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Technical Memorandum

To: David South, Washington State Department of Ecology

Copies: Paul Agid and Don Robbins, Port of Seattle

From: Matt Woltman

Date: August 6, 2010

Project No: POS-LLA

Re: **Deep Monitoring Well Installation and Sampling and Analysis Plan for the Lora Lake Apartments Parcel Phase of the Site Remedial Investigation**

INTRODUCTION

This technical memorandum presents the proposed protocols for installing up to three deep monitoring wells at the Lora Lake (LL) Apartments Parcel, as part of the LL Apartments Parcel Phase of the Site Remedial Investigation to be completed in summer 2010. These additional monitoring wells are required per recent Washington State Department of Ecology (WSDOE) and public comments to the Draft Remedial Investigation/Feasibility Study (RI/FS) Work Plan. The purpose of completing this additional deep well investigation is to provide further information regarding subsurface geologic and hydrogeologic conditions at the LL Apartments Parcel, and to also identify if dense non-aqueous phase liquid (DNAPL) contamination has formed at depths below the vertical extents of previous LL Apartments Parcel investigations.

The proposed well installation program calls for installation of a minimum of two deep monitoring wells, with conditional installation of a third deep well pending review of data and observations collected during installation of the first two wells. The process for this deep monitoring well installation sequence is described within this technical memorandum. This technical memorandum also presents the proposed approach for collection and laboratory analysis of soil and groundwater samples as part of the deep well installation and development activities.

This proposed approach for installing the deep monitoring wells has been developed based on a recent geology/hydrogeology evaluation completed by Aspect Consulting (Aspect) with focus on the LL Apartments Parcel and surrounding areas (Aspect 2010). This evaluation was completed to provide a summary of known geologic/hydrogeologic conditions within the vicinity of the LL Apartments Parcel, and to identify potential locations and depths where subsurface confining units may be encountered. A brief

summary of the Aspect Consulting geology/hydrogeology evaluation is provided herein and a copy of the evaluation technical memorandum is provided in Attachment 1.

This deep-well technical memorandum has been prepared to serve as an addendum to the Sampling and Analysis Plan/Quality Assurance Project Plan (SAQ/QAPP), included as Appendix B of the current Lora Lake Apartments RI/FS Work Plan (Floyd|Snider 2010). Relevant information regarding project organization and responsibility; laboratory quality assurance objectives; sample handling and custody documentation; data reduction, validation and management; corrective actions; waste management; and data reporting is provided in the RI/FS Work Plan SAP/QAPP.

GEOLOGY/HYDROGEOLOGY EVALUATION SUMMARY

The purpose of the geology/hydrogeology evaluation was to estimate the potential target depths for the first confining unit based on the review of existing geologic and groundwater information in the near vicinity of the Site (as it is described in the current Lora Lake Apartments RI/FS Work Plan) , per WSDOE comments to the RI/FS Work Plan. Most of the geology/hydrogeology data used in the evaluation were obtained from a groundwater study commissioned by the Port of Seattle (Port) that describes in detail regional geology and groundwater conditions within a 42-square-mile study area surrounding the Seattle-Tacoma International Airport (STIA; Aspect and S.S. Papadopulos 2005). The groundwater study was conducted under an Agreed Order with WSDOE and represents the most current and comprehensive understanding of the geologic and hydrogeologic framework in the area surrounding the STIA (Aspect 2010). The LL Apartments Parcel is included within the northwest region of the groundwater study data collection boundary.

In summary, the Puget Lowland is underlain at depth by volcanic and sedimentary bedrock, and is filled to the present day land surface with both glacial and non-glacial deposits (non-glacial or inter-glacial deposits are those derived between periods of glaciation) that occurred during the Quaternary Period (within the last 2 million years; Aspect 2010). These glacial and non-glacial deposits (from youngest to oldest) are commonly referred to as recent post-glacial deposits, Fraser Glacial Deposits (also known as Vashon Drift), and Pre-Fraser deposits. Located within these general glacial and non-glacial deposits are sub-units of fine and coarse-grained materials that make up the regional aquifer and confining layer system.

The geology/hydrogeology evaluation examined boring logs from many deep investigations and monitoring well installations that have been completed within the vicinity of the LL Apartments Parcel (and overall Site). Although no deep investigations or monitoring well installations have been completed within the current boundaries of the LL Apartments Parcel, interpretation of the available information suggests the following site stratigraphy, from youngest to oldest units:

- **Post-glacial Deposits.** These materials are commonly identified to be fill, topsoil, recent alluvium, or lacustrine deposits that were deposited following

the most recent period of glaciation. Based on development history at the LL Apartments Parcel, a unit of fill is known to be present in the southern and central areas of the property, as it was placed as part of development of the former apartment building complex. The fill is known to have a variable thickness of up to 15 feet throughout the property, and is absent in the northern portion of the property. Based on recent explorations at the property, a sand/gravel unit is located beneath the fill (and at the surface in the northern portion of property) and is assumed to be either a recent alluvium or recessional outwash deposit. Based on the locations of previous explorations at the property, it is unclear if borings have extended below this sand/gravel unit and into the upper portion of the units below. Therefore the thickness of this unit is unknown.

- **Fraser Glacial Deposits.** These glacial deposits are located beneath the post-glacial deposits and contain sub-units of both sand/gravel and silt/clay materials. The Fraser Glacial Deposits consist of outwash (recessional and advance), till, and glaciolacustrine (Lawton Clay) deposits. Typically, outwash deposits are associated with aquifers and till and glaciolacustrine deposits represent confining layers.

  Borings at the LL Apartments Parcel may extend into the upper portions of a recessional outwash deposit associated with the Fraser Glaciation; however, this deposit is similar in appearance and density to the recent alluvium deposit described above and it is currently unknown whether existing property borings have encountered this unit.

  Underlying the recessional outwash unit is the Vashon Glacial Till. This unit represents the first potential confining layer for the LL Apartments Parcel; however, no borings have been completed at the property to sufficient depths to identify if this till unit is present. According to interpretation of deeper off-property boring logs, the Vashon Glacial Till unit (if present) is expected to be encountered at depths below ground surface (bgs) of approximately 15 to 35 feet (in the northwest area of the LL Apartments Parcel) to 45 to 65 feet (in the eastern and southeastern area of the parcel).

  The Vashon Advance Outwash unit underlies the Vashon Glacial Till and is a sand/gravel aquifer unit that is expected to be approximately 35 to 40 feet in thickness at the LL Apartments Parcel. Underlying the Vashon Advance Outwash unit is the Lawton Clay, which represents a second potential confining layer and the bottom of the Fraser Glacial Deposits. The Lawton Clay (if present) is expected to be encountered at depths of approximately 80 to 100 bgs (in the northwest area of the parcel) and 95 to 115 feet bgs (in the eastern and southeastern area of the parcel).

- **Pre-Fraser Glacial Deposits.** Similar to the Fraser Glacial Deposits, the Pre-Fraser Glacial Deposits are also composed of alternating aquifer and confining layer units extending down to the bedrock contact. Less information is known about these older glacial deposits, as fewer explorations have

encountered them due to their increased depth; however, it is expected that the next potential confining layer would be a Pre-Fraser fine-grained deposit that may be located at depths exceeding 200 feet bgs at the LL Apartments Parcel.

The summary stratigraphic interpretation described above represents the known deposits and sub-units within the geologic record for this region. However, glacial advance and recessional processes can often completely erode stratigraphic units or deposits, resulting in gaps in the geologic record. Although the aquifers and confining layers discussed above have been identified in borings near the LL Apartments Parcel, it is possible that these units may not be present beneath the parcel. A detailed discussion of the stratigraphic interpretation and potential for erosion of stratigraphic units at and around the LL Apartments Parcel is presented in the geology/hydrogeology evaluation technical memorandum included as Attachment 1 (Aspect 2010).

DEEP MONITORING WELL INSTALLATION PROGRAM

The following section presents details of the proposed deep monitoring well installation program, including protocols for collection and analysis of soil and groundwater samples.

Monitoring Well Location and Depth

Up to three deep monitoring wells (MW-15 through MW-17) are proposed for installation at the LL Apartments Parcel at the locations shown on Figure 1. Monitoring wells will be co-located with proposed primary soil borings and installed at the following locations:

- MW-15 will be co-located with Primary Soil Boring PSB-15 and installed adjacent to existing Monitoring Well MW-5. The proposed location for MW-15 will serve as a downgradient groundwater contamination monitoring point within the known extent of groundwater contamination at the LL Apartments Parcel. Additionally, the co-location of MW-15 with existing Monitoring Well MW-5 will allow for vertical gradients to be measured between the shallow and deep aquifers.
- MW-16 will be co-located with Primary Soil Boring PSB-9 to the southwest of the assumed source area for soil and groundwater DNAPL-forming chemical contamination. The proposed location of MW-16 will serve as a source area monitoring location.
- MW-17 will be a conditional deep monitoring well to be co-located with Primary Soil Boring PSB-17 and installed adjacent to existing Monitoring Well MW-4. The proposed location for MW-17 will serve as a downgradient groundwater contamination monitoring point outside the known extent of groundwater contamination at the LL Apartments Parcel. Additionally, the co-location of MW-17 with existing Monitoring Well MW-4 will allow for vertical

gradients to be measured in the shallow and deep aquifers, and proposed locations for the three deep monitoring wells provide a configuration to evaluate horizontal flow gradients and directions in the deep aquifer unit.

As a conditional monitoring well, MW-17 will be installed only if DNAPL chemicals are found in samples taken from MW-15 or MW-16. The Port will share well installation data (soil boring logs, field screening results, and chemical data) with WSDOE during installation of MW-15 and MW-16 so that a collaborative decision can be made regarding the need to install MW-17.

Deep monitoring wells will be installed to a depth where the first confining layer is encountered. The confining layer will be defined as a low permeability material (i.e., silt, clay, or till) with a minimum thickness of 5 feet. According to the stratigraphic description provided above and in the geology/hydrogeology evaluation (Aspect 2010), the uppermost potential confining layer (Vashon Glacial Till), if present, would be encountered at approximately 15 to 35 feet bgs in the northwest area of the parcel and 45 to 65 feet bgs in the eastern and southeastern area of the parcel. If the Vashon Glacial Till unit is absent, the next confining layer (Lawton Clay) would be encountered at approximately 80 to 100 feet bgs in the northwest area of the parcel and 95 to 115 feet bgs in the eastern and southeastern area of the parcel. In the event neither confining unit is encountered, borings will be terminated at a maximum depth of 125 feet bgs, 10 feet below the deepest predicted surface of the Lawton Clay unit, and deep monitoring wells will be installed to that maximum depth.

Deep Monitoring Wells MW-15 through MW-17 will be installed in numerical sequence. If no confining layer and no DNAPL contamination are encountered during the installation of Monitoring Wells MW-15 and MW-16, then the Port and WSDOE will discuss the need for installing MW-17.

DEEP MONITORING WELL BORINGS AND SOIL SAMPLING

Geologic Logging

Deep monitoring well soil borings will be completed using a sonic drilling methodology at the locations shown on Figure 1. This methodology will allow for a detailed inspection of the geologic structure and identification of discontinuous low permeability zones where DNAPL could accumulate at locations above the first confining layer. Soil core intervals can be arranged in vertical sequence so that direct observation of the stratigraphic sequence at each deep monitoring well soil boring location can be determined and to assist with accurate identification of monitoring well screen intervals.

All soil boring drilling activities will be monitored by a field technician and soil borings will be continuously logged throughout the entire length of the exploration. Interpretations of soil conditions will be made according to the United Soil Classification

System (USCS) and will be recorded on the soil boring log. Photographs of the soil boring core intervals will also be obtained.

Deep Monitoring Well Soil Boring Sampling

Field Screening

The deep monitoring well soil cores will be field screened to identify intervals that are potentially contaminated with volatile constituents by the following methods:

- Using a photoionization detector (PID)
- Conducting sheen tests
- Recording visual and olfactory signs of contamination.

Soil will also be screened for the presence of staining, sheens, odors, or anthropogenic materials (i.e., slag, metal fragments, woody debris, etc.). Soil field screening procedures will be conducted according to the methods described in the existing SAP/QAPP document for the LL Apartments Parcel investigations (Floyd|Snider 2010).

Soil Sampling

Soil samples will be collected from the core barrel samplers at approximate 5-foot-depth intervals of interest, as identified by results of the field screening methods described above. The co-located primary soil borings, drilled prior to the installation of the deep monitoring wells, will be used to determine the shallowest depth at which soil samples will be logged and collected from the deep monitoring well soil borings. For the deep borings, geologic logging of the soil cores will start at the ground surface. Soil samples will be collected starting at the sampling interval below the deepest soil sample collected at the co-located primary soil boring. For example, if the maximum depth of soil sample collection for Primary Soil Boring PSB-15 is 20 feet, then the first soil sample collected for potential analytical testing associated with deep Monitoring Well MW-15 will be at 25 feet bgs. Deep soil borings will be logged, and soil samples collected for analytical testing or archiving, to a depth where a confining layer is encountered or a maximum depth of 125 feet bgs, whichever occurs first.

Similar to soil logging procedures, soil samples will also be described and classified according to the USCS and photographed. As part of soil sampling activities, the following information will be recorded on the soil boring log:

- Date, time, and name of the person logging the sample
- Weather conditions
- Soil sample location number
- Soil sample depth and soil description

- Soil sample recovery
- Presence of debris
- PID readings
- Presence of sheen or any other indications of contamination such as odor

Soil samples will be collected for analytical testing or archiving (at the identified sample location) directly from the core barrel sampler using U.S. Environmental Protection Agency (USEPA) Method 5035A for volatile organic compounds (VOCs). This preservation method uses a Teflon corer to collect an undisturbed, sealed sample that minimizes loss of volatiles during sampling and transport. The remainder of soil within the designated sample interval will be placed into a decontaminated stainless steel bowl for homogenization.

Soil Sample Handling

Following homogenization, the sample material will be placed into laboratory-supplied sample containers with the lids tightly sealed, labeled, and placed in a cooler on ice. Standard chain-of-custody procedures will be implemented for all sampling events. These sampling procedures described above are consistent with the soil sampling and analysis methods presented in the existing SAP/QAPP document for the LL Apartments Parcel investigations (Floyd Snider 2010).

Decontamination

Field sampling equipment used in the collection of soil samples from soil borings (i.e., stainless steel bowl and spoons, etc.) will be decontaminated by washing with an Alconox and tap water wash, and rinsing with deionized water. All field sampling equipment and drilling equipment will be decontaminated according to the procedures described in the existing SAP/QAPP document for the LL Apartments Parcel investigations (Floyd|Snider 2010).

Quality Control Sample Collection

Additional quality control soil samples will be collected to verify that field collection and laboratory analytical procedures are completed in an acceptable manner. Specifics regarding requirements for collection of quality control soil samples are presented in Section 4.0 and Section 6.0 of the existing SAQ/QAPP document for the LL Apartments Parcel investigations (Floyd|Snider 2010).

DEEP MONITORING WELL INSTALLATION AND DEVELOPMENT

Deep Monitoring Well Installation

Deep monitoring wells will be installed following the "Minimum Standards for Construction and Maintenance of Wells" from WAC 173-160. Monitoring wells will be completed by Cascade Drilling of Woodinville, Washington at well locations shown in Figure 1. All wells will be constructed of 2-inch diameter, flush-threaded, Schedule 40 PVC well casing and screen. Well screen assemblies will consist of a 10-foot length of 0.010-inch (10-slot), flush-threaded, machine-slotted, Schedule 40 PVC set in a 10/20 sand or equivalent silica sand filter pack. Deep monitoring well screens will be 10 feet in length, with bottoms set at the contact with the identified confining layer, or, in the absence of a confining layer, the 125 foot bgs maximum boring depth. The well design includes a 0.5-foot long flush-threaded, Schedule 40 PVC sump with a flush-threaded end cap. The sand filter pack will be a pre-pack filter that will be installed between the well casing and the drill casing as the casing is withdrawn. A weighted tape will be used to monitor filter pre-pack placement and depth during installation. The sand filter pack will extend 3 feet above the top of the screened interval. A minimum 2-foot thick seal of hydrated bentonite chips will be installed in the annular space immediately above the sand filter pack and hydrated with potable water if installed above the water table. The remainder of the annular space will be sealed with bentonite grout or hydrated bentonite chips to within 1 foot of the ground surface.

The monitoring wells will be secured with a flush-to-ground locking steel protective monument with expansion seals on the well casing to minimize the potential for rain/surface water entering the monument. Installed wells will be labeled with a permanent marker on the well casing on the well cover of flush mounts. All newly installed monitoring wells will be surveyed by a licensed surveyor.

Deep Monitoring Well Development

Development activities, including purging and surging, will be performed on each newly installed deep monitoring well to remove water and fines from the well casing, filter pack, and surrounding formation. This will be done to remove water and fines in the formation disrupted by well installation, and to establish a hydraulic connection between each well and the surrounding aquifer matrix. The goal of well development is to allow groundwater representative of the formation to flow into the well.

All deep monitoring wells will be developed according to the procedures presented in Section 8.3.4 of the existing SAP/QAPP document for the LL Apartments Parcel investigations (Floyd|Snider 2010). Well development will be completed by continuous pumping at a steady rate using a pump that is capable of completing well development activities depending on the finished depth of the deep soil boring. Wells will be developed using the described methodologies or equivalents at least 48 hours following

well installation. Well development equipment will be decontaminated by pumping clean water through the pump and washing to the satisfaction of the field technical staff.

Based on field screening observations made during well installation and analysis of initial soil sample data, samples may be collected using the sump prior to well development in order to determine potential waste characterization issues and disposal alternatives.

GROUNDWATER SAMPLING

Groundwater samples will be collected from all deep monitoring wells during the three quarterly monitoring events as described in the existing SAP/QAPP document for the LL Apartments Parcel investigations (Floyd|Snider 2010). Deep monitoring wells will be purged and sampled using low-flow procedures with a pump suitable for deep groundwater sample collection and disposable polyethylene tubing. Samples will be collected sufficiently close to the well bottom to be representative of groundwater or DNAPL near the contact with the low permeability unit (if present).

Field procedures including measuring the depth to water, purging deep monitoring wells, groundwater sample collection, and sampling equipment decontamination will be completed as described in Section 8.5.1 of the existing SAP/QAPP document for the LL Apartments Parcel investigations (Floyd|Snider 2010).

Quality Control Sample Collection

Quality control soil samples will be collected according to the procedures described in the existing SAQ/QAPP document for the LL Apartments Parcel investigations (Floyd|Snider 2010).

DEEP MONITORING WELL SLUG TEST AND SURVEYING

After completing the installation and development of the deep monitoring wells, slug tests will be conducted at each deep monitoring well location to estimate the aquifer hydraulic conductivity in the vicinity of the well. Pneumatic slug test methods may be required if the aquifer formation is very permeable. Hydraulic conductivity data will be collected to assist with future evaluation of groundwater contaminant migration and potential transport modeling, if determined to be necessary. Slug tests will be completed according to the procedures described in Section 8.6 of the existing SAP/QAPP document for the LL Apartments Parcel investigations (Floyd|Snider 2010).

Additionally, all deep monitoring well locations will be surveyed for reference and mapping purposes according to the requirements specified in the Agreed Order for the Site (as defined in the current Lora Lake Apartments RI/FS Work Plan). Requirements for monitoring well survey procedures are provided in Section 8.7 of the existing SAP/QAPP document for the LL Apartments Parcel investigations (Floyd|Snider 2010).

LABORATORY ANALYSIS PROGRAM

Soil and groundwater samples collected from each of the proposed deep monitoring well will be analyzed for the following constituent groups using the methods presented below. For soil and groundwater samples, the chemical analyses will be performed by Analytical Resources, Incorporated (ARI).

Deep Monitoring Well Installation Soil Samples

The deep monitoring well installation soil sample collected at the confining layer contact, if present, or at the bottom of the boring, will be immediately analyzed for the following constituents by the methods indicated below:

- Pentachlorophenol (PCP) by USEPA Method 8041
- Tetrachloroethene (PCE), trichloroethene (TCE), dichloroethene (DCE), and 1,2-dichloroethane (1,2-DCA) by USEPA Method 8260C
- Total organic carbon (TOC) by Plumb 1981

All other soil samples collected during installation of the deep monitoring wells will be archived at the analytical laboratory. Following receipt of analytical data, a coordination meeting will be scheduled with WSDOE to discuss the following:

- Review of soil data from the co-located primary soil borings. A review of these data will be conducted to evaluate the need for additional laboratory analyses of archived deep monitoring well soil samples in the event that the vertical extent of contamination has not been bounded.
- Review of soil boring/well installation logs and results of field screening efforts to identify specific archived soil samples that may be beneficial for analytical testing.
- Review of soil sample results from the sample immediately analyzed at the bottom of the soil boring.

Results of this coordination meeting will be used to identify the need for analysis of additional archived soil samples for the constituents of concern (COCs) described above. Efficient coordination with WSDOE will be necessary in order to ensure that sample holding times do not expire for the archived soil samples selected for laboratory analysis.

Deep Monitoring Well Installation Groundwater Samples

The groundwater samples collected at the deep monitoring well locations will be analyzed for the following constituents by the methods indicated below:

- PCP by USEPA Method 8041

- PCE, TCE, DCE, and 1,2-DCA by USEPA Method 8260C-SIM
- Total suspended solids by SM 2540D
- pH by USEPA Method 150.1

Deep monitoring wells will be sampled according to the same schedule as the other monitoring wells that are being sampled at the LL Apartments Parcel.

Quality Control Sample Analyses

Quality control (QC) groundwater samples will be collected according to the procedures described in the existing SAQ/QAPP document for the LL Apartments Parcel investigations (Floyd|Snider 2010).

Reporting Limits and Data Validation

The analytical methods identified in this technical memorandum result in the lowest analytically achievable method detection limits and reporting limits or Practical Quantitation Limits (PQLs). The existing SAP/QAPP for the LL Apartments Parcel investigations presents the target reporting limits and the project data quality assurance criteria for each analytical method as performed by the analytical laboratories (Floyd|Snider 2010). These reporting limits are goals only, insofar as instances may arise where high sample concentrations, non-homogeneity of samples, or matrix interferences preclude achieving the desired reporting limit and associated QC criteria. In such instances, the laboratory will report the reason for any deviation from these reporting limits.

All data generated as part of the deep monitoring well installation program will be validated according to the same procedures described in Section 6.0 of the existing SAP/QAPP document (Floyd|Snider 2010).

REFERENCES

Aspect Consulting, LLC. 2010. *Geology/Hydrogeology Technical Memorandum – Lora Lake Apartment Parcel Remedial Investigation/Feasibility Study Work Plan Addendum*. Prepared for Floyd|Snider. 21 July.

Aspect Consulting and S. S. Papadopulos & Associates, Inc. (Aspect and S.S. Papadopulos). 2005. *Seattle-Tacoma International Airport: Phase 1 Groundwater Study Report.* Prepared for Port of Seattle. February.

Floyd|Snider. 2010. *Final Remedial Investigation/Feasibility Study Work Plan*. Prepared for Port of Seattle. July.

Figure

Legend

Proposed RI Supplemental Boring Locations

PSB-4 Primary Shallow Soil Dioxin Investigation Borings – **Samples Analyzed for Dioxins Only (8).**

PSB-10 Primary Central and Eastern Source Area Investigation Boring – **Samples Analyzed for All Site COCs (13).**

PSB-22 Primary NE Corner Petroleum Investigation Boring – **Samples Analyzed for All Site COCs (3).**[1]

SSB-6 Secondary Shallow Soil Dioxin Investigation Boring – **Samples Archived for Potential Dioxins Analysis (10).**

MW-14 Subsurface Soil Boring and Monitoring Well Completion Analyzed for All Site COCs (3)

MW-16 Deep Subsurface Soil Boring and Monitoring Well Completion Analyzed for PCP and Select VOCs (3)

Existing Sampling Locations

MW-2 Monitoring Well Location (2007, 2008)

LL-12 Geoprobe Location (2008)

LLP-8 Geoprobe Location (2007)

Plume Locations (AECOM 2009)

Dioxin in Soil

Lead and cPAH in Soil

Lead in Soil

PCP in Soil

TPH-Dx in Soil

Former Locations of Buildings and Structures[2]

Lora Lake Apartments Parcel Property Boundary[3]

Notes:

1. Borings installed for delineation of TPH source area.
2. All buildings and structures were demolished as part of the 2009 interim action and to comply with FAA flight path requirements. These demoition activities were completed by fall 2009.
3. Lora Lake Apartments Parcel Property Boundary provided by AECOM.

· Existing locations of monitoring wells, soil borings, and plumes based on AECOM Summary Report (AECOM 2009b).

· All proposed locations by Floyd|Snider are approximate and are subject to change.

· Aerial image provided by Bing Maps © 2009. (Aerial image has been modified to show demolished buildings with foundations left intact.) Image date ~2004-2006.

· Proposed Deep monitoring wells not shown. Locations to be presented in a Technical Memorandum Addendum.

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Deep Monitoring Well Installation and Sampling and Analysis Plan
Port of Seattle
Lora Lake Apartments
Burien, Washington

Figure 1
Proposed Deep Soil Boring and Monitoring Well Locations and Approximate Extents of Soil Contamination

File: F:\projects\POS-LLA\GIS\MXD\Deep MW Installation SAP\Figure 1 (Proposed Deep Soil Boring and MW Locations).mxd
Date: 7/15/2010

Attachment 1
Geology/Hydrogeology Technical Memorandum

Aspect CONSULTING

MEMORANDUM

Project No.: 090134-004-01

July 21, 2010

To: Matt Woltman – Floyd|Snider

Jeremy Michael Shaha

John Jacob Strunk

From: **Jeremy M. Shaha, LG**
Senior Staff Hydrogeologist

John J. Strunk, LHG
Senior Associate Geologist

Re: **Geology/Hydrogeology Technical Memorandum – Lora Lake Apartment Parcel Remedial Investigation/Feasibility Study Work Plan Addendum**

Introduction

This technical memorandum provides an evaluation of the geologic and hydrostratigraphic conditions in the near vicinity of the Lora Lake Apartment Parcel (Site). The primary objective of this evaluation is to provide information and data on the geologic formations and groundwater conditions in support of developing protocols for deep monitoring well placement and design of an associated dense non-aqueous phase liquid (DNAPL) testing program. Information contained in this memorandum addresses comments received on the Draft Lora Lake Apartments Remedial Investigation/Feasibility Study Work Plan (Floyd|Snider, 2010) which, in general, required:

- An evaluation of aquifer boundaries and hydraulic connections;
- Description of groundwater flow components;
- Rationale for deep monitoring well screen placement; and
- DNAPL characterization.

Work Plan review comments from the Department of Ecology (Ecology) (Ecology, 2010) require that adequate site characterization occurs to the depth of the first confining unit underlying the water table aquifer and a sampling program be developed to evaluate if DNAPLs have accumulated on top of the confining unit. This technical memorandum provides estimates of the target depths for the first confining unit based on the review of existing geologic and groundwater information in the near vicinity of the Site.

The bulk of the geology/hydrogeology data used in developing this technical memorandum is obtained from a Port of Seattle (Port) commissioned Groundwater Study (Aspect and S.S. Papadopulos, 2008) which describes in detail regional geology and groundwater conditions within a 42-square mile study area surrounding the Seattle-Tacoma International Airport (STIA). The Groundwater Study was conducted under an Ecology Agreed Order and represents the most current and comprehensive understanding of the geologic and hydrogeologic framework in the area surrounding STIA. The Site falls within the northwest region of the Groundwater Study data collection boundary.

Site Description and Existing Characterization

The Site is located at 15001 Des Moines Memorial Drive in Burien, Washington. The Site occupies approximately 8.3 acres of currently vacant land that is bound to the north by State Route 518 (SR518), to the east and southeast by Des Moines Memorial Drive, to the west by 8th Avenue South, and to the south by an open area that was the former Seattle City Light Sunnydale substation and other open land parcels that have been cleared from prior industrial and commercial land use (Figure 1). Lora Lake, a secured Port-owned land parcel, is located to the southeast of the Site, across Des Moines Memorial Drive. Lora Lake is a man-made water body resulting from peat mining activities that occurred sometime from the late 1930s through the 1950s.

The Site is located in the Puget Lowland, within the Miller Creek Watershed, just northwest of STIA. The Site topography gradually slopes to the southeast, towards Lora Lake, with steeper slopes located adjacent to Des Moines Memorial Drive and from the Highway 518 embankment to the north. The existing Site topography was created as a result of construction associated with the former apartment building complex in 1987.

Several environmental investigations have been performed at the Site providing insight on shallow geology and groundwater conditions (Golder, 1987; GeoScience Management, 2008; ENSR|AECOM, 2008a, and ENSR|AECOM, 2008b). Soil borings and monitoring wells completed at the Site range in depth from approximately 15 to 30 feet below ground surface (bgs). These explorations have identified a discontinuous fill layer which overlays glacial outwash deposits. Detailed descriptions of these shallow geologic units in the context of deeper units and groundwater aquifer systems are presented in the following sections. Figure 2 presents the surficial geologic map (Booth and Waldron, 2002) showing that the Site is located within a recessional outwash (Qvr) channel that generally trends to the southwest on the west side of STIA.

A network of 11 groundwater monitoring wells were installed by AECOM in 2008. The wells are located within the Site boundary and east of Des Moines Memorial Drive at depths ranging between 15 to 30 feet bgs (AECOM, 2009). Appendix A provides the well logs for the monitoring wells installed at the Site and cross sections developed based on the lithologic interpretations of the well logs. Groundwater has been measured in the wells at depths of between 6 to 20 feet bgs and is present in the glacial outwash deposits and some fill materials. A southeast groundwater flow direction, across the Site towards Lora Lake, has been documented from groundwater level measurements collected between March and December 2008 (ENSR|AECOM, 2008b and AECOM, 2009).

Regional Geologic Setting

The Puget Lowland is underlain at depth by volcanic and sedimentary bedrock, and is filled to the present-day land surface with both glacial and non-glacial sediments (non-glacial or inter-glacial sediments are those derived between periods of glaciation) deposited during the Quaternary Period (within the last 2 million years).

The Quaternary geologic history of the Puget Sound region is dominated by a succession of at least six dated and named periods of ice sheet glaciations. In the Puget Lowland, the most recent continental glacier was present as a lobe of ice that reached its maximum extent just south of Olympia during the Vashon stade (a short period of regional glacial advance) of the Fraser glaciation (a major period of regionwide glaciation). The Fraser glaciation locally occurred between about 13,000 and 15,000 years ago and consists of (from youngest to oldest): recessional lacustrine deposits (Qls), Vashon recessional outwash (Qvr), weathered Vashon glacial till (Qvtw), Vashon glacial till (Qvt), Vashon advance outwash (Qva), and transition beds (Qtb). Sediments that were deposited prior to the Vashon glaciation are collectively referred to as “pre-Fraser”. These generally consist of alternating sequences of coarse- (C) and fine-grained (F) deposits. Table 1 provides the geologic unit descriptions based on a categorization system previously established by a Phase I Groundwater Study (Aspect and S.S. Papadopulos, 2008) conducted in the area.

During the Vashon stade, glacial ice was about 3,000 feet thick in the study area (Thorson, 1980). Sediments that were overridden by the glacier are termed glacially overconsolidated. The weight of the ice compacted the underlying sediments to a very dense or hard state. Sediments that were not glacially overridden and thus were not overconsolidated are termed normally consolidated. These sediments, such as recessional outwash and recent alluvium, are typically much less dense or hard.

During the glacial cycles, a tremendous amount of sediment was deposited in the lowland. However, during both the glacial and non-glacial cycles, some of the glacial sediment deposits were eroded and re-deposited elsewhere. Due to these cycles of deposition, erosion, and re-deposition, there may be gaps in the stratigraphic sequences, and very young deposits may rest on much older deposits. For example, in the vicinity of the Site, there may be areas where the till was eroded during the deposition of the recessional outwash, and the transition beds were eroded during the deposition of the advance outwash.

Geologic processes following the Vashon glaciation are dominated by erosion of the uplands and deposition of recent alluvium and lacustrine deposits in the valleys and water bodies of the Puget Lowland. Extensive filling of former wetlands and grading for construction projects has further modified the land surface. Sediments that were deposited after the Vashon stade of the Fraser glaciation (during the Holocene Epoch) are usually termed “recent” to identify their stratigraphic position relative to the older deposits. These deposits include (Table 1): fill (fill), topsoil (Qts), recent alluvium (Qal), and recent lacustrine deposits (Ql).

Regional Hydrostratigraphy

In general, the coarse-grained (C) units composed of sand and gravel form the regional aquifer systems beneath the Site; whereas, the fine-grained (F) units composed of low permeability silt and clay form the aquitards, which impede groundwater flow. Table 1 provides the hydrostratigraphic unit designations for the geologic units discussed above. The following sections provide a brief

description of the respective geologic and hydrostratigraphic units (from oldest to youngest) present within the vicinity of the Site.

Pre-Fraser Fine- and Coarse-Grained Units

Interconnected deposits of pre-Fraser coarse-grained units (Qpfc) are composed primarily of sand, gravel, or silty sand and are grouped as hydrostratigraphic units C2 through C6. Pre-Fraser fine-grained units (Qpff) are composed primarily of silt and clay, and where laterally extensive, are grouped as fine-grained hydrostratigraphic units F2 through F7. Both the F and C hydrostratigraphic units contain interbeds of other sediments.

Transition Beds – Lawton Clay and Pre-Fraser Fine-Grained Deposits

Transition beds (Qtb) are the fine-grained deposits that mark the transition during a glacial advance from non-glacial lake deposition to glacial lake deposition. In the Seattle area, the Vashon advance glaciolacustrine (glacial lake) deposits are known as the Lawton Clay, and are commonly recognized as a distinctive geologic unit. For the hydrostratigraphy in the vicinity of the Site, the Vashon glaciolacustrine deposits (Lawton Clay) are grouped within the transition beds as the F2 unit because it is generally not possible to distinguish between Lawton Clay and fine-grained deposits of the Olympia beds in the boring and well logs. The F2 unit may also include some older glacial and non-glacial fine-grained deposits. The F2 unit overlies the C2 and older units.

The fine-grained Olympia bed non-glacial deposits contain silt, clay, and silt-sand mixtures, with scattered to abundant organics and thin interbeds of peat and organic-rich wetland deposits. Lawton Clay is composed of hard, gray, interbedded silt and clay with thin fine sand interbeds and scattered sand and gravel dropstones (sand or gravel particles that fell into fine-grained sediments after they melted out of floating glacial ice).

Vashon Glacial Deposits

Sediments deposited during the Vashon glacial advance are collectively termed Vashon Drift. The main components of the Vashon Drift glacial sequence present within the vicinity of the Site are described below from oldest to youngest. These deposits date from the advance of the Vashon ice-sheet glacier about 15,000 years ago to the retreat of the ice about 13,500 years ago. The earliest Vashon deposit, the glaciolacustrine Lawton Clay was described above.

Advance Outwash (Qva) – Advance glaciofluvial (glacial meltwater) deposits of the Vashon Stade are also called Vashon advance outwash. A prominent sandy Vashon advance outwash unit, known in the Seattle area as the Esperance sand, occurs widely across the study area. Advance outwash present within the vicinity of the Site is generally very dense, brown to gray, homogeneous, clean (no appreciable silt or clay) to slightly silty, fine to medium sand, although some deposits are composed of sand and gravel. The advance outwash unit forms a regional aquifer which exhibits both unconfined and confined groundwater conditions. Where the C1 unit is confined and exposed at the surface through hillside erosion or downcutting by a natural drainage, such as in the Miller Creek drainage, discharge from the C1 unit may occur as seeps or wetlands or springs contributing to surface water baseflow.

Vashon Till (Qvt) – This unit consists primarily of lodgement till, a very dense, gray mixture of clay, silt, sand, and gravel with cobbles that was deposited at the base of the Vashon glacier. Interbeds or lenses of water-worked outwash-like sand and gravel are present within the till. The interbeds and lenses commonly range from several inches to about 5 feet thick. Thin lacustrine lenses and boulders are also present in Vashon till.

Unweathered till generally exhibits very low permeability and forms an aquitard as hydrostratigraphic unit F1. Where low areas in the till surface are present, groundwater will perch atop this unit. Wetlands commonly occur in enclosed depressions on the till surface. Where Vashon till caps units such as the C1 unit, it may form a confining layer.

Weathered Vashon Till (Qvtw) – Where the upper surface of the till has been weathered, a subunit of the Vashon till, called weathered till (Qvtw) had been identified. Although typically not greater than 5 feet thick, this unit is brown to gray, and is looser and has higher permeability (and transmits water more rapidly) than unweathered till. It is usually grouped with the F1 hydrostratigraphic unit.

Recessional Outwash (Qvr) – Recessional outwash deposits consist of coarse-grained fluvial (river and stream) sediments (Qvr) associated with the retreat of the Vashon ice sheet. The fluvial sediments consist of sand, gravel, and silty sand. Recessional outwash is the only Vashon glacial deposit that was never overridden by glacial ice and compressed, and is therefore substantially less dense and softer than the older deposits.

Recessional outwash occurs as thin deposits on upland areas, typically less than 20 feet thick, and in broad low areas that were former recessional meltwater channels. Along the walls and bottoms of most major drainages within the vicinity of the Site, recessional outwash is more continuous and may exceed 30 feet in thickness. Recessional outwash may occur in the same geographic locations as recent alluvium (modern stream and river deposits). It has sedimentary characteristics similar to alluvium, and may be grouped with alluvium. In upland areas where drainage is poor, recessional outwash commonly forms a perched aquifer. Recessional outwash is included in the C0 hydrostratigraphic unit.

Recessional Lacustrine Deposits (Qvrl) - Fine-grained deposits associated with the recession of the Vashon ice sheet glacier are identified as recessional lacustrine deposits (Qvrl). These normally consolidated (not glacially overridden) glacial lake, pond, and kettle (a depression that formed by melting of buried glacial ice) deposits generally consist of silty to clayey sediments with interbedded silty fine sands. They are usually restricted to poorly-drained ice meltout kettles on the uplands, and as thin interbeds within coarse-grained recessional outwash deposits in the low-lying areas. Recessional lacustrine deposits are included in the F0 hydrostratigraphic unit.

Recent (Holocene) Deposits

Holocene sediments are those that have been deposited since the disappearance of glacial ice following the last ice age. In the central Puget Lowland, this disappearance of ice occurred approximately 13,500 years ago. The sediments were deposited by non-glacial geologic processes that are largely active today, such as erosion, landslides, streams and rivers, and human activities such as excavating and filling. Because these sediments have not been glacially overridden, they are normally consolidated or slightly over consolidated, and are typically very loose to dense or soft to

very stiff. The most extensive Holocene deposits include recent alluvium and fill. Recent deposits are either C0 if coarse-grained, or F0 if fine-grained. There is no stratigraphic order among the recent deposits.

Recent Alluvium (Qal) – Recent alluvium consists of young stream and river (fluvial) sands and gravels and silty sands, commonly containing some interbedded silt and clay and organic matter. Thin ribbons of recent alluvium fill the ravines and creek bottoms that drain the upland, including portions of Miller Creek. The alluvium thickens where the creeks approach the shoreline.

Recent Lacustrine Deposits (Ql) – Recent deposits of lake (lacustrine), pond, floodplain and other low-energy or slack water bodies are generally composed of silt, clay, and silty fine sand. These fine-grained deposits commonly contain some organics and wood and may include peat. This geologic unit is included in the F0 hydrostratigraphic group.

Topsoil (Qts) – Topsoil consists of organic-enriched soil that typically marks the top of native soils or any formerly vegetated older surface. Although typically less than 2 feet thick, topsoil is commonly present below fill soils and is an important marker bed for delineating the thickness and extent of fill that covers the topsoil. Topsoil is included in the C0 unit.

Artificial Fill (Fill) – Fills of various thickness and composition are present within the vicinity of the Site. Fills are most common in low-lying areas around drainage bottoms. Fills may be composed of any mixture of fine or coarse grained soils. Fills are considered to be water bearing zones if coarse-grained and classified as C0. Fine grained fills, classified as F0, tend to exhibit poor water bearing capabilities.

Site Hydrostratigraphy

In the vicinity of the Site, only Fraser glacial deposits are exposed at land surface (Figure 2). The Fraser glacial deposits consist primarily of recessional outwash (C0), which was deposited in what may have been a relatively large, southwest-northeast trending ancestral outwash channel. Adjacent to this channel, older Quaternary deposits consisting of till (F1) and advance outwash (C1) are exposed at the surface.

Several cross sections were developed by ENSR|AECOM (2008a and 2008b), based on 11 monitoring wells installed at the Site (Appendix A), in order to determine the subsurface stratigraphy in the vicinity of the Site. The cross sections indicate that up to 15 feet of fill (fill) is present over much of the Site, except within the northern region of the Site, where it is absent. The cross sections also indicate that recessional outwash (C0) is present to depths of at least 30 feet bgs. However, because all of the Site monitoring wells are completed in the recessional outwash (C0), at depths of less than 30 feet, they do not provide information on the presence/absence of deeper stratigraphic units. Therefore, an additional cross section was created for the Site, incorporating nearby wells completed at greater depths, in the older till (F1) and advance outwash (C1) units. Figure 3 presents the cross section location map and relevant well locations and Figure 4 presents the additional cross section.

Based on Figure 4, recessional outwash (C0) is present at the surface in the vicinity of the Site, where fill is not present, and extends to depths of more than 15 feet bgs (northwestern property boundary), to more than 30 feet bgs (southeastern property boundary), based on the respective well logs. Although there are currently no existing deep wells (depths greater than 30 feet) at the Site, several wells located to the southeast of the Site (NDW-1A and NDW-4) indicate the presence of a relatively thick (between 25 and 35 feet) till unit (F1), near the east side of the Miller Creek valley. In addition, a well to the north of the Site (23N4E-20C1) also indicates the presence of an approximately 10-foot thick till unit (F1) exposed at the surface. If the till (F1) is continuous across the Site, as illustrated in Figure 4, the unit would be expected to occur at depths ranging between 15 (northwestern property boundary) and 45 (southeastern property boundary) feet bgs, or at elevations of between 290 and 265 feet NGVD 29, respectively. This range of elevations, based on site-specific interpretation of vicinity data (Figure 4), is slightly lower than those predicted by a structure contour map (Figure 5) developed as part of the Phase I Groundwater Study (Aspect and S.S. Papadopulos, 2008) for the top of the advance outwash (C1), which occurs immediately below the till (F1). The structure contour map predicts the top of the advance outwash (C1) to occur at an elevation of approximately 300 feet NGVD 29, meaning that the top of the till (F1) would occur at an elevation of more than 300 feet NGVD 29.

It also important to note that areas of the till (F1) may have been eroded during the deposition of the younger recessional outwash (C0). There is a nearby cross section (A-A'), developed as part of the Phase I Groundwater Study (Aspect and S.S. Papadopulos, 2008), which is located immediately to the north of the Site (Figure 3) and cuts across the recessional outwash channel. This cross section (Figure 6) indicates that the till (F1) may not be present at the center of the recessional outwash channel (vicinity of well B-211, 23N4E20B1) and that the recessional outwash (C0) may transition directly into the advance outwash (C1). Although Figure 6 indicates the potential for the till (F1) to be absent within the outwash channel, it is uncertain whether this is the case beneath the Site.

If the till (F1) is absent beneath the Site, the next significant confining layer that would be present beneath the site is the transition beds (F2). However, due to the limited deep (depths greater than 30 feet) well data in the vicinity of the Site, it is not possible to say with any certainty whether the transition beds (F2) are present. Based on the cross section through the Site (Figure 4), the transition beds (F2) are about 20 feet thick to the north of the Site (well 23N4E20C1) and are encountered at an elevation of approximately 225 feet NGVD 29. However, as illustrated in Figure 4, the unit is likely dipping slightly to the south-southeast, towards the center of the recessional outwash channel. Therefore, the transition beds (F2) would be expected to be encountered at a slightly lower elevation beneath the site. A structure contour map (Figure 7), developed as part of the Phase I Groundwater Study (Aspect and S.S. Papadopulos, 2008) for the top of the transition beds (F2), indicates that in the vicinity of the Site, the transition beds are expected to be encountered at an elevation of about 220 feet NGVD 29. This elevation for the top of the transition beds (F2) is very similar to that observed on the cross section located immediately to the north of the site (Figure 6). However, it is important to note that as with the till (F1), the transition beds (F2) may have been eroded during the deposition of the advance outwash (C1). If the transition beds (F2) are present beneath the Site, they would be expected to be encountered at depths of between 80 (southeastern property boundary) to 95 (north central property boundary) feet bgs.

Underlying the transition beds (F2), if they are present beneath the Site, is a relatively thick (approximately 150 feet thick, based on Figure 6) unit of pre-Fraser coarse-grained deposits (C2). These deposits would extend to depths of more than 230 (southeastern property boundary) to 245 (north central property boundary) feet beneath the Site. Within the pre-Fraser coarse-grained deposits (C2), there is a relatively thin (approximately 10-foot thick) confining unit of pre-Fraser fine-grained deposits (C2F). This unit is found at an elevation of approximately 160 feet NGVD 29, or between depths of approximately 140 (southeastern property boundary) to 155 (north central property boundary) feet beneath the Site. Depending on the thickness of this unit, it may cause the upper and lower portions of the pre-Fraser coarse-grained deposits (C2) to be hydraulically discontinuous. Beneath the pre-Fraser coarse-grained deposits (C2) is a relatively thick (greater than 140 feet thick, based on Figure 6) unit of pre-Fraser fine-grained deposits (F3).

Hydrogeologic Setting

The following sections provide a brief description of groundwater occurrence in the various aquifers expected to be present beneath the Site and the potential for groundwater interactions between the aquifers.

Groundwater Occurrence

The initial and supplemental groundwater investigations completed by ENSR|AECOM (2008a and 2008b), reveal that the recessional outwash (C0) is the uppermost aquifer at the Site, with groundwater levels of between 6 to 20 feet bgs, and groundwater elevations between 275 to 293 feet NGVD 29. A groundwater elevation contour map for the Site (Appendix A), completed by ENSR|AECOM (2008a and 2008b), indicates that groundwater flow within the recessional outwash (C0) is to the southeast, towards Lora Lake. However, it is important to note that the lower boundary of this aquifer has not been defined at the Site, and it is currently uncertain whether groundwater in the recessional outwash (C0) is perched on the till (F1); or if the till (F1) is absent, whether groundwater in the recessional outwash (C0) is in hydraulic continuity with the underlying advance outwash (C1) aquifer.

The Phase I Groundwater Study (Aspect and S.S. Papadopulos, 2008) indicates groundwater levels in the advance outwash (C1) aquifer appear to be very similar (within about 5 feet) to groundwater levels observed in the overlying recessional outwash (C0). If the till (F1) is absent beneath the Site, and the recessional outwash (C0) and advance outwash (C1) aquifers are in hydraulic continuity, it would be expected that the groundwater levels would be about the same elevation. Figure 8 presents a groundwater elevation contour map for the advance outwash (C1) aquifer. Based on Figure 8, groundwater flow in the advance outwash (C1) aquifer is also to the southeast in the vicinity of the Site, towards Lora Lake. However, Figure 8 demonstrates that regional groundwater flow in the advance outwash (C1) aquifer is to the southwest, converging and flowing sub-parallel to Miller Creek towards Puget Sound.

A groundwater elevation contour map for the uppermost pre-Fraser coarse-grained deposits (C2) was also developed as part of the Phase I Groundwater Study (Aspect and S.S. Papadopulos, 2008) and is presented as Figure 9. The pre-Fraser coarse-grained deposits (C2) aquifer is the uppermost aquifer in which the nearest municipal water supply wells (City of Seattle Highline Well Field) are completed. Based on Figure 9, groundwater flow in the pre-Fraser coarse-grained deposits (C2) in

the vicinity of the Site appears to be to the southwest, towards Puget Sound, which is consistent with the regional groundwater flow direction.

Vertical Gradients

Because all of the Site monitoring wells are completed in the recessional outwash (C0), it is not possible to determine vertical gradients beneath the Site at this time. However, several multi-completion piezometers were installed as part of a Predesign Study for the Renton Effluent Transfer System (URS Engineers, et al., 1983). Two of these piezometers (B-9 23N4E20C1 and B-8 23N4E20A1) are located to the northwest and northeast of the Site, respectively (Figure 4 and Figure 6). Table 2 provides a summary of the vertical gradients for the various hydrostratigraphic units of completion, based on the available data.

In the center of the recessional outwash channel (vicinity of piezometer B-8 23N4E20A1), there appears to be an upward vertical gradient (-0.03) from the underlying pre-Fraser coarse-grained deposits (C2) towards the overlying advance outwash (C1) and recessional outwash (C0). This is consistent with the groundwater elevation contour map for the area in which the advance outwash (C1) appears to be discharging to Miller Creek (Figure 8). This upward gradient would thus likely limit the downward migration of dissolved DNAPL constituents and could provide a natural hydraulic barrier to contaminant transport into deeper aquifer systems.

However, there also appears to be a downward vertical gradient (0.190) from the pre-Fraser coarse-grained deposits (C2) towards the pre-Fraser fine-grained deposits (F3). This downward gradient is likely associated with recharge which occurs on the upland at topographic elevations that are higher than those of the Site. Further to the west and closer to the edge of the recessional outwash channel (vicinity of piezometer B-9 23N4E20C1), there appears to be a downward gradient (0.140) from the recessional outwash (C0) towards the underlying advance outwash (C1) and pre-Fraser coarse-grained deposits (C2). There is also a downward gradient (0.186) from the pre-Fraser coarse-grained deposits (C2) towards the underlying pre-Fraser fine-grained deposits (F3).

To better understand the vertical component of groundwater flow at the Site, two of the proposed deep monitoring wells will be completed adjacent to existing monitoring wells MW-4 and MW-5. The deep and shallow well pairs will allow for water level measurements in the recessional outwash (C0) and deeper units necessary to calculate a vertical gradient for the Site.

Recommendations

Based on review of the available geologic and hydrostratigraphic information in the vicinity of the Site, as summarized in the previous sections, the following recommendations are provided for the locations and completion depths of the additional deep monitoring wells to be installed at the Site for the purpose of DNAPL monitoring. The deep monitoring wells will be completed to the first confining unit observed beneath the Site. The proposed target depths to the confining units and the locations for the deep wells are described below.

Proposed Monitoring Well Completion Intervals

Based on comments provided in the letter from Ecology to the Port of Seattle (Ecology, 2010), dated May 26, 2010, Ecology is requiring that additional deep monitoring wells installed at the Site extend to the first confining unit beneath the sand and gravel water table aquifer, defined as the recessional outwash (C0) aquifer.

Based on review of the nearby existing geologic and hydrostratigraphic information, the uppermost confining unit likely to be encountered beneath the Site is the till unit (F1). This confining unit is expected to be encountered at a depth of approximately 15 feet bgs in the northwestern region of the property (290 feet NGVD 29); at a depth of approximately 30 feet bgs in the central portion of the property (270 feet NGVD 29); and at a depth of approximately 45 feet bgs in the southeastern region of the property (255 feet NGVD 29).

If the till (F1) is not encountered, due to being eroded during the deposition of the recessional outwash (C0), then the next confining unit likely to be encountered beneath the Site is the transition beds (F2). This confining unit, if present, is expected to be encountered at an elevation of approximately 220 feet NGVD 29. Therefore, it would be expected to be encountered at a depth of 95 feet bgs in the north-central region of the property; and at approximately 80 feet bgs in both the central and southeastern regions of the property.

It is important to note that all of the depths provided in this section are extrapolated from off-site investigations and are therefore only approximates. Actual depths could likely vary by as much as 20 feet; therefore, these depths should be considered minimum depths and exploration wells should be drilled at least an additional 20 feet in order confirm whether the respective units are present/absent.

The till (F1) and transition beds (F2), if present, are the most likely confining units beneath the Site based on an analysis of existing data. However, it is also possible that less extensive confining units may exist within either the recessional outwash (C0) or advance outwash (C1) aquifers. If confining units are encountered within these aquifers exhibiting a thickness of greater than 5 feet, the deep monitoring wells may instead be completed on top of these aquitards. Care will be taken during drilling not to penetrate the uppermost confining unit and sample cores will be collected continuously to evaluate the thickness of the aquitards.

As previously discussed, the deep monitoring wells will be completed on top of the uppermost confining unit that is at least 5 feet in thickness. If the first potential confining unit (F1) is not encountered, then the monitoring well will drilled to the depth of the next expected confining unit (F2). Once a confining unit with a thickness of more than 5 feet is encountered, the monitoring well will be completed on top of the respective confining unit.

Proposed Monitoring Well Locations

Ecology is also requiring that one additional deep well be installed in the vicinity of the potential drum cleanout pond and another deep well be installed in the vicinity of MW-5, at the downgradient property boundary of the recessional outwash (C0) aquifer. A third deep well may be installed to further refine the downslope extent of any DNAPL migration along the uppermost confining unit present beneath the Site. The third deep well would also provide an additional location for determining groundwater flow directions in the aquifer above the confining unit. Due to the potential

for penetrating an aquitard beneath the Site that is currently preventing the downward migration of contaminants, all of the additional deep monitoring wells will be installed immediately downgradient or downslope of the extents of previously detected source areas and soil and groundwater contamination.

Based on the Site cross section (Figure 4), the till (F1) confining unit generally appears to be locally sloping to the south-southeast. However, based on the structural contour map of the transition beds (F2) confining unit (Figure 7), the regional slope of the transition beds (F2) and possibly the till (F1) is likely more towards the south-southwest. Therefore, the downslope direction along any perspective confining unit is considered to be south-southwest.

Based on this information, the additional deep monitoring wells will be located as follows:

- MW-15 will be located less than 20 feet south-southwest of MW-5. This well will be downgradient of previous detections of PCPs in the soil and groundwater. The well pair (MW-5 and MW-15) will also provide a better estimate of vertical gradients beneath the Site.
- MW-16 will be located approximately 40 feet south of the potential drum cleanout pond. The well will be located downslope of previous detections of TPH-Dx and lead in the soil; and previous detections of TPH-Dx, arsenic, cPAHs, dioxin, and PCPs in the groundwater.
- MW-17 will be located less than 20 feet to the south-southwest of MW-4. This well will be downslope of previous detections of lead, cPAHs and PCPs in the soil. The well pair (MW-4 and MW-17) will also provide a better estimate of vertical gradients beneath the Site.

Figure 10 presents the proposed locations of the additional deep monitoring wells discussed above.

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Attachments

Table 1 – Geologic and Hydrogeologic Stratigraphy
Table 2 – Vertical Groundwater Gradients in the Vicinity of the Site
Figure 1 – Site Map
Figure 2 – Geologic Map
Figure 3 – Lora Lake Cross Section Location Map
Figure 4 – Lora Lake Cross Section D-D'
Figure 5 – Hydrostratigraphic Contour Map, Top of C1 Unit
Figure 6 – Cross Section A-A'
Figure 7 – Hydrostratigraphic Contour Map, Top of F2 Unit
Figure 8 – Groundwater Elevation Contour Map, C1 Aquifer
Figure 9 – Groundwater Elevation Contour Map, C2 Aquifer
Figure 10 – Proposed Deep Monitoring Well Locations
Appendix A – Site Groundwater Flow Direction Map, Monitoring Well Logs and Cross Sections

Limitations

Work for this project was performed and this memorandum prepared in accordance with generally accepted professional practices for the nature and conditions of work completed in the same or similar localities, at the time the work was performed. It is intended for the exclusive use of Floyd|Snider for specific application to the referenced property. This memorandum does not represent a legal opinion. No other warranty, expressed or implied, is made.

Table 1 - Geologic and Hydrogeologic Stratigraphy

Lora Lake Apartment Parcel

Geologic Group	Geologic Unit Name	Geologic Unit Abbr.[1]	Geologic & Sedimentologic Characteristics	Hydro-Stratigraphic Unit		Model Condition	South King Co. Groundwater Mgmt. Plan Unit	USGS[2]
Post-Glacial Deposits	Fill	Fill	All man-placed fill and extensively graded areas.	C0/F0	*Order is variable*	Perched Water Bearing Zones and Aquitards[3]	Qal and Qvr	m
	Topsoil	Qts	Topsoil.	C0				
	Recent Alluvium	Qal	Sand and gravel deposited by streams and rivers.	C0				Qyal
	Recent Lacustrine Deposits	Ql	Clay, silt, and peat deposited in lakes, ponds and wetlands.	F0				
Fraser Glacial Deposits (Vashon Drift)	Recessional Lacustrine Deposits	Qvrl	Silt and clay deposited in quiet water recessional glacial environments including lakes, ponds, floodplains, and kettles.	F0				Qvrl
	Recessional Outwash	Qvr	Sandy to gravelly recessional glacial stream and river deposits.	C0				Qvr
	All deposits above are normally consolidated. All deposits below are glacially overconsolidated.							
	Weathered Vashon Glacial Till	Qvtw	Weathered till.	F1		Aquitard[3]	Qvt	Qvt
	Vashon Glacial Till	Qvt	Glacial lodgement till composed of poorly-sorted clay, silt, sand and gravel. Includes interbeds of outwash and glaciolacustrine sediments.					
	Vashon Advance Outwash	Qva	Pro-glacial outwash composed primarily of silty sand, sand, and sand-gravel mixtures. (Known in the Seattle area as Esperance Sand.)	C1		Aquifer	Qva "Shallow Aquifer"	Qva
Pre-Fraser Glacial & Non-Glacial Deposits	Transition Beds	Qtb	Includes both Vashon glaciolacustrine silt and clay deposits (Lawton Clay) and pre-Fraser fine-grained non-glacial deposits.	F2		Aquitard	Qvl and Qf(1)	Qpf$_f$
	Pre-Fraser Fine-Grained Deposits	Qpff	Undifferentiated pre-Fraser fine-grained deposits.					
	Pre-Fraser Coarse-Grained Deposits	Qpfc	Uppermost extensive coarse-grained deposit below Vashon Drift. Chiefly sand and gravel. Likely includes Olympia non-glacial beds, Possession glacial outwash, and Whidbey non-glacial deposits. Includes a discontinuous fine-grained interbed (C2F).	C2		Aquifer	Qc(3) "Intermediate Aquifer"	Qpf$_c$
				C2F				Qpf$_f$
				C2				Qpf$_c$
	Pre-Fraser Fine-Grained Deposits	Qpff	Older undifferentiated fine-grained deposits.	F3		Aquitard	Qf(3)	Qpf$_f$
	Pre-Fraser Coarse-Grained Deposits	Qpfc	Older undifferentiated coarse-grained deposits.	C3		Aquifer	Qc(4) "Deep Aquifer"	Qpf$_c$
	Pre-Fraser Fine-Grained Deposits	Qpff	Older undifferentiated fine-grained deposits.	F4		Aquitard	Qf(4)	Qpf$_f$
	Pre-Fraser Coarse-Grained Deposits	Qpfc	Older undifferentiated coarse-grained deposits.	C4		Aquifer		Qpf$_c$
	Pre-Fraser Fine-Grained Deposits	Qpff	Older undifferentiated fine-grained deposits.	F5		Aquitard		Qpf$_f$
	Pre-Fraser Coarse-Grained Deposits	Qpfc	Older undifferentiated coarse-grained deposits.	C5		Aquifer		Qpf$_c$
	Pre-Fraser Fine-Grained Deposits	Qpff	Older undifferentiated fine-grained deposits.	F6		Aquitard		Qpf$_f$
	Pre-Fraser Coarse-Grained Deposits	Qpfc	Older undifferentiated coarse-grained deposits.	C6		Aquifer		Qpf$_c$
Bedrock	Tertiary Bedrock	Br	Siltstone, sandstone and shale with minor coal seams. Includes basaltic and andesitic intrusives.	Br		Aquitard	Tbr	Ti, Tpr, Tpt, Tpta, and Tptm

Notes:

1. The Geologic Unit Abbreviations are those used in this report.
2. USGS designations are those used in the *Geologic Map of the Des Moines 7.5' Quadrangle, Washington* (Booth and Waldron, 2002).
3. The hydrostratigraphic units C0, F0, and F1 were combined into a single layer for the groundwater model.

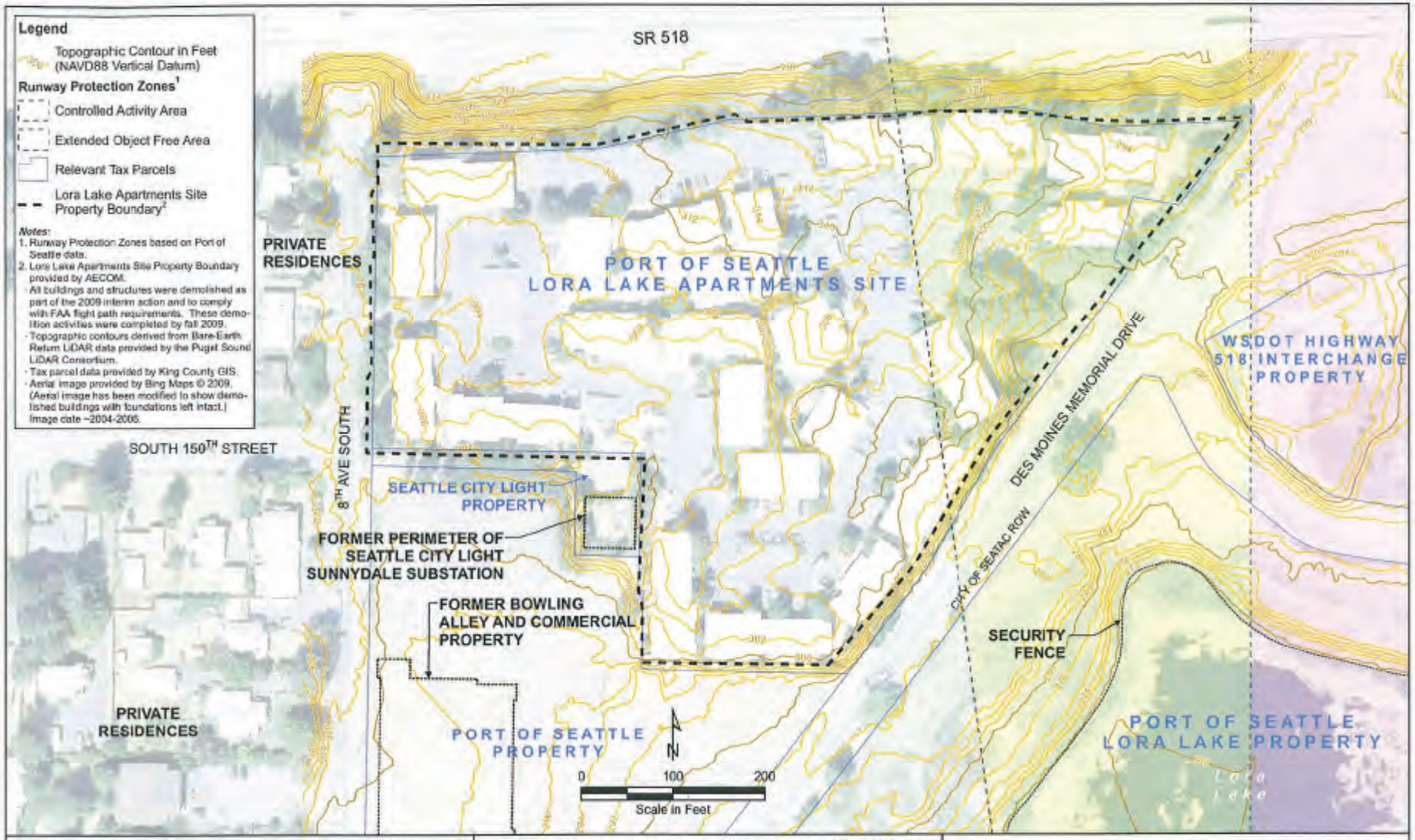
Table 2 - Vertical Groundwater Gradients in the Vicinity of the Site

Lora Lake Appartment Parcel

Well ID	Completion Information	Unit				
		C0	C1	C2	F3	
B-8 23N4E20A1	Top of Screen Elevation (ft NGVD 29)	280.4	-	140.4	5.4	-49.6
	Bottom of Screen Elevation (ft NGVD 29)	275.4	-	110.4	-4.6	-59.6
	Average Screen Elevation (ft NGVD 29)	277.9	-	125.4	0.4	-54.6
	Static Water Level Elevation (ft NGVD 29)	279.1	-	283.6	-	249.4
	Vertical Gradient[1]	**-0.030**	**-**	**0.190**	**-**	**-**
B-9 23N4E20C1	Top of Screen Elevation (ft NGVD 29)	319.8	-	120.3	38.8	-55.2
	Bottom of Screen Elevation (ft NGVD 29)	304.8	-	80.3	28.8	-60.2
	Average Screen Elevation (ft NGVD 29)	312.3	-	100.3	33.8	-57.7
	Static Water Level Elevation (ft NGVD 29)	310.3	-	280.7	268.3	266.2
	Vertical Gradient[1]	**0.140**	**-**	**0.186**	**0.023**	**-**

Notes:

- The vertical gradient was calculated between the hydrostratigraphic unit in which the vertical gradient value is listed and the next underlying hydrostratigraphic unit with a valid static water level.
- Negative vertical gradients are upwards and positive vertical gradients are downwards.



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Port of Seattle
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Figure 2.3
Site Topography

File: F:\projects\POS-LLA\GIS\MXD\Public Review DRAFT RIFS\Figure 2.3 (Site Topography from LiDAR Data).mxd
Date: 3/23/2010

0 160 320
Feet

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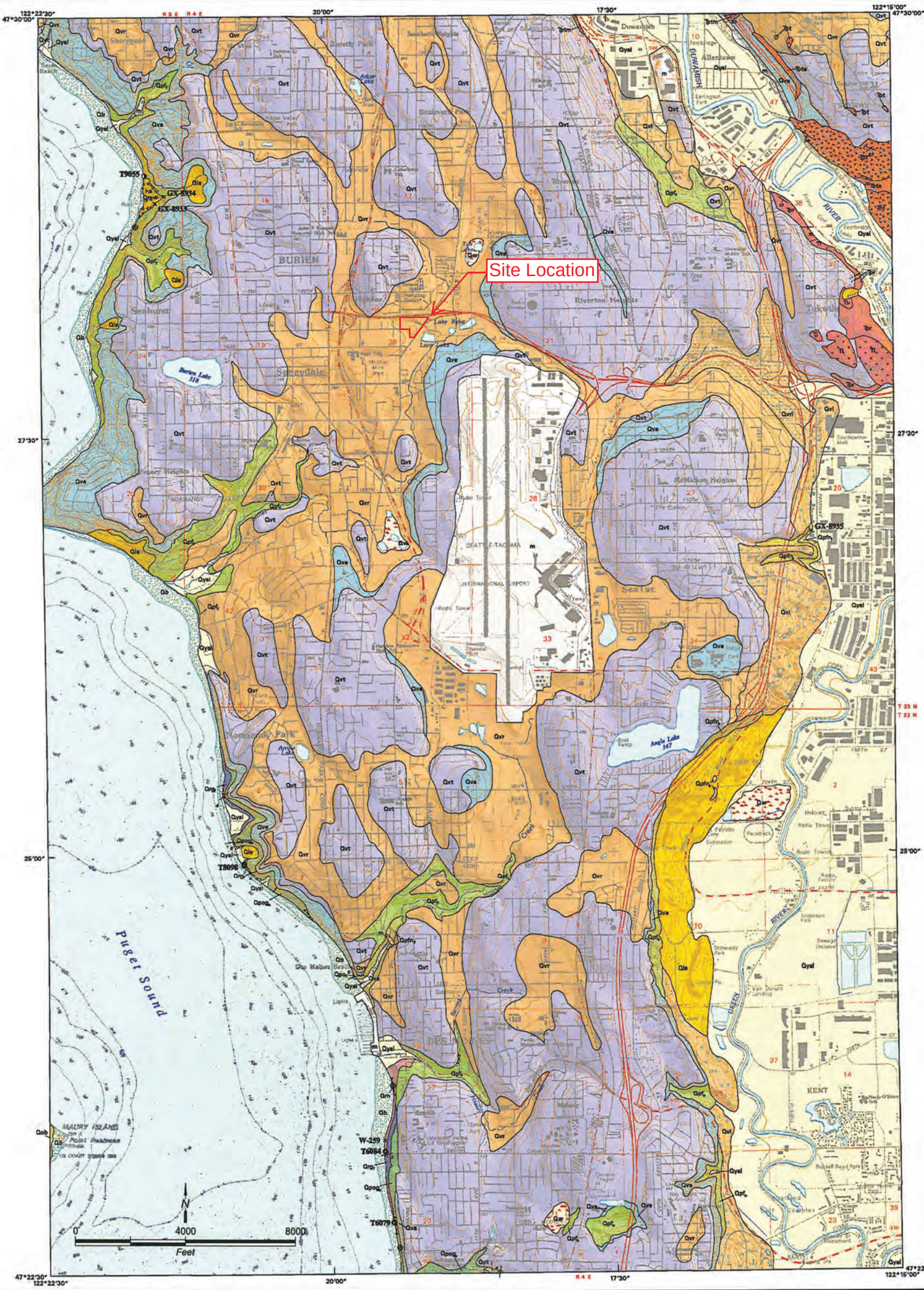
Site Map

Lora Lake Apartment Parcel
SeaTac, Washington

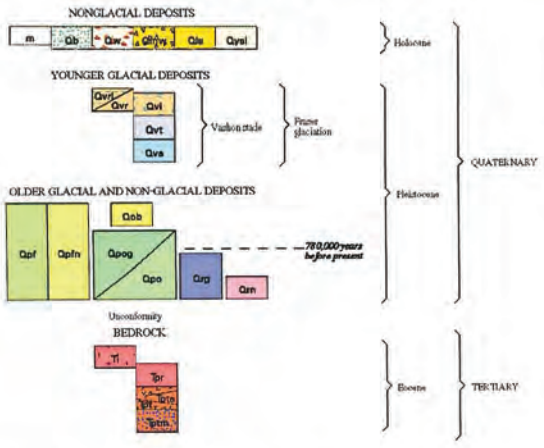
DATE: June 2010	PROJECT NO. 090134
DESIGNED BY: JMS	
DRAWN BY: PMB	FIGURE NO. 1
REVISED BY: -	

Q:\POS\090134 Lora Lake\2010-06\090134-01.dwg



Legend

CORRELATION OF MAP UNITS



- Contact
- Fault—Dotted where concealed
- Strike and dip of beds
- Horizontal beds
- Pre-Vashon till—Mapped within units Qpf and Qpog where exposed on valley walls or coastal bluffs
- Peat bed or other organic-rich layer
- Paleomagnetic sample locality
- Transitional magnetization
- Reversed magnetization
- ^{14}C age locality

DESCRIPTION OF MAP UNITS

NONGLACIAL DEPOSITS

m — **Modified land (Holocene)**—Sand and gravel as fill, and extensively graded natural deposits. Where topographic base map (1949) does not reflect subsequent human modification, the original (unmodified) geologic deposit has been mapped where information is available

Qb — **Beach deposits (Holocene)**—Locally well sorted sand, pebbles, silt, and shells deposited or reworked by wave action. Includes upper-beach deposits above mean high water line, extensive tideflats below mean high water, and local thin veneer of modern beach sediment that overlies older deposits. At stream mouths grades into unit Qyal

Qvrf — **Wetland deposits (Holocene)**—Peat and alluvium, poorly drained and intermittently wet. Grades into unit Qyal. Compiled from King County (1983); areas shown here are not a complete inventory of such deposits

Qls — **Mass-wastage deposits (Holocene)**—Undifferentiated colluvium, soil, and landslide debris with indistinct morphology. Mapped along the coast as a fan-shaped deposit 2 km south of the north map boundary where landslide debris intermingles with stream-channel alluvium. Numerous unmapped areas of mass-wastage deposits occur elsewhere in quadrangle along coastal bluffs of Puget Sound and in ravines draining eastward to the Green and Duwamish valleys. Deposits, both mapped and unmapped, include abundant discrete landslides meters to tens of meters in lateral extent

Qls — **Landslide deposits (Holocene)**—Diamict of broken to internally coherent surficial deposits transported downslope *en masse* by gravity. Numerous unmapped areas of both landslide and related mass-wastage deposits occur along coastal bluffs of Puget Sound and ravines draining east to the Green River, particularly where coarse deposits (units Qva and Qpog$_c$) overlie fine deposits (particularly unit Qpf(r)

Qyal — **Younger alluvium (Holocene)**—Moderately sorted deposits of cobble gravel, pebbly sand, and sandy silt along the floodplain of the Green and Duwamish rivers; and as alluvial fans at the mouths of small streams along Puget Sound, where they are gradational with sediments of unit Qb

YOUNGER GLACIAL DEPOSITS

Deposits of the Vashon stade of Fraser glaciation of Armstrong and others (1965) (Pleistocene)—Consists of:

Qvr — **Recessional outwash deposits**—Stratified sand and gravel, moderately sorted to well sorted, and less common silty sand and silt. Deposited in broad anastomosing outwash channels that carried south-draining glacial meltwater away from the ice margin during ice retreat. Typically slightly oxidized. Deposits less than about 1 m thick not shown on map. Locally subdivided into:

Qvrl — **Recessional lacustrine deposits**—Very fine-grained sand, silt, and clay deposited in small lakes during ice recession

Qvi — **Ice-contact deposits**—Deposits similar in texture to unit Qvr but commonly less well sorted and with silt-rich matrix. Contains lenses and pods of till. Deposits intermittently flank west margin of Green River valley from Tukwila south to edge of quadrangle, forming a kame terrace built against late-recessional ice tongue in the Green River valley

Qvt — **Till**—Compact diamict containing subrounded to well-rounded clasts in a massive, silt- or sand-rich matrix; glacially transported and deposited. Generally a few meters to a few tens of meters thick, forming an undulatory surface. Also found sporadically within areas mapped as unit Qvi

Qva — **Advance outwash deposits**—Well-bedded sand and gravel deposited subaqueously or by streams and rivers in front of the advancing ice sheet. Almost devoid of silt or clay, except near base of unit. Generally unoxidized

OLDER GLACIAL AND NONGLACIAL DEPOSITS

Subscripts locally indicate predominant grain size:
c—gravel and sand predominate
f—silt and clay predominate

Qpf — **Deposits of pre-Fraser glaciation age (Pleistocene)**—Weakly to moderately oxidized sand and gravel, lacustrine sediments containing local peat layers, and moderately oxidized to strongly oxidized diamict composed of silty matrix and rounded gravel clasts. Locally mapped as:

Qpfn — **Non-glacial deposits**—Abundant organic debris or pumice indicates non-glacial origin

Qob — **Olympia beds of Minard and Booth (1988) (Pleistocene)**—Thinly interbedded sand and silt, deposited by lowland streams. Mapped only on Maury Island, on extreme west edge of quadrangle, where Booth (1991) inferred a pre-Fraser age on basis of stratigraphic position and elevation

Qpog — **Glacial deposits of pre-Olympia age (Pleistocene)**—Weakly to strongly oxidized silt, sand, and sparse gravel of glacial origin as determined by clast provenance. Underlies all Vashon-age deposits and thus also must be of pre-Olympia age

Qpo — **Pre-Olympia deposits (Pleistocene)**—Silt at south edge of map; underlies glacial deposits of pre-Olympia age

Qrg — **Reversely magnetized glacial deposits (Pleistocene)**—Fine-grained silt containing dropstones or interstratified with pebbly diamict and so of presumed glacial origin. Reversely magnetized and thus presumably more than 780,000 years old

Qrm — **Reversely magnetized nonglacial deposits (Pleistocene)**—Silt, fine to medium sand, clay, ash, peat, and mudflow deposits. Abundant wood and volcanic debris demonstrate nonglacial origin. Underlies silt of unit Qrg in bluffs near Zenith

BEDROCK

Ti — **Intrusive rocks**—Irregular masses of porphyritic basalt and andesite

Tpr — **Puget Group (Eocene)**—Divided into:

Renton Formation—Nonmarine arkosic and feldspathic, micaceous sandstone; also siltstone and claystone containing locally abundant coal beds

Tpt — **Tukwila Formation**—Andesitic sandstone, tuff, mudflow breccia, and minor lava flows or sills. Locally subdivided into:

Tpta — **Arkosic sandstone**—Similar to Renton Formation

Tpbm — **Marine and nonmarine sedimentary rocks**—Volcanic conglomerate and marine sandstone; some siltstone and shale. Mostly comprised of volcanic rock fragments, minor arkose. Deposits at north edge of quadrangle contain marine shells

Reference:

Booth, D.B. and Waldron, H.H., 2002, Geologic Map of the Des Moines 7.5' Quadrangle, Washington, draft copy: U.S. Geological Survey Miscellaneous Field Studies, scale 1:24 000, 1 sheet.

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Geologic Map

Lora Lake Apartment Parcel
SeaTac, Washington

DATE:	PROJECT NO.
Nov 2004	090134
DESIGNED BY: JJS/DHM	
DRAWN BY: SDM	FIGURE NO. 2
REVISED BY: -	

Q:\STIA\970016 Groundwater Study\2004-01 Groundwater Model\970016-01.dwg

18 17 16 15

23N4E17K1 23N4E16M1

Tub Lake

A 23N4E19B3 23N4E19A1 23N4E20C1 D 23N4E21D6 23N4E21C2 23N4E21B1 23N4E21A1 23N4E22D1 A'

23N4E19C1 23N4E20B1 23N4E20A1 23N4E22C1

99

23N4E21C1

518

TP-6 Lora Lake Apts TP-9 TP-11 MW-4 MW-3 CHARLEX MW-3

Lora Lake Lake Reba

23N4E21H7

21 22

19 20

NDW-1A D' NDW-4 GTRUN_A8-B2-2061

Creek Miller

23N4E22N1

29

Legend

- Line of Section
- 36 | 31 / 1 | 6 — Township/Range/Section Lines and Numbers
- Extraction Well
- Excavation
- Gas Probe
- Geotechnical
- Injection Well
- Lagoon
- Monitoring Well
- Private or Public Well
- Piezometer
- Recovery Well
- Soil Boring
- Soil Strataprobe
- Test Pit
- Vapor Extraction Well

N

0 1000 2000

Feet

Note: The information shown on this map has been derived from a variety of sources and should be field verified.

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Lora Lake Cross Section Location Map

Lora Lake Apartment Parcel
SeaTac, Washington

DATE: June 2010	PROJECT NO. 090134
DESIGNED BY: JMS	
DRAWN BY: PMB	FIGURE NO. 3
REVISED BY: -	

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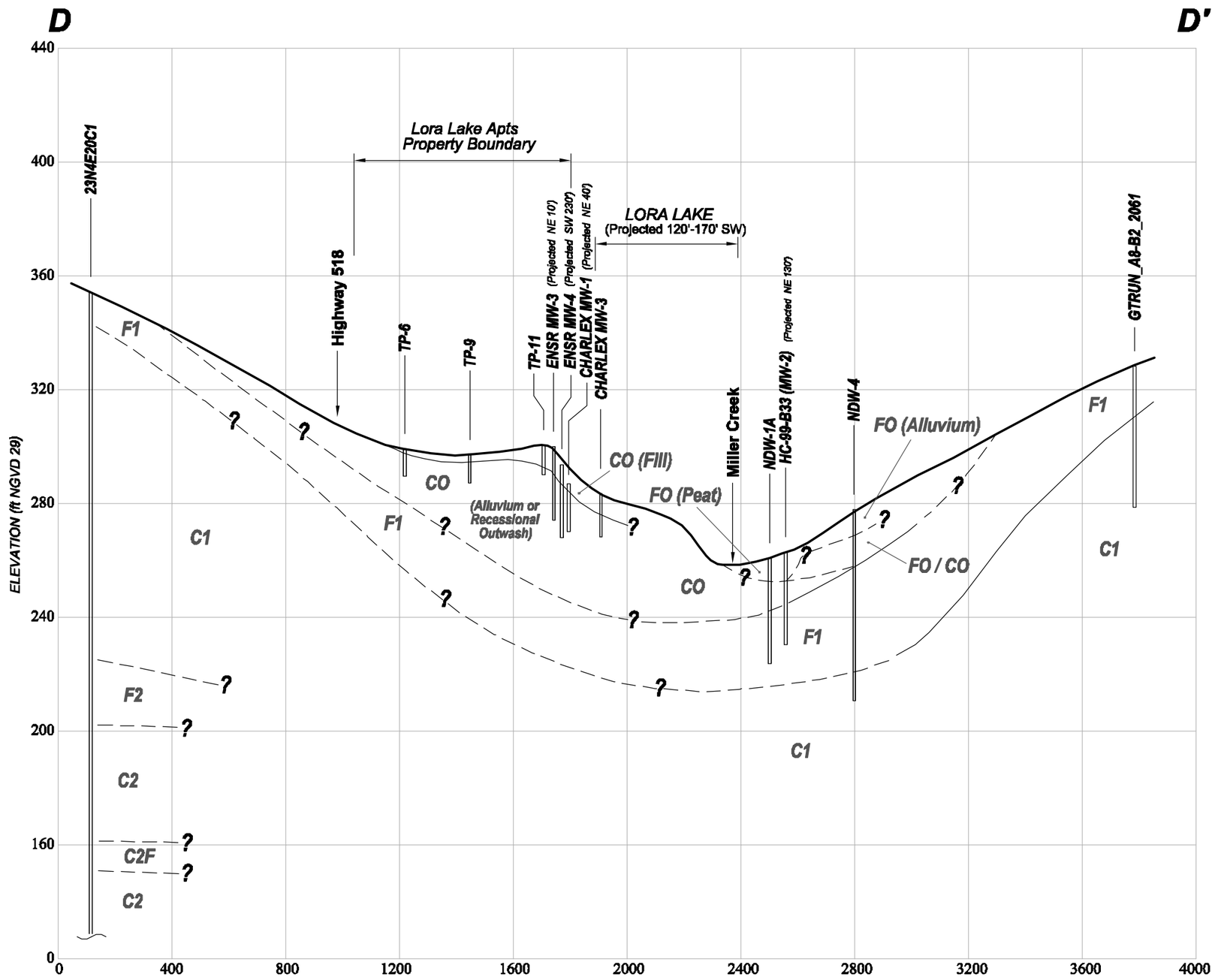

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Feet

Scale: 1" = 40' Vertical
1" = 400' Horizontal

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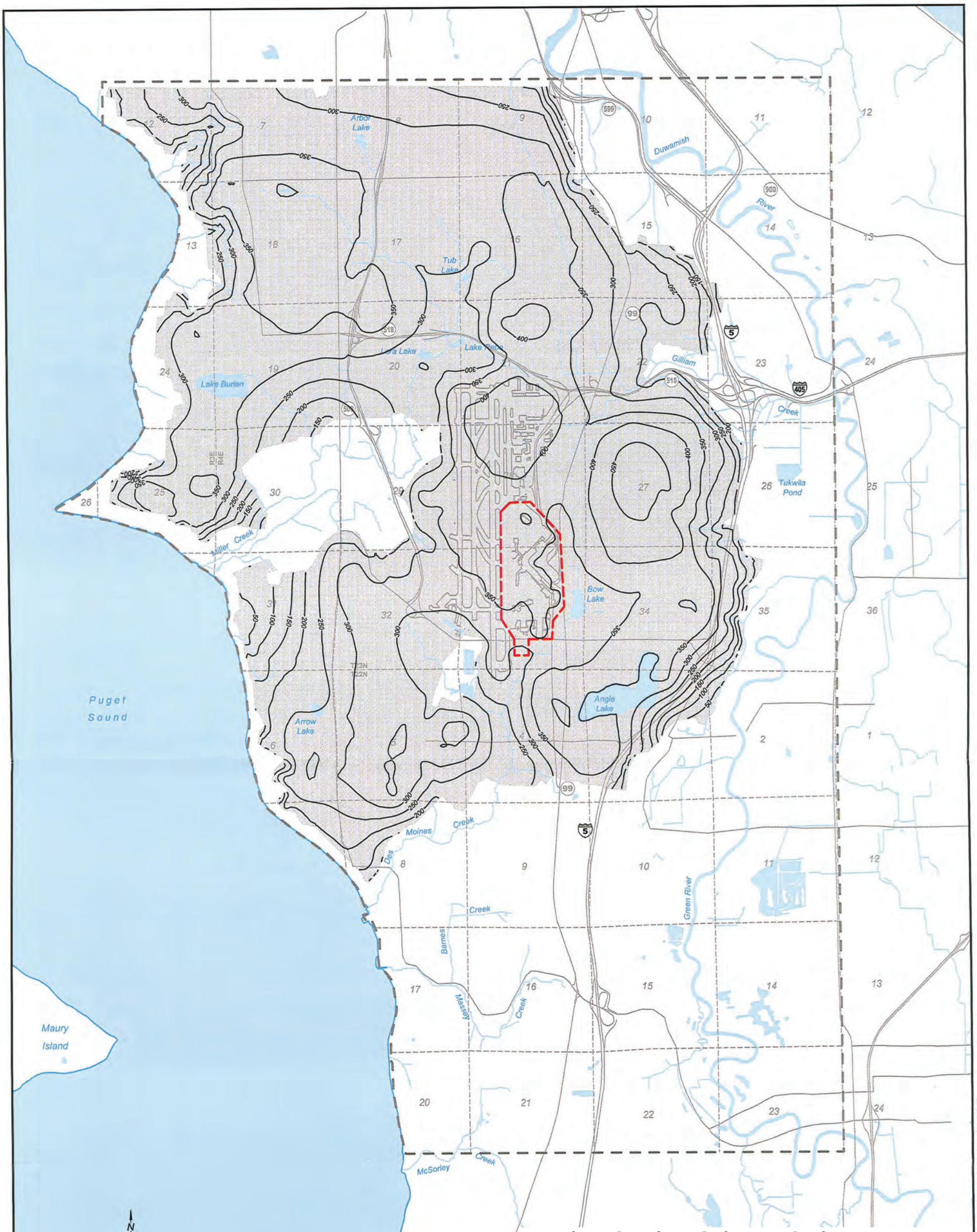
Lora Lake Cross Section D-D'

Lora Lake Apartment Parcel
SeaTac, Washington

DATE: June 2010	PROJECT NO. 090134
DESIGNED BY: JMS	
DRAWN BY: PMB	FIGURE NO. 4
REVISED BY: -	

Q:\POS\090134 Lora Lake\2010-06\090134-04.dwg



From: Phase I Groundwater Study Report, Seattle-Tacoma International Airport (Aspect Consulting and S.S. Papadopulos 2008).

Legend

- Elevation Contours of Model Layer
- Area of Model Layer
- Aircraft Operations and Maintenance Area (AOMA)
- Data Collection Boundary
- 36 | 31 / 1 | 6 — Township/Section/Range with Section Numbers

Note: The information shown on this map has been derived from a variety of sources and should be field verified.

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Hydrostratigraphic Contour Map, Top of C1 Unit

Lora Lake Apartment Parcel
SeaTac, Washington

DATE:	PROJECT NO.
Dec 2004	090134
DESIGNED BY: JJS/DHM	
DRAWN BY: SDM	FIGURE NO. 5
REVISED BY: Rev1 - PMB	

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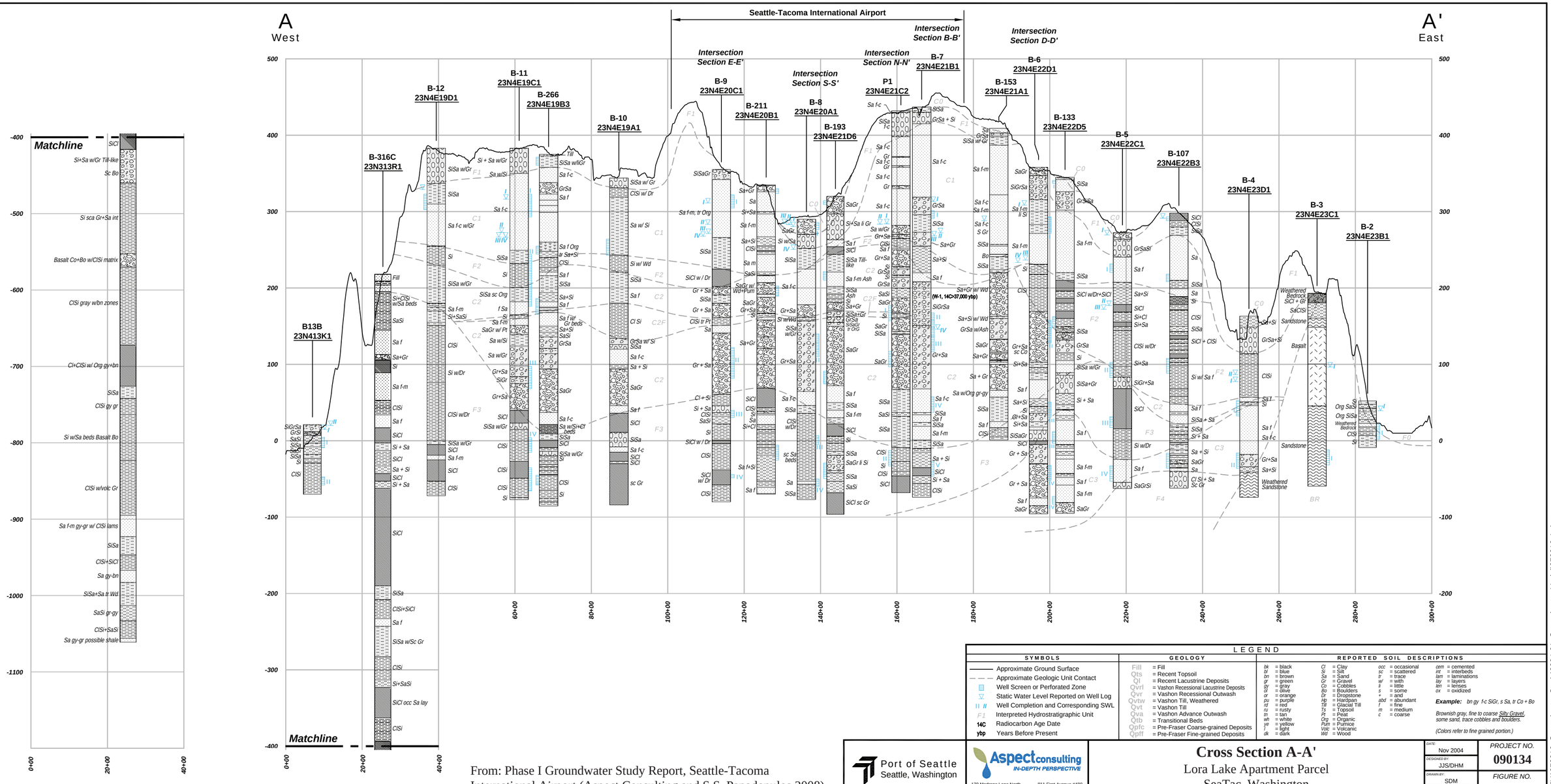

LEGEND

SYMBOLS

- Approximate Ground Surface
- Approximate Geologic Unit Contact
- Well Screen or Perforated Zone
- Static Water Level Reported on Well Log
- Well Completion and Corresponding SWL
- F1 Interpreted Hydrostratigraphic Unit
- 14C Radiocarbon Age Date
- ybp Years Before Present

GEOLOGY

- Fill = Fill
- Qts = Recent Topsoil
- Ql = Recent Lacustrine Deposits
- Qvrl = Vashon Recessional Lacustrine Deposits
- Qvr = Vashon Recessional Outwash
- Qvtw = Vashon Till, Weathered
- Qvt = Vashon Till
- Qva = Vashon Advance Outwash
- Qtb = Transitional Beds
- Qpfc = Pre-Fraser Coarse-grained Deposits
- Qpff = Pre-Fraser Fine-grained Deposits

REPORTED SOIL DESCRIPTIONS

bk = black, bl = blue, bn = brown, gr = green, gy = gray, ol = olive, or = orange, pu = purple, rd = red, ru = rusty, tn = tan, wh = white, ye = yellow, l = light, dk = dark

Cl = Clay, Si = Silt, Sa = Sand, Gr = Gravel, Cb = Cobbles, Bo = Boulders, Dr = Dropstone, Hp = Hardpan, Till = Glacial Till, Ts = Topsoil, Pt = Peat, Org = Organic, Pum = Pumice, Volc = Volcanic, Wd = Wood

occ = occasional, sc = scattered, tr = trace, w/ = with, li = little, s = some, + = and, abd = abundant, f = fine, m = medium, c = coarse

cem = cemented, int = interbeds, lam = laminations, lay = layers, len = lenses, ox = oxidized

Example: *bn gy f-c SiGr, s Sa, tr Co + Bo*

Brownish gray, fine to coarse Silty Gravel, some sand, trace cobbles and boulders.

(Colors refer to fine grained portion.)

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(206) 328-7443

Cross Section A-A'

Lora Lake Apartment Parcel
SeaTac, Washington

DATE: Nov 2004	PROJECT NO. 090134
DESIGNED BY: JJS/DHM	
DRAWN BY: SDM	FIGURE NO. 6
REVISED BY: PMB	

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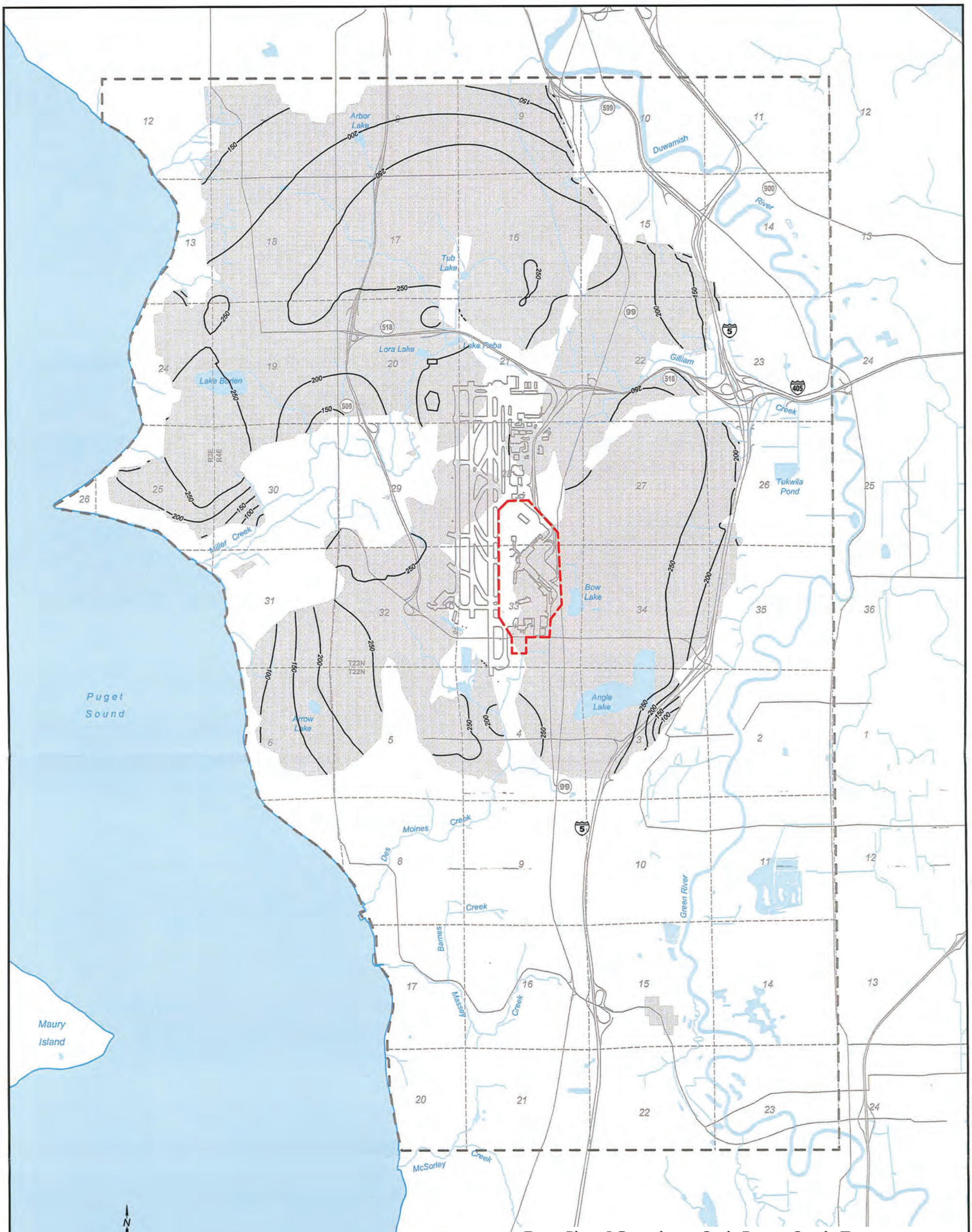

From: Phase I Groundwater Study Report, Seattle-Tacoma International Airport (Aspect Consulting and S.S. Papadopulos 2008).

Legend

- Elevation Contours of Model Layer
- Area of Model Layer
- Aircraft Operations and Maintenance Area (AOMA)
- Data Collection Boundary
- 36 | 31 / 1 | 6 — Township/Section/Range with Section Numbers

Note: The information shown on this map has been derived from a variety of sources and should be field verified.

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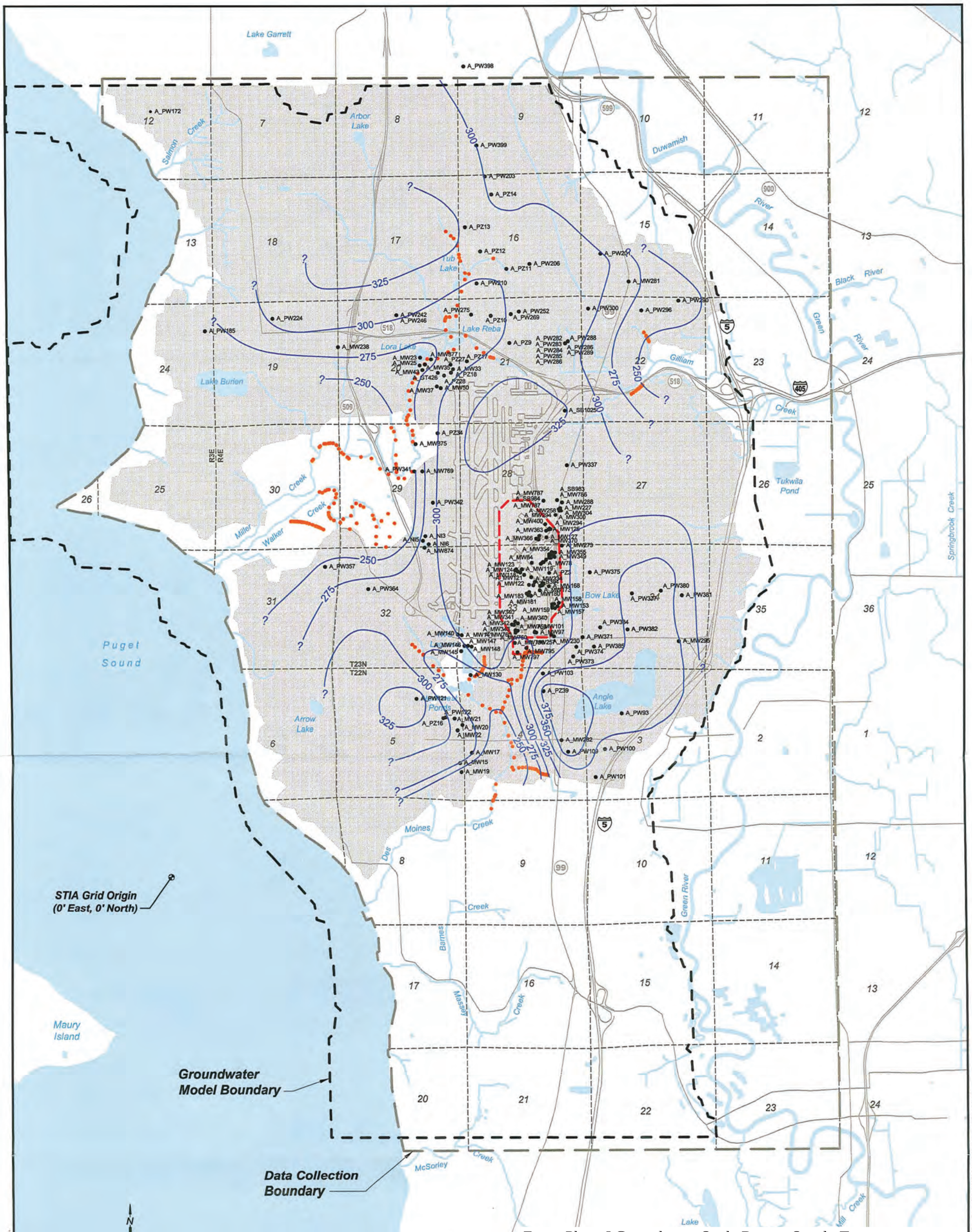
Hydrostratigraphic Contour Map, Top of F2 Unit

Lora Lake Apartment Parcel
SeaTac, Washington

DATE: Dec 2004	PROJECT NO. 090134
DESIGNED BY: JJS/DHM	
DRAWN BY: SDM	FIGURE NO. 7
REVISED BY: Rev1 - PMB	

Q:\STIA\970016 Groundwater Study\2004-12 Groundwater Study Revised\970016-03.dwg (Fig 7-6)



From: Phase I Groundwater Study Report, Seattle-Tacoma International Airport (Aspect Consulting and S.S. Papadopulos 2008).

Legend

- Extent of Modeled Aquifer Unit
- Aircraft Operations and Maintenance Area (AOMA)
- Data Collection Boundary
- Township/Range/Section Lines and Numbers (36 | 31 / 1 | 6)
- A_PW100 — Well
- 100 — Groundwater Contour
- Control Point

Note: The information shown on this map has been derived from a variety of sources and should be field verified.

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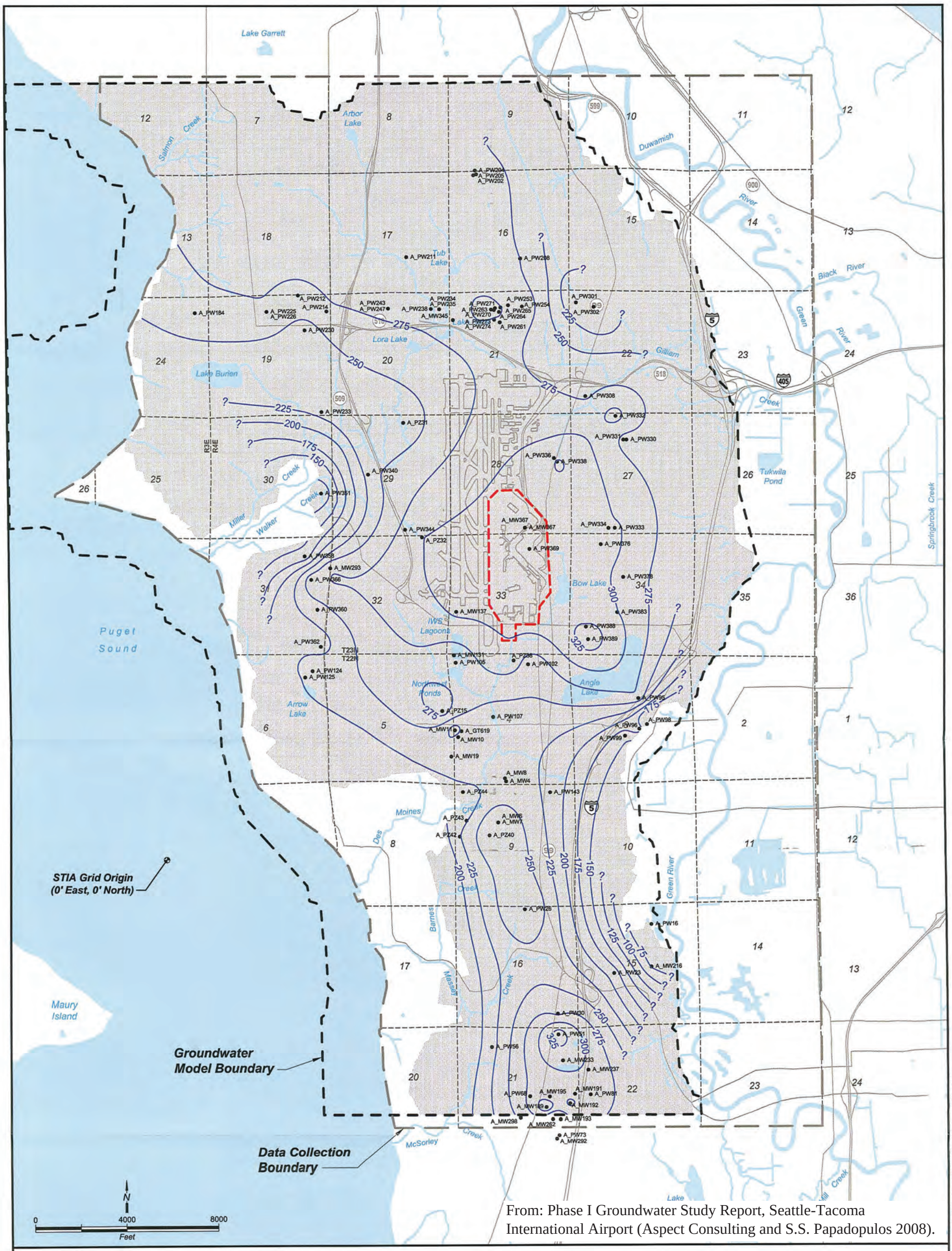
Groundwater Elevation Contour Map, C1 Aquifer

Lora Lake Apartment Parcel
SeaTac, Washington

DATE:	PROJECT NO.
Dec 2004	090134
DESIGNED BY: JSL	
DRAWN BY: PMB	FIGURE NO. 8
REVISED BY: Rev1 - PMB	

Q:\STIA\970016 Groundwater Study\2004-12\ Groundwater Study Revised\970016-11.dwg (Fig 5-2)



From: Phase I Groundwater Study Report, Seattle-Tacoma International Airport (Aspect Consulting and S.S. Papadopulos 2008).

Legend

- Extent of Modeled Aquifer Unit
- Aircraft Operations and Maintenance Area (AOMA)
- Data Collection Boundary
- Township/Range/Section Lines and Numbers (36 | 31 / 1 | 6)
- A_PW68 — Well
- 150 — Groundwater Contour

Note: The information shown on this map has been derived from a variety of sources and should be field verified.

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Groundwater Elevation Contour Map, C2 Aquifer

Lora Lake Apartment Parcel
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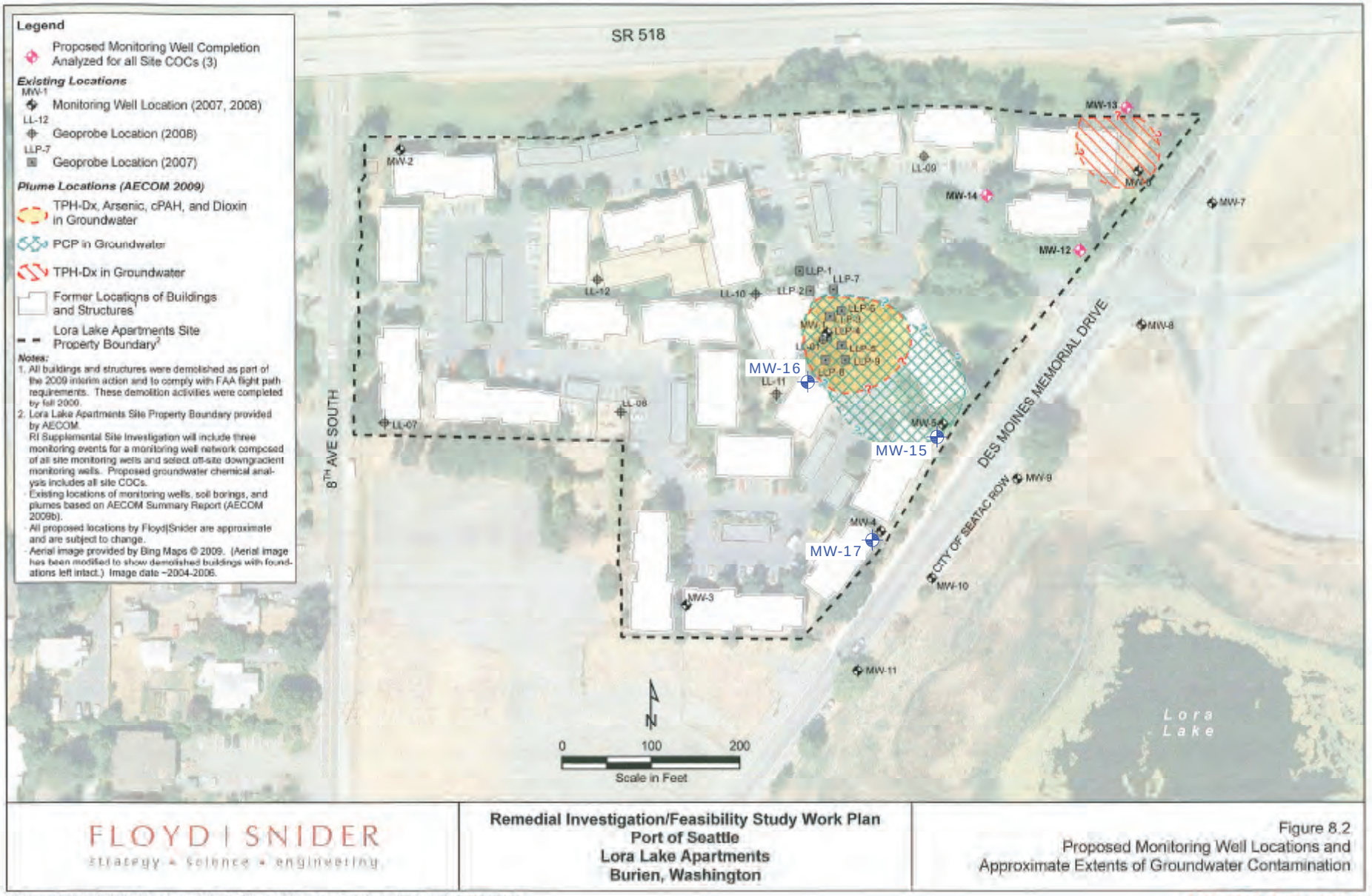
DATE:	PROJECT NO.
Dec 2004	090134
DESIGNED BY: JSL	
DRAWN BY: PMB	FIGURE NO. 9
REVISED BY: Rev1 - PMB	

Q:\STIA\970016 Groundwater Study\2004-12 Groundwater Study Revised\970016-11.dwg (Fig 5-3)



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Remedial Investigation/Feasibility Study Work Plan
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Figure 8.2
Proposed Monitoring Well Locations and Approximate Extents of Groundwater Contamination

File: F:\projects\POS-LLA\GIS\MXD\Public Review DRAFT RI\FS\Figure 8.2 (MW Locations and Approx Extents of GW Contamination).mxd
Date: 9/23/2010

MW-15 Proposed Deep Monitoring Well

Modified Scale:
0 160 320
Feet

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Proposed Deep Monitoring Well Locations

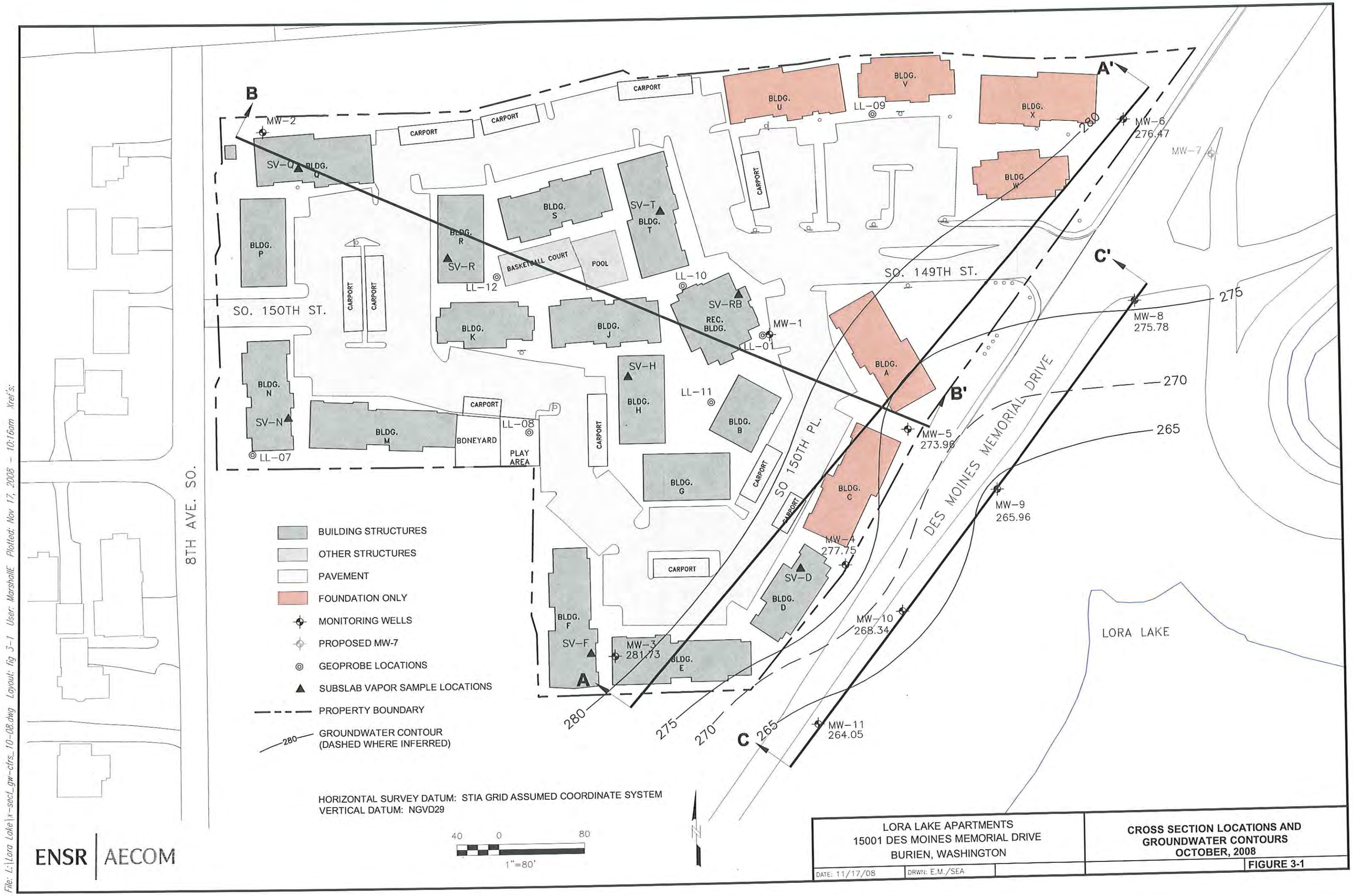
Lora Lake Apartment Parcel
SeaTac, Washington

DATE: June 2010	PROJECT NO. 090134
DESIGNED BY: JMS	
DRAWN BY: PMB	FIGURE NO. 10
REVISED BY: -	

Q:\POS\090134 Lora Lake\2010-06\090134-10.dwg

APPENDIX A

Site Groundwater Flow Direction Map, Monitoring Well Logs and Cross Sections

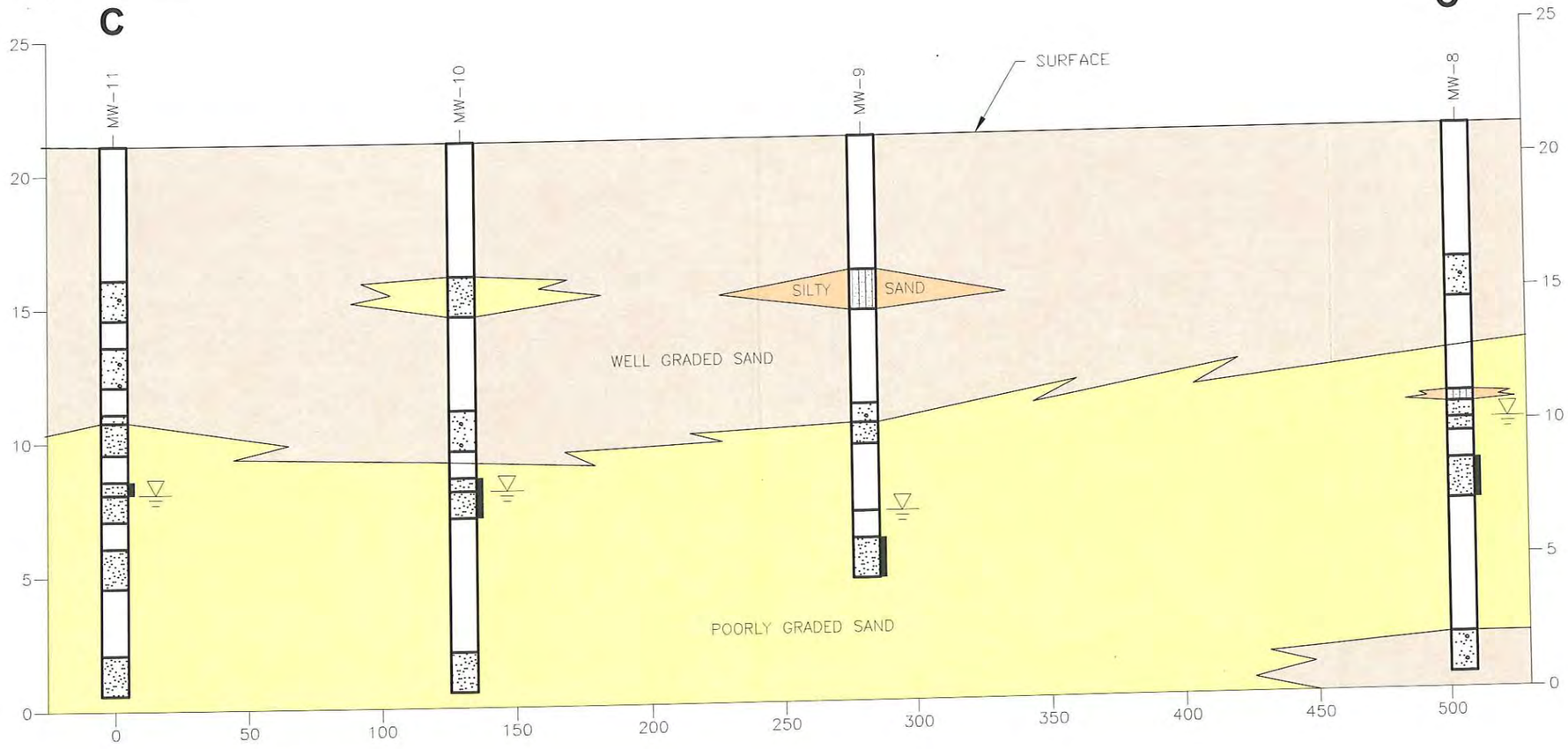

B
A'
C'
B'
A
C
MW-2
MW-6
276.47
MW-7
MW-8
275.78
MW-1
MW-5
273.96
MW-9
265.96
MW-4
277.75
MW-10
268.34
MW-11
264.05
MW-3
281.73
LL-01
LL-07
LL-08
LL-09
LL-10
LL-11
LL-12
SV-Q
SV-R
SV-T
SV-RB
SV-H
SV-N
SV-D
SV-F
BLDG. P
BLDG. Q
BLDG. R
BLDG. S
BLDG. T
BLDG. U
BLDG. V
BLDG. W
BLDG. X
BLDG. K
BLDG. J
REC. BLDG.
BLDG. A
BLDG. N
BLDG. M
BLDG. H
BLDG. B
BLDG. G
BLDG. C
BLDG. D
BLDG. F
BLDG. E
CARPORT
BASKETBALL COURT
POOL
BONEYARD
PLAY AREA
SO. 150TH ST.
SO. 149TH ST.
150TH PL.
DES MOINES MEMORIAL DRIVE
8TH AVE. SO.
LORA LAKE
280
275
270
265
BUILDING STRUCTURES
OTHER STRUCTURES
PAVEMENT
FOUNDATION ONLY
MONITORING WELLS
PROPOSED MW-7
GEOPROBE LOCATIONS
SUBSLAB VAPOR SAMPLE LOCATIONS
PROPERTY BOUNDARY
GROUNDWATER CONTOUR
(DASHED WHERE INFERRED)
HORIZONTAL SURVEY DATUM: STIA GRID ASSUMED COORDINATE SYSTEM
VERTICAL DATUM: NGVD29
40 0 80
1"=80'
N
ENSR | AECOM
LORA LAKE APARTMENTS
15001 DES MOINES MEMORIAL DRIVE
BURIEN, WASHINGTON
DATE: 11/17/08
DRWN: E.M./SEA
CROSS SECTION LOCATIONS AND GROUNDWATER CONTOURS
OCTOBER, 2008
FIGURE 3-1
File: L:\Lora Lake\x-sect_gw-ctrs_10-08.dwg Layout: fig 3-1 User: MarshallE Plotted: Nov 17, 2008 - 10:16am Xref's:

SOUTHWEST

C

NORTHEAST

C'



LEGEND

- SP
- SM
- SW
- Not sampled for lithology
- Sample Location
- WL Groundwater elevation collected on August 12, 2008

NOTE: Section is not projected, it is shown as direct distance
* Survey elevations not available at time of production.

25 0 50

SCALE IN FEET

Vertical Exaggeration: 10

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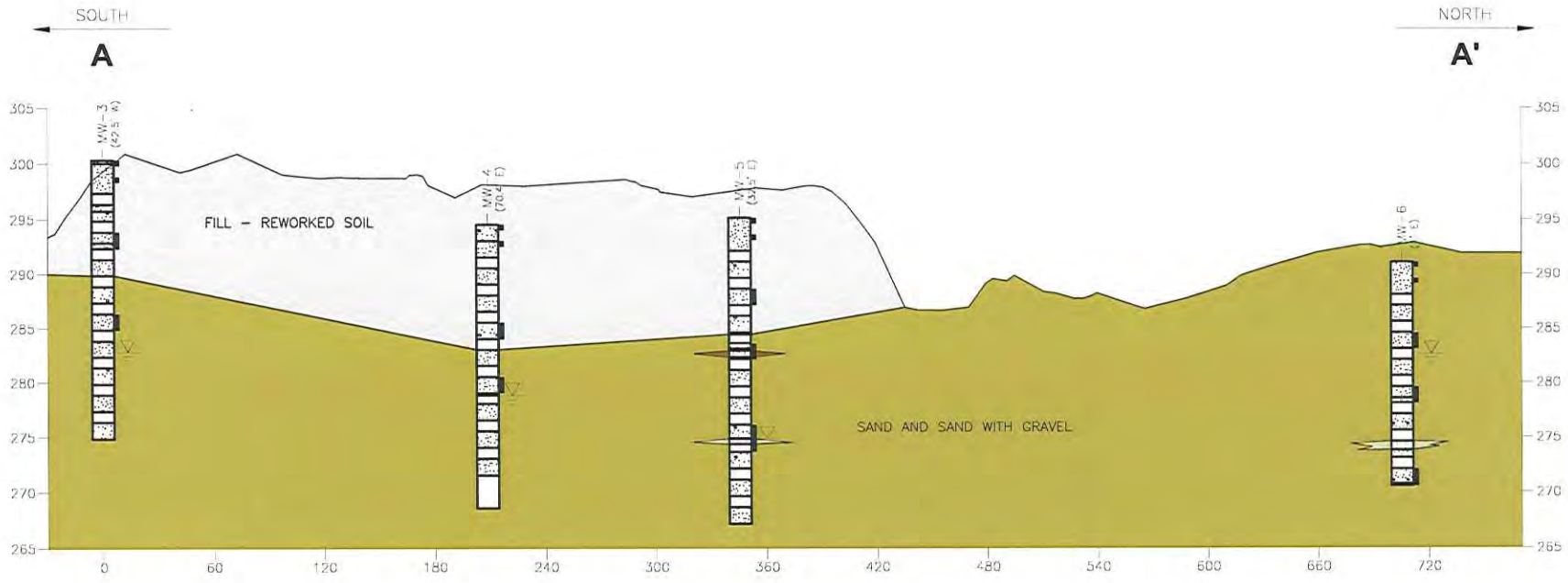
LORA LAKE APARTMENT 15001 DES MOINES MEMORIAL DRIVE BURIEN, WASHINGTON		CROSS SECTION C-C' AUGUST 2008
DATE: 11/17/08	DRWN: E.M./SEA	FIGURE 3-2

File: L:\Lora Lake\MW-8_11 X-SECT.dwg Layout: FIGURE 3-2 User: MarshallE Plotted: Nov 17, 2008 - 12:47pm Xref's:



LEGEND

- ML Silt
- SM Silty sand
- SW Well-graded sand
- SP Poorly-graded sand
- Mulch
- Sample Location
- W.L. Groundwater elevation collected on March 27, 2008

30 0 60

1"=60'

Vertical Exaggeration: 6x

NOTE: Section is projected.
Fill contact determined by silt lenses.

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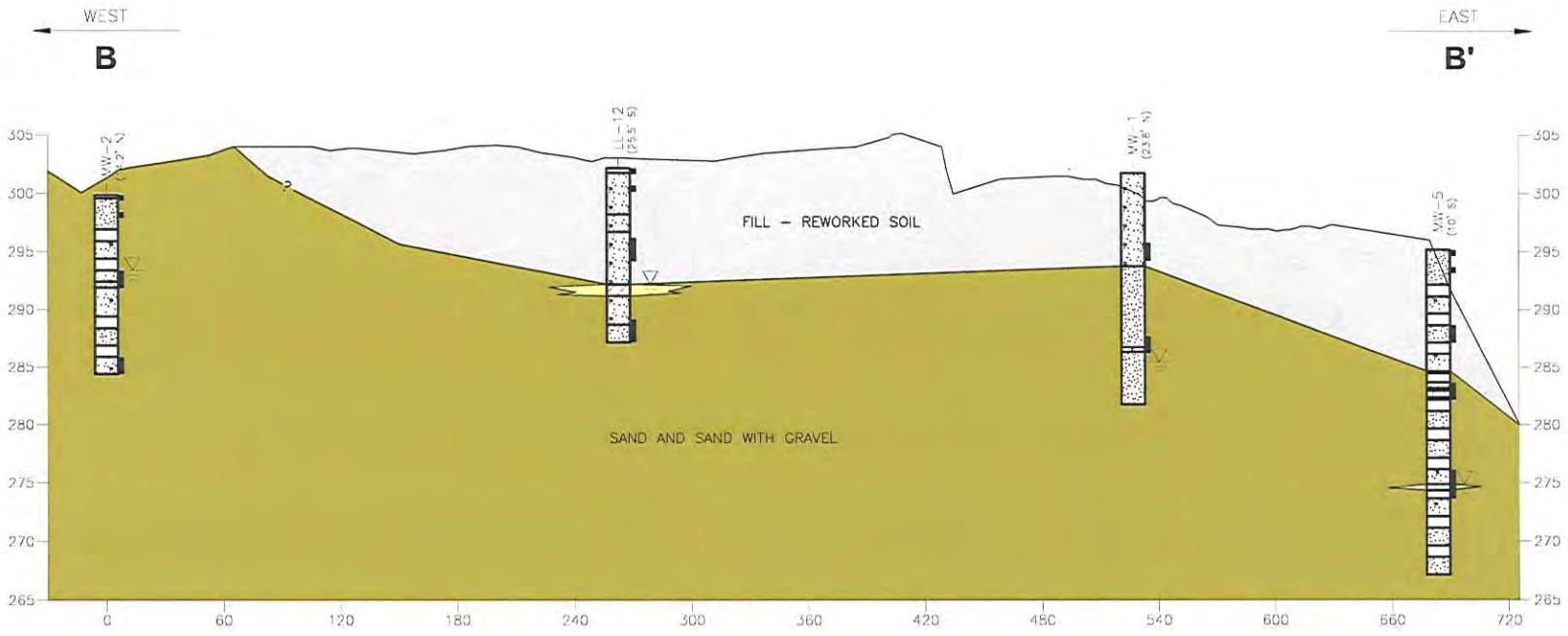
LORA LAKE APARTMENT 15001 DES MOINES MEMORIAL DRIVE BURIEN, WASHINGTON			CROSS SECTION A-A'
DATE: 05/10/08	DRWN: E.M./SEA		FIGURE 4-1

File: L:\Lora Lake\x-sect-a\b\dwg Layout: TIC 4-1 User: emarshall Plotted: Jun 24, 2008 - 2:12pm Xref's:



LEGEND

- ML Silt
- SM Silty sand
- SW Well-graded sand
- SP Poorly-graded sand
- Mulch
- Sample Location
- WL Groundwater elevation collected on March 27, 2008

30 0 60

1"=60'

Vertical Exaggeration: 6x

NOTE: Section is projected.
Fill contact determined by silt lenses.

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LORA LAKE APARTMENTS 15001 DES MOINES MEMORIAL DRIVE BURIEN, WASHINGTON			CROSS SECTION B-B'
DATE: 06/10/08	DRWN: E.M./SEA		FIGURE 4-2

Boring & Well Construction Log

Well MW-1 (Boring LLP-4 Location)

GeoScience Management, Inc.
Environmental Consulting Services
809 156th Street NE
Arlington, WA 98223

PROJECT
Lora Lake Apartments

CLIENT
Port of Seattle

DRILLING COMPANY
Hollow-stem Auger

GEOLOGIST
H. W. Small, L.HG.

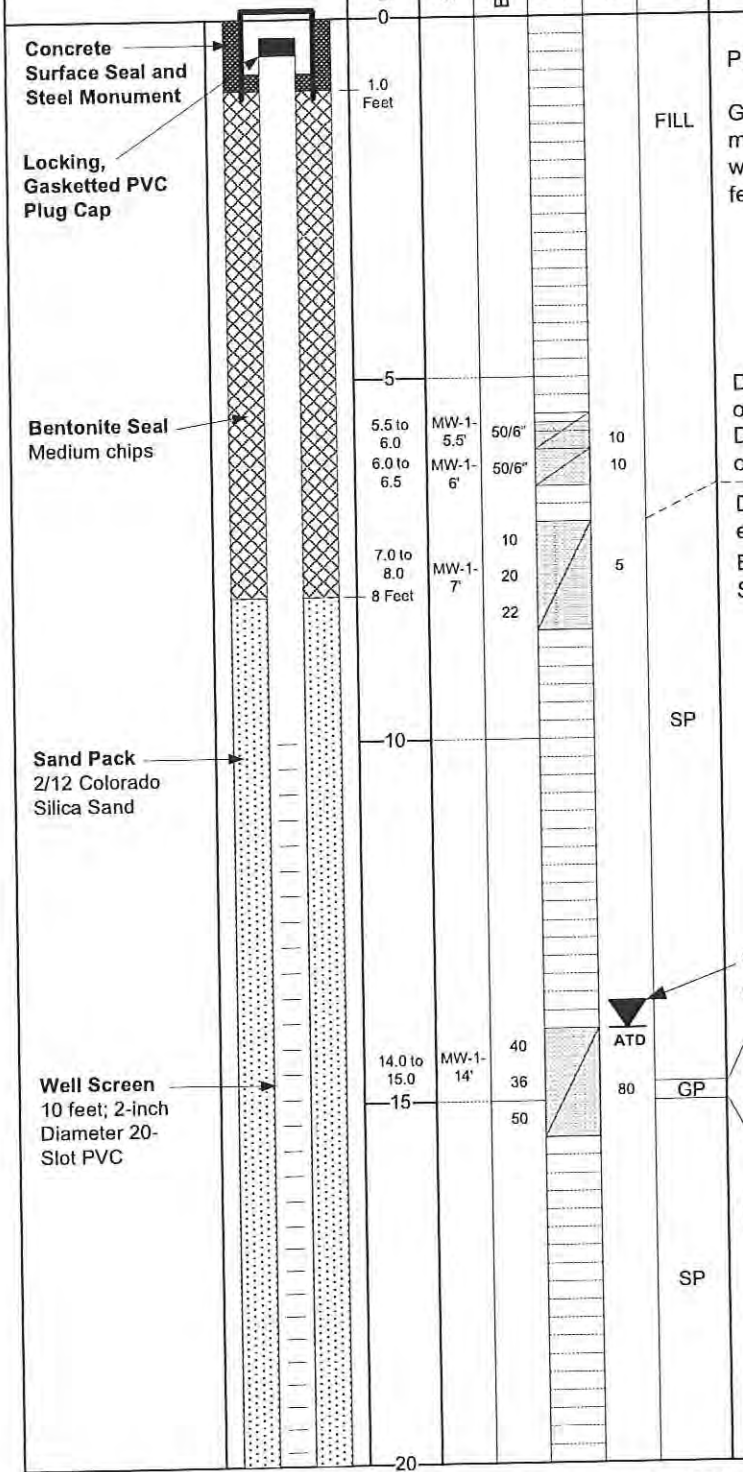
START DATE 10/25/2007 **END DATE** 10/25/2007

DRILLING METHOD
Hollow-stem Auger (4.25 ID x 9 OD)

SAMPLING METHOD
3-in. O.D. Split-Spoon Sampler

SURFACE COMPLETION
Flush-mount steel monument

Elevation Ground: Not Measured
Elevation TOC: Not Measured
Total Boring Depth: 20 Feet
Depth to Water ATD: 14 Feet



Depth (Feet)	Sample ID	Blow Count (per 6 inches)	Sample Interval and Recovery	PID Readings (ppm)	USCS	
0						Planter soil over:
1.0 Feet					FILL	Gray, brown and black, damp, slightly silty, gravelly, medium to fine SAND (Fill). Occasional fragments of wood, debris, roots and organic matter to approximately 6 feet bgs.
5						
5.5 to 6.0	MW-1-5.5'	50/6"		10		Drove sample at 5.5 feet, but did not encounter target zone of substantial organics, as observed in boring LLP-4.
6.0 to 6.5	MW-1-6'	50/6"		10		Drove sample at 6.0 feet, but did not encounter target zone of substantial organics. Gravel in shoe.
7.0 to 8.0	MW-1-7'	10 20 22		5		Drilled to 7 feet and drove sample again, but did not encounter target zone of substantial organics.
8 Feet						Brown, damp, trace to slightly silty, gravelly, medium to fine SAND (Native soil).
10					SP	
				ATD		Water level approximately 14.0 feet below ground surface at time of drilling.
14.0 to 15.0	MW-1-14'	40 36		80	GP	Gray, wet, sandy gravel zone approximately 3-inch thick. Strong hydrocarbon-like odor, sheen on gravel.
15		50				Gray, wet, trace to slightly silty, gravelly, medium to fine SAND.
					SP	
20						Total depth = 20 feet.

Construction Notes: Installed 2-inch diameter PVC well screen from 20 to 10 feet (see as-built diagram this page). Completed at the ground surface in concrete pad with steel, traffic-rated well monument. No water added during drilling except to hydrate bentonite seal.

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Boring/Well Log

Well #: MW-2
Sheet 1 of 2

Project: **Lora Lake Apartments**	Monument: **Flush Mount**	Stick Up: **-**
Project #: **05482-025-210**	Northing: **-** Easting: **-**	Ground Elevation: **-**
Location: **Burien, WA**	Drill Rig Type: **HSA Limited Access**	MP Elevation: **-**
Client: **Port of Seattle**	Method: **HSA**	Total Depth: **15.5'**
Start Date & Time: **3/18/08 0800**	Casing ID: **2"**	Filter Pack: **10/20 Silica Sand**
Finish Date & Time: **3/18/08 0850**	Boring ID: **8.25"**	Seal: **Bentonite chips**
Contractor: **Cascade Drilling Inc.**	Bit Type: **4.25" HSA**	Grout: **-**
Operator: **Curtis Askew**	Logged By: **R. Knecht/ C. Smith**	Screen: **0.010" slot Sch. 40 PVC 5-15 ft-bgs**

Sample Type & Number	Sample Depth Range	Sample % Rec	Sample Blows per 6"	Sample PID (ppm)	Well Completion Log	Graphic	Depth (ft.)	Soil and Rock Description (Classification Scheme: USCS/ASTM)	Elevation (ft.)	Comments & Samples
							0		0	
SS-1	0.0-1.5	66	4 5 9	0.7 (Amb. 0.3)				(0.0-0.3) MULCH (0.3-1.5) SP: POORLY GRADED SAND, dark yellowish brown, fine, medium dense, moist. Trace rootlets, and fine, rounded, gravel. No odor or visible contamination.		Flush Mount Monument 2-inch Sch. 40 PVC riser from 0-5 ft-bgs
SS-2	1.5-3.0	72	11 13 14	1.2 (Amb. 0.3)				(1.5-3.0) SP: POORLY GRADED SAND, light yellowish gray, fine, medium dense, moist. One large, long root, 1/8" in diameter. Trace coarse sand, and rounded, fine gravel, up to 0.5" in diameter. No odor or visible contamination.		0.0-0.5' Sampled for analytical 1.5-2.0' Sampled for analytical
								(3.0-4.0) Not Sampled.		Bentonite seal from 2 to 4 ft-bgs
SS-3	4.0-5.5	66	13 23 25	1.1 (Amb. 0.3)			5	(4.0-5.5) SW: WELL GRADED SAND, yellowish gray grading to dark yellowish gray, fine to medium, dense, moist to wet. Trace fine gravel, up to 3/4" in diameter. No odor or visible contamination.	-5	
								(5.5-6.5) Not Sampled.		
SS-4	6.5-8.0	75	20 50/6"	1.4 (Amb. 0.6)				(6.5-8.0) SW: WELL GRADED SAND, yellowish brown, fine to coarse, very dense, wet. Trace rounded, fine gravel, up to 3/4" in diameter. No odor or visible contamination.		6.5-8.0' Sampled for analytical
								(8.0-9.0) Not Sampled.		

Remarks and Datum Used:

ft-bgs - feet below ground surface
HSA - Hollow Stem Auger
Sch. - Schedule
Amb. - ambient air

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Seattle, WA 98134-1162
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Fax: (206) 624-2839

Sample Type
N = SPT
DP = Direct Push
SS = Split Spoon
C = Core

Groundwater		
Date	Time	Depth (ft.)
03/18/08	0944	6.46'

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Boring/Well Log

Well #: MW-3
Sheet 1 of 3

Project: **Lora Lake Apartments**	Monument: **Flush Mount**	Stick Up: -
Project #: **05482-025-210**	Northing: - Easting: -	Ground Elevation: -
Location: **Burien, WA**	Drill Rig Type: **HSA Limited Access**	MP Elevation: -
Client: **Port of Seattle**	Method: **HSA**	Total Depth: **25.5'**
Start Date & Time: **3/18/08 1015**	Casing ID: **2"**	Filter Pack: **10/20 Silica Sand**
Finish Date & Time: **3/18/08 1115**	Boring ID: **8.25"**	Seal: **Bentonite chips**
Contractor: **Cascade Drilling Inc.**	Bit Type: **4.25" HSA**	Grout: -
Operator: **Curtis Askew**	Logged By: **R. Knecht/ C. Smith**	Screen: **0.010" slot Sch. 40 PVC 13-23 ft-bgs**

Sample Type & Number	Sample Depth Range	Sample % Rec	Sample Blows per 6"	Sample PID (ppm)	Well Completion Log	Graphic	Depth (ft.)	Soil and Rock Description (Classification Scheme: USCS/ASTM)	Elevation (ft.)	Comments & Samples
							0		0	
SS-1	0.0-1.5	66	5 8 23	0.7 (Amb. 0.5)				(0.0-0.3) MULCH (0.3-1.5) SP: POORLY GRADED SAND, dark yellowish brown to yellowish brown, fine, dense, moist. 10% medium to coarse sand and rounded, fine to coarse gravel, up to 1.5" long. Trace rootlets. No odor or visible contamination.		Flush Mount Monument 2-inch diameter, Sch. 40 PVC riser from 0-13 ft-bgs
SS-2	1.5-3.0	72	13 17 20	1.2 (Amb. 0.5)				(1.5-3.0) SP: POORLY GRADED SAND, brown to slightly dark brown, fine, dense, moist. 10% medium to coarse sand. Trace, elongated, fine to coarse gravel, up to 1.5" long. No odor or visible contamination.		0.0-0.5' Sampled for analytical; mulch not included in sample
								(3.0-4.0) Not Sampled.		
SS-3	4.0-5.5	66	13 17 16	1.1 (Amb. 0.6)			5	(4.0-4.6) SP: POORLY GRADED SAND, brown to dark brown, fine, dense, moist. 10% rounded to sub rounded, elongate, coarse sand and fine gravel, up to 0.5" long. No odor or visible contamination.	-5	1.5-2.0' Sampled for analytical
								(4.6-5.5) SW: WELL GRADED SAND, yellowish brown, fine to medium, dense, moist. Trace rounded, coarse sand and fine gravel, up to 0.5" in diameter. No odor or visible contamination.		Bentonite seal from 2 to 11 ft-bgs
								(5.5-6.5) Not Sampled.		
SS-4	6.5-8.0	75	20 23 27	1.4 (Amb. 0.6)				(6.5-7.5) SP: POORLY GRADED SAND, brown to dark brown, fine, very dense, moist. 20% medium to coarse sand. 10% rounded, fine gravel, up to 1/4" in diameter. No odor or visible contamination.		6.5-8.0' Sampled for analytical
								(7.5-8.0) SW: WELL GRADED SAND, yellowish brown, fine to medium. Trace rounded coarse sand and fine gravel, up to 1/2" long. No odor or visible contamination.		
SS-	9.0-	66	14	1.3						

Remarks and Datum Used:

ft-bgs - feet below ground surface
HSA - Hollow Stem Auger
Sch. - Schedule
Amb. - ambient air

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Sample Type
N = SPT
DP = Direct Push
SS = Split Spoon
C = Core

Groundwater

Date	Time	Depth (ft.)
03/18/08	1220	17.46'

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Boring/Well Log

Well #: MW-3
Sheet 2 of 3

Project: **Lora Lake Apartments**	Monument: **Flush Mount**	Stick Up: -
Project #: **05482-025-210**	Northing: - Easting: -	Ground Elevation: -
Location: **Burien, WA**	Drill Rig Type: **HSA Limited Access**	MP Elevation: -
Client: **Port of Seattle**	Method: **HSA**	Total Depth: **25.5'**
Start Date & Time: **3/18/08 1015**	Casing ID: **2"**	Filter Pack: **10/20 Silica Sand**
Finish Date & Time: **3/18/08 1115**	Boring ID: **8.25"**	Seal: **Bentonite chips**
Contractor: **Cascade Drilling Inc.**	Bit Type: **4.25" HSA**	Grout: -
Operator: **Curtis Askew**	Logged By: **R. Knecht/ C. Smith**	Screen: **0.010" slot Sch. 40 PVC 13-23 ft-bgs**

Sample Type & Number	Sample Depth Range	Sample % Rec	Sample Blows per 6"	Sample PID (ppm)	Well Completion Log	Graphic	Depth (ft.)	Soil and Rock Description (Classification Scheme: USCS/ASTM)	Elevation (ft.)	Comments & Samples
5	10.5		50/6"	(Amb. 0.7)			10	(8.0-9.0) Not Sampled. (9.0-10.5) SP: POORLY GRADED SAND, light yellowish gray, fine, very dense. 20% medium to coarse sand. Trace rounded, fine gravel, up to 3/4" long. No odor or visible contamination.	-10	2-inch diameter, 0.010-inch slot, Sch. 40 PVC screen from 13 to 23 ft-bgs
SS-6	11.5-13.0	83	50/6"	1.7 (Amb. 0.7)				(10.5-11.5) Not Sampled. (11.5-13.0) SW: WELL GRADED SAND, light grayish brown to brown, fine to medium, very dense. 15% coarse sand. 10-15% sub rounded to rounded, fine to coarse gravel, up to 1" in diameter. Trace silt and iron staining. No odor or visible contamination.		
								(13.0-14.0) Not Sampled.		
SS-7	14.0-15.5	-	23 50/6"	0.5 (Amb. 0.5)			15	(14.0-15.5) SP: POORLY GRADED SAND, yellowish brown, fine, very dense, moist to wet. Trace medium sand and silt. No odor or visible contamination.	-15	14-15.5' Sampled for analytical 10/20 silica sand pack from 11 to 23.5 ft-bgs
								(15.5-16.5) Not Sampled.		
SS-8	16.5-18	94	50/6"	2.2 (Amb. 0.9)				(16.5-18.0) SP: POORLY GRADED SAND, brownish gray, medium, very dense, moist to wet. 10-15% fine sand. Trace silt. No odor or visible contamination.		
								(18.0-19.0) Not Sampled.		

Remarks and Datum Used: ft-bgs - feet below ground surface

HSA - Hollow Stem Auger

Sch. - Schedule

Amb. - ambient air

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Sample Type
N = SPT
DP = Direct Push
SS = Split Spoon
C = Core

Groundwater		
Date	Time	Depth (ft.)
03/18/08	1220	17.46'

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Boring/Well Log

Well #: MW-3
Sheet 3 of 3

Project: **Lora Lake Apartments**	Monument: **Flush Mount**	Stick Up: -
Project #: **05482-025-210**	Northing: - Easting: -	Ground Elevation: -
Location: **Burien, WA**	Drill Rig Type: **HSA Limited Access**	MP Elevation: -
Client: **Port of Seattle**	Method: **HSA**	Total Depth: **25.5'**
Start Date & Time: **3/18/08 1015**	Casing ID: **2"**	Filter Pack: **10/20 Silica Sand**
Finish Date & Time: **3/18/08 1115**	Boring ID: **8.25"**	Seal: **Bentonite chips**
Contractor: **Cascade Drilling Inc.**	Bit Type: **4.25" HSA**	Grout: -
Operator: **Curtis Askew**	Logged By: **R. Knecht/ C. Smith**	Screen: **0.010" slot Sch. 40 PVC 13-23 ft-bgs**

Sample Type & Number	Sample Depth Range	Sample % Rec	Sample Blows per 6"	Sample PID (ppm)	Well Completion Log	Graphic	Depth (ft.)	Soil and Rock Description (Classification Scheme: USCS/ASTM)	Elevation (ft.)	Comments & Samples
SS-9	19.0-20.5	77	50/6"	2.2 (Amb. 2.2)			20	(19.0-20.5) SW: WELL GRADED SAND, grayish brown to brown, fine to medium, very dense, wet. Trace silt and mica flakes. 10% winnowing. No odor or visible contamination.	-20	
								(20.5-21.5) Not Sampled.		
SS-10	21.5-23.0	92	36 50/6"	1.0 (Amb. 0.9)				(21.5-23.0) SP: POORLY GRADED SAND, gray to bluish gray, fine, very dense, wet. Abundant wood pieces. Trace large, mica flakes. 2mm thick lamination in soil layer. Very slight H2S-like odor. No visible contamination.		
								(23.0-24.0) Not Sampled.		
SS-11	24.0-25.5	100	50/6"	-			25	(24.0-25.5) SW: WELL GRADED SAND, slightly yellowish brown ro gray, medium to fine, very dense, wet. Iron stained beds, up to 1/4" thick at top of interval. No odor or visible contamination.	-25	heaving sand, filled top foot of SS-11 with slough

Remarks and Datum Used:

ft-bgs - feet below ground surface

HSA - Hollow Stem Auger

Sch. - Schedule

Amb. - ambient air

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Sample Type
N = SPT
DP = Direct Push
SS = Split Spoon
C = Core

Groundwater		
Date	Time	Depth (ft.)
03/18/08	1220	17.46'

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Boring/Well Log

Well #: MW-4
Sheet 1 of 3

Project: **Lora Lake Apartments**	Monument: **Flush Mount**	Stick Up: -
Project #: **05482-025-210**	Northing: - Easting: -	Ground Elevation: -
Location: **Burien, WA**	Drill Rig Type: **HSA Limited Access**	MP Elevation: -
Client: **Port of Seattle**	Method: **HSA**	Total Depth: **26'**
Start Date & Time: **3/17/08 1400**	Casing ID: **2"**	Filter Pack: **10/20 Silica Sand**
Finish Date & Time: **3/17/08 1515**	Boring ID: **8.25"**	Seal: **Bentonite chips**
Contractor: **Cascade Drilling Inc.**	Bit Type: **4.25" HSA**	Grout: -
Operator: **Curtis Askew**	Logged By: **R. Knecht/ C. Smith**	Screen: **0.010" slot Sch. 40 PVC 11-25.75 ft-bgs**

Sample Type & Number	Sample Depth Range	Sample % Rec	Sample Blows per 6"	Sample PID (ppm)	Well Completion Log	Graphic	Depth (ft.)	Soil and Rock Description (Classification Scheme: USCS/ASTM)	Elevation (ft.)	Comments & Samples
SS-1	0.0-1.5	66	11 10 10	0.0			0	(0.0-1.5) SW: SAND, brown, fine to medium, medium dense, moist. 20% rounded, coarse sand to fine gravel. Trace silt and rounded, coarse gravel, up to 1" long. Abundant grass and rootlets from 0.0-0.2'. Moderate organic-like odor, no visible contamination.	0	Flush Mount Monument 2-inch diameter, Sch. 40 PVC riser from 0 to 11 ft-bgs
SS-2	1.5-3.0	72	17 10 10	0.0				(1.5-2.0) SP: POORLY GRADED SAND, brown, fine, medium dense, moist. 15% silt. Trace rounded, fine, gravel. Organic-like odor, no visible contamination. (2.0-3.0) SP: POORLY GRADED SAND, yellowish brown with pockets of gray from 2.5-3', fine, medium dense, moist. 20% medium sand from 2-2.5'. Trace rounded, fine gravel. No odor or visible contamination.		0.0-0.5' Sampled for analytical
SS-3	4.0-5.5	66	12 10 10	0.0			5	(3.0-4.0) Not Sampled. (4.0-5.5) SP: POORLY GRADED SAND, yellowish brown grading to light yellowish brown at 5.0', fine, medium dense, moist. 20% medium sand from 4-5'. Trace rounded, fine gravel, content decreases downhole. Trace rootlets at 4.5'. No odor or visible contamination.	-5	1.5-2.0' Sampled for analytical Bentonite seal from 2 to 9 ft-bgs
SS-4	6.5-8.0	75	10 50/6"	0.0				(5.5-6.5) Not Sampled. (6.5-8.0) SP: POORLY GRADED SAND, yellowish brown, medium, very dense, moist. 20% rounded, fine to coarse gravel. Trace rootlets. No odor or visible contamination. (8.0-9.0) Not Sampled.		

Remarks and Datum Used: ft-bgs - feet below ground surface

HSA - Hollow Stem Auger

Sch. - Schedule

-

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Sample Type
N = SPT
DP = Direct Push
SS = Split Spoon
C = Core

Groundwater

Date	Time	Depth (ft.)
03/17/08	1644	15.70'

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Boring/Well Log

Well #: MW-4
Sheet 2 of 3

Project: **Lora Lake Apartments**	Monument: **Flush Mount**	Stick Up: -
Project #: **05482-025-210**	Northing: - Easting: -	Ground Elevation: -
Location: **Burien, WA**	Drill Rig Type: **HSA Limited Access**	MP Elevation: -
Client: **Port of Seattle**	Method: **HSA**	Total Depth: **26'**
Start Date & Time: **3/17/08 1400**	Casing ID: **2"**	Filter Pack: **10/20 Silica Sand**
Finish Date & Time: **3/17/08 1515**	Boring ID: **8.25"**	Seal: **Bentonite chips**
Contractor: **Cascade Drilling Inc.**	Bit Type: **4.25" HSA**	Grout: -
Operator: **Curtis Askew**	Logged By: **R. Knecht/ C. Smith**	Screen: **0.010" slot Sch. 40 PVC 11-25.75 ft-bgs**

Sample Type & Number	Sample Depth Range	Sample % Rec	Sample Blows per 6"	Sample PID (ppm)	Well Completion Log	Graphic	Depth (ft.)	Soil and Rock Description (Classification Scheme: USCS/ASTM)	Elevation (ft.)	Comments & Samples
SS-5	9.0-10.5	66	19 50/6"	0.0			10	(9.0-10.5) SW: WELL GRADED SAND WITH GRAVEL, brown to yellowish brown, fine to coarse, very dense, moist. 30% rounded to sub rounded, flat, elongate, fine to coarse gravel, up to 1" long. Slight sweet odor, no visible contamination.	-10	9.5-10.5' Sampled for analytical
								(10.5-11.5) Not Sampled.		
SS-6	11.5-13.0	83	19 21 24	0.0				(11.5-13.0) SP: POORLY GRADED SAND, slightly yellowish brown grading to yellowish gray, fine, dense, moist. Few 0.5" thick lenses of very fine sand. Trace coarse sand. No odor or visible contamination.		2-inch diameter, 0.010-inch slot, Sch. 40 PVC screen from 11 to 25.75 ft-bgs
								(13.0-14.0) Not Sampled.		
SS-7	14.0-15.5	-	23 50/6"	0.0			15	(14.0-15.5) SP: POORLY GRADED SAND, brownish gray, fine, very dense, moist. 10-15% silt. Trace mica. No odor or visible contamination.	-15	14-15.5' Sampled for analytical 10/20 silica sand pack from 9 to 26 ft-bgs
								(15.5-16.5) Not Sampled.		
SS-8	16.5-18	94	19 50/6"	0.0				(16.5-18.0) SP: POORLY GRADED SAND, gray to grayish brown, fine, very dense, moist. 20% medium sand at 16.75-17'. Little iron staining at 17.5-18'. At 17.9', 4mm thick black and iron stained bed. No odor or visible contamination.		

Remarks and Datum Used:

ft-bgs - feet below ground surface

HSA - Hollow Stem Auger

Sch. - Schedule

-

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Sample Type
N = SPT
DP = Direct Push
SS = Split Spoon
C = Core

Groundwater		
Date	Time	Depth (ft.)
03/17/08	1644	15.70'

ENSR | AECOM

Boring/Well Log

Well #: MW-4
Sheet 3 of 3

Project: **Lora Lake Apartments**	Monument: **Flush Mount**	Stick Up: -
Project #: **05482-025-210**	Northing: - Easting: -	Ground Elevation: -
Location: **Burien, WA**	Drill Rig Type: **HSA Limited Access**	MP Elevation: -
Client: **Port of Seattle**	Method: **HSA**	Total Depth: **26'**
Start Date & Time: **3/17/08 1400**	Casing ID: **2"**	Filter Pack: **10/20 Silica Sand**
Finish Date & Time: **3/17/08 1515**	Boring ID: **8.25"**	Seal: **Bentonite chips**
Contractor: **Cascade Drilling Inc.**	Bit Type: **4.25" HSA**	Grout: -
Operator: **Curtis Askew**	Logged By: **R. Knecht/ C. Smith**	Screen: **0.010" slot Sch. 40 PVC 11-25.75 ft-bgs**

Sample Type & Number	Sample Depth Range	Sample % Rec	Sample Blows per 6"	Sample PID (ppm)	Well Completion Log	Graphic	Depth (ft.)	Soil and Rock Description (Classification Scheme: USCS/ASTM)	Elevation (ft.)	Comments & Samples
								(18.0-19.0) Not Sampled.		
SS-9	19.0-20.5	77	22 50/6"	0.0			20	(19.0-20.0) SP: POORLY GRADED SAND, gray, fine, very dense, wet. 2.5" long, gray, friable, clay pocket with one white rock at 19.75'. No odor or visible contamination.	-20	
								(20.0-20.5) SP: POORLY GRADED SAND, brown, fine, very dense, wet. Trace rounded, coarse sand. No odor or visible contamination.		
								(20.5-21.5) Not Sampled.		
SS-10	21.5-23.0	92	19 50/6"	0.0				(21.5-23.0) SP: POORLY GRADED SAND, brown to slightly yellowish brown, fine, very dense, wet. Wood pieces and gray sand at top of interval. No odor or visible contamination.		
								(23.0-24.0) Not Sampled.		Slight heaving sand at bottom of borehole
SS-11	24.0-25.5	100	50/5"	0.0			25	(24.0-25.5) SP: POORLY GRADED SAND, yellowish brown to brown, medium, very dense, wet. 25% winnowing. No odor or visible contamination.	-25	
								(25.5-26.0) Not Sampled.		

Remarks and Datum Used: ft-bgs - feet below ground surface

HSA - Hollow Stem Auger

Sch. - Schedule

-

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Sample Type
N = SPT
DP = Direct Push
SS = Split Spoon
C = Core

Groundwater		
Date	Time	Depth (ft.)
03/17/08	1644	15.70'

ENSR | AECOM

Boring/Well Log

Well #: MW-5
Sheet 1 of 3

Project: **Lora Lake Apartments**	Monument: **Flush Mount**	Stick Up: -
Project #: **05482-025-210**	Northing: - Easting: -	Ground Elevation: -
Location: **Burien, WA**	Drill Rig Type: **HSA Limited Access**	MP Elevation: -
Client: **Port of Seattle**	Method: **HSA**	Total Depth: **28'**
Start Date & Time: **3/17/08 1025**	Casing ID: **2"**	Filter Pack: **10/20 Silica Sand**
Finish Date & Time: **3/17/08 1210**	Boring ID: **8.25"**	Seal: **Bentonite chips**
Contractor: **Cascade Drilling Inc.**	Bit Type: **4.25" HSA**	Grout: -
Operator: **Curtis Askew**	Logged By: **R. Knecht/ C. Smith**	Screen: **0.010" slot Sch. 40 PVC 13-28 ft-bgs**

Sample Type & Number	Sample Depth Range	Sample % Rec	Sample Blows per 6"	Sample PID (ppm)	Well Completion Log	Graphic	Depth (ft.)	Soil and Rock Description (Classification Scheme: USCS/ASTM)	Elevation (ft.)	Comments & Samples
SS-1	0.0-1.5	66	15 14 20	0.0			0	(0.0-1.5) SP: POORLY GRADED SAND, brown to dark brown, fine, loose, moist. 15% rounded, fine gravel, 0.25-0.5" long. One rounded gravel, 3" in diameter. Trace straw. No odor or visible contamination.	0	Flush Mount Monument 2-inch diameter Sch. 40 PVC riser from 0 to 13 ft-bgs
SS-2	1.5-3.0	100	50/5"	0.0				(1.5-3.0) SP: POORLY GRADED SAND, yellowish brown, fine, dense, moist. Trace coarse sand to fine gravel, rounded, up to 0.5" long. No odor or visible contamination.		0.0-0.5' Sampled for analytical
	3.0-4.0							(3.0-4.0) Not Sampled.		1.5-2.0' Sampled for analytical
SS-3	4.0-5.5	91	24 50/6"	0.0			5	(4.0-5.5) SW: WELL GRADED SAND, yellowish brown, fine to medium, very dense, moist. 20% sub rounded, gravel, up to 1/2" in diameter. Gravel content increases to 30% with depth. No odor or visible contamination.	-5	Bentonite seal from 2 to 11 ft-bgs
	5.5-6.5							(5.5-6.5) Not Sampled.		
SS-4	6.5-8.0	100	50/6"	0.0				(6.5-8.0) SM: SILTY SAND, gray to slightly brownish gray, fine, very dense, moist. 20% silt. 10% rounded, sand and fine gravel. One gravel up to 2" long. No odor or visible contamination.		6.5-8.0' Sampled for analytical
	8.0-9.0							(8.0-9.0) Not Sampled.		
SS-5	9.0-10.5	75	30 50/6"	0.0			10	(9.0-10.5) SW: WELL GRADED SAND, gray to brownish gray, fine to medium, very dense, moist to wet. Trace coarse sand, fine gravel, and 1" thick pockets of silt and very fine sand. Trace hydrocarbon-like odor in 0.5" thick silt lense at 10.5'. No visible contamination.	-10	

Remarks and Datum Used: ft-bgs - feet below ground surface

HSA - Hollow Stem Auger

Sch. - Schedule

-

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Sample Type
N = SPT
DP = Direct Push
SS = Split Spoon
C = Core

Groundwater		
Date	Time	Depth (ft.)
03/17/08	1332	20.27'

ENSR | AECOM

Boring/Well Log

Well #: MW-5
Sheet 3 of 3

Project: **Lora Lake Apartments**	Monument: **Flush Mount**	Stick Up: **-**
Project #: **05482-025-210**	Northing: **-** Easting: **-**	Ground Elevation: **-**
Location: **Burien, WA**	Drill Rig Type: **HSA Limited Access**	MP Elevation: **-**
Client: **Port of Seattle**	Method: **HSA**	Total Depth: **28'**
Start Date & Time: **3/17/08 1025**	Casing ID: **2"**	Filter Pack: **10/20 Silica Sand**
Finish Date & Time: **3/17/08 1210**	Boring ID: **8.25"**	Seal: **Bentonite chips**
Contractor: **Cascade Drilling Inc.**	Bit Type: **4.25" HSA**	Grout: **-**
Operator: **Curtis Askew**	Logged By: **R. Knecht/ C. Smith**	Screen: **0.010" slot Sch. 40 PVC 13-28 ft-bgs**

Sample Type & Number	Sample Depth Range	Sample % Rec	Sample Blows per 6"	Sample PID (ppm)	Well Completion Log	Graphic	Depth (ft.)	Soil and Rock Description (Classification Scheme: **USCS/ASTM**)	Elevation (ft.)	Comments & Samples
SS-10	21.5-23.0	66	32 50/6"	0.0				(21.5-23.0) SW: WELL GRADED SAND, grayish brown grading to yellowish brown, sub angular to sub rounded, very dense, wet. 20% sub angular to rounded, elongated, fine to coarse, gravel. No odor or visible contamination.		
								(23.0-24.0) Not Sampled.		
SS-11	24.0-25.5	100	25 50/6"	0.0			25	(24.0-25.5) SP: POORLY GRADED SAND, grayish brown, fine, very dense, wet. Trace medium sand and rounded, fine gravel. No odor or visible contamination.	-25	
								(25.5-26.5) Not Sampled.		
SS-12	26.5-28	100	50/6"	0.0				(26.5-28.0) SP: POORLY GRADED SAND, gray from 26.5-27.0', sharp contact to yellowish brown at 27.0', fine, very dense, wet. 15% gray, medium to coarse sand. Trace, soft, silt. 50% winnowing. No odor or visible contamination.		Slight heaving sand at bottom of borehole

Remarks and Datum Used:

ft-bgs - feet below ground surface

HSA - Hollow Stem Auger

Sch. - Schedule

-

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Sample Type

N = SPT
DP = Direct Push
SS = Split Spoon
C = Core

Groundwater

Date	Time	Depth (ft.)
03/17/08	1332	20.27'

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Boring/Well Log

Well #: MW-6
Sheet 1 of 2

Project: **Lora Lake Apartments**	Monument: **Flush Mount**	Stick Up: -
Project #: **05482-025-210**	Northing: - Easting: -	Ground Elevation: -
Location: **Burien, WA**	Drill Rig Type: **HSA Limited Access**	MP Elevation: -
Client: **Port of Seattle**	Method: **HSA**	Total Depth: **20.5'**
Start Date & Time: **3/18/08 1344**	Casing ID: **2"**	Filter Pack: **10/20 Silica Sand**
Finish Date & Time: **3/18/08 1445**	Boring ID: **8.25"**	Seal: **Bentonite chips**
Contractor: **Cascade Drilling Inc.**	Bit Type: **4.25" HSA**	Grout: -
Operator: **Curtis Askew**	Logged By: **R. Knecht/ C. Smith**	Screen: **0.010" slot Sch. 40 PVC 5-15 ft-bgs**

Sample Type & Number	Sample Depth Range	Sample % Rec	Sample Blows per 6"	Sample PID (ppm)	Well Completion Log	Graphic	Depth (ft.)	Soil and Rock Description (Classification Scheme: USCS/ASTM)	Elevation (ft.)	Comments & Samples
SS-1	0.0-1.5	83	3 5 14	0.9 (Amb. 0.3)			0	(0.0-1.5) SP: POORLY GRADED SAND, brown, fine, medium dense, moist. 20-25% silt. 10% medium to coarse sand. Trace fine gravel, up to 1/4" in diameter. Abundant rootlets throughout, grass on top. Moderate organic odor, no visible contamination.	0	Flush Mount Monument 2-inch diameter Sch. 40 PVC riser from 0 to 5 ft-bgs
SS-2	1.5-3.0	66	20 25 25	1.2 (Amb. 0.3)				(1.5-3.0) SP: POORLY GRADED SAND, brown to slightly dark brown, fine, very dense, moist. 20% silt. Trace rounded, coarse sand to fine gravel. Little rootlets. Friable. Moderate organic odor, no visible contamination.		0.0-0.5' Sampled for analytical
SS-3	4.0-5.5	66	3 4 5	1.3 (Amb. 0.4)			5	(3.0-4.0) Not Sampled. (4.0-5.5) SP: POORLY GRADED SAND, slightly reddish brown, fine, loose, moist. 10-15% medium to coarse sand. Trace rounded, fine gravel, up to 3/4" in diameter. Trace rootlets in catcher. No odor or visible contamination.	-5	1.5-2.0' Sampled for analytical
SS-4	6.5-8.0	72	11 9 13	1.4 (Amb. 0.6)				(5.5-6.5) Not Sampled. (6.5-8.0) SP: POORLY GRADED SAND, reddish brown grading to light reddish brown, fine, medium dense, moist. Trace fine gravel, up to 1/2" in diameter. No odor or visible contamination.		6.5-8.0' Sampled for analytical
SS-5	9.0-10.5	94	20 20 20	1.5 (Amb. 0.6)			10	(8.0-9.0) Not Sampled. (9.0-10.5) SP: POORLY GRADED SAND, gray with iron staining, fine, dense, moist. Trace organic matter and silt. No odor or visible contamination.	-10	Bentonite seal from 2 to 4 ft-bgs
								(10.5-11.5) Not Sampled.		

Remarks and Datum Used: ft-bgs - feet below ground surface

HSA - Hollow Stem Auger

Sch. - Schedule

Amb. - ambient air

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Sample Type
N = SPT
DP = Direct Push
SS = Split Spoon
C = Core

Groundwater		
Date	Time	Depth (ft.)
03/18/08	1553	12.51'

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Boring/Well Log

Well #: MW-6
Sheet 2 of 2

Project: **Lora Lake Apartments**	Monument: **Flush Mount**	Stick Up: -
Project #: **05482-025-210**	Northing: - Easting: -	Ground Elevation: -
Location: **Burlen, WA**	Drill Rig Type: **HSA Limited Access**	MP Elevation: -
Client: **Port of Seattle**	Method: **HSA**	Total Depth: **20.5'**
Start Date & Time: **3/18/08 1344**	Casing ID: **2"**	Filter Pack: **10/20 Silica Sand**
Finish Date & Time: **3/18/08 1445**	Boring ID: **8.25"**	Seal: **Bentonite chips**
Contractor: **Cascade Drilling Inc.**	Bit Type: **4.25" HSA**	Grout: -
Operator: **Curtis Askew**	Logged By: **R. Knecht/ C. Smith**	Screen: **0.010" slot Sch. 40 PVC 5-15 ft-bgs**

Sample Type & Number	Sample Depth Range	Sample % Rec	Sample Blows per 6"	Sample PID (ppm)	Well Completion Log	Graphic	Depth (ft.)	Soil and Rock Description (Classification Scheme: USCS/ASTM)	Elevation (ft.)	Comments & Samples
SS-6	11.5-13.0	92	25 50/6"	1.4 (Amb. 0.6)				(11.5-13.0) SP: POORLY GRADED SAND, gray, fine, very dense, wet. 25% sub angular, fine to coarse gravel. 10% coarse sand. Slight to moderate soapy-like to hydrocarbon-like odor, no visible contamination.		11.5-13.0' Sampled for analytical
								(13.0-14.0) Not Sampled.		2-inch diameter, 0.010-inch slot, Sch. 40 PVC screen from 5 to 15 ft-bgs
SS-7	14.0-15.5	100	50/6"	2.4 (Amb. 0.7)			15	(14.0-15.5) SW: WELL SORTED SAND, gray to brownish gray, fine to coarse, very dense, wet. 10-15% rounded, fine to coarse gravel, up to 2" in diameter. Trace to little iron mottles. Slight soapy-like to hydrocarbon-like odor, no visible contamination.	-15	
								(15.5-16.5) Not Sampled.		10/20 silica sand pack from 4 to 16 ft-bgs
SS-8	16.5-18	61	19 50/6"	2.1 (Amb. 0.8)				(16.5-17.25) ML: SILT, gray to brownish gray, high plasticity, hard, wet. 15% clay. Slight soap-like odor, no visible contamination.		
								(17.25-18.0) SW: WELL GRADED SAND, gray, fine to coarse, very dense, wet. 25% rounded, fine gravel, up to 1/2" in diameter. Slight soap-like odor, no visible contamination.		Bentonite from 16 to 20.5 ft-bgs
								(18.0-19.0) Not Sampled.		
SS-9	19.0-20.5	55	21 36 50/4"	2.2 (Amb. 1.0)			20	(19.0-20.3) SW: WELL GRADED SAND, gray, fine to medium, very dense, wet. 10% silt and rounded, fine gravel, up to 1/4" in diameter. No odor or visible contamination.	-20	19.0-20.5' Sampled for analytical
								(20.3-20.5) SP: POORLY GRADED SAND, black, fine, wet. No odor or visible contamination.		

Remarks and Datum Used:

ft-bgs - feet below ground surface

HSA - Hollow Stem Auger

Sch. - Schedule

Amb. - ambient air

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Sample Type
N = SPT
DP = Direct Push
SS = Split Spoon
C = Core

Groundwater		
Date	Time	Depth (ft.)
03/18/08	1553	12.51'

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Boring/Well Log

Well #: MW-8
Sheet 1 of 2

Project: **Lora Lake Apartments**	Monument: **Flush Mount**	Stick Up: **-**
Project #: **05482-025-3000**	Northing: **174627.2741** Easting: **1272775.8574'**	Ground Elevation: **282.534'**
Location: **Seattle, WA**	Drill Rig Type: **Limited Access Track Rig**	MP Elevation: **287.907'**
Client: **Port of Seattle**	Method: **HSA**	Total Depth: **20.5'**
Start Date & Time: **08/12/08 1357**	Casing ID: **2"**	Filter Pack: **10/20 Silica Sand**
Finish Date & Time: **08/12/08 1429**	Boring ID: **4.25"**	Seal: **Bentonite Chips**
Contractor: **Cascade Drilling Inc.**	Bit Type: **4.25" HSA**	Grout: **-**
Operator: **Curtis Askew**	Logged By: **C. Smith**	Screen: **0.010-inch slot, Sch. 40 PVC**

Sample Type &	Sample Depth Range	Sample % Rec	Sample Blows per 6"	Sample PID (ppm)	Well Completion Log	Graphic	Depth (ft.)	Soil and Rock Description (Classification Scheme: USCS/ASTM)	Elevation (ft.)	Comments
							0	(0.0-5.0) Not sampled.	280	Flush mount monument. Bentonite chip plug from 1.5-8 ft-bgs.
SS -1	5-6.5	80	7 8 17	0.4 aa= 0.4			5	(5.0-6.5) SW: WELL GRADED SAND, brown, fine to coarse, sub angular to sub rounded, medium dense, dry. Trace rootlets. No odor or visible contamination.		2-inch schedule 40 riser pipe from 0-10 ft-bgs.
								(6.5-10.0) Not sampled.	275	10/20 silica sand pack from 8-20.5 ft-bgs.
SS -2	10-11.5	46	50/6"	0.3 aa= 0.3			10	(10.0-10.4) SM: SILTY SAND, gray and brown, fine to medium, very dense, moist. 40% silt. Trace, angular, coarse sand. Trace rootlets. No odor or visible contamination.		
								(10.4-11.5) SP: POORLY GRADED SAND, brown, fine, very dense, moist. Trace coarse sand. One rounded peice of large gravel. No odor or visible contamination.		0.010-inch slot, 2-inch schedule 40 PVC screen from 10-20 ft-bgs.
								(11.5-12.5) Not sampled.	270	

Remarks and Datum Used:

aa = ambient air

ft-bgs = feet below ground suface

Sch. = schedule

HSA = Hollow Stem Auger

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Sample Type

N = SPT
DP = Direct Push
SS = Split Spoon
C = Core

Groundwater

Date	Time	Depth (ft.)
8/12/08	**1415**	**12'**

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Boring/Well Log

Well #: MW-8
Sheet 2 of 2

Project: **Lora Lake Apartments**	Monument: **Flush Mount**	Stick Up: **-**
Project #: **05482-025-3000**	Northing: **174627.2741** Easting: **1272775.8574'**	Ground Elevation: **282.534'**
Location: **Seattle, WA**	Drill Rig Type: **Limited Access Track Rig**	MP Elevation: **287.907'**
Client: **Port of Seattle**	Method: **HSA**	Total Depth: **20.5'**
Start Date & Time: **08/12/08 1357**	Casing ID: **2"**	Filter Pack: **10/20 Silica Sand**
Finish Date & Time: **08/12/08 1429**	Boring ID: **4.25"**	Seal: **Bentonite Chips**
Contractor: **Cascade Drilling Inc.**	Bit Type: **4.25" HSA**	Grout: **-**
Operator: **Curtis Askew**	Logged By: **C. Smith**	Screen: **0.010-inch slot, Sch. 40 PVC**

Sample Type &	Sample Depth Range	Sample % Rec	Sample Blows per 6"	Sample PID (ppm)	Well Completion Log	Graphic	Depth (ft.)	Soil and Rock Description (Classification Scheme: USCS/ASTM)	Elevation (ft.)	Comments
SS -3	12.5-14	80	50/6"	0.3 aa= 0.3				(12.5-14.0) SP: POORLY GRADED SAND, white, black, orange, and yellow grains, medium, sub rounded, very dense, wet. Trace coarse sand to large gravel. Trace, orange, iron oxide staining. One cobble, 3" in diameter. No odor or visible contamination.	270	12.5-14': Sampled for analytical.
							15	(14.0-19.0) Not sampled.	265	
SS -4	19-20.5	26	50/4"	0.3 aa= 0.3			20	(19.0-20.5) SW: WELL GRADED SAND, brown with white, black, and yellow grains, fine to medium, very dense, wet. Trace coarse sand. 10% winnowing. No odor or visible contamination.		Threaded end cap from 20-20.35 ft-bgs.

Remarks and Datum Used:
aa = ambient air
ft-bgs = feet below ground suface
Sch. = schedule
HSA = Hollow Stem Auger

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Sample Type
N = SPT
DP = Direct Push
SS = Split Spoon
C = Core

Groundwater		
Date	Time	Depth (ft.)
8/12/08	1415	12'

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Boring/Well Log

Well #: MW-9
Sheet 1 of 2

Project: **Lora Lake Apartments**	Monument: **Flush Mount**	Stick Up: **-**
Project #: **05482-025-3000**	Northing: **174474.2134** Easting: **1272627.3356'**	Ground Elevation: **283.698'**
Location: **Seattle, WA**	Drill Rig Type: **Limited Access Track Rig**	MP Elevation: **283.335'**
Client: **Port of Seattle**	Method: **HSA**	Total Depth: **20.5'**
Start Date & Time: **08/12/08 1217**	Casing ID: **2"**	Filter Pack: **10/20 Silica Sand**
Finish Date & Time: **08/12/08 1240**	Boring ID: **4.25"**	Seal: **Bentonite Chips**
Contractor: **Cascade Drilling Inc.**	Bit Type: **4.25" HSA**	Grout: **-**
Operator: **Curtis Askew**	Logged By: **C. Smith**	Screen: **0.010-inch slot, Sch. 40 PVC**

Sample Type &	Sample Depth Range	Sample % Rec	Sample Blows per 6"	Sample PID (ppm)	Well Completion Log	Graphic	Depth (ft.)	Soil and Rock Description (Classification Scheme: USCS/ASTM)	Elevation (ft.)	Comments
							0	(0.0-5.0) Not sampled.		Flush mount monument. Bentonite chip plug from 1.5-8 ft-bgs.
									280	
SS -1	5-6.5	53	24 50/6"	0.4 aa= 0.4			5	(5.0-6.5) SM: SILTY SAND, brown, fine to medium, very dense, moist. At 5-5.3', trace coarse sand and rootlets, large 3", rounded, cobble. At 5.3-5.6', color grades to gray. No odor or visible contamination.		2-inch schedule 40 riser pipe from 0-10 ft-bgs.
								(6.5-10.0) Not sampled.		
									275	10/20 silica sand pack from 8-20.5 ft-bgs.
SS -2	10-11.5	-	21 25 30	0.3 aa= 0.3			10	(10.0-10.7) SW: WELL GRADED SAND, brown, fine to coarse, sub rounded, very dense, moist. Angular, crushed, dark gray boulder at 10.5'. No odor or visible contamination.		0.010-inch slot, 2-inch schedule 40 PVC screen from 10-20 ft-bgs.
								(10.7-11.5) SP: POORLY GRADED SAND, brown, fine, very dense, moist. Few 1/4" thick gray lenses at 11.1' and 11.3'. No odor or visible contamination.		
								(11.5-15.0) Not sampled.		

Remarks and Datum Used:

aa = ambient air

ft-bgs = feet below ground suface

Sch. = schedule

HSA = Hollow Stem Auger

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Sample Type

N = SPT
DP = Direct Push
SS = Split Spoon
C = Core

Groundwater

Date	Time	Depth (ft.)
8/12/08	1230	14'

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Boring/Well Log

Well #: MW-9
Sheet 2 of 2

Project: **Lora Lake Apartments**	Monument: **Flush Mount**	Stick Up: **-**
Project #: **05482-025-3000**	Northing: **174474.2134** Easting: **1272627.3356'**	Ground Elevation: **283.698'**
Location: **Seattle, WA**	Drill Rig Type: **Limited Access Track Rig**	MP Elevation: **283.335'**
Client: **Port of Seattle**	Method: **HSA**	Total Depth: **20.5'**
Start Date & Time: **08/12/08 1217**	Casing ID: **2"**	Filter Pack: **10/20 Silica Sand**
Finish Date & Time: **08/12/08 1240**	Boring ID: **4.25"**	Seal: **Bentonite Chips**
Contractor: **Cascade Drilling Inc.**	Bit Type: **4.25" HSA**	Grout: **-**
Operator: **Curtis Askew**	Logged By: **C. Smith**	Screen: **0.010-inch slot, Sch. 40 PVC**

Sample Type &	Sample Depth Range	Sample % Rec	Sample Blows per 6"	Sample PID (ppm)	Well Completion Log	Graphic	Depth (ft.)	Soil and Rock Description (Classification Scheme: USCS/ASTM)	Elevation (ft.)	Comments
									270	
SS -3	15-16.5	66	50/6"	0.3 aa= 0.3			15	(15.0-16.5) SP: POORLY GRADED SAND, brown with white, black and yellow grains, fine, very dense, wet. Trace silt. 15% winnowing. No odor or visible contamination.		15-16.5 ft-bgs: Sampled for analytical.
								(16.5-19) Not sampled.	265	Threaded end cap from 20-20.35 ft-bgs.
SS -4	19-20.5	-	50/6"	0.3 aa= 0.3			20	(19.0-20.5) SP: POORLY GRADED SAND, brown with white, black and yellow grains, fine, very dense, wet. Trace silt. 15% winnowing. No odor or visible contamination.		

Remarks and Datum Used:

aa = ambient air

ft-bgs = feet below ground suface

Sch. = schedule

HSA = Hollow Stem Auger

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Sample Type

N = SPT
DP = Direct Push
SS = Split Spoon
C = Core

Groundwater

Date	Time	Depth (ft.)
8/12/08	1230	14'

ENSR | AECOM

Boring/Well Log

Well #: MW-10
Sheet 1 of 2

Project: **Lora Lake Apartments**	Monument: **Flush Mount**	Stick Up: **-**
Project #: **05482-025-3000**	Northing: **174386.6154** Easting: **1272561.6472'**	Ground Elevation: **284.397'**
Location: **Seattle, WA**	Drill Rig Type: **Limited Access Track Rig**	MP Elevation: **284.149'**
Client: **Port of Seattle**	Method: **HSA**	Total Depth: **20.5'**
Start Date & Time: **08/12/08 1041**	Casing ID: **2"**	Filter Pack: **10/20 Silica Sand**
Finish Date & Time: **08/12/08 1115**	Boring ID: **4.25"**	Seal: **Bentonite Chips**
Contractor: **Cascade Drilling Inc.**	Bit Type: **4.25" HSA**	Grout: **-**
Operator: **Curtis Askew**	Logged By: **C. Smith**	Screen: **0.010-inch slot, Sch. 40 PVC**

Sample Type &	Sample Depth Range	Sample % Rec	Sample Blows per 6"	Sample PID (ppm)	Well Completion Log	Graphic	Depth (ft.)	Soil and Rock Description (Classification Scheme: USCS/ASTM)	Elevation (ft.)	Comments
							0	(0.0-5.0) Not sampled.		Flush mount monument. Bentonite chip plug from 1.5-8 ft-bgs.
									280	
SS -1	5-6.5	46	24 50/6"	0.3 aa= 0.3			5	(5.0-6.5) SP: POORLY GRADED SAND, orangish brown, medium, very dense, dry. Trace, angular, coarse sand to small gravel. Some fine sand and silt. No odor or visible contamination.		2-inch schedule 40 riser pipe from 0-10 ft-bgs.
								(6.5-10.0) Not sampled.		10/20 silica sand pack from 8-20.5 ft-bgs.
									275	
SS -2	10-11.5	44	21 25 30	0.3 aa= 0.3			10	(10.0-11.5) SW: WELL GRADED SAND, brown, fine to medium, very dense, moist. Some silt and coarse sand. No odor or visible contamination.		0.010-inch slot, 2-inch schedule 40 PVC screen from 10-20 ft-bgs.
								(11.5-12.5) Not sampled.		

Remarks and Datum Used:

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ft-bgs = feet below ground suface

Sch. = schedule

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Sample Type

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DP = Direct Push
SS = Split Spoon
C = Core

Groundwater

Date	Time	Depth (ft.)
8/12/08	1115	13'

ENSR | AECOM

Boring/Well Log

Well #: MW-10
Sheet 2 of 2

Project: **Lora Lake Apartments**	Monument: **Flush Mount**	Stick Up: **-**
Project #: **05482-025-3000**	Northing: **174386.6154** Easting: **1272561.6472'**	Ground Elevation: **284.397'**
Location: **Seattle, WA**	Drill Rig Type: **Limited Access Track Rig**	MP Elevation: **284.149'**
Client: **Port of Seattle**	Method: **HSA**	Total Depth: **20.5'**
Start Date & Time: **08/12/08 1041**	Casing ID: **2"**	Filter Pack: **10/20 Silica Sand**
Finish Date & Time: **08/12/08 1115**	Boring ID: **4.25"**	Seal: **Bentonite Chips**
Contractor: **Cascade Drilling Inc.**	Bit Type: **4.25" HSA**	Grout: **-**
Operator: **Curtis Askew**	Logged By: **C. Smith**	Screen: **0.010-inch slot, Sch. 40 PVC**

Sample Type &	Sample Depth Range	Sample % Rec	Sample Blows per 6"	Sample PID (ppm)	Well Completion Log	Graphic	Depth (ft.)	Soil and Rock Description (Classification Scheme: **USCS/ASTM**)	Elevation (ft.)	Comments
SS -3	12.5-14	60	50/6"	0.3 aa= 0.3				(12.5-14.0) SP: POORLY GRADED SAND, brown, medium, sub rounded, very dense, moist to wet at 13'. Trace, fine sand and silt. No odor or visible contamination.		
								(14.0-18.5) Not sampled.	270	12.5-14 ft-bgs: Sampled for analytical.
							15			
SS -4	19-20.5	80	50/6"	0.3 aa= 0.3				(19.0-20.5) SP: POORLY GRADED SAND, brown with black, white, yellow, and orange grains, medium, sub rounded, very dense, wet. Trace silt. No odor or visible contamination.	265	Threaded end cap from 20-20.35 ft-bgs.
							20			

Remarks and Datum Used:

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Sample Type

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SS = Split Spoon
C = Core

Groundwater

Date	Time	Depth (ft.)
8/12/08	**1115**	**13'**

ENSR | AECOM

Boring/Well Log

Well #: MW-11
Sheet 1 of 2

Project: **Lora Lake Apartments**	Monument: **Flush Mount**	Stick Up: **-**
Project #: **05482-025-3000**	Northing: **174287.7124** Easting: **1272485.4391'**	Ground Elevation: **284.948'**
Location: **Seattle, WA**	Drill Rig Type: **Limited Access Track Rig**	MP Elevation: **284.36'**
Client: **Port of Seattle**	Method: **HSA**	Total Depth: **20.5'**
Start Date & Time: **08/12/08 0930**	Casing ID: **2"**	Filter Pack: **10/20 Silica Sand**
Finish Date & Time: **08/12/08 1005**	Boring ID: **4.25"**	Seal: **Bentonite Chips**
Contractor: **Cascade Drilling Inc.**	Bit Type: **4.25" HSA**	Grout: **-**
Operator: **Curtis Askew**	Logged By: **C. Smith**	Screen: **0.010-inch slot, Sch. 40 PVC**

Sample Type &	Sample Depth Range	Sample % Rec	Sample Blows per 6"	Sample PID (ppm)	Well Completion Log	Graphic	Depth (ft.)	Soil and Rock Description (Classification Scheme: **USCS/ASTM**)	Elevation (ft.)	Comments
							0	(0.0-5.0) Not sampled.		Flush mount monument. Bentonite chip plug from 1.5-8 ft-bgs.
SS -1	5-6.5	100	50/2"	0.0			5	(5.0-6.5) SW: WELL GRADED SAND, dark brown, fine to medium, very dense, moist. Trace coarse sand. Few, angular gravel up to 1" in diameter. Few grass and rootlets. No odor or visible contamination.	280	2-inch schedule 40 riser pipe from 0-10 ft-bgs.
								(6.5-7.5) Not sampled.		
SS -2	7.5-9	100	50/6"	0.0				(7.5-9.0) SW: WELL GRADED SAND, dark brown, fine to medium, very dense, moist. Trace, angular, coarse sand and small gravel. Some rootlets. No odor or visible contamination.		10/20 silica sand pack from 8-20.5 ft-bgs.
								(9.0-10.0) Not sampled.		
SS -3	10-11.5	100	50/6"	0.0			10	(10.0-10.3) SW: WELL GRADED SAND, brown, fine to medium, very dense, moist. Trace coarse sand. No odor or visible contamination.	275	0.010-inch slot, 2-inch schedule 40 PVC screen from 10-20 ft-bgs.
								(10.3-11.5) SP: POORLY GRADED SAND, brown, medium, very dense, moist. No odor or visible contamination.		
								(11.5-12.5) Not sampled.		

Remarks and Datum Used:

ft-bgs = feet below ground suface

Sch. = schedule

HSA = Hollow Stem Auger

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Sample Type

N = SPT
DP = Direct Push
SS = Split Spoon
C = Core

Groundwater		
Date	Time	Depth (ft.)
8/12/08	**0950**	**12.8'**

ENSR | AECOM

Boring/Well Log

Well #: MW-11
Sheet 2 of 2

Project: **Lora Lake Apartments**	Monument: **Flush Mount**	Stick Up: **-**
Project #: **05482-025-3000**	Northing: **174287.7124** Easting: **1272485.4391'**	Ground Elevation: **284.948'**
Location: **Seattle, WA**	Drill Rig Type: **Limited Access Track Rig**	MP Elevation: **284.36'**
Client: **Port of Seattle**	Method: **HSA**	Total Depth: **20.5'**
Start Date & Time: **08/12/08 0930**	Casing ID: **2"**	Filter Pack: **10/20 Silica Sand**
Finish Date & Time: **08/12/08 1005**	Boring ID: **4.25"**	Seal: **Bentonite Chips**
Contractor: **Cascade Drilling Inc.**	Bit Type: **4.25" HSA**	Grout: **-**
Operator: **Curtis Askew**	Logged By: **C. Smith**	Screen: **0.010-inch slot, Sch. 40 PVC**

Sample Type &	Sample Depth Range	Sample % Rec	Sample Blows per 6"	Sample PID (ppm)	Well Completion Log	Graphic	Depth (ft.)	Soil and Rock Description (Classification Scheme: **USCS/ASTM**)	Elevation (ft.)	Comments
SS -4	12.5-14	100	60/5"	0.0				(12.5-14.0) SP: POORLY GRADED SAND, brown, medium, moist to wet at 12.8'. Trace coarse sand. No odor or visible contamination.		
								(14.0-15.0) Not sampled.		
SS -5	15-16.5	100	50/5"	0.0			15	(15.0-16.5) SP: POORLY GRADED SAND, brown, medium, very dense, wet. Trace silt at 16'. No odor or visible contamination.	270	12.5-13 ft-bgs: Sampled for analytical.
								(16.5-19.0) Not sampled.		
SS -6	19-20.5	100	50/6"	0.0			20	(19.0-20.5) SP: POORLY GRADED SAND, brown with white, black, orange and yellow grains, medium, sub angular, very dense, wet. Trace silt. 10% winnowing. No odor or visible contamination.	265	Threaded end cap from 20-20.35 ft-bgs.

Remarks and Datum Used:

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Sch. = schedule

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Groundwater

Date	Time	Depth (ft.)
8/12/08	0950	12.8'


Aspect
CONSULTING