%, Lag= 2.5 min

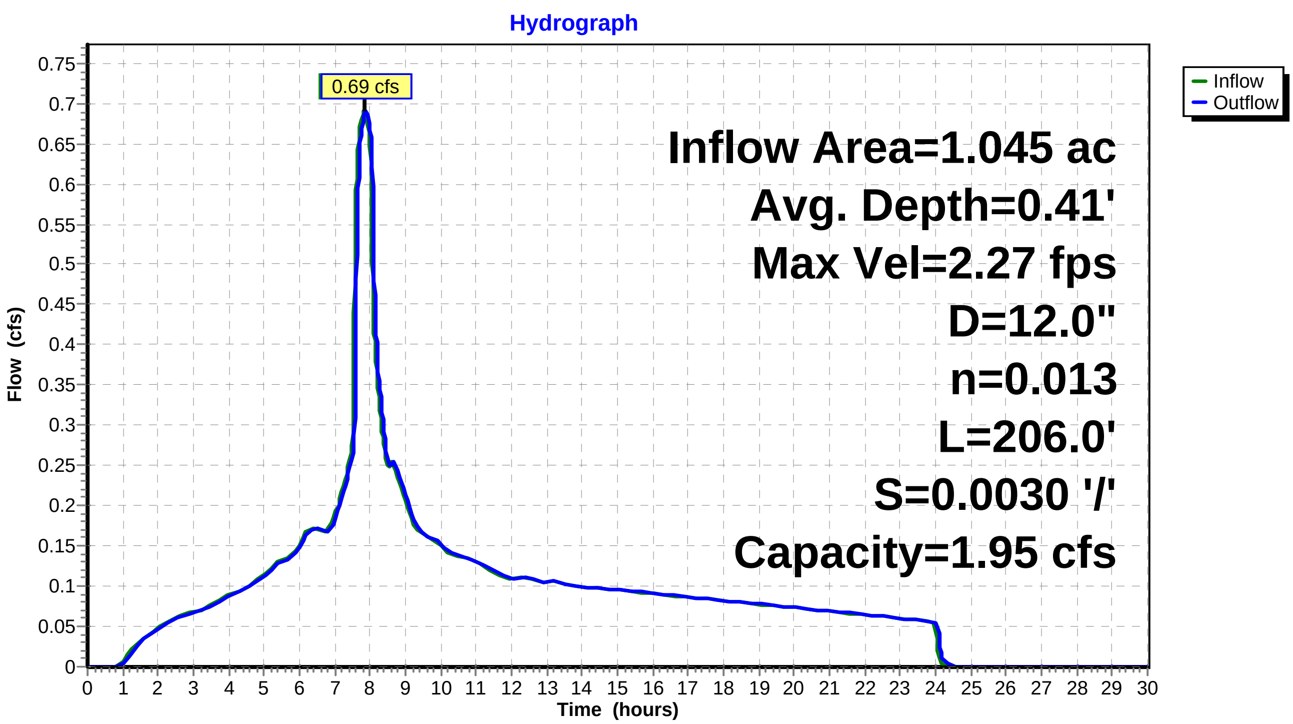
Routing by Stor-Ind+Trans method, Time Span= 0.00-30.00 hrs, dt= 0.01 hrs
Max. Velocity= 2.27 fps, Min. Travel Time= 1.5 min
Avg. Velocity = 1.25 fps, Avg. Travel Time= 2.8 min

Peak Storage= 63 cf @ 7.86 hrs, Average Depth at Peak Storage= 0.41'
Bank-Full Depth= 1.00', Capacity at Bank-Full= 1.95 cfs

12.0" Diameter Pipe, n= 0.013
Length= 206.0' Slope= 0.0030 '/'
Inlet Invert= 15.25', Outlet Invert= 14.63'



Reach 8R: Pipe at Basin 3



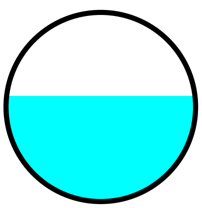
Summary for Reach 9R: Pipe at Basin 4

Inflow Area = 1.781 ac,100.00% Impervious, Inflow Depth = 2.57" for 10-yr event
Inflow = 1.17 cfs @ 7.86 hrs, Volume= 0.381 af
Outflow = 1.17 cfs @ 7.91 hrs, Volume= 0.381 af, Atten= 0%, Lag= 3.1 min

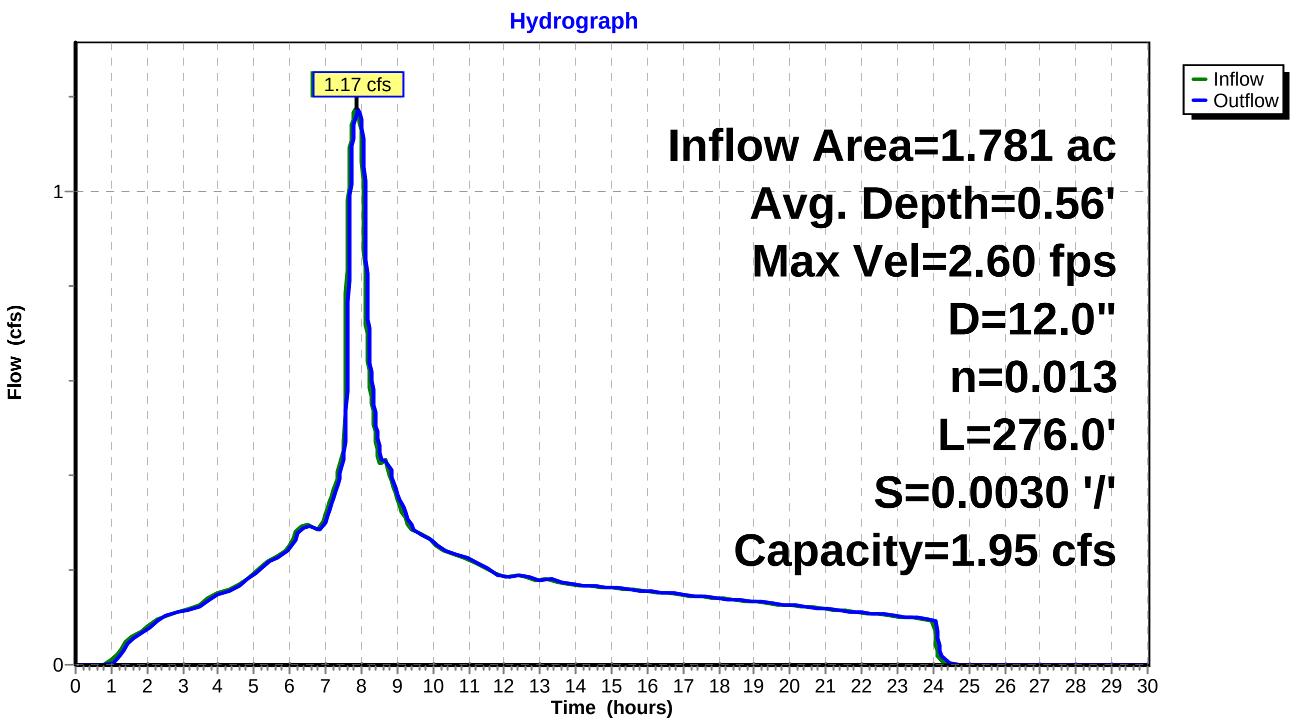
Routing by Stor-Ind+Trans method, Time Span= 0.00-30.00 hrs, dt= 0.01 hrs
Max. Velocity= 2.60 fps, Min. Travel Time= 1.8 min
Avg. Velocity = 1.43 fps, Avg. Travel Time= 3.2 min

Peak Storage= 125 cf @ 7.88 hrs, Average Depth at Peak Storage= 0.56'
Bank-Full Depth= 1.00', Capacity at Bank-Full= 1.95 cfs

12.0" Diameter Pipe, n= 0.013 Corrugated PE, smooth interior
Length= 276.0' Slope= 0.0030 '/'
Inlet Invert= 14.63', Outlet Invert= 13.80'



Reach 9R: Pipe at Basin 4



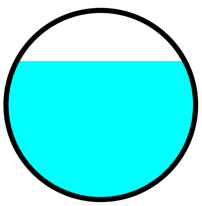
Summary for Reach 10R: Pipe to O/W & SF

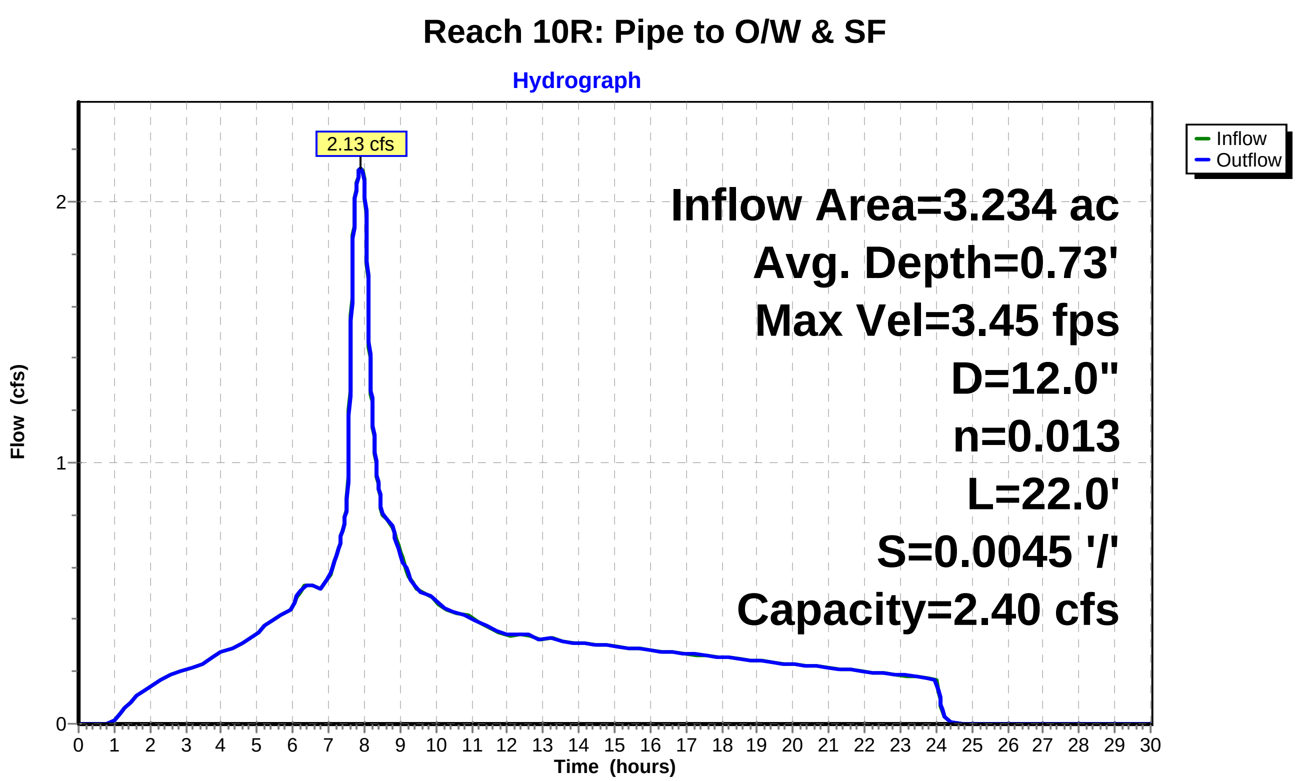
Inflow Area = 3.234 ac,100.00% Impervious, Inflow Depth = 2.57" for 10-yr event
Inflow = 2.13 cfs @ 7.88 hrs, Volume= 0.692 af
Outflow = 2.13 cfs @ 7.89 hrs, Volume= 0.692 af, Atten= 0%, Lag= 0.4 min

Routing by Stor-Ind+Trans method, Time Span= 0.00-30.00 hrs, dt= 0.01 hrs
Max. Velocity= 3.45 fps, Min. Travel Time= 0.1 min
Avg. Velocity = 1.96 fps, Avg. Travel Time= 0.2 min

Peak Storage= 14 cf @ 7.89 hrs, Average Depth at Peak Storage= 0.73'
Bank-Full Depth= 1.00', Capacity at Bank-Full= 2.40 cfs

12.0" Diameter Pipe, n= 0.013 Corrugated PE, smooth interior
Length= 22.0' Slope= 0.0045 '/'
Inlet Invert= 13.80', Outlet Invert= 13.70'





Time span=0.00-30.00 hrs, dt=0.01 hrs, 3001 points
Runoff by SCS TR-20 method, UH=SCS
Reach routing by Stor-Ind+Trans method - Pond routing by Stor-Ind method

Subcatchment 1S: West 1/2 Basin 2 Runoff Area=13,413 sf 100.00% Impervious Runoff Depth=3.77"
Flow Length=150' Slope=0.0200 '/' Tc=2.3 min CN=98 Runoff=0.30 cfs 0.097 af

Subcatchment 2S: East 1/2 Basin 2 Runoff Area=13,413 sf 100.00% Impervious Runoff Depth=3.77"
Flow Length=200' Slope=0.0190 '/' Tc=3.0 min CN=98 Runoff=0.29 cfs 0.097 af

Subcatchment 3S: Basin 3 Runoff Area=18,692 sf 100.00% Impervious Runoff Depth=3.77"
Flow Length=170' Slope=0.0220 '/' Tc=2.5 min CN=98 Runoff=0.41 cfs 0.135 af

Subcatchment 4S: Basin 4 Runoff Area=32,059 sf 100.00% Impervious Runoff Depth=3.77"
Flow Length=200' Slope=0.0220 '/' Tc=2.8 min CN=98 Runoff=0.71 cfs 0.231 af

Subcatchment 5S: Basin 5 Runoff Area=33,317 sf 100.00% Impervious Runoff Depth=3.77"
Flow Length=215' Slope=0.0210 '/' Tc=3.0 min CN=98 Runoff=0.73 cfs 0.240 af

Subcatchment 6S: Mitigation Area Runoff Area=30,000 sf 100.00% Impervious Runoff Depth=3.77"
Flow Length=400' Slope=0.0100 '/' Tc=7.2 min CN=98 Runoff=0.66 cfs 0.216 af

Reach 6R: Pipe at Basin 2 Avg. Depth=0.31' Max Vel=1.84 fps Inflow=0.30 cfs 0.097 af
D=8.0" n=0.013 L=180.0' S=0.0030 '/' Capacity=0.66 cfs Outflow=0.29 cfs 0.097 af

Reach 8R: Pipe at Basin 3 Avg. Depth=0.51' Max Vel=2.50 fps Inflow=1.00 cfs 0.328 af
D=12.0" n=0.013 L=206.0' S=0.0030 '/' Capacity=1.95 cfs Outflow=1.00 cfs 0.328 af

Reach 9R: Pipe at Basin 4 Avg. Depth=0.72' Max Vel=2.80 fps Inflow=1.70 cfs 0.559 af
D=12.0" n=0.013 L=276.0' S=0.0030 '/' Capacity=1.95 cfs Outflow=1.70 cfs 0.559 af

Reach 10R: Pipe to O/W & SF Avg. Depth=1.00' Max Vel=3.49 fps Inflow=3.08 cfs 1.015 af
D=12.0" n=0.013 L=22.0' S=0.0045 '/' Capacity=2.40 cfs Outflow=2.55 cfs 1.015 af

Total Runoff Area = 3.234 ac Runoff Volume = 1.015 af Average Runoff Depth = 3.77"
0.00% Pervious = 0.000 ac 100.00% Impervious = 3.234 ac

Summary for Subcatchment 1S: West 1/2 Basin 2

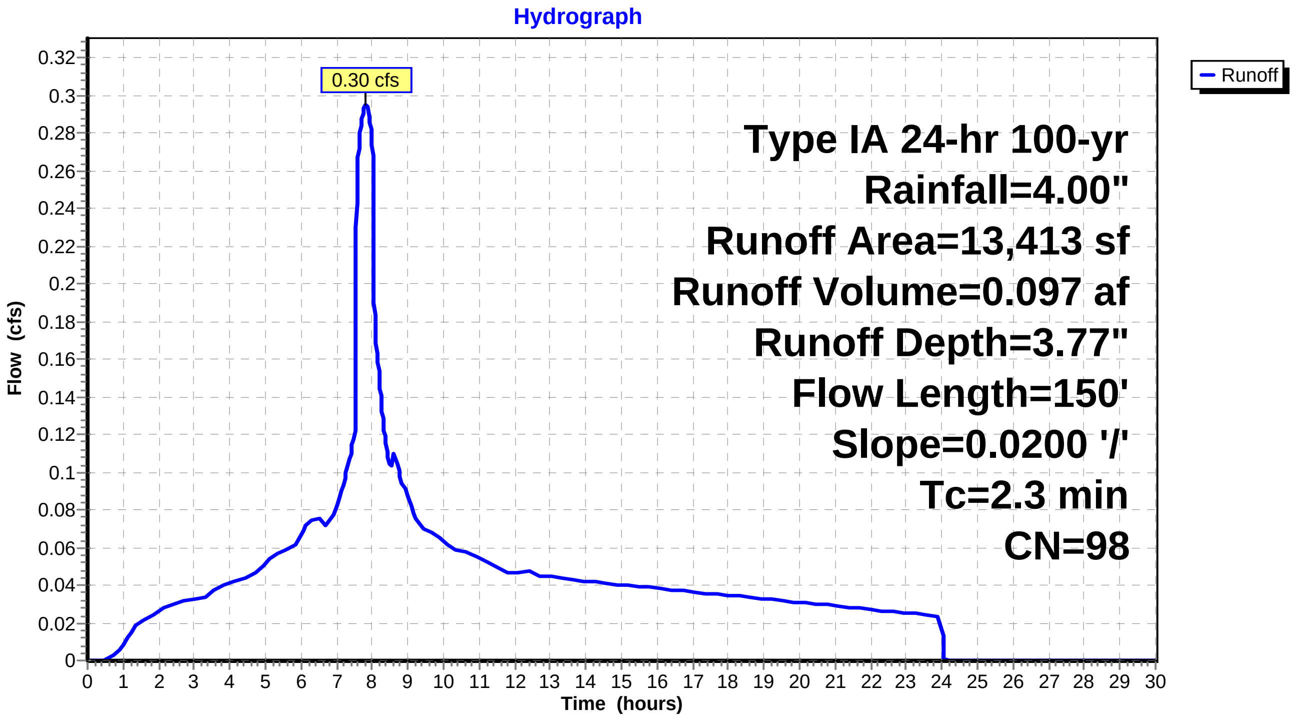
Runoff = 0.30 cfs @ 7.81 hrs, Volume= 0.097 af, Depth= 3.77"

Runoff by SCS TR-20 method, UH=SCS, Time Span= 0.00-30.00 hrs, dt= 0.01 hrs
Type IA 24-hr 100-yr Rainfall=4.00"

Area (sf)	CN	Description
13,413	98	Paved parking & roofs
13,413		Impervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
2.3	150	0.0200	1.07		**Lag/CN Method,**

Subcatchment 1S: West 1/2 Basin 2



Summary for Subcatchment 2S: East 1/2 Basin 2

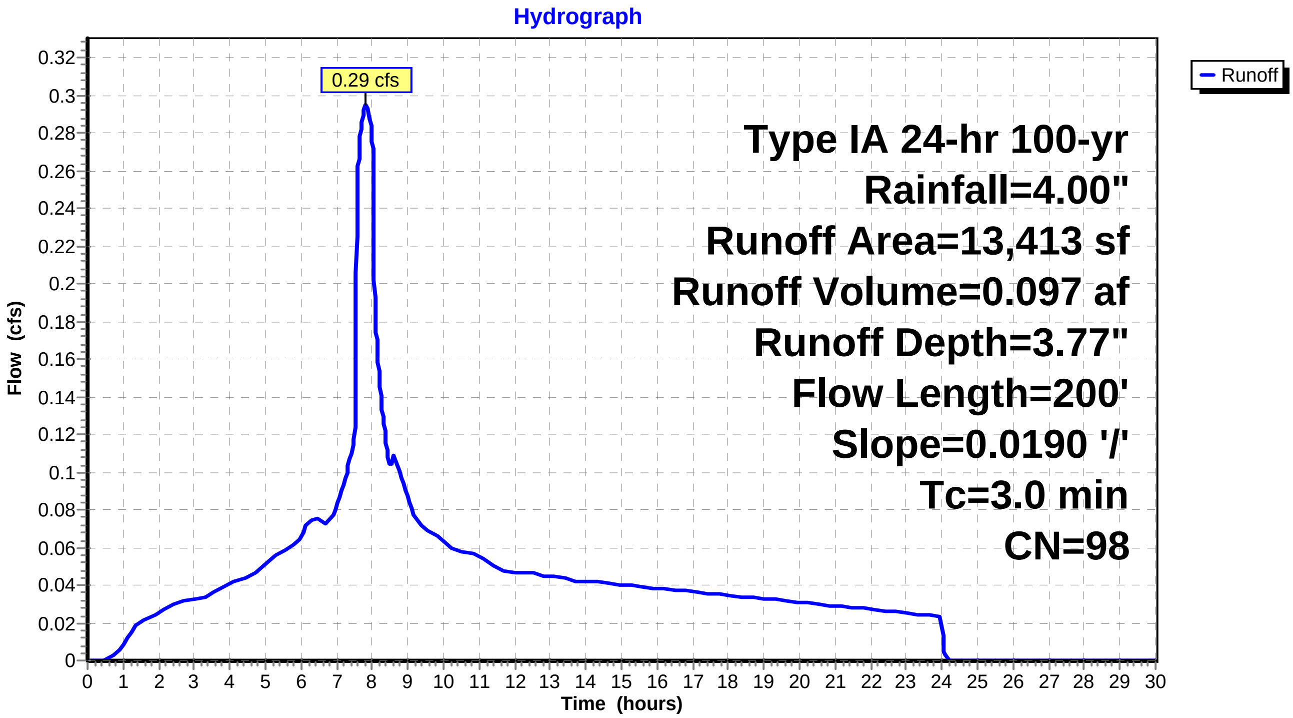
Runoff = 0.29 cfs @ 7.82 hrs, Volume= 0.097 af, Depth= 3.77"

Runoff by SCS TR-20 method, UH=SCS, Time Span= 0.00-30.00 hrs, dt= 0.01 hrs
Type IA 24-hr 100-yr Rainfall=4.00"

Area (sf)	CN	Description
13,413	98	Paved parking & roofs
13,413		Impervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
3.0	200	0.0190	1.11		**Lag/CN Method,**

Subcatchment 2S: East 1/2 Basin 2



Summary for Subcatchment 3S: Basin 3

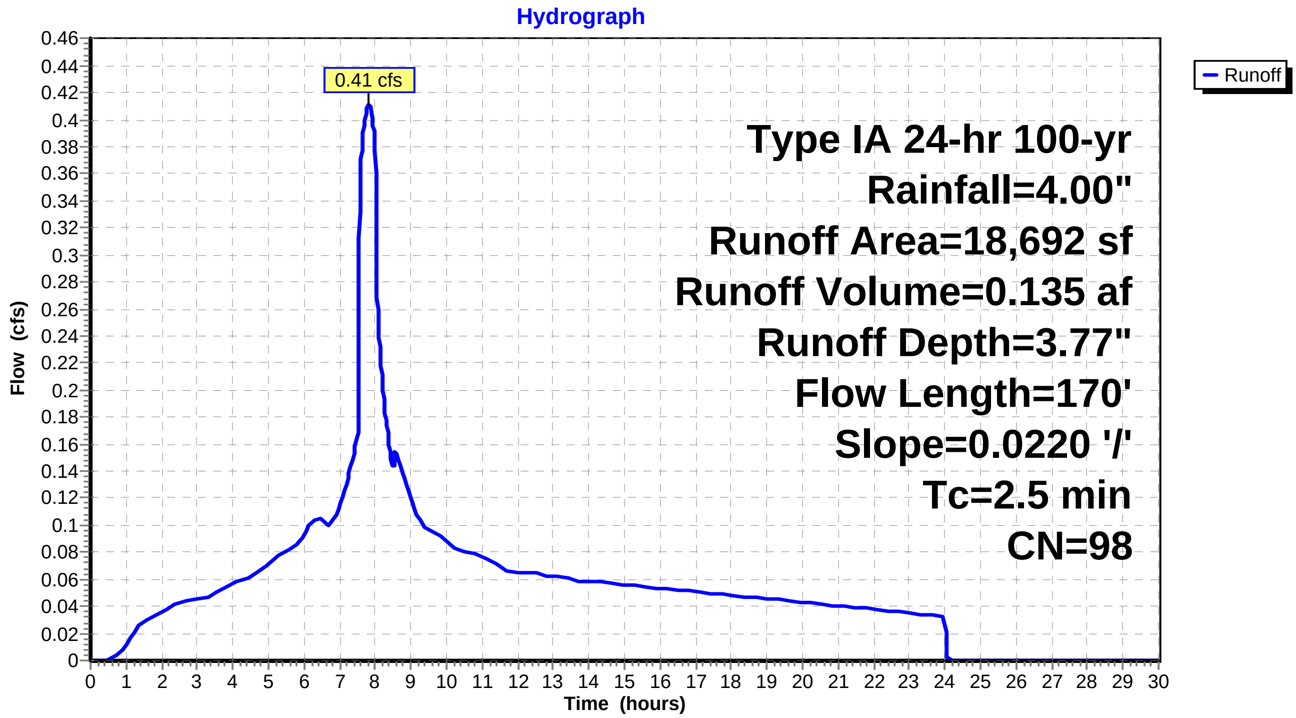
Runoff = 0.41 cfs @ 7.82 hrs, Volume= 0.135 af, Depth= 3.77"

Runoff by SCS TR-20 method, UH=SCS, Time Span= 0.00-30.00 hrs, dt= 0.01 hrs
Type IA 24-hr 100-yr Rainfall=4.00"

Area (sf)	CN	Description
18,692	98	Paved parking & roofs
18,692		Impervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
2.5	170	0.0220	1.15		**Lag/CN Method,**

Subcatchment 3S: Basin 3



Summary for Subcatchment 4S: Basin 4

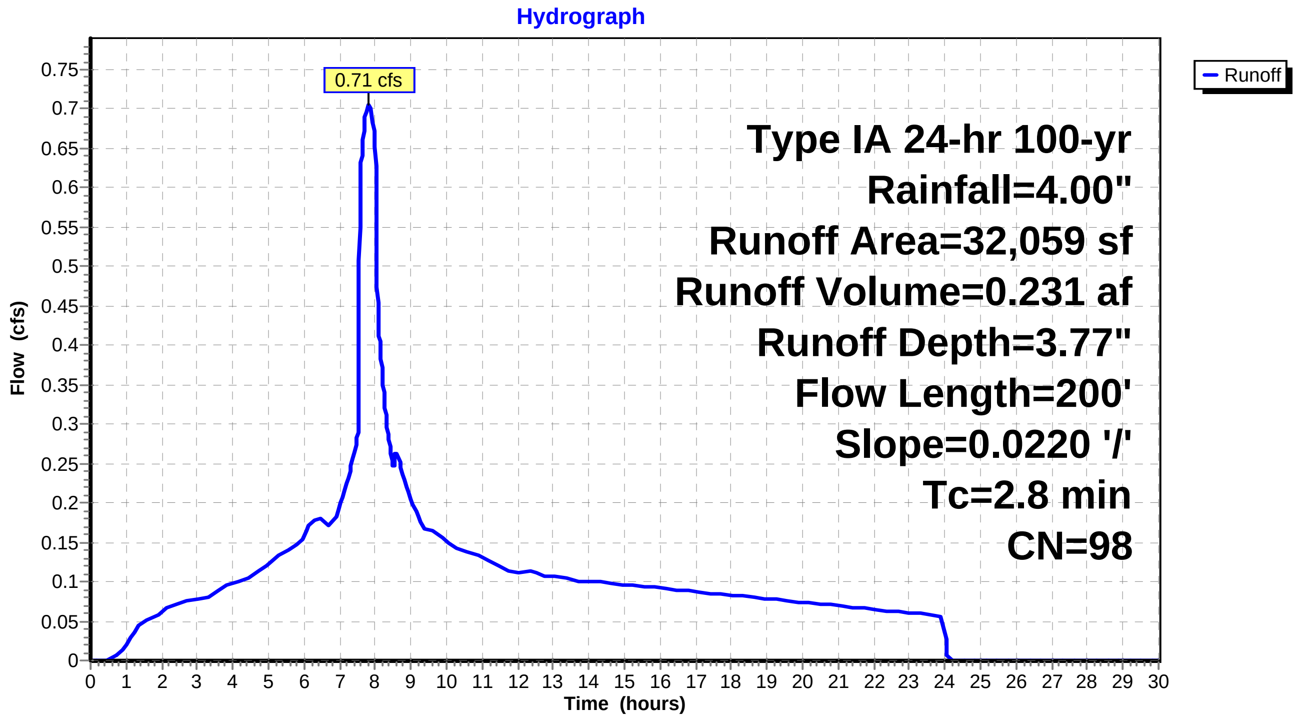
Runoff = 0.71 cfs @ 7.82 hrs, Volume= 0.231 af, Depth= 3.77"

Runoff by SCS TR-20 method, UH=SCS, Time Span= 0.00-30.00 hrs, dt= 0.01 hrs
Type IA 24-hr 100-yr Rainfall=4.00"

Area (sf)	CN	Description
32,059	98	Paved parking & roofs
32,059		Impervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
2.8	200	0.0220	1.19		**Lag/CN Method,**

Subcatchment 4S: Basin 4



Summary for Subcatchment 5S: Basin 5

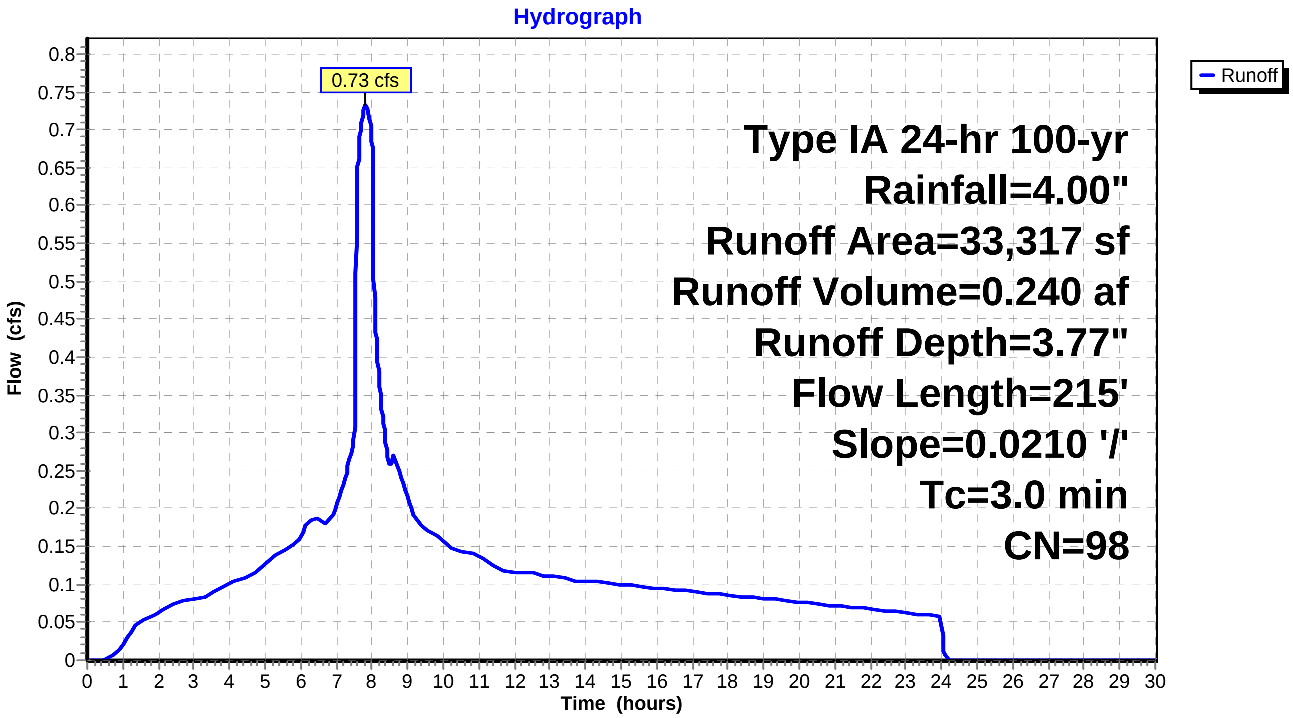
Runoff = 0.73 cfs @ 7.82 hrs, Volume= 0.240 af, Depth= 3.77"

Runoff by SCS TR-20 method, UH=SCS, Time Span= 0.00-30.00 hrs, dt= 0.01 hrs
Type IA 24-hr 100-yr Rainfall=4.00"

Area (sf)	CN	Description
33,317	98	Paved roads w/curbs & sewers
33,317		Impervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
3.0	215	0.0210	1.18		**Lag/CN Method,**

Subcatchment 5S: Basin 5



Summary for Subcatchment 6S: Mitigation Area

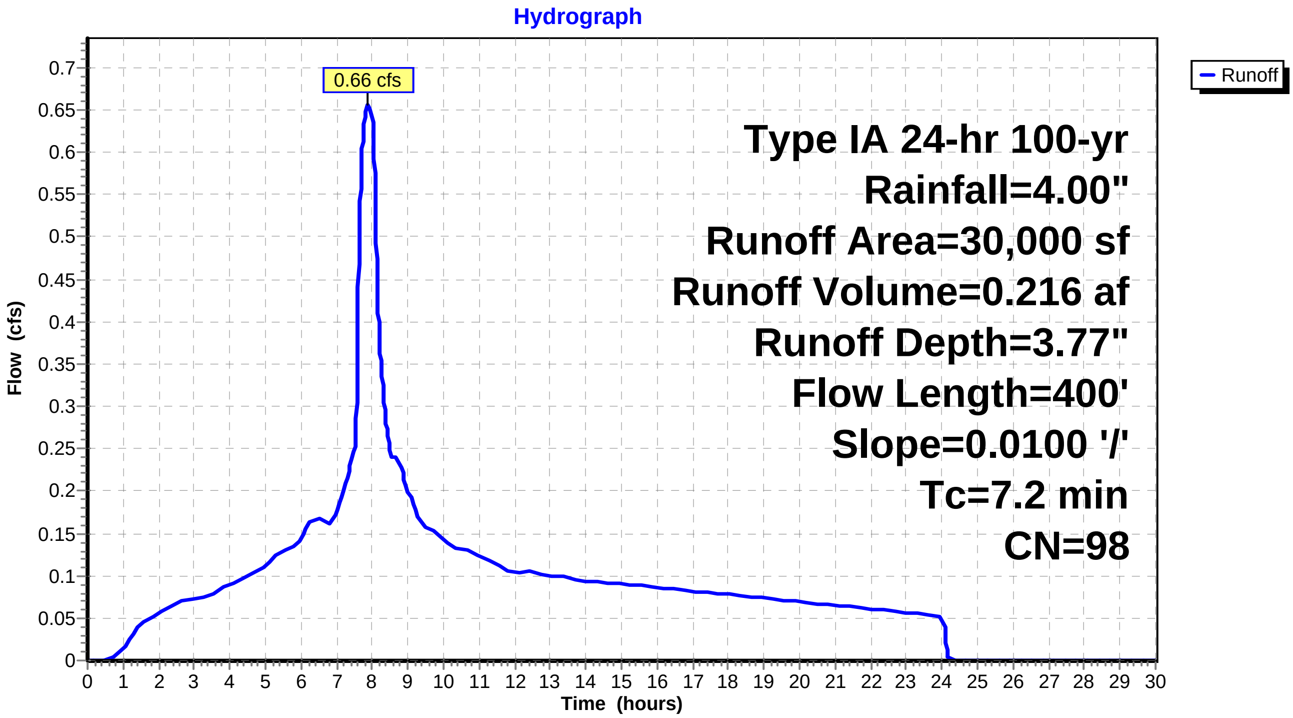
Runoff = 0.66 cfs @ 7.88 hrs, Volume= 0.216 af, Depth= 3.77"

Runoff by SCS TR-20 method, UH=SCS, Time Span= 0.00-30.00 hrs, dt= 0.01 hrs
Type IA 24-hr 100-yr Rainfall=4.00"

Area (sf)	CN	Description
30,000	98	Paved parking & roofs
30,000		Impervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
7.2	400	0.0100	0.92		**Lag/CN Method,**

Subcatchment 6S: Mitigation Area



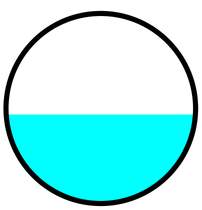
Summary for Reach 6R: Pipe at Basin 2

Inflow Area = 0.308 ac,100.00% Impervious, Inflow Depth = 3.77" for 100-yr event
Inflow = 0.30 cfs @ 7.81 hrs, Volume= 0.097 af
Outflow = 0.29 cfs @ 7.86 hrs, Volume= 0.097 af, Atten= 0%, Lag= 2.8 min

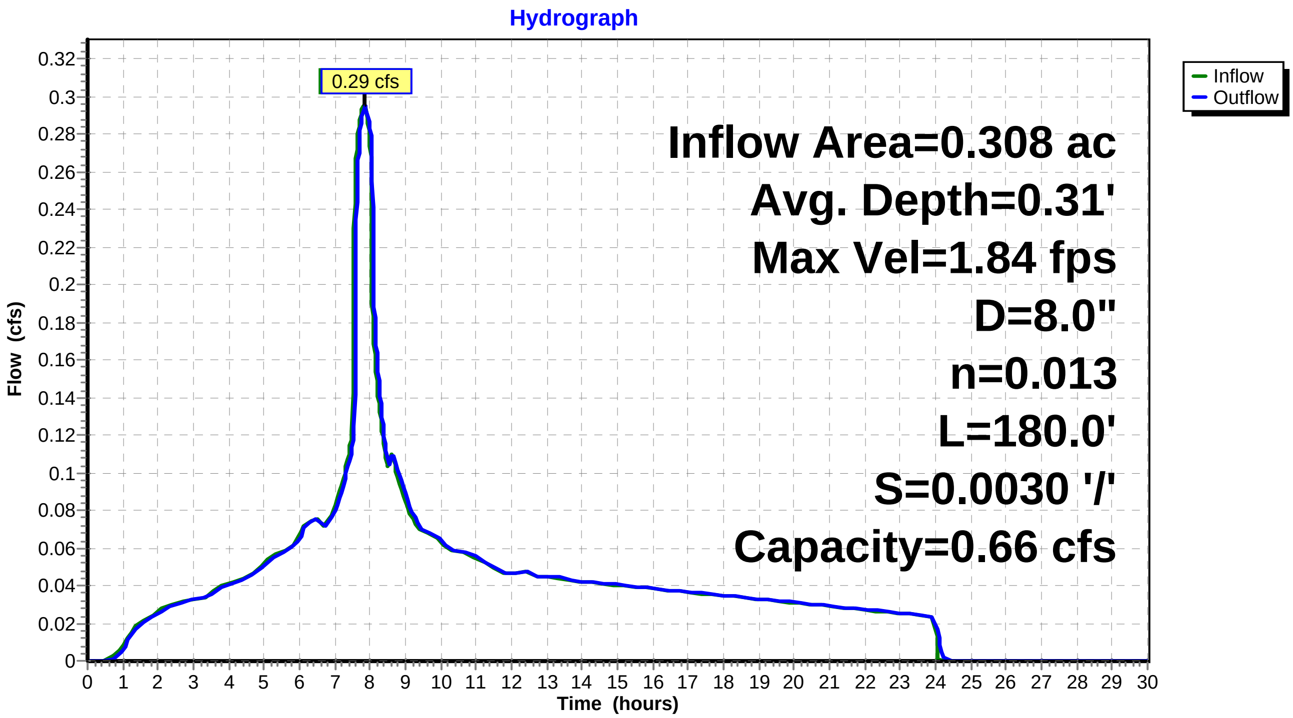
Routing by Stor-Ind+Trans method, Time Span= 0.00-30.00 hrs, dt= 0.01 hrs
Max. Velocity= 1.84 fps, Min. Travel Time= 1.6 min
Avg. Velocity = 1.03 fps, Avg. Travel Time= 2.9 min

Peak Storage= 29 cf @ 7.83 hrs, Average Depth at Peak Storage= 0.31'
Bank-Full Depth= 0.67', Capacity at Bank-Full= 0.66 cfs

8.0" Diameter Pipe, n= 0.013 Corrugated PE, smooth interior
Length= 180.0' Slope= 0.0030 '/'
Inlet Invert= 15.79', Outlet Invert= 15.25'



Reach 6R: Pipe at Basin 2



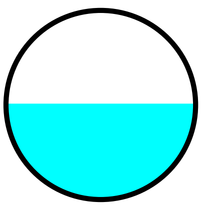
Summary for Reach 8R: Pipe at Basin 3

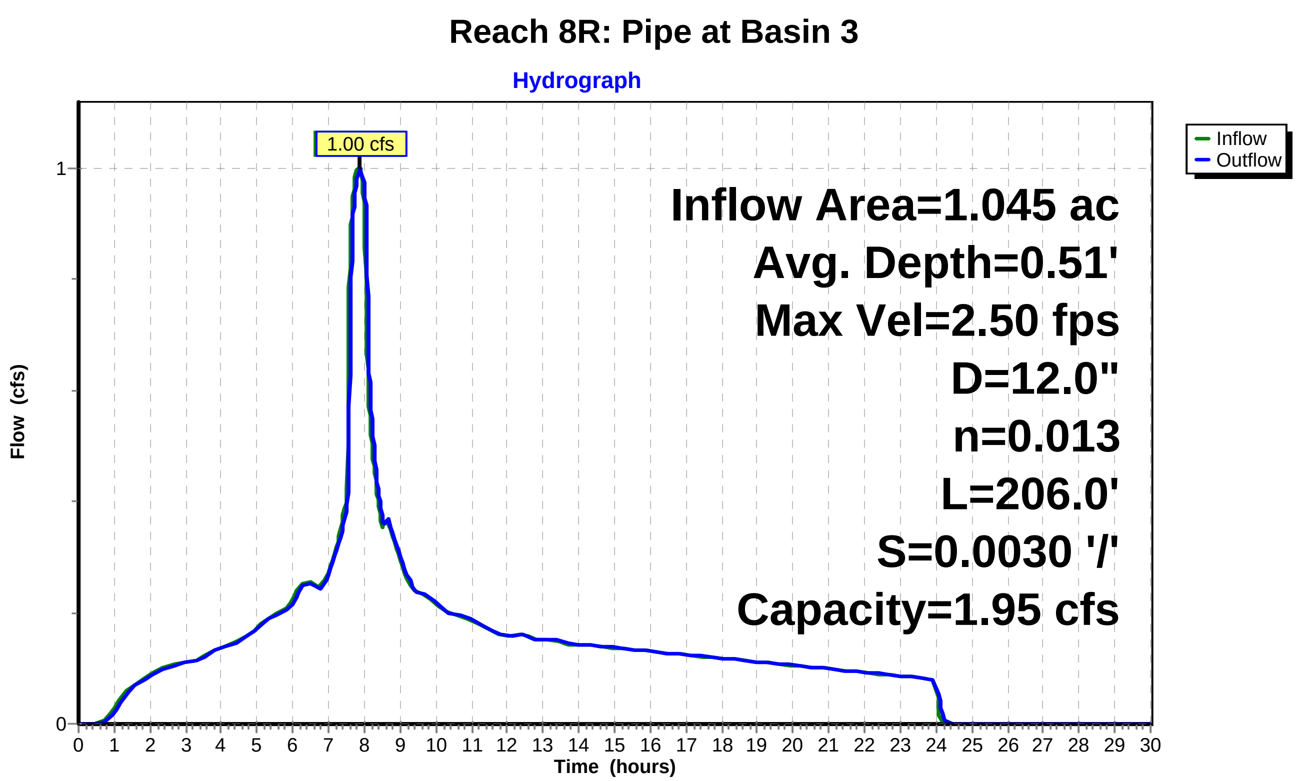
Inflow Area = 1.045 ac,100.00% Impervious, Inflow Depth = 3.77" for 100-yr event
Inflow = 1.00 cfs @ 7.83 hrs, Volume= 0.328 af
Outflow = 1.00 cfs @ 7.87 hrs, Volume= 0.328 af, Atten= 0%, Lag= 2.3 min

Routing by Stor-Ind+Trans method, Time Span= 0.00-30.00 hrs, dt= 0.01 hrs
Max. Velocity= 2.50 fps, Min. Travel Time= 1.4 min
Avg. Velocity = 1.39 fps, Avg. Travel Time= 2.5 min

Peak Storage= 82 cf @ 7.85 hrs, Average Depth at Peak Storage= 0.51'
Bank-Full Depth= 1.00', Capacity at Bank-Full= 1.95 cfs

12.0" Diameter Pipe, n= 0.013
Length= 206.0' Slope= 0.0030 '/'
Inlet Invert= 15.25', Outlet Invert= 14.63'





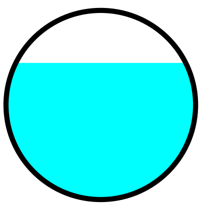
Summary for Reach 9R: Pipe at Basin 4

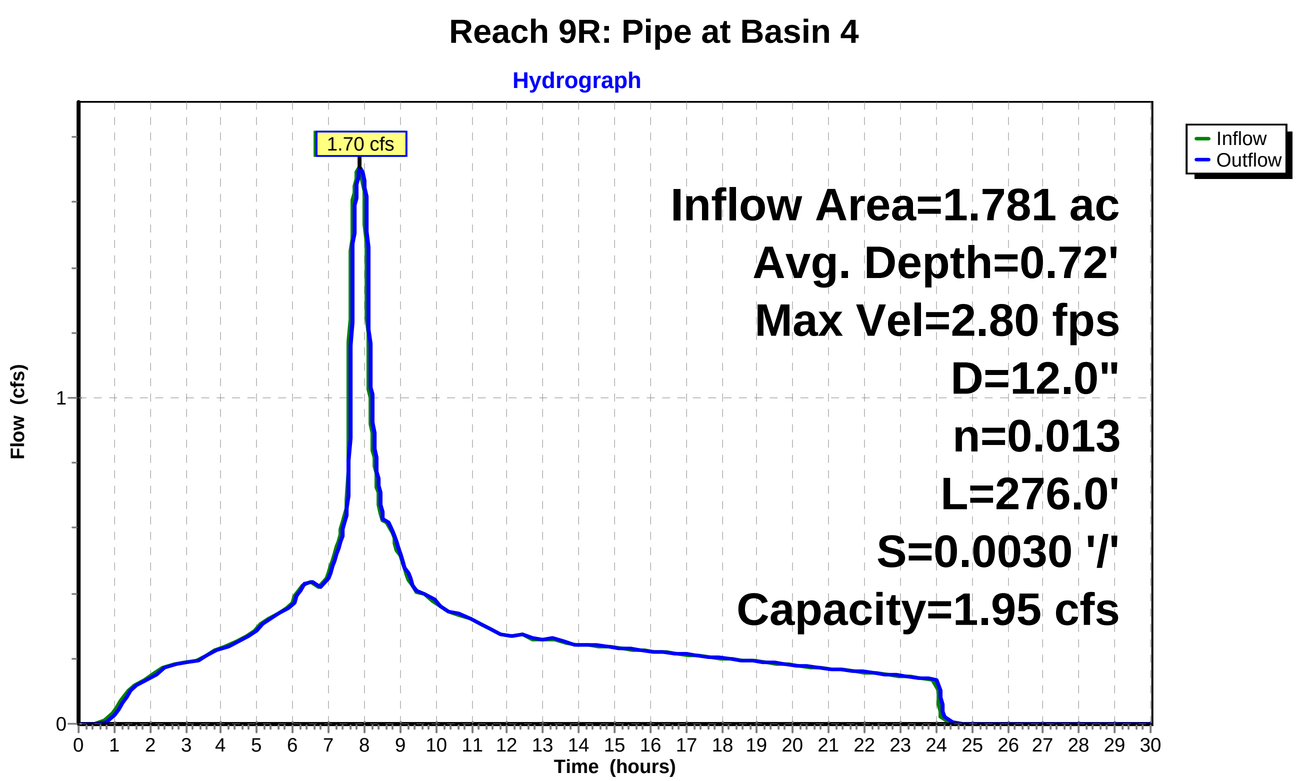
Inflow Area = 1.781 ac,100.00% Impervious, Inflow Depth = 3.77" for 100-yr event
Inflow = 1.70 cfs @ 7.85 hrs, Volume= 0.559 af
Outflow = 1.70 cfs @ 7.90 hrs, Volume= 0.559 af, Atten= 0%, Lag= 3.0 min

Routing by Stor-Ind+Trans method, Time Span= 0.00-30.00 hrs, dt= 0.01 hrs
Max. Velocity= 2.80 fps, Min. Travel Time= 1.6 min
Avg. Velocity = 1.59 fps, Avg. Travel Time= 2.9 min

Peak Storage= 167 cf @ 7.87 hrs, Average Depth at Peak Storage= 0.72'
Bank-Full Depth= 1.00', Capacity at Bank-Full= 1.95 cfs

12.0" Diameter Pipe, n= 0.013 Corrugated PE, smooth interior
Length= 276.0' Slope= 0.0030 '/'
Inlet Invert= 14.63', Outlet Invert= 13.80'





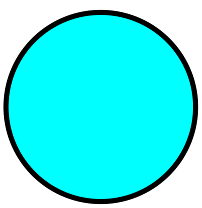
Summary for Reach 10R: Pipe to O/W & SF

Inflow Area = 3.234 ac,100.00% Impervious, Inflow Depth = 3.77" for 100-yr event
Inflow = 3.08 cfs @ 7.88 hrs, Volume= 1.015 af
Outflow = 2.55 cfs @ 7.66 hrs, Volume= 1.015 af, Atten= 17%, Lag= 0.0 min

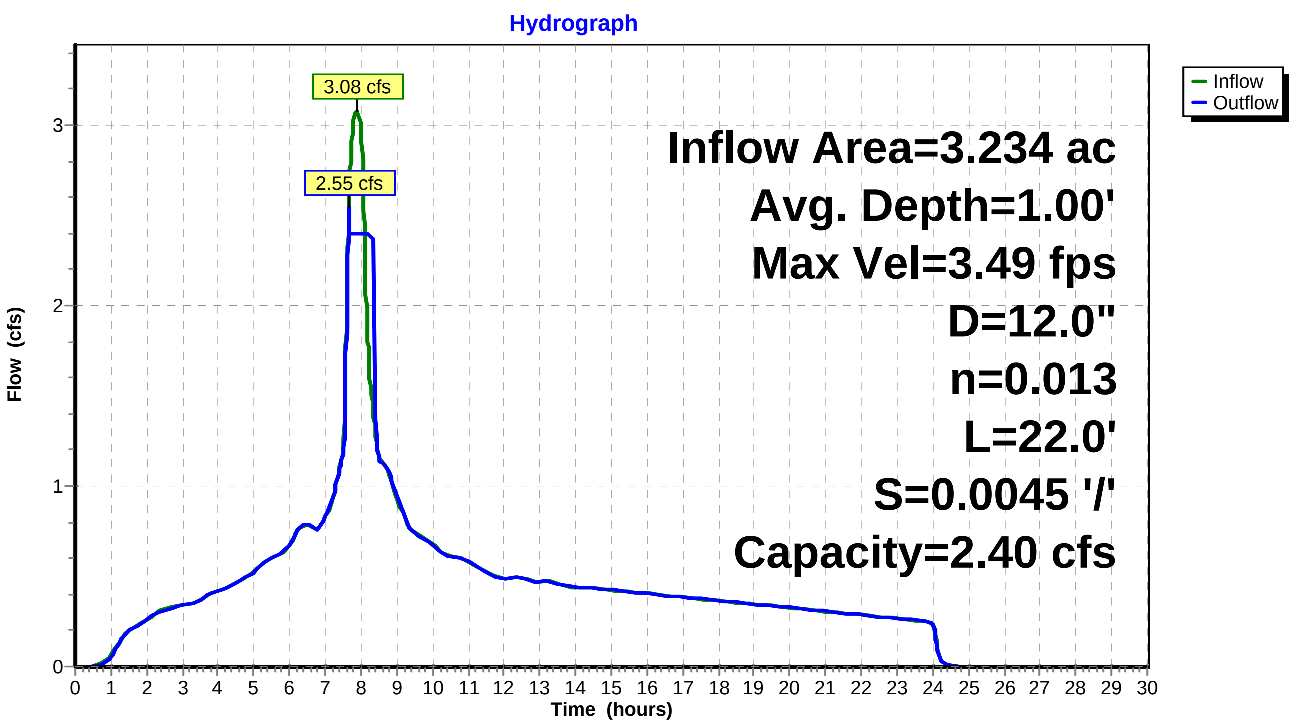
Routing by Stor-Ind+Trans method, Time Span= 0.00-30.00 hrs, dt= 0.01 hrs
Max. Velocity= 3.49 fps, Min. Travel Time= 0.1 min
Avg. Velocity = 2.16 fps, Avg. Travel Time= 0.2 min

Peak Storage= 17 cf @ 7.67 hrs, Average Depth at Peak Storage= 1.00'
Bank-Full Depth= 1.00', Capacity at Bank-Full= 2.40 cfs

12.0" Diameter Pipe, n= 0.013 Corrugated PE, smooth interior
Length= 22.0' Slope= 0.0045 '/'
Inlet Invert= 13.80', Outlet Invert= 13.70'



Reach 10R: Pipe to O/W & SF



ATTACHMENT B

WATER QUALITY ANALYSIS

Western Washington Hydrology Model
PROJECT REPORT

Project Name: Term 91 WQ Flow
Site Address:
City : Seattle
Report Date : 1/9/2013
Gage : Seatac
Data Start : 1948/10/01
Data End : 1998/09/30
Precip Scale: 1.00
WWHM3 Version:

PREDEVELOPED LAND USE
Name : Basin 1-5
Bypass: No
GroundWater: No
Pervious Land Use Acres
Impervious Land Use Acres
ROADS MOD 3.24

Element Flows To:
Surface Interflow Groundwater

MITIGATED LAND USE

ANALYSIS RESULTS
Flow Frequency Return Periods for Predeveloped. POC #1
Return Period Flow(cfs)
2 year 0.8793
5 year 1.0693
10 year 1.1946
25 year 1.3535
50 year 1.4727
100 year 1.5929
Flow Frequency Return Periods for Mitigated. POC #1
Return Period Flow(cfs)
2 year 0
5 year 0
10 year 0
25 year 0
50 year 0
100 year 0

Yearly Peaks for Predeveloped and Mitigated. POC #1
Year Predeveloped Mitigated

Ranked Yearly Peaks for Predeveloped and Mitigated. POC #1
Rank Predeveloped Mitigated

POC #1
The Facility PASSED
The Facility PASSED.
Flow(CFS) Predev Dev Percentage Pass/Fail
0.0000 0 0 0 Pass
0.0000 0 0 0 Pass
0.0000 0 0 0 Pass

0.0000 0 0 0 Pass
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Water Quality BMP Flow and Volume for POC 1.
On-line facility volume: 0.3855 acre-feet
On-line facility target flow: 0.01 **cfs.**
Adjusted for 15 min: 0.5536 **cfs.**
Off-line facility target flow: 0.2842 **cfs.**
Adjusted for 15 min: 0.3211 **cfs.**

Perlnd and Implnd Changes

No changes have been made.

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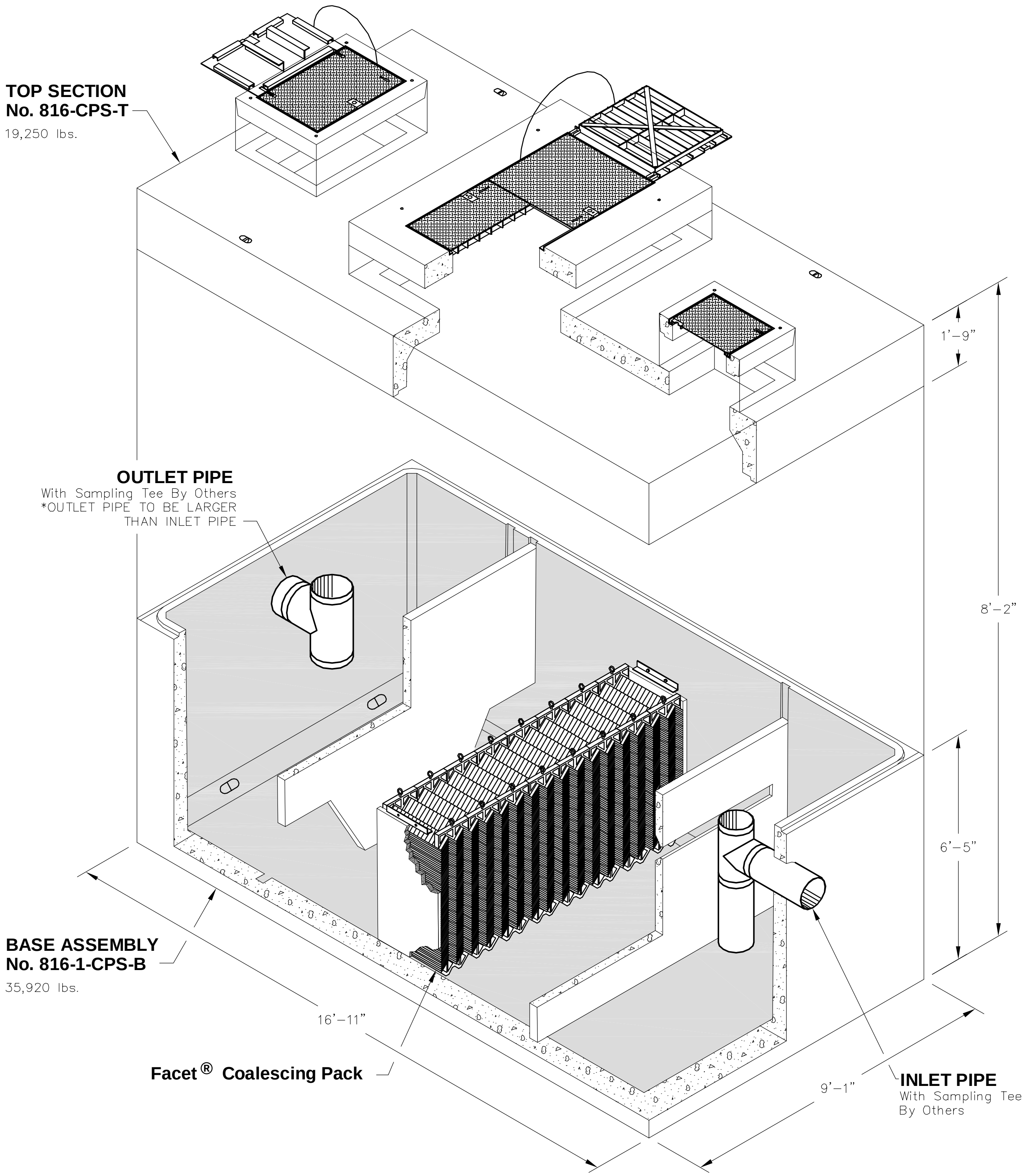
liable for any damages whatsoever (including without limitation to damages for loss of business profits, loss of business information, business interruption, and the like) arising out of the use of, or inability to use this program even if Clear Creek Solutions or the Washington State Department of Ecology has been advised of the possibility of such damages.

ATTACHMENT C

OIL WATER SEPARATOR DETAILS

816-1-CPS

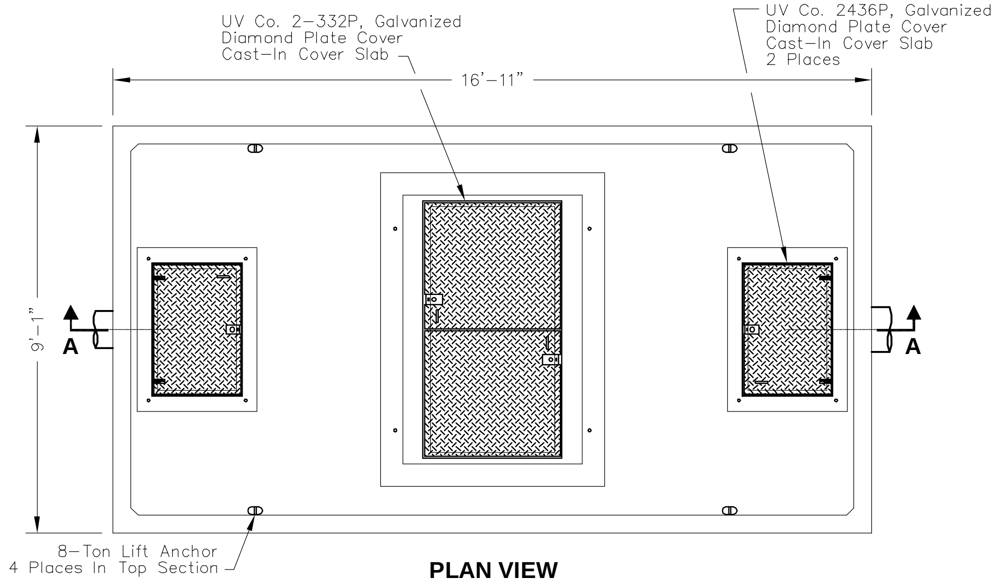


SCALE: 1/4" = 1'-0"

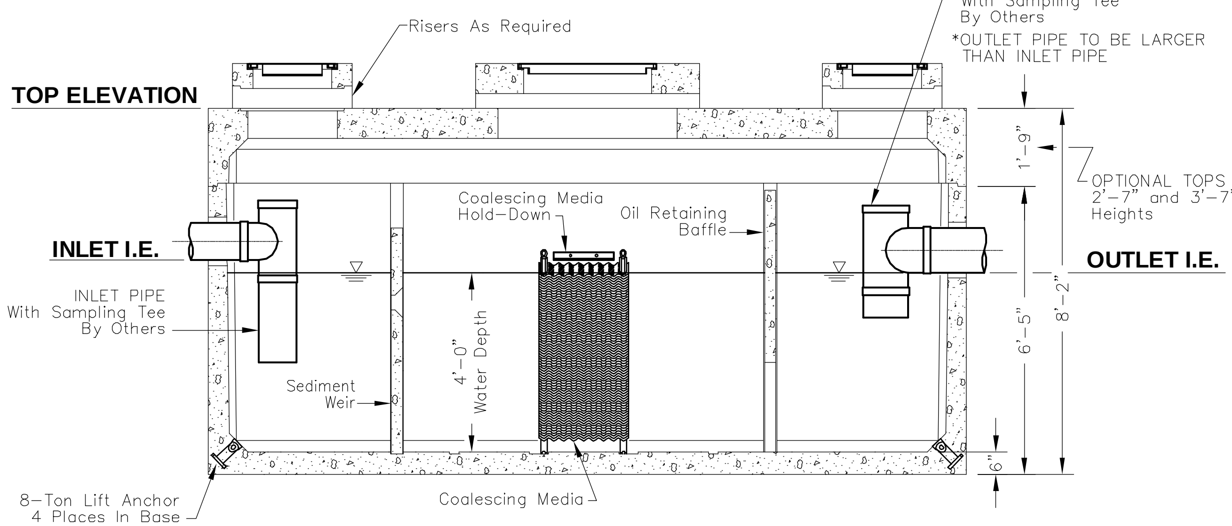
Oldcastle Precast® Utility Vault PO Box 588, Auburn, Washington 98071-0588 Tel: (253) 839-3500 Fax: (253) 735-4201	**816-1 CPS** File Name: 010-8161CPS Issue Date: 2010 **www.uvauburn.com**	**816-1-CPS** **OIL WATER SEPARTOR** **COALESCING - 292 GPM** ©1995–2010 Oldcastle Precast, Inc.

816-1-CPS

PROJECTED PLATE AREA = 1,184 Sq/ft **MAXIMUM PROCESS FLOW = 1,100 GPM**



PLAN VIEW



SECTION AA

STRUCTURAL NOTES:
1. Concrete: 28 Day Compressive Strength f'c= 7000 psi
2. Rebar: ASTM A-615 Grade 60
3. Mesh: ASTM A-185 Grade 65
4. Design: ACI-318-05 Building Code
   ASTM C-890 "Minimum Structural Design Loading For Underground Precast Concrete Water and Wastewater Structures"
5. Loads: HS-20 Truck Wheel w/ 30% Impact Per AASHTO

GENERAL NOTES:
1. All Baffles and Weirs To Be Precast Concrete
2. Static Water Depth = 4'-0"
3. Contractor to:
   - Supply and Install All Piping & Sampling Tees
   - Grout In All Pipes
   - Fill With Clean Water Prior To "Start-Up" Of System
   - Verify All BLockout Sizes and Locations

SCALE: 1/4" = 1'-0"

INFORMATION NEEDED:
Top Of Separator Elevation:
Inlet Pipe Size:
Inlet Pipe Elevation:
Outlet Pipe Size:
Outlet Pipe Elevation:

BASIC DESIGN INFORMATION:
INFLUENT CHARACTERISTICS:
Oil Specific Gravity: 0.88
Operating Temperature: 50°
Influent Oil Concentration: 100 ppm
Mean Oil Droplet Size: 130 Microns
0.033 ft/min Oil Rise Rate
Designed Per Washington State Department Of Ecology

FLOW RATE	EFFLUENT QUALITY	100% COLLECTED SIZE

Oldcastle Precast® Utility Vault PO Box 588, Auburn, Washington 98071-0588 Tel: (253) 839-3500 Fax: (253) 735-4201	**816-1 CPS** File Name: 010-8161CPS Issue Date: 2010 **www.uvauburn.com**	**816-1-CPS** **OIL WATER SEPARTOR** **COALESCING - 292 GPM** ©1995-2010 Oldcastle Precast, Inc.

APPENDIX B
DRAWINGS
(Provided Under Separate Cover)

APPENDIX C
TECHNICAL SPECIFICATIONS
(Provided Under Separate Cover)

APPENDIX D
CONSTRUCTION QUALITY ASSURNACE MANUAL
(Provided Under Separate Cover)

APPENDIX F
COMPLIANCE MONITORING PLAN
(Provided Under Separate Cover)

APPENDIX G
OPERATIONS AND MAINTENANCE PLAN
(Provided Under Separate Cover)

APPENDIX E
REGULATED BUILDING MATERIALS
ASSESSMENT REPORT

ARGUS PACIFIC
TRAINING • CONSULTING

Regulated Building Materials
Assessment Report
T-91 Tank Farm Cleanup Project
Buildings 25, 27, and Substation 11
at Terminal 91
PES Environmental, Inc.
Seattle, Washington

December 11, 2012

PROVIDING
ORGANIZATIONS
WITH
HEALTH
AND
SAFETY
SOLUTIONS

Project Title:	Regulated Building Materials Assessment T-91 Tank Farm Cleanup Project Buildings 25, 27, and Substation 11 at Terminal 91 Seattle, Washington
Prepared for:	Mr. Brian O'Neal PES Environmental, Inc. 1215 4th Avenue #1315 Seattle, Washington 98161
Assessment Conducted by:	Argus Pacific, Inc. 1900 W. Nickerson Street, Suite 315 Seattle, Washington 98119
Argus Pacific Project Number:	640480R
Assessment Personnel:	Mr. Scott Rinear AHERA-Accredited Building Inspector Number 134900 (exp. 1/10/2013) Washington State Department of Commerce- Accredited Lead Inspector/Risk Assessor Number 6241 (exp. 10/19/2013)
Assessment Date:	November 13, 2012
Report Prepared by:	Scott Rinear Project Manager Argus Pacific, Inc.
Report Reviewed by:	Nicole Gladu Senior Consultant Argus Pacific, Inc.
Report Issue Date:	December 11, 2012

TABLE OF CONTENTS

EXECUTIVE SUMMARY

PES Environmental, Inc. retained Argus Pacific, Inc. (Argus Pacific) to conduct a regulated building materials assessment of Buildings 25, 27, and Substation 11 at Terminal 91 (T-91) for the T-91 Tank Farm Cleanup Project in Seattle, Washington. Argus Pacific's representative, Mr. Scott Rinear, conducted the assessment on November 13, 2012. The scope of the services provided is described in Argus Pacific Proposal Number P640480 dated October 11, 2012.

Argus Pacific assessed the buildings for the following regulated building materials:

- Asbestos-containing materials (ACM);
- Assumed asbestos-containing materials;
- Lead-containing coatings (paints);
- Suspected heavy metal-containing coatings (paints);
- Suspected PCB-containing caulking;
- Mercury-containing light tubes, switches, and thermostats;
- Suspected high-intensity discharge (HID) lamps; and
- Suspected PCB-containing fluorescent light ballasts.

Thirty-eight (38) bulk samples of suspect asbestos-containing materials were collected and analyzed using Polarized Light Microscopy (PLM). None of the materials were found to contain detectable asbestos and four materials were assumed to contain asbestos. In addition, two materials were visually assessed and determined to be non-suspect.

Eighteen paint chip samples were collected and analyzed for total lead content. Sixteen of the paint chip samples were found to contain detectable levels of lead.

Two paint chip samples were collected and analyzed for heavy metals, including silver, arsenic, barium, cadmium chromium, mercury, lead, and selenium. Both of the samples had detectable levels of heavy metals. Both samples had detectable levels of lead, and those two samples are included in the lead paint sample count in the previous paragraph. Regarding heavy metals other than lead, one of the samples was found to contain detectable levels of arsenic, barium, cadmium, chromium, and selenium. One sample was found to contain detectable levels of barium, cadmium, and chromium.

No suspect PCB-containing caulking was observed on the buildings.

Mercury-containing fluorescent light tubes were identified in Building 25. HID lamps were identified on the exterior of the buildings. One PCB-containing transformer was identified on the north exterior of Building 25.

The interior of Substation 11 was not accessible at the time of the assessment.

In addition, Argus Pacific characterized the anticipated construction waste by collecting Toxicity Characteristic Leachate Process (TCLP) samples. The TCLP samples were found to contain no detectable lead in the leachate. The construction waste may be disposed of as general construction debris.

1.0 INTRODUCTION

PES Environmental, Inc. retained Argus Pacific, Inc. (Argus Pacific) to conduct a regulated building materials assessment of Buildings 25, 27, and Substation 11 at Terminal 91 (T-91) for the T-91 Tank Farm Cleanup Project in Seattle, Washington. Argus Pacific's representative, Mr. Scott Rinear, conducted the assessment on November 13, 2012. The scope of the services provided is described in Argus Pacific Proposal Number P640480 dated October 11, 2012.

Argus Pacific assessed the buildings for the following regulated building materials:

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- Assumed asbestos-containing materials;
- Lead-containing coatings (paints);
- Suspected heavy metal-containing coatings (paints);
- Suspected PCB-containing caulking;
- Mercury-containing light tubes, switches, and thermostats;
- Suspected high-intensity discharge (HID) lamps; and
- Suspected PCB-containing fluorescent light ballasts.

2.0 PROJECT BACKGROUND

This report presents the results of our regulated building materials assessment of Buildings 25, 27, and Substation 11 at Terminal 91 (T-91) for the T-91 Tank Farm Cleanup Project in Seattle, Washington. The purpose of the assessment was to identify potential asbestos-containing material, lead-containing coatings, TCLP, heavy-metal-containing coatings, PCB-containing caulking, PCB-containing light ballasts, and mercury-containing components prior to demolition and for purposes of hazard communication and on-going management. The assessment included the interiors, exteriors, and roofs except for the interior of Substation 11. In addition to the structures described above, Argus Pacific assessed the former loading dock and ramp on the east side of the project area, several sump pumps and associated piping, and a remaining tank pad.

This assessment will assist the Port of Seattle with communicating the presence of lead-containing coatings, heavy-metal-containing coatings, and mercury and PCB-containing components, and the presence, location, and quantity of ACM to employees, vendors, and contractors working in the project area and to meet the requirements for an asbestos survey for the Puget Sound Clean Air Agency (PSCAA) and a good faith inspection as required by Washington State Department of Labor and Industries' Division of Occupational Safety and Health (DOSH) regulations prior to building demolition. Regulations require that a complete copy of this assessment be kept in a conspicuous location on-site at all times during activities that may impact known and suspect ACM.

2.1 Sources of Information

During the course of the assessment, the following individuals, drawings, and documents provided assistance to the Argus Pacific inspector:

- Mr. Brian O'Neal, PES Environmental, Inc.
- *Terminal 91-Tank Farm Demolition*, Regulated Material Drawings, Argus Pacific, Inc., dated August 12, 2004
- *Good Faith Asbestos and Lead Survey Terminal 91 Tank Farm*, Port of Seattle, Port Construction Services, dated December 31, 2003

2.2 Building Description

The T-91 Tank Farm Cleanup Project includes the demolition of Buildings 25, 27, and Substation 11, as well as, other remaining above ground ramps and piping. The project also includes the removal of asphalt covering and removal of sub-surface infrastructure. Buildings 25, 27, and Substation 11 are located at Terminal 91 in Seattle, Washington.

Building 25 (B25) is located on the west side of the project area. Building 25 is a single-story brick structure and contains approximately 100 square feet of interior floor space. The roof and siding are metal with metal-framed windows and doors. Interior finishes include window glazing compound, residual flooring, and various sealants and paints. The building contains a single electrical room.

Building 27 (B27) is located on the east side of the project area. Building 27 is a single-story metal-framed structure and contains approximately 435 square feet of interior floor space. The roof and siding are metal with metal-framed windows and doors. Interior finishes include window glazing compound and various sealants and paints. The building contains a single room.

Substation 11 (SS11) is adjacent to Building 25 and is a metal structure. The interior of the substation was inaccessible at the time of the assessment.

In addition to the structures described above, Argus Pacific assessed the former loading dock and ramp on the east side of the project area near Building 27, several sump pumps and associated piping, and a remaining portion of a tank pad. A sample was collected from a remaining portion of a tank pad in the central area of project area. This sample is not shown on the sample location drawings.

3.0 ASBESTOS ASSESSMENT

3.1 Building Assessment

Mr. Rinear, an Asbestos Hazard Emergency Response Act (AHERA)-accredited building inspector (Certification 134900, expiration date: 1/10/2013) from Argus Pacific, performed the sampling on November 13, 2012. Argus Pacific's inspector collected 38 samples of materials identified as suspect ACM.

This assessment was conducted using a modified protocol adapted from AHERA. The protocol is as follows:

- Identify suspect asbestos-containing materials.
- Group materials into homogeneous sampling areas/materials.

- Quantify each homogeneous material and collect representative samples. The number of samples collected of miscellaneous materials was determined by the inspector.
- Samples of each material were taken to the substrate, ensuring that all components and layers of the material were included.
- Sample locations are referenced on the field data forms according to sample number.
- Sampling was performed by an AHERA-accredited building inspector, and the use of proper protective equipment and procedures was followed.

For reference purposes, sample number designations include a project identifier, homogenous sampling area (HSA) identifier, and sample number of the HSA. For example, 640480-1-01 is based on the following information: 640480: Argus Pacific internal project number; HSA number; and "-01" is the number of samples for that HSA number. In other words, 640480-1-01 is sample number one of HSA number one.

3.2 Sampling Procedures

This sampling was conducted using the following procedures:

1. Spread the plastic drop cloth (if needed) and set up other equipment, e.g., ladder.
2. Don protective equipment (respirator and protective clothing if needed).
3. Label sample container with its identification number and record number. Record sample location and type of material sampled on a sampling data form.
4. Moisten area where sample is to be extracted (spray the immediate area with water).
5. Extract sample using a clean knife, drill capsule, or cork boring tool to cut out or scrape off approximately one tablespoon of the material. Penetrate all layers of material.
6. Place sample in a container and tightly seal it.
7. Wipe the exterior of the container with a wet wipe to remove any material that may have adhered to it during sampling.
8. Clean tools with wet wipes and wet mop; or vacuum area with HEPA vacuum to clean all debris.
9. Discard protective clothing, wet wipes and rags, cartridge filters, and drop cloth in a labeled plastic waste bag.

3.3 Analytical Methodology

Suspect ACMs were sampled in general accordance with 40 CFR 763.86 by an Environmental Protection Agency (EPA) AHERA-accredited building inspector. Each sample was collected and stored in a heavy-duty, self-sealing plastic bag, and delivered to Seattle Asbestos Test, LLC in Bellevue, Washington. Samples were analyzed via polarized light microscopy (PLM) in accordance with EPA/600/R-93/116. Seattle Asbestos Test, LLC is accredited to perform PLM analysis by the National Institute of Standards and Technology National Voluntary Laboratory Accreditation Program (NVLAP).

3.4 Asbestos Results

Table 3.4-1 provides a list of suspect HSA material descriptions, material locations, and results for the sampling. Asbestos-containing materials and assumed asbestos-containing materials are presented in bold text. Refer to the attached Figures for sample locations and room number designations (as applicable). Refer to the attached photographs for HSA pictures.

Table 3.4-1. Results of Bulk Sample Analyses

HSA ID, Material Description, and AHERA Classification	Material Location	HSA Results
1: Grey interior window glazing compound (M)	B27: Windows throughout and associated debris on floor	ND
2: Grey exterior window glazing compound (M)	B27: Windows throughout and associated debris on ground	ND
3: Electrical panel (M)	**B27: East wall in northeast corner of room**	**Assumed to contain asbestos**
4: Electrical wiring (M)	**B27: Interior of electrical panel and conduit**	**Assumed to contain asbestos**
5: Grey fibrous paper (M)	B27: On floor in places	ND
6: Brown fibrous paper debris (M)	B27: Southwest corner on floor and on wall framing	ND
7: Clear silicone sealant (M)	B27: Spot locations on exterior siding	Visually assessed and determined to be non-suspect
8: Grey cementitious material (M)	B27: southwest exterior sump pump B25: exterior pump	ND
9: Black asphaltic coating (M)	B27: southeast exterior, on one pipe below ground level	ND
10: Black paper wrap (M)	B27: southeast exterior, on one pipe below ground level	ND
11: Black coating (M)	B27: southeast exterior, majority of piping below ground level	ND
12: Black asphalt coating and canvas material (M)	B27: southeast exterior, one pipe elbow below ground level	Asphalt: ND Canvas: ND

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Table 3.4-1. Results of Bulk Sample Analyses

HSA ID, Material Description, and AHERA Classification	Material Location	HSA Results
13: Gaskets (M)	**Associated with exterior piping throughout site**	**Assumed to contain asbestos**
14: Grey/beige sealant (M)	Loading dock southeast of B27: on seams	ND
15: Light grey sealant (M)	Loading ramp southeast of B27: on loading dock and cracks in stem wall	ND
16: Black coating (M)	B27: on door	ND
17: Silver paint and trace powdery material (M)	B27: throughout metal roof, gutters, and roof vent	Paint: ND Powdery material: ND
18: Off-white coating/sealant (M)	B27: spot locations on exterior siding	ND
19: Grey fibrous paper gasket (M)	B27: at bell on southwest exterior panel	ND
20: Silver paint and brittle material (M)	B27: on interior corrugated metal walls and ceiling	Paint: ND Brittle material : ND
21: Grey exterior window glazing compound (M)	B25: throughout windows	ND
22: Grey interior window glazing compound (M)	B25: throughout windows	ND
23: Red brick and grey mortar (M)	B25: majority of walls	Brick: ND Mortar: ND
24: Larger red brick and mortar (M)	B25: west interior wall	Brick: ND Mortar: ND
25: Grey stucco/plaster with metal lath (S)	B25: west exterior wall	ND
26: Penetration patching compound (M)	B25: spots on walls	ND
27: Brown residual floor sheeting (M)	B25: in spots on floor	ND
28: Black coating (M)	B25: on door	ND
29: Red gasket (M)	B25: associated with electrical component	ND
30: Red gasket (M)	Associated with pipe northeast of B25	ND
31: Black gasket (M)	B25: associated with conduit access panels	ND
32: Large electrical panels and wiring (M)	**B25: interior of building**	**Assumed to contain asbestos**

Table 3.4-1. Results of Bulk Sample Analyses

HSA ID, Material Description, and AHERA Classification	Material Location	HSA Results
33: Newer electrical panels (M)	B25: interior and exterior of building	Visually assessed and determined to be non-suspect
34: Black residual material (M)	On exposed tank pad	ND
35: Electrical panels and wiring (M)	**SS11: interior of building**	**Assumed to contain asbestos**

ND: none detected, HSA: material that is uniform in color, texture, general appearance, and construction and application date, S: Surfacing material per AHERA, M: Miscellaneous material per AHERA

Additional suspect ACMs may be present in inaccessible or concealed spaces. These spaces include, but are not limited to electrical systems, interior of substation, beneath asphalt, pipe chases, spaces between wall/ceiling/door/floor cavities, interior of mechanical components, beneath foundation pads, etc. If future maintenance, renovation, and/or demolition activities make these areas accessible, Argus Pacific recommends that a thorough assessment of these spaces be conducted at that time to identify and confirm the presence or absence of additional suspect ACMs. Until then, all such unidentified materials must be treated as assumed ACMs in accordance with applicable federal, state, and local regulations.

If the analytical results indicate that all the samples collected per HSA do not contain asbestos, then the HSA (material) is considered a non-ACM. However, if the analytical results of one or more of the samples collected per HSA indicate that asbestos is present in quantities of greater than one percent asbestos as defined by the EPA, all of the HSA (material) is considered to be an ACM regardless of any other analytical results (unless a representative number of samples have been analyzed by PLM point counting as described below, and the results indicate the material contains less than one percent asbestos).

Any material that contains greater than one percent asbestos is considered an ACM and must be handled according to Occupational Safety and Health Administration (OSHA), EPA, and applicable state and local regulations. The EPA National Emission Standard for Hazardous Air Pollutants (NESHAP) 40 CFR 61, Subparts A and M has a requirement related to assessment of suspect ACM in buildings. When the asbestos content of a friable material is visually estimated by PLM to be detectable but less than ten percent, your firm may elect to (1) assume the amount is greater than one percent and treat the material as asbestos-containing or (2) require verification of the amount by the PLM point counting technique. If the results obtained by point counting and visual estimation are different, the point count result must be used. When no asbestos is detected by PLM, point counting is not required.

4.0 LEAD ASSESSMENT

Homogeneous areas of suspected lead-containing coatings (paints) were identified and sampled in accessible areas throughout Buildings 25, 27, and Substation 11 at Terminal 91 for the T-91 Tank Farm Cleanup Project located in Seattle, Washington. Homogeneous painted surfaces were defined by substrate, application, and color.

4.1 Sampling Methodology

Paint chip samples were collected to the substrate to ensure that all layers present on the substrate were included in the laboratory analysis. Each sample was collected and stored in a heavy-duty, self-sealing plastic bag and delivered to NVL Laboratories in Seattle, Washington. Samples were analyzed via Atomic Absorption Spectrophotometry in accordance with Method EPA 7000B. NVL Laboratories in Seattle, Washington are accredited by the American Industrial Hygiene Association (AIHA) for lead analysis.

4.2 Lead Sampling Results

Eighteen paint chip samples were collected and analyzed and 15 of the samples had reportable levels of lead. The results of the analyses are presented in Table 4.2-1. Two of the 18 paint chip samples were collected and analyzed for the RCRA 8 heavy metals (including lead). The results of the analyses for RCRA 8 heavy metals can be found in Tables 6.3-1.

Table 4.2-1. Paint Chip Sample Results

Paint Number and Description	Paint Location	Sample Result in parts per million (ppm)
PB1: Silver paint on metal	B27: roof	11,000
PB2: Off-white paint on metal	B27: exterior window frames	25,000
PB3: Off-white paint on metal	B27: interior walls and ceiling	3,400
PB4: Off-white paint on metal	B27: interior window frames	2,700
PB5: Light grey paint on concrete	B27: interior foundation walls	5,100
PB6: Yellow paint on metal	B27 southeast exterior: on metal guard rails	93,000
PB7: Off-white paint on metal	B27: exterior gutters	27,000
PB8: White paint on metal	B27: door	6,900
PB9: Light grey paint on brick	B25: exterior brick walls	2,800
PB10: Light grey paint on metal	B25: door and door frame	1,200
PB11: Grey paint on metal	B25: interior window frames	2,100
PB12: Grey paint on wood	B25: floor	2,200
PB13: Light grey paint on brick	B25: interior brick walls	800

Paint Number and Description	Paint Location	Sample Result in parts per million (ppm)
PB14: Light grey paint on metal	B25: building framing	6,000
PB15: Grey and yellow paint n metal	B25: exterior window frames	18,000
PB16: Grey paint on metal	SS11: exterior panels of transformers	<47

<: below the reporting limit

5.0 WASTE CHARACTERIZATION OF LEAD BY TCLP

Building demolition and waste debris must be characterized before it can be accepted by a landfill in accordance with WAC 173-303. The characterization of waste streams known to contain lead is determined using the Toxicity Characteristic Leachate Process (TCLP), which determines the leaching potential of lead in the construction debris. A material "fails" the TCLP when there is greater than 5.0 parts per million (ppm) of lead in the leachate.

5.1 Methodology

Field estimates of the individual building components comprising the entire waste stream were made on a percentage basis. Building materials were assessed in place. Argus Pacific assumed metal components would be recycled and were not included in the TCLP samples.

The following building components were included in the composite samples:

Building 27

- Unpainted concrete: 90%
- Painted concrete stem wall: 10%

Building 25

- Painted brick and mortar walls: 50%
- Exterior unpainted stucco/plaster wall: 15%
- Interior painted wood floor: 20%
- Unpainted wood: 15%

Composite samples containing the relative percentage of each of the individual building materials was submitted to NVL Laboratories, Inc. in Seattle, WA. Analysis of the samples was conducted to determine the presence of leachable lead using Atomic Absorption Spectrophotometry (AAS) in accordance with EPA SW-846 Method 1311 (Toxicity Leachate Characteristic Process). This method reports results in milligrams of leachable lead per liter (mg/L or ppm).

5.2 Results

Both TCLP samples were found to contain no reportable levels of lead in the leachate. Laboratory results are included as appendices.

6.0 OTHER REGULATED BUILDING MATERIALS

6.1 Methodology – Heavy Metals (Paints)

Suspected heavy metal-containing paint chip samples were collected in the same manner as suspected lead-containing paint chip samples. Each sample was collected and stored in a heavy-duty, self-sealing plastic bag and delivered to NVL Laboratories in Seattle, Washington. Samples were analyzed in accordance with EPA 7000B. NVL Laboratories in Seattle, Washington is accredited by the Washington State Department of Ecology for heavy metals analysis.

6.2 Methodology – Universal Wastes

An inventory of fluorescent light tubes, HID lamps, and potential PCB-containing ballasts was conducted in accessible areas of the project.

Where fluorescent light fixtures were accessible, the ballast covers were removed, and the ballast labels were visually examined. Different types of fluorescent fixtures were distinguished by shield shape, fixture dimension, diffuser type, and the manner in which the ballast covers were connected to the fixture. Inspectors attempted to visually inspect at least two of each type of fluorescent light fixture.

Where fluorescent light fixtures could not be visually examined, the number of potential PCB-containing ballasts in fixture were estimated based on the following assumptions:

- Each single light tube fluorescent fixture contains one ballast.
- Each multiple light tube fluorescent fixture contains one ballast for every pair of light tubes.
- All light ballasts are assumed to contain PCBs unless the manufacturer's label indicates they are electronic ballasts.

Where high intensity discharge lamps could not be accessed or examined, the following assumptions were made:

- Each HID lamp contains one ballast;
- Each HID lamp contains a minimum of one mercury bulb, sodium vapor bulb, or metal halide bulb.

6.3 Results

Heavy metals were detected in the paints sampled. The following table shows the results of the suspected heavy metal-containing paint sampling, including sample number and description, material location, and laboratory results.

Table 6.3-1. Heavy Metals (Paints) Sample Results

Sample Number and Description	Material Location	Sample Result in parts per million (ppm)
RCRA1: Off-white paint on metal	B27: exterior siding	Silver: <20 Arsenic: 140 Barium: 130 Cadmium: 72 Chromium: 230 Mercury: <1 Lead: 21,000 Selenium: 24
RCRA2: Off-white paint on metal	B27: interior metal framing	Silver: <21 Arsenic: <21 Barium: 140 Cadmium: 24 Chromium: <21 Mercury: <1.1 Lead: 1,200 Selenium: <21

<: below the reporting limit

Mercury-containing fluorescent light tubes were identified in Building 25. HID lamps were identified on the exterior of the buildings. One potential PCB-containing transformer was identified on the north exterior of Building 25.

Table 6.3-2. Universal Wastes Results

Other Regulated Building Materials Description	Approximate Quantity
B25: Mercury-containing fluorescent light tubes (8' length)	2
B25: HID lamp	1
B25: Suspect PCB-containing transformer	1
B27: HID lamps	2

7.0 CONCLUSIONS AND RECOMMENDATIONS

On November 13, 2012, Argus Pacific conducted a regulated building materials assessment of Buildings 25, 27, and Substation 11 at Terminal 91 and for the T-91 Tank Farm Cleanup Project located at in Seattle, Washington. In addition to the structures listed above, Argus Pacific assessed the former loading dock and ramp on the east side of the project area near Building 27, several sump pumps and associated piping, and a remaining portion of a tank pad.

7.1 Asbestos

As per client direction, some materials were assumed to contain asbestos but were not sampled. These materials were not sampled for the safety of the inspector. The following table identifies the confirmed ACM and assumed ACM.

Table 7.1-1. ACM and Assumed ACM

HSA ID, Material Description, and AHERA Classification	Material Location	HSA Quantity (approximate)
3: Electrical panels (M)	B27: East wall in northeast corner of room	1 Each
4: Electrical wiring in panel and metal conduit (M)	B27: Interior of electrical panel and conduit	Not quantified
13: Gaskets (M)	Associated with exterior piping throughout site	15 Each
32: Large electrical panels with wiring and other components (M)	B25	4 Each
35: Electrical panels with wiring and other components (M)	SS11: interior	Inaccessible

Asbestos-related work must be performed in compliance with Washington State worker protection and environmental protection regulations. See WAC 296-62, WAC 296-65, and PSCAA Regulation III, Article 4 for additional information.

7.2 Lead

Sixteen of the 18 paints sampled and analyzed contained detectable levels of lead. The Washington State Department of Labor and Industries requires an exposure assessment be conducted during operations that may disturb the lead paint in such a way that the airborne exposure may reach or exceed the Action level of 30 micrograms per cubic meter ($\mu g/m^3$) or the Permissible Exposure Limit of 50 $\mu g/m^3$. The worker protection requirements of WAC 296-62-155-176 "Lead in Construction" may apply.

Some of the coatings contained detectable levels of lead. Argus Pacific collected two toxicity characteristic leachate procedure (TCLP) samples and both had no reportable levels of leachable lead. If the actual waste stream differs, additional sampling may be required. If the results of the TCLP analysis determine the waste to be a "dangerous waste" as defined by WAC 173-303, it must be disposed of accordingly.

The lead paint chip samples were collected by a Washington State Department of Commerce (DOC)-accredited lead inspector/risk assessor and therefore can be used to meet the requirements of the Washington State Department of Commerce's Lead; Renovation, Repair, and Painting rule (RRP). Refer to WAC 365-230 for additional information. However, if painted surfaces are to be impacted that were not sampled as part of this inspection, those surfaces must be assessed for lead content by an RRP Contractor or a DOC-accredited lead inspector in order to meet the RRP rule.

7.3 Other Regulated Building Materials

Regarding heavy metals, all of the paint samples were found to contain detectable levels of certain heavy metals. Two paint chip samples were collected and analyzed for heavy metals, including silver, arsenic, barium cadmium chromium, mercury, lead, and selenium. Both of the samples had detectable levels of lead, and those two samples are included in the lead paint sample count in Section 7.2 above. Regarding heavy metals other than lead, one of the samples was found to contain detectable levels of arsenic, barium, cadmium, chromium, and selenium. One sample was found to contain detectable levels of barium, cadmium, and chromium. For impacting materials with detectable levels of arsenic, barium, cadmium, chromium, and selenium, refer to WAC 296-841.

Fluorescent light tubes, HID lamps, switches, and thermostats may contain mercury. Fluorescent light ballasts and HID lamp ballasts may contain PCBs. In Washington State, even ballasts labeled with "No PCBs" may have regulated amount of PCBs and therefore should be handled in accordance with Washington Department of Ecology requirements. Employers must inform their employees of mercury and PCB hazards in accordance with WAC 296-800-170.

Fluorescent light tubes, HID lamps, switches, and thermostats light ballasts must be removed and recycled or disposed of prior to building demolition as per 40 CFR 262, 40 CFR 265, and WAC 173-303.

8.0 LIMITATIONS

This report presents the results of the regulated building materials assessment conducted of Buildings 25, 27, and Substation 11 at Terminal 91 for the T-91 Tank Farm Cleanup Project located at in Seattle, Washington. The assessment was for the purposes of identifying ACM, lead-containing paint and TCLP sampling, heavy metals in paint, PCB caulking, mercury-containing components, PCB ballasts, and HID lamps prior to demolition.

Regulated building material assessments are non-comprehensive and subject to many limitations, including those presented below. Our assessment has considered risks pertaining to asbestos, lead in coatings and TCLP, heavy metals in paint, PCB caulking, fluorescent lamps, mercury switches, PCB ballasts, and HID lamps; however, this assessment is limited to only those locations and materials assessed. This assessment was not designed to identify all potential concerns or to eliminate all risks associated with renovation, demolition, material removal, construction, or transferring of property title. Evaluation of other risks not specifically described in the Scope of Work have not been included; for example: structural integrity; engineering loads; electrical; mechanical; radon gas; slope stability; building settlement; and evaluation of toxic and hazardous substances in, or in contact with, soil and groundwater. No warranty, expressed or implied, is made.

Argus Pacific has performed the services set forth in the Scope of Work in accordance with generally accepted industrial hygiene practices in the same or similar localities, related to the nature of the work accomplished, at the time the services were performed.

The regulated building materials and conditions presented in this report represent those observed on the dates we conducted the sampling. This sampling is intended for the exclusive use of PES Environmental, Inc. for specific application to the referenced property. This assessment does not replace nor can be used as professionally developed construction or demolition plans, specifications, or bidding documents. This report is not a legal opinion.

Prepared by:

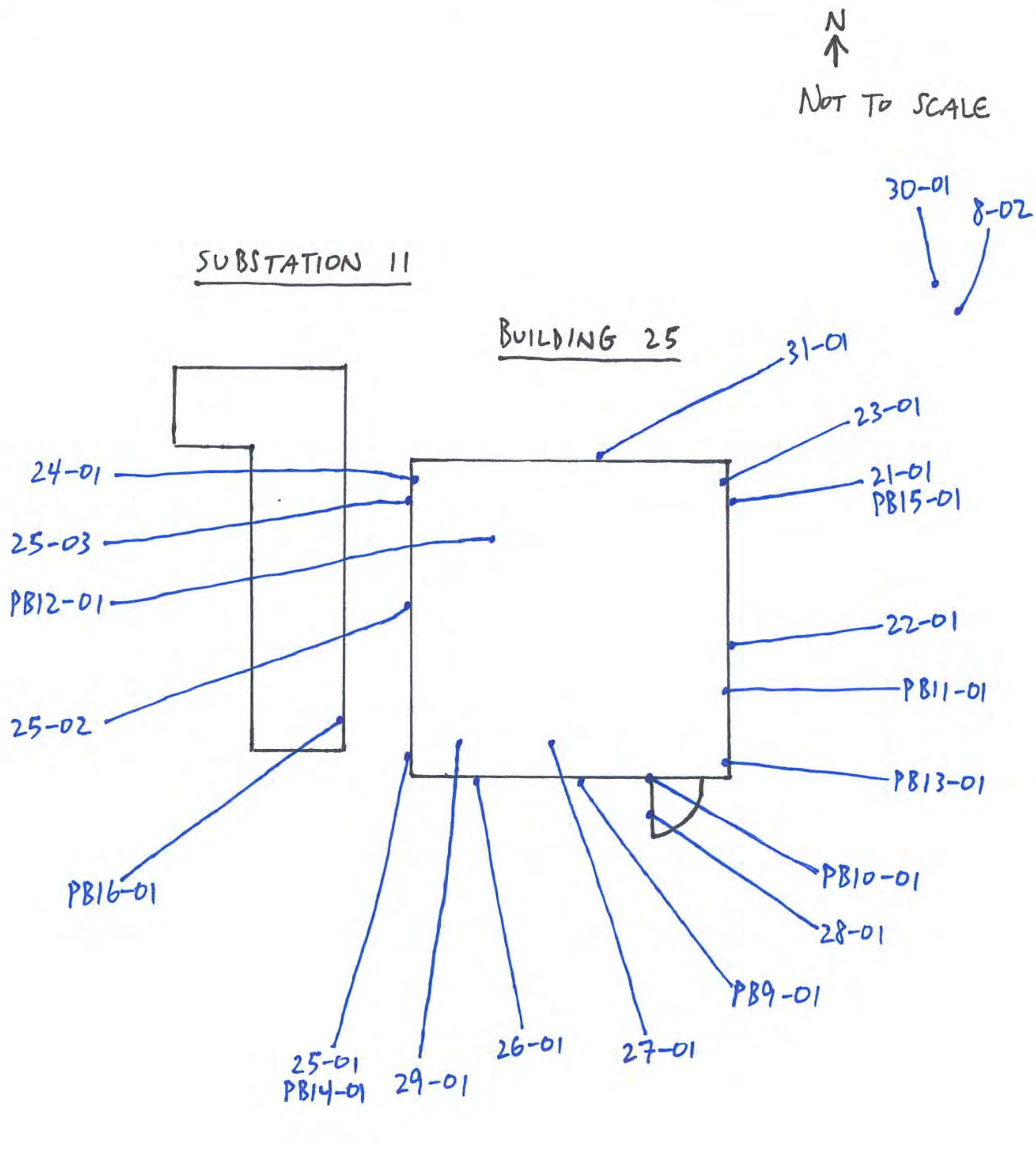
Scott Rinear
Project Manager
Argus Pacific, Inc.

Reviewed by:

Nicole Gladu
Senior Consultant
Argus Pacific, Inc.

Figures

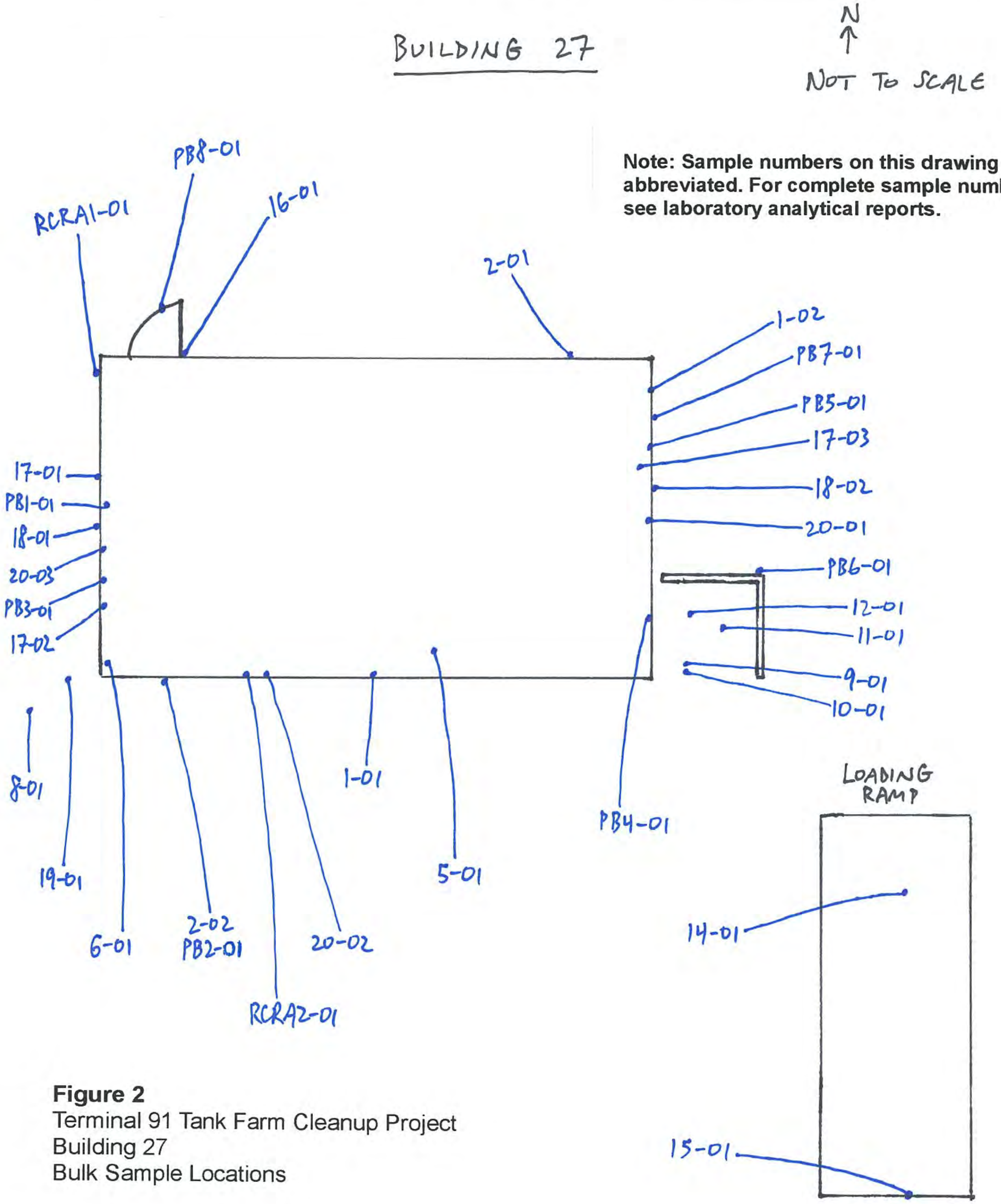
PROJECT NAME		
TERMINAL 91 TANK FARM CLEANUP PROJECT		ARGUS PACIFIC TRAINING • CONSULTING
SUBJECT: BUILDING 25 & SUBSTATION 11		PROJECT NUMBER: 640480R.1
CREATED BY: SR	DATE: 11/13/12	PAGE OF



Note: Sample numbers on this drawing are abbreviated. For complete sample numbers, see laboratory analytical reports.

Figure 1
Terminal 91 Tank Farm Cleanup Project
Building 25 and Substation 11
Bulk Sample Locations

PROJECT NAME		
TERMINAL 91 TANK FARM CLEANUP PROJECT		ARGUS PACIFIC TRAINING•CONSULTING
SUBJECT: BUILDING 27		PROJECT NUMBER: 640480R.1
CREATED BY: SR	DATE: 11/13/12	PAGE OF



Note: Sample numbers on this drawing are abbreviated. For complete sample numbers, see laboratory analytical reports.

Figure 2
Terminal 91 Tank Farm Cleanup Project
Building 27
Bulk Sample Locations

Photographs

HSA No. 1. Grey interior window glazing compound (M)

HSA No. 2. Grey exterior window glazing compound (M)

HSA No. 3. Electrical panel (M)

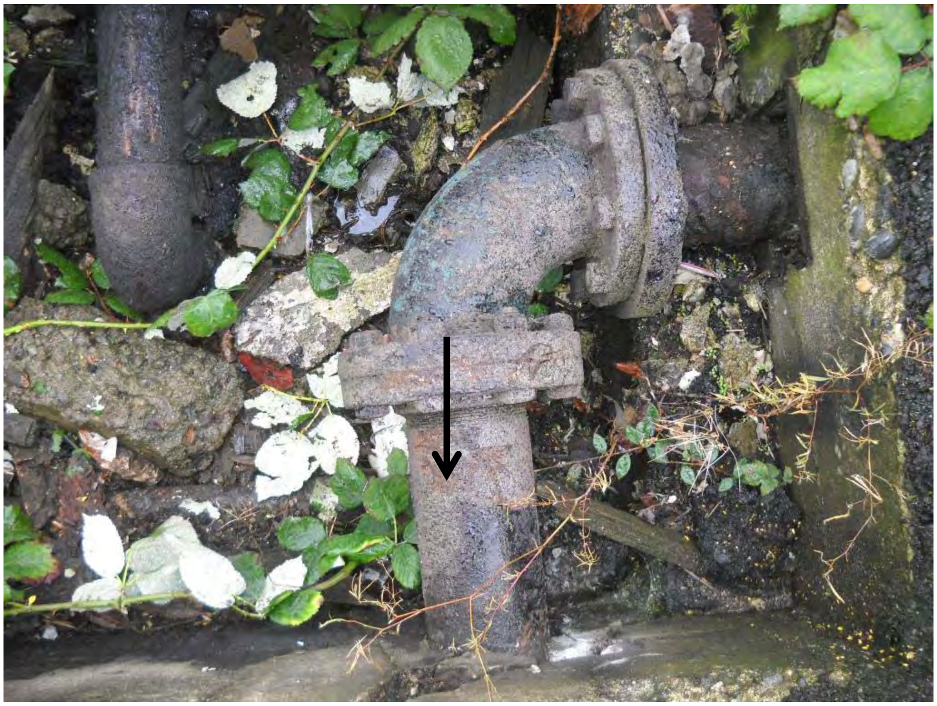
HSA No. 4. Electrical wiring (in electrical panel and conduit) (M)

HSA No. 5. Grey fibrous paper (M)

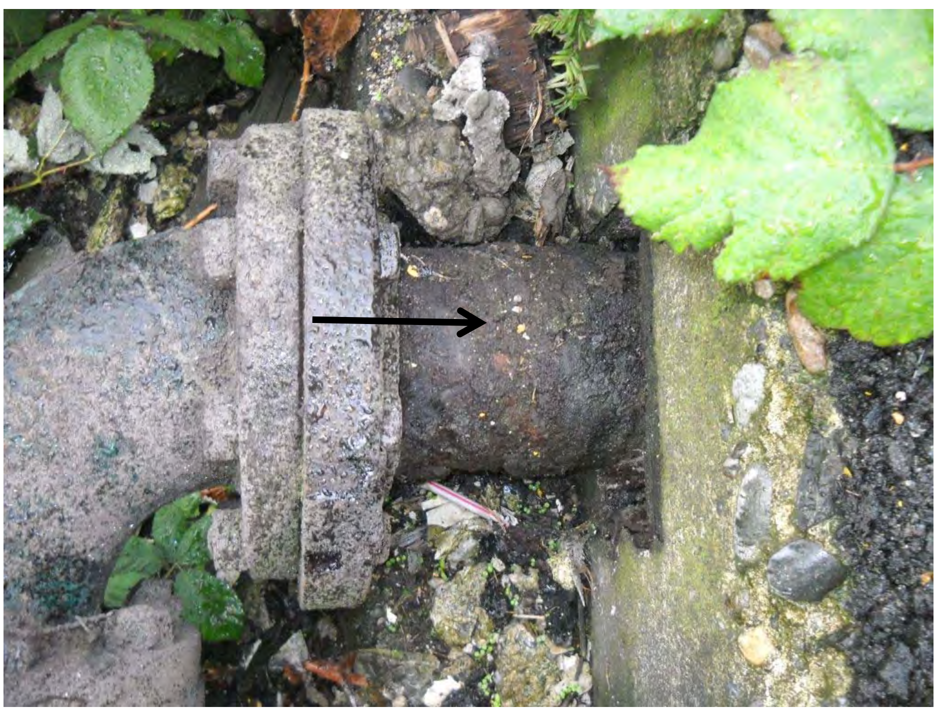
HSA No. 6. Brown fibrous paper debris (M)

HSA No. 7. Clear silicone sealant (M)

HSA No. 8. Grey cementitious material (M)



HSA No. 9. Black asphaltic coating (M)



HSA No. 10. Black paper wrap (M)

HSA No. 11. Black coating (M)

HSA No. 12. Black asphalt coating and canvas material (M)

HSA No. 13. Gaskets (M)

HSA No. 14. Grey/beige sealant (M)

HSA No. 15. Light grey sealant (M)

HSA No. 16. Black coating (M)

HSA No. 17. Silver paint and trace powdery material (M)

HSA No. 18. Off-white coating/sealant (M)

HSA No. 19. Grey fibrous paper gasket (M)

HSA No. 20. Silver paint and brittle material (M)

HSA No. 21. Grey exterior window glazing compound (behind metal panels) (M)

HSA No. 22. Grey interior window glazing compound (M)

HSA No. 23. Red brick and grey mortar (M)

HSA No. 24. Larger red brick and mortar (M)

HSA No. 25. Grey stucco/plaster with metal lath (S)

HSA No. 26. Penetration patching compound (M)

HSA No. 27. Brown residual floor sheeting (M)

HSA No. 28. Black coating (M)

HSA No. 29. Red gasket (M)

HSA No. 30. Red gasket (M)

HSA No. 31. Black gasket (M)

HSA No. 32. Large electrical panels and wiring (M)

HSA No. 33. Newer electrical panels (M)

HSA No. 34. Black residual material (M)

HSA No. 35. Electrical panels and wiring (M)

Appendix A
Asbestos Laboratory Analytical Results

SEATTLE ASBESTOS TEST, LLC

NVLAP Accreditation Lab Codes:
LYNNWOOD LAB: 200768-0, BELLEVUE LAB: 200876-0

19711 Scriber Lake Road, Suite D, Lynnwood, WA 98036, Tel:425.673.9850
12727 Northup Way, Suite 1, Bellevue, WA 98005, Tel:425.861.1111
www.seattleasbestostest.com, admin@seattleasbestostest.com

Date Analyzed: 11/16/2012

Client Job# 640480R.1
Project Loc.: T91 Building 25 & 27
Laboratory Batch#: 201214707
Samples Received: 38

Mr. Scott Rinear
Argus Pacific
1900 W Nickerson St # 315, Seattle, WA 98119

Enclosed please find the test results for the bulk samples submitted to our laboratory for asbestos analysis. Analysis was performed using polarized light microscopy (PLM) in accordance with Test Method US EPA/600/R-93/116.

Percentages for this report are done by visual estimate. Since variation in data increases as the quantity of asbestos decreases toward the limit of detection, the EPA recommends point counting for samples containing between <1% and 10% asbestos (NESHAP, 40 CFR Part 61). Statistically, point counting is a more accurate method. If you feel a point count might be beneficial, please feel free to call and request one.

The test results refer only to the samples or items submitted and tested. The accuracy with which these samples represent the actual materials is totally dependent on the acuity of the person who took the samples. This report must not be used by the client to claim product certification, approval, or endorsement by Seattle Asbestos Test, LLC, NVLAP, NIST, or any agency of the Federal government.

This report is highly confidential and will not be released without your consent. Samples are archived for two weeks after the analysis, and disposed of as hazardous waste thereafter.

Thank you for using our service and let us know if we can further assist you.

Sincerely

Steve (Fanyao) Zhang
President

SEATTLE ASBESTOS TEST, LLC **Analyzing Quality**

Lynnwood Lab: 19711 Scriber Lake Road, Suite D, Lynnwood, WA 98036, T:425.673.9850, F:425.673.9810
Bellevue Lab: 12727 Northup Way, Suite 24, Bellevue, WA 98005, T:425.861.1111, F:425.861.1118
Email: admin@seattleasbestostest.com, website: www.seattleasbestostest.com
NVLAP Lab Code: Lynnwood: 200768-0, Bellevue: 200876-0

Batch#: #201214707

CHAIN OF CUSTODY

CLIENT INFORMATON

Company: Argus Pacific, Inc. **Address:** 1900 W Nickerson Street, #315, Seattle, WA 98119
Phone: (206) 285-3373 Fax: (206) 285-3927 Email: srinear@arguspacific.com

METHOD (SELECT ONE)

(●) Bulk Asbestos (PLM) ( ) PointCount400 ( ) PointCount1000 ( ) Pt. Count Gravimetric ( ) Other (Specify)

PROJECT INFORMATION

\# of Samples: 38 Job#: 640480R.1 Project Location: T91 Building 25 & 27

PROJECT MANAGERS (SELECT ONE OR MORE)

	Name	Phone	Email		Name	Phone	Email
☐	Elizabeth Black			☐	Nicole Gladu		nicole@arguspacific.com
☐	Melodie McNab			☐	Tim Nickell		
☐	Scott Parker		sparker@arguspacific.con	☑	Scott Rinear		srinear@arguspacific.com
☐	Christopher Selders		chris@arguspacific.com	☐	John Terrill		john@arguspacific.com
☐	Joe White			☐	Megan Yoshimoto		

TURNAROUND TIME

( ) 1 Hour ( ) 2 Hours ( ) Same Day (4 to 6 hrs) ( ) 1 Day (●) Number of Days: 3

SEQ#	CLIENT SAMPLE #	SAMPLE DESCRIPTION	GROUP	COMPOSITE	PT. COUNT
1	640480-1-01				
2	640480-1-02				
3	640480-2-01				
4	640480-2-02				
5	640480-5-01				
6	640480-6-01				
7	640480-8-01				
8	640480-8-02				
9	640480-9-01				
10	640480-10-01				
11	640480-11-01				
12	640480-12-01				
13	640480-14-01				
14	640480-15-01				
15	640480-16-01				
16	640480-17-01				
17	640480-17-02				
18	640480-17-03				
19	640480-18-01				
20	640480-18-02				

	Print Name	Signature	Company Name	Date	Time
Sampled by	Scott Rinear	[signature]	Argus Pacific	11/13/12	9-2
Relinquished by	Scott Rinear	[signature]	Argus Pacific	11/13/12	5P FEDEX
Delivered by	FEDEX				
Received by	Christina Bud	[signature]	Seattle Asbestos Test, LLC-B	11/14/12	1225
Analyzed by	Christina Bud	[signature]	Seattle Asbestos Test, LLC-B	11/16/12	0940
Reported by	Steve Zhang	[signature]	Seattle Asbestos Test, LLC	11/16/12	

PREFERRED REPORTING METHOD ☐ Phone ☐ Fax ☑ Email ☐ Postal Mail

SEATTLE ASBESTOS TEST, LLC

Analyzing Quality

Lynnwood Lab: 19711 Scriber Lake Road, Suite D, Lynnwood, WA 98036, T:425.673.9850, F:425.673.9810
Bellevue Lab: 12727 Northup Way, Suite 24, Bellevue, WA 98005, T:425.861.1111, F:425.861.1118
Email: admin@seattleasbestostest.com, website: www.seattleasbestostest.com
NVLAP Lab Code: Lynnwood: 200768-0, Bellevue: 200876-0

Batch# #201214707

CHAIN OF CUSTODY

CLIENT INFORMATON

Company: Argus Pacific, Inc. Address: 1900 W Nickerson Street, #315, Seattle, WA 98119
Phone: (206) 285-3373 Fax: (206) 285-3927 Email: srinear@arguspacific.com

METHOD (SELECT ONE)

(●) Bulk Asbestos (PLM) ( ) PointCount400 ( ) PointCount1000 ( ) Pt. Count Gravimetric ( ) Other (Specify)

PROJECT INFORMATION

# of Samples: 38 Job#: 640480R.1 Project Location: T91 Building 25 & 27

PROJECT MANAGERS (SELECT ONE OR MORE)

	Name	Phone	Email		Name	Phone	Email
☐	Elizabeth Black			☐	Nicole Gladu		nicole@arguspacific.com
☐	Melodie McNab			☐	Tim Nickell		
☐	Scott Parker		sparker@arguspacific.con	☑	Scott Rinear		srinear@arguspacific.com
☐	Christopher Selders		chris@arguspacific.com	☐	John Terrill		john@arguspacific.com
☐	Joe White			☐	Megan Yoshimoto		

TURNAROUND TIME

( ) 1 Hour ( ) 2 Hours ( ) Same Day (4 to 6 hrs) ( ) 1 Day (●) Number of Days: 3

SEQ#	CLIENT SAMPLE #	SAMPLE DESCRIPTION	GROUP	COMPOSITE	PT. COUNT
21	640480-19-01				
22	640480-20-01				
23	640480-20-02				
24	640480-20-03				
25	640480-21-01				
26	640480-22-01				
27	640480-23-01				
28	640480-24-01				
29	640480-25-01				
30	640480-25-02				
31	640480-25-03				
32	640480-26-01				
33	640480-27-01				
34	640480-28-01				
35	640480-29-01				
36	640480-30-01				
37	640480-31-01				
38	640480-34-01				
39					
40					

	Print Name	Signature	Company Name	Date	Time
Sampled by	Scott Rinear	[signature]	Argus Pacific	11/13/12	9-2
Relinquished by	Scott Rinear	[signature]	Argus Pacific	11/13/12	5P FEDEX
Delivered by	FEDEX				
Received by	Christina Bxe	[signature]	Seattle Asbestos Test, LLC - B	11/14/12	1225
Analyzed by	Christina Bxe	[signature]	Seattle Asbestos Test, LLC - B	11/16/12	0940
Reported by	Steve Zhang	[signature]	Seattle Asbestos Test, LLC	11/16/12	

PREFERRED REPORTING METHOD ☐ Phone ☐ Fax ☑ Email ☐ Postal Mail

SEATTLE ASBESTOS TEST, LLC NVLAP Accreditation Lab Codes - Bellevue:200876; Lynnwood:200768
Lynnwood Laboratory: 19711 Scriber Lake Rd, Suite D, Lynnwood, WA 98036; Tel: 425.673.9850, Fax:425.673.9810
Bellevue Laboratory: 12727 Northup Way, Suite 1, Bellevue, WA 98005; Tel: 425.861.1111, Fax: 425.861.1118
Website: http://www.seattleasbestostest.com, E-mail: admin@seattleasbestostest.com

ANALYTICAL LABORATORY REPORT
PLM by Method EPA/600/R-93/116

Attn.: Mr. Scott Rinear
Client: Argus Pacific
Address: 1900 W Nickerson St # 315, Seattle, WA 98119

Project: T91 Building 25 & 27

Client Job#: 640480R.1
Laboratory Batch #: 201214707
Date Received: 11/14/2012
Samples Received: 38
Date Analyzed: 11/16/2012
Samples Analyzed: 38

Lab ID	Client Sample ID	Layer	Description	%	Asbestos Fibers	Non-Fibrous Components	%	Non-asbestos Fibers
1	640480-1-01	1	Tan brittle material with paint		**None detected**	Paint, Filler, Binder	2	Cellulose
2	640480-1-02	1	Light gray brittle material with paint		**None detected**	Paint, Filler, Binder	3	Cellulose
3	640480-2-01	1	Tan/white brittle material with debris		**None detected**	Filler, Binder, Debris	2	Cellulose
4	640480-2-02	1	Tan/gray brittle material with debris		**None detected**	Filler, Binder, Debris	3	Cellulose
5	640480-5-01	1	Black fibrous material with soft material and debris		**None detected**	Filler, Fine particles, Debris	60	Synthetic fibers, Cellulose
6	640480-6-01	1	Brown fibrous material		**None detected**	Filler, Fine particles	91	Cellulose
7	640480-8-01	1	Dark gray sandy/brittle material		**None detected**	Sands, Filler, Binder	3	Cellulose
8	640480-8-02	1	Dark gray sandy/brittle material		**None detected**	Sands, Filler, Binder	2	Cellulose
9	640480-9-01	1	Black soft asphaltic material		**None detected**	Asphalt/binder, Binder/filler	5	Cellulose
10	640480-10-01	1	Black asphaltic material with fibrous material		**None detected**	Asphalt/binder, Binder/filler	62	Cellulose
11	640480-11-01	1	Black asphaltic material with fibrous material and debris		**None detected**	Asphalt/binder, Binder/filler, Debris	36	Cellulose
12	640480-12-01	1	Black asphaltic material with brittle material		**None detected**	Asphalt/binder, Binder/filler, Synthetic foam	31	Cellulose
		2	Black woven fibrous material		**None detected**	Asphalt/binder	76	Synthetic fibers, Cellulose
13	640480-14-01	1	Gray soft/elastic material with debris		**None detected**	Binder, Filler, Debris	5	Synthetic fibers, Cellulose
14	640480-15-01	1	Gray/white soft/elastic material with debris		**None detected**	Binder, Filler, Debris	4	Cellulose
		2	Gray sandy/brittle material		**None detected**	Sands, Filler, Binder	3	Cellulose
15	640480-16-01	1	Trace gray sandy/brittle material with paint		**None detected**	Paint, Filler, Binder	2	Cellulose
16	640480-17-01	1	Silver paint		**None detected**	Paint, Filler	4	Cellulose
		2	Trace white powdery material with paint		**None detected**	Binder/filler, Paint	5	Cellulose
17	640480-17-02	1	Silver paint with debris		**None detected**	Paint, Filler, Debris	3	Cellulose
18	640480-17-03	1	Silver paint with soft materal and debris		**None detected**	Paint, Filler, Debris	5	Cellulose
19	640480-18-01	1	Gray/white brittle material with paint		**None detected**	Paint, Filler, Binder	2	Cellulose
20	640480-18-02	1	Gray/white brittle material with paint		**None detected**	Paint, Filler, Binder	3	Cellulose
21	640480-19-01	1	Gray fibrous material		**None detected**	Filler, Fine particles	85	Cellulose
22	640480-20-01	1	Silver paint with brittle material and debris		**None detected**	Paint, Filler, Debris	2	Cellulose
23	640480-20-02	1	Silver paint with brittle material and debris		**None detected**	Paint, Filler, Debris	3	Cellulose
24	640480-20-03	1	Silver paint with brittle material and debris		**None detected**	Paint, Filler, Debris	2	Cellulose

Analyzed by: Christina Buce / April Smith

Report reviewed by: Steve (Fanyao) Zhang, President

SEATTLE ASBESTOS TEST, LLC NVLAP Accreditation Lab Codes - Bellevue:200876; Lynnwood:200768
Lynnwood Laboratory: 19711 Scriber Lake Rd, Suite D, Lynnwood, WA 98036; Tel: 425.673.9850, Fax:425.673.9810
Bellevue Laboratory: 12727 Northup Way, Suite 1, Bellevue, WA 98005; Tel: 425.861.1111, Fax: 425.861.1118
Website: http://www.seattleasbestostest.com, E-mail: admin@seattleasbestostest.com

ANALYTICAL LABORATORY REPORT
PLM by Method EPA/600/R-93/116

Attn.: Mr. Scott Rinear
Client: Argus Pacific
Address: 1900 W Nickerson St # 315, Seattle, WA 98119

Project: T91 Building 25 & 27

Client Job#: 640480R.1
Laboratory Batch #: 201214707
Date Received: 11/14/2012
Samples Received: 38
Date Analyzed: 11/16/2012
Samples Analyzed: 38

Lab ID	Client Sample ID	Layer	Description	%	Asbestos Fibers	Non-Fibrous Components	%	Non-asbestos Fibers
25	640480-21-01	1	Trace white brittle material with paint		**None detected**	Filler, Binder, Paint	2	Cellulose
		2	Trace tan powdery material with paint		**None detected**	Filler, Binder, Paint	5	Cellulose
26	640480-22-01	1	Off-white brittle material with paint		**None detected**	Filler, Binder, Paint	2	Cellulose
		2	Trace gray sandy/brittle material		**None detected**	Sands, Filler, Binder	3	Cellulose
27	640480-23-01	1	Red brittle material with paint		**None detected**	Brick/binder, Paint		None detected
		2	White brittle/sandy material		**None detected**	Binder, Sands	2	Cellulose
28	640480-24-01	1	Red brittle material		**None detected**	Brick/binder		None detected
		2	Gray brittle/sandy material		**None detected**	Filler, Binder, Sands	3	Cellulose
29	640480-25-01	1	Gray brittle/sandy material		**None detected**	Binder, Sands	2	Cellulose
30	640480-25-02	1	Gray brittle/sandy material		**None detected**	Binder, Sands	2	Cellulose
31	640480-25-03	1	Gray brittle/sandy material		**None detected**	Binder, Sands	3	Cellulose
32	640480-26-01	1	Gray sandy/brittle material		**None detected**	Filler, Binder, Sands	3	Cellulose
33	640480-27-01	1	Brown brittle material with sand and debris		**None detected**	Filler, Binder, Debris	5	Cellulose
34	640480-28-01	1	Gray/black paint with debris		**None detected**	Paint, Filler, Debris	4	Cellulose
35	640480-29-01	1	Red soft material with debris		**None detected**	Binder, Filler, Debris	3	Cellulose
36	640480-30-01	1	Red soft/elastic material		**None detected**	Binder, Filler	4	Cellulose
37	640480-31-01	1	Black soft/elastic material		**None detected**	Binder, Filler	2	Cellulose
38	640480-34-01	1	Black brittle material		**None detected**	Asphalt/binder, Binder/filler	6	Cellulose

Analyzed by: Christina Buce / April Smith

Report reviewed by: Steve (Fanyao) Zhang, President

Appendix B
Lead Laboratory Analytical Results

November 20, 2012

NVL LABS
INDUSTRIAL HYGIENE SERVICES
Laboratory | Management | Training

Scott Rinear
Argus Pacific, Inc.
1900 W. Nickerson St., Suite 315
Seattle, WA 98119

RE: Metals Analysis; NVL Batch # 1218242.00

Dear Mr. Rinear,

Enclosed please find the test results for samples submitted to our laboratory for analysis. Preparation of these samples was conducted following protocol outlined in EPA Method SW 846-3051 unless stated otherwise. Analysis of these samples was performed using analytical instruments in accordance with U.S. EPA, NIOSH, OSHA and other ASTM methods.

For matrix materials submitted as paint, dust wipe, soil or TCLP samples, analysis for the presence of total metals is conducted using published U.S. EPA Methods. Paint and soil results are usually expressed in mg/Kg which is equivalent to parts per million (ppm). Lead (Pb) in paint is usually expressed in mg/Kg (ppm) , Percent (%) or mg/cm^2 by area. Dust wipe sample results are usually expressed in ug/wipe and ug/ft^2. TCLP samples are reported in mg/L (ppm). For air filter samples, analyses are conducted using NIOSH and OSHA Methods. Results are expressed in ug/filter and ug/m^3. Other matrix materials are analyzed accordingly using published methods or specified by client. The reported test results pertain only to items tested. Lead test results are not blank corrected.

For recent regulation updates pertaining to current regulatory levels or permissible exposure levels, please call your local regulatory agencies for more details.

This report is considered highly confidential and will not be released without your approval. Samples are archived for two weeks following analysis. Samples that are not retrieved by the client are discarded after two weeks.

Thank you for using our laboratory services. if you need further assistance please feel free to call us at 206-547-0100 or 1-888-NVLLABS.

Sincerely,

Nick Ly, Technical Director

Enclosure:

ilac-MRA
AIHA LAP, LLC
ACCREDITED LABORATORY
LAB # 101861

NVL Laboratories, Inc.
4708 Aurora Ave. N., Seattle, WA 98103
Tel: 206.547.0100, Fax: 206.634.1936
www.nvllabs.com

Analysis Report

AIHA - IH # 101861
WA - DOE # C1765

AIHA Environmental Lead and Industrial Hygiene ACCREDITED LABORATORY

Total Lead (Pb)

Client: Argus Pacific, Inc.
Address: 1900 W. Nickerson St., Suite 315
Seattle, WA 98119

Attention: Mr. Scott Rinear
Project Location: B25 & B27

Batch #: 1218242.00
Matrix: Paint Chips
Method: EPA 7000B
Client Project #: 640480R.1
Date Received: 11/14/2012
Samples Received: 16
Samples Analyzed: 16

Lab ID	Client Sample #	Sample Weight (g)	RL in mg/Kg	Results in mg/Kg	Results in percent
12103722	640480-PB1-01	0.2200	42.0	11000.0	1.1000
12103723	640480-PB2-01	0.1929	48.0	25000.0	2.5000
12103724	640480-PB3-01	0.1961	47.0	3400.0	0.3400
12103725	640480-PB4-01	0.1990	46.0	2700.0	0.2700
12103726	640480-PB5-01	0.1927	48.0	5100.0	0.5100
12103727	640480-PB6-01	0.2109	43.0	93000.0	9.3000
12103728	640480-PB7-01	0.2099	44.0	27000.0	2.7000
12103729	640480-PB8-01	0.2106	44.0	6900.0	0.6900
12103730	640480-PB9-01	0.1985	46.0	2800.0	0.2800
12103731	640480-PB10-01	0.1966	47.0	1200.0	0.1200
12103732	640480-PB11-01	0.1994	46.0	2100.0	0.2100
12103733	640480-PB12-01	0.1967	47.0	2200.0	0.2200
12103734	640480-PB13-01	0.1995	46.0	800.0	0.0800
12103735	640480-PB14-01	0.2004	46.0	6000.0	0.6000

Sampled by: Client
Analyzed by: Jacob Blair
Reviewed by: Nick Ly

Date Analyzed: 11/20/2012
Date Issued: 11/20/2012

Nick Ly, Technical Director

mg/ Kg =Milligrams per kilogram
Percent = Milligrams per kilogram / 10000
Note : Method QC results are acceptable unless stated otherwise.
Unless otherwise indicated, the condition of all samples was acceptable at time of receipt.

RL = Reporting Limit
'<' = Below the reporting Limit

Bench Run No: 32-1120-04

NVL Laboratories, Inc.

4708 Aurora Ave. N., Seattle, WA 98103
Tel: 206.547.0100, Fax: 206.634.1936
www.nvllabs.com

Analysis Report

AIHA - IH # 101861
WA - DOE # C1765

AIHA Environmental Lead and Industrial Hygiene ACCREDITED LABORATORY

Total Lead (Pb)

Client: Argus Pacific, Inc.
Address: 1900 W. Nickerson St., Suite 315
Seattle, WA 98119

Attention: Mr. Scott Rinear
Project Location: B25 & B27

Batch #: 1218242.00
Matrix: Paint Chips
Method: EPA 7000B
Client Project #: 640480R.1
Date Received: 11/14/2012
Samples Received: 16
Samples Analyzed: 16

Lab ID	Client Sample #	Sample Weight (g)	RL in mg/Kg	Results in mg/Kg	Results in percent
12103736	640480-PB15-01	0.1899	48.0	18000.0	1.8000
12103737	640480-PB16-01	0.1941	47.0	< 47.0	< 0.0047

Sampled by: Client
Analyzed by: Jacob Blair
Reviewed by: Nick Ly

Date Analyzed: 11/20/2012
Date Issued: 11/20/2012

Nick Ly, Technical Director

mg/ Kg =Milligrams per kilogram
Percent = Milligrams per kilogram / 10000
RL = Reporting Limit
'<' = Below the reporting Limit
Note : Method QC results are acceptable unless stated otherwise.
Unless otherwise indicated, the condition of all samples was acceptable at time of receipt.

Bench Run No: 32-1120-04

BATCH ID 1218242.00

NVL LABS
HAZARDOUS MATERIALS SERVICES

METALS CHAIN OF CUSTODY

Turn Around Time
- ☐ 2 Hour ☐ 4 Hours ☐ 24 Hours
- ☐ 2 Days ☐ 3 Days ☐ 4 Days
- ☒ 5 Days ☐ 6-10 Days

Please call for TAT less than 24 Hours

Company: Argus Pacific, Inc.
Address: 1900 W Nickerson St, Suite 315
Seattle, WA 98119
Phone: 206-285-3373

Project Manager: Scott Rinear
Cell: (206) 571-5591
Email: srinear@arguspacific.com
Fax: ( ) -

Project Name/Number: 640480R.1 | Project Location: B25 & B27

- ☒ Total Metals ☐ TCLP
- ☒ FAA (ppm ☐ ICP (PPM ☐ GFAA (ppb) ☐ CVAA (ppb)
- ☐ Air Filter ☐ Paint Chips (cm) ☐ Drinking Water ☐ Other
- ☒ Paint Chips (%) ☐ Dust Wipes ☐ Waste Water
- ☐ Soil

RCRA 8
- ☐ Barium ☐ Chromium ☐ Silver
- ☐ Arsenic ☐ Mercury ☒ Lead
- ☐ Selenium ☐ Cadmium

RCRA 11
- ☐ Copper
- ☐ Zinc
- ☐ Other

Reporting Instructions: Email
☐ Call ( ) - ☐ Fax ( ) - ☒ Email srinear@arguspacific.com

Total Number of Samples 16

	Sample ID	Description	A/R
1	640480-PB1-01		
2	640480-PB2-01		
3	640480-PB3-01		
4	640480-PB4-01		
5	640480-PB5-01		
6	640480-PB6-01		
7	640480-PB7-01		
8	640480-PB8-01		
9	640480-PB9-01		
10	640480-PB10-01		
11	640480-PB11-01		
12	640480-PB12-01		
13	640480-PB13-01		
14	640480-PB14-01		
15	640480-PB15-01		

	Print Name	Signature	Company	Date	Time
Sampled by	Scott Rinear	[signature]	Argus Pacific	11/13/12	9-2
Relinquish by	Scott Rinear	[signature]	Argus Pacific	11/14/12	8:50 am

Office Use Only

	Print Name	Signature	Company	Date	Time
Received by	SHAISTA SHAW	[signature]	NVL	11/14/12	8:50
Analyzed by	Jacob Blair	[signature]	NVL	11/20/12	17:30
Called by					
Faxed/Email by					

BATCH ID
1218242.00

NVL LABS
HAZARDOUS MATERIALS SERVICES

METALS CHAIN OF CUSTODY

Turn Around Time
☐ 2 Hour ☐ 4 Hours ☐ 24 Hours
☐ 2 Days ☐ 3 Days ☐ 4 Days
☒ 5 Days ☐ 6-10 Days
Please call for TAT less than 24 Hours

Company: Argus Pacific, Inc.
Address: 1900 W Nickerson St, Suite 315
Seattle, WA 98119
Phone: 206-285-3373

Project Manager: Scott Rinear
Cell: (206) 571 - 5591
Email: srinear@arguspacific.com
Fax: ( ) -

Project Name/Number: 640480R.1 | Project Location: B25 & B27

☒ Total Metals ☐ TCLP
☒ FAA (ppm ☐ ICP (PPM ☐ GFAA (ppb) ☐ CVAA (ppb)
☐ Air Filter ☐ Paint Chips (cm) ☐ Drinking Water ☐ Other
☒ Paint Chips (%) ☐ Dust Wipes ☐ Waste Water
☐ Soil

RCRA 8: ☐ Barium ☐ Chromium ☐ Silver ☐ Arsenic ☐ Mercury ☒ Lead ☐ Selenium ☐ Cadmium

RCRA 11: ☐ Copper ☐ Zinc ☐ Other

Reporting Instructions: Email
☐ Call ( ) - ☐ Fax ( ) - ☒ Email srinear@arguspacific.com

Total Number of Samples 16

	Sample ID	Description	A/R
1	640480-PB16-01		
2			
3			
4			
5			
6			
7			
8			
9			
10			
11			
12			
13			
14			
15			

	Print Name	Signature	Company	Date	Time
Sampled by	Scott Rinear	[signature]	Argus Pacific	11/13/12	9-2
Relinquish by	Scott Rinear	[signature]	Argus Pacific	11/14/12	8:50 am

Office Use Only

	Print Name	Signature	Company	Date	Time
Received by	Shalsta Chon	[signature]	NVL	11/14/12	8:50
Analyzed by	Jacob Blair	[signature]	NVL	11/20/12	17:30
Called by					
Faxed/Email by					

Appendix C
TCLP Laboratory Analytical Results

NVL LABS
INDUSTRIAL HYGIENE SERVICES
Laboratory | Management | Training

November 20, 2012

Scott Rinear
Argus Pacific, Inc.
1900 W. Nickerson St., Suite 315
Seattle, WA 98119

RE: Metals Analysis; NVL Batch # 1218245.00

Dear Mr. Rinear,

Enclosed please find the test results for samples submitted to our laboratory for analysis. Preparation of these samples was conducted following protocol outlined in EPA Method SW 846-3051 unless stated otherwise. Analysis of these samples was performed using analytical instruments in accordance with U.S. EPA, NIOSH, OSHA and other ASTM methods.

For matrix materials submitted as paint, dust wipe, soil or TCLP samples, analysis for the presence of total metals is conducted using published U.S. EPA Methods. Paint and soil results are usually expressed in mg/Kg which is equivalent to parts per million (ppm). Lead (Pb) in paint is usually expressed in mg/Kg (ppm) , Percent (%) or mg/cm^2 by area. Dust wipe sample results are usually expressed in ug/wipe and ug/ft^2. TCLP samples are reported in mg/L (ppm). For air filter samples, analyses are conducted using NIOSH and OSHA Methods. Results are expressed in ug/filter and ug/m^3. Other matrix materials are analyzed accordingly using published methods or specified by client. The reported test results pertain only to items tested. Lead test results are not blank corrected.

For recent regulation updates pertaining to current regulatory levels or permissible exposure levels, please call your local regulatory agencies for more details.

This report is considered highly confidential and will not be released without your approval. Samples are archived for two weeks following analysis. Samples that are not retrieved by the client are discarded after two weeks.

Thank you for using our laboratory services. if you need further assistance please feel free to call us at 206-547-0100 or 1-888-NVLLABS.

Sincerely,

Nick Ly, Technical Director

Enclosure:

ilac-MRA

AIHA LAP, LLC
ACCREDITED LABORATORY
INDUSTRIAL HYGIENE & ENVIRONMENTAL LEAD
ISO/IEC 17025:2005
WWW.AIHAACCREDITEDLABS.ORG
LAB # 101861

NVL Laboratories, Inc.

4708 Aurora Ave. N., Seattle, WA 98103
Tel: 206.547.0100, Fax: 206.634.1936
www.nvllabs.com

Analysis Report

AIHA - IH # 101861
WA - DOE # C1765

AIHA Environmental Lead and Industrial Hygiene ACCREDITED LABORATORY

Toxicity Characteristic Leaching Procedure - Lead (Pb)

Client: Argus Pacific, Inc.
Address: 1900 W. Nickerson St., Suite 315
Seattle, WA 98119

Attention: Mr. Scott Rinear
Project Location: B25 & B27

Batch #: 1218245.00
Matrix: Bulk
Method: EPA 1311/7000B
Client Project #: 640480R.1
Date Received: 11/14/2012
Samples Received: 2
Samples Analyzed: 2

Lab ID	Client Sample #	RL mg/ L	Results in mg/L	Results in ppm
12103746	640480-25-TCLP1	0.5	<0.5	< 0.5
12103747	640480-27-TCLP1	0.5	<0.5	< 0.5

Sampled by: Client
Analyzed by: Aaron Brown
Reviewed by: Nick Ly

Date Analyzed: 11/20/2012
Date Issued: 11/20/2012

Nick Ly, Technical Director

mg/ L =Milligrams per liter
ppm = parts per million

RL = Reporting Limit
'<' = Below the reporting Limit

Note : Method QC results are acceptable unless stated otherwise.
Unless otherwise indicated, the condition of all samples was acceptable at time of receipt.

Bench Run No: 32-1119-10

NVL LABS
HAZARDOUS MATERIALS SERVICES

METALS CHAIN OF CUSTODY

BATCH ID
1218245.00

Turn Around Time
☐ 2 Hour ☐ 4 Hours ☐ 24 Hours
☐ 2 Days ☐ 3 Days ☐ 4 Days
☑ 5 Days ☐ 6-10 Days
Please call for TAT less than 24 Hours

Company: Argus Pacific, Inc.
Address: 1900 W Nickerson St, Suite 315
Seattle, WA 98119
Phone: 206-285-3373

Project Manager: Scott Rinear
Cell: (206) 571 - 5591
Email: srinear@arguspacific.com
Fax: ( ) -

Project Name/Number 640480R.1	Project Location B25 & B27

☐ Total Metals ☑ TCLP
☑ FAA (ppm ☐ ICP (PPM ☐ GFAA (ppb) ☐ CVAA (ppb)
☐ Air Filter ☐ Paint Chips (cm) ☐ Drinking Water ☑ Other
☐ Paint Chips (%) ☐ Dust Wipes ☐ Waste Water
☐ Soil

RCRA 8: ☐ Barium ☐ Chromium ☐ Silver ☐ Arsenic ☐ Mercury ☑ Lead ☐ Selenium ☐ Cadmium

RCRA 11: ☐ Copper ☐ Zinc ☐ Other

Reporting Instructions: EMAIL
☐ Call ( ) - ☐ Fax ( ) - ☑ Email srinear@arguspacific.com

Total Number of Samples 2

	Sample ID	Description	A/R
1	640480-25-TCLP1	BAG 1: 50%	
2		BAG 2: 15%	
3		BAG 3: 20%	
4		BAG 4: 15%	
5			
6	640480-27-TCLP1	BAG 1: 90%	
7		BAG 2: 10%	
8			
9			
10			
11			
12			
13			
14			
15			

	Print Name	Signature	Company	Date	Time
Sampled by	Scott Rinear	[signature]	Argus Pacific	11/13/12	9-2
Relinquish by	Scott Rinear	[signature]	Argus Pacific	11/14/12	8:50am

Office Use Only

	Print Name	Signature	Company	Date	Time
Received by	SHASTACHAN	[signature]	NVL	11/14/12	8:80 Am
Analyzed by	Aimon Brown		NVL	11/20/12	8:45
Called by					
Faxed/Email by					

ARGUS PACIFIC
TRAINING • CONSULTING

Appendix D
Heavy Metals Analytical Results

November 16, 2012

NVL LABS
INDUSTRIAL HYGIENE SERVICES
Laboratory | Management | Training

Scott Rinear
Argus Pacific, Inc.
1900 W. Nickerson St., Suite 315
Seattle, WA 98119

RE: Metals Analysis; NVL Batch # 1218204.00

Dear Mr. Rinear,

Enclosed please find the test results for samples submitted to our laboratory for analysis. Preparation of these samples was conducted following protocol outlined in EPA Method SW 846-3051 unless stated otherwise. Analysis of these samples was performed using analytical instruments in accordance with U.S. EPA, NIOSH, OSHA and other ASTM methods.

For matrix materials submitted as paint, dust wipe, soil or TCLP samples, analysis for the presence of total metals is conducted using published U.S. EPA Methods. Paint and soil results are usually expressed in mg/Kg which is equivalent to parts per million (ppm). Lead (Pb) in paint is usually expressed in mg/Kg (ppm) , Percent (%) or mg/cm^2 by area. Dust wipe sample results are usually expressed in ug/wipe and ug/ft^2. TCLP samples are reported in mg/L (ppm). For air filter samples, analyses are conducted using NIOSH and OSHA Methods. Results are expressed in ug/filter and ug/m^3. Other matrix materials are analyzed accordingly using published methods or specified by client. The reported test results pertain only to items tested. Lead test results are not blank corrected.

For recent regulation updates pertaining to current regulatory levels or permissible exposure levels, please call your local regulatory agencies for more details.

This report is considered highly confidential and will not be released without your approval. Samples are archived for two weeks following analysis. Samples that are not retrieved by the client are discarded after two weeks.

Thank you for using our laboratory services. if you need further assistance please feel free to call us at 206-547-0100 or 1-888-NVLLABS.

Sincerely,

Nick Ly, Technical Director

Enclosure:

ilac-MRA

AIHA LAP, LLC
ACCREDITED LABORATORY
INDUSTRIAL HYGIENE & ENVIRONMENTAL LEAD
ISO/IEC 17025:2005
LAB # 101861

NVL Laboratories, Inc.
4708 Aurora Ave. N., Seattle, WA 98103
Tel: 206.547.0100, Fax: 206.634.1936
www.nvllabs.com

Analysis Report

AIHA - IH # 101861
WA - DOE # C1765
AIHA Environmental Lead and Industrial Hygiene ACCREDITED LABORATORY

Total Metals

Client: Argus Pacific, Inc.
Address: 1900 W. Nickerson St., Suite 315
Seattle, WA 98119

Attention: Mr. Scott Rinear
Project Location: B27

Batch #: 1218204.00
Matrix: Paint Chips
Method: EPA 6010 / 7471 (Hg)
Client Project #: 640480R.1
Date Received: 11/14/2012
Samples Received: 2
Samples Analyzed: 2

Lab ID	Client Sample #	Elements	Sample wt (g)	RL mg / kg	Results in mg / kg	Results in ppm
12103587	640480-RCRA1-01	Silver (Ag)	0.1969	20.0	< 20.0	< 20.0
		Arsenic (As)	0.1969	20.0	140.0	140.0
		Barium (Ba)	0.1969	20.0	130.0	130.0
		Cadmium (Cd)	0.1969	20.0	72.0	72.0
		Chromium (Cr)	0.1969	20.0	230.0	230.0
		Mercury (Hg)	0.1969	1.0	< 1.0	< 1.0
		Lead (Pb)	0.1969	20.0	21000.0	21000.0
		Selenium (Se)	0.1969	20.0	24.0	24.0
12103588	640480-RCRA2-01	Silver (Ag)	0.1867	21.0	< 21.0	< 21.0
		Arsenic (As)	0.1867	21.0	< 21.0	< 21.0
		Barium (Ba)	0.1867	21.0	140.0	140.0
		Cadmium (Cd)	0.1867	21.0	24.0	24.0
		Chromium (Cr)	0.1867	21.0	< 21.0	< 21.0
		Mercury (Hg)	0.1867	1.1	< 1.1	< 1.1
		Lead (Pb)	0.1867	21.0	1200.0	1200.0
		Selenium (Se)	0.1867	21.0	< 21.0	< 21.0

Sampled by: Client
Analyzed by: Jacob Blair
Reviewed by: Nick Ly

Date Analyzed: 11/16/2012
Date Issued: 11/16/2012

Nick Ly, Technical Director

mg/ kg = Milligrams per kilogram
ppm = Parts per million

RL = Reporting Limit
'<' = Below the reporting Limit

Note : Method QC results are acceptable unless stated otherwise.
Unless otherwise indicated, the condition of all samples was acceptable at time of receipt.

Bench Run No: 32-1116-06

NVL LABS
HAZARDOUS MATERIALS SERVICES

METALS CHAIN OF CUSTODY

BATCH ID
1218204.00

Turn Around Time
☐ 2 Hour ☐ 4 Hours ☐ 24 Hours
☐ 2 Days ☐ 3 Days ☐ 4 Days
☒ 5 Days ☐ 6-10 Days
Please call for TAT less than 24 Hours

Company	Argus Pacific, Inc.	Project Manager	Scott Rinear
Address	1900 W Nickerson St, Suite 315	Cell	(206) 571 - 5591
	Seattle, WA 98119	Email	srinear@arguspacific.com
Phone	206-285-3373	Fax	( ) -

Project Name/Number 640480R.1 | Project Location B27

☒ Total Metals ☐ TCLP
☒ FAA (ppm ☐ ICP (PPM ☐ GFAA (ppb) ☐ CVAA (ppb)
☐ Air Filter ☐ Paint Chips (cm) ☐ Drinking Water ☐ Other
☒ Paint Chips (%) ☐ Dust Wipes ☐ Waste Water
☐ Soil

RCRA 8 All 8
☒ Barium ☒ Chromium ☒ Silver
☒ Arsenic ☒ Mercury ☒ Lead
☒ Selenium ☒ Cadmium

RCRA 11
☐ Copper ☐ Zinc ☐ Other

Reporting Instructions Email
☐ Call ( ) - ☐ Fax ( ) - ☒ Email srinear@arguspacific.com

Total Number of Samples 2

	Sample ID	Description	A/R
1	640480-RCRA1-01		
2	640480-RCRA2-01		
3			
4			
5			
6			
7			
8			
9			
10			
11			
12			
13			
14			
15			

	Print Name	Signature	Company	Date	Time
Sampled by	Scott Rinear	[signature]	Argus Pacific	11/13/12	9-2
Relinquish by	Scott Rinear	[signature]	Argus Pacific	11/14/12	8:50am

Office Use Only

	Print Name	Signature	Company	Date	Time
Received by	SHAISTA CHAN	[signature]	NVL	11/14/12	8:50AM
Analyzed by	Jacob Blair	[signature] 32	NVL	11/16/12	14:15
Called by					
Faxed/Email by					

Appendix E
Personnel and Laboratory Accreditations

Certificate of Completion

This is to certify that

Scott Rinear

has satisfactorily completed
4 hours of refresher training as an

Asbestos Building Inspector

to comply with the training requirements of
TSCA Title II / 40 CFR 763 (AHERA)

134900
Certificate Number

Instructor
EPA Provider Cert. Number: 1085

ARGUS PACIFIC
TRAINING • CONSULTING

Jan 11, 2012
Date(s) of Training
Exam Score: NA
Expiration Date: Jan 10, 2013

Argus Pacific, Inc. • 1900 W. Nickerson, Suite 315 • Seattle, Washington • 98119 • 206.285.3373 • fax 206.285.3927

STATE OF WASHINGTON

Department of Commerce

Lead-Based Paint Program

Scott Rinear

Has fulfilled the certification requirements of Washington Administrative code (WAC) 365-230 and has been certified to conduct lead-based paint activities pursuant to WAC 365-230-200 as a:

Risk Assessor

Certification #	Issuance Date	Expiration Date
6241	10/19/2010	10/19/2013

United States Department of Commerce
National Institute of Standards and Technology

NVLAP®

Certificate of Accreditation to ISO/IEC 17025:2005

NVLAP LAB CODE: 200876-0

Seattle Asbestos Test Bellevue

Bellevue, WA

is accredited by the National Voluntary Laboratory Accreditation Program for specific services, listed on the Scope of Accreditation, for:

BULK ASBESTOS FIBER ANALYSIS

This laboratory is accredited in accordance with the recognized International Standard ISO/IEC 17025:2005. This accreditation demonstrates technical competence for a defined scope and the operation of a laboratory quality management system (refer to joint ISO-ILAC-IAF Communique dated January 2009).

DEPARTMENT OF COMMERCE · UNITED STATES OF AMERICA

2012-07-01 through 2013-06-30

Effective dates

For the National Institute of Standards and Technology

AIHA

Laboratory Accreditation Programs, LLC

AIHA Laboratory Accreditation Programs, LLC

acknowledges that

NVL Laboratories, Inc.

4708 Aurora Avenue North, Seattle, WA 98103

Laboratory ID: 101861

along with all premises from which key activities are performed, as listed above, has fulfilled the requirements of the AIHA Laboratory Accreditation Programs (AIHA-LAP), LLC accreditation to the ISO/IEC 17025:2005 international standard, *General Requirements for the Competence of Testing and Calibration Laboratories in t*he following:

LABORATORY ACCREDITATION PROGRAMS

✓	**INDUSTRIAL HYGIENE**	Accreditation Expires: 05/01/2013
✓	**ENVIRONMENTAL LEAD**	Accreditation Expires: 05/01/2013
✓	**ENVIRONMENTAL MICROBIOLOGY**	Accreditation Expires: 05/01/2013
☐	**FOOD**	Accreditation Expires:

Specific Field(s) of Testing (FoT)/Method(s) within each Accreditation Program for which the above named laboratory maintains accreditation is outlined on the attached **Scope of Accreditation**. Continued accreditation is contingent upon successful on-going compliance with ISO/IEC 17025:2005 and AIHA-LAP, LLC requirements. This certificate is not valid without the attached **Scope of Accreditation**. Please review the AIHA-LAP, LLC website (www.aihaaccreditedlabs.org) for the most current Scope.

Christine Powell

Christine Powell

Chairperson, Analytical Accreditation Board

Cheryl O. Morton

Cheryl O. Morton

Director, AIHA Laboratory Accreditation Programs, LLC

Revision 10: 01/13/2011

Date Issued: 05/01/2011

AIHA
Laboratory Accreditation Programs, LLC

AIHA Laboratory Accreditation Programs, LLC
SCOPE OF ACCREDITATION

NVL Laboratories, Inc.
4708 Aurora Avenue North, Seattle, WA 98103

Laboratory ID: **101861**
Issue Date: 05/01/2011

The laboratory is approved for those specific field(s) of testing/methods listed in the table below. Clients are urged to verify the laboratory's current accreditation status for the particular field(s) of testing/Methods, since these can change due to proficiency status, suspension and/or revocation. A complete listing of currently accredited Industrial Hygiene laboratories is available on the AIHA-LAP, LLC website at: http://www.aihaaccreditedlabs.org

Industrial Hygiene Laboratory Accreditation Program (IHLAP)

Initial Accreditation Date: 04/01/1997

IHLAP Scope Category	Field of Testing (FoT)	Technology sub-type/ Detector	Published Reference Method/Title of In-house Method	Method Description or Analyte *(for internal methods only)*
Spectrometry Core	Atomic Absorption	FAA	NIOSH 7024	
			NIOSH 7030	
			NIOSH 7048	
			NIOSH 7082	
	Inductively-Coupled Plasma	ICP/AES	EPA SW-846 3051	
			NIOSH 7300	
Asbestos/Fiber Microscopy Core	Phase Contrast Microscopy (PCM)		NIOSH 7400	
Miscellaneous Core	Gravimetric		NIOSH 0500	
			NIOSH 0600	

AIHA

Laboratory Accreditation Programs, LLC

The laboratory participates in the following AIHA-LAP, LLC-approved proficiency testing programs:

- √ AIHA-PAT Programs, LLC IHPAT Metals
- ❑ AIHA-PAT Programs, LLC IHPAT Organic Solvents
- √ AIHA-PAT Programs, LLC IHPAT Silica
- ❑ AIHA-PAT Programs, LLC IHPAT Diffusive Sampler (3M)
- ❑ AIHA-PAT Programs, LLC IHPAT Diffusive Sampler (SKC)
- ❑ AIHA-PAT Programs, LLC IHPAT Diffusive Sampler (AT)
- √ AIHA-PAT Programs, LLC IHPAT Asbestos
- ❑ AIHA-PAT Programs, LLC Bulk Asbestos (BAPAT)
- ❑ AIHA-PAT Programs, LLC Beryllium (BePAT)
- ❑ HSE Workplace Analytical Scheme for Proficiency (WASP) (Formaldehyde)
- ❑ HSE Workplace Analytical Scheme for Proficiency (WASP) (Thermal Desorption Tubes)
- ❑ Pharmaceutical Round Robin
- ❑ Compressed/Breathing Air Round Robin
- ❑ National Voluntary Laboratory Accreditation Program (NVLAP - determined at the time of site assessment)
- ❑ New York State Department of Health (NYS DOH – PCM and TEM)
- ❑ ERA Air and Emissions standards for indoor air quality
- ❑ Institut für Arbeitsschutz der Deutschen Gesetzlichen Unfallversicherung (IFA, formerly BGIA)
- ❑ Institut de Recherche Robert-Sauvé en Santé et en Sécurité du Travail (IRSST)

AIHA

Laboratory Accreditation Programs, LLC

AIHA Laboratory Accreditation Programs, LLC

SCOPE OF ACCREDITATION

NVL Laboratories, Inc.
4708 Aurora Avenue N., Seattle, WA 98103

Laboratory ID: **101861**
Issue Date: 05/24/2011

The laboratory is approved for those specific field(s) of testing/methods listed in the table below. Clients are urged to verify the laboratory's current accreditation status for the particular field(s) of testing/Methods, since these can change due to proficiency status, suspension and/or revocation. A complete listing of currently accredited Environmental Lead laboratories is available on the AIHA-LAP, LLC website at: http://www.aihaaccreditedlabs.org

The EPA recognizes the AIHA-LAP, LLC ELLAP program as meeting the requirements of the National Lead Laboratory Accreditation Program (NLLAP) established under Title X of the Residential Lead-Based Paint Hazard Reduction Act of 1992 and includes paint, soil and dust wipe analysis. Air analysis is not included as part of the NLLAP.

Environmental Lead Laboratory Accreditation Program (ELLAP)

Initial Accreditation Date: 02/07/1997

Field of Testing (FoT)	Method	Method Description *(for internal methods only)*
Paint	16 CFR Part 1303 (CPSC-CH-E1003-09)	
	EPA SW-846 3051	
	EPA SW-846 7000B	
Soil	EPA SW-846 3051	
	EPA SW-846 7000B	
Settled Dust by Wipe	EPA SW-846 3051	
	EPA SW-846 7000B	
Airborne Dust	EPA SW-846 3051	
	NIOSH 7082	

The laboratory participates in the following AIHA-LAP, LLC-approved proficiency testing programs:

- ✓ Paint
- ✓ Soil
- ✓ Settled Dust by Wipe
- ✓ Airborne Dust

AIHA

Laboratory Accreditation Programs, LLC

AIHA Laboratory Accreditation Programs, LLC
SCOPE OF ACCREDITATION

NVL Laboratories, Inc.
4708 Aurora Avenue North, Seattle, WA 98103

Laboratory ID: **101861**
Issue Date: 05/01/2011

The laboratory is approved for those specific field(s) of testing/methods listed in the table below. Clients are urged to verify the laboratory's current accreditation status for the particular field(s) of testing/Methods, since these can change due to proficiency status, suspension and/or revocation. A complete listing of currently accredited Environmental Microbiology laboratories is available on the AIHA-LAP, LLC website at: http://www.aihaaccreditedlabs.org

Environmental Microbiology Laboratory Accreditation Program (EMLAP)

Initial Accreditation Date: 02/01/2007

EMLAP Category	Field of Testing (FoT)	Method	Method Description *(for internal methods only)*
Fungal	**Bulk - Direct Examination**	SOP 12.130	In-House: Analysis of Bulk and Surface for Fungi
	Surface - Direct Examination	SOP 12.130	In-House: Analysis of Bulk and Surface for Fungi

The laboratory participates in the following AIHA-LAP, LLC-approved proficiency testing programs:

- √ Fungal Culturable
- ☐ Bacterial Culturable
- ☐ Fungal Direct Examination

APPENDIX H
DRAFT ENVIRONMENTAL COVENANT

Restrictive Covenant

After Recording Return to:
____
Department of Ecology

Northwest Regional Office
3190 160th Avenue SE
Bellevue, WA 98008-5452

Environmental Covenant

Grantor: The Port of Seattle
Grantee: State of Washington, Department of Ecology
Legal: [fill in brief legal description] [Will require survey of relevant portions]
Tax Parcel Nos.: [fill in]

Grantor, The Port of Seattle ("Port"), hereby binds Grantor, its successors and assigns to the land use restrictions identified herein and grants such other rights under this environmental covenant (hereafter "Covenant") made this day of _______, 201__ in favor of the State of Washington Department of Ecology (Ecology). Ecology shall have full right of enforcement of the rights conveyed under this Covenant pursuant to the Model Toxics Control Act, RCW 70.105D.030(1)(g), and the Uniform Environmental Covenants Act, 2007 Wash. Laws ch. 104, sec. 12.

This Declaration of Covenant is made pursuant to RCW 70.105D.030(1)(f) and (g) and WAC 173-340-440 by the Port, its successors and assigns, and the State of Washington Department of Ecology, its successors and assigns (hereafter "Ecology").

A remedial action (hereafter "Remedial Action") occurred at the property that is the subject of this Covenant. The Remedial Action conducted at the property is described in the following documents:

Final Cleanup Action Plan, Port of Seattle Terminal 91 Site, Seattle, Washington (June 2010) ("CAP");

[Engineering Design Report – title and date for approved final]

These documents are on file at Ecology's Northwest Regional Office located at 3190 160th Avenue Southeast, Bellevue, Washington, 98008-5452.

This Covenant is required because the Remedial Action resulted in residual concentrations of hazardous substances, including *[SPECIFICALLY LIST SUBSTANCE(S) or SELECT REFERENCE IN CLEANUP DOCUMENTS AND CITE THAT HERE AS SUMMARY OF SUBSTANCES FOUND],* which exceed Remediation Levels identified in the CAP, as well as cleanup levels in excess of the Model Toxics Control Act Method A Cleanup Levels for soil and Method B Cleanup Levels for groundwater established under Ch. 173-340 WAC. This Restrictive Covenant is also required because a conditional point of compliance has been established for groundwater as provided by WAC 173-340-720(7), and because the cleanup levels established under the Remedial Action are based on a determination that the groundwater is non-potable as provided by WAC 173-340-720(2).

The undersigned, the Port, is the fee owner of real property (hereafter "Property") in the County of King, State of Washington, that is subject to this Covenant. The Property is legally described Exhibit A.

The Port makes the following declaration as to limitations, restrictions, and uses to which the Property may be put and specifies that such declarations shall constitute covenants to run with the land, as provided by law and shall be binding on all parties and all persons claiming under them, including all current and future owners of any portion of or interest in the Property (hereafter "Owner").

<u>Section 1</u>.

A. No groundwater may be taken for domestic use from the Property.

B. A portion of the Property contains *[SPECIFICALLY LIST SUBSTANCES or REFER TO SUCH LISTS IN CLEANUP DOCUMENTS – as appropriate, can list in the following subsections with the areas in which they remain]* contaminated soil located in

(i) The area depicted as the "Tank Farm Affected Area" on Exhibit B ("Tank Farm Affected Area"; and *[(ii) the area depicted as the "Short Fill" on Exhibit B][1].*

C. The Owner shall not alter, modify, or remove any existing structures within the Tank Farm Affected Area in any manner that may result in the release or exposure to the environment of that contaminated soil or create a new exposure pathway without prior written approval from Ecology. Qualified personnel must evaluate soil and/or groundwater that may be removed as part of construction activities and manage the material consistent with applicable regulations.

D. The *[cutoff wall area – define with reference to as built diagram to identify]* depicted in Exhibit C contains soil contaminated with hazardous substances, including *[LIST HS or refer to list in cleanup documents]* at levels over Remediation Levels and cleanup levels, which [was] covered with asphalt paving during implementation of the Remedial Action. Any activity on the Property that may result in the release or exposure to the environment of the contaminated soil that was contained within *[cutoff wall area]* as part of the Remedial Action, or create a new exposure pathway, is prohibited without prior written approval from Ecology, excepting activities permitted by the *[O&M Plan]* or which are conducted under Agreed Order (No. DE 8938, April 10, 2012, as amended) to monitor hazardous substances or to repair or augment Remedial Action components. Some examples of activities that are prohibited in the cutoff wall area include: drilling, digging, placement of any objects or use of any equipment which deforms or stresses the surface beyond its load bearing capability, piercing the surface with a rod, spike or similar item, bulldozing or earthwork.

E. The Remedial Action requires that the exposure pathway for indoor air be managed in the event that any building or enclosed structure is constructed over the Tank Farm Affected Area in the future. If so, one of the following approaches must be taken to address this exposure pathway:

(1) include engineering controls (for example., vapor barriers, sub-slab venting systems) in site development plans to prevent the potential exposure; or

---

1 The Port is researching historic documents to determine the original basis for subjecting the short fill to a restrictive covenant, to determine which if any of the covenants should now be applied. All references to the "short fill" are marked to indicate that they are subject to the outcome of this research.

(2) conduct a development-specific evaluation of the soil/groundwater to indoor air pathway (i.e., developing risk-based cleanup levels for the specific potential exposures related to the proposed development). If concentrations of indicator hazardous substances exceed the cleanup levels developed under this option, appropriate supplemental remedial actions will be evaluated and implemented or engineering controls implemented, as appropriate.

Section 2. Any activity on the Tank Farm Affected Area that may interfere with the integrity of the Remedial Action, including the *[cutoff wall, LNAPL trenches and Final Cover (as defined in design documents)]* and continued protection of human health and the environment is prohibited.

Section 3. Any activity on the Tank Farm Affected Area *[or the Short Fill]* that may result in the release or exposure to the environment of a hazardous substance that remains on the Property as part of the Remedial Action, or create a new exposure pathway, is prohibited without prior written approval from Ecology.

Section 4. The Owner of the Property must give fourteen (14) day advance written notice to Ecology of the Owner's intent to convey any interest in the portion of the Property identified as the Tank Farm Affected Area, which conveyance would be likely to affect the continued monitoring, operation and maintenance of the Remedial Action. No conveyance of title, easement, lease, or other interest in the Tank Farm Affected Area shall be consummated by the Owner without adequate and complete provision for continued monitoring, operation, and maintenance of the Remedial Action. For purposes of this provision, only those property interest transfers that involve planned capital improvements (for example, such as excavation or pile driving) shall be considered likely to affect the continued monitoring, operation and maintenance of the Remedial Action.

Section 5. The Owner must restrict leases to uses and activities consistent with the Covenant and notify all lessees of the restrictions on the use of the Tank Farm Affected Area.

Section 6. The Owner must notify and obtain approval from Ecology prior to any use of the Tank Farm Affected Area that is inconsistent with the terms of this Covenant. Ecology may approve any inconsistent use only after public notice and comment. This section applies to ongoing uses of the Tank Farm Affected Area, but not to occasional activities conducted with

Ecology's approval such as construction, repair or replacement of utilities, remediation of hazardous substances, or conduct of geotechnical investigations. Uses deemed consistent with the terms of this Covenant (for purposes of this section only) include development and use of warehouses, manufacturing facilities, office buildings, parking structures and surface storage.

Section 7. The Owner shall allow authorized representatives of Ecology the right to enter the Property at reasonable times for the purpose of evaluating the Remedial Action; to take samples, to inspect remedial actions conducted at the Property, to determine compliance with this Covenant, and to inspect records that are related to the Remedial Action.

Section 8. The Owner of the Property reserves the right under WAC 173-340-440 to record an instrument that provides that this Covenant shall no longer limit use of the Property or be of any further force or effect. However, such an instrument may be recorded only if Ecology, after public notice and opportunity for comment, concurs.

Port of Seattle

____

[Name of Signatory]
[Title]

Dated: ____________________

STATE OF WASHINGTON
DEPARTMENT OF ECOLOGY

____

[Name of Person Acknowledging Receipt]
[Title]

Dated: ____________________

[INDIVIDUAL ACKNOWLEDGMENT]

STATE OF ____________________
COUNTY OF __________________

On this ______ day of __________________, 20__, I certify that ______________ personally appeared before me, and acknowledged that **he/she** is the individual described herein and who executed the within and foregoing instrument and signed the same at **his/her** free and voluntary act and deed for the uses and purposes therein mentioned.

____
Notary Public in and for the State of
Washington, residing at ______________.
My appointment expires______________.

[CORPORATE ACKNOWLEDGMENT]

STATE OF ____________________
COUNTY OF __________________

On this ______ day of __________________, 20__, I certify that ______________ personally appeared before me, acknowledged that **he/she** is the _____________________ of the corporation that executed the within and foregoing instrument, and signed said instrument by free and voluntary act and deed of said corporation, for the uses and purposes therein mentioned, and on oath stated that **he/she** was authorized to execute said instrument for said corporation.

____
Notary Public in and for the State of
Washington, residing at
_______________.
My appointment
expires_______________.

[REPRESENTATIVE ACKNOWLEDGEMENT]

STATE OF ____________________
COUNTY OF __________________

On this ______ day of __________________, 20__, I certify that ______________ ______ personally appeared before me, acknowledged that **he/she** signed this instrument, on oath stated that **he/she** was authorized to execute this instrument, and acknowledged it as the

__________________________ [type of authority] of ________________________ [name of party being represented] to be the free and voluntary act and deed of such party for the uses and purposes mentioned in the instrument.

____
Notary Public in and for the State of
Washington, residing at _____________.
My appointment expires _____________.

Exhibit A
Legal Description

Exhibit B

Depiction of Tank Farm Affected Area

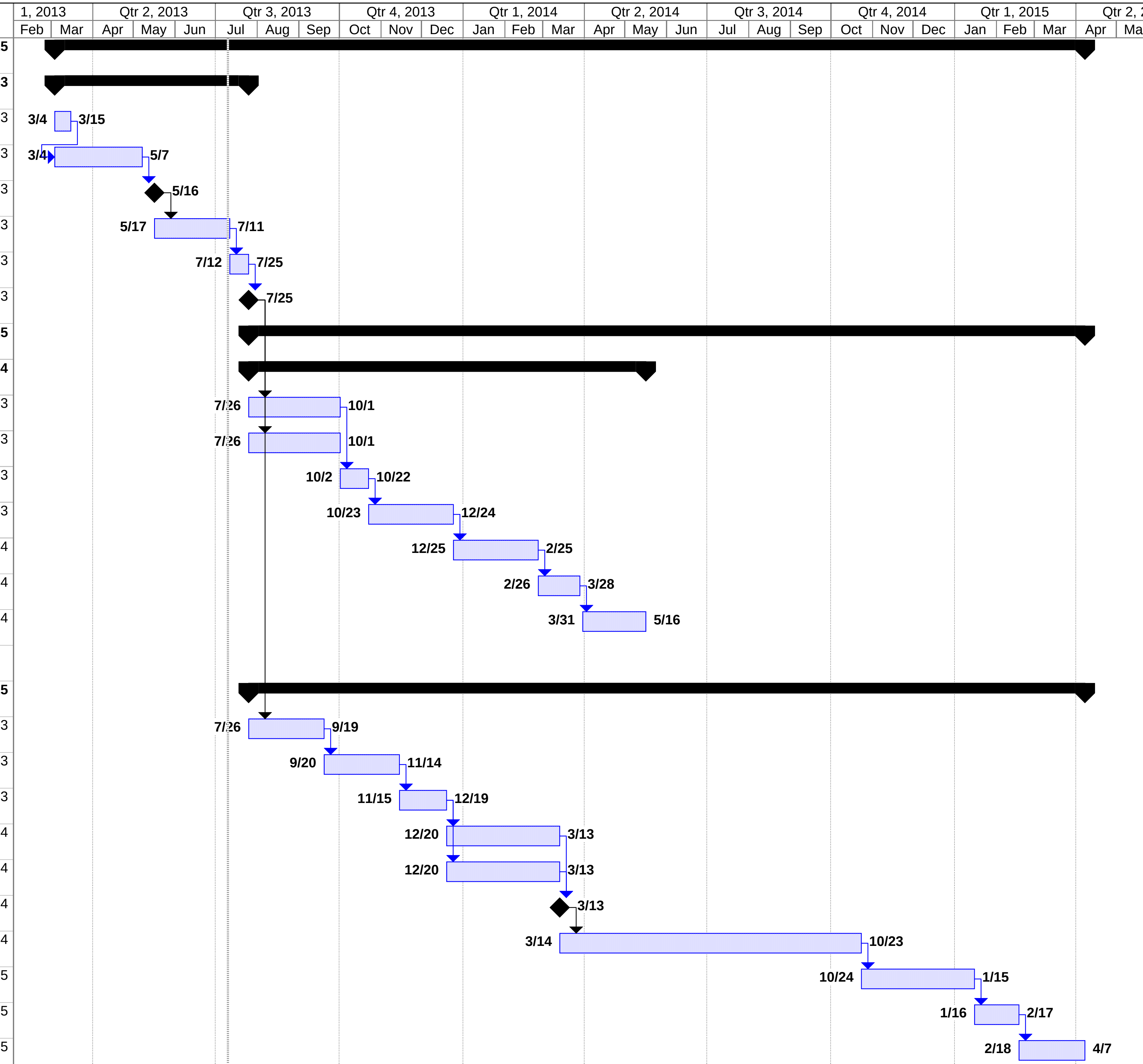
[and the Short Fill]

Exhibit C
Depiction of Area within Cutoff Wall

APPENDIX I
IMPLEMENTATION SCHEDULE

Tank Farm Cleanup Design and Construction Schedule
July 2013

ID	Task Name	Duration	Start	Finish
1	**Tank Farm Cleanup**	**547 days**	**Mon 3/4/13**	**Tue 4/7/15**
2	**Design Process**	**104 days**	**Mon 3/4/13**	**Thu 7/25/13**
3	Submit Draft Engineering Design Report (EDR)	10 days	Mon 3/4/13	Fri 3/15/13
4	Ecology Review Draft EDR	47 days	Mon 3/4/13	Tue 5/7/13
5	Meeting to Discuss Comments on Draft EDR	0 days	Thu 5/16/13	Thu 5/16/13
6	Prepare Final EDR (100% Design)	40 days	Fri 5/17/13	Thu 7/11/13
7	Ecology Review and Approval of Final EDR	10 days	Fri 7/12/13	Thu 7/25/13
8	Design Complete	0 days	Thu 7/25/13	Thu 7/25/13
9	**Construction**	**443 days**	**Fri 7/26/13**	**Tue 4/7/15**
10	**SWMU 30 Construction**	**211 days**	**Fri 7/26/13**	**Fri 5/16/14**
11	Coordination with Port Construction Services	48 days	Fri 7/26/13	Tue 10/1/13
12	Construction Stormwater Permitting	48 days	Fri 7/26/13	Tue 10/1/13
13	Traffic Control and Rerouting	15 days	Wed 10/2/13	Tue 10/22/13
14	Construction	45 days	Wed 10/23/13	Tue 12/24/13
15	Prepare Draft SWMU 30 Implementation Report	45 days	Wed 12/25/13	Tue 2/25/14
16	Ecology Review of Draft SWMU 30 Implementation Report	23 days	Wed 2/26/14	Fri 3/28/14
17	Prepare Final SWMU 30 Implementation Report	35 days	Mon 3/31/14	Fri 5/16/14
18				
19	**Tank Farm and Pipelines**	**443 days**	**Fri 7/26/13**	**Tue 4/7/15**
20	Finalize Construction Bid Documents	40 days	Fri 7/26/13	Thu 9/19/13
21	Advertise, Receive, and Evaluate Bids	40 days	Fri 9/20/13	Thu 11/14/13
22	Award Contract	25 days	Fri 11/15/13	Thu 12/19/13
23	Preconstruction Submittals	60 days	Fri 12/20/13	Thu 3/13/14
24	Construction Stormwater and Sanitary Sewer Permitting	60 days	Fri 12/20/13	Thu 3/13/14
25	Notice to Proceed	0 days	Thu 3/13/14	Thu 3/13/14
26	Construction	160 days	Fri 3/14/14	Thu 10/23/14
27	Prepare Draft Tank Farm Implementation Report	60 days	Fri 10/24/14	Thu 1/15/15
28	Ecology Review of Tank Farm Implementation Report	23 days	Fri 1/16/15	Tue 2/17/15
29	Prepare Final Tank Farm Implementation Report	35 days	Wed 2/18/15	Tue 4/7/15



Project: Tank Farm Schedule (Final EI
Date: Wed 7/10/13

Task | Milestone | Rolled Up Task | Rolled Up Progress | External Tasks | Group By Summary
Progress | Summary | Rolled Up Milestone | Split | Project Summary

DISTRIBUTION
ENGINEERING DESIGN REPORT
TERMINAL 91 TANK FARM CLEANUP
JULY 11, 2013

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