Subsurface Conditions Report

Point Wells Redevelopment

Snohomish County, Washington

Prepared for

BSRE Point Wells, LP

April 20, 2018

17203-54

HARTCROWSER

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Prepared by

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1.0 EXECUTIVE SUMMARY

This report presents our geotechnical engineering study for the environmental impact analysis for the proposed mixed-use redevelopment at Point Wells in unincorporated Snohomish County, Washington. An environmental impact statement is being prepared for one alternative that was selected previously by the design team from a variety of alternatives considered. The Urban Center alternative was selected, which includes multiple mixed use (office, retail, and residential) mid- and high-rise buildings, supporting infrastructure, open space, and a Secondary Access Road.

The site consists of a 56-acre “Lower Bench” adjacent to Puget Sound and a 5-acre “Upper Bench” to the east. The Upper and Lower Benches are split by the BNSF railroad tracks that run along Puget Sound. East of the site is an ascending slope about 150 to 200 feet high with average overall slope gradient ranging from about 18 to 50 percent (or about 3H:1V to 2H:1V). The slope gradient varies locally, maximizing at about 100 percent (1H:1V).

Soil at the site and in the adjacent eastern slope include Fill, Colluvium, Vashon Till, Advance Outwash, Lawton Clay, and Pre-Fraser Deposits. Shallow groundwater is present below the Upper and Lower Benches, and groundwater is also present at varying levels in the eastern slope. Areas of localized slope instability were observed in the field and reported historically along similar slopes on Puget Sound.

Geologically hazardous areas at the site and in the eastern slope include erosion, landslide, seismic, and tsunami. The impacts of the proposed alternatives on these hazardous areas, as well as the potential impacts of the hazardous areas on the proposed alternatives, can be mitigated during design.

2.0 INTRODUCTION

This report presents our geotechnical engineering study for the environmental impact analysis for the proposed mixed-use redevelopment at the Point Wells asphalt plant and marine fuel terminal in unincorporated Snohomish County, Washington (the Project). We understand an environmental impact statement (EIS) is being prepared for the preferred development alternative selected from three alternatives originally considered. The EIS describes one redevelopment alternative, which is an Urban Center with multiple mixed use (office, retail, and residential) low-, mid-, and high-rise buildings, supporting infrastructure, open space, and a secondary access road. This report provides our findings on geotechnical aspects of the proposed development of the site and supplements our previous preliminary geotechnical engineering study (Hart Crowser 2010) and draft subsurface conditions reports (Hart Crowser 2015, 2016a, 2016b).

This report contains several sections. The main body of the report presents our findings and is organized as follows:

- Introduction;
- Site and Project Descriptions;
- Field Activities;
- Site Geology and Subsurface Conditions;
- Geologic Hazards; and
- Hazard Mitigation and Geotechnical Design and Construction Considerations for the Project.

Tables are in the text following their initial reference, and figures are at the end of the text. The field exploration procedures and logs are in Appendix A. The laboratory procedures and test results are in Appendix B. Appendix C presents vibrating wire piezometer (VWP) data and groundwater measurements Hart Crowser collected at the site. Appendix D presents logs of field explorations performed by Hart Crowser and others previously at this site. This report presents the results of our geotechnical assessment for the EIS; additional supporting information is provided in our previous study (Hart Crowser 2010). Appendix E includes supplemental Brightwater EIS outfall geophysical and bathymetric information.

2.1 Purpose

The purpose of our work is to assess geotechnical conditions (i.e., geology, soil, and groundwater and seismic conditions) at the site to support preparation of the EIS for the Project. This includes assessing potential impacts of geologic hazards that may impact the proposed development, and assessing how the proposed development would impact the surrounding environment, considering these potential geologic hazards. This report provides geotechnical engineering findings to support planning-level decisions, but is not intended to be sufficient for final design.

2.2 Scope

The scope of our work was based on "Summary of the Public EIS Scoping Process" from the Snohomish County Planning and Development Services (PDS), dated August 8, 2014; the detailed EIS scope (Draft 8.27.14) provided by EA Engineering, Science, and Technology, Inc.; Exhibit A of "Point Wells Mixed Use Redevelopment EIS, EIS Preparation Protocols and Guidance," dated September 17, 2014, and Point Wells Urban Center Review Completion Letter from the Snohomish County PDS, dated October 6, 2017.

Our scope of work to address the geotechnical engineering aspects at this phase of the Project includes:

- Describe existing soil and geologic/topographic conditions on and in the vicinity of the site, including the adjacent hillside area to the east (Section 5);

- Describe geologically hazardous areas on and adjacent to the site, including the relationship of the proposed development to identified geologic hazard areas (Sections 5 and 6);

- Evaluate anticipated earthwork associated with construction of the proposed redevelopment (Sections 6.4, 7.1.4, and 7.2);
- Describe proposed grading activities and construction techniques required or recommended for consideration for development, including sources of fill (Section 7.2);
- Analyze the potential for geotechnical impacts with development and for the No Action alternatives (Section 6);
- Assess potential for erosion during construction (Sections 6.4 and 7.1.4);
- Discuss potential vibration impacts to existing structures on and immediately adjacent to the site resulting from redevelopment activities including construction and truck traffic (Section 7.6.2);
- Discuss potential for vibration from the adjacent railroad operations to impact proposed development (Section 7.6.2);
- Analyze overall suitability of soil to accommodate redevelopment (Section 7);
- Discuss geotechnical impacts associated with development of the Secondary Access Road (Section 6);
- Identify mitigation measures necessary to minimize impacts on earth [soil] (Section 7);
- Respond to geotechnical comments in the Point Wells Urban Center Review Completion Letter Urban Center Comment Letter by PDS dated October 6, 2017, including slope stability at the Secondary Access Road (multi-disciplinary response form included with this submittal references specific sections of this report addressing County comments); and
- Present the results of our study in this report.

We developed our geotechnical engineering findings considering the combined geotechnical data from previous and current explorations, as well as our experience with the local geology. This study focuses on the proposed development alternatives described in the following section.

Description of contaminated soil and discussions related to Model Toxics Control Act cleanup/remediation processes area addressed in our separate environmental remediation approach memorandum (Hart Crowser 2018).

2.3 The Use of This Report

We completed this work in general accordance with our proposals and written authorization to proceed. This report is for the exclusive use of BSRE Point Wells, LP, and its consultants for specific application to the Project and site. We completed this study in accordance with generally accepted geotechnical practices for the nature and conditions of the work completed in the same or similar localities, at the time the work was performed. We make no other warranty, express or implied.

The explorations performed for this study represent subsurface conditions only at discrete locations across the Project site and that actual conditions in other areas could vary.

3.0 SITE AND PROJECT DESCRIPTIONS

3.1 Site Description

The Point Wells facility is in Snohomish County, Washington, on Puget Sound near the border of King County with Snohomish County (Figure 1). Figure 2 shows the existing site topography, which was provided by the Project team. The elevations in this report correspond to NAVD88, unless specified otherwise. Figure 3 is an aerial photo that shows existing site features and the location of soil borings used in our evaluation of the Project site.

The west side of the site consists of a semicircular area of about 56 acres adjacent to Puget Sound, referred to as the “Lower Bench” because it is at a lower elevation than the rest of the site. The southeast portion of the site is a more or less rectangular area of about 5 acres, referred to as the “Upper Bench” because it is at a higher elevation. The two areas are separated by the approximately north–south Burlington Northern Santa Fe (BNSF) railroad tracks.

On the east side of the proposed development, across the railroad tracks, is an ascending slope. The slope is approximately 150 to 200 feet high and is covered with vegetation. The average overall slope gradient ranges from about 18 to 50 percent (or about 3H:1V to 2H:1V), with gradients generally increasing from the south end to the north end of the site (Figure 4). The slope gradient varies locally, maximizing at 100 percent (1H:1V).

Several buildings and a retention pond are on the Upper Bench. The Upper Bench is relatively flat, with a steep ascending slope along its eastern perimeter having an average gradient of about 50 percent and locally steeper sections approaching 100 percent. A short concrete block retaining wall is located on the east portion of the Upper Bench, adjacent to the toe of the existing slope. The western boundary of the Upper Bench descends on a short steep slope to the BNSF railroad tracks.

The Lower Bench contains an asphalt plant and marine fuel terminal. The Lower Bench is generally flat with less than 10 feet of elevation change across the site. The Lower Bench is protected from the adjacent Puget Sound by a concrete seawall, sheet pile wall, and/or riprap.

Figure 3 is an aerial photograph of the site and shows impervious surfaces and roads. Over 200 borings and/or monitoring wells have been advanced at the site. Hart Crowser’s report titled “2008 Remediation System and Groundwater Quality Evaluation, Richmond Beach Asphalt and Marine Fuels Terminal” contains information on our most recent groundwater study. Because site use dates back to the early 20th century, there may be existing drain fields or other subsurface constructed features on the site. Utility and easement information is not part of our scope of work.

3.2 Project Description

We understand the site is being considered for development of a waterfront community of mixed use (office, retail, and residential). Potential development plans call for multiple mid- and high-rise buildings, supporting infrastructure, and open space.

Once specific building layout and structural loads are available, design-level geotechnical explorations and engineering analyses will be necessary to develop specific design criteria and recommendations for the Project.

3.2.1 Preferred Alternative

The Urban Center alternative includes construction of residential space, commercial/office space, and retail space. The Project would also provide passive recreational activity areas, open space, a public dock, and associated infrastructure. The alternative is anticipated to support approximately several thousand residents and several hundred on-site employees.

3.2.1.1 Urban Plaza at Upper Bench

As part of this alternative, an Urban Plaza would be developed on the Upper Bench and would include residential units and all of the proposal's commercial floor space. It would consist of three low-rise buildings (2 above ground and 1 below ground stories), and three tower buildings (13 to 15 stories). The towers would include two levels of below-grade parking and transportation service/access. The bottom level of the development would be at about elevation 25 feet.

3.2.1.2 Villages at Lower Bench

The South, Central, and North Villages described below would all be constructed on the Lower Bench. In general, the final grades in the South, Central, and North Villages would be raised about 15 to 30 feet above the existing grade of the Lower Bench over the majority of the development, with less grade change at the Puget Sound edge. The bottom of the lowest levels of the planned structures would be about 0 to 6 feet below the existing grades of the Lower Bench.

South Village. The South Village would include retail space and residential units. It would consist of five low-rise buildings (about 3 stories), two mid-rise buildings (about six stories) and six towers (11 to 16 stories). The South Village would have one to two levels of below-grade parking, depending on varying final site grades.

Central Village. The Central Village would include retail space and residential units. It would consist of 10 low-rise buildings (three to four stories), three mid-rise buildings (six to seven stories) and seven towers (14 to 17 stories). The South Village would have one to two levels of below-grade parking, depending on varying final site grades. There would also be a one-level public building with one level of below-grade parking in this area.

North Village. The North Village would include residential units. It would consist of three mid-rise buildings (six to eight stories), and four towers (13 to 16 stories). The North Village would have two levels of below-grade parking.

The site has an existing seawall approximately 3,300 feet long that is a combination of concrete, timber sheet pile, and rip-rap rock seawall on the Lower Bench. This wall would be totally removed and reconstructed. Most of the new seawall would be located 40 to more than 100 feet landward of its existing location. The primary purpose of this realignment would be to create approximately 5.7 acres of new intertidal habitat area.

3.2.1.3 Secondary Access Road

As part of the proposed redevelopment, a Secondary Access Road is proposed. Figure 2 shows the location of the proposed Secondary Access Road. It would connect 116th Avenue West to the southern part of the site by coming down the slope above the Upper Bench. It would wrap around the back of the Upper Bench near the base of the slope where it would cross the BNSF railroad tracks via a bridge to the Lower Bench at the north end of the Upper Bench. To accommodate road grades, retained fill up to about 40 feet above existing grades (60 feet above the lowest basement level) is proposed near the base of the slope. Limited sections of roadway cuts (up to 8 feet) and fills (up to 20 feet) are anticipated.

4.0 FIELD ACTIVITIES

To help assess soil conditions and potential geologic hazards, we completed a 250-foot soil boring at the top of the eastern slope, three deep borings along the Secondary Access Road (Figure 2), and installed vibrating wire piezometers (VWPs) to monitor groundwater levels in different stratigraphic units. Data from these additional deep borings supplement data from over 200 shallower borings previously completed on the eastern slope, Upper Bench, and Lower Bench at the site. Field reconnaissance was performed on the eastern slope to document slope conditions and evaluate potential landslide features identified on light detection and ranging (LiDAR) imagery of the site with respect to the proposed development alternatives. LiDAR imagery was collected in April 2013 and provided by the Washington State Department of Transportation (WSDOT 2013). As part of the reconnaissance, five hand-auger soil borings were advanced on the slope. Details of these activities are in the following section, and exploration locations are shown on Figures 2 and 3.

4.1 Soil Borings

In April 2015, soil boring HC-1 was advanced to 250 feet below ground surface (bgs) by Gregory Drilling of Redmond, Washington. A Hart Crowser geologist logged soil samples collected and subsurface conditions. Following completion of the soil boring, four VWPs were installed to record groundwater pore pressures in different geologic units.

In February of 2018, three new soil borings were advanced by Gregory Drilling of Redmond, Washington. HC-10 was drilled to 200 feet bgs near the crest of the bluffs and outfitted with three VWPs. HC-11 was drilled to 102 feet bgs near the mid-slope of the bluffs and one VWP was installed at 30 feet bgs. HC-12 was drilled to 52 feet bgs in the existing pavement of the Upper Bench.

Site geology and groundwater measurements are discussed in Section 5, below. Detailed boring logs are in Appendix A, and VWP calibrations and readings are in Appendix C.

4.2 Slope Reconnaissance

On April 21 and 22, and on May 26, 2015, two Hart Crowser geologists traversed the slope east of the BNSF railroad tracks. The primary focus of the reconnaissance was to document surface features on the steep slopes, identify potential geologic hazards, and evaluate potential landslide features identified on LiDAR imagery. This reconnaissance was limited to areas that were readily accessible and did not include a detailed survey of the slope. Observations made during the reconnaissance included identification of geologic contacts (interface of one predominant soil type with another), landslides, and other features related to downslope soil movement; springs, seeps, or other expressions of groundwater at the surface; location or evidence of surface water; and the extent and type of vegetative cover. Details of the reconnaissance are discussed in Section 5.1.5, and field observations are summarized on Figure 5.

4.2.1 Hand Auger Borings

During the field reconnaissance, five hand auger borings were advanced to approximately 3 to 8.5 feet bgs. Soil conditions encountered in these shallow borings are shown in Table 1. Hand auger locations are on Figures 2 and 3.

Table 1 – Hand Auger Details

Hand Auger ID	Depth in Feet	Depth in Feet – Soil Description	Depth to Water
HA-1	3	0 to 1 – Moist to wet, gray, silty, clayey sand (Colluvium) 1 to 3 – Wet, gray sand (Lawton Formation?)	1 feet bgs
HA-2	5	0 to 4 – Moist gray silty sand and sand silt (Colluvium) 4 to 5 – Wet, gray, sand	4 feet bgs
HA-3	4	0 to 5 - Wet, gray, silt, clayey, sand	At surface
HA-4	8.5	0 to 1 – Moist, gray, silt and sand (Colluvium) 1 to 2 – Moist, gray with orange mottled, silt 2 to 7.5 – Moist, gray, clayey silt 7.5 – 8 – Wet, gray, sand trace silt	7 feet bgs, rising to 2.5 feet bgs prior to backfill
HA-5	8	0 to 7 – Wet, gray, sand (Outwash) 7 to 8 – Moist, gray silty clay (Lawton Formation)	0 feet; water is at surface

Terms such as Colluvium, Outwash, and the Lawton Formation refer to soil units at the site that are described below in Section 5.1.2.

5.0 SITE GEOLOGY AND SUBSURFACE CONDITIONS

The following sections describe surface and subsurface conditions at the site.

5.1 Subsurface and Topographic Conditions

5.1.1 Site Geology

A geologic map of the site and surrounding vicinity based on the work by Booth et al. (2004) is shown on Figure 6. The surficial soil of the Lower and Upper Benches consist of artificial fill (af) and pre-Fraser deposits (Qpf), respectively. The pre-Fraser deposits are sedimentary deposits typically consisting of poorly to well-sorted gravel, sand, silt, and clay. The original ground surface of the Lower Bench was modified and fill was placed to raise grade for construction of the existing facility. The artificial fill consists of loose to dense, trace to silty, gravelly sand.

The surficial geologic units decrease in age to the east of the site. On the hillside east of the site, the pre-Fraser deposits are overlain by Lawton Clay (Qvlc), Advance Outwash (Qva), Vashon Till (Qvt), and Recessional Outwash (Qvr). The geologic map does not indicate the presence of a significant amount of colluvium on the slope. The colluvium that is present was deposited from ongoing erosion and historical landslides. In addition to these natural processes, the slope was likely graded to facilitate construction of the now-abandoned access road shown on Figures 2 and 3, as well as other structures built on the hillside. During our field reconnaissance, neighborhood residents reported observing fill material being deposited on the hillside during historical operation of the Point Wells facilities.

5.1.2 Soil Conditions

Soil conditions at the site and on the eastern hillsides are discussed in the following sections. Subsurface contamination during past use of the site is discussed separately for the EIS (Hart Crowser 2018), and so is omitted from this discussion.

The soil on the eastern hillside and the Upper and Lower Benches fall into six basic soil units, as indicated by our recent borings and historical borings. These soil units reflect the geologic depositional history at the site, and are, in order of increasing age, fill, colluvium, Vashon Till, Advance Outwash, Lawton Clay, and alternating pre-Fraser nonglacial fluvial and lacustrine deposits. Figures 7, 8, and 9 are generalized subsurface cross sections of the site and eastern hillside based on subsurface conditions encountered in the explorations. Descriptions of these soils are presented in detail below.

Fill. This layer was observed underlying the Upper and Lower Benches and consists of loose to medium dense, gray brown to brown to dark gray, moist to wet, none to silty, none to gravelly, sand and sandy gravel. The Fill layer extends to a depth of up to 5 feet bgs where observed in the borings and may be deeper at other locations. This Fill unit is below asphalt and concrete in the Upper Bench, and below a layer of surface gravel on the Lower Bench. The fill may contain cobbles and possibly boulders or debris.

Colluvium. This material consists of very soft, moist to wet, gray, none to sandy, silt and loose to medium dense, very moist, gray silty sand as indicated in some borings and observed on the eastern hillside. Scattered zones of gravelly sand were observed as well as scattered wood fragments and organic material.

Vashon Till. This layer consists of an unsorted mixture of silts, clays, gravel, cobbles, and occasional scattered boulders. The unit is compact and very hard or dense because of loading of as much as

3,000 feet of overriding ice during the last glaciation. This unit was generally at the surface in explorations at the top of the slope and was up to 56.5 feet thick, as observed in HC-1. The upper 10 to 15 feet of the till appeared weathered.

Advance Outwash. This unit generally underlies the Vashon Till and consists of dense sand, gravelly sand, and slightly silty, gravelly sand. The sand is compact and less cohesive because it lacks fines. This material varied from about 0 to 30 feet thick in explorations at the top of the slope. In general, the unit appears to be thicker to the north and may have been completely eroded by the Vashon Till in areas to the south. Perched water is frequently encountered in this material overlying fine-grained Lawton Clay below.

Lawton Clay. This unit underlies the Advance Outwash and generally consists of massive, hard clay and silt, with scattered silty sand and sand layers. The fine-grained materials (silts and clays) are less permeable, resulting in perched groundwater at its contact with the overlying Advance Outwash. This unit was 116 feet thick in HC-1, which was the only boring at the top of the slope deep enough to drill through the unit. While known to be relatively strong, Lawton Clay can weaken when exposed to water. Slickensides were observed on exposed outcrops during the field reconnaissance and in samples collected from exploration HC-1.

Pre-Fraser Nonglacial Fluvial Deposits. Pre-Fraser nonglacial fluvial deposits underlie the Lawton Clay on the eastern slope, the Colluvium in the Upper Bench and the Fill in the Lower Bench. This unit was observed in the borings in the Lower Bench and HC-1. Underlying the Colluvium on the Upper Bench and Fill on the Lower Bench, this unit consists of loose to very dense, moist to wet, gray to dark gray, none to gravelly, none to silty sand and none to silty, sandy gravel. Scattered shell fragments and trace scattered organic material were observed in this unit in the Lower Bench explorations. In HC-1, located on top of the east hillside, the fluvial deposits consisted of layers of very dense silty sand, clayey sand, and sand that alternated with lacustrine deposits (described in the next paragraph) from 175 feet bgs to the bottom of boring HC-1 at 248.5 feet bgs.

Pre-Fraser Nonglacial Lacustrine Deposits. This unit was observed to alternate with fluvial deposits (described in the previous paragraph) within the borings located in the Lower Bench. This unit consists of medium dense, wet, olive gray, silty sand to stiff to very stiff, sandy silt. Traces of scattered shell, gravel, and wood fragments were observed. In HC-1, located on top of the east hillside, nonglacial lacustrine layers of hard silt and clay alternated with fluvial deposits from 175 feet to the bottom of the boring at 248.5 feet bgs.

5.1.3 Groundwater

Our understanding of groundwater conditions at the site is based on field reconnaissance, observations reported during drilling, and VWP and water level measurements completed by Hart Crowser and others at the site. Groundwater conditions on the Upper and Lower Benches and the eastern slope are described in the following sections. The focus of our reconnaissance and VWP measurements was on the eastern slope. Our understanding of the groundwater conditions below the Upper and Lower Benches is from our 2010 analysis (Hart Crowser 2010). Note that measured groundwater levels are representative for the times indicated. Fluctuations in groundwater levels may occur because of variations in rainfall, tides, temperature, seasons, and other factors.

Perched groundwater can result from infiltrating groundwater encountering a low-permeability soil layer and building up as groundwater slowly flows laterally on top of the low-permeability layer. Soil layers below the low-permeability layer may not be saturated.

Confined groundwater conditions result when groundwater in a high-permeability soil layer wants to rise above the bottom of an overlying low-permeability layer. Groundwater pressures build up in the high-permeability layer because vertical flow is impeded. Soil layers above the confining low-permeability layer may not be saturated. Groundwater head is a measurement used to represent the groundwater pressure measured in soil pores, often referred to as pore pressure. Groundwater head is the height the groundwater would rise to in an open standpipe above the point at which the groundwater pore pressure is measured.

5.1.3.1 Upper Bench

Exploration B09-1 was advanced in December 2009. At the time of drilling, groundwater was encountered at a depth of 2.5 feet. This corresponds to an elevation of 44.5 feet.

As shown on Figure 3, several monitoring wells were previously advanced on the Upper Bench. The explorations shown on Figure 3 are 20 feet deep or greater. Water level was measured at the site on October 5, 2009, in monitoring wells MW-95 and MW-122. At that time, the groundwater in MW-95 was observed at an elevation of about 40 feet. Artesian flowing conditions were observed at MW-122, as indicated by water flowing from the top of the monitoring well. Artesian flowing conditions occur when groundwater is confined and groundwater pressures increase enough to cause groundwater to rise through the well and flow at ground surface. The ground surface elevation in MW-122 is approximately 48 feet.

5.1.3.2 Lower Bench

In Lower Bench explorations B09-2 and B09-3, groundwater was observed in B09-2 only, at a depth of 1.5 feet bgs in December 2009. This corresponds to an elevation of 5.5 feet. The soil was wet in B09-3 starting at a depth of 7.5 feet bgs, which corresponds to an elevation of approximately 3.5 feet.

In the vicinity of B09-2, several monitoring wells were previously advanced at the site, as shown on Figure 3. The explorations shown are 20 feet deep or greater. Hart Crowser measured water levels between October 5 and 7, 2009, for MW-42, MW-103, and MW-110. At that time, the groundwater elevation was between about 5 to 8 feet bgs.

5.1.3.3 Eastern Slope

Soil Boring Measurements. In exploration HC-1, located at the top of the north part of the eastern slope, perched groundwater was encountered at 186 feet elevation at the time of drilling. Groundwater was encountered in HC-10, HC-11, and HC-12 at elevations of 166, 130, and 46 feet, respectively, at the time of drilling. VWPs were installed in all but boring HC-12 after drilling using the grout-in method. The VWPs were placed in HC-1 to monitor groundwater conditions at the contact between the weathered and unweathered Vashon Till (229-foot elevation), within the Advance Outwash overlying the Lawton Clay (184-foot elevation), and in water-bearing silty sand and sand layers within the Lawton Clay (129- and 89-foot elevations). VWP's at the south part of the eastern slope in HC-10 were placed at 30, 60, and 90 feet bgs (elevations shown in Table 2), and placed in HC-11 at 30 feet bgs (elevations shown in Table 2). Water levels were measured in HC-1, HC-10, HC-11, and HC-12 as shown in Table 2 and on Figures 7 to 9. Because of the relative permeability of the soil layers, groundwater measurements indicate perched and/or confined conditions, and not all layers below the reported groundwater depth or elevation are saturated.

Table 2 – Vibrating Wire Piezometer Water Level Measurements

Boring ID	Approx. Ground Surface Elevation in Feet	VWP Elevation in Feet[1]	Date	Measured Head in Feet	Groundwater Depth in Feet	Groundwater Elevation in Feet
HC-1[1]	243	229	5/6/2015	7.6	6.4	236.6
			5/21/2015	6.9	7.1	235.9
			5/26/2015	6.9	7.1	235.9
		184	5/6/2015	39.0	19.8	223.2
			5/21/2015	40.0	18.7	224.3
			5/26/2015	40.5	18.3	224.7
		129	5/6/2015	55.3	58.7	184.3
			5/21/2015	57.2	56.8	186.2
			5/26/2015	58.0	56.0	187.0
		89	5/6/2015	38.4	115.6	127.4
			5/21/2015	38.2	115.8	127.2
			5/26/2015	38.4	115.6	127.4
HC-10[2]	180	151	3/23/2018	16.8	12.6	167.4
		121	3/23/2018	5.1	54.5	125.6
		91	3/23/2018	6.5	82.9	97.1
HC-11[2]	142	112	3/23/2018	22.1	7.5	134.5
HC-12[2]	47	31	3/23/2018	18.7	-2.2	49.2

Notes:

1. HC-1 VWPs installed on 4/22/15.

2. HC-10, -11, and -12 VWPs installed on 2/22/18, 2/26/18, and 2/19/18 respectively.

Groundwater heads measured at the VWP elevations were higher than anticipated based on piezometer measurements at the Woodway Landslide, which were typically about 8 feet or less as measured near the top of the Lawton Clay (Savage et al. 2000) and about 18 feet in a sand layer underlying the Lawton Clay (Landau 1998). Before installing the VWPs, we took measurements from each VWP in a 5-gallon bucket of water, which confirmed the VWPs were functioning properly. We also allowed sufficient time for the grout to set, as indicated by VWP temperature readings, and the readings have been fairly consistent over time, as shown in Table 2. More detailed VWP information, including raw data and VWP calibration certifications, are in Appendix C.

Slope Reconnaissance Observations. Numerous seeps, springs, and areas of wet soil were observed on the slope during our reconnaissance. The locations of surface water observed on the slope are shown on Figure 5. Surface water was generally observed at contacts above and below the Lawton Clay, as well as at sand layers and interbeds within the formation. The Vashon Till and the Lawton Clay are known to have relatively low permeability, resulting in confined and/or perched groundwater; however, pore pressure measurements from the VWPs and observations of seeps and springs along the slope indicate the presence of these water-bearing zones within these units. Our groundwater measurements and field observations suggest that multiple groundwater zones are present on the hillside.

We observed numerous streams that may be seasonal on the hillside above the site. Because of dense vegetation on the slope, the origin of most of the small streams was not determined, so it is unclear how much flow is due to stormwater runoff and how much is due to groundwater flow from seeps and springs. Stream discharge near the bottom of the hillside was generally approximately 5 to 10 gallons per minute or higher in the larger creeks at the time of our observations in April and May 2015. The larger drainages, Drainages 1 and 2 (Figure 2), started at the top of the slope and were primarily fed by runoff.

A relatively large, roughly contiguous area of wet soil and scattered ponded surface water was observed on the eastern slope near the abandoned access road (Figure 5). The access road fill and compacted base material appear to be damming surface water on the slope, creating small ponds and large areas of wet soil. Surface water in this area likely originates from the Advance Outwash and from sandy layers and joints within the Lawton Formation.

Water-bearing sand layers and joints were observed in the Lawton Formation, as confirmed by the pore pressure readings from VWPs placed in HC-1 (Table 2) within sandy zones of the formation. Field observations of exposed Lawton Formation confirmed the presence of joints and thin sand layers. Similar observations were made during investigations of the Woodway Landslide to the north (Landau 1998); however, the post-landslide groundwater pore pressures were lower at the Woodway Landslide than those recorded at HC-1 in the eastern slope above the site.

Near the bottom of the slope, approximately 150 feet east of the railway at an elevation of roughly 65 feet, a confined layer of wet sand was observed in hand auger boring HA-4. The water was initially observed at 7.5 feet bgs within a sand unit and quickly rose to apparent equilibrium at 2.5 feet bgs, indicating pore pressures in the sand were confined by the overlying silty clay.

Near the bottom of the slope, a retaining wall extends along a portion of the BNSF tracks and intercepts the creeks that drain the hillside, channeling the water into a culvert east of the railway.

5.1.4 Site Topography

The Upper and Lower Benches are generally flat, but the slope east of the railway rises approximately 150 to 200 feet. Site topography is shown on Figure 2 and LiDAR imagery is shown on Figure 5. The majority of the slope is steeper than 33 percent (3H:1V), and is designated a landslide hazard area under the Snohomish County Code (SCC 30.62B.340), as shown on Figure 10; including setbacks from the 2007 SCC 30.62.340 vested for this project. However, the steepness of the slope varies considerably. LiDAR-derived slope calculations for the site and the east hillside are shown on Figure 11. Slope profiles through representative sections of the site and slopes to the east are shown on Figure 4. The overall slopes are less steep moving from north to south.

In general, steeper slopes and vertical scarps were encountered in the northern portion of the slope, adjacent to Drainages 2, 3, and 4, which are located in the middle and northern portion of the slope (Figure 2). A near-vertical, approximately 50-foot-high bluff is at the top of the northwest slope, just west of residential homes. Throughout the site, the steepest slopes were generally adjacent to drainages or along the upper 1/5 of the slope of the bluffs.

The main portion of the Lower Bench is generally flat, with approximately 10 feet of elevation change across the area. The Upper Bench is also generally flat with only a few feet of elevation change across the area.

5.1.5 Slope Reconnaissance

We conducted field reconnaissance of the site with a primary focus on the condition of the steep slopes east of the BNSF railroad tracks. No significant rainfall had occurred in the previous week. The SCC, Section 30.62B, requires the geotechnical study to include specific information relevant to the geologic hazards. The following section provides relevant information for landslide hazards based on our field reconnaissance. Figure 5 shows LiDAR-derived surface topography and important features observed during our reconnaissance. In Figure 5, “recent” landslide activity refers to observed evidence of slope movement interpreted to have occurred within the last 20 years, and “historical” refers to observed evidence of older landslide activity.

Observed Landslides or Downslope Soil Movement. Evidence of historical landslide activity was observed during our field reconnaissance of the steep slope east of the BNSF railroad tracks. Above the site, between Drainages 1 and 2, evidence of slope movement was observed, as indicated by pistol-butted leaning or dead trees and hummocky topography. It is unclear whether activity in this area is related to a deep rotational slide as described in a 2004 geotechnical report (Earth Consultants 2004) or a result of ponded surface water and highly saturated soil resulting in localized shallow rotational slides, sloughing, and small debris flows. Shallow landslides are more typical in Puget Sound bluffs and generally do not travel as far as deep-seated slides (see Potential Landslide Travel Distance/Runout in Section 5.1.6.1). Additional explorations and slope instrumentation (e.g., inclinometers) could be used to better characterize this area during design.

The abandoned asphalt access road connecting historical Chevron operations on top of the hillside to the terminal below may be contributing to the extremely wet soil conditions generally observed in the area. The roadway and compacted base material appear to be damming surface water on the slope, creating small ponds and large areas of wet soil. It is not clear whether the road was abandoned because of landslide activity. The road is now barely recognizable because portions have been transported down the slope by erosion and localized instability, and the road is covered by dense vegetation.

As documented in our preliminary geotechnical engineering study (Hart Crowser 2010), a clearly defined head scarp or crest was observed on the slope east of the Upper Bench. Immediately below the scarp, an oversteepened slope was observed, followed by hummocky terrain to the toe of the slope. We observed trees of similar ages grouped together, trees leaning downslope (indicating downslope soil movement), and trees tilted upslope (indicating potential soil block rotation as part of landslide activity). These observations are consistent with the landslide descriptions from the coastal atlas of the area (Ecology 2004), as shown on Figure 12.

Our observations found recent landslide activity to be primarily confined to the immediate vicinity of the drainages and likely the result of erosion at the toe of the slope and saturated soil conditions resulting from seeps and springs on the hillside. Examples of these slides are shown in Photographs 1 and 2.

Photographs 1 (top) and 2 (bottom): Localized small landslides near Drainage 1.

Evidence of larger block slides and bluff erosion was observed along the northern portion of the upper bluff. At the base of the upper bluff, where the Advance Outwash-Lawton Clay contact could be observed, seeps within the Advance Outwash formed a small creek (Photograph 3).

Photograph 3: Creek forming from seepage at the Advance Outwash-Lawton Clay contact.

Evidence of older, large rotation and block failure landslides were observed adjacent to drainages in the northern and southern portions of the hillside, but none appeared to have been large enough for landslide debris to reach the site. In general, as indicated in cross Section B-B' (Figure 8), colluvium was widespread on the slope, indicating relatively frequent historical landslide activity.

Along the toe of the slope and at a wood retaining wall, evidence of surficial, slow downslope movement (i.e., creep) was observed east of the BNSF railroad tracks, as shown on Figure 2. In some locations, a small amount of soil had eroded from behind the wall. In some areas, the wall itself appeared to bulge out slightly because of soil movement.

A concrete ecology block wall was observed at the toe of the slope in the Upper Bench area during our 2010 reconnaissance. Its presence suggests that soil needed to be retained in this area because of cutting of the toe of the slope and/or past landslide activity. The slope in this area was not explored during the site visit because of access limitations.

Significant Geologic Contacts. Because of slope vegetation, observation of significant geologic contacts was limited. As mentioned above, Vashon Till, Advance Outwash, and Lawton Clay were observed in the upper portion of the hillside and generally correlated with drilling observations.

In the lower third of the slope, a contact was observed between the pre-Fraser Formation and the overlying Lawton Clay during the 2010 reconnaissance. Hand auger boring HA-4 appeared to encounter Pre-Fraser or Whidbey Formation sands underlying the Lawton Clay.

In other areas of the slope, exposed soil appeared consistent with expected geology, as shown on Figure 6. On the slope between the Upper Bench and the BNSF railroad tracks and south of the abandoned bridge, an exposed colluvium face was observed. The presence of the colluvium is consistent with the area being the site of past landslide activity. In Drainage 2 (Figure 2), a near-vertical exposure of Lawton Clay was observed at approximately elevation 150 to 170 feet. Overlying this unit, wet sand and seeps were observed within the Advance Outwash. These exposures are consistent with the geologic map of the area.

Location or Evidence of Any Springs, Seeps, or Other Surface Expressions of Groundwater. As discussed Section 5.1.3, numerous springs and seeps were identified on the eastern hillside. Large areas of wet soil and surface water were observed in several areas on the slope, near the abandoned Chevron access road. The observed seeps and springs appear to be primarily flowing from Advance Outwash sand overlying the Lawton Clay and from sand layers and joints within the Lawton Formation. Pooled water was observed at the toe of the slope located along the east side of the BNSF railroad tracks.

During our field reconnaissance, we identified two primary drainages (Drainages 1 and 2) extending from the top to the toe of the slope, as shown on Figure 2. Two additional drainages (Drainages 3 and 4) were located north of the primary drainages and did not appear to extend to the top of the slope, although this was not verified in the field because of dense vegetation and steep slopes. The estimated extent of the creeks is shown on Figures 5 and 11. Seeps and springs appear to account for a large portion of the water in all the drainages, particularly in the northern portion of the hillside.

Location or Evidence of Any Surface Water. Streams in Drainages 1 and 2 were observed to originate from upslope runoff. Drainage 1 originates from a retention pond at approximately elevation 175 feet. Immediately below the retention pond, a 6-inch-diameter pipe was observed to be leaking into the stream at a rate in excess of roughly 10 gallons per minute. Drainage 1 empties into a 6-foot-deep retention pond on the northeastern part of the Upper Bench. At the time of the field visit, the retention pond was full and water was continuously flowing through it, despite the lack of recent rainfall.

Drainage 2 begins at approximately elevation 235 feet, where a storm drain discharges to the surface near the private property gate at the end of 238th Street Southeast, as shown in Photograph 4.

Photograph 4: Surface runoff at gate to the private property at the top of the slope, above Drainage 2.

Surface water was observed west of the existing detention pond on the Upper Bench during our 2010 investigation. The water was observed to have migrated to the surface from below existing asphalt. We understand previous test results indicated the water was most likely linked to a water pipe in the perimeter of the Upper Bench.

During our 2010 investigation, an unidentified pipe was observed on the slope between the Upper Bench and the railroad tracks. At the time, water was visible flowing from the pipe and ice was present on the ground below the discharge.

Numerous pipes that are mostly buried and likely related to historical Chevron activities at the top of the slope were observed near Drainage 1. As mentioned above, one of these was leaking near the upper retention pond, as shown in Photograph 5. It is unclear whether water is conveyed through the other pipes.

Photograph 5: Leaking pipes below retention pond in Drainage 1.

Extent and Type of Vegetative Cover. The vegetation on the slope generally consisted of mature deciduous trees and second-growth conifers. The understory is heavily vegetated with brush and small trees. In areas near seeps, hydrophytic plants such as horsetail, cattail, and watercress were observed.

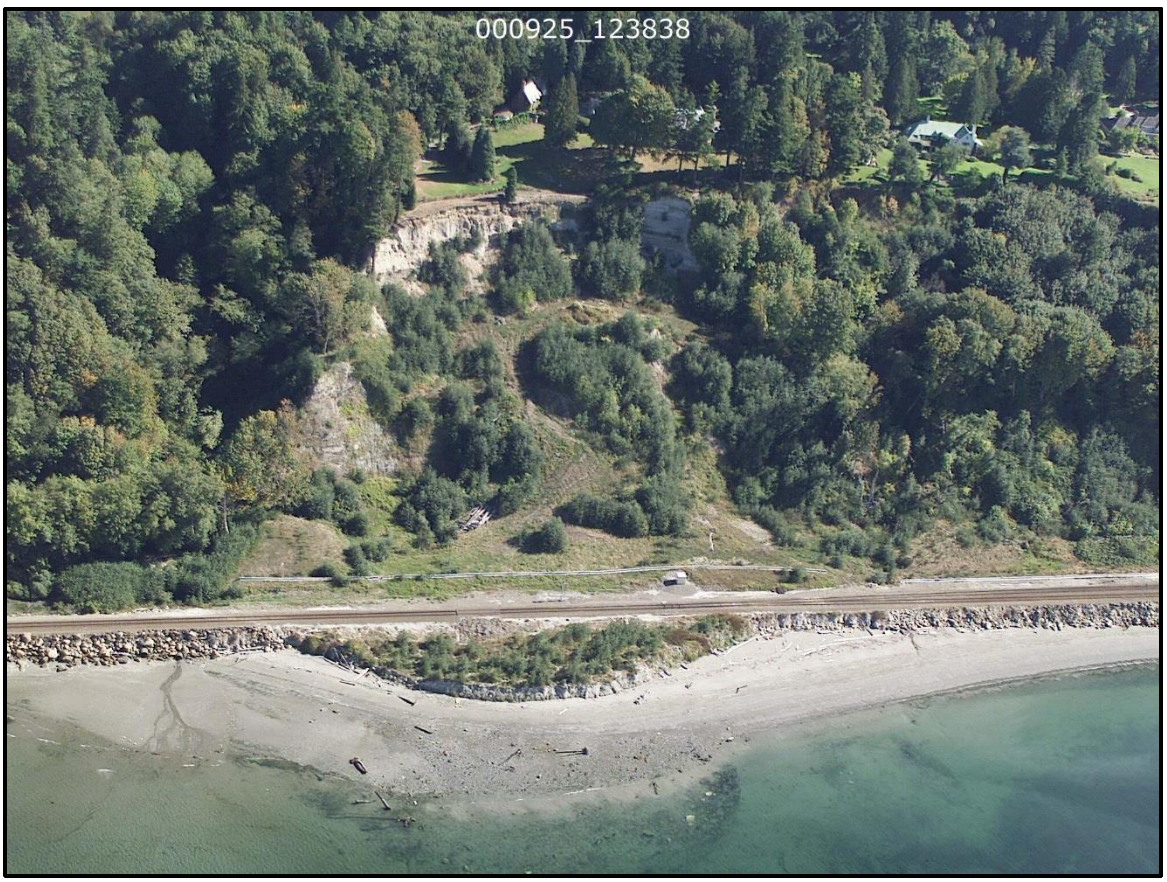
5.1.6 Steep Slope Assessment

In general, landslides on steep slopes adjacent to Puget Sound are common. Coastal bluff erosion is an ongoing, natural process. Our investigation and numerous previous geotechnical and slope assessments have been completed in the vicinity of the site and along other coastal bluffs in the region. Landslides of varying sizes have occurred on the slope above the site and will continue to occur unless engineering controls are put in place to stabilize the slope.

Our field reconnaissance identified many areas where landsliding has occurred or is ongoing. In general, most of the recent slope movement appears to be related to wet surface soil, seeps, and surface water erosion, which causes small block failures, localized rotational slides, and surface sloughing, as shown in Photographs 1 and 2. However, evidence of larger landslides was observed on the steeper bluffs located northeast of the site and above the Upper Bench. It is unknown whether runout from these larger slides reached the site.

Wet weather and similar subsurface conditions likely triggered these larger slides. In both areas, sand with a relatively high hydraulic conductivity underlies the relatively impermeable Vashon Till and the fine-grained layers within the Lawton Clay. It appears likely that increased pore pressures in these sand layers resulted in increased groundwater flow from the formation to the surface as springs or seeps and decreased soil strength. Under these conditions, increased rates of erosion undermine the overlying material, generally causing surface sloughing or localized shallow landslides. If the erosion becomes severe enough, block failure landslides can occur if a large section of the overlying material becomes undermined. If pore pressures build up high enough behind the face of the bluff, deep-seated landslides may be triggered.

Large, deep-seated landslides have occurred in the vicinity of the site. The well-documented Woodway Landslide, approximately 1,500 feet north of the site and shown in Photograph 6, is an example of the type of large, deep-seated landslides that occur on Puget Sound coastal bluffs. The Woodway slide followed a prolonged period of heavy precipitation, which resulted in increased water infiltration into the subsurface, increased groundwater pore pressures, and reduced soil strength; these combined factors are believed to have triggered the landslide (Landau 1998 and Savage et al. 2000). Based on finite element slope stability modeling, Savage et al. estimated the slide was triggered when the accumulation of perched groundwater above the Lawton Clay increased to about 16.5 feet from its typical 8 feet measured over a period of 2.5 years after the slide occurred.



Photograph 6: 1997 Woodway Landslide in 2000 (Ecology 2002).

5.1.6.1 Slope Stability Analysis

Many factors affect the stability of slopes including:

- Soil strength;
- Angle of existing slope;
- Slope height;
- Static loads/surcharges on or above the slope;
- Seismic earthquake loadings; and
- Groundwater conditions.

We analyzed slope stability along Sections B-B' (in 2015) and G-G' (in 2018) shown on Figures 2 and 3. The cross sections with the steepest topography were selected since they appear to represent the most critical slope conditions and are near geotechnical borings, and water level wells/VWPs. We performed slope stability analysis on Section B-B' which is a tall, steep section of the bluff adjacent to the site at the north end to provide a preliminary assessment of the risk and impact of a potential deep-seated landslide similar to the Woodway Landslide to the north of the site. We analyzed slope stability at Section G-G', which was identified as the critical section through the proposed Secondary Access Road above the upper bench at the southeast part of the site. Additional slope stability evaluations will be needed to assess other areas of proposed development during design.

We performed limit equilibrium stability analysis using the computer program SLOPE/W Version 8.11.1 (Geo-Slope International 2013) for the 2015 analyses. We used the program SLIDE 2018 (Rocscience, Inc.) for our current (2018) analyses. The analysis method calculates the ratio of resisting forces to driving forces (i.e., factor of safety or FS) to aid in determining if a specific set of conditions achieves "stable" conditions. A factor of safety of 1.0 or less indicates unstable conditions. We used the Morgenstern-Price method (satisfies both moment and force equilibrium) for slope stability analysis to search for rotational circular surface failure mechanisms, in both programs.

Soil properties used in the analyses were interpreted from the borings near each section and are shown in each stability figure. Piezometric surfaces in the slope were identified by the VWPs installed in the borings. We used the topography, soil stratigraphy, and soil parameters shown on Figures 13 to 17 for 2015 analyses and on Figures 18 to 25 for 2018 analyses. These properties were estimated based on our field observations, typical soil properties for the same or similar geologic units in the Puget Sound region, and our local experience with similar soil types.

Section B-B' North, High, and Steep Bluff Slope. The stratigraphy for the slope stability section includes the assumed presence of sand layers within the Lawton Clay to model the influence of the measured groundwater pore pressures. Because these sandy, higher-permeability layers are perched and/or confined layers with little evidence of static groundwater in the lower-permeability Vashon Till and massive clays in the Lawton Clay, pore pressures were only applied to the higher-permeability layers in which the pore pressures were measured. The four piezometric lines shown on Figure 13 for Section B-B' were only applied to the adjacent sandy layers in the model. The piezometric heads, or pore pressures, are based on the measurements in HC-1, which is set back about 400 to 600 feet from where seeps or springs in these layers would occur at the slope face and where potential failure surfaces are likely to occur. While we anticipate that piezometric heads would decrease toward the face of the slope where groundwater emerges as seeps and springs at atmospheric pressure, we conservatively assumed the piezometric lines were approximately horizontal until reaching the slope face.

We evaluated two cases for a deep-seated landslide for both static and seismic conditions: (1) a shallower failure of the steepest portion of the profile and (2) a deeper failure of a large portion of the bluff. The seismic condition was modeled using a pseudostatic approach that applies a horizontal force coefficient (k_h) to the slope to represent forces experienced during a design earthquake. A k_h of one-half the design peak ground acceleration (PGA; see Section 6.2.2.2) equal to 0.168 g was used in the seismic slope stability analysis.

Slope stability analysis results for Section B-B’ are summarized in Table 3 and shown on Figures 14 to 17. Table 3 shows Section B-B’ slope stability analysis results indicating the effect that groundwater has on stability at this location. These “drained case” is intended to provide a frame of reference for the influence of groundwater conditions on slope stability. The estimated factors of safety indicate the slope is marginally stable to stable under current conditions and the estimated groundwater heads. However, the estimated seismic factors of safety are less than 1, indicating a slope failure would occur for the assumed ground acceleration and groundwater conditions. The results suggest slope drainage would generally be affective to achieve the minimum factors of safety required in the SCC.

Table 3 – Summary of Slope Stability Factors of Safety

Section		Scenario (Piezometric Surface Estimated from VWPs)	Factor of Safety (FS)	
			Static	Pseudostatic
2015	B-B'	Existing Conditions - Shallow Slip Surface	1.11	0.82
		Existing Conditions - Deeper Slip Surface	1.29	0.87
		Existing Conditions - Shallow Slip Surface (No Groundwater/Drained Case)	1.40	1.11
		Existing Conditions - Deeper Slip Surface (No Groundwater/Drained Case)	1.68	1.19
2018	G-G'	Existing Conditions - Shallow Slip Surface	1.26	0.86
		Proposed 2 Walls - Shallow Slip Surface (50 k/ft shoring force)	1.33	0.90
		Proposed Wall + Backfill - Medium Depth Slip Surface (78 k/ft shoring force)	1.97	1.11
		Proposed 2 Walls + Upslope Anchor Block - Medium Depth Surface (50 k/ft shoring force + 60 k/ft anchor block)	2.09	1.13

Notes:

a. County minimum factors of safety for development in landslide areas are 1.5 for static and 1.1 for seismic cases per SCC 30.62B.340(3)(b).

b. Figures are included for shaded cells.

Section G-G’ South, Flat, Secondary Access Road Slope. Perched groundwater conditions were observed with up to three piezometric surfaces observed in the slope at different elevations.

Conservatively, the highest groundwater surface was applied to the entire thickness of the soil profile for analyses at Section G-G'.

Slope stability analysis results for Section G-G' are summarized in Table 3 and shown on Figures 18 to 25. Section G-G' was first analyzed under existing conditions to provide a baseline for the factor of safety in the slope. Results show the existing slope is stable under static conditions, but a factor of safety less than one in pseudostatic conditions indicates unstable conditions are expected in the event of the design earthquake (Figures 19). These results indicate the need for a permanent retaining wall to achieve target factors of safety at the Secondary Access Road.

Two retaining wall alternatives were considered to support the slope above the Secondary Access Road. The first alternative considered two retaining walls on either side of the road. We anticipate this would require permanent ground anchors for the west wall and an internally stable (tierods to west wall, mechanically stabilized earth, counterfort, etc.) east wall. The second alternative would have an anchored west wall, like the first option, and backfill to the existing slope. For both options, the downslope retaining wall is also adjacent to the Urban Plaza basement at a minimum elevation of 25 feet, creating a retained soil height of about 60 feet high.

First, the two-wall option was analyzed to determine a shoring force on the order of 50 kips per foot of wall length is necessary to retain the roadway section. After applying this force in the model, our analyses show the proposed system meets minimum factor of safety requirements under static conditions but is unstable in pseudostatic conditions (FS<1, Figures 20 and 21). The wall was modeled as a high strength soil material to prevent internal instability of the retained section, but still allow a large slope failure through the material. The two-wall concept required additional up slope support of 60 kips per foot of wall (e.g., anchor block and ground anchor in addition to the west wall shoring force of 50 kips per foot of wall to reach the minimum required factors of safety (Figures 24 and 25).

The one wall with backfill option would require a shoring force of approximately 78 kips per foot along the retaining wall for internal stability due to the larger amount of material to be retained. The backfill acts as a buttress to existing slope to increase the factor of safety in both static and pseudostatic conditions over the existing slope. No additional up slope support is required (Figures 22 and 23).

Both options bring the factor of safety of the proposed roadway location above the minimum requirements for Snohomish County as shown in Table 3. The wall loads indicated are feasible based on our local experience with seismic wall loads as high as 190 kips per foot of wall. Both wall options require appropriate drainage measures (see section 7.1.1).

Potential Landslide Travel Distance/Runout. Models are available to estimate landslide travel distance, or runout, but they do not account for trees and vegetation, which may become entrained in the debris flow (Harp et al. 2006). The best available information on runout lengths is measured data from actual debris flows. The USGS evaluated Puget Sound coastal bluffs from Seattle to Everett following the significant landslide events of the 1996 to 1997 rainy season, as reported by Baum et al. (2000).

Baum et al. mapped 326 landslides in their study, and Harp et al. evaluated the landslide runout data from Baum et al. The mapped landslides included three shallow earth slides or debris flows on the slope east of the site and the Woodway Landslide about 1,500 feet to the north of the site. Runout lengths were measured from the landslide headscarp to the furthest edge of the mapped debris downslope. The three mapped landslides adjacent to the site were of similar size, had a runout length of about 155 feet, and did not reach the toe of the slope. The Woodway Landslide had a runout length of about 770 feet, and the landslide debris extended about 425 feet from the toe of the slope across the BNSF railroad tracks and into Puget Sound. The Woodway Landslide was one of two landslides in the study with a runout length greater than 650 feet. The average (50th percentile) runout length of the landslides studied was about 200 feet, and the 90th percentile runout length was about 330 feet or less. The Baum et al. study represents a small sample size, because it primarily includes landslides occurring over a single rainy season during which landslide activity was primarily associated with two significant rain events, one in January and one in March (Harp et al. 2006). However, the study provides some of the most valuable information on landslide runout for the coastal bluffs in this stretch of Puget Sound.

While subsurface conditions in the slope east of the site appear similar to those at the Woodway Landslide, the overall slopes adjacent to the site appear flatter than the Woodway Landslide site was estimated to be prior to sliding. As shown on Figure 4, the average slope gradient of Section B-B' is about 40 percent east on the hillside at the north end of the site, and slopes generally appear to flatten moving south (20% average at Section G-G'). Savage et al. (2000) estimated the pre-failure slope gradient at the Woodway Landslide was about 70 percent, and we estimated similar pre-failure slope gradients of about 60 to 80 percent from the USGS Edmonds West Quadrangle Map. Using the same map, we checked the slope of Section B-B'; our results using the map are similar to slopes described in the profile from the site survey.

6.0 GEOLOGIC HAZARDS

The SCC includes requirements for the protection of critical areas according to the Growth Management Act (RCW 36.70A.060 and 36.70A.170). Our geotechnical study addresses critical areas that are geologic hazards. Specific standards are provided in Critical Area Regulations (CAR) Section 30.62B.300 for treatment of erosion, landslide, seismic, mine, volcanic, and tsunami hazard areas. The following sections describe applicable geologic hazards and their potential impacts to the proposed development. Figure 10 shows the geologic hazard areas relevant to the site.

Because of the distance between the site and known mine and volcanic hazards, the risk for these particular hazards is low for the Project site. Potential hazards associated with sea level rise and coastal/shoreline erosion from wind and wave energy are addressed in a separate technical report by Moffat & Nichol (2018).

The following section describes the impacts of the proposed development on geologic hazard areas, as well as the potential impacts of the geologic hazard areas on the proposed development. Preliminary considerations for mitigating these impacts are discussed in Section 7.

6.1 Landslide Hazard Areas

SCC 30.62B defines landslide hazard areas as "areas potentially subject to mass earth movement based on a combination of geologic, topographic, and hydrologic factors, with a vertical height of 10 feet or more." This includes areas with slopes that are steeper than 33 percent, where the geologic contacts are susceptible to landslide activity, and where springs or groundwater seeps are present. Landslide hazard areas also include areas of historical landslide activity and areas susceptible to undercutting by waves.

According to the SCC, a structural setback is required from the top and bottom of the slope unless the County approves a deviation. The toe of the slope is defined by SCC 30.91S.390 as the lowest first significant and regular break in the slope. The top of the slope is defined by SCC 30.91S.400 as the top of the first significant and regular break in a slope. The minimum top of slope setback is 50 feet, or the height of the slope divided by three. The minimum toe of slope setback is 50 feet, or the height of the slope divided by two. Figure 10 shows the landslide area and setbacks from the top and toe of slope based on a slope height of 200 feet.

Impact

The impact of the development to the site can be mitigated, provided that appropriate setbacks (which may be greater than the code minimum) or engineering solutions are used. Slope stabilization measures to minimize impact to the slope are described in Section 7.

Lower Bench. Development of the Lower Bench would have minimal impact to the existing slope conditions. The proposed development generally appears to be outside the standard code setback distance. Based on the estimated landslide runout (distance traveled) lengths measured from the landslide scarp in Harp et al. (2006) for the 50th percentile (average) and 90th percentile, it is not anticipated landslide runout would reach the Lower Bench if a static slope failure occurred. However, if a landslide on the scale of the Woodway Landslide were to occur (greater than 99th percentile), the landslide runout would reach the proposed development. In general, as the slopes become less steep overall from north to south, the potential impact from the landslide hazard area likely decreases. The retaining wall on the west side of the railroad to retain site grades as much as 30 feet above existing grades site would prevent most landslide runout from affecting the development on the Lower Bench. Additional evaluations would be needed during design to better assess potential landslide runout and design mitigation for the different areas of the slope and development.

For the seismic case, the anticipated runout is less clear because Harp et al. (2006) is based on extreme weather events rather than on a seismic event, and these two events would typically not be combined for design given the low probability of the two events occurring at the same time. Additional investigation and analyses would be needed during design to better define groundwater conditions (e.g., additional borings and piezometers) and better assess the likelihood of a seismic failure and anticipated seismic slope displacement.

Upper Bench. Development of the Upper Bench would impact the existing slope conditions. Portions of the proposed development would be inside the standard code setback distance. Because the Upper Bench is directly at the base of a section of shorter steep slopes that have slid in the past, slope failures above the Upper Bench would likely result in potential landslide debris runout reaching the proposed development without any retaining walls. Excavation at the Upper Bench at the toe of the adjacent steep slopes would be required for below-grade structures. The temporary shoring for excavation and permanent retaining structures would be designed to accommodate the proposed development and mitigate landslide hazards. Retaining walls required for the Secondary Access Road would improve slope stability as discussed below.

Secondary Access Road. Development of the Secondary Access Road on the slope face would affect the existing slope conditions. Grading would be performed on or adjacent to steep slopes and observed recent landslides. Areas of cut and fill would be necessary, and drainage along the alignments would likely be impacted and require mitigation. Adding a Secondary Access Road would increase impervious surfaces on and adjacent to the landslide hazard areas. Surface water drainage controls would be designed to prevent increased risk of landslides from surface water runoff associated with the Secondary Access Road. Specific impacts to landslide hazard areas are discussed below.

- The road would cross steep slopes and cross through a historical landslide area immediately above the Upper Bench. The alignment would include grading on the steep slopes over about 600 feet, which would include up to about 20 feet of fill and 8 feet of cut. However, most of the alignment would be on shallower slopes, so minimal grading would be necessary.
- Temporary construction disturbance would be significantly less than that associated with secondary along the former abandoned road farther north on the east slope.
- The proposed embankment and associated retaining wall at the base of the steep slope above the Upper Bench (about 40 feet above existing grades) would increase slope stability.
- The proposed fill and wall would cut across Drainage 1, and the design would accommodate slope drainage (e.g., convey to new creek inlet structure moved further upstream from current location). Drainage of the existing slopes would be accounted for in the design so that the stability of the existing and proposed slopes would achieve stability factors of safety noted in Table 3.
- Additional slope stabilization measures, such as surface water and groundwater controls, may be necessary to mitigate potential deep slope instability that may affect the proposed road.

6.2 Seismic Hazard Areas

The site is in a seismically active area. In this section, we describe the seismic setting at the Project site, discuss potential development of a code-based design response spectrum, and discuss seismically induced geological hazards.

6.2.1 Seismic Setting

The seismicity of Western Washington is dominated by the Cascadia Subduction Zone (CSZ), in which the offshore Juan de Fuca plate is subducting beneath the continental North American plate. Three main types of earthquakes are typically associated with subduction zone environments—crustal, intraplate, and interplate. Seismic records in the Puget Sound area clearly indicate the existence of a distinct shallow zone of crustal seismicity (e.g., the Seattle Fault) that may have surficial expressions and can extend to depths of up to 25 to 30 kilometers (km; 15 to 18 miles). A deeper zone is associated with the subducting Juan de Fuca plate and produces intraplate earthquakes at depths of 40 to 70 km (24 to 42 miles) beneath the Puget Sound region (e.g., the 1949, 1965, and 2001 earthquakes) and interplate earthquakes at shallow depths near the Washington coast (e.g., the 1700 earthquake, with an approximate magnitude of 9.0).

6.2.2 Seismic Design

At this time, we assume that seismic design of the proposed development would be in accordance with the 2015 International Building Code (IBC). The basis of structural design, including retaining walls, for this code is two-thirds of the hazard associated with the risk-targeted maximum considered earthquake (MCE_R). The basis of slope stability evaluations is also two-thirds of the hazard associated with MCE_R, in accordance with SCC 30.62B.340(3)(b) and standard of practice. IBC refers to ASCE 7-10 for the basis of soil liquefaction evaluation, which is the full maximum considered earthquake geometric mean (MCE_G) peak ground acceleration (PGA) not adjusted for targeted risk. The maximum considered earthquake for IBC is an earthquake with 2 percent probability of exceedance in a 50-year time period, which corresponds to an average return period of 2,475 years.

We obtained the seismic hazard from the United States Geologic Survey 2008 National Seismic Hazard Maps (USGS 2008) for latitude 47.781 and longitude –122.395. This location corresponds most closely with the middle of the Lower Bench. The parameters for a code-based seismic design provided below assume Site Class B soil and need to be adjusted using the appropriate site factors for the actual soil site class, as discussed in the following subsections.

- Risk-targeted maximum considered earthquake (MCE_R) seismic parameters for structural design and slope stability
  - Spectral response acceleration at short periods (S_S) = 1.262 g
  - Spectral response acceleration at 1-second period (S_1) = 0.495 g

- Maximum considered earthquake geometric mean (MCE_G) seismic parameters for liquefaction evaluation
  - PGA = 0.500 g
  - Magnitude = 7.0

6.2.2.1 Upper and Lower Benches

Without consideration of liquefaction-susceptibility, the soil site class was determined for the current explorations advanced in this study. Based on B09-1, the Upper Bench soil were determined to be Site Class E. However, soil conditions varied across the Upper Bench, and previous borings suggest these soils may be classified as Site Class D. Based on B09-2 and B09-3, the Lower Bench soil were determined to be Site Class D. However, soil conditions varied across the Lower Bench, and some of the previous borings suggest these soils may be classified as Site Class E. After the building locations are determined, we recommend advancing location-specific deep borings to better characterize the soil site class.

We performed liquefaction analyses for the three explorations advanced at the site as part of our geotechnical study in 2010. We checked our analysis based on the updated 2015 IBC liquefaction evaluation criteria, and found the results were similar.

The factor of safety against liquefaction in the loose to medium-dense, saturated soil layers was less than 1.2 in the Upper Bench and Lower Bench locations. In the Upper Bench, layers in the fill and colluvium were estimated to be liquefiable. One existing exploration (MW-95) on the Upper Bench suggests low liquefaction potential, but the other exploration (MW-122) suggests high liquefaction potential. This dichotomy reflects variability in soil conditions observed at the site.

In the Lower Bench, layers in the lacustrine deposit (up to 47 feet bgs) were estimated to be liquefiable in B09-2. Isolated layers in the upper 23 feet of B09-3 have the potential to liquefy. The amount of liquefaction depends on the soil density, type, and saturation. Because the site area is large, there is significant variability in the amount of liquefaction expected. After the building locations are determined, we recommend advancing location-specific borings to better characterize the liquefaction hazard.

Because the site is potentially liquefiable, the soil is Site Class F. A site-specific site response analysis is required by code for Site Class F sites with building periods of more than 0.5 seconds. Based on the proposed building heights, we expect that some or all of the proposed mid-rise buildings and towers are likely to have a fundamental period greater than 0.5 seconds; therefore, a site response analysis would need to be performed at a later stage of design.

6.2.2.2 Slope

Based on HC-1, HC-10, HC-11, and HC-12 (drilled for this study), the slope soil classifies as Site Class C, and no potentially liquefiable soil were encountered.

Borings completed by Earth Consultants (2004) along the top of the slope appear to indicate the slope soil classify as Site Class C or D. Three borings advanced in the slope above the Upper Bench (B-3, B-9, and B-10) appear to indicate that there are some potentially liquefiable sand and silt layers, depending on groundwater conditions. The potentially liquefiable soil was identified as wet with zones of seepage or possible seepage. Groundwater conditions in this area should be confirmed during design (e.g., with additional piezometers) to assess potential for liquefaction in these layers.

The CDM (2006) borings to the south, but further upslope of the Earth Consultants borings, may have encountered potentially liquefiable layers, based on soil descriptions (medium dense, wet, flowing/caving). However, only E-102 included standard penetration test (SPT) data, which did not start until 20 feet deep.

For our slope stability analysis, we assumed Site Class C[1], based on boring HC-1, drilled at the top of the selected critical slope Section B-B' and HC-10 at the top of Section G-G'. Based on 2015 IBC and the code-based design spectrum, we calculated the following parameters:

- Site Class C short period site coefficient (F_a) = 1.0
- Spectral response acceleration at short periods adjusted for site class effects (S_{MS})
  - $S_{MS} = F_a S_S = 1.0 \times 1.262\ g = 1.262\ g$
- Design spectral response acceleration at short periods (S_{DS})
  - $S_{DS} = \frac{2}{3} S_{MS} = \frac{2}{3} \times 1.262\ g = 0.841\ g$
- Design spectral response acceleration at period equal to zero seconds (i.e., design PGA)
  - $Design\ PGA = S_{DS} \times 0.4 = 0.841\ \text{g} \times 0.4 = 0.336\ g$

Standard of practice is to assume a seismic (pseudostatic) horizontal acceleration coefficient (k_h) of one-third to one-half of the design PGA for evaluating seismic slope stability (Kramer 1996). For our seismic slope stability analysis, we assumed a pseudostatic horizontal acceleration coefficient of one-half the design PGA or

- $k_h = \frac{1}{2} Design\ PGA = \frac{1}{2} \times 0.336\ g = 0.168$

Note that PGA, and thus k_h, have not been corrected for slope wave scatting effects as they could be per NCHRP 2008 and FHWA 2011, which would likely result in lower values.

6.2.3 Seismically Induced Hazards

Development in Snohomish County must meet applicable standards of the IBC and SCC Chapter 30.51A. Potential seismically induced geotechnical hazards at the proposed site include surface rupture, liquefaction and subsidence, lateral spread, and seismically induced landslides. Our review of these hazards is based on the existing soil explorations presented in this report and our limited preliminary evaluations, as well as on our regional experience and knowledge of local seismicity.

6.2.3.1 Surface Rupture

As measured from the middle of the Lower Bench, the site is approximately 12 km (about 7.5 miles) south of the Southern Whidbey Island Fault, and approximately 20 km (about 12.5 miles) north of the northern trace of the Seattle Fault (USGS 2006).

[1] If Site Class D were assumed, the calculations would be the same, because F_a is also 1.0 for Site Class D at this site.

Impact

The probability that these faults would produce surface rupture that would affect the site is low, so impacts to any of the alternatives from surface rupture are unlikely.

6.2.3.2 Liquefaction and Settlement

When cyclic loading occurs during a seismic event, the shaking can increase the pore pressure in loose to medium-dense saturated sands and cause liquefaction, or temporary loss of soil strength. This can lead to surface settlement and lateral spreading (discussed in the following section).

Our liquefaction potential assessment for site-specific borings was discussed in Section 6.2.2.

Lower Bench. We encountered saturated soil in a loose to medium-dense condition in the borings conducted for this Project. We estimate a high likelihood of widespread liquefaction capable of causing damage to the Lower Bench. The Palmer et al. (2004) map of liquefaction susceptibility in Snohomish County indicates high susceptibility for the Lower Bench (Figure 10). This conclusion is in agreement with our preliminary analysis of the soil characteristics for the Lower Bench.

Upper Bench. The soil observed on the Upper Bench are potentially liquefiable. As Figure 10 shows, Palmer et al. (2004) indicate this location does not have high liquefaction potential. The discrepancy may be attributed to the scale at the Palmer et al. study was performed, as well as the variability in the soil conditions on the Upper Bench; specifically, whether the location was in the colluvium deposit (MW-122 and B09-1) or in the native soil (MW-95).

Slope. Only limited soil layers in the slopes east of the site appear to be potentially liquefiable (B-3, B-9, and B-10), depending on groundwater conditions, as previously discussed in Section 6.2.2.2. These soils are in the slopes above the Upper Bench and adjacent to the potential Secondary Access Road alignment at the south end of the Upper Bench.

Palmer et al. (2004) show the area of the slope with the abandoned road as having a high liquefaction susceptibility (Figure 10). This mapped area appears to coincide with a zone Minard (1983) mapped as landslide deposits, and Palmer et al. may have interpreted this area as having high liquefaction susceptibility based on the landslide deposits mapped by Minard. However, site observations and the coastal atlas (Ecology 2004), as shown in Figure 12, did not agree that the unstable areas extended all the way to the existing road between the top of the slope and residences to the east as mapped by Minard. Borings at the top of the slope in this area (B-4, B-6, and B-7) do not indicate a high liquefaction susceptibility. Based on our hand auger exploration (HA-1) in the middle of this area, we observed about 1 foot of colluvium over native sand. Our qualitative assessment in the field was that the colluvium was loose and the native soil was dense, consistent with information from borings drilled at the top of the slope. From this exploration we interpret the thin layer of surficial colluvium may be potentially liquefiable, but the underlying native soil did not appear to be susceptible to liquefaction. Additional borings would need to be drilled in this area during design to assess the potential for liquefaction, since liquefaction on the slope could lead to a slope failure and significant runout.

Impact

Potential significant liquefaction-induced settlement or bearing capacity failure of buildings and infrastructure may occur, if not mitigated. However, mitigation as part of design would be relatively straightforward and similar to liquefaction mitigation at other sites around the Puget Sound region. Potential post-earthquake loss of soil strength on the east slope due to liquefaction could result in a landslide/debris flow of significant runout that could impact development on the Upper and Lower Benches, where there is a significant thickness of liquefiable soil.

Developing on a site that is potentially liquefiable will require engineering solutions to minimize the impacts of liquefaction. Several alternatives would be feasible, including a variety of ground improvement methods or pile-supported structures.

The Secondary Access Road could also be severely damaged or destroyed by liquefaction-induced settlement or lateral movement, if the alignment goes through or is adjacent to areas with potentially liquefiable soil. Along the secondary access alignment (upslope to the east from the south end of the Upper Bench on Figure 2), existing explorations indicate there may be potentially liquefiable soil, depending on groundwater conditions. For the secondary access alignment, the liquefaction hazard map (Palmer et al. 2004) indicates potentially liquefiable soil. Additional explorations during design would be needed to better assess potential for liquefaction, impacts, and mitigation. Potential drainage impacts of developing the secondary access road would need to be addressed during design to keep from increasing soil saturation and thereby potentially increasing liquefaction susceptibility. Feasible drainage concepts are discussed in Section 7.1.1.

6.2.3.3 Lateral Spreading

Lateral spreading is typically associated with slope movement caused by the liquefaction of underlying soil, or movement of level ground near a sloping shoreline. The site perimeter of the Lower Bench is currently constructed of retaining walls and shoring. The depth of these elements is reported to extend up to 25 feet bgs. However, as-built plans or further reconnaissance would be required to accurately determine the shoring depth. There is no retaining wall around the Upper Bench. Without considering retaining structures, we estimate lateral spread to be on the order of several to tens of feet near the existing shoreline, decreasing closer inland. This estimate may be refined using more sophisticated analysis tools, but a refined estimate is not needed for an EIS.

Impact

The development includes replacing the existing retaining walls landward of their current location to re-establish the beach for intertidal habitat and redevelop the waterfront area for recreational access. Lateral spread can affect the stability of the overlying or adjacent structures. Appropriate engineering solutions will be needed to mitigate lateral spread for structure design, or foundations will need to be designed for the influence of lateral spread. Non-building elements (e.g., walkway, beach, utilities) may be affected by lateral spread, and maintenance of these elements will be required. Development would not increase the likelihood of lateral spreading since ground improvement or deep foundation methods would be needed to support structures.

6.2.3.4 Seismically Induced Landslides

Landslides can be triggered by the increase in load from an earthquake or potential weakening of soil due to liquefaction. Preliminary stability analysis based on estimated groundwater conditions at the northern third of the slope east of the Lower Bench indicates a landslide would likely occur during a design seismic event. Similar analysis at the Secondary Access Road at the south part of the east slope indicate retaining structures will be needed to stabilized slopes for seismic conditions. Additional analysis would be needed to assess potential for seismically induced landslides at other locations during design.

Impact

Landslide impacts were discussed in Section 6.1.

6.3 Tsunami Hazard Areas

Tsunami flooding hazards are possible at the site because of the close proximity of Puget Sound. Tsunami inundation hazard maps are not available for the Project area. We reviewed an available inundation model for the entire Puget Sound (Koshimura and Mofjeld 2001) and a recently published tsunami hazard map for Everett, Washington, (Walsh et al. 2014) to provide a general idea of potential site risks from tsunamis.

Koshimura and Mofjeld (2001) and Walsh et al. (2014) were the only publicly available sources of information to use to assess tsunami hazards at the site when this report was originally prepared in 2016. Both of these publications model a predicted tsunami based on the maximum credible event/credible worst-case scenario for the Seattle Fault, which is estimated to be an earthquake with magnitude 7.2 (Koshimura and Mofjeld 2001) to 7.3 (Walsh et al. 2014). We acknowledge that the maximum credible event for the Seattle Fault is not the same as the IBC maximum *considered* event (MCE). The IBC MCE is based on a USGS probabilistic seismic hazard assessment of several faults, including the Seattle Fault and the Cascadia Subduction Zone, among others, to estimate an MCE with an average return period of 2,475 years. The recurrence interval of the maximum credible event for the Seattle Fault is not well known, but is estimated to be thousands of years. Based on current knowledge of the interior Puget Sound, the Seattle fault poses the highest potential risk for tsunami inundation. A tsunami resulting from a Cascadia Subduction Zone earthquake off the coast, which could have a magnitude of 9.0+ and would result in a much larger tsunami out on the Pacific Coast, is expected to have less severe effects at the site than would a magnitude 7.2 to 7.3 earthquake on the Seattle Fault.

From the Koshimura and Mofjeld (2001) and Walsh et al. (2014) models we reviewed, we estimate increases in water levels near the site due to a magnitude 7.2 to 7.3 earthquake on the Seattle Fault to be on the order of 1.5 feet to 5 feet, based on the Edmonds location in Koshimura and Mofjeld and the Central Puget Sound location in Walsh et al., respectively. This estimate is based on the tsunami occurring while the water is at mean high water (MHW) level, which corresponds to a maximum expected water level elevation of approximately 15.5 feet at the project site, as shown on Figure 10.

Should a tsunami occur during a tide higher than MHW, the maximum expected water level elevation may be higher.

Walsh et al. (2014) also evaluated a less severe, but more likely, magnitude 6.7 Seattle Fault earthquake; the estimated increase in water level was about 4 inches. This less-severe event is estimated to have a 5 percent probability of exceedance in a 50-year time period, which corresponds to an average return period of 975 years. The predicted 4 inches of water level rise in this case is based on a tsunami occurring during mean tide level (MTL), which corresponds to a water level elevation of approximately 11 feet at the project site.

Both models indicate the tsunami would arrive about 10 minutes after the earthquake.

He most recent tsunami inundation method is the American Society of Civil Engineers recently developed a Tsunami Design Geodatabase as part of the ASCE 7-16 building code (ASCE 2016). This geodatabase provides maximum tsunami runup elevations for magnitude-9 (on the Richter scale) CSZ earthquake scenarios as well as the Seattle and Tacoma local faults in Puget Sound. The maximum runup elevation for the site is elevation 14.94 feet, based on MHW. However, this method has not been adopted by Snohomish County. This elevation agrees well with the maximum elevation of the methods noted above.

The SCC (1) requires that development activities comply with associated tsunami disclosure and recording requirements, and (2) encourages developers to follow the recommendations in “Designing for Tsunamis” (National Tsunami Hazard Mitigation Program 2001).

Impact

Based on the proposed changes in grade for the development, it appears the overall site grades would be above the estimated increase in water level. Some erosion to beaches may occur, which could be addressed through maintenance, if necessary. The new seawall will need to be designed to resist the impacts and potential erosion related to a tsunami, or potential damage to the seawall could be addressed through maintenance or reconstruction, if necessary.

6.4 Erosion Hazard Areas

In SCC 30.91E.160, erosion hazard areas include areas at high risk of water erosion according to the mapped description units of the United States Department of Agriculture (USDA) Natural Resources Conservation Service (NRCS), river-channel migration zones, and shorelines of other waterbodies subject to wind and wave erosion.

Lower Bench. The USDA NRCS maps the Lower Bench soil as “Urban Land” (Figure 10) and does not indicate a high risk of water erosion. In general, increased sand and silt content increases the risk of water erosion. Lower Bench soil are generally sand and gravel; silt content varies. Soil appear to be generally non-silty to slightly silty (typically less than 12 percent silt) and do not appear to have a significant water erosion risk, though more silty zones are present.

The site is not adjacent to any of the rivers with listed migration zones in the SCC; however, it is adjacent to a shoreline. The current influence of wave erosion on the site and adjacent slopes is likely low because of the presence of a series of steel sheet pile seawalls, concrete seawalls, and/or riprap adjacent to Puget Sound along the shoreline. Others are evaluating coastal wind/wave erosion and shoreline stabilization considerations for the project (Moffatt and Nichol 2018).

Upper Bench. The USDA NRCS maps the Upper Bench soil as “Moderate” erosion hazard (Figure 10). Upper Bench soil are generally silty sand and silt and appear susceptible to erosion.

The proposed development site is not adjacent to any of the rivers with listed migration zones in the SCC. Although the Upper Bench is isolated from Puget Sound shoreline and creeks/stream, appropriate runoff management will be needed during construction to prevent turbid stormwater from entering the Sound.

Slope. The USDA NRCS maps the slope soil as gravelly sandy loam with “Severe” erosion hazard and. In general, increased sand and silt content increases the risk of water erosion. Borings at the top of the slope and on the face of the slope encountered till, outwash, lacustrine clay and silt, as well as loose granular sand and silt. The loose and wet sand, silty sand, and silt layers are very susceptible to erosion and appropriate care will need to be taken to use appropriate erosion control best management practices (BMPs) during construction.

Impact

Lower Bench. Development involves re-establishing the beach and seawall protecting the Lower Bench from erosion. Protection of the beach and seawall from wave erosion is being addressed by others (Moffatt and Nichol 2018).

Soil erosion during construction will need be addressed by using appropriate, but common, erosion and sediment control BMPs.

Upper Bench. Soil erosion due to stormwater runoff during construction will need to be addressed through erosion and sediment control best management practices (BMPs).

Development includes excavation of about 15 feet of soil from the Upper Bench for construction of the below-grade structures. These excavations will encounter silty sands and silts that are susceptible to erosion. Soil erosion during construction will need be addressed by using appropriate, but common, erosion and sediment control BMPs.

Secondary Access Road. Grading for the secondary access road alignment on the slope will likely encounter silty sands and silts that are very susceptible to erosion. Because of site grades along the potential secondary access road alignment, this grading would present a higher erosion risk than grading in other areas. Soil erosion during construction will need be addressed using appropriate, but common, erosion and sediment control BMPs. Surface water management will be critical for secondary access road grading activities, especially if they are performed during the rainy season.

Temporary construction access roads would be abandoned and mitigated (e.g., revegetated, graded for positive drainage) after completion of secondary access road construction.

The secondary access road would increase impervious surfaces on and adjacent to the erosion hazard areas. Surface water drainage controls would be designed to prevent increased risk of erosion from surface water runoff associated with the secondary access road.

7.0 HAZARD MITIGATION AND PRELIMINARY GEOTECHNICAL DESIGN AND CONSTRUCTION CONSIDERATIONS

In the following sections, we describe potential mitigation strategies for proposed development on or adjacent to the geologically hazardous areas at the site. The mitigation strategies presented are intended to support development of the EIS and are not design-level geotechnical recommendations. Once specific building layout and structural loads are available, design-level geotechnical explorations and engineering analyses will be necessary to develop specific design criteria and recommendations for the Project.

7.1 Geotechnical Hazard Area Design Considerations and Mitigation

7.1.1 Landslide Hazard Areas

The slope reconnaissance, existing historical data, and preliminary slope stability analysis suggest that additional slope stability analyses would need to be performed during design. Groundwater pore pressures are a key factor in estimating slope stability. Additional investigations (e.g., by advancing borings and installing piezometers) or analyses should be performed to estimate how groundwater pore pressures vary perpendicular to the bluff face and along its length. The results of the stability analyses would be used to design engineering solutions to mitigate slope instability and/or minimize impact to structures if the slope becomes unstable.

Engineering solutions to mitigate the existing landslide hazards may include:

- Improving slope vegetation; this could help reduce surface water infiltration, erosion, and shallow sloughing.

- Reducing surface water discharge and/or infiltration onto/into the slope. This could be accomplished by diverting surface water flow away from landslide hazard areas or piping water to the bottom of and away from landslide hazard areas.

    - For the Secondary Access Road, this would likely involve collecting surface water in ditches upslope of the road and conveying flow to Chevron Creek in lined (or low infiltration) diches or pipes, or culverts under the road/retaining wall(s) that limit infiltration. The drainage should be connected to the existing pipe conveyance of the creek, or other suitable discharge conveyance at the base of the slope.

- Existing leaking pipes or drainage on or above the east slope should be repaired to improve slope stability. This may have to be coordinated with adjacent property owners responsible for such water sources.

- Retaining walls and associate fill would include subsurface drainage measures such as drainage layers with perforated collection pipes connected to solid walled pipes to convey water to suitable discharge points (i.e., existing Chevron Creek conveyance pipe). Subsurface drainage collection would be designed to be resistant to the effects of freezing (i.e., drainage layers and subgrade piping below the frost depth).

- Reducing groundwater pore pressures in slope soil. This could be accomplished using horizontal drains, interceptor trenches, or pumped wells.

- Stabilizing slopes using piles, drilled shafts, tiebacks, soil nails, spiral nails, or other appropriate technologies, depending on the depth of potential instability. Retaining walls near or at the toe of the slope could be used to stabilize slopes, and the height of the wall could be increased, with the top designed as a catchment for shallow, surficial slide debris. Considering the proposed development geometry for the Upper Bench and subsurface conditions, a soldier pile and lagging or secant pile wall with tiebacks is one effective option (see Section 5.1.6).

Implementing some of these potential landslide hazard area mitigation strategies effectively may require easements and coordination with neighboring properties and municipalities. Drainage improvements may require regular operations and maintenance (O&M), especially for active pumping systems, to keep them functional. Slope stabilization measures would be designed considering the design life of proposed structures and would not require regular O&M except for drain line cleaning.

Grading in or adjacent to landslide hazard areas for the potential Secondary Access Road should be minimized as much as possible. Drainage will need to be designed to minimize or mitigate potential effects on slope stability. The potential need for slope stabilization measures or use of deep foundations to support portions of the Secondary Access Road will need to be addressed during design.

7.1.2 Seismic Hazard Areas

Mitigation of seismic hazards is generally focused on reducing the risk and potential impact of liquefaction at the site, which appears to be the most significant seismic hazard. The extent to which mitigation of liquefaction may be mitigated will be determined during design. According to the 2015 IBC, seismic design of buildings is generally based on life safety/no collapse performance criteria. However, essential facilities (e.g., fire, rescue, ambulance and police stations, and emergency vehicle garages) are intended to remain operational after an earthquake, so would require greater seismic performance.

During design it will be necessary to advance location-specific borings and install piezometers to better characterize the liquefaction hazard for proposed buildings and infrastructure during design. This should include additional explorations and testing to assess the presence and extent of the potentially liquefiable soil for the mapped high liquefaction susceptibility in the recent slide area of the abandoned access road, slopes above the Upper Bench, as well as areas in the Lower Bench.

7.1.2.1 Ground Improvement

Ground improvement is the modification of in situ soil to achieve desirable soil characteristics. In this case, loose, liquefiable soil can be modified to increase the soil's resistance to liquefaction to mitigate liquefaction induced settlement, loss of strength, and lateral spreading. Several ground improvement options are described below.

Stone Columns. The stone columns ground improvement technique involves using actuated long cylindrical-shaped vibrating probe to penetrate and densify loose soil by placing and compacting open-graded coarse crushed stone in deep columns. In applications related to liquefaction mitigation, stone columns are typically 30 to 42 inches in diameter and spaced 6 to 10 feet on center. Installation of stone columns typically densifies liquefaction-susceptible granular soil surrounding the stone columns. It has been our experience that, in certain cases, stone columns installed within shallow depths can cause ground heave (thereby loosening rather than densifying surrounding soil) if the fines content of the soil exceeds 15 to 35 percent. Thus, care has to be taken during the design stage to determine where this method is used. If this option is considered, we recommend completing more sampling and laboratory testing to evaluate the feasibility of stone columns. Stone columns can also be used to support shallow foundation in lieu of deep foundations. It is typical for the stone column contractor's engineer who specializes in stone column design to design the stone column layout based on performance criteria determined by the geotechnical engineer.

Geopiers or Rammed Aggregate Piers. The geopier system consists of augering out undesirable soil to a depth that reaches underlying, more competent material and then filling the augered hole with compacted aggregate. For the Project, geopiers should extend at least 2 feet into the bearing soil. A contractor who specializes in geopiers should design the geopier system. The spacing and distribution of geopiers depends on the settlement requirements. Typically, geopiers are 24 to 30 inches in diameter and are spaced 6 to 10 feet on center, depending on loading, settlement, and liquefaction mitigation requirements.

Grouting and Soil Mixing. Grouting is a ground improvement procedure used to create in situ soil-cement formations. In compaction grouting, the surrounding soil is displaced and bulbs of cementatious grout are formed. Jet grouting consists of mixing high-pressure grout with soil to form soil-cement columns. Soil mixing consists of mechanically mixing grout in the soil with single large-diameter paddle, triple augers, or a twin cutter-head wheels. The result is a soil-cement "column" or, using several grouting locations, a soil-cement mass of variable geometry. The geometry and physical properties of the soil-cement are engineered. Typically, the grouting should be contracted as design-build to allow the contractor to optimize the installation method.

7.1.2.2 Overexcavation

The unsuitable soil may also be excavated and replaced by compact structural fill. Because of the depth of the unsuitable soil, existing contamination, and high groundwater table, this option may not be economical and will generate potentially contaminated soil and groundwater that requires disposal. However, some excavation may be required as part of the remediation of contaminated soil (Hart Crowser 2018).

7.1.2.3 Deep Foundations

As an alternative to ground improvement or overexcavation and replacement, deep foundations can be used to mitigate seismic hazards. Deep foundation options are discussed in Section 7.4.

7.1.2.4 Groundwater Drainage

As discussed in Section 7.1.1 for landslide hazard areas, drainage of groundwater in slopes with potentially liquefiable soil could potentially be used to mitigate liquefaction because liquefaction will not occur if the soil is not saturated. The effectiveness of this potential mitigation would need to be address during design.

7.1.3 Tsunami Hazard Areas

The proposed increase in grade and reconstruction/relocation of the seawall appear to be effective mitigation of potential tsunami impacts since new grades are predominantly above the estimated tsunami highest water elevation of 15.5 feet.

7.1.4 Erosion Hazard Areas

Construction and long-term impacts to erosion can be mitigated through application of erosion and sediment control BMPs including limiting soil exposure time, limiting disturbance to vegetation, covering exposed soil with plastic sheeting, and managing surface water.

Permanent landscaping, surface water management, and re-vegetation plans for areas disturbed will be developed during design.

7.2 Proposed Earthwork

The preferred alternative includes a significant amount of earthwork for excavating the Upper Bench for below-grade structures and raising grade on the Lower Bench. Our understanding is that about 650,000 cubic yards of material would be imported, about 125,000 cubic yards of clean soil excavated, and a preliminary estimate of 460,000 cubic yards of excavation associated with site remediation. The Secondary Access Road alternative also includes areas of cut and fill to accommodate proposed road grades.

The suitability of excavated site soil for compacted structural fill depends on the gradation and moisture content of the soil when it is placed. As the amount of fines (that portion passing the No. 200 sieve) increases, the soil becomes increasingly sensitive to small changes in moisture content and adequate compaction becomes more difficult to achieve. Soil containing more than about 5 percent fines cannot be consistently compacted to a dense, non-yielding condition when the water content is greater than about 2 percent above or below optimum. Reusable soil must also be free of organic and other unsuitable material.

Explorations indicate that the site soil contain variable percent fines. The excavation of the Upper Bench, where the most significant excavation is anticipated for below-grade structures, appears likely to encounter moist to wet silty sand and gravel and silt. Grading for the secondary access on the slope is likely to encounter moist to wet silty sand and silt. In general, site soil does not appear suitable for structural fill because of their composition and gradation; however, soil will need to be evaluated at the time of construction. Site soil can be used for non-structural purposes such as in landscaped areas. Another consideration for the potential re-use of on-site soil is potential contamination that may be encountered, which will be addressed in other Project documents (Hart Crowser 2018).

Earthwork will likely be performed with standard excavation, grading, and compaction equipment. While all earthwork activities benefit from dry weather, timing of the earthwork for the Upper Bench and Secondary Access Road to coincide with drier periods may greatly facilitate these efforts, due to the potential for high groundwater below the Upper Bench and significant springs and seeps on slopes.

BMPs will need to be used to manage surface water and control erosion during earthwork. Managing surface water and controlling erosion will be critical for any earthwork on slopes associated with the Secondary Access Road.

7.3 Temporary Shoring

The proposed development for the Upper Bench will require temporary shoring for construction of basement levels below existing grade. The proposed development in these alternatives on the Lower Bench may also require shoring, though excavations of limited depth could be accomplished with cut slopes.

Because of the high water table observed in the explorations, a temporary dewatering system would typically be required in the excavation, or a “water tight” shoring system could be used with the wall designed to resist hydrostatic groundwater pressures. Potential alternatives would include a soldier pile with tiebacks or a cement-soil-mix (CSM) or slurry wall.

The type of shoring system would depend on the depth of the excavation as well as the possibility of obtaining permits to discharge the collected water. Foundation types would be determined based on the depth of the excavation and building loads, as discussed below.

Lateral earth pressures on the Upper Bench shoring system will be significant because of the presence of the slopes above, which have overall slope gradients ranging from about 30 to 45 percent.

7.4 Foundation Considerations

The types of foundations that may be recommended for the proposed site development depends on the nature of the underlying soil and the depth below grade of the structures. General comments are provided in the following sections.

The development generally has the lowest level near the existing grade on the Lower Bench. Because the subsurface soil are potentially liquefiable, shallow foundations are not recommended to support the building loads without first performing ground improvement or overexcavation and replacement. Deep foundations that extend to and are supported by the dense to very dense pre-Fraser Nonglacial Fluvial soil are likely the preferred approach.

Where retaining walls are used to support grade changes, the foundation type would be similar to that required for structures developed on the ground surface.

Structures associated with the Secondary Access Road alternatives would likely need to be supported on deep foundations so they would not impart loads on the slope that could decrease slope stability. The deep foundations would be designed to resist shallow, surficial slope movement commonly observed at the site.

Contaminated soil could be encountered during overexcavation or construction of drilled foundations; disposal would incur additional costs. These issues will be addressed in other Project documentation.

7.5 Foundation Types

7.5.1 Shallow Foundations

We do not recommend the use of shallow foundations in areas where there are potentially liquefiable soils, unless the soils are treated with ground improvement or overexcavated and replaced. These methods were discussed in Section 7.1.

7.5.2 Deep Foundations

A variety of deep foundation types will most likely be required to support the proposed development. Vertical compressive loads can be resisted by friction along the pile sides and by end bearing at the tip. Therefore, it is critical to embed piles sufficiently into competent soil. We define competent soil (or bearing stratum) as the dense to very dense, pre-Fraser Nonglacial Fluvial Deposits. The depth to the competent soil may vary across the site. The explorations from the current study indicate these soils begin at a depth of 47 to 50 feet bgs below the Lower Bench and are shallower to the east. To determine pile tip depths, additional subsurface explorations will be needed once the building locations are determined.

Embedment of deep foundations on slopes for structures associated with the Secondary Access Road can be designed to provide the necessary lateral resistance to help stabilize potential deep slope failures to meet SCC requirements, as well as resist shallow, surficial slope movement commonly observed at the site.

Several pile types are described in the following sections. The type of pile that would be considered suitable for this Project depends on the loads and locations of the proposed structures. In addition, concerns about vibration or noise during installation, and contaminated soil cuttings should factor into pile type selection.

7.5.2.1 Drilled Shafts

A drilled shaft is a drilled, cast-in-place, concrete-reinforced pile. It is installed by augering down to the pile depth, lowering a reinforced steel cage into the bored hole, and using a tremie pipe to pump concrete to the base of the hole. Drilled shafts are typically larger in diameter (3 to 10 feet), which may allow penetration through cobbles and boulders where smaller-diameter holes may not succeed. Drilled shaft installation is a low-vibration and relatively quiet process. However, due to the generally large diameter of drilled shafts, a significant amount of soil cuttings may be generated.

7.5.2.2 Augercast Piles

An augercast pile is a mid-sized (14 to 24 inches in diameter), drilled and grouted replacement pile that is typically reinforced. Augercast piles are a good alternative to driven piles because of their lower vibration and noise. Augercast piles are installed by continuously auguring down to the pile depth with a plug in the auger tip. When the pile depth is reached, the plug is removed and concrete flows out of the auger under pressure as the auger is extracted from the hole. To increase the uplift pile capacity, a steel bar is usually placed in the center of the pile and a steel cage is placed in the upper portion to provide increased lateral resistance. Augercast piles can be a cost-effective foundation system; however, soil cuttings will be generated.

7.5.2.3 Micropiles

A micropile is a small-diameter (6 to 12 inches in diameter), drilled and grouted replacement pile that is typically reinforced. A micropile is installed by rotary drilling a borehole, grouting from the bottom up, and placing reinforcement. The end-bearing capacity of micropiles is typically neglected because it is minor compared with the grout-to-ground capacity along the pile's perimeter. The soil conditions and installation procedure strongly influence the grout-to-ground strength. Micropiles, like augercast piles, are bored piles that generate cuttings. Micropiles are typically used when overhead room is limited or when the loads are light.

7.5.2.4 Driven Piles

Driven piles include prefabricated steel and concrete piles that are installed into the ground using a pile-driving rig equipped with a vibratory or impact hammer. H-piles and pipe piles are examples of steel piles. Concrete piles typically include octagonal or square precast reinforced concrete members. Noise and vibration are generated during installation. Localized ground heave may occur surrounding the driven piles, but soil is displaced which densifies soil immediately adjacent to the piles. In loose soil, ground settlement may also result at distance from the piles because of ground vibration from driving the piles. The benefits of using driven piles are that cuttings are not generated, installation is relatively quick compared with installation of bored piles, and pile capacities can be verified during installation. Steel piles can be spliced or cut to adjust length to accommodate variable bearing layer conditions much easier than concrete piles, which should also be considered.

7.6 Vibration Considerations

7.6.1 Construction Vibrations

We performed a screening-analysis-level review of the potential construction vibration impacts on existing structures and future development. Our review focused on potential damage to structures and did not include human annoyance vibration levels.

Vibration sources during construction include truck traffic, heavy on-site equipment, vibratory compaction equipment, and impact or vibratory installation methods associated with foundations (e.g., piles) or ground improvement (e.g., stone columns, geopiers).

Typical vibration source levels for construction equipment are provided in Table 4; these source levels are based on measured data as reported in FTA (2006).

Table 4 – Typical Vibration Source Level for Construction Equipment

Equipment		Peak Particle Velocity (PPV) at 25 Feet (inches/second)
Pile driver (impact)	Upper range	1.518
	Typical	0.644
Pile driver (sonic)	Upper range	0.734
	Typical	0.170
Clam shovel drop (slurry wall)		0.202
Hydromill (slurry wall)	In soil	0.008
	In rock	0.017
Vibratory roller		0.210
Hoe ram		0.089
Large bulldozer		0.089
Caisson drilling		0.089
Loaded trucks		0.076
Jackhammer		0.035
Small bulldozer		0.003

Recommended threshold vibration criteria for structures are provided in Table 5. These criteria are based on recommendations in FTA (2006) and are generally considered conservative for structures. Our pile driving and construction experience indicates that the PPV values listed are conservative. The criteria in Table 5 may also be applied to tracks and utilities.

Table 5 – Construction Vibration Damage Criteria

Structure Category	Peak Particle Velocity in inches/second
Reinforced concrete, steel or timber (no plaster)	0.5
Engineered concrete and masonry (no plaster)	0.3
Non-engineered timber and masonry structures	0.2
Structures extremely susceptible to vibration damage	0.12

7.6.1.1 Off-Site Structures

In general, we do not anticipate that the effects of construction vibration on off-site structures will be significant.

The BNSF railroad tracks adjacent to the proposed development regularly experience more significant vibrations from the freight trains than are anticipated to result from construction.

Residences are within about 100 feet of the proposed development at the south end of the Upper Bench. These residences appear to have been above the approximate path of the Brightwater Conveyance Tunnel. They are as close as 200 feet from the tunnel receiving pit at the south end of the Lower Bench, 150 feet from the BNSF railroad tracks, and 50 feet from the existing industrial access road to the site. Vibrations at these residences during Project construction are not anticipated to be damaging to the structures.

Residences are within about 50 feet of the potential secondary access alignment at the southern third of the Upper Bench. Vibrations at these locations will be similar to vibrations from standard road construction (e.g., graders, vibratory compactors); we do not anticipate they will damage structures.

Vibrations from construction traffic should be similar to those from the current industrial truck traffic and Brightwater construction traffic. If the frequency of truck traffic increases, we do not anticipate they will damage structures. We understand some construction materials (e.g., import fill) will likely be barged in, which would significantly reduce potential construction traffic.

7.6.1.2 On-Site Structures

Construction vibration impacts to existing structures, utilities, and slopes near the proposed construction activity will depend on their condition at the time of construction and their distance from the construction activity. Tables 4 and 5 summarize typical vibration source levels for construction equipment and construction vibration damage criteria, respectively. As noted, the data in Table 4 are for a reference distance of 25 feet, and are conservative values. Typically, vibration magnitude diminishes rapidly with increasing distance from the source of vibration.

Pile-driving and vibratory ground improvement methods would have the most significant potential impacts, because of both potential vibration levels and local vibration-induced settlement. Potential effects of construction activity on existing structures will depend on phasing/demolition and construction methods that will be determined during design. These impacts may be mitigated through logistical and scheduling consideration or selection of appropriate construction methods.

7.6.1.3 Vibration Monitoring

A geotechnical instrumentation program should be used to document and monitor work performed near settlement- and vibration-sensitive areas, structures, and/or utilities. This program would include preconstruction surveys, frequent monitoring, and an alert system during construction.

7.6.2 Railroad

We performed a screening-analysis-level review of the potential railroad vibration impacts on existing structures and future development. Our review focused on potential damage to structures and did not include human annoyance vibration levels.

Based on screening criteria in FTA (2006), we do not anticipate that vibrations from the railroad tracks will damage the existing structures or proposed development structures. No additional soil settlement related to railroad operations are anticipated, as the railroad has operated in this location historically. Also, potential issues related to settlement will be addressed during design of specific structures (e.g., deep foundations, ground improvement).

As part of completing the Seattle to Everett Commuter Rail EIS for the BNSF corridor adjacent to the site, Sound Transit and its consultants assessed the potential influence of railroad vibrations on stability of the adjacent slopes (Sound Transit 1999). Sound Transit concluded vibrations from commuter rail traffic would not contribute significantly to overall slope instability and were unlikely to increase the potential for landslides or create new landslides, but they could affect the timing of landslides. In other words, railroad vibrations could trigger an imminent landslide on the verge of failing to slide sooner rather than later. Sound Transit (1999) focused on commuter trains and indicated longer, heavier freight trains produce greater vibrations and would be more likely to trigger an imminent landslide than would a commuter train.

7.7 Submarine Landslide Considerations

A public comment was provided from the Town of Woodway regarding the potential impacts of submarine landslides on existing structures and future development. From our research, there do not appear to be any Department of Ecology regulations or assessments regarding risk related to submarine landslides. Additionally, the SCC does not address hazards from submarine landslides. As requested, we researched available information to address the potential impacts of a submarine landslide on the Point Wells site to support planning-level decisions. Additional review and evaluations may be needed during design.

The best available information for assessing the potential impacts of submarine landslides on existing structures and future development at Point Wells is from the Brightwater Wastewater Outfall investigations and analyses. Detailed bathymetric measurements were performed from adjacent to Point Wells to over 1 mile offshore in Puget Sound for the Brightwater EIS (King County, 2003). The geophysical surveys for the Brightwater Outfall are provide in Appendix E.

The Brightwater bathymetric survey shows a steep drop-off starting at a depth below mean lower low water (MLLW) elevation from about 350 feet to 650 feet. This drop-off starts about 2,200 feet from the western edge of Point Wells. At its steepest, the submarine drop-off has a slope of about 62 percent, or 32 degrees. The shallower submerged slope between Point Wells and the crest of the steep drop-off has an average slope of about 13 percent, or 7 degrees, with the steepest section approximately 800 feet offshore having a slope of about 19 percent, or 11 degrees.

In addition to the bathymetric survey, a sub-bottom geophysical survey was performed. The geophysical survey indicated a thin veneer of beach deposits/marine sediment overlies glacially overridden soil out to about 3,000 feet offshore, where it appears thicker marine sediments are accumulating beyond the toe of the steep submerged slope in the flatter seabed.

Based on the significant distance from the west edge of Point Wells to the crest of the steep submarine slope, the shallow submarine slopes in between, and the glacially overridden soil these slopes are comprised of, the risk of potential impacts at Point Wells from deep-seated, submarine landslides is considered low. Recent beach deposits and marine sediments in the nearshore may be potentially liquefiable, which will be considered during design, as part of the seismic slope stability and lateral spreading analysis.

Our assessment appears consistent with that of HWA, who performed the geotechnical investigations and analysis for the Brightwater outfall. The details of the HWA study were not yet available at the time of preparing this assessment. However, HWA performed six offshore borings, seismic ground response, and liquefaction analysis, focusing on the upper loose to medium dense beach deposits (HWA 2016). The final design anchored the outfall in the nearshore, adjacent to Point Wells, with steel sheet piles embedded in the glacially overridden soil below the recent beach deposits.

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Scale in Feet

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Point Wells
Richmond Beach, Washington

Vicinity Map

17203-54 4/18

HARTCROWSER

Figure

1

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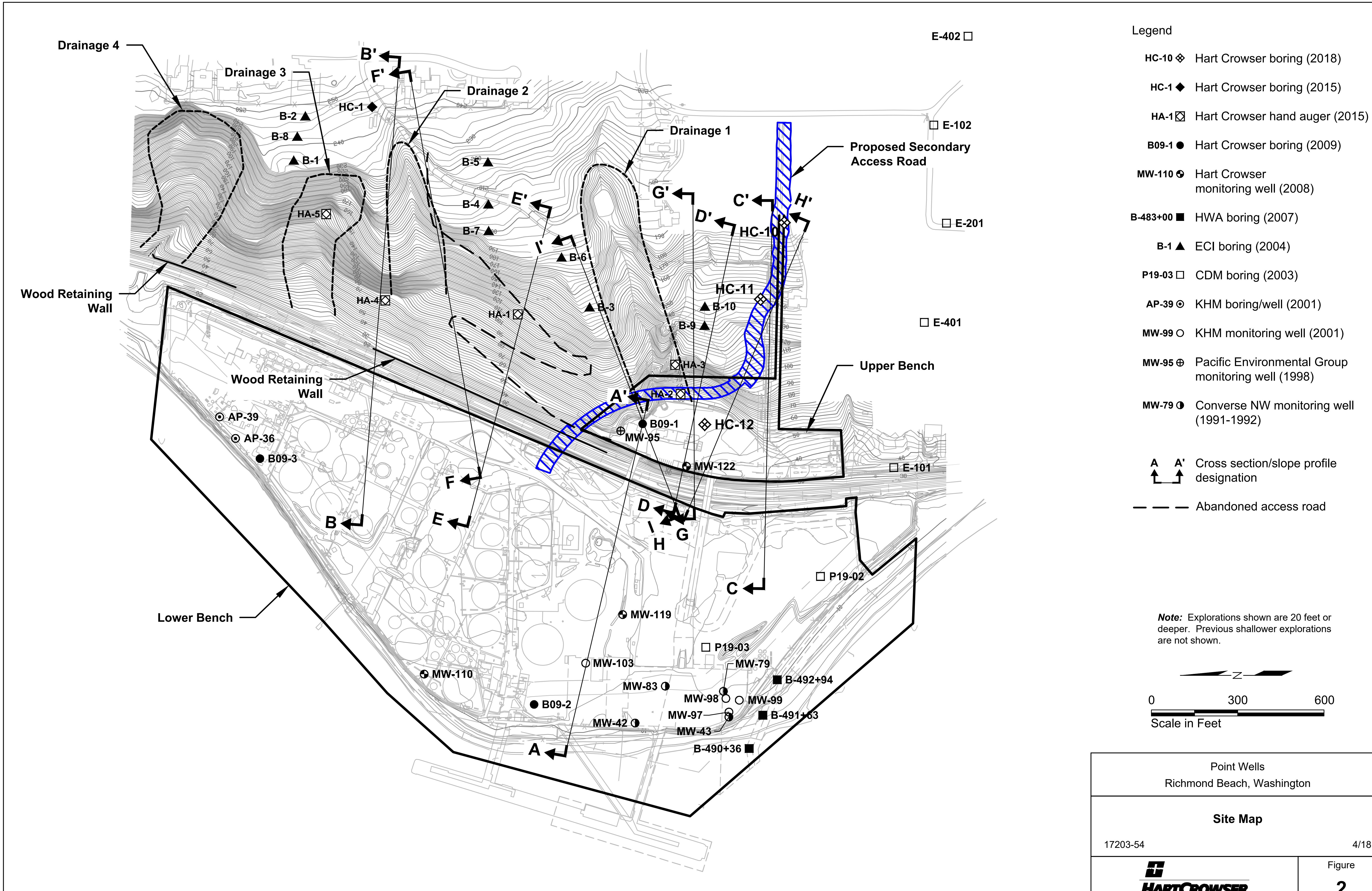

Point Wells
Richmond Beach, Washington

Site Map

17203-54 4/18

HARTCROWSER

Figure **2**

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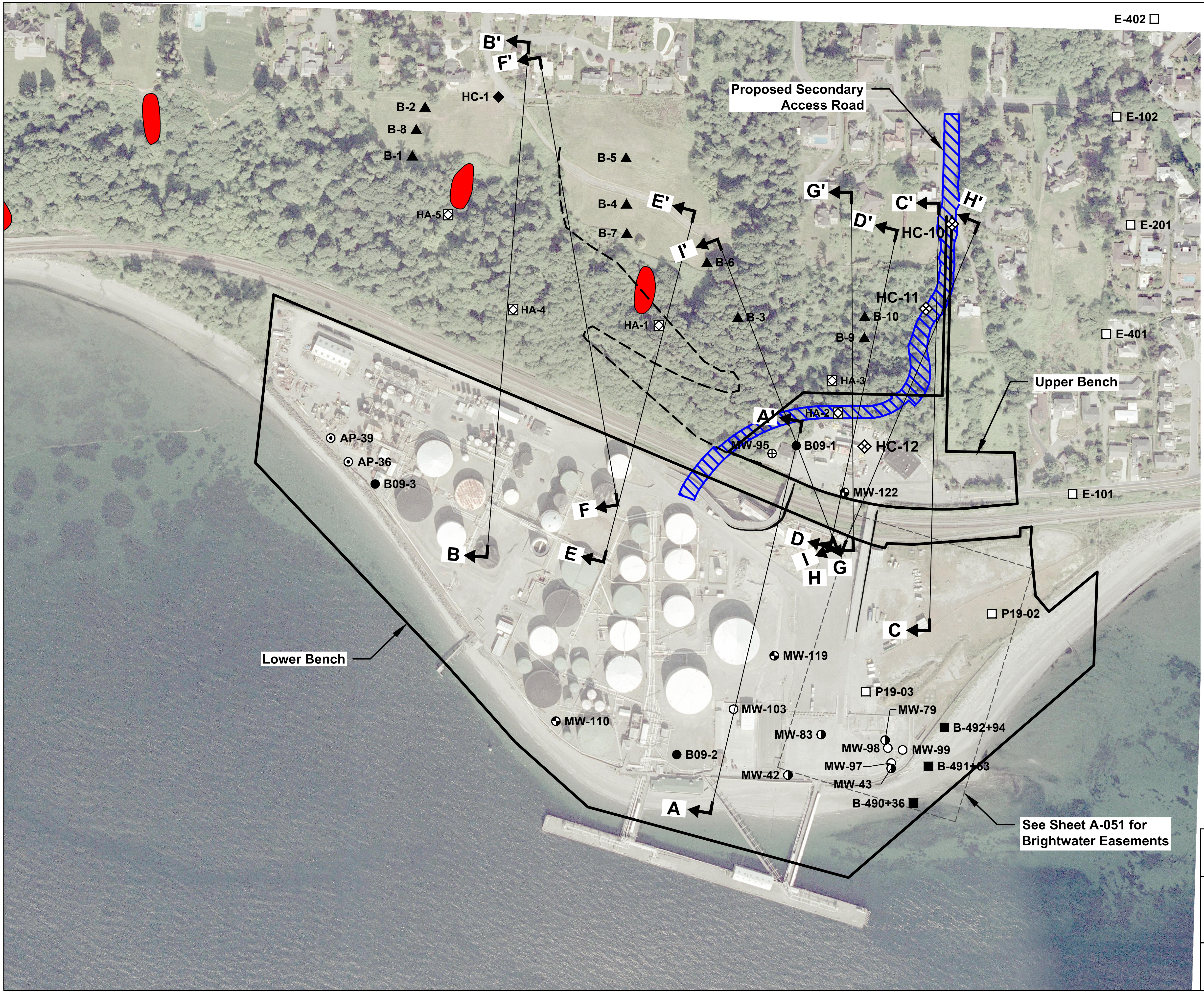

Legend

- HC-10 Hart Crowser boring (2018)
- HC-1 Hart Crowser boring (2015)
- HA-1 Hart Crowser hand auger (2015)
- B09-1 Hart Crowser boring (2009)
- MW-110 Hart Crowser monitoring well (2008)
- B-483+00 HWA boring (2007)
- B-1 ECI boring (2004)
- P19-03 CDM boring (2003)
- AP-39 KHM boring/well (2001)
- MW-99 KHM monitoring well (2001)
- MW-95 Pacific Environmental Group monitoring well (1998)
- MW-79 Converse NW monitoring well (1991-1992)
- A A' Cross section/slope profile designation
- Abandoned access road
- Shallow earth slide or debris flow that occurred in 1996-97 (Baum et al. 2000)

Note: Explorations shown are 20 feet or deeper. Previous shallower explorations are not shown.

N

0 300 600

Scale in Feet

Point Wells
Richmond Beach, Washington

Site and Exploration Plan

17203-54 4/18

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Figure
3

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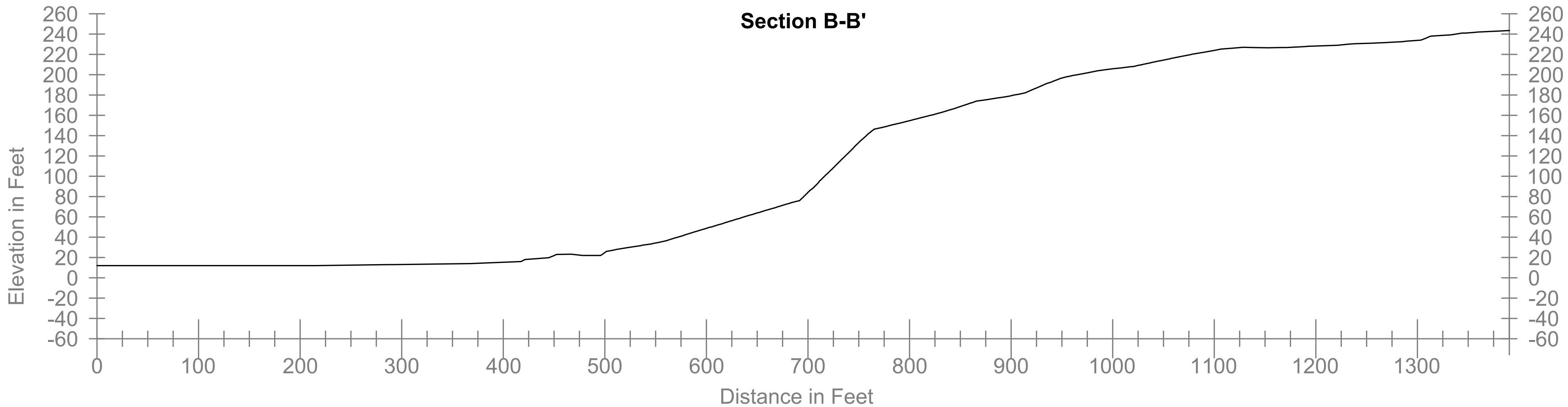
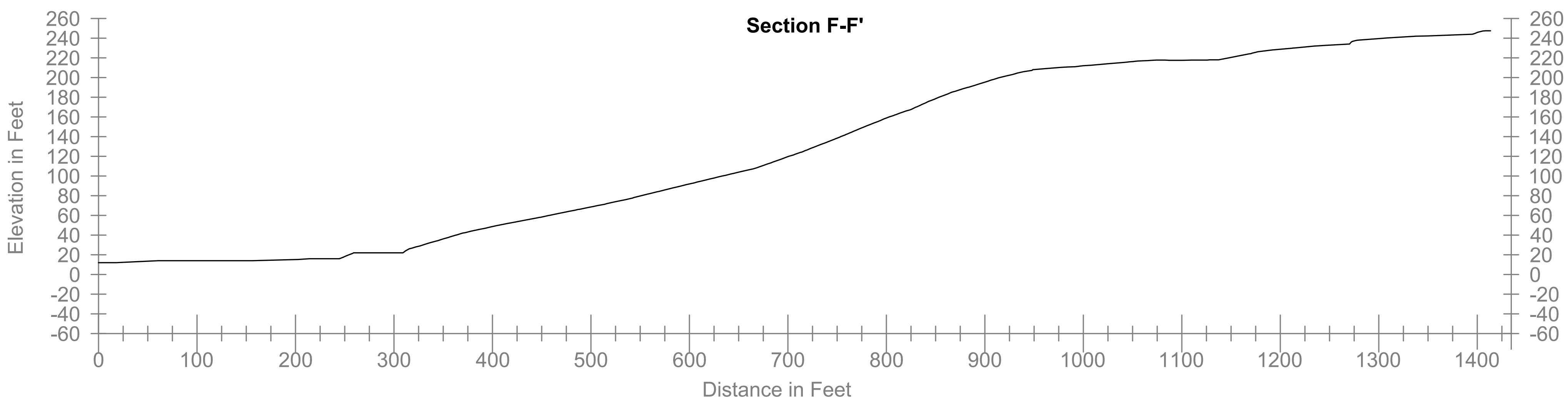
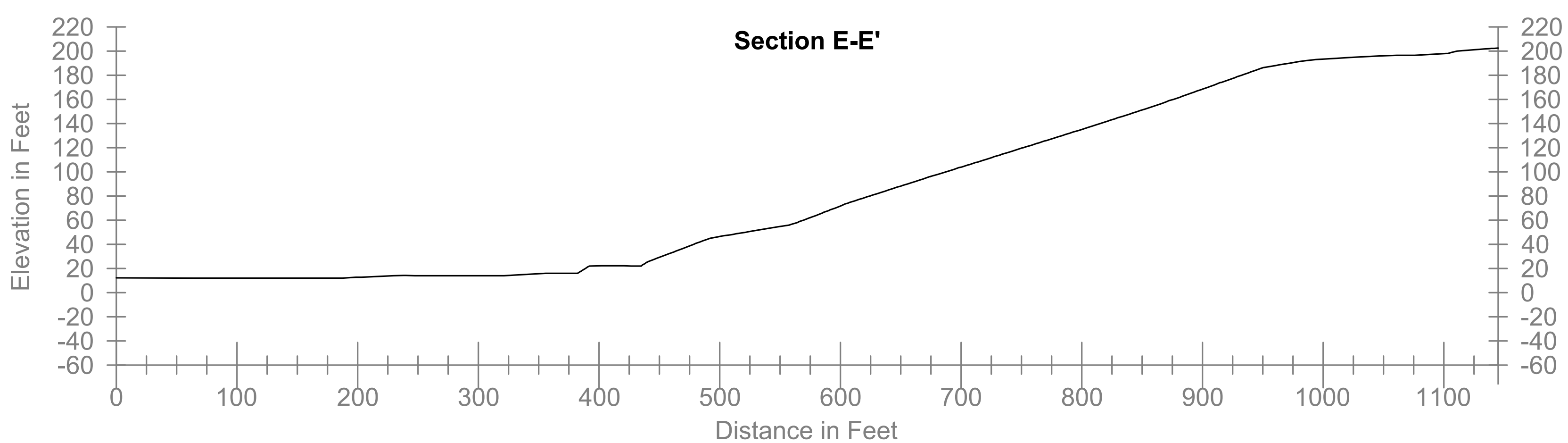






Note: Profiles are arranged from north to south (see Figure 2), top to bottom across two sheets.

0 150 300
Scale in Feet

Point Wells
Richmond Beach, Washington

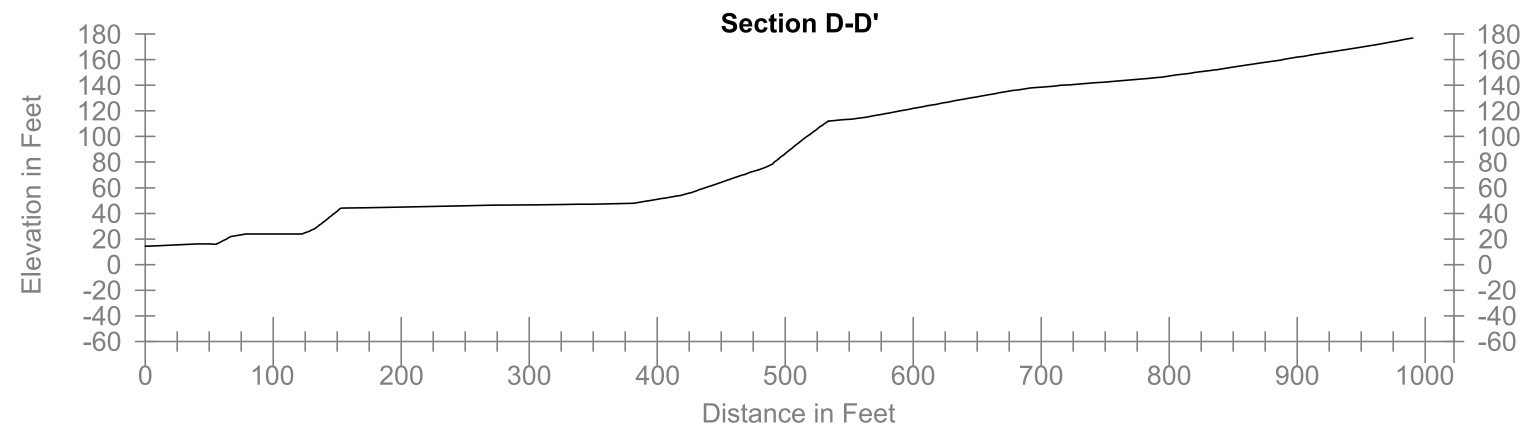
Slope Profile Comparison

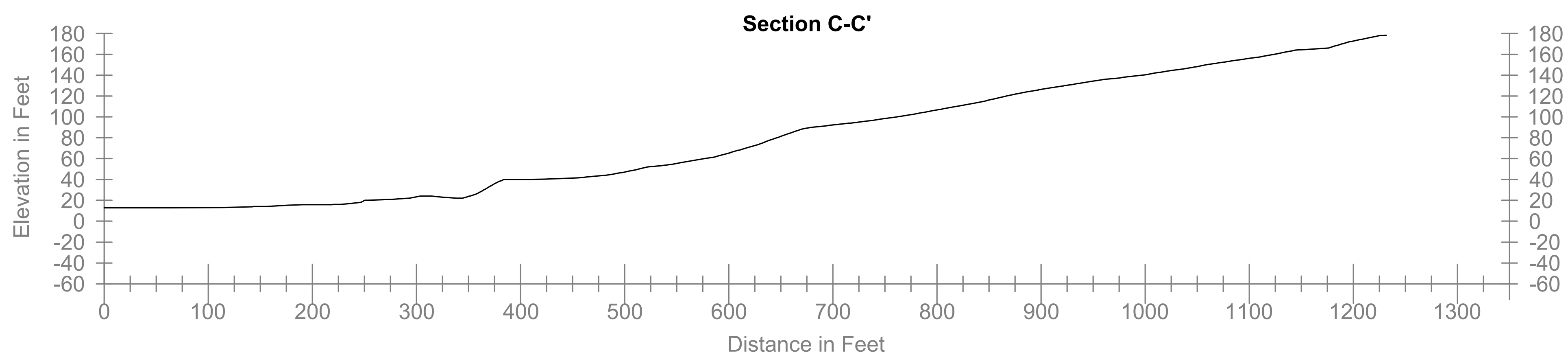
17203-54 4/18

HARTCROWSER

Figure
4
Sheet 1 of 3

EAL 04/13/18 1720354-009 (XSecComp).dwg





Note: Profiles are arranged from north to south (see Figure 2), top to bottom across two sheets.

0 150 300
Scale in Feet

Point Wells
Richmond Beach, Washington

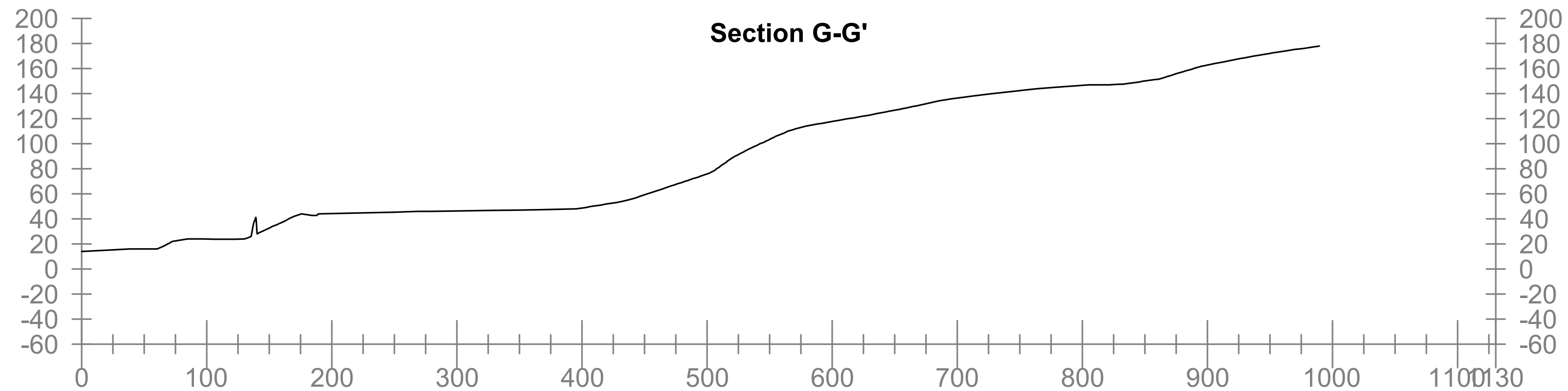
Slope Profile Comparison

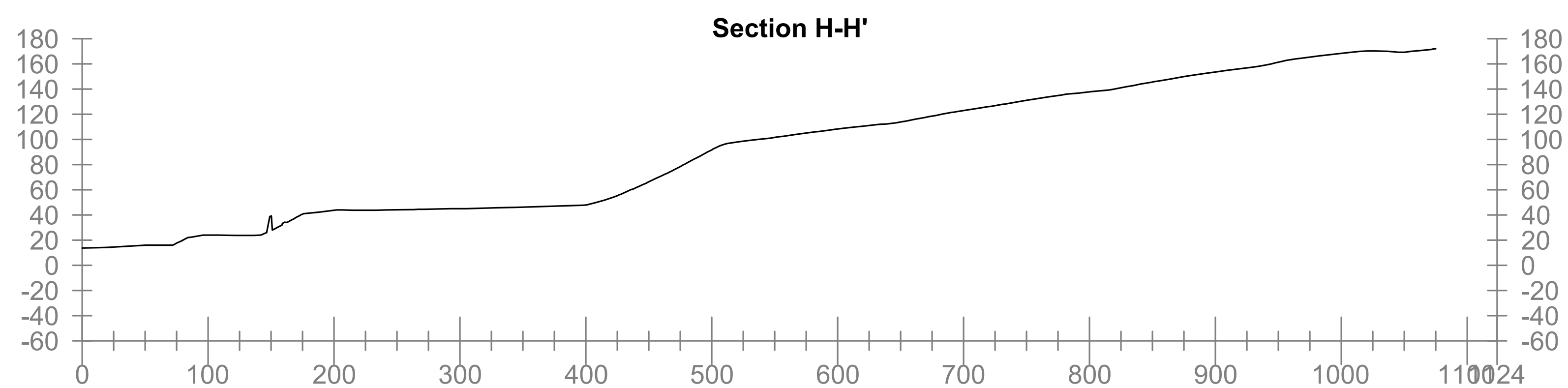
17203-54 4/18

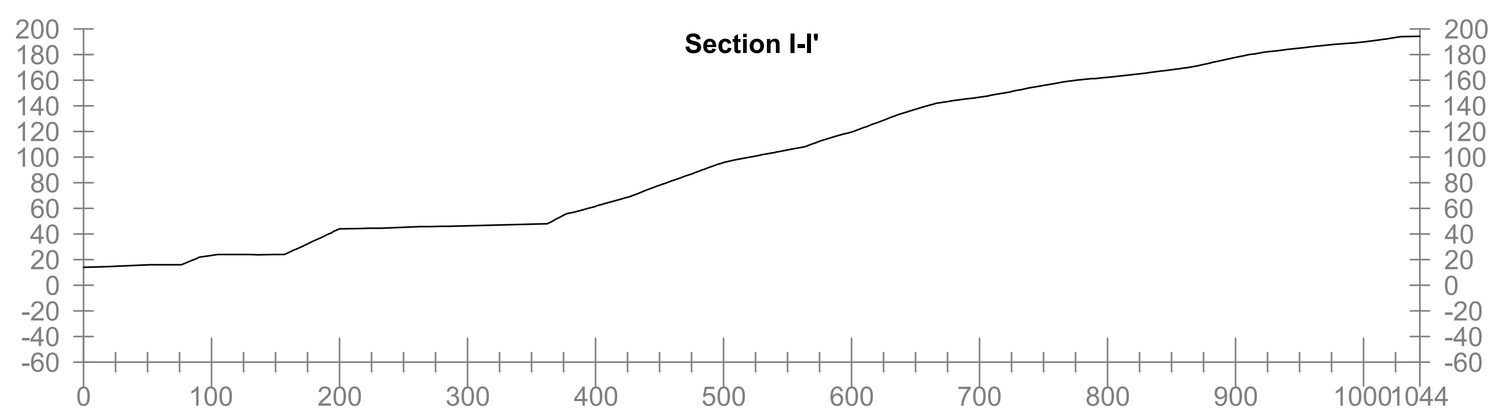
HARTCROWSER

Figure
4
Sheet 2 of 3

EAL 04/13/18 1720354-009 (XSecComp).dwg







Note: Profiles are arranged from north to south (see Figure 2), top to bottom across two sheets.

0 150 300
Scale in Feet

Point Wells
Richmond Beach, Washington

Slope Profile Comparison

17203-54 4/18

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Figure **4**
Sheet 3 of 3

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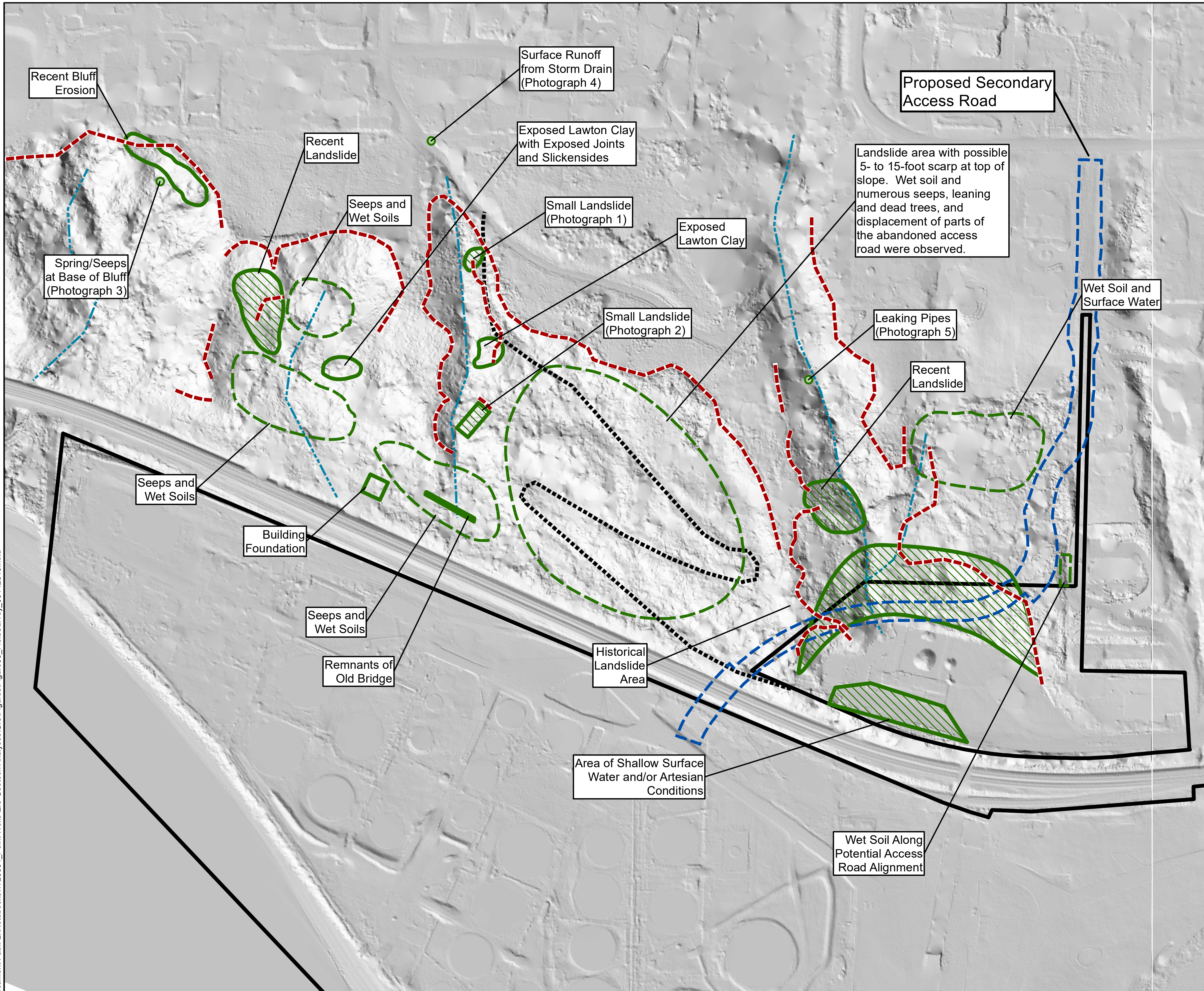

Legend

- Abandoned Access Road
- Possible Scarps
- Approximate Location of Seasonal Streams
- Project Boundary
- Field Reconnaissance Observations

Note: LiDAR source Washington State Department of Transportation Rail Division, 2013.

See Section 5.1.6.1 of test for potential landslide runout distances.

N

0 100 200 400 Feet

1 inch = 200 feet

Point Wells
Richmond Beach, WA

LiDAR Topography and Field Survey

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Figure 5

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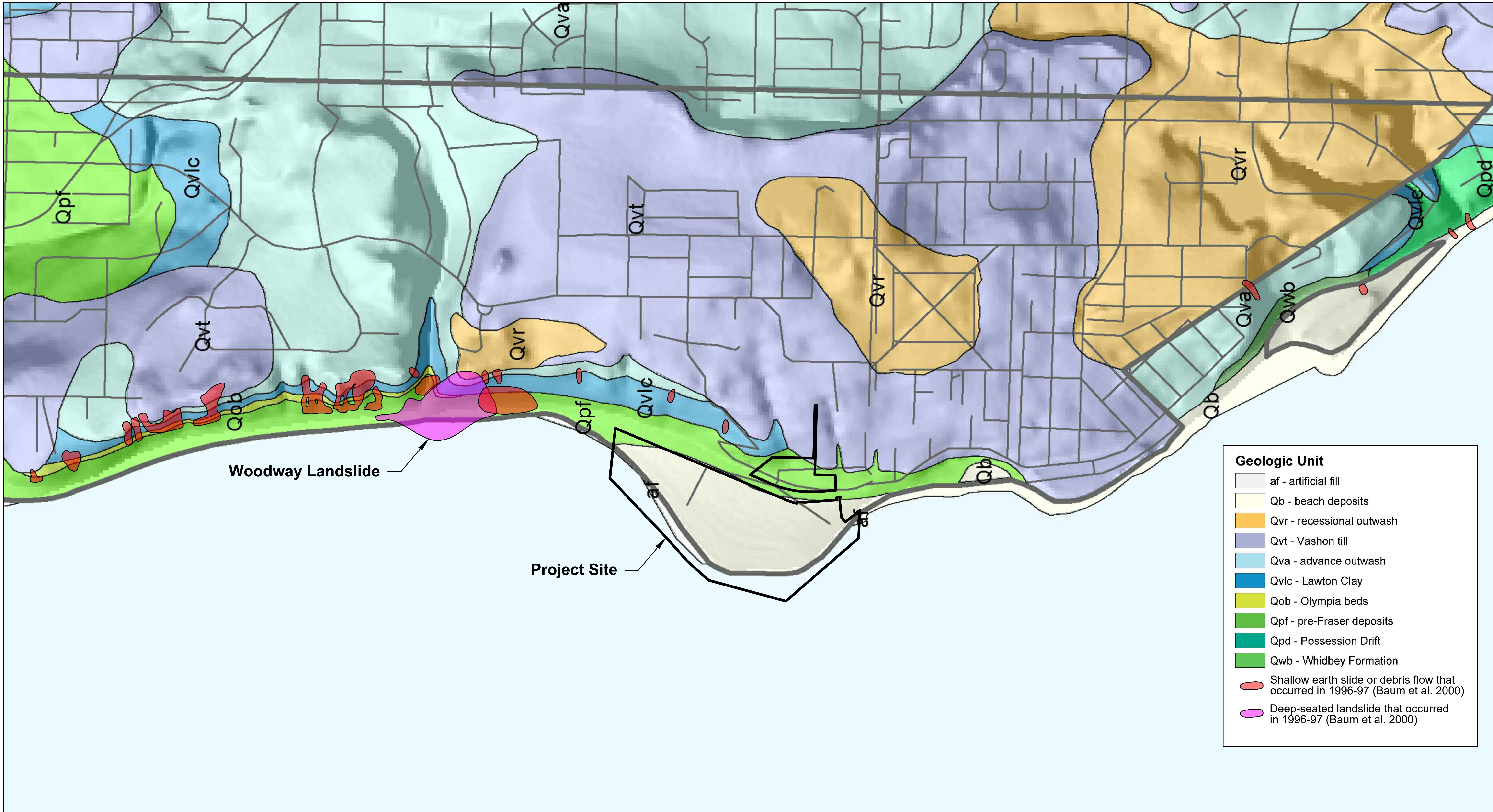

Source: "Composite Geologic Map of the Sno-King Area," Central Puget Lowland, Washington, by Derek Booth, Brett Cox, Kathy Troost, and Scott Shimel. Seattle-Area Geologic Mapping Project (SGMP), University of Washington, and the United States Geological Survey (USGS) January 5, 2004. Map scale 1:24,000.

N

0 1000 2000

Scale in Feet

Point Wells
Richmond Beach, Washington

Geologic Map

17203-54 4/18

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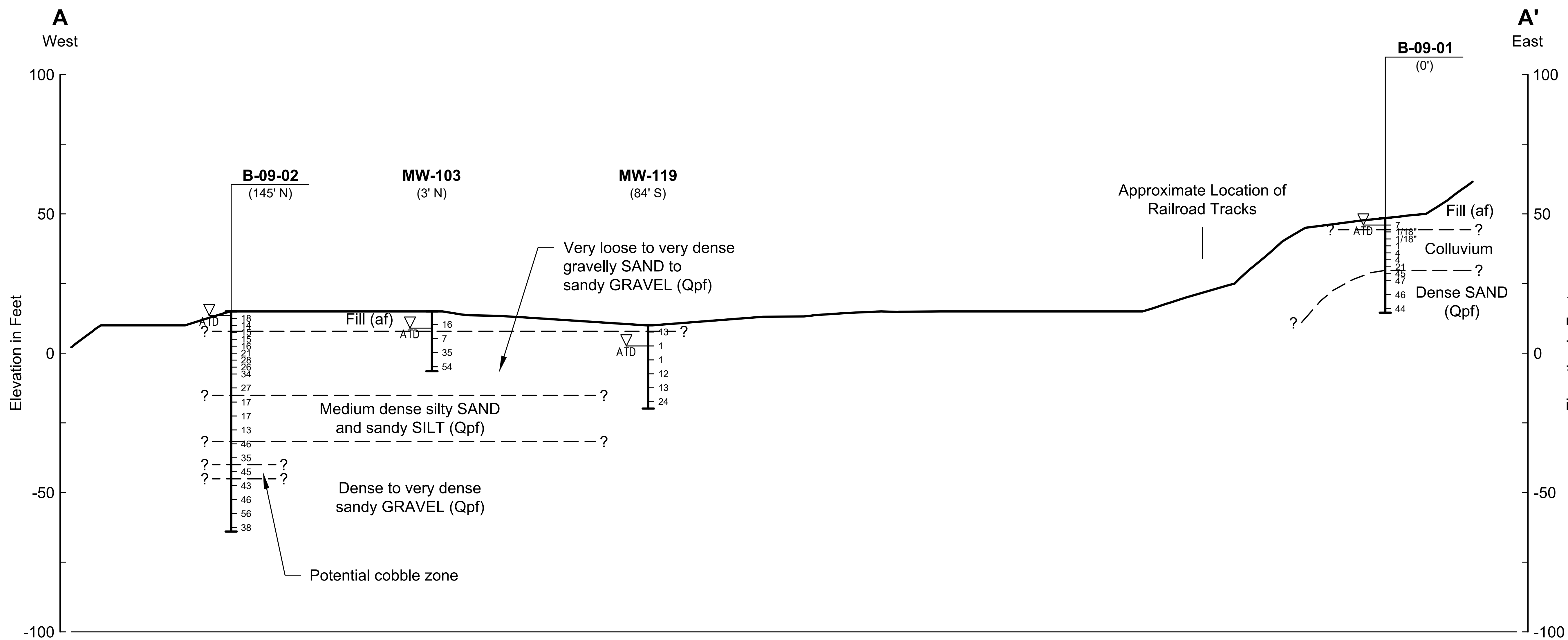
Figure

6

EAL 04/17/18 1720354-003 (Geol).dwg



Legend

HC-102 (34.5' E) Exploration Number (Offset Distance and Direction)

Exploration Location

ATD Water Level

9 Standard Penetration Resistance in Blows per Foot

Note:
1. Contacts between soil units are based upon interpolation between borings and represent our interpretation of subsurface conditions based on currently available data.
2. Slopes appear steeper than they actually are because of vertical exaggeration used for figure clarity. See Figure 4 for slope profile without vertical exaggeration.

Horizontal Scale in Feet
0 100 200

0 40 80
Vertical Scale in Feet
Vertical Exaggeration x 2.5

Point Wells
Richmond Beach, Washington

Generalized Subsurface Cross Section A-A'

17203-54 4/18

HARTCROWSER

Figure
7

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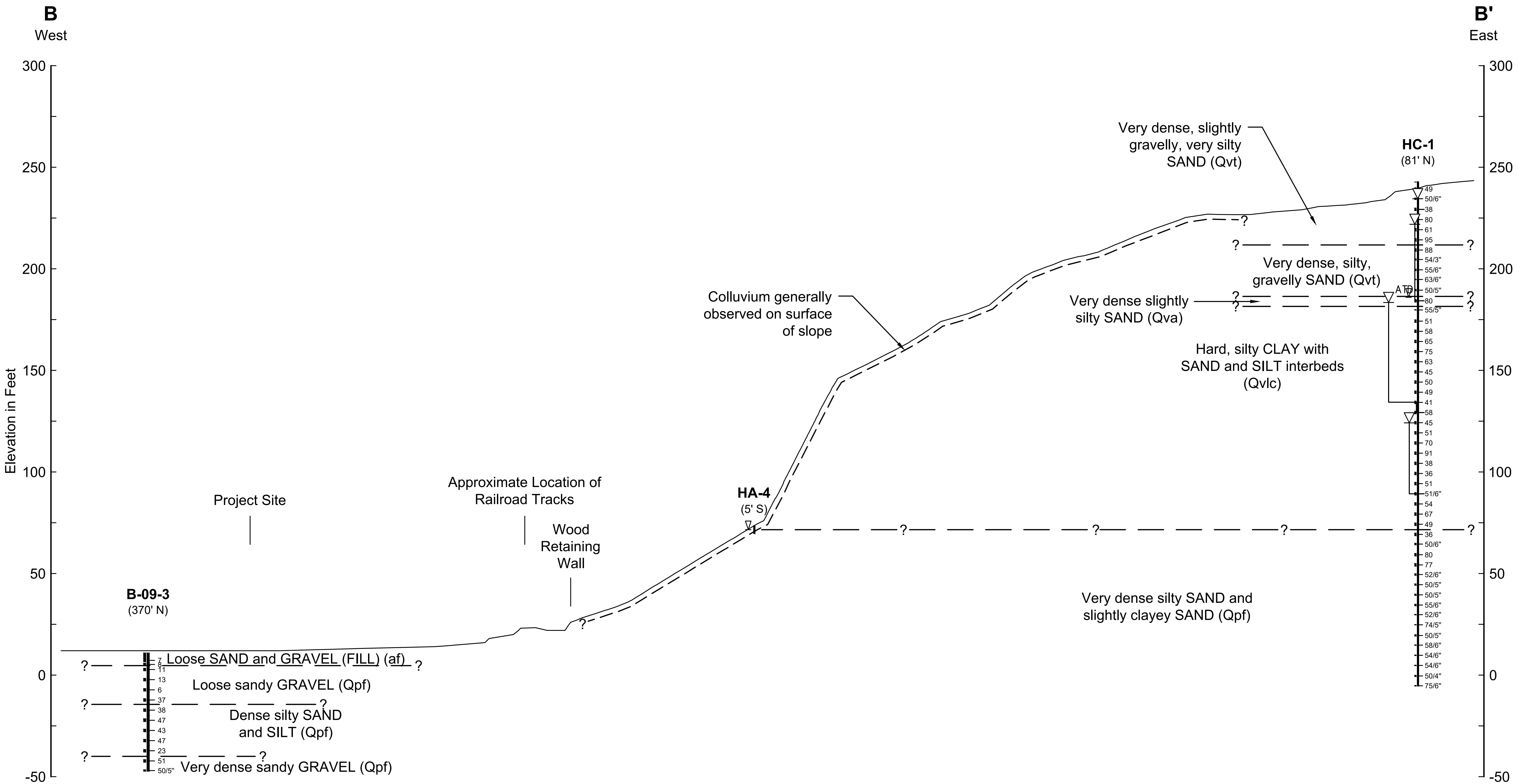


Legend

HC-1 (81' N) Exploration Number (Offset Distance and Direction)

Exploration Location

Water Level (ATD)

Standard Penetration Resistance in Blows per Foot

Vibrating Wire Piezometer and Measured Groundwater Head

Horizontal Scale in Feet: 0, 100, 200

Vertical Scale in Feet: 0, 50, 100

Vertical Exaggeration x 2

Note:

1. Contacts between soil units are based upon interpolation between borings and represent our interpretation of subsurface conditions based on currently available data.
2. Slopes appear steeper than they actually are because of vertical exaggeration used for figure clarity. See Figure 4 for slope profile without vertical exaggeration.

Point Wells
Richmond Beach, Washington

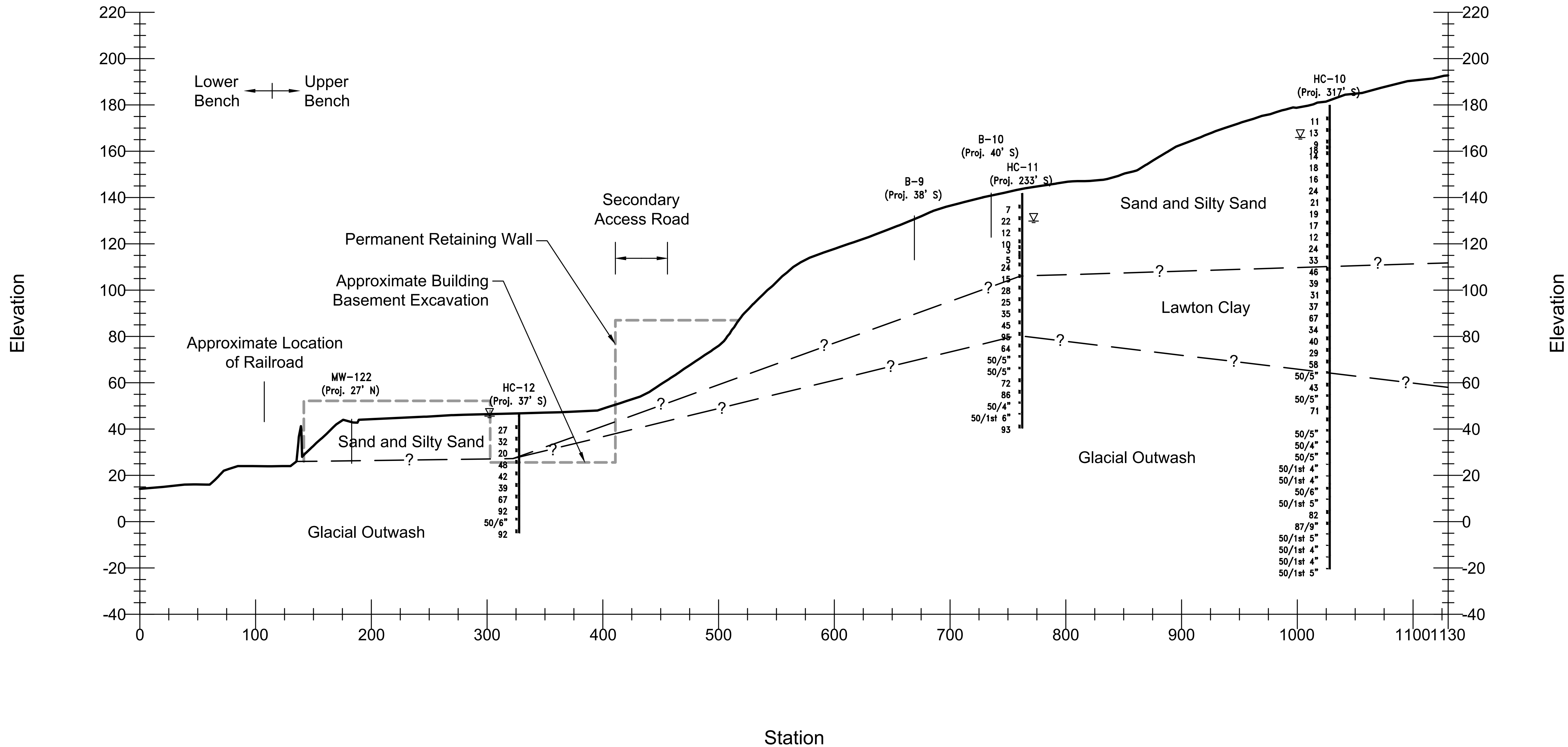
Generalized Subsurface Cross Section B-B'

17203-54 4/18

HARTCROWSER

Figure **8**

EAL 04/17/18 1720354-008 (XSecB).dwg



Legend

HC-102 (34.5' E) Exploration Number (Offset Distance and Direction)

Exploration Location

ATD Water Level

9 Standard Penetration Resistance in Blows per Foot

Note:

1. Contacts between soil units are based upon interpolation between borings and represent our interpretation of subsurface conditions based on currently available data.
2. Slopes appear steeper than they actually are because of vertical exaggeration used for figure clarity. See Figure 4 for slope profile without vertical exaggeration.

Point Wells
Richmond Beach, Washington

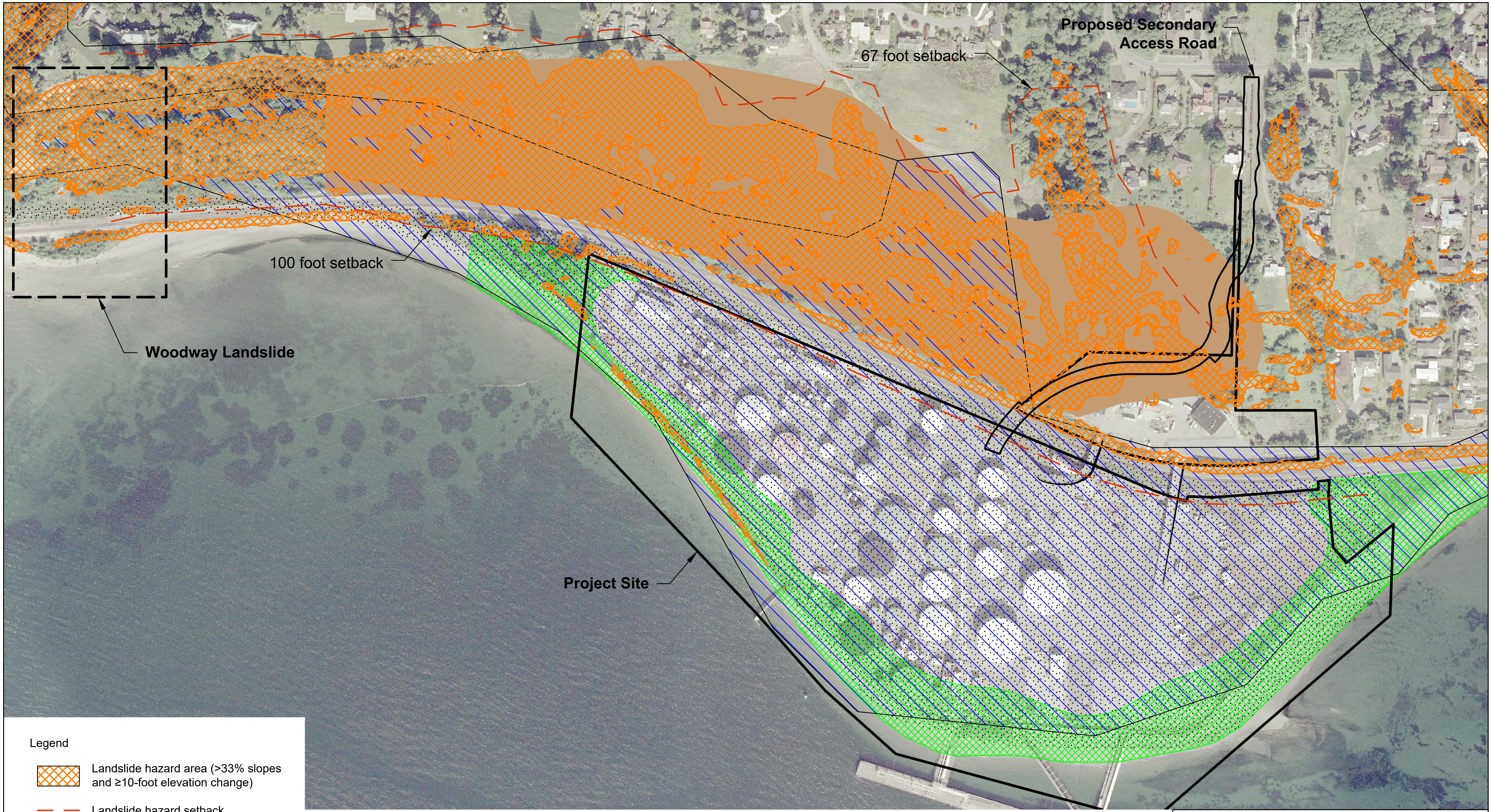
Generalized Subsurface Cross Section G-G'

17203-54 4/18

HARTCROWSER

Figure **9**

EAL 04/17/18 1720354-010 (XSec).dwg



Legend

- Landslide hazard area (>33% slopes and ≥10-foot elevation change)
- Landslide hazard setback
- Modified land
- High liquefaction susceptibility
- High erosion susceptibility
- Maximum expected tsunami water level (elevation 15.5 ft, see Section 6.3 of Report Text)

Note:
This map is for information purposes. Data were compiled from multiple sources as listed on this map. The data sources do not guarantee these data are accurate or complete. There may have been updates to the data since publication of this map. Locations of all features shown are approximate.

Source:
1. Slope data based on LiDAR from Washington State Department of Transportation Rail Division, 2013. Slope data were calculated using GIS tools.
2. Modified land data from Washington State Department of Ecology Coastal Atlas.
3. Liquefaction Susceptibility Map of Snohomish County from Washington State Department of Natural Resources.
4. Erosion Susceptibility Map of Snohomish County from Snohomish County.

N

0 300 600

Scale in Feet

Point Wells
Richmond Beach, Washington

Geologic Hazard Areas

17203-54 4/18

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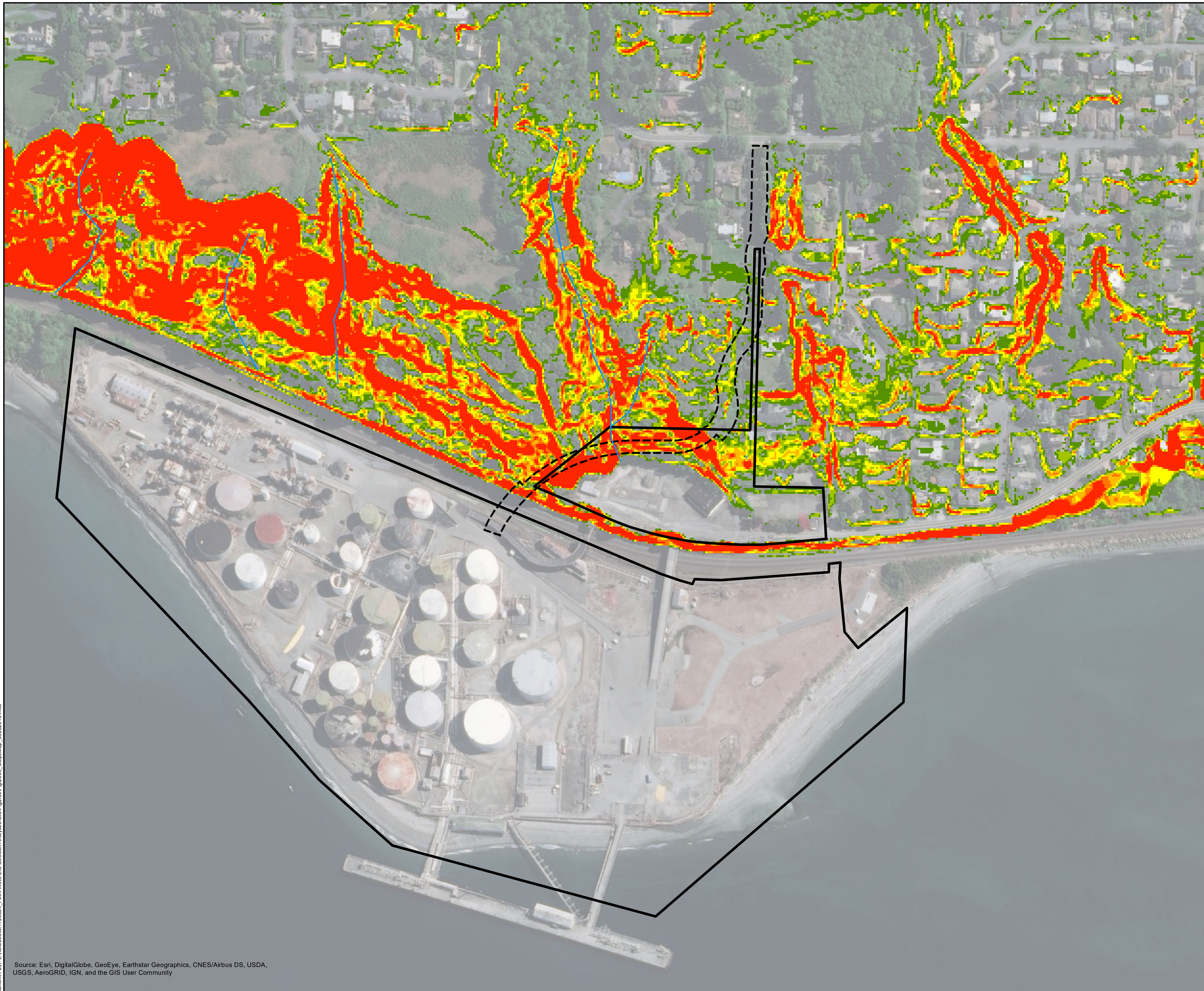
Figure
10

EAL 04/17/18 1720354-004 (Haz).dwg



Slope

- < 20%
- 21% - 25%
- 26% - 30%
- 31% - 35%
- 36% - 40%
- 41% - 45%
- >45%
- Approximate Location of Seasonal Streams
- Project Boundary
- Proposed Secondary Access

Note: Slope data based on LiDAR from Washington State Department of Transportation Rail Division, 2013. Slope data were calculated using GIS tools.

N

0 300 600 Feet

1 inch = 300 feet

Point Wells
Richmond Beach, WA

LiDAR-Derived Slopes

17203-54 4/18

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Figure
11

Document Path: L:\Notebooks\1720354_Point Wells EIS Geotech Analyses\GIS\Figures\Figure09_SlopeMap_05262015.mxd

Coastal Atlas Mapped Unstable Areas (Ecology 2004)

- Recent unstable area
- Unstable area

0 500 1000

Scale in Feet

N

Point Wells

Richmond Beach, Washington

Mapped and Observed Unstable Areas

17203-54 4/18

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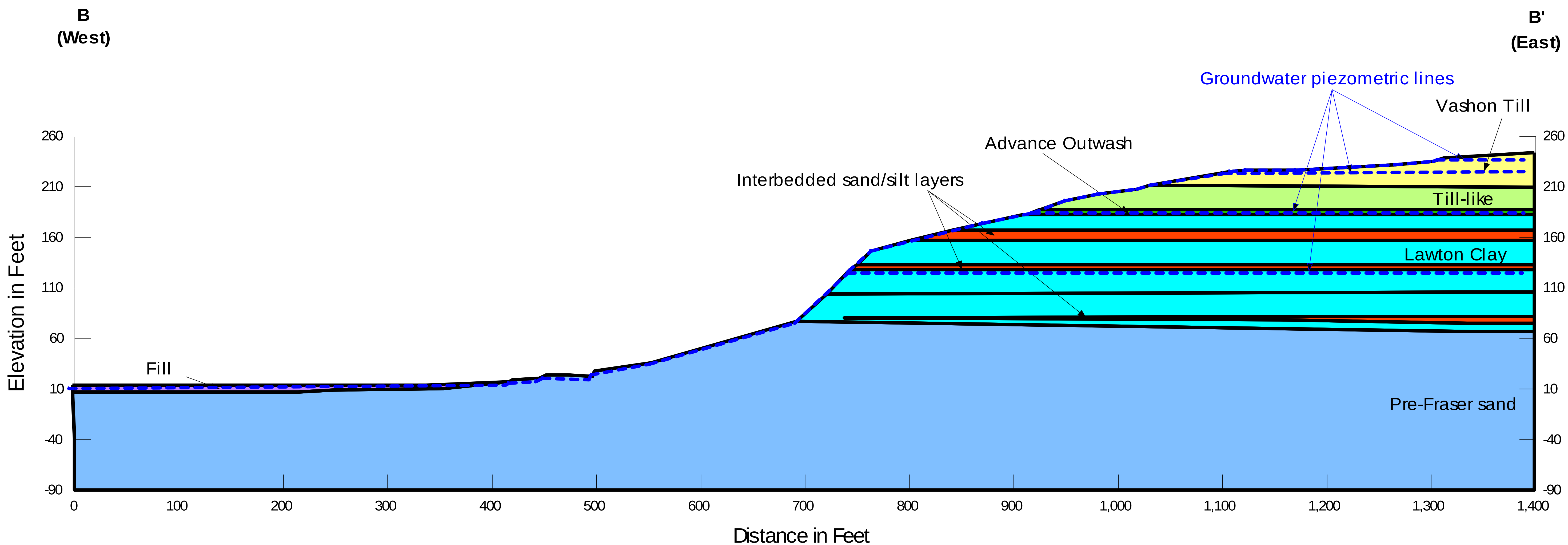
Figure

12

EAL 04/13/18 1720354-005 (Geol).dwg



Stratigraphy inferred from available subsurface explorations and field reconnaissance observations for stability analysis.

Material Properties			
Name	Unit Weight in pcf	Friction Angle in degrees	Cohesion in psf
Vashon Till	140	40	2,000
Till-like	140	40	0
Advance Outwash	135	38	0
Lawton Clay	120	25	1,000
Interbedded sand/silt layers	135	38	0
Pre-Fraser sand	135	38	0
Fill	110	32	0

Point Wells
Richmond Beach, Washington

Slope Stability Stratigraphy - Cross Section B-B'

17203-54 06/15

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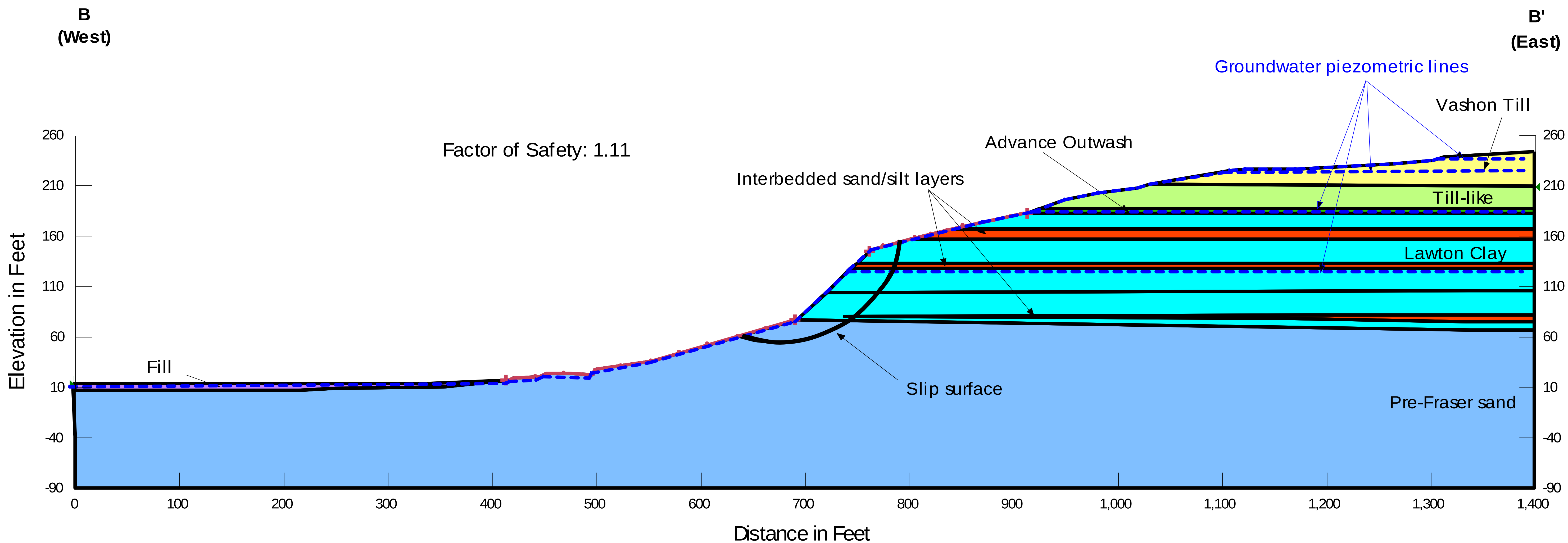
Figure **13**



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Point Wells
Richmond Beach, Washington

Static, Shallower Failure Slope Stability Model - Cross Section B-B'

17203-54 06/15

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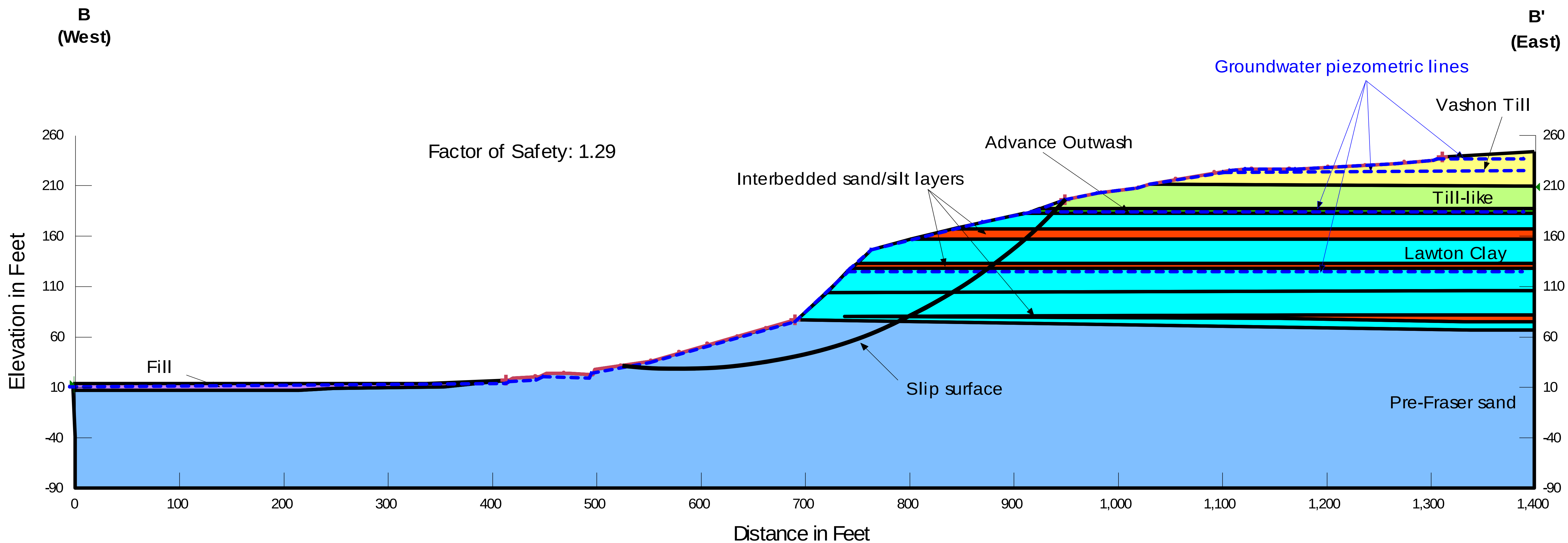
Figure
14



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Point Wells
Richmond Beach, Washington

Static, Deeper Failure Slope Stability Model - Cross Section B-B'

17203-54 06/15

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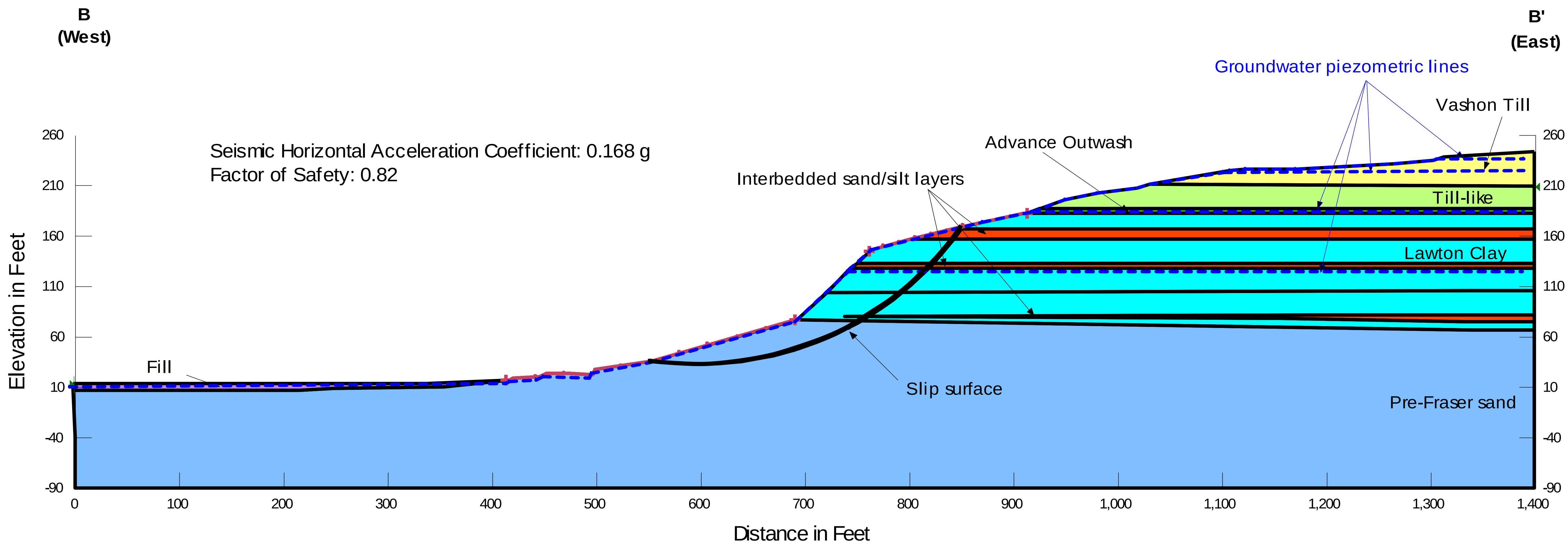
Figure

15



Point Wells
Richmond Beach, Washington

Seismic, Shallower Failure Slope Stability Model - Cross Section B-B'

17203-54 06/15

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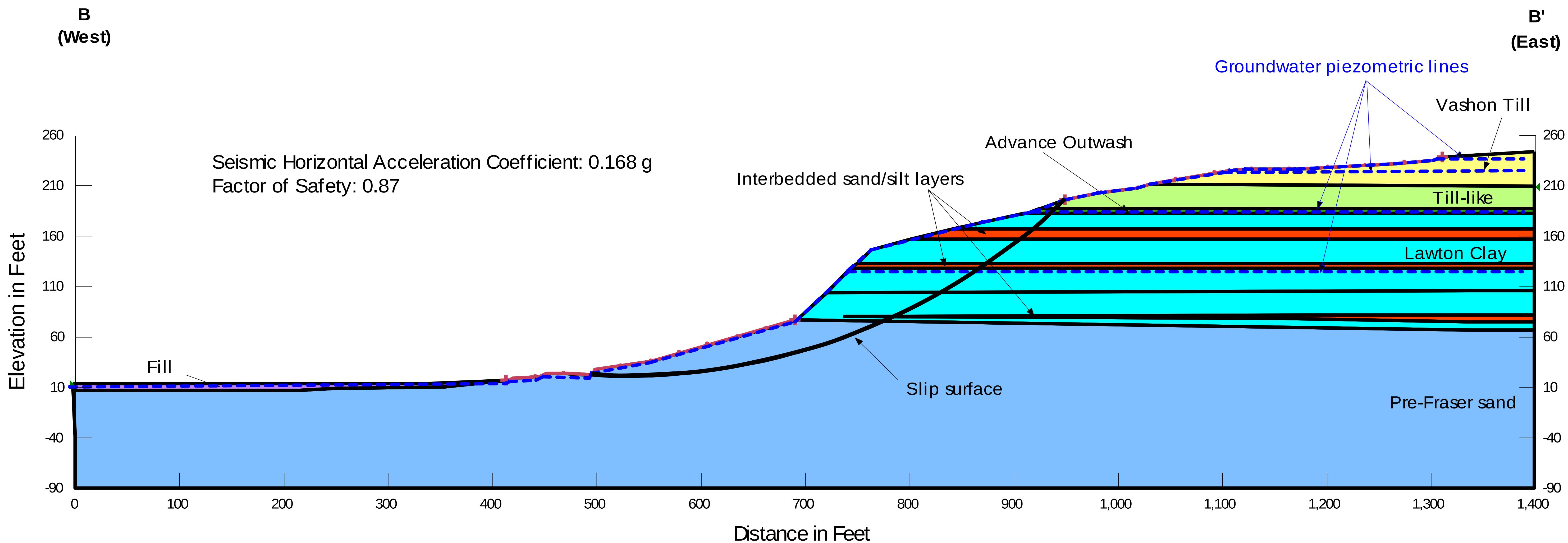
Figure **16**

MJS 06/02/2015 L:\Notebooks\1720354_Point Wells EIS Geotech Analyses\Workspace\Geotech Rpt\Slope W Excel Figs\Excel Figures.xls



Point Wells
Richmond Beach, Washington

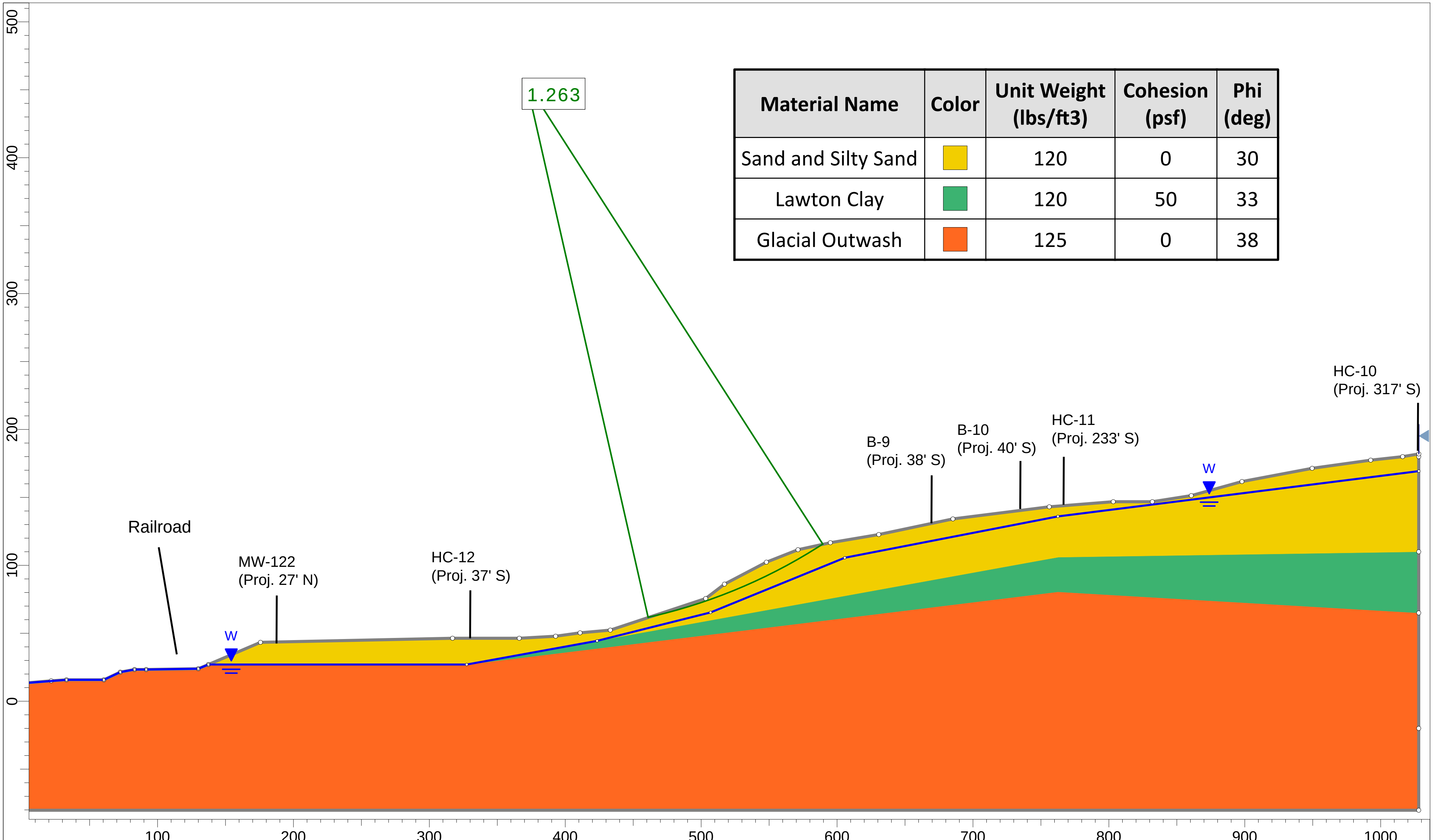
Seismic, Deeper Failure Slope Stability Model - Cross Section B-B'

17203-54 06/15

HARTCROWSER

Figure
17

MJS 06/02/2015 L:\Notebooks\1720354_Point Wells EIS Geotech Analyses\Workspace\Geotech Rpt\Slope W Excel Figs\Excel Figures.xls



Material Name	Color	Unit Weight (lbs/ft3)	Cohesion (psf)	Phi (deg)
Sand and Silty Sand	(yellow)	120	0	30
Lawton Clay	(green)	120	50	33
Glacial Outwash	(orange)	125	0	38

Point Wells
Richmond Beach, Washington

Section G-G'
Existing Conditions - Static

17203-54 Scale 1:1200 4/18

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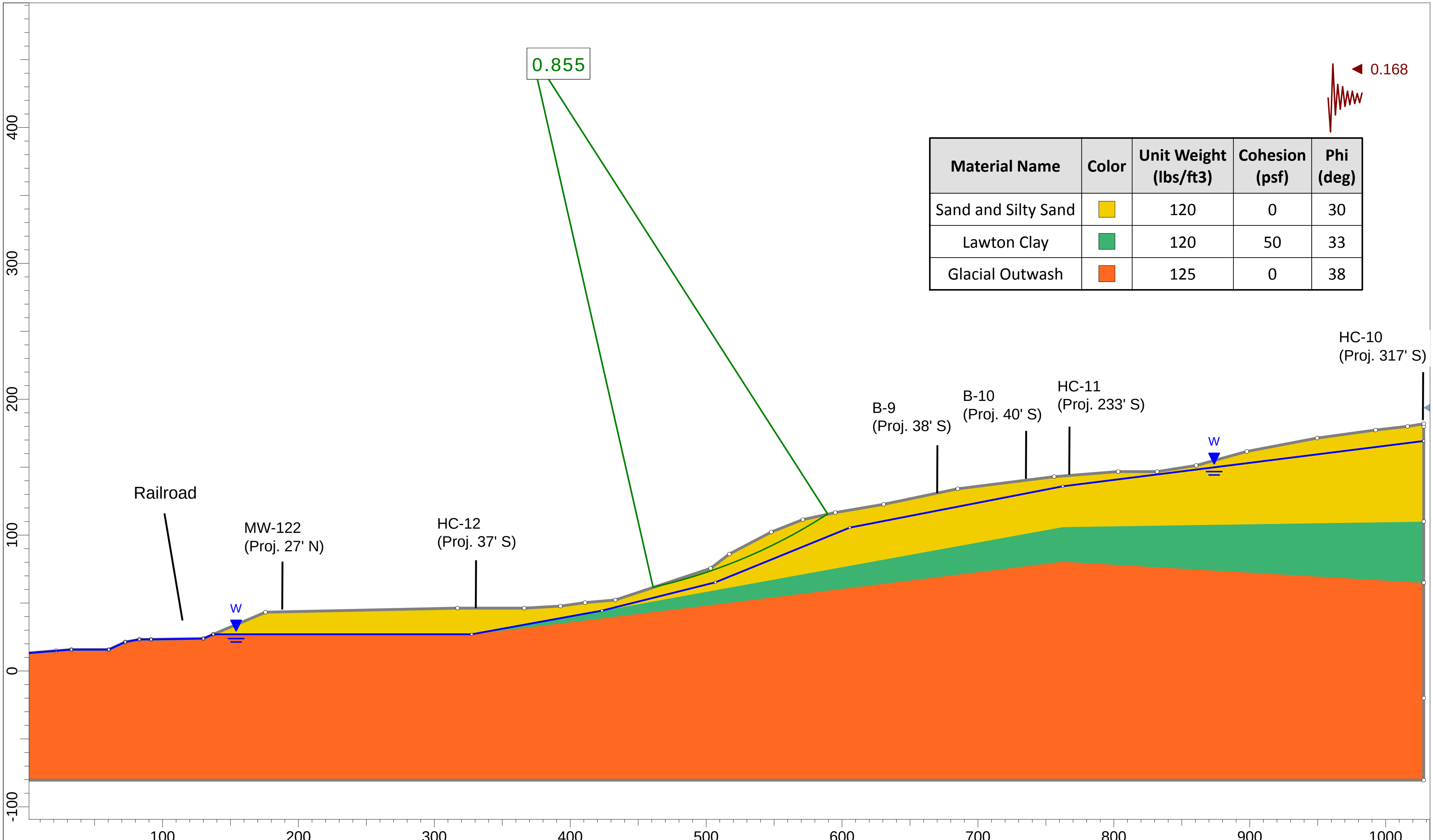
Figure
18



Material Name	Color	Unit Weight (lbs/ft3)	Cohesion (psf)	Phi (deg)
Sand and Silty Sand	Yellow	120	0	30
Lawton Clay	Green	120	50	33
Glacial Outwash	Orange	125	0	38

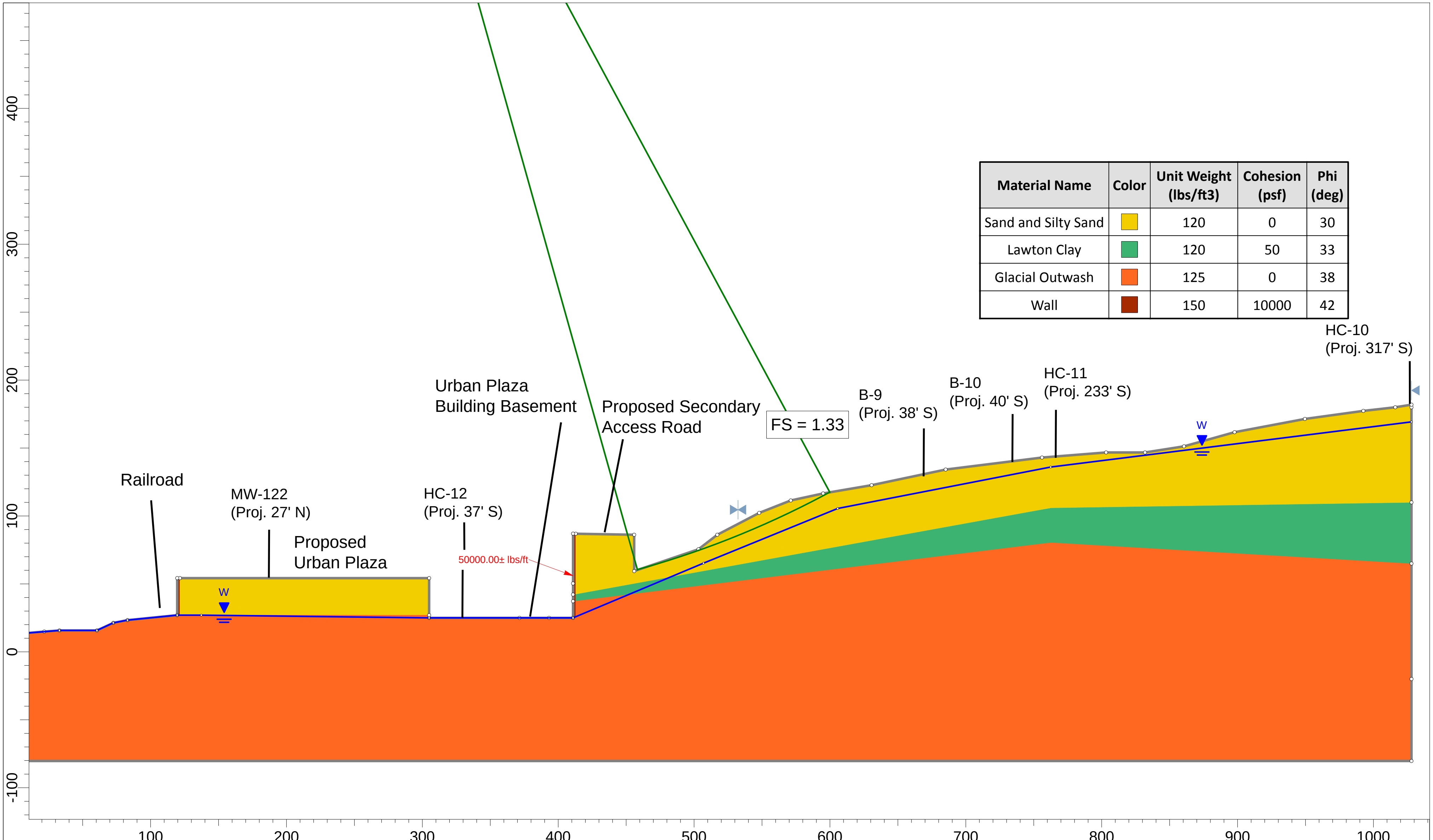
Point Wells
Richmond Beach, Washington

Section G-G'
Existing Conditions - Pseudostatic

17203-54 Scale 1:1200 4/18

HARTCROWSER

Figure
19



Material Name	Color	Unit Weight (lbs/ft3)	Cohesion (psf)	Phi (deg)
Sand and Silty Sand		120	0	30
Lawton Clay		120	50	33
Glacial Outwash		125	0	38
Wall		150	10000	42

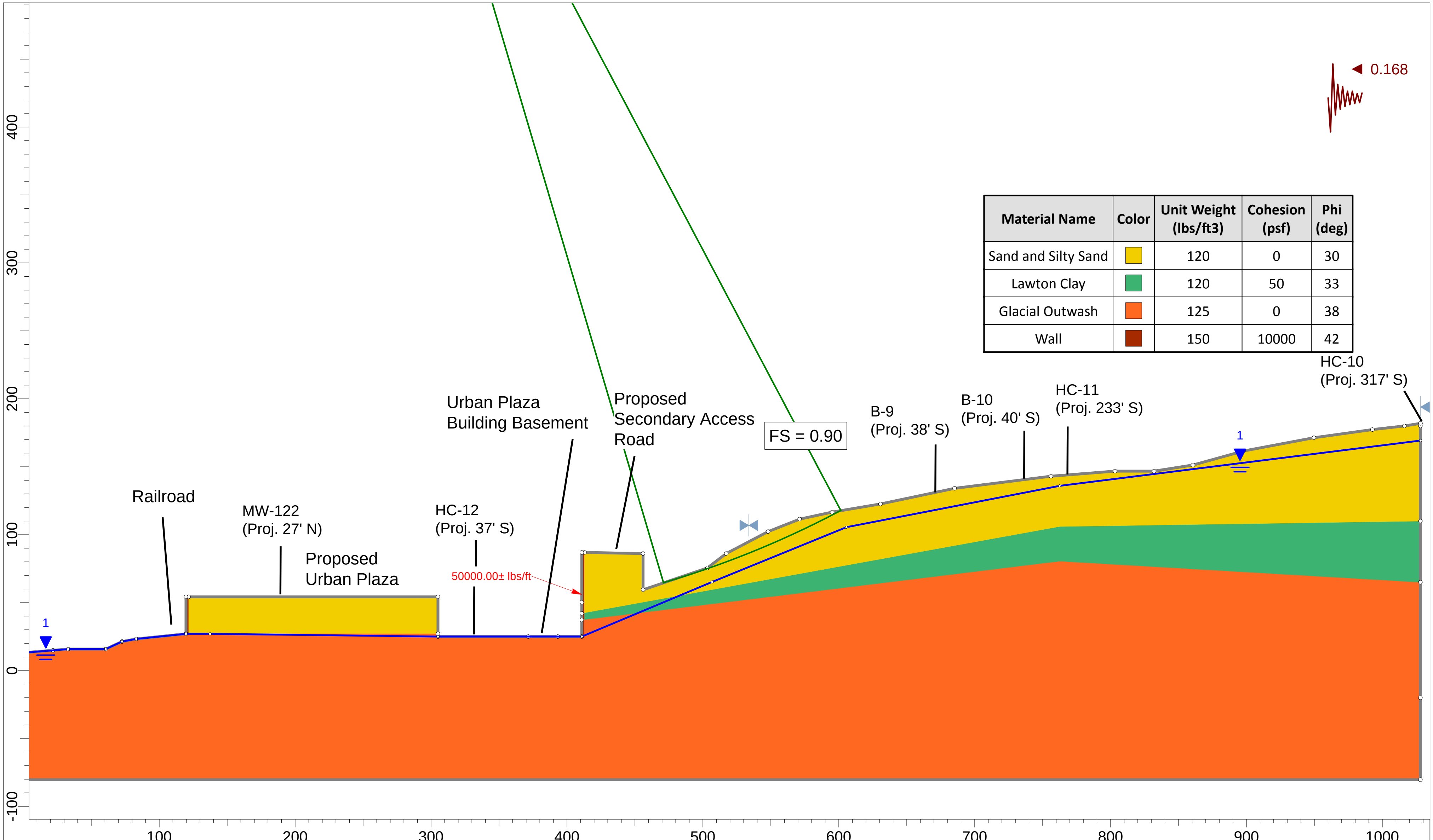
Point Wells
Richmond Beach, Washington

Section G-G'
Proposed Two Walls - Static

17203-54 Scale 1:1200 4/18

HARTCROWSER

Figure
20



Material Name	Color	Unit Weight (lbs/ft3)	Cohesion (psf)	Phi (deg)
Sand and Silty Sand		120	0	30
Lawton Clay		120	50	33
Glacial Outwash		125	0	38
Wall		150	10000	42

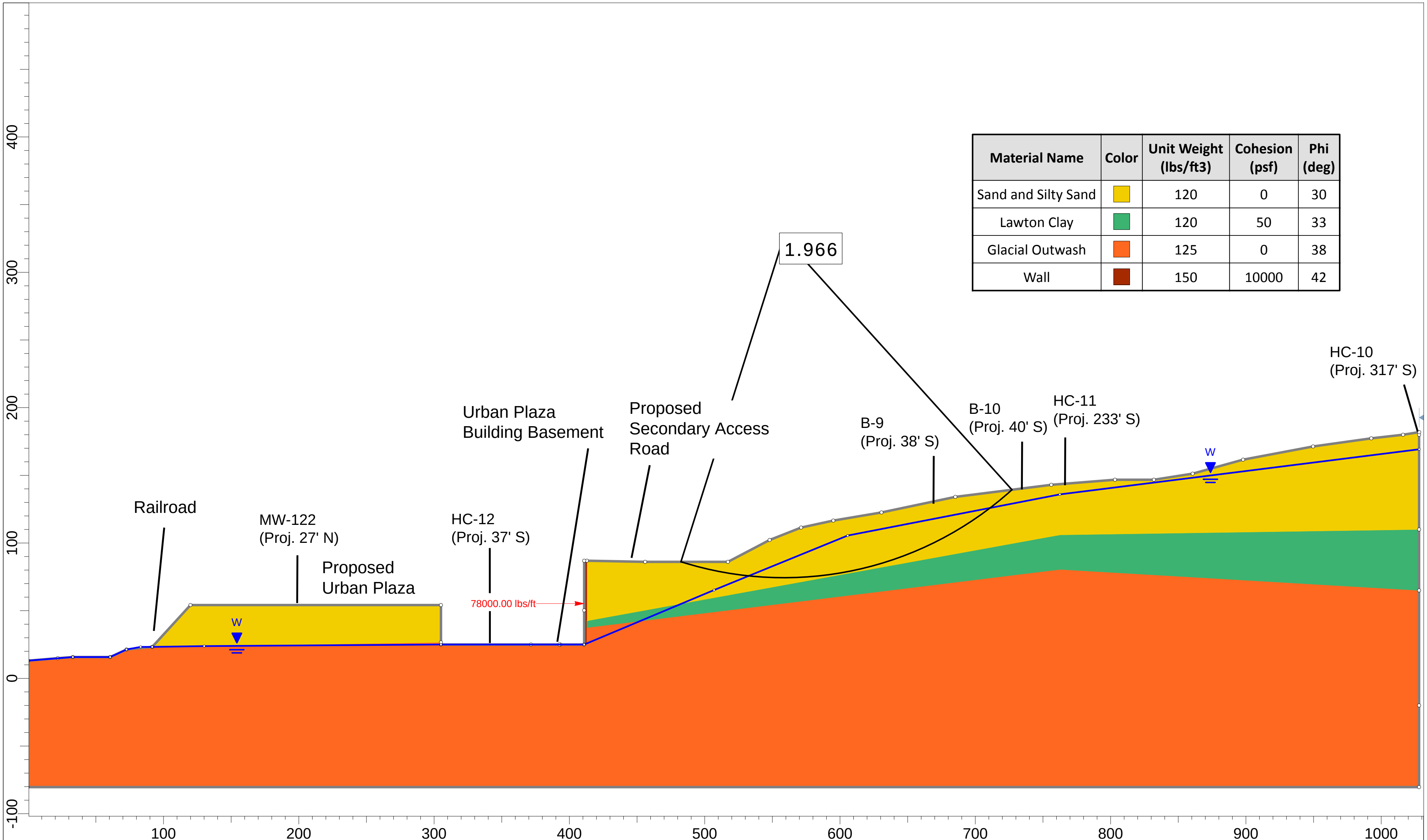
Point Wells
Richmond Beach, Washington

Section G-G'
Proposed Two Walls - Pseudostatic

17203-54 Scale 1:1200 4/18

HARTCROWSER

Figure
21



Material Name	Color	Unit Weight (lbs/ft3)	Cohesion (psf)	Phi (deg)
Sand and Silty Sand		120	0	30
Lawton Clay		120	50	33
Glacial Outwash		125	0	38
Wall		150	10000	42

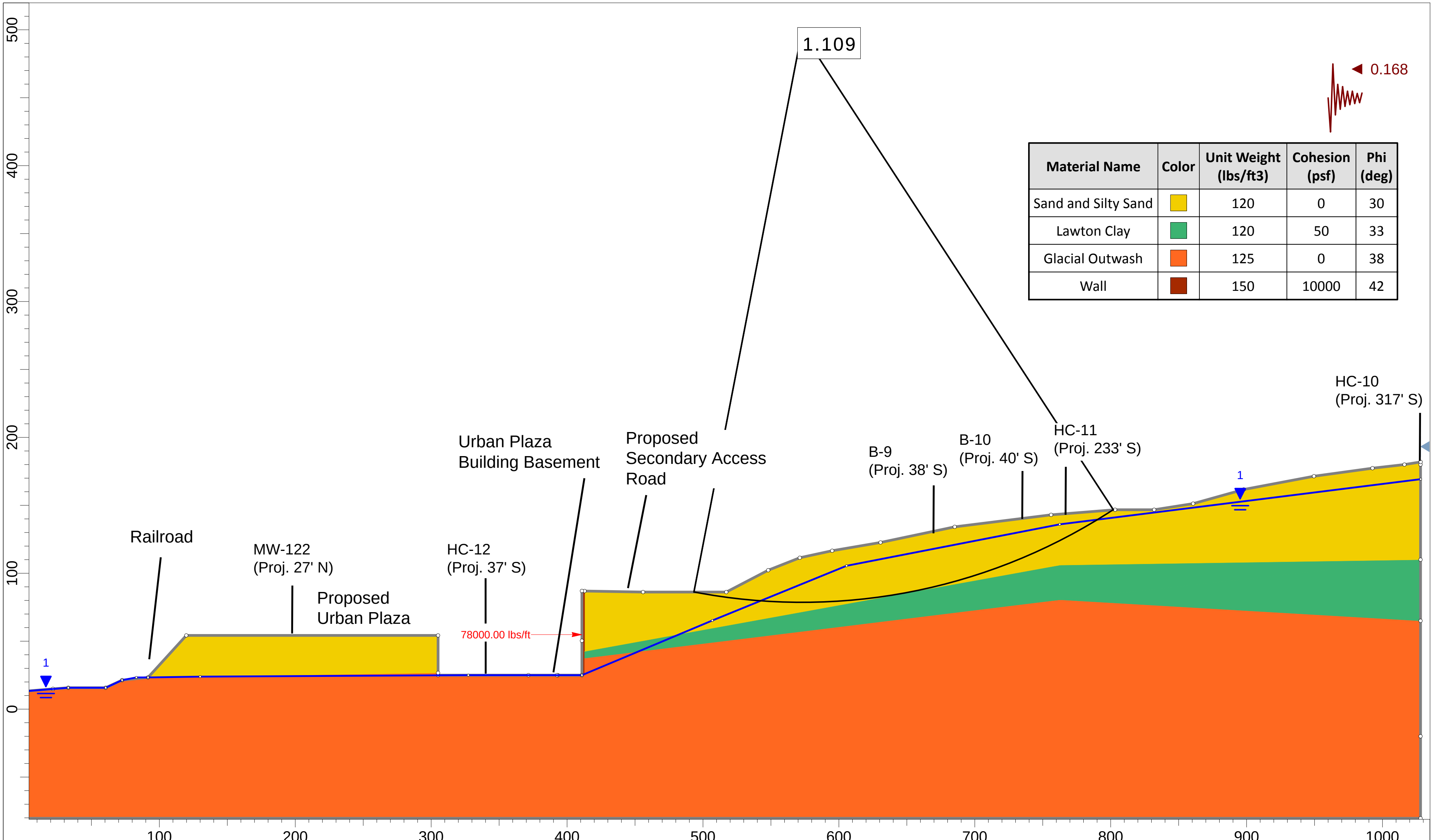
Point Wells
Richmond Beach, Washington

Section G-G'
Wall with Backfill - Static

17203-54 Scale 1:1200 4/18

HARTCROWSER

Figure
22



Material Name	Color	Unit Weight (lbs/ft3)	Cohesion (psf)	Phi (deg)
Sand and Silty Sand		120	0	30
Lawton Clay		120	50	33
Glacial Outwash		125	0	38
Wall		150	10000	42

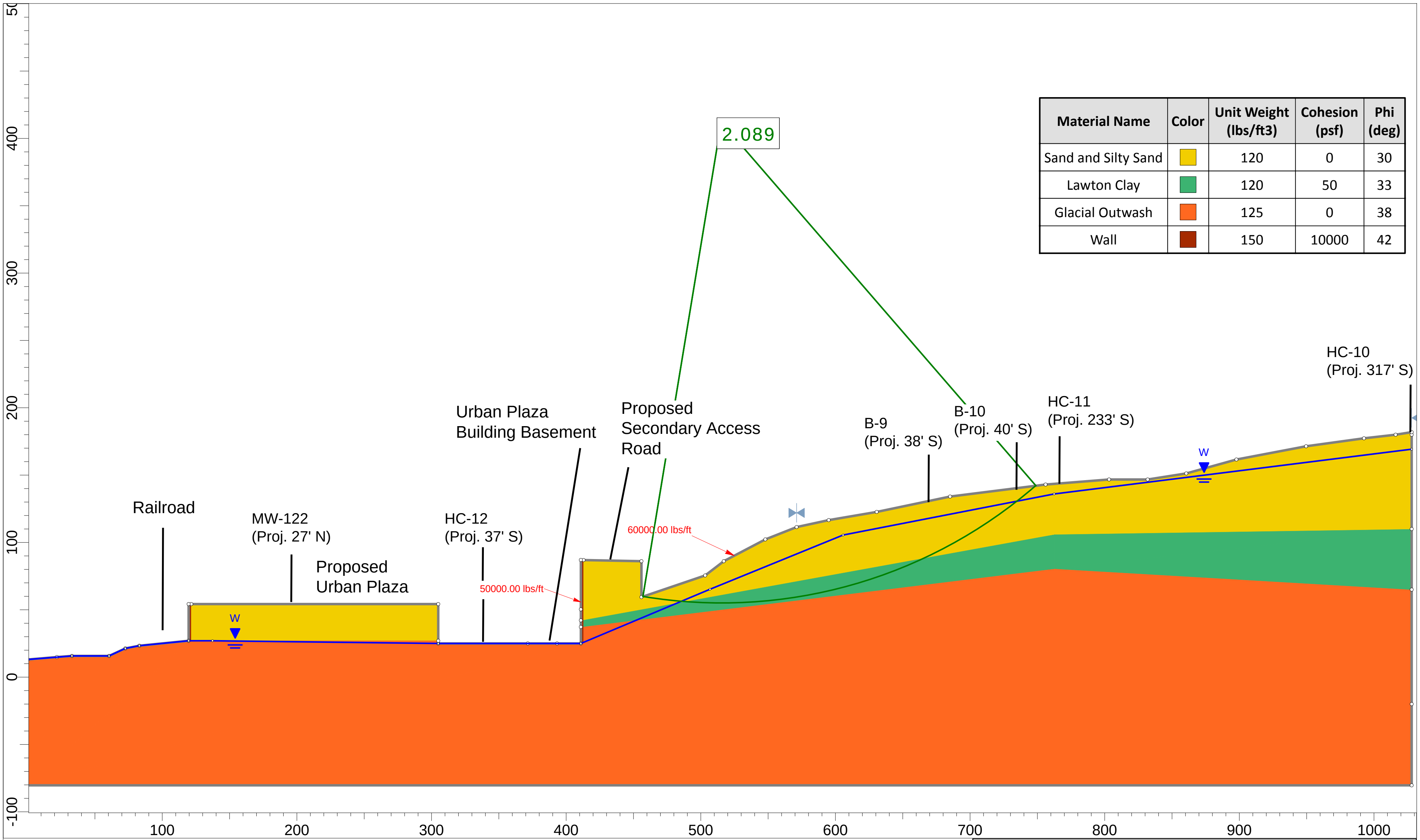
Point Wells
Richmond Beach, Washington

Section G-G'
Wall with Backfill - Pseudostatic

17203-54 Scale 1:1200 4/18

HARTCROWSER

Figure
23



Material Name	Color	Unit Weight (lbs/ft3)	Cohesion (psf)	Phi (deg)
Sand and Silty Sand		120	0	30
Lawton Clay		120	50	33
Glacial Outwash		125	0	38
Wall		150	10000	42

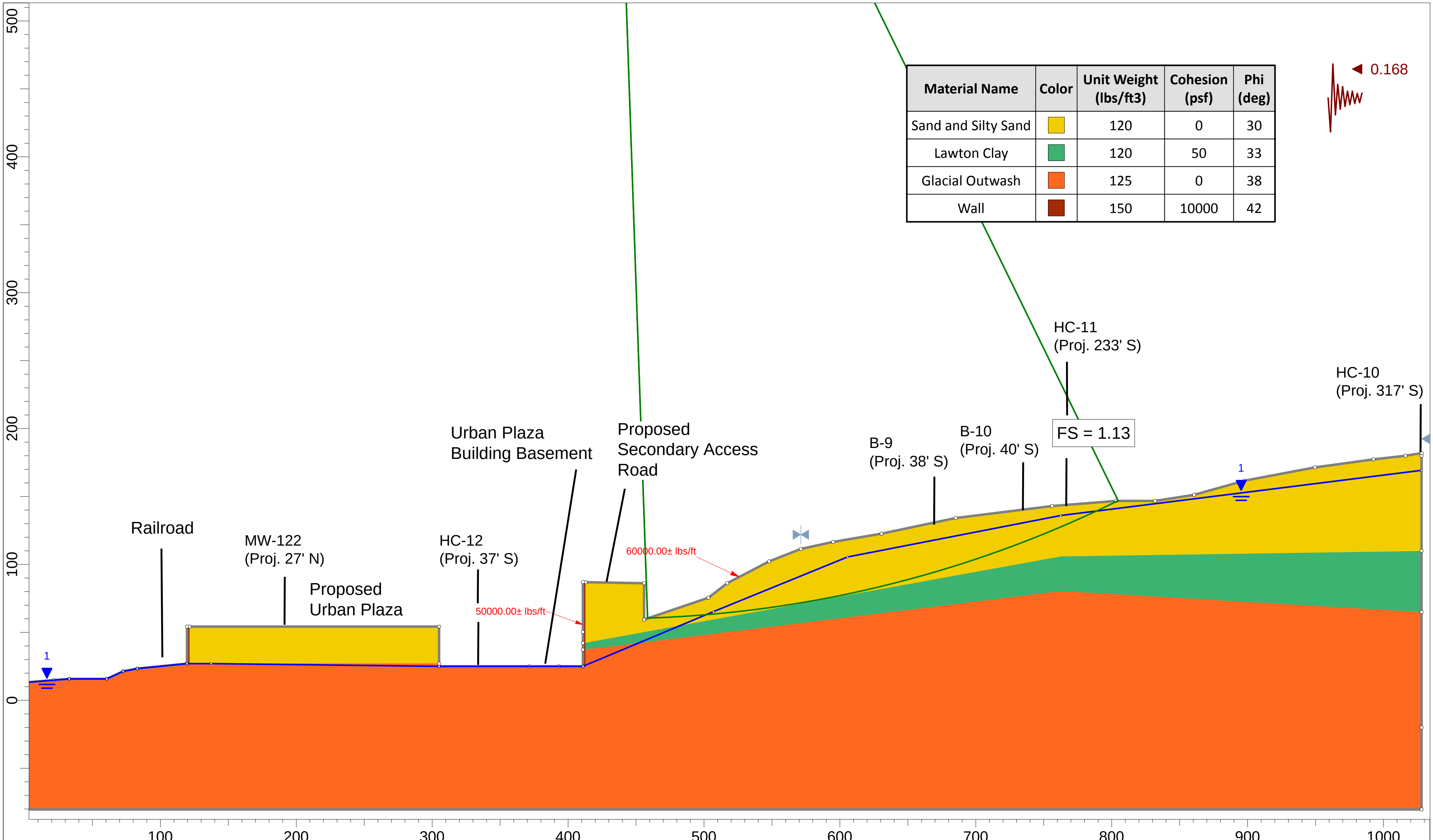
Point Wells
Richmond Beach, Washington

Section G-G' - Proposed Two Walls with Upslope Anchor Block - Static

17203-54 Scale 1:1200 4/18

HARTCROWSER

Figure
24



Material Name	Color	Unit Weight (lbs/ft3)	Cohesion (psf)	Phi (deg)
Sand and Silty Sand		120	0	30
Lawton Clay		120	50	33
Glacial Outwash		125	0	38
Wall		150	10000	42

Point Wells
Richmond Beach, Washington

Section G-G' - Proposed Two Walls with Upslope Anchor Block - Pseudostatic

17203-54 Scale 1:1200 4/18

HARTCROWSER

Figure
25

APPENDIX A
Field Exploration Methods and Analysis

APPENDIX A
FIELD EXPLORATIONS METHODS AND ANALYSIS

This appendix documents the processes Hart Crowser used to determine the nature (and quality) of the soil and groundwater underlying the Project site addressed by this report. The sections are:

- Exploration and Its Location;
- Mud Rotary Borings;
- Standard Penetration Test (SPT) Procedures;
- Vibrating Wire Piezometer Installation; and
- Groundwater Level Measurements.

Exploration and Its Location

The subsurface explorations for this Project were HC-1 in 2015 and HC-10, -11, and -12 conducted in 2018. The exploration logs in this appendix show our interpretation of the drilling, sampling, and testing data. The logs indicate the depth at which the soil change. The change may be gradual. In the field, we classified the samples taken from the explorations according to the methods presented on Figure A-1 – Key to Exploration Logs. This figure also provides a legend explaining the symbols and abbreviations used in the logs.

The location of the exploration is based on GPS measurements referenced to Washington State Plane North coordinates (HC-1) and latitude/longitude (2018 borings). The ground surface elevations were determined by an available digital survey map of the area. The method used determines the accuracy of the information given on the exploration's location and elevation.

Mud Rotary Borings

A 250-foot-deep mud rotary boring, designated HC-1, was drilled from April 16 to April 22, 2015. HC-10, -11 and -12 were drilled from February 19 to February 26, 2018 with total depths of 200.4, 101.5, and 51.5 feet respectively. 2018 borings were drilled using hollow stem auger methods in about the top 20 feet to observe groundwater levels and then mud rotary to depth. The borings all used an approximately 4-inch-diameter tri-cone bit and were advanced with a truck-mounted drill rig (2015) or track rig (2018) subcontracted by Hart Crowser. A geologist from Hart Crowser observed the drilling continuously. Detailed field logs were prepared of each boring. Using the standard penetration test (SPT), we obtained samples at 5-foot depth intervals.

The boring logs are on Figures A-2 through A-5 at the end of this appendix.

Standard Penetration Test Procedures

The SPT (as described in ASTM D1586) provides an approximate measure of soil density and consistency. The results must be used in conjunction with other tests and according to engineering judgment. To obtain disturbed samples, a standard 2-inch-outside-diameter split-spoon sampler is driven into the soil for 18 inches using a 140-pound autohammer, free-falling 30 inches. The number of blows required to drive the sampler the last 12 inches only is the standard penetration resistance. This resistance, or blow count, measures the relative density of granular soil and the consistency of cohesive soil. The blow counts are plotted on the boring logs at their respective sample depths.

Soil samples are recovered from the split-barrel sampler, field classified, placed into water-tight jars, and taken to Hart Crowser's laboratory for further testing.

In the Event of Hard Driving

Occasionally, very dense materials preclude driving the total 18-inch sample. When this happens, the penetration resistance is entered on logs as described below.

Penetration Less than 6 Inches. The blow count is noted on the boring log as 100 blows per foot.

Penetration Greater than 6 Inches. The number of blows completed after the first 6 inches of penetration is divided by the total number of blows and multiplied by 12 inches to determine the blow count in blows per foot. For example, a blow count series of 12 blows for 6 inches, 20 blows for 6 inches, and 50 (the maximum number of blows counted within a 6-inch increment for SPT) for 4 inches would be recorded as 84 blows per foot. The blow count is noted on the log and limited to 100 blows per foot.

Vibrating Wire Piezometer Installation

Vibrating wire piezometers (VWPs) were installed in HC-1 on April 22, 2015, and in HC-10, -11, and -12 on February 22, February 26, and February 19, 2018 respectively, in accordance with Washington State Department of Ecology regulations to allow for long-term groundwater level monitoring at the site. The VWPs were installed to the desired depth with the readout wires extending to the ground surface and encased in the grout backfill. VWPs were installed tip up to prevent any trapped air in the filter that may affect readings. Grout backfill was bentonite-cement slurry with a ratio of 1 pound of bentonite to 3.75 pounds Type II Portland Cement and 1.2 gallons of water. The VWP construction details are illustrated on the boring logs on Figures A-2 through A-5 and the serial numbers of the VWPs are shown on the logs.

Groundwater Level Measurements

VWPs were used to determine groundwater pressure at the depth of the VWP instruments. Groundwater pressure is measured using a data readout connected to the VWP wires at the ground surface. The measured groundwater pressure is then converted to a groundwater elevation. The calibration data for converting the electronic VWP signal to groundwater pressure as well as our field VWP measurements are provided in Appendix C.

Sample Description

Identification of soils in this report is based on visual field and laboratory observations which include density/consistency, moisture condition, grain size, and plasticity estimates and should not be construed to imply field nor laboratory testing unless presented herein. ASTM D 2488 visual-manual identification methods were used as a guide. Where laboratory testing confirmed visual-manual identifications, then ASTM D 2487 was used to classify the soils.

Relative Density/Consistency

Soil density/consistency in borings is related primarily to the standard penetration resistance (N). Soil density/consistency in test pits and probes is estimated based on visual observation and is presented parenthetically on the logs.

SAND or GRAVEL Relative Density	N (Blows/Foot)	SILT or CLAY Consistency	N (Blows/Foot)
Very loose	0 to 4	Very soft	0 to 1
Loose	5 to 10	Soft	2 to 4
Medium dense	11 to 30	Medium stiff	5 to 8
Dense	31 to 50	Stiff	9 to 15
Very dense	>50	Very stiff	16 to 30
		Hard	>30

Moisture

Dry	Absence of moisture, dusty, dry to the touch
Moist	Damp but no visible water
Wet	Visible free water, usually soil is below water table

USCS Soil Classification Chart (ASTM D 2487)

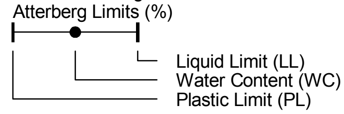
Major Divisions			Symbols: Graph	Symbols: USCS	Typical Descriptions
Coarse Grained Soils More than 50% of Material Retained on No. 200 Sieve	Gravel and Gravelly Soils More than 50% of Coarse Fraction Retained on No. 4 Sieve	Clean Gravels *(<5% fines)*		GW	Well-Graded Gravel; Well-Graded Gravel with Sand
				GP	Poorly Graded Gravel; Poorly Graded Gravel with Sand
		Gravels *(5-12% fines)*		GW-GM	Well-Graded Gravel with Silt; Well-Graded Gravel with Silt and Sand
				GW-GC	Well-Graded Gravel with Clay; Well-Graded Gravel with Clay and Sand
				GP-GM	Poorly Graded Gravel with Silt; Poorly Graded Gravel with Silt and Sand
				GP-GC	Poorly Graded Gravel with Clay; Poorly Graded Gravel with Clay and Sand
		Gravels with Fines *(>12% fines)*		GM	Silty Gravel; Silty Gravel with Sand
				GC	Clayey Gravel; Clayey Gravel with Sand
	Sand and Sandy Soils More than 50% of Coarse Fraction Passing No. 4 Sieve	Sands with few Fines *(<5% fines)*		SW	Well-Graded Sand; Well-Graded Sand with Gravel
				SP	Poorly Graded Sand; Poorly Graded Sand with Gravel
		Sands *(5-12% fines)*		SW-SM	Well-Graded Sand with Silt Well-Graded Sand with Silt and Gravel
				SW-SC	Well-Graded Sand with Clay; Well-Graded Sand with Clay and Gravel
				SP-SM	Poorly Graded Sand with Silt; Poorly Graded Sand with Silt and Gravel
				SP-SC	Poorly Graded Sand with Clay; Poorly Graded Sand with Clay and Gravel
		Sands with Fines *(>12% fines)*		SM	Silty Sand; Silty Sand with Gravel
				SC	Clayey Sand; Clayey Sand with Gravel
Fine Grained Soils More than 50% of Material Passing No. 200 Sieve	Silts			ML	Silt; Silt with Sand or Gravel; Sandy or Gravelly Silt
				MH	Elastic Silt; Elastic Silt with Sand or Gravel; Sandy or Gravelly Elastic Silt
	Silty Clay *(based on Atterberg Limits)*			CL-ML	Silty Clay; Silty Clay with Sand or Gravel; Gravelly or Sandy Silty Clay
	Clays			CL	Lean Clay; Lean Clay with Sand or Gravel; Sandy or Gravelly Lean Clay
				CH	Fat Clay; Fat Clay with Sand or Gravel; Sandy or Gravelly Fat Clay
	Organics			OL/OH	Organic Soil; Organic Soil with Sand or Gravel; Sandy or Gravelly Organic Soil
Highly Organic *(>50% organic material)*				PT	Peat - Decomposing Vegetation - Fibrous to Amorphous Texture

Minor Constituents

	Estimated Percentage
Sand, Gravel	
Trace	<5
Few	5 - 15
Cobbles, Boulders	
Trace	<5
Few	5 - 10
Little	15 - 25
Some	30 - 45

Soil Test Symbols

%F	Percent Passing No. 200 Sieve
AL	Atterberg Limits (%)



CA	Chemical Analysis
CAUC	Consolidated Anisotropic Undrained Compression
CAUE	Consolidated Anisotropic Undrained Extension
CBR	California Bearing Ratio
CIDC	Consolidated Drained Isotropic Triaxial Compression
CIUC	Consolidated Isotropic Undrained Compression
CK0DC	Consolidated Drained k0 Triaxial Compression
CK0DSS	Consolidated k0 Undrained Direct Simple Shear
CK0UC	Consolidated k0 Undrained Compression
CK0UE	Consolidated k0 Undrained Extension
CRSCN	Constant Rate of Strain Consolidation
DSS	Direct Simple Shear
DT	In Situ Density
GS	Grain Size Classification
HYD	Hydrometer
ILCN	Incremental Load Consolidation
K0CN	k0 Consolidation
kc	Constant Head Permeability
kf	Falling Head Permeability
MD	Moisture Density Relationship
OC	Organic Content
OT	Tests by Others
P	Pressuremeter
PID	Photoionization Detector Reading
PP	Pocket Penetrometer
SG	Specific Gravity
TRS	Torsional Ring Shear
TV	Torvane
UC	Unconfined Compression
UUC	Unconsolidated Undrained Triaxial Compression
VS	Vane Shear
WC	Water Content (%)

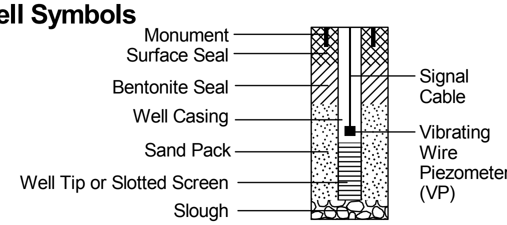
Groundwater Indicators

- Groundwater Level on Date or At Time of Drilling (ATD)
- Groundwater Level on Date Measured in Piezometer
- Groundwater Seepage (Test Pits)

Sample Symbols

1.5" I.D. Split Spoon	Core Run	Grab
3.0" I.D. Split Spoon	Sonic Core	Cuttings
Modified California Sampler	Thin-walled Sampler	

Well Symbols



HARTCROWSER

Project: Point Wells
Location: Snohomish County, WA
Project No.: 17203-54

Key to Exploration Logs

Figure **A-1**
Sheet **1 of 1**

Date Started: 2/20/18 Date Completed: 2/22/18
Logged by: J. Thomas/D. Knapp Checked by: A. Hultz
Location: Lat: 47.779300 Long: -122.389860
Ground Surface Elevation: 182 feet
Horizontal Datum: WGS 84
Vertical Datum: NAVD 88
Comments: Well Tag ID: BKB-607 Geologic unit names apply to all material below until next unit is noted.

Drilling Contractor/Crew: Gregory Drilling / Josh
Drilling Method: Mud Rotary/Hollow Stem Auger
Rig Model/Type: CME-85 / Track-mounted drill rig
Hammer Type: Auto-hammer
Hammer Weight (pounds): 140 Hammer Drop Height (inches): 30
Measured Hammer Efficiency (%): NA
Hole Diameter: 4 inches Casing Diameter:
Total Depth: 200.4 feet Depth to Ground Water: 14 feet

Elevation (feet)	Depth (feet)	Blow Count	Type	Recovery (RQD)	Length (inches)	Number / Tests	Material Description	Water Level	SPT N Value	Fines Content (%)
182	0						SILTY SAND (SM), few gravel, medium dense, moist, light brown, scattered organics. [WEATHERED TILL (QVT)]			
	5	4 5 6		18in.	18	S-1 GS, WC			11	19
	10	3 5 8		18in.	18	S-2A S-2B AL, WC	grades to gray-brown, no gravel or organics		13	
	~11						LEAN CLAY (CL), stiff, moist, gray, upper 3 inches gray with orange mottling. [TRANSITIONAL BEDS (QTB)]			
	~14							ATD		
	15	0 3 6		18in.	18	S-3 WC	POORLY GRADED SAND (SP), loose, wet, gray.		9	
	~18	5 8 10		18in.	18	S-4	SILT (ML), trace sand, stiff to very stiff, wet, gray.		18	
	20	4 6 8		18in.	18	S-5 GS, WC			14	98
	25	4 9 9		18in.	18	S-6			18	
	~29						Vibrating wire S/N 1703868.			
	30	6 8 8		18in.	18	S-7			16	
	35	5 10 14		18in.	18	S-8 WC			24	

Elevation (feet): 180, 175, 170, 165, 160, 155, 150, 145

Legend: PL — WC (%) — LL; ✖ Fines Content (%); ▲ SPT N Value (scale 10, 20, 30, 40)

General Notes:
1. Refer to Figure A-1 for explanation of descriptions and symbols.
2. Material descriptions and stratum lines are interpretive and actual changes may be gradual. Solid stratum lines indicate distinct contact between material strata or geologic units. Dashed stratum lines indicate gradual or approximate change between material strata or geologic units.
3. USCS designations are based on visual-manual identification (ASTM D 2488) unless otherwise supported by laboratory testing (ASTM D 2487).
4. Groundwater level, if indicated, is at time of drilling/excavation (ATD) or for date specified. Level may vary with time.

Date Started: 2/20/18	Date Completed: 2/22/18	Drilling Contractor/Crew: Gregory Drilling / Josh	
Logged by: J. Thomas/D. Knapp	Checked by: A. Hultz	Drilling Method: Mud Rotary/Hollow Stem Auger	
Location: Lat: 47.779300 Long: -122.389860		Rig Model/Type: CME-85 / Track-mounted drill rig	
Ground Surface Elevation: 182 feet		Hammer Type: Auto-hammer	
Horizontal Datum: WGS 84		Hammer Weight (pounds): 140	Hammer Drop Height (inches): 30
Vertical Datum: NAVD 88		Measured Hammer Efficiency (%): NA	
Comments: Well Tag ID: BKB-607 Geologic unit names apply to all material below until next unit is noted.		Hole Diameter: 4 inches	Casing Diameter:
		Total Depth: 200.4 feet	Depth to Ground Water: 14 feet

Elevation (feet)	Depth (feet)	Blow Count	Recovery (RQD)	Length (inches)	Number / Tests	Material Description	SPT N Value	Fines Content (%)
	40	6 9 12	(100%)	18	S-9A, S-9B / AL, WC	SILT (ML), trace sand, stiff to very stiff, wet, gray. *(continued)* FAT CLAY (CH), trace fine sand, stiff, moist, gray. [LAWTON CLAY (QVLC)]	21	
140								
135	45	4 8 11	18in.	18	S-10	subvertical fractures, possible slickensides	19	
130	50	3 8 9	18in.	18	S-11		17	
125	55	0 3 9	15in.	18	S-12A, S-12B	POORLY GRADED SAND (SP), loose, wet, gray. LEAN CLAY (CL), stiff, moist, gray, fine sand. Vibrating wire S/N 1800203.	12	
120	60	5 9 15	18in.	18	S-13 / GS, WC	SILT WITH SAND (ML), very stiff to hard, moist, gray, fine sand.	24	90
115	65	7 15 18	18in.	18	S-14	occasional organics	33	
110	70	13 21 25	6in.	18	S-15 / WC	LEAN CLAY WITH SAND (CL), hard, moist, gray, sand layers.	46	
105	75	8 15 24	18in.	18	S-16A, S-16B / WC	SILT WITH SAND (ML), hard, moist, gray. SILTY SAND (SM), dense, wet, gray, fine sand, interbedded silt and sand.	39	

Legend: PL — WC (%) — LL; ✖ Fines Content (%); ▲ SPT N Value; scale 10, 20, 30, 40

General Notes:
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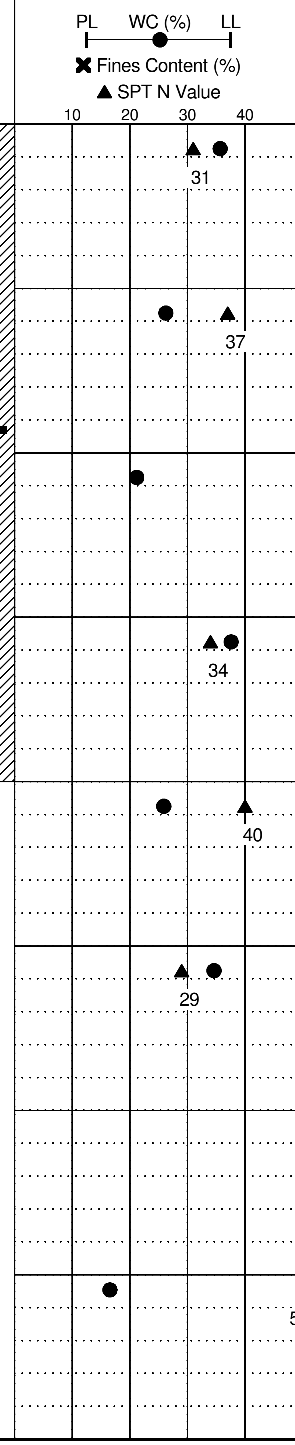
4. Groundwater level, if indicated, is at time of drilling/excavation (ATD) or for date specified. Level may vary with time.

Date Started: 2/20/18	Date Completed: 2/22/18
Logged by: J. Thomas/D. Knapp	Checked by: A. Hultz
Location: Lat: 47.779300 Long: -122.389860	
Ground Surface Elevation: 182 feet	
Horizontal Datum: WGS 84	
Vertical Datum: NAVD 88	
Comments: Well Tag ID: BKB-607 Geologic unit names apply to all material below until next unit is noted.	

Drilling Contractor/Crew: Gregory Drilling / Josh	
Drilling Method: Mud Rotary/Hollow Stem Auger	
Rig Model/Type: CME-85 / Track-mounted drill rig	
Hammer Type: Auto-hammer	
Hammer Weight (pounds): 140	Hammer Drop Height (inches): 30
Measured Hammer Efficiency (%): NA	
Hole Diameter: 4 inches	Casing Diameter:
Total Depth: 200.4 feet	Depth to Ground Water: 14 feet

Elevation (feet)	Depth (feet)	Blow Count	Recovery (RQD)	Length (inches)	Number Tests	Material Description	SPT N Value
100 (at 82 ft)	80	7 15 16	18in.	18	S-17 WC	LEAN CLAY (CL), hard, moist, gray.	31
95 (at 87 ft)	85	7 14 23	18in.	18	S-18 WC	SANDY SILT (ML), hard, moist to wet, gray.	37
	~89.5					Vibrating wire S/N 1703302.	
90 (at 92 ft)	90	25 31 36	18in.	18	S-19 WC	SILTY SAND (SM), very dense, moist to wet, gray, fine sand.	67
85 (at 97 ft)	95	8 15 19	18in.	18	S-20 WC	LEAN CLAY (CL), hard, moist, gray.	34
80 (at 102 ft)	100	8 16 24	18in.	18	S-21 WC	SANDY SILT (ML), hard, wet, gray.	40
75 (at 107 ft)	105	9 13 16	18in.	18	S-22 WC	LEAN CLAY (CL), very stiff, moist, gray.	29
70 (at 112 ft)	110	14 29 29	18in.	18	S-23A / S-23B	SANDY SILT (ML), hard, moist, gray. / LEAN CLAY (CL), hard, dry to moist, gray.	58
65 (at 117 ft)	115	35 50	11in.	11	S-24 WC	POORLY GRADED SAND (SP), very dense, moist, gray, fine to medium sand. [PRE-FRASER DEPOSITS (QPF)]	50/5"



General Notes:
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Date Started: 2/20/18 Date Completed: 2/22/18
Logged by: J. Thomas/D. Knapp Checked by: A. Hultz
Location: Lat: 47.779300 Long: -122.389860
Ground Surface Elevation: 182 feet
Horizontal Datum: WGS 84
Vertical Datum: NAVD 88
Comments: Well Tag ID: BKB-607 Geologic unit names apply to all material below until next unit is noted.

Drilling Contractor/Crew: Gregory Drilling / Josh
Drilling Method: Mud Rotary/Hollow Stem Auger
Rig Model/Type: CME-85 / Track-mounted drill rig
Hammer Type: Auto-hammer
Hammer Weight (pounds): 140 Hammer Drop Height (inches): 30
Measured Hammer Efficiency (%): NA
Hole Diameter: 4 inches Casing Diameter:
Total Depth: 200.4 feet Depth to Ground Water: 14 feet

Depth (feet)	Blow Count	Recovery (RQD)	Length (inches)	Number / Tests	Material Description	PL / WC (%) / LL; Fines Content (%); SPT N Value
120	10, 20, 23	18in.	18	S-25 AL, WC	LEAN CLAY (CL), hard, dry to moist, gray.	43
125	32, 50	11in.	11	S-26	SILTY SAND (SM), very dense, moist to wet, gray, fine sand.	50/5"
130	19, 35, 36	18in.	18	S-27A; S-27B WC	SILT (ML), trace fine sand, hard, moist, gray. SILTY SAND (SM), very dense, moist to wet, gray, fine sand.	71
135	39, 50	11in.	18	S-28		
140	39, 50	11in.	11	S-29 GS, WC		21; 50/5"
145	46, 50	10in.	10	S-30 WC	POORLY GRADED SAND (SP), very dense, moist, gray to light gray, fine to medium sand.	50/4"
150	46, 50	11in.	11	S-31		50/5"
155	50	4in.	4	S-32 WC	POORLY GRADED SAND WITH SILT (SP-SM), very dense, moist, gray to light gray, fine to medium sand.	50/1st 4"

Elevation (feet): 60, 55, 50, 45, 40, 35, 30, 25

General Notes:
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Date Started: 2/20/18	Date Completed: 2/22/18
Logged by: J. Thomas/D. Knapp	Checked by: A. Hultz
Location: Lat: 47.779300 Long: -122.389860	
Ground Surface Elevation: 182 feet	
Horizontal Datum: WGS 84	
Vertical Datum: NAVD 88	
Comments: Well Tag ID: BKB-607 Geologic unit names apply to all material below until next unit is noted.	
Drilling Contractor/Crew: Gregory Drilling / Josh	
Drilling Method: Mud Rotary/Hollow Stem Auger	
Rig Model/Type: CME-85 / Track-mounted drill rig	
Hammer Type: Auto-hammer	
Hammer Weight (pounds): 140	Hammer Drop Height (inches): 30
Measured Hammer Efficiency (%): NA	
Hole Diameter: 4 inches	Casing Diameter:
Total Depth: 200.4 feet	Depth to Ground Water: 14 feet

Elevation (feet) markers: 20, 15, 10, 5, 0, -5, -10, -15

Depth (feet)	Blow Count	Recovery (RQD)	Length (inches)	Number / Tests	Material Description	SPT N Value
160	50	4in.	4	S-33	SILTY SAND (SM), very dense, moist, gray, fine sand, fine sandy silt laminations.	50/1st 4"
					LEAN CLAY (CL), hard, dry to moist, gray-green, scattered organics with odor. [OLYMPIA BEDS (QOB)]	
165	21 50	12in.	12	S-34A WC S-34B	SANDY SILT (ML), hard, moist, gray-green, scattered organics with odor.	50/6"
					POORLY GRADED SAND WITH SILT (SP-SM), very dense, moist, gray to light gray, medium sand.	
170	50	5in.	5	S-35 WC		50/1st 5"
175	31 32 50	17in.	18	S-36	SANDY SILT (ML), hard, moist, gray-brown, fine sand layers.	82
180	25 37 50	15in.	15	S-37	SILTY SAND (SM), very dense, moist, gray-brown to brown, fine sandy silt layers, scattered organics.	87/9"
					WELL-GRADED SAND WITH SILT (SW-SM), trace gravel, very dense, moist, gray, fine to coarse sand.	
185	50	5in.	5	S-38 WC		50/1st 5"
190	50	3in.	4	S-39		50/1st 4"
					POORLY GRADED SAND WITH SILT (SP-SM), very dense, moist to wet, gray to light gray, medium sand.	
195	50	4in.	4	S-40 WC		50/1st 4"

PL WC (%) LL
Fines Content (%)
SPT N Value
10 20 30 40

General Notes:
1. Refer to Figure A-1 for explanation of descriptions and symbols.
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3. USCS designations are based on visual-manual identification (ASTM D 2488) unless otherwise supported by laboratory testing (ASTM D 2487).
4. Groundwater level, if indicated, is at time of drilling/excavation (ATD) or for date specified. Level may vary with time.

Date Started: 2/20/18	Date Completed: 2/22/18
Logged by: J. Thomas/D. Knapp	Checked by: A. Hultz
Location: Lat: 47.779300 Long: -122.389860	
Ground Surface Elevation: 182 feet	
Horizontal Datum: WGS 84	
Vertical Datum: NAVD 88	
Comments: Well Tag ID: BKB-607 Geologic unit names apply to all material below until next unit is noted.	

Drilling Contractor/Crew: Gregory Drilling / Josh	
Drilling Method: Mud Rotary/Hollow Stem Auger	
Rig Model/Type: CME-85 / Track-mounted drill rig	
Hammer Type: Auto-hammer	
Hammer Weight (pounds): 140	Hammer Drop Height (inches): 30
Measured Hammer Efficiency (%): NA	
Hole Diameter: 4 inches	Casing Diameter:
Total Depth: 200.4 feet	Depth to Ground Water: 14 feet

Elevation (feet)	Depth (feet)	Blow Count	Type	Recovery (RQD)	Length (inches)	Number Tests	Graphic Log	Material Description	Water Level	Well Construction	PL — WC (%) — LL; ✖ Fines Content (%); ▲ SPT N Value (10 20 30 40)	Depth (feet)
	200	50	☒	5in.	5	S-41		Bottom of Borehole at 200.4 feet.			▲ 50/1st 5"	200

Elevation scale: -20, -25, -30, -35, -40, -45, -50, -55

Depth scale: 205, 210, 215, 220, 225, 230, 235

General Notes:
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3. USCS designations are based on visual-manual identification (ASTM D 2488) unless otherwise supported by laboratory testing (ASTM D 2487).
4. Groundwater level, if indicated, is at time of drilling/excavation (ATD) or for date specified. Level may vary with time.

Date Started: 2/23/18	Date Completed: 2/26/18
Logged by: D. Knapp	Checked by: A. Hultz
Location: Lat: 47.779428 Long: -122.391436	
Ground Surface Elevation: 125 feet	
Horizontal Datum: WGS 84	
Vertical Datum: NAVD 88	
Comments: Well Tag ID: BKB-608 Geologic unit names apply to all material below until next unit is noted.	

Drilling Contractor/Crew: Gregory Drilling / Josh	
Drilling Method: Mud Rotary/Hollow Stem Auger	
Rig Model/Type: CME-85 / Track-mounted drill rig	
Hammer Type: Auto-hammer	
Hammer Weight (pounds): 140	Hammer Drop Height (inches): 30
Measured Hammer Efficiency (%): NA	
Hole Diameter: 4 inches	Casing Diameter:
Total Depth: 101.5 feet	Depth to Ground Water: 12 feet

Sample Data

Elevation (feet)	Depth (feet)	Blow Count	Recovery Length (inches)	Number / Tests	SPT N Value
120	5	3 3 4	12in. / 18	S-1	7
115	10	5 10 12	18in. / 18	S-2	22
110	15	3 5 7	18in. / 18	S-3 AL, WC	12
105	20	4 4 6	12in. / 18	S-4	10
		1 1 2	18in. / 18	S-5	3
100	25		22in. / 22	S-6	
		1 2 3	16in. / 18	S-7	5
95	30	6 10 14	18in. / 18	S-8A S-8B WC	24
90	35	4 7 8	18in. / 18	S-9 AL, WC	15

Material Description

0 ft: ORGANIC SOIL WITH SAND (OL), trace gravel, loose, moist, brown. [COLLUVIUM]

10 ft: SILT (ML), medium stiff to very stiff, moist, gray, silt laminations. [LAWTON CLAY (QVLC)]

Water Level: ATD ∇ (approx. 12 ft)

becomes soft, increasing sand, interbedded silt and sand

Vibrating wire S/N 1800204.

30 ft: SILTY SAND (SM), medium dense, moist, gray, fine sand.

35 ft: FAT CLAY (CH), stiff, moist, gray, clay laminations.

Legend: PL — WC (%) — LL; ✖ Fines Content (%); ▲ SPT N Value (10, 20, 30, 40)

General Notes:
1. Refer to Figure A-1 for explanation of descriptions and symbols.
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4. Groundwater level, if indicated, is at time of drilling/excavation (ATD) or for date specified. Level may vary with time.

Date Started: 2/23/18 Date Completed: 2/26/18
Logged by: D. Knapp Checked by: A. Hultz
Location: Lat: 47.779428 Long: -122.391436
Ground Surface Elevation: 125 feet
Horizontal Datum: WGS 84
Vertical Datum: NAVD 88
Comments: Well Tag ID: BKB-608 Geologic unit names apply to all material below until next unit is noted.

Drilling Contractor/Crew: Gregory Drilling / Josh
Drilling Method: Mud Rotary/Hollow Stem Auger
Rig Model/Type: CME-85 / Track-mounted drill rig
Hammer Type: Auto-hammer
Hammer Weight (pounds): 140 Hammer Drop Height (inches): 30
Measured Hammer Efficiency (%): NA
Hole Diameter: 4 inches Casing Diameter:
Total Depth: 101.5 feet Depth to Ground Water: 12 feet

Elevation (feet)	Depth (feet)	Blow Count	Recovery	Length (inches)	Number / Tests	Material Description	WC (%)	Fines Content (%)	SPT N Value
	40	6 12 16	18in.	18	S-10A S-10B S-10	FAT CLAY (CH), stiff, moist, gray, clay laminations. *(continued)*			28
						SANDY SILT (ML), very stiff, moist, gray.			
80	45	5 11 14	18in.	18	S-11	LEAN CLAY (CL), trace fine sand, very stiff to hard, dry to moist, gray, clay laminations, scattered organics.			25
75	50	10 13 22	18in.	18	S-12 AL, WC	no sand or organics			35
70	55	14 16 29	18in.	18	S-13A S-13B	SANDY SILT (ML), hard, moist, gray.			45
65	60	12 45 50	18in.	18	S-14A S-14B	decreasing sand SILTY SAND (SM), very dense, moist, gray, fine sand. [PRE-FRASER DEPOSITS (QPF)]			95
						SILT (ML), hard, moist, gray.			
60	65	11 18 46	18in.	18	S-15A S-15B	LEAN CLAY (CL), hard, moist, gray.			64
55	70	41 50	11in.	11	S-16	SILTY SAND (SM), very dense, moist, gray, fine to medium sand.			50/5"
50	75	30 50	11in.	11	S-17 GS, WC			18	50/5"

General Notes:
1. Refer to Figure A-1 for explanation of descriptions and symbols.
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4. Groundwater level, if indicated, is at time of drilling/excavation (ATD) or for date specified. Level may vary with time.

Date Started: 2/23/18	Date Completed: 2/26/18	Drilling Contractor/Crew: Gregory Drilling / Josh	
Logged by: D. Knapp	Checked by: A. Hultz	Drilling Method: Mud Rotary/Hollow Stem Auger	
Location: Lat: 47.779428 Long: -122.391436		Rig Model/Type: CME-85 / Track-mounted drill rig	
Ground Surface Elevation: 125 feet		Hammer Type: Auto-hammer	
Horizontal Datum: WGS 84		Hammer Weight (pounds): 140	Hammer Drop Height (inches): 30
Vertical Datum: NAVD 88		Measured Hammer Efficiency (%): NA	
Comments: Well Tag ID: BKB-608 Geologic unit names apply to all material below until next unit is noted.		Hole Diameter: 4 inches	Casing Diameter:
		Total Depth: 101.5 feet	Depth to Ground Water: 12 feet

Elevation (feet)	Depth (feet)	Blow Count	Type	Recovery	Length (inches)	Number / Tests	Material Description	PL / WC (%) / LL; Fines Content (%); SPT N Value
	80	18 30 42		18in.	18	S-18A / S-18B / GS, WC	SILT (ML), hard, moist, gray-green, numerous organics. SILTY SAND (SM), very dense, moist to wet, gray, fine to medium sand.	Fines 35; SPT 72
40	85	27 41 45		18in.	18	S-19	POORLY GRADED SAND WITH SILT (SP-SM), very dense, wet, gray, fine to medium sand.	SPT 86
35	90	44 50		10in.	10	S-20 / GS, WC	SILT (ML), hard, moist to wet, gray-green, numerous organics.	Fines 94; SPT 50/4"
30	95	50		6in.	6	S-21 / WC	POORLY GRADED SAND WITH SILT (SP-SM), very dense, moist, gray, fine to medium sand.	SPT 50/1st 6"
25	100	31 43 50		18in.	18	S-22		SPT 93
							Bottom of Borehole at 101.5 feet.	
20	105							
15	110							
10	115							

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Date Started: 2/19/18	Date Completed: 2/19/18	Drilling Contractor/Crew: Gregory Drilling / Josh	
Logged by: J. Thomas	Checked by: A. Hultz	Drilling Method: Mud Rotary/Hollow Stem Auger	
Location: Lat: 47.780000 Long: -122.392650		Rig Model/Type: CME-85 / Track-mounted drill rig	
Ground Surface Elevation: 46 feet		Hammer Type: Auto-hammer	
Horizontal Datum: WGS 84		Hammer Weight (pounds): 140	Hammer Drop Height (inches): 30
Vertical Datum: NAVD 88		Measured Hammer Efficiency (%): NA	
Comments: Well Tag ID: BKB-606 Geologic unit names apply to all material below until next unit is noted.		Hole Diameter: 4 inches	Casing Diameter:
		Total Depth: 51.5 feet	Depth to Ground Water: 1 feet

Elevation (feet)	Depth (feet)	Blow Count	Type	Recovery	Length (inches)	Number / Tests	Material Description	Water Level	SPT N Value	WC (%)	Fines Content (%)
46	0						Asphalt concrete (12-inch thick)	ATD ▽ (1 ft)			
	1						SILTY SAND WITH GRAVEL (SM), moist, gray. [FILL]				
41	5	9 12 15		18in.	18	S-1	POORLY GRADED SAND WITH SILT (SP-SM), medium dense, wet, gray, medium sand. [PRE-FRASER DEPOSITS (QPF)]		27		
36	10	6 14 18		18in.	18	S-2 / WC	SANDY SILT (ML), hard, moist, gray. [LACUSTRINE]		32		
31	15	1 11 9		18in.	18	S-3 / GS, WC	SILTY SAND (SM), medium dense to dense, moist, gray, fine to medium sand. [LACUSTRINE] Vibrating wire S/N 1703869.		20		16
26	20	15 21 27		18in.	18	S-4			48		
21	25	24 22 20		18in.	18	S-5			42		
16	30	17 19 20		18in.	18	S-6 / WC	SANDY SILT (ML), hard, moist, gray. [LACUSTRINE]		39		
11	35	16 32 35		18in.	18	S-7 / GS, WC	SILTY SAND (SM), trace gravel, very dense, moist, gray, fine to medium sand. [LACUSTRINE]		67		13

General Notes:

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Logged by: J. Thomas	Checked by: A. Hultz	Drilling Method: Mud Rotary/Hollow Stem Auger	
Location: Lat: 47.780000 Long: -122.392650		Rig Model/Type: CME-85 / Track-mounted drill rig	
Ground Surface Elevation: 46 feet		Hammer Type: Auto-hammer	
Horizontal Datum: WGS 84		Hammer Weight (pounds): 140	Hammer Drop Height (inches): 30
Vertical Datum: NAVD 88		Measured Hammer Efficiency (%): NA	
Comments: Well Tag ID: BKB-606 Geologic unit names apply to all material below until next unit is noted.		Hole Diameter: 4 inches	Casing Diameter:
		Total Depth: 51.5 feet	Depth to Ground Water: 1 feet

Elevation (feet)	Depth (feet)	Blow Count	Type	Recovery	Length (inches)	Number / Tests	Material Description	WC (%) / Fines Content (%) / SPT N Value
5	40	23 42 50		18in.	18	S-8 GS, WC	WELL-GRADED SAND WITH SILT AND GRAVEL (SW-SM), very dense, moist to wet, gray, fine to medium sand. [FLUVIAL]	Fines 8; SPT 92
0	45	23 50		11in.	12	S-9		SPT 50/6"
-5	50	28 43 49		18in.	18	S-10	POORLY GRADED SAND WITH SILT (SP-SM), very dense, moist, gray, fine to medium sand.	SPT 92

Bottom of Borehole at 51.5 feet.

General Notes:
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Key to Exploration Logs

Sample Description

Classification of soils in this report is based on visual field and laboratory observations which include density/consistency, moisture condition, grain size, and plasticity estimates and should not be construed to imply field nor laboratory testing unless presented herein. Visual-manual classification methods of ASTM D 2488 were used as an identification guide.

Soil descriptions consist of the following:
Density/consistency, moisture, color, minor constituents, MAJOR CONSTITUENT, additional remarks.

Density/Consistency

Soil density/consistency in borings is related primarily to the Standard Penetration Resistance. Soil density/consistency in test pits and probes is estimated based on visual observation and is presented parenthetically on the logs.

SAND or GRAVEL Density	Standard Penetration Resistance (N) in Blows/Foot	SILT or CLAY Consistency	Standard Penetration Resistance (N) in Blows/Foot	Approximate Shear Strength in TSF
Very loose	0 to 4	Very soft	0 to 2	<0.125
Loose	4 to 10	Soft	2 to 4	0.125 to 0.25
Medium dense	10 to 30	Medium stiff	4 to 8	0.25 to 0.5
Dense	30 to 50	Stiff	8 to 15	0.5 to 1.0
Very dense	>50	Very stiff	15 to 30	1.0 to 2.0
		Hard	>30	>2.0

Sampling Test Symbols

- 1.5" I.D. Split Spoon
- Grab (Jar)
- 3.0" I.D. Split Spoon
- Shelby Tube (Pushed)
- Bag
- Cuttings
- Core Run

SOIL CLASSIFICATION CHART

MAJOR DIVISIONS			SYMBOLS GRAPH	SYMBOLS LETTER	TYPICAL DESCRIPTIONS
COARSE GRAINED SOILS	GRAVEL AND GRAVELLY SOILS	CLEAN GRAVELS		GW	WELL-GRADED GRAVELS, GRAVEL - SAND MIXTURES, LITTLE OR NO FINES
		(LITTLE OR NO FINES)		GP	POORLY-GRADED GRAVELS, GRAVEL - SAND MIXTURES, LITTLE OR NO FINES
	MORE THAN 50% OF COARSE FRACTION RETAINED ON NO. 4 SIEVE	GRAVELS WITH FINES		GM	SILTY GRAVELS, GRAVEL - SAND - SILT MIXTURES
		(APPRECIABLE AMOUNT OF FINES)		GC	CLAYEY GRAVELS, GRAVEL - SAND - CLAY MIXTURES
MORE THAN 50% OF MATERIAL IS LARGER THAN NO. 200 SIEVE SIZE	SAND AND SANDY SOILS	CLEAN SANDS		SW	WELL-GRADED SANDS, GRAVELLY SANDS, LITTLE OR NO FINES
		(LITTLE OR NO FINES)		SP	POORLY-GRADED SANDS, GRAVELLY SAND, LITTLE OR NO FINES
	MORE THAN 50% OF COARSE FRACTION PASSING ON NO. 4 SIEVE	SANDS WITH FINES		SM	SILTY SANDS, SAND - SILT MIXTURES
		(APPRECIABLE AMOUNT OF FINES)		SC	CLAYEY SANDS, SAND - CLAY MIXTURES
FINE GRAINED SOILS	SILTS AND CLAYS	LIQUID LIMIT LESS THAN 50		ML	INORGANIC SILTS AND VERY FINE SANDS, ROCK FLOUR, SILTY OR CLAYEY FINE SANDS OR CLAYEY SILTS WITH SLIGHT PLASTICITY
				CL	INORGANIC CLAYS OF LOW TO MEDIUM PLASTICITY, GRAVELLY CLAYS, SANDY CLAYS, SILTY CLAYS, LEAN CLAYS
				OL	ORGANIC SILTS AND ORGANIC SILTY CLAYS OF LOW PLASTICITY
MORE THAN 50% OF MATERIAL IS SMALLER THAN NO. 200 SIEVE SIZE	SILTS AND CLAYS	LIQUID LIMIT GREATER THAN 50		MH	INORGANIC SILTS, MICACEOUS OR DIATOMACEOUS FINE SAND OR SILTY SOILS
				CH	INORGANIC CLAYS OF HIGH PLASTICITY
				OH	ORGANIC CLAYS OF MEDIUM TO HIGH PLASTICITY, ORGANIC SILTS
HIGHLY ORGANIC SOILS				PT	PEAT, HUMUS, SWAMP SOILS WITH HIGH ORGANIC CONTENTS

NOTE: DUAL SYMBOLS ARE USED TO INDICATE BORDERLINE SOIL CLASSIFICATIONS

Moisture

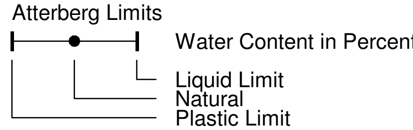
Dry	Little perceptible moisture
Damp	Some perceptible moisture, likely below optimum
Moist	Likely near optimum moisture content
Wet	Much perceptible moisture, likely above optimum

Minor Constituents

Minor Constituents	Estimated Percentage
Trace	<5
Slightly (clayey, silty, etc.)	5 - 12
Clayey, silty, sandy, gravelly	12 - 30
Very (clayey, silty, etc.)	30 - 50

Laboratory Test Symbols

GS	Grain Size Classification
CN	Consolidation
UU	Unconsolidated Undrained Triaxial
CU	Consolidated Undrained Triaxial
CD	Consolidated Drained Triaxial
QU	Unconfined Compression
DS	Direct Shear
K	Permeability
PP	Pocket Penetrometer Approximate Compressive Strength in TSF
TV	Torvane Approximate Shear Strength in TSF
CBR	California Bearing Ratio
MD	Moisture Density Relationship
AL	Atterberg Limits

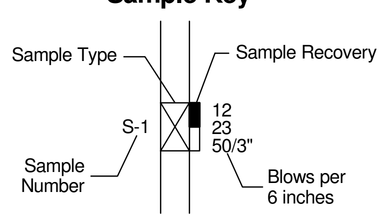


PID	Photoionization Detector Reading
CA	Chemical Analysis
DT	In Situ Density in PCF
OT	Tests by Others

Groundwater Indicators

- Groundwater Level on Date or (ATD) At Time of Drilling
- Groundwater Seepage (Test Pits)

Sample Key



HARTCROWSER

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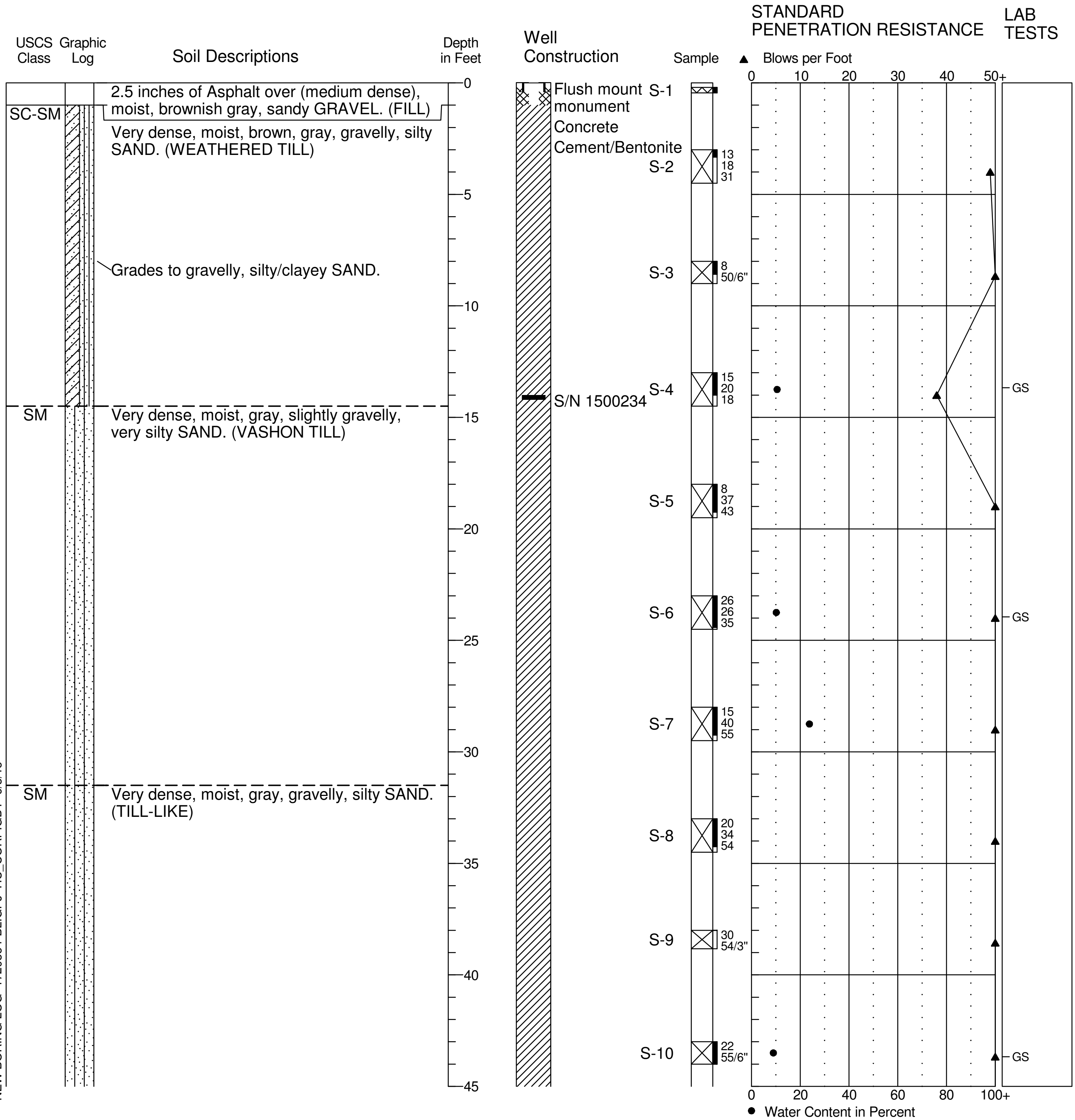
Figure A-5 *1 of 2*

KEY SHEET 1720354-BL.GPJ HC_CORP.GDT 6/3/15

Boring Log HC-1

Location: N 289560 E 1258161
Approximate Ground Surface Elevation: 243 Feet
Horizontal Datum: NAD 83, WA State Plane N, US Feet
Vertical Datum: NAVD88

Drill Equipment: CME 85/Mud Rotary
Hammer Type: SPT w/140 lb. Automatic hammer
Hole Diameter: 4 inches
Logged By: B. McDonald Reviewed By: N. Campbell

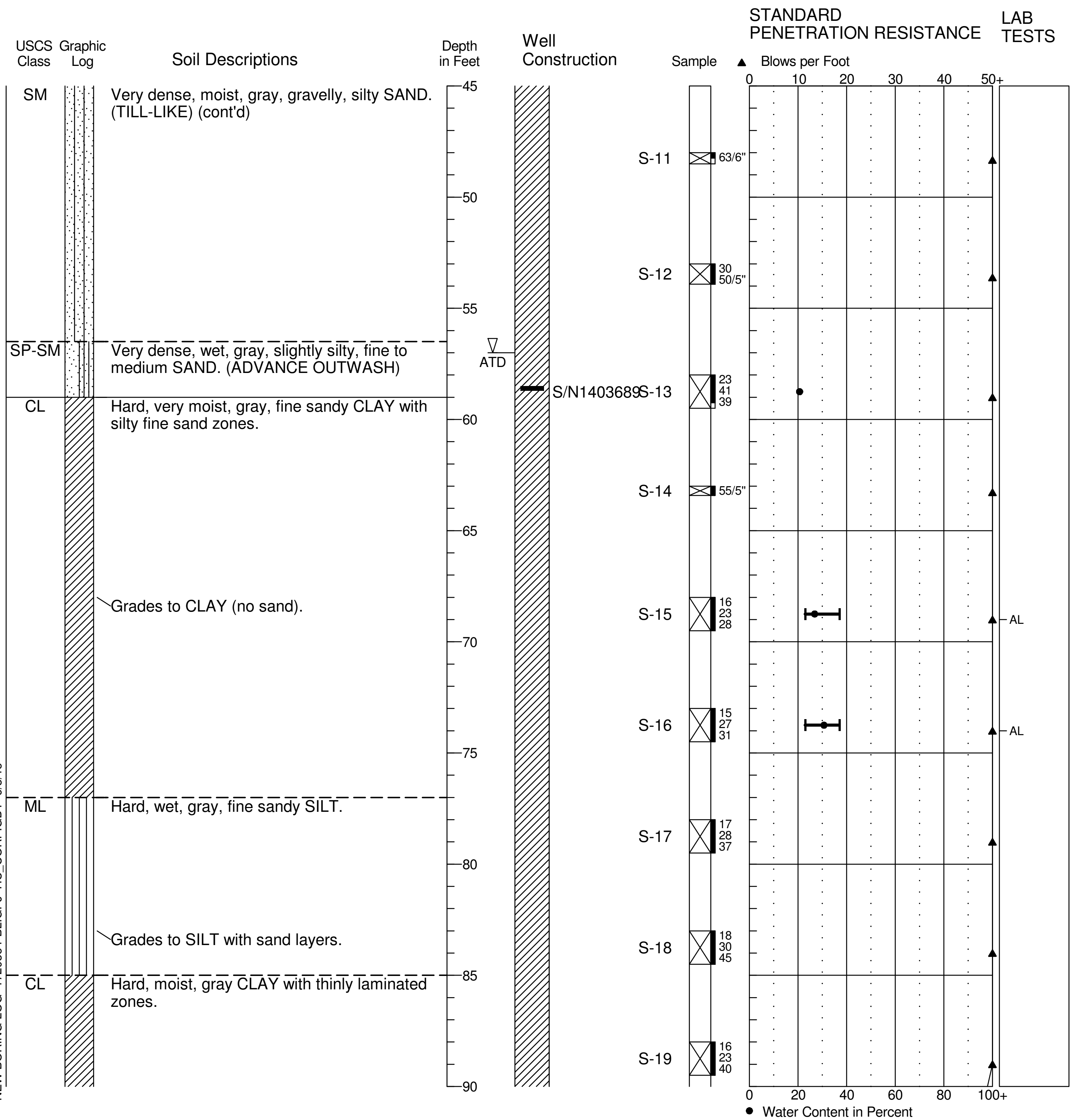


1. Refer to Figure A-1 for explanation of descriptions and symbols.
2. Soil descriptions and stratum lines are interpretive and actual changes may be gradual.
3. USCS designations are based on visual manual classification (ASTM D 2488) unless otherwise supported by laboratory testing (ASTM D 2487).
4. Groundwater level, if indicated, is at time of drilling (ATD) or for date specified. Level may vary with time.

Boring Log HC-1

Location: N 289560 E 1258161
Approximate Ground Surface Elevation: 243 Feet
Horizontal Datum: NAD 83, WA State Plane N, US Feet
Vertical Datum: NAVD88

Drill Equipment: CME 85/Mud Rotary
Hammer Type: SPT w/140 lb. Automatic hammer
Hole Diameter: 4 inches
Logged By: B. McDonald   Reviewed By: N. Campbell



NEW BORING LOG 1720354-BL.GPJ HC_CORP.GDT 6/3/15

1. Refer to Figure A-1 for explanation of descriptions and symbols.
2. Soil descriptions and stratum lines are interpretive and actual changes may be gradual.
3. USCS designations are based on visual manual classification (ASTM D 2488) unless otherwise supported by laboratory testing (ASTM D 2487).
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HARTCROWSER

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Figure A-6   2/6

Boring Log HC-1

Location: N 289560 E 1258161
Approximate Ground Surface Elevation: 243 Feet
Horizontal Datum: NAD 83, WA State Plane N, US Feet
Vertical Datum: NAVD88

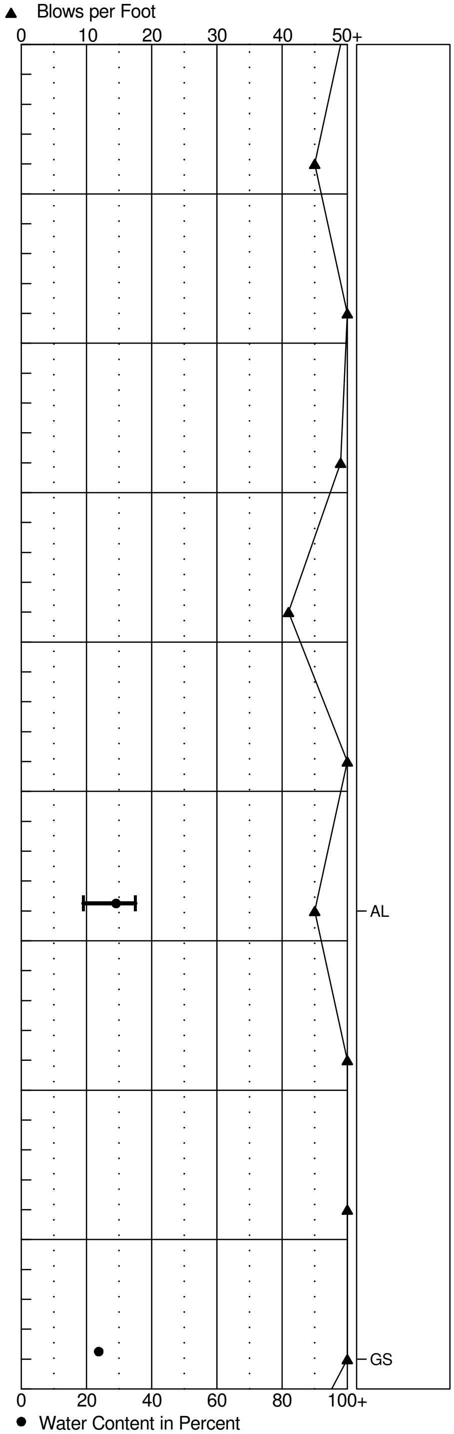
Drill Equipment: CME 85/Mud Rotary
Hammer Type: SPT w/140 lb. Automatic hammer
Hole Diameter: 4 inches
Logged By: B. McDonald   Reviewed By: N. Campbell

USCS Class	Soil Descriptions	Depth in Feet
CL	Hard, moist, gray CLAY with thinly laminated zones. (cont'd)	90
	Occasional scattered partings.	
ML	Hard, moist, gray, fine sandy SILT and SILT.	~101
SM	(Dense), moist, gray, very silty, fine to medium SAND.	~104
ML	Hard, moist, gray SILT, thinly laminated, with fine sandy silt and silty fine sand interbeds. Increased moisture content in silty sand interbeds.	~106.5
CL	Hard, moist, gray CLAY with zones of fine sandy CLAY.	~115.5
	Trace slickensides.	
SM	Very dense, moist, gray, very silty, fine SAND.	~130.5

Well Construction: S/N 1402210 (at approx. 114 ft)

Sample	Blows
S-20	10 / 20 / 25
S-21	13 / 23 / 27
S-22	12 / 20 / 29
S-23	9 / 19 / 22
S-24	10 / 27 / 31
S-25	10 / 18 / 27
S-26	18 / 20 / 31
S-27	26 / 36 / 34
S-28	26 / 43 / 48

STANDARD PENETRATION RESISTANCE — ▲ Blows per Foot; LAB TESTS



1. Refer to Figure A-1 for explanation of descriptions and symbols.
2. Soil descriptions and stratum lines are interpretive and actual changes may be gradual.
3. USCS designations are based on visual manual classification (ASTM D 2488) unless otherwise supported by laboratory testing (ASTM D 2487).
4. Groundwater level, if indicated, is at time of drilling (ATD) or for date specified. Level may vary with time.

Boring Log HC-1

Location: N 289560 E 1258161
Approximate Ground Surface Elevation: 243 Feet
Horizontal Datum: NAD 83, WA State Plane N, US Feet
Vertical Datum: NAVD88

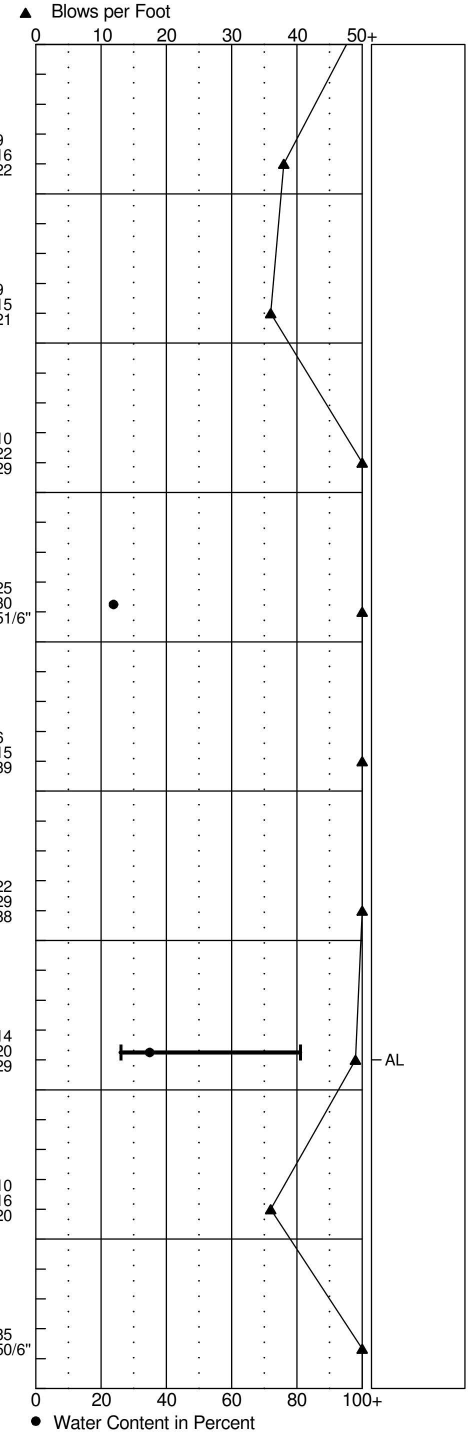
Drill Equipment: CME 85/Mud Rotary
Hammer Type: SPT w/140 lb. Automatic hammer
Hole Diameter: 4 inches
Logged By: B. McDonald   Reviewed By: N. Campbell

USCS Class	Soil Descriptions	Depth in Feet
CH	Hard, moist, gray CLAY, thinly laminated.	135
	Occasional sandy CLAY zones.	
	Fine, clayey SAND.	
SM	Very dense, moist, gray, very silty, fine SAND.	160
CH	Hard, moist, gray CLAY with occasional partings and faint slickensides.	
SC	Very dense, moist, gray, very clayey, fine SAND with zones of sandy CLAY.	175

Well Construction: S/N 1404211

Sample	Blows
S-29	9 16 22
S-30	9 15 21
S-31	10 22 29
S-32	25 30 51/6"
S-33	6 15 39
S-34	22 29 38
S-35	14 20 29
S-36	10 16 20
S-37	35 50/6"

STANDARD PENETRATION RESISTANCE — LAB TESTS



1. Refer to Figure A-1 for explanation of descriptions and symbols.
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NEW BORING LOG 1720354-BL.GPJ HC_CORP.GDT 6/3/15

HARTCROWSER

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Boring Log HC-1

Location: N 289560 E 1258161
Approximate Ground Surface Elevation: 243 Feet
Horizontal Datum: NAD 83, WA State Plane N, US Feet
Vertical Datum: NAVD88

Drill Equipment: CME 85/Mud Rotary
Hammer Type: SPT w/140 lb. Automatic hammer
Hole Diameter: 4 inches
Logged By: B. McDonald Reviewed By: N. Campbell

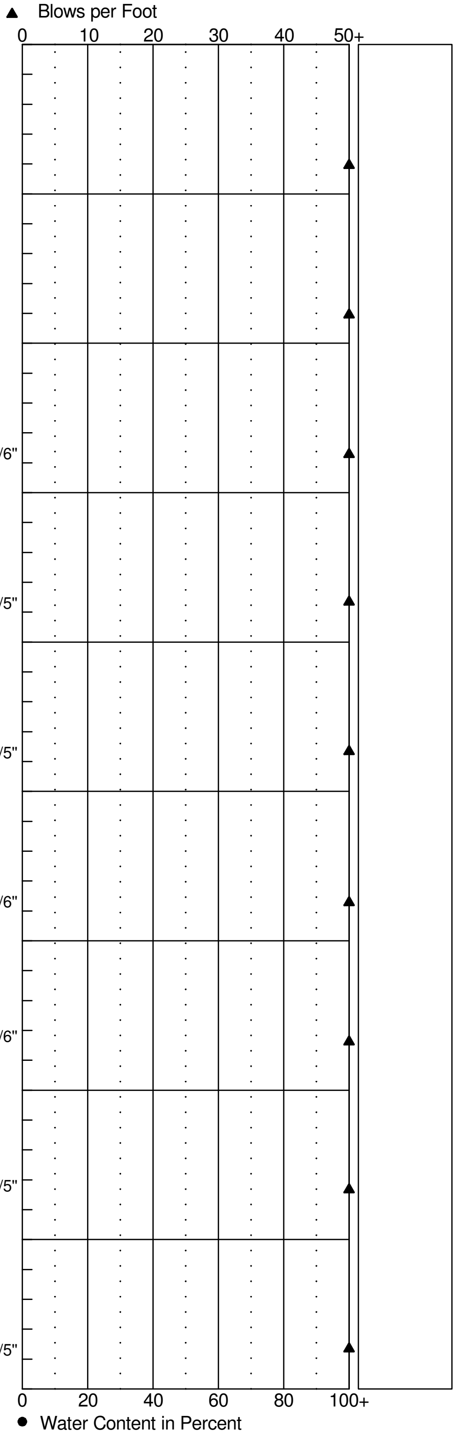
USCS Class	Soil Descriptions	Depth in Feet
SC		180
CL	Hard, moist, gray CLAY and sandy CLAY with laminations.	
SM SC	Very dense, moist, dark gray, silty, fine SAND with interbedded CLAY zones.	185
ML SM	Hard, moist, dark gray SILT with silty, fine SAND interbeds.	
SM	Very dense, moist, dark gray, silty, fine SAND.	
	Grades to fine to medium, silty SAND.	200
SW	Very dense, dark gray, fine to coarse, gravelly SAND with interbedded CLAY zones.	215
SM	Very dense, dark gray, silty, fine SAND.	220
		225

Well Construction

Sample	Blows
S-38	17 34 46
S-39	35 45 32
S-40	32 52/6"
S-41	39 50/5"
S-42	36 50/5"
S-43	35 55/6"
S-46	52/6"
S-47	74/5"
S-48	43 50/5"

STANDARD PENETRATION RESISTANCE

LAB TESTS



1. Refer to Figure A-1 for explanation of descriptions and symbols.
2. Soil descriptions and stratum lines are interpretive and actual changes may be gradual.
3. USCS designations are based on visual manual classification (ASTM D 2488) unless otherwise supported by laboratory testing (ASTM D 2487).
4. Groundwater level, if indicated, is at time of drilling (ATD) or for date specified. Level may vary with time.

NEW BORING LOG 1720354-BL.GPJ HC_CORP.GDT 6/3/15

HARTCROWSER

17203-54 *4/15*

Boring Log HC-1

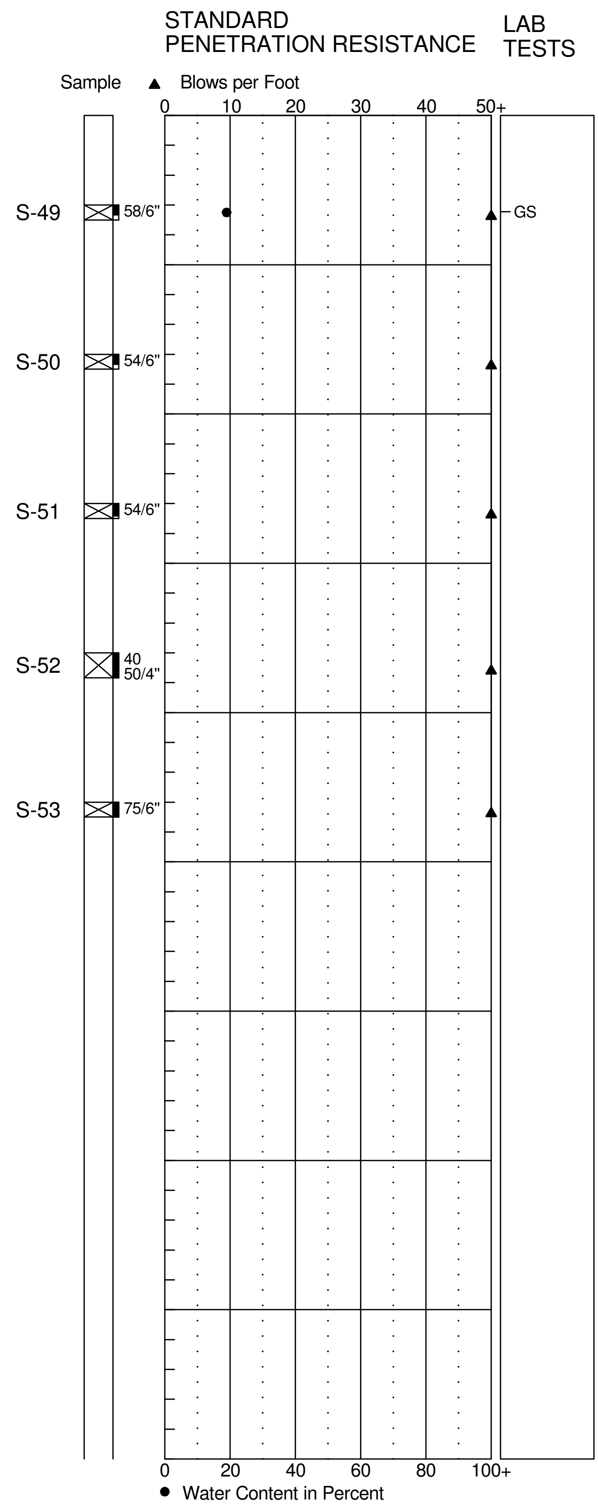
Location: N 289560 E 1258161
Approximate Ground Surface Elevation: 243 Feet
Horizontal Datum: NAD 83, WA State Plane N, US Feet
Vertical Datum: NAVD88

Drill Equipment: CME 85/Mud Rotary
Hammer Type: SPT w/140 lb. Automatic hammer
Hole Diameter: 4 inches
Logged By: B. McDonald   Reviewed By: N. Campbell

USCS Class	Soil Descriptions	Depth in Feet
SM	Very dense, dark gray, silty, fine SAND. (cont'd)	225
	Zones of silty CLAY.	
ML SM	Hard, moist, gray, very fine sandy SILT and very silty, fine SAND with trace organic material.	240
SW	Very dense, moist, dark gray, fine to coarse, gravelly SAND with zones of CLAY.	245
	Bottom of Boring at 248.5 Feet. Started 04/16/15. Completed 04/22/15.	248.5

Depth scale: 225, 230, 235, 240, 245, 250, 255, 260, 265, 270

Well Construction



NEW BORING LOG 1720354-BL.GPJ HC_CORP.GDT 6/3/15

1. Refer to Figure A-1 for explanation of descriptions and symbols.
2. Soil descriptions and stratum lines are interpretive and actual changes may be gradual.
3. USCS designations are based on visual manual classification (ASTM D 2488) unless otherwise supported by laboratory testing (ASTM D 2487).
4. Groundwater level, if indicated, is at time of drilling (ATD) or for date specified. Level may vary with time.

HARTCROWSER

17203-54 4/15

APPENDIX B
Laboratory Testing Program

APPENDIX B
LABORATORY TESTING PROGRAM

Laboratory tests were run for this study to evaluate the basic index and geotechnical engineering properties of the site soil. The tests performed and the procedures followed are outlined below.

Soil Classification

Field Observation and Laboratory Analysis. Soil samples from the explorations were visually classified in the field and then taken to our laboratory where the classifications were verified in a relatively controlled laboratory environment. Field observations and laboratory tests included density/consistency, moisture condition, and grain size and plasticity estimates.

The classifications of selected samples were checked by laboratory tests such as Atterberg limits determinations and grain size analyses. Classifications were made in general accordance with the Unified Soil Classification (USC) System, ASTM D2487, as presented on Figure B-1.

Water Content Determinations

Water content was determined for most samples recovered in the explorations in general accordance with ASTM D2216 as soon as possible following the samples' arrival in our laboratory. Water content was not determined for very small samples or for samples whose large gravel content would result in unrepresentative values. The test results are plotted on the exploration log at the depth from which each sample was taken. In addition, water content is routinely determined for samples subjected to other testing. These results are also presented on the exploration logs.

Grain Size Analysis

Grain size distribution was analyzed on representative samples in general accordance with ASTM D422. Wet sieve analysis was used to determine the size distribution greater than the U.S. No. 200 mesh sieve. The results of the tests are presented as curves plotting percent finer by weight versus grain size on Figures B-3, B-4, B-5, B-7 and B-8.

Atterberg Limits (AL)

We determined Atterberg limits for selected fine-grained soil samples. The liquid limit and plastic limit were determined in general accordance with ASTM D4318-84. The results of the Atterberg limit analyses and the plasticity characteristics are summarized in Figure B-2, B-6, and B-9. This relates the plasticity index (liquid limit minus the plastic limit) to the liquid limit. The results of the Atterberg limits tests are shown graphically on the boring log.

TABLE B-1: SUMMARY OF LABORATORY RESULTS

HARTCROWSER

PROJECT NAME Point Wells

PROJECT NUMBER 1720354 **PROJECT LOCATION**

Borehole	Sample ID	Depth	% Gravel	% Sand	% Fines	Liquid Limit	Plastic Limit	Water Content (%)	USCS Group Symbol	Soil Description
HC-10	S-1	5.0	9.8	71.3	18.9			12.9	SM	SILTY SAND
HC-10	S-2A	10.0								
HC-10	S-2B	10.8				36	24	23.7	CL	LEAN CLAY
HC-10	S-3	15.0						34.7		
HC-10	S-4	17.5								
HC-10	S-5	20.0	0.0	2.3	97.7			29.8	ML	SILT
HC-10	S-6	25.0								
HC-10	S-7	30.0								
HC-10	S-8	35.0						28.1		
HC-10	S-9A	40.0								
HC-10	S-9B	41.0				59	29	30.1	CH	FAT CLAY
HC-10	S-10	45.0								
HC-10	S-11	50.0								
HC-10	S-12A	55.0								
HC-10	S-12B	55.8								
HC-10	S-13	60.0	0.0	10.2	89.8			27.9	ML	SILT WITH SAND
HC-10	S-14	65.0								
HC-10	S-15	70.0						32.7		
HC-10	S-16A	75.0								
HC-10	S-16B	76.0						27.6		
HC-10	S-17	80.0						35.7		
HC-10	S-18	85.0						26.2		
HC-10	S-19	90.0						21.2		
HC-10	S-20	95.0						37.6		
HC-10	S-21	100.0						25.9		
HC-10	S-22	105.0						34.6		
HC-10	S-23A	110.0								
HC-10	S-23B	111.0								
HC-10	S-24	115.0						16.5		
HC-10	S-25	120.0				46	26	29.0	CL	LEAN CLAY
HC-10	S-26	125.0								
HC-10	S-27A	130.0								
HC-10	S-27B	131.0						23.9		
HC-10	S-28	135.0								
HC-10	S-29	140.0	0.0	79.5	20.5			16.5	SM	SILTY SAND
HC-10	S-30	145.0						15.6		
HC-10	S-31	150.0								
HC-10	S-32	155.0						16.7		
HC-10	S-33	160.0								
HC-10	S-34A	165.0						20.6		
HC-10	S-34B	165.4								
HC-10	S-35	170.0						17.4		
HC-10	S-36	175.0								

SELECT SUMMARY WITH DESC MOD01 - GINT STD US LAB.GDT - 3/21/18 09:31 - L:\NOTEBOOKS\1720354_POINT WELLS EIS GEOTECH ANALYSES\FIELD DATA\PERM_GINT FILES\1720354-BL-2-18.GPJ

TABLE B-1: SUMMARY OF LABORATORY RESULTS

HARTCROWSER

PROJECT NAME Point Wells

PROJECT NUMBER 1720354 **PROJECT LOCATION**

Borehole	Sample ID	Depth	% Gravel	% Sand	% Fines	Liquid Limit	Plastic Limit	Water Content (%)	USCS Group Symbol	Soil Description
HC-10	S-37	180.0								
HC-10	S-38	185.0						11.2		
HC-10	S-39	190.0								
HC-10	S-40	195.0						18.5		
HC-10	S-41	200.0								
HC-11	S-1	5.0								
HC-11	S-2	10.0								
HC-11	S-3	15.0				40	29	30.4	ML	SILT
HC-11	S-4	20.0								
HC-11	S-5	22.5								
HC-11	S-6	25.0								
HC-11	S-7	26.8								
HC-11	S-8A	30.0								
HC-11	S-8B	30.3						23.6		
HC-11	S-9	35.0				61	29	34.9	CH	FAT CLAY
HC-11	S-10	40.0								
HC-11	S-10A	40.0								
HC-11	S-10B	40.5								
HC-11	S-11	45.0								
HC-11	S-12	50.0				57	30	23.3	CH	FAT CLAY
HC-11	S-13A	55.0								
HC-11	S-13B	55.5								
HC-11	S-14A	60.0								
HC-11	S-14B	60.6								
HC-11	S-15A	65.0								
HC-11	S-15B	65.9								
HC-11	S-16	70.0								
HC-11	S-17	75.0	0.0	82.1	17.9			16.9	SM	SILTY SAND
HC-11	S-18A	80.0								
HC-11	S-18B	80.7	0.0	65.3	34.7			20.4	SM	SILTY SAND
HC-11	S-19	85.0								
HC-11	S-20	90.0	0.0	5.6	94.4			26.1	ML	SILT
HC-11	S-21	95.0						21.4		
HC-11	S-22	100.0								
HC-12	S-1	5.0								
HC-12	S-2	10.0						24.6		
HC-12	S-3	15.0	0.2	83.7	16.1			22.6	SM	SILTY SAND
HC-12	S-4	20.0								
HC-12	S-5	25.0								
HC-12	S-6	30.0						26.5		
HC-12	S-7	35.0	1.6	84.9	13.5			22.0	SM	SILTY SAND
HC-12	S-8	40.0	17.0	75.4	7.6			14.4	SW-SM	SAND with silt and gravel
HC-12	S-9	45.0								

TABLE B-1: SUMMARY OF LABORATORY RESULTS

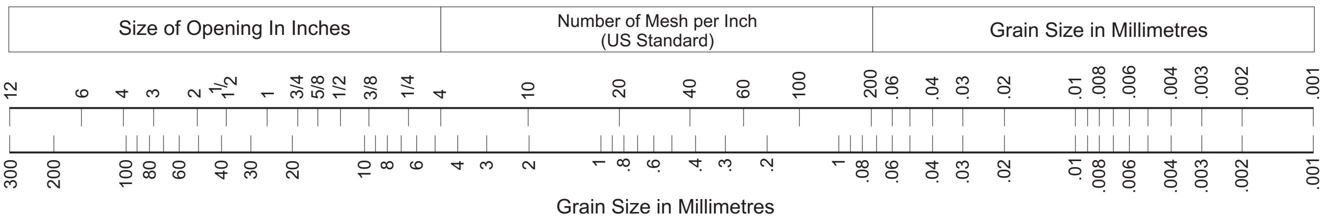
HARTCROWSER

PROJECT NAME Point Wells

PROJECT NUMBER 1720354 **PROJECT LOCATION**

Borehole	Sample ID	Depth	% Gravel	% Sand	% Fines	Liquid Limit	Plastic Limit	Water Content (%)	USCS Group Symbol	Soil Description
HC-12	S-10	50.0								

Unified Soil Classification (USC) System
Soil Grain Size



COBBLES	GRAVEL	SAND	SILT and CLAY
Coarse-Grained Soils			Fine-Grained Soils

Coarse-Grained Soils

G W	G P	G M	G C	S W	S P	S M	S C
Clean GRAVEL <5% fines		* GRAVEL with >12% fines		Clean SAND <5% fines		* SAND with >12% fines	
GRAVEL >50% coarse fraction larger than No. 4				SAND >50% coarse fraction smaller than No. 4			
Coarse-Grained Soils >50% larger than No. 200 sieve							

G W and S W $\left(\frac{D_{60}}{D_{10}}\right)$ >4 for G W, >6 for S W & $1 \leq \left(\frac{(D_{30})^2}{D_{10} \times D_{60}}\right) \leq 3$

G P and S P Clean GRAVEL or SAND not meeting requirements for G W and S W

G M and S M Atterberg limits below A line with PI <4

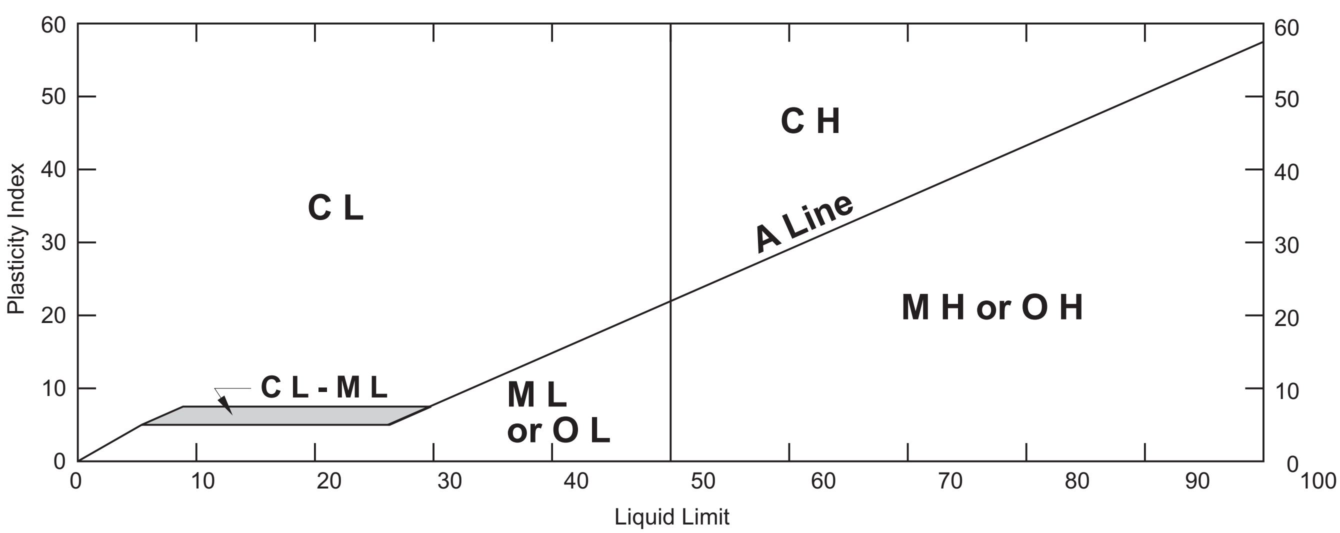
G C and S C Atterberg limits above A Line with PI >7

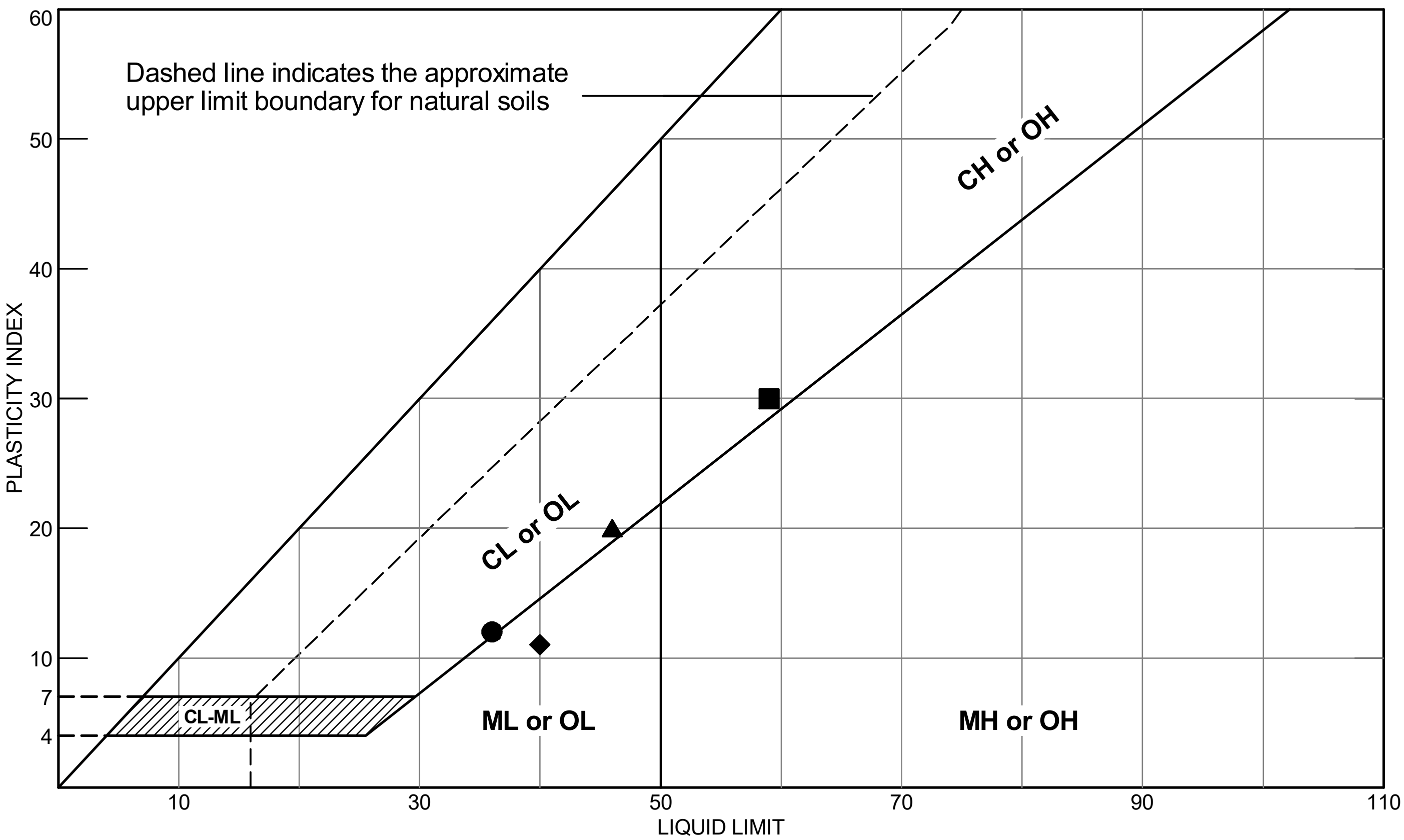
* Coarse-grained soils with percentage of fines between 5 and 12 are considered borderline cases requiring use of dual symbols.

D_{10}, D_{30}, and D_{60} are the particles diameter of which 10, 30, and 60 percent, respectively, of the soil weight are finer.

Fine-Grained Soils

M L	C L	O L	M H	C H	O H	Pt
SILT	CLAY	Organic	SILT	CLAY	Organic	Highly Organic Soils
Soils with Liquid Limit <50%			Soils with Liquid Limit >50%			
Fine-Grained Soils >50% smaller than No. 200 sieve						





Location and Description			LL	PL	PI	-#200	MC%	USCS
● **Source:** HC-10 LEAN CLAY	**Sample No.:** S-2B	**Depth:** 10.8 to	36	24	12	NT	24	CL
■ **Source:** HC-10 FAT CLAY	**Sample No.:** S-9B	**Depth:** 41.0 to	59	29	30	NT	30	CH
▲ **Source:** HC-10 LEAN CLAY	**Sample No.:** S-25	**Depth:** 120.0 to 121.5 feet	46	26	20	NT	29	CL
◆ **Source:** HC-11 SILT	**Sample No.:** S-3	**Depth:** 15.0 to 16.5 feet	40	29	11	NT	30	ML

Remarks:

●

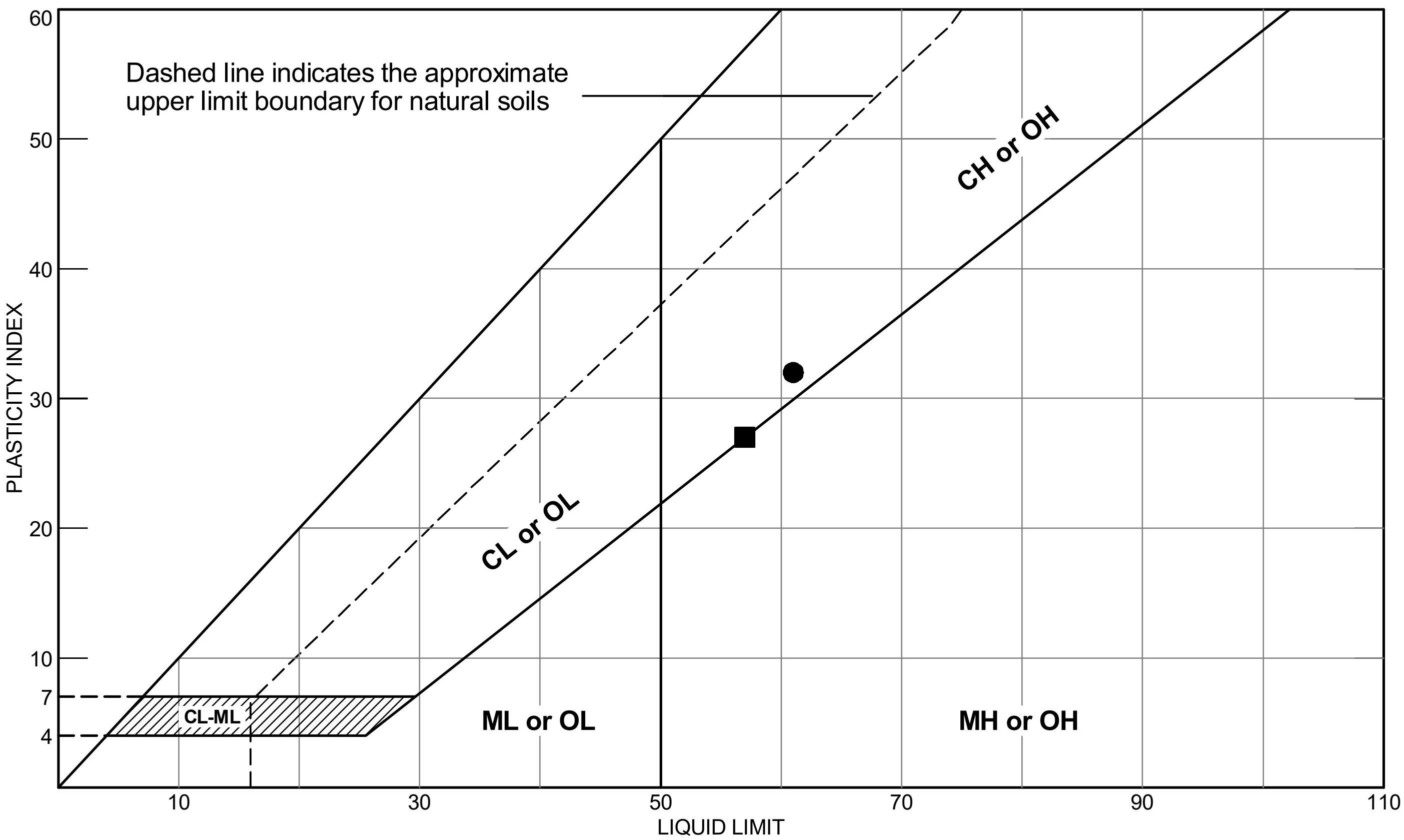
■

▲

◆

HC ATTERBERG LIMITS - J:\GINT\HC_LIBRARY.GLB - 3/21/18 09:26 - L:\NOTEBOOKS\1720354_POINT WELLS EIS GEOTECH ANALYSES\FIELD DATA\PERM_GINT FILES\1720354-BL-2-18.GPJ - hclab

HARTCROWSER	Project: Point Wells Location: Project No.: 17203-54	**Liquid Limit, Plastic Limit, and Plasticity Index**	Figure **B-2** Sheet **1 of 2**



Location and Description			LL	PL	PI	-#200	MC%	USCS
● **Source:** HC-11 FAT CLAY	**Sample No.:** S-9	**Depth:** 35.0 to 36.5 feet	61	29	32	NT	35	CH
■ **Source:** HC-11 FAT CLAY	**Sample No.:** S-12	**Depth:** 50.0 to 51.5 feet	57	30	27	NT	23	CH

Remarks:
●
■

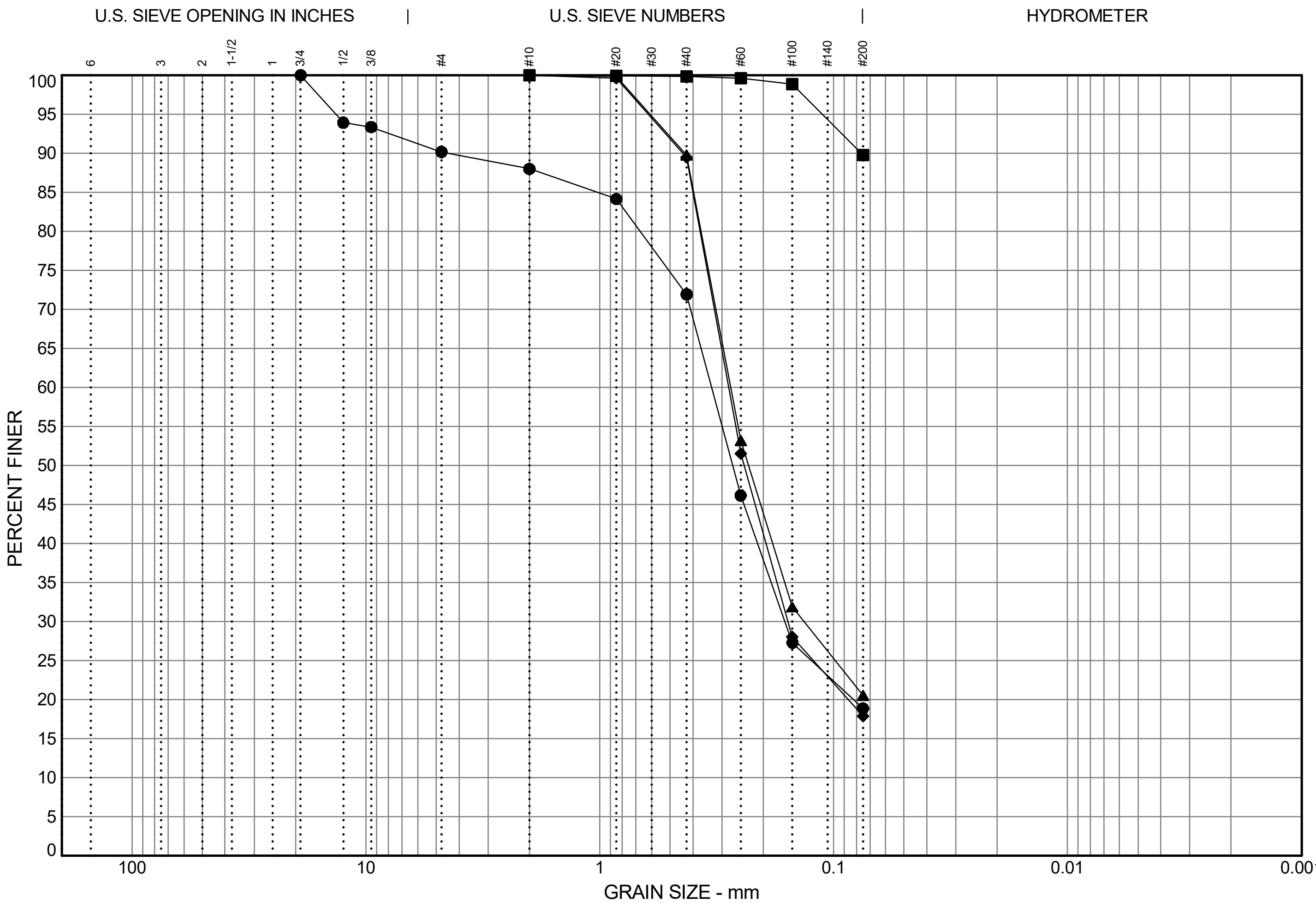
HC ATTERBERG LIMITS - J:\GINT\HC_LIBRARY.GLB - 3/21/18 09:26 - L:\NOTEBOOKS\1720354_POINT WELLS EIS GEOTECH ANALYSES\FIELD DATA\PERM_GINT FILES\1720354-BL-2-18.GPJ - hclab

HARTCROWSER

Project: Point Wells
Location:
Project No.: 17203-54

Liquid Limit, Plastic Limit, and Plasticity Index

Figure **B-2**
Sheet **2 of 2**



COBBLES	GRAVEL		SAND			SILT OR CLAY
	coarse	fine	coarse	medium	fine	

Location and Description	% Cobbles	% Gravel	% Sand	% Silt / % Clay	MC%	USCS
● **Source:** HC-10 **Sample No.:** S-1 **Depth:** 5.0 to 6.5 SILTY SAND	0.0	9.8	71.3	18.9	13	SM
■ **Source:** HC-10 **Sample No.:** S-13 **Depth:** 60.0 to 61.5 SILT WITH SAND	0.0	0.0	10.2	89.8	28	ML
▲ **Source:** HC-10 **Sample No.:** S-29 **Depth:** 140.0 to 140.9 SILTY SAND	0.0	0.0	79.5	20.5	16	SM
◆ **Source:** HC-11 **Sample No.:** S-17 **Depth:** 75.0 to 75.9 SILTY SAND	0.0	0.0	82.1	17.9	17	SM

	LL	PI	D_{85}	D_{60}	D_{50}	D_{30}	D_{15}	D_{10}	C_c	C_u
●			1.030	0.333	0.271	0.161				
■										
▲			0.397	0.276	0.232	0.134				
◆			0.399	0.281	0.242	0.157				

Remarks:

●
■
▲
◆

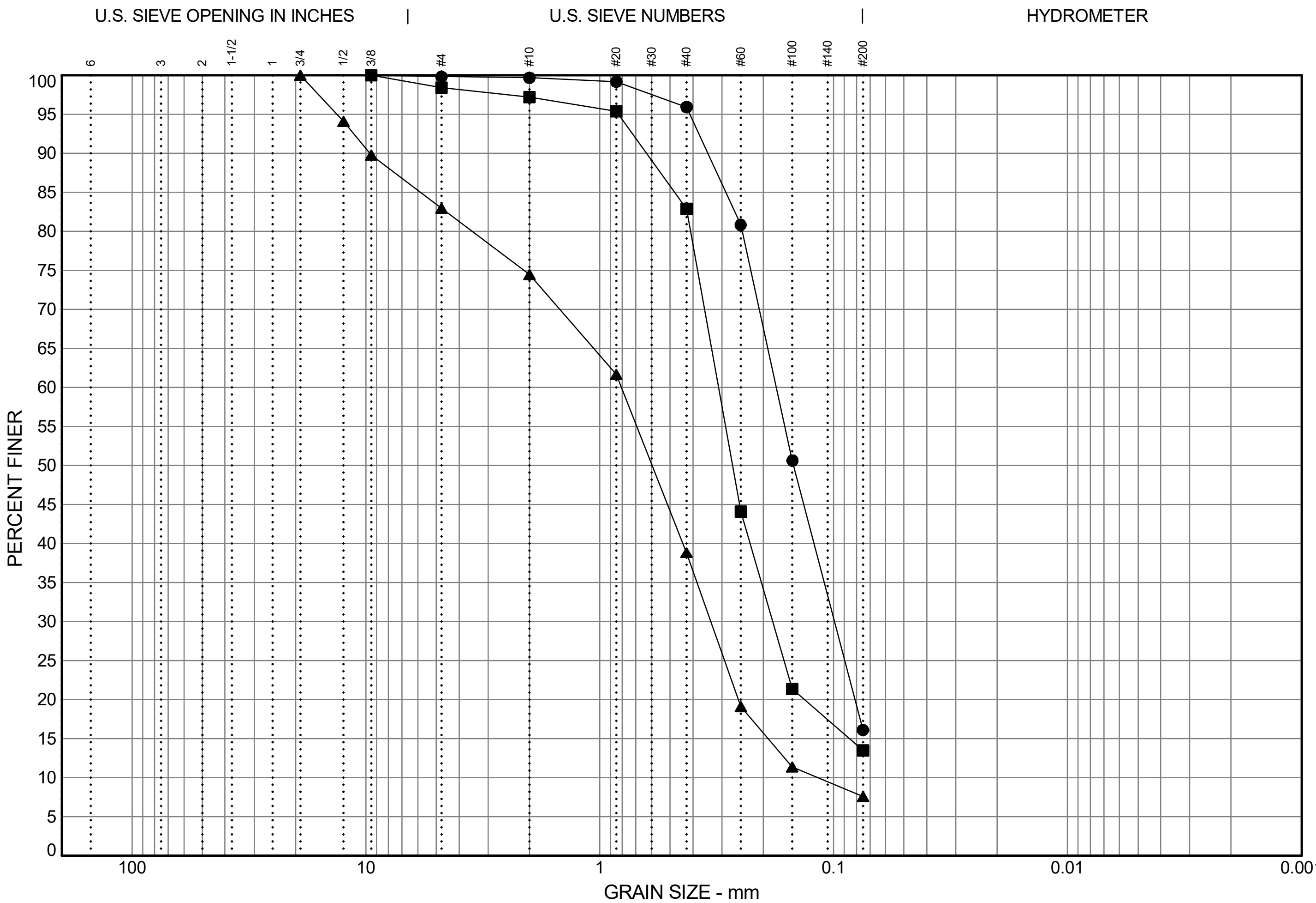
HARTCROWSER

Project: Point Wells
Location:
Project No.: 17203-54

Particle-Size Analysis

Figure **B-3**
Sheet **1 of 2**

HC GRAIN SIZE - J:\GINT\HC_LIBRARY.GLB - 3/21/18 09:28 - L:\NOTEBOOKS\1720354_POINT WELLS EIS GEOTECH ANALYSES\FIELD DATA\PERM_GINT FILES\1720354-BL-2-18.GPJ - hclab



COBBLES	GRAVEL		SAND			SILT OR CLAY
	coarse	fine	coarse	medium	fine	

Location and Description	% Cobbles	% Gravel	% Sand	% Silt / % Clay	MC%	USCS
● **Source:** HC-12 **Sample No.:** S-3 **Depth:** 15.0 to 16.5 SILTY SAND	0.0	0.2	83.7	16.1	23	SM
■ **Source:** HC-12 **Sample No.:** S-7 **Depth:** 35.0 to 36.5 SILTY SAND	0.0	1.6	84.9	13.5	22	SM
▲ **Source:** HC-12 **Sample No.:** S-8 **Depth:** 40.0 to 41.5 SAND WITH SILT AND GRAVEL	0.0	17.0	75.4	7.6	14	SW-SM

	LL	PI	D_{85}	D_{60}	D_{50}	D_{30}	D_{15}	D_{10}	C_c	C_u
●			0.289	0.176	0.148	0.099				
■			0.478	0.311	0.271	0.182	0.086			
▲			5.846	0.809	0.597	0.335	0.191	0.117	1.19	6.92

Remarks:

●

■

▲

HARTCROWSER

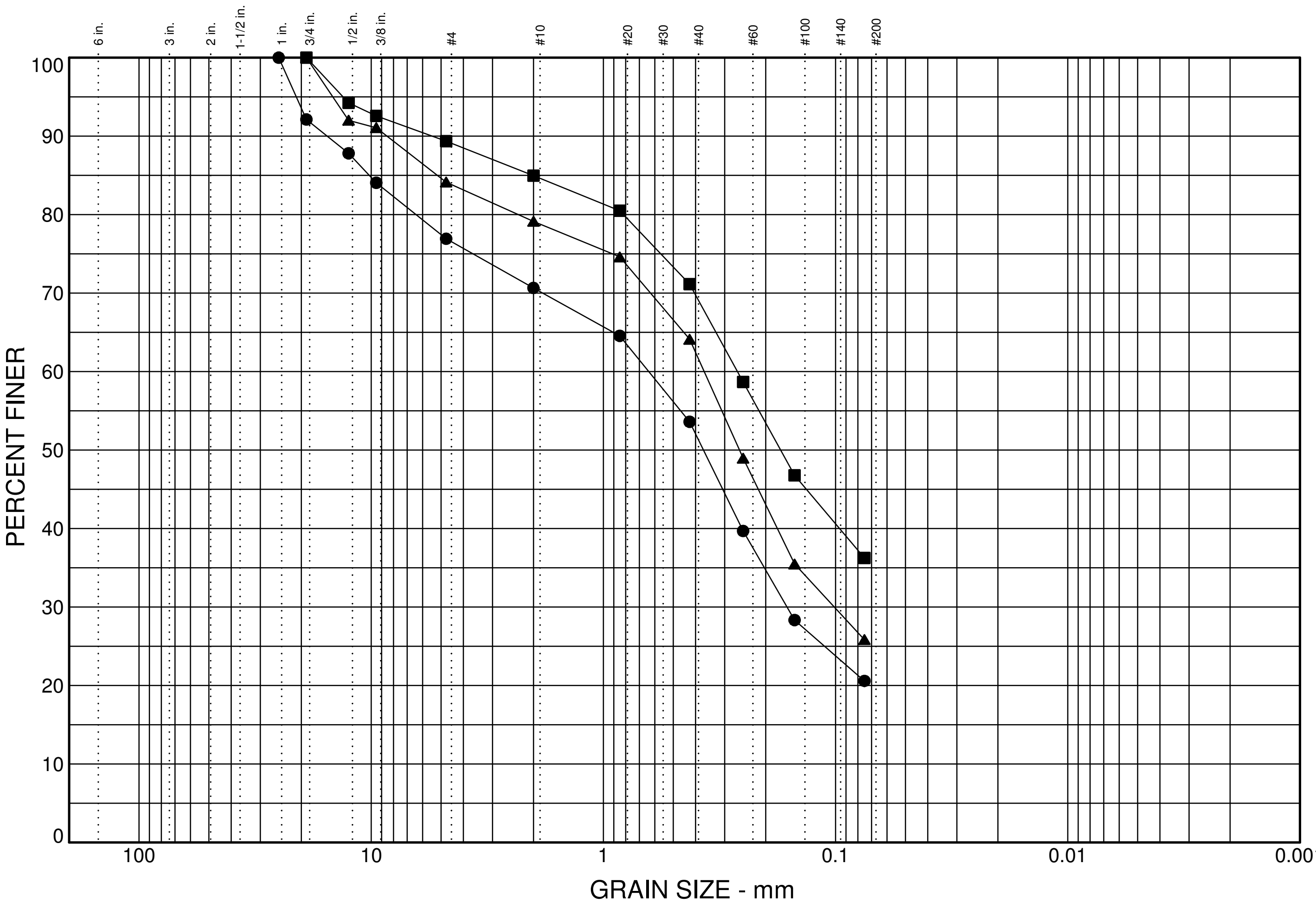
Project: Point Wells
Location:
Project No.: 17203-54

Particle-Size Analysis

Figure **B-3**
Sheet **2 of 2**

HC GRAIN SIZE - J:\GINT\HC_LIBRARY.GLB - 3/21/18 09:28 - L:\NOTEBOOKS\1720354_POINT WELLS EIS GEOTECH ANALYSES\FIELD DATA\PERM_GINT FILES\1720354-BL-2-18.GPJ - hclab

Particle Size Distribution Test Report



	% COBBLES	% GRAVEL	% SAND	% SILT	% CLAY
●	0.0	23.1	56.3	20.6	
■	0.0	10.6	53.1	36.3	
▲	0.0	15.9	58.3	25.9	

	LL	PI	D_{85}	D_{60}	D_{50}	D_{30}	D_{15}	D_{10}	C_c	C_u
●			10.174	0.637	0.37	0.162				
■			2.015	0.265	0.172					
▲			5.173	0.368	0.259	0.101				

MATERIAL DESCRIPTION	USCS	NAT. MOIST.
● silty gravelly SAND	SM	10.5%
■ slightly gravelly, very silty SAND	SM	10.2%
▲ gravelly, silty SAND	SM	9.0%

Remarks:
●

■

▲

Project: Richmond Beach

Client:

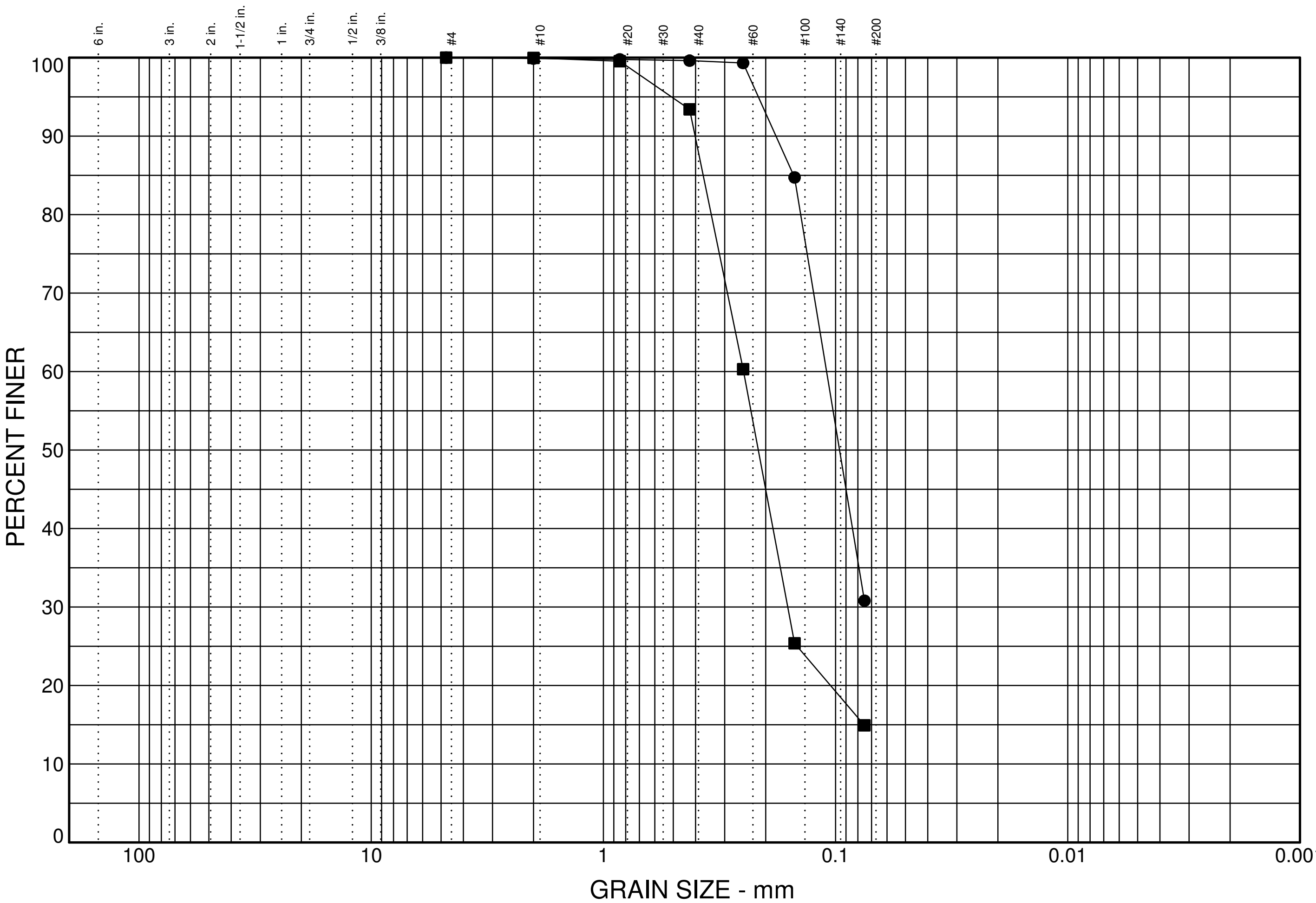
● Source: HC-1 Sample No.: S-4 Depth: 13.0 to 14.0
■ Source: HC-1 Sample No.: S-6 Depth: 23.0 to 24.0
▲ Source: HC-1 Sample No.: S-10 Depth: 43.0 to 44.0

HARTCROWSER

17203-54 *4/15*

Figure B-4

Particle Size Distribution Test Report



	% COBBLES	% GRAVEL	% SAND	% SILT	% CLAY
●	0.0	0.0	69.2	30.8	
■	0.0	0.0	85.1	14.9	

	LL	PI	D_{85}	D_{60}	D_{50}	D_{30}	D_{15}	D_{10}	C_c	C_u
●			0.151	0.109	0.096					
■			0.371	0.249	0.215	0.16	0.075			

MATERIAL DESCRIPTION	USCS	NAT. MOIST.
● very silty SAND	SM	23.8%
■ silty SAND	SM	18.9%

Remarks:
●

■

Project: Richmond Beach

Client:

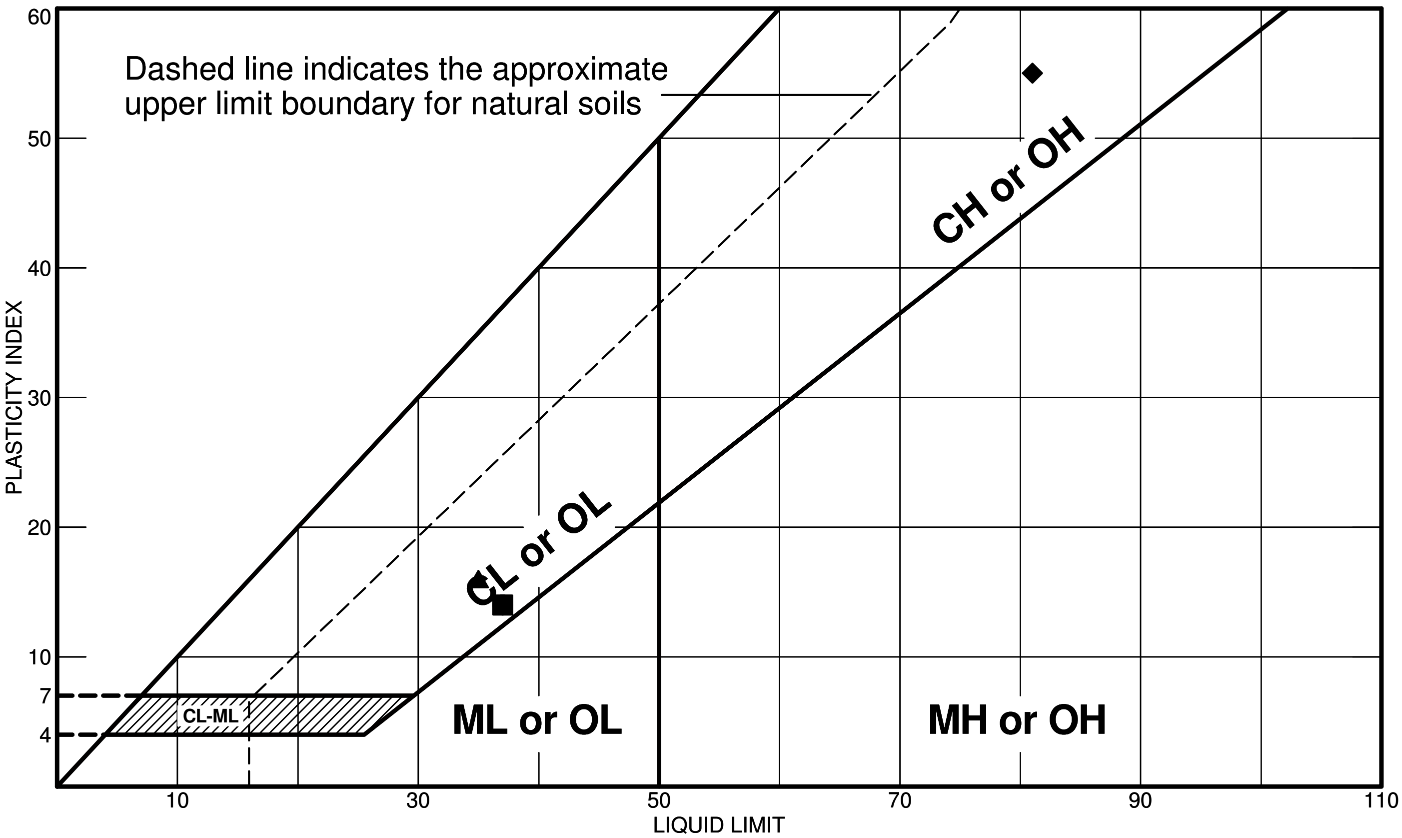
● Source: HC-1 Sample No.: S-28 Depth: 133.0 to 133.5
■ Source: HC-1 Sample No.: S-49 Depth: 228.0 to 228.5

HARTCROWSER

17203-54 **4/15**

Figure B-5

Liquid and Plastic Limits Test Report



Location + Description	LL	PL	PI	-200	USCS
● Source: HC-1 Sample No.: S-15 Depth: 68 CLAY	37	23	14		CL
■ Source: HC-1 Sample No.: S-16 Depth: 73 CLAY	37	23	14		CL
▲ Source: HC-1 Sample No.: S-25 Depth: 118 CLAY	35	19	16		CL
◆ Source: HC-1 Sample No.: S-35 Depth: 168 CLAY	81	26	55		CH

Remarks:

●

■

▲

◆

Project: Richmond Beach

Client:

Location:

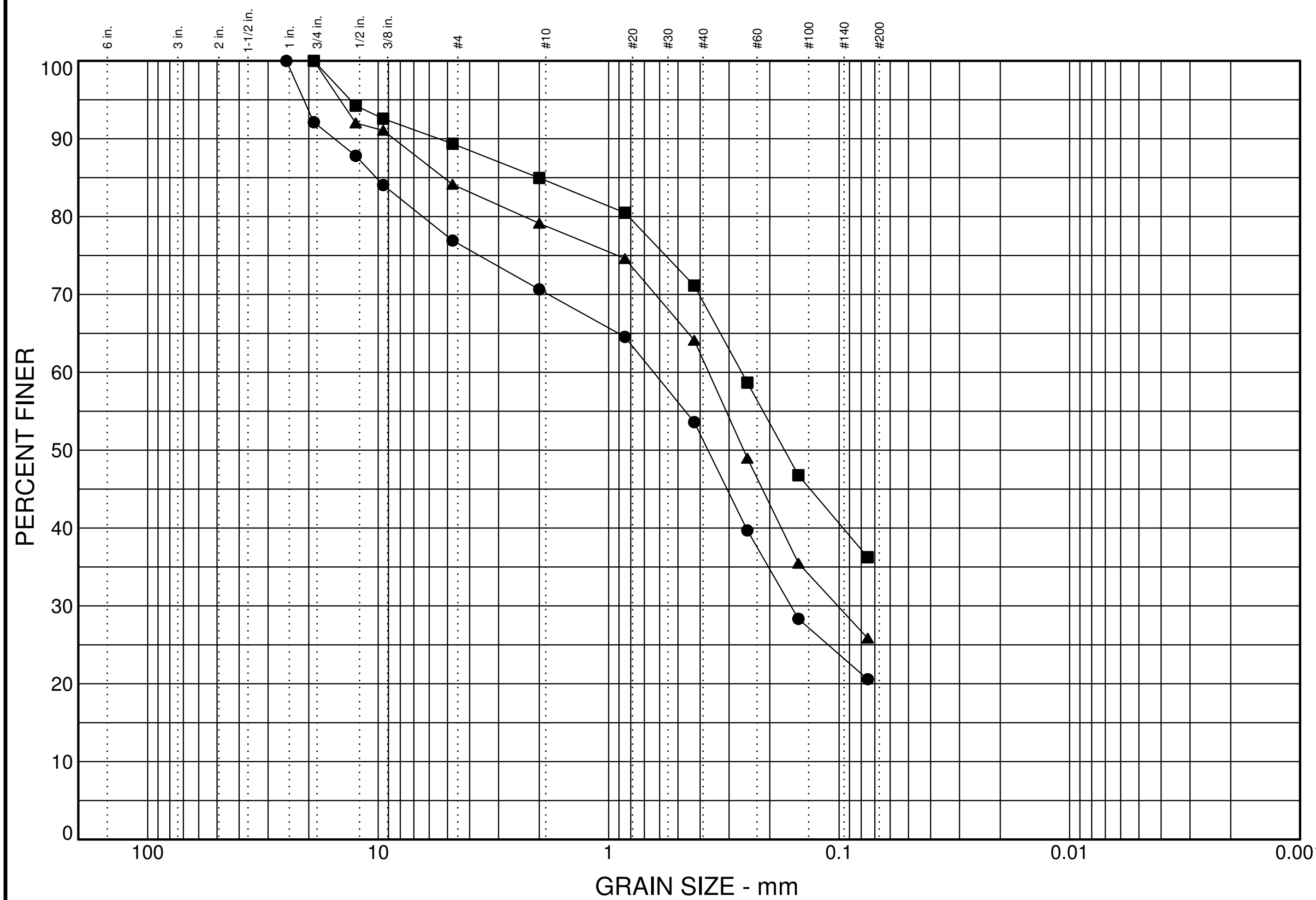
HARTCROWSER

17203-54 *4/15*

Figure B- 6

ATTERBERG LIMITS 1720354-BL.GPJ HC_CORP.GDT 6/3/15

Particle Size Distribution Test Report



	% COBBLES	% GRAVEL	% SAND	% SILT	% CLAY
●	0.0	23.1	56.3	20.6	
■	0.0	10.6	53.1	36.3	
▲	0.0	15.9	58.3	25.9	

	LL	PI	D_{85}	D_{60}	D_{50}	D_{30}	D_{15}	D_{10}	C_c	C_u
●			10.174	0.637	0.37	0.162				
■			2.015	0.265	0.172					
▲			5.173	0.368	0.259	0.101				

MATERIAL DESCRIPTION	USCS	NAT. MOIST.
● silty gravelly SAND	SM	10.5%
■ slightly gravelly, very silty SAND	SM	10.2%
▲ gravelly, silty SAND	SM	9.0%

Remarks:

●

■

▲

Project: Richmond Beach

Client:

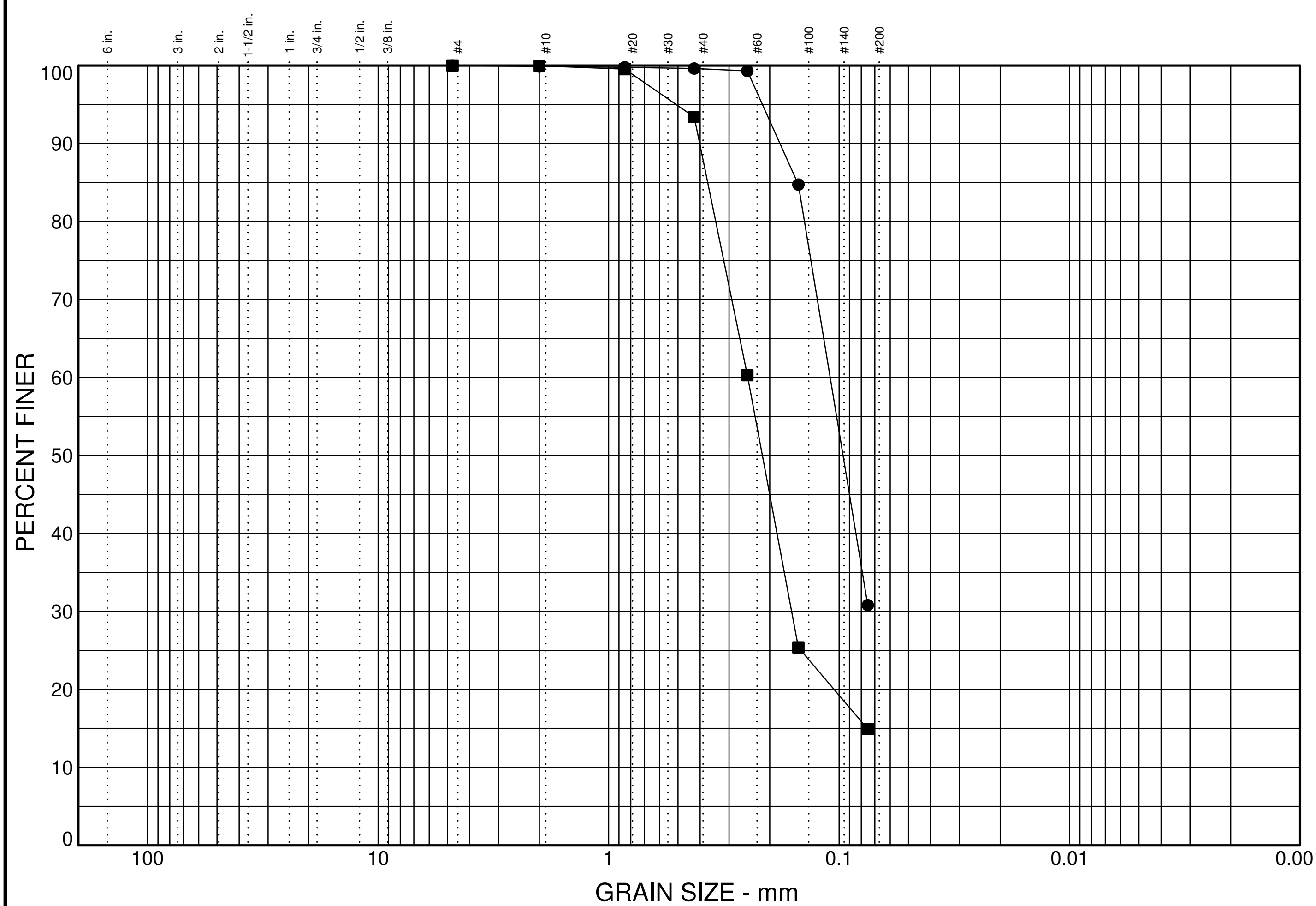
● Source: HC-1 Sample No.: S-4 Depth: 13.0 to 14.0
■ Source: HC-1 Sample No.: S-6 Depth: 23.0 to 24.0
▲ Source: HC-1 Sample No.: S-10 Depth: 43.0 to 44.0

HARTCROWSER

17203-54 *4/15*

Figure B-7

Particle Size Distribution Test Report



	% COBBLES	% GRAVEL	% SAND	% SILT	% CLAY
●	0.0	0.0	69.2	30.8	
■	0.0	0.0	85.1	14.9	

	LL	PI	D_{85}	D_{60}	D_{50}	D_{30}	D_{15}	D_{10}	C_c	C_u
●			0.151	0.109	0.096					
■			0.371	0.249	0.215	0.16	0.075			

MATERIAL DESCRIPTION	USCS	NAT. MOIST.
● very silty SAND	SM	23.8%
■ silty SAND	SM	18.9%

Remarks:
●

■

Project: Richmond Beach

Client:

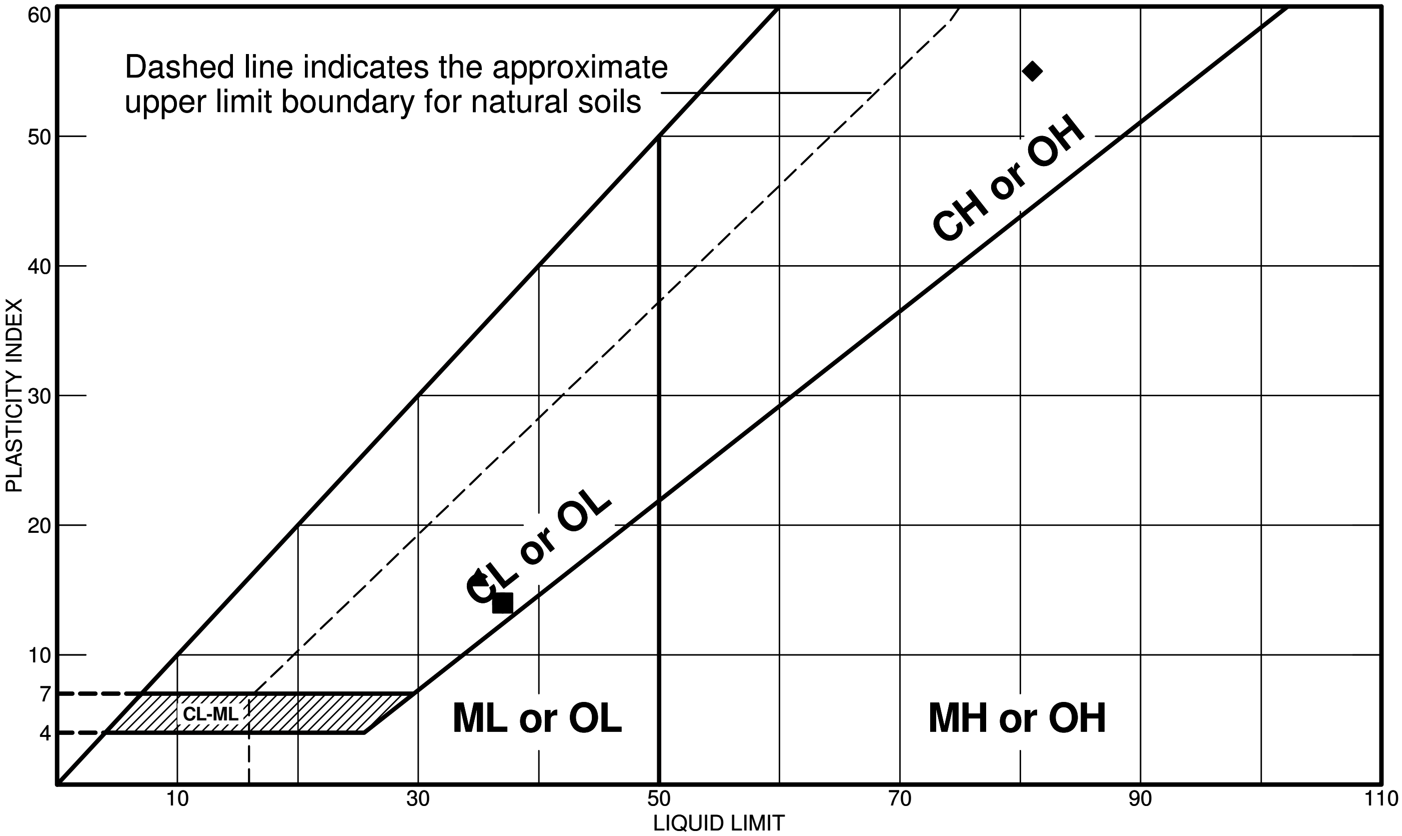
● Source: HC-1 Sample No.: S-28 Depth: 133.0 to 133.5
■ Source: HC-1 Sample No.: S-49 Depth: 228.0 to 228.5

HARTCROWSER

17203-54 *4/15*

Figure B-8

Liquid and Plastic Limits Test Report



Location + Description	LL	PL	PI	-200	USCS
● Source: HC-1 Sample No.: S-15 Depth: 68 CLAY	37	23	14		CL
■ Source: HC-1 Sample No.: S-16 Depth: 73 CLAY	37	23	14		CL
▲ Source: HC-1 Sample No.: S-25 Depth: 118 CLAY	35	19	16		CL
◆ Source: HC-1 Sample No.: S-35 Depth: 168 CLAY	81	26	55		CH

Remarks:

●

■

▲

◆

Project: Richmond Beach

Client:

Location:

HARTCROWSER

17203-54 *4/15*

Figure B- 9

ATTERBERG LIMITS 1720354-BL.GPJ HC_CORP.GDT 5/29/15

APPENDIX C
Vibrating Wire Piezometer Measurements and Calibration Certificates

APPENDIX C
VIBRATING WIRE PIEZOMETER MEASUREMENTS AND CALIBRATION CERTIFICATES

Vibrating wire piezometer measurement data are summarized in Table C-1, and vibrating wire piezometer calibration certificates for the vibrating wire are attached.

Table C1 - Vibrating Wire Piezometer (VWP) Meaurements

Boring ID	VWP Information[1]				VWP Measurements			Groundwater			
	Approx. Ground Surface Elevation in Feet	Depth in Feet	Elevation in Feet	Serial No.	Date	Reading in Hz	Temperature in Celsius	Pressure in psi	Head in Feet	Depth in Feet	Elevation in Feet
HC-1[2]	243	14	229	1500234	4/22/2015	2730.7	9.2	0.28	0.6	N/A[1]	N/A[1]
					5/6/2015	2700.5	12.3	3.27	7.6	6.4	236.6
					5/21/2015	2703.5	12.4	2.99	6.9	7.1	235.9
					5/26/2015	2703.5	12.5	2.99	6.9	7.1	235.9
		58.75	184.25	1403689	4/22/2015	2756.2	8.9	0.31	0.7	N/A[1]	N/A[1]
					5/6/2015	2645.2	12.4	16.89	39.0	19.8	223.2
					5/21/2015	2642	12.3	17.35	40.0	18.7	224.3
					5/26/2015	2640.7	12.2	17.54	40.5	18.3	224.7
		114	129	1402210	4/22/2015	2839.6	9.1	0.30	0.7	N/A[1]	N/A[1]
					5/6/2015	2678.9	11.0	23.97	55.3	58.7	184.3
					5/21/2015	2673.1	10.8	24.79	57.2	56.8	186.2
					5/26/2015	2670.6	10.7	25.14	58.0	56.0	187.0
		154	89	1404211	4/22/2015	2872.2	8.8	0.33	0.8	N/A[1]	N/A[1]
					5/6/2015	2766.7	10.5	16.65	38.4	115.6	127.4
					5/21/2015	2767.3	10.2	16.55	38.2	115.8	127.2
					5/26/2015	2766.7	10.2	16.64	38.4	115.6	127.4
HC-10	180	29.4	150.6	1703868	3/23/2018	2883.392	10.4	7.30	16.8	12.6	167.4
		59.5	120.5	1800203	3/23/2018	2757.897	11.1	2.19	5.1	54.5	125.6
		89.4	90.6	1703302	3/23/2018	2805.338	10.2	2.82	6.5	82.9	97.1
HC-11	142	29.6	112.4	1800204	3/23/2018	2819.4	10.7	9.56	22.1	7.5	134.5
HC-12	47	16.5	30.5	1703869	3/23/2018	2805.1	10.5	8.09	18.7	-2.2	49.2

Notes:

[1]HC-10, -11, and -12 VWPs installed on 2/22/18, 2/26/18, and 2/19/18 respectively.

[2]HC-1 VWPs installed on 4/22/15. Measurements shown for 4/22/2015 are prior to installation with all VWPs in a 5-gallon bucket of water with about 1-foot of water above piezometer tips.

VW Piezometer Calibration Certificate

Serial #: 1500234
Range : 350 kPa
Cable Length: 15 m
Date of Calibration: 1/27/2015

Part #: 52611028
Cable Part # : 50613524
Calibrated by: AM
Note:

ABC Calibration Factors

	A	B	C
kPa	-1.252835E-4	1.821970E-2	8.875334E+2
psi	-1.817084E-5	2.642544E-3	1.287258E+2

Pressure in kPa/psi $= (A \times Hz^2) + (B \times Hz) + C$, where Hz is frequency in Hertz.

TI Calibration Factors

	C0	C1	C2	C3	C4	C5
kPa	8.863479E+2	1.714305E-2	1.542821E-1	-1.251720E-4	3.211352E-5	-1.254770E-3
psi	1.285494E+2	2.486302E-3	2.237594E-2	-1.815402E-5	4.657508E-6	-1.819826E-4

Pressure in kPa/psi $= C0 + (C1 \times Hz) + (C2 \times T) + (C3 \times Hz^2) + (C4 \times Hz \times T) + (C5 \times T^2)$

Where Hz is the frequency reading in Hertz and T is the Thermistor reading in degrees C.
TI factors are calculated from temperatures at 5.0, 15.0 and 25.0 degrees C.
Applied pressure and temperature are NIST traceable.

Summary of Test Results at 15°C

Thermistor reading is 14.7 °C.

Applied Pressure is referenced to 1 atm. Calculated Pressure uses ABC Calibration factors.

Applied (kPa)	Equivalent (psi)	Frequency (Hz)	Calculated (kPa)	Calculated (psi)	Error (%FS)
0.0	0.00	2735.2	0.1	0.01	-0.02
35.0	5.08	2682.4	35.0	5.07	0.01
70.0	10.15	2628.5	69.8	10.13	0.05
105.0	15.23	2573.0	105.0	15.23	0.00
140.0	20.31	2516.4	140.1	20.31	-0.01
175.0	25.38	2458.6	175.0	25.39	-0.01
210.0	30.46	2399.3	210.0	30.46	-0.01
245.0	35.53	2338.5	245.0	35.54	0.00
280.0	40.61	2276.0	280.0	40.61	0.00
315.0	45.69	2211.7	315.0	45.69	0.00
350.0	50.76	2145.3	350.0	50.77	-0.01

VW Piezometer Calibration Certificate

Serial #: 1403689
Range : 700 kPa
Cable Length: 30 m
Date of Calibration: 11/5/2014

Part #: 52611033
Cable Part # : 50613524
Calibrated by: KB
Note:

ABC Calibration Factors

	A	B	C
kPa	-1.682822E-4	-1.122758E-1	1.591547E+3
psi	-2.440727E-5	-1.628423E-2	2.308344E+2

Pressure in kPa/psi $= (A \times Hz^2) + (B \times Hz) + C$, where Hz is frequency in Hertz.

TI Calibration Factors

	C0	C1	C2	C3	C4	C5
kPa	1.588037E+3	-1.114441E-1	1.168997E-1	-1.686665E-4	6.713741E-5	-1.672841E-3
psi	2.303172E+2	-1.616303E-2	1.695427E-2	-2.446215E-5	9.737115E-6	-2.426165E-4

Pressure in kPa/psi $= C0 + (C1 \times Hz) + (C2 \times T) + (C3 \times Hz^2) + (C4 \times Hz \times T) + (C5 \times T^2)$

Where Hz is the frequency reading in Hertz and T is the Thermistor reading in degrees C.
TI factors are calculated from temperatures at 5.0, 15.0 and 25.0 degrees C.
Applied pressure and temperature are NIST traceable.

Summary of Test Results at 15°C

Thermistor reading is 14.8 °C.

Applied Pressure is referenced to 1 atm. Calculated Pressure uses ABC Calibration factors.

Applied (kPa)	Equivalent (psi)	Frequency (Hz)	Calculated (kPa)	Calculated (psi)	Error (%FS)
0.0	0.00	2759.4	0.4	0.06	-0.05
70.0	10.15	2691.9	69.9	10.14	0.02
140.0	20.31	2622.6	139.6	20.25	0.05
210.0	30.46	2551.1	209.9	30.45	0.01
280.0	40.61	2477.9	280.1	40.62	-0.01
350.0	50.76	2403.0	350.0	50.77	0.00
420.0	60.92	2325.9	420.0	60.92	0.00
490.0	71.07	2246.4	490.1	71.09	-0.02
560.0	81.22	2164.5	560.1	81.24	-0.02
630.0	91.37	2079.9	630.0	91.38	-0.01
700.0	101.53	1992.4	699.8	101.50	0.02

VW Piezometer Calibration Certificate

Serial #: 1402210
Range : 700 kPa
Cable Length: 45 m
Date of Calibration: 7/8/2014

Part #: 52611034
Cable Part # : 50613524
Calibrated by: KB
Note:

ABC Calibration Factors

	A	B	C
kPa	-1.885533E-4	2.856795E-2	1.443441E+3
psi	-2.734735E-5	4.143431E-3	2.093534E+2

Pressure in kPa/psi $= (A \times Hz^2) + (B \times Hz) + C$, where Hz is frequency in Hertz.

TI Calibration Factors

	C0	C1	C2	C3	C4	C5
kPa	1.440101E+3	2.806768E-2	2.117773E-1	-1.885909E-4	4.307205E-5	-1.609062E-3
psi	2.088616E+2	4.070730E-3	3.071462E-2	-2.735183E-5	6.246853E-6	-2.333665E-4

Pressure in kPa/psi $= C0 + (C1 \times Hz) + (C2 \times T) + (C3 \times Hz^2) + (C4 \times Hz \times T) + (C5 \times T^2)$

Where Hz is the frequency reading in Hertz and T is the Thermistor reading in degrees C.
TI factors are calculated from temperatures at 5.0, 15.0 and 25.0 degrees C.
Applied pressure and temperature are NIST traceable.

Summary of Test Results at 15°C

Thermistor reading is 16.5 °C.

Applied Pressure is referenced to 1 atm. Calculated Pressure uses ABC Calibration factors.

Applied (kPa)	Equivalent (psi)	Frequency (Hz)	Calculated (kPa)	Calculated (psi)	Error (%FS)
0.0	0.00	2843.5	0.1	0.02	-0.02
70.0	10.15	2775.8	69.9	10.14	0.01
140.0	20.31	2706.2	139.9	20.29	0.02
210.0	30.46	2634.6	209.9	30.45	0.01
280.0	40.61	2560.9	280.0	40.61	0.00
350.0	50.76	2485.1	350.0	50.76	0.00
420.0	60.92	2406.7	420.1	60.92	-0.01
490.0	71.07	2325.7	490.0	71.07	0.00
560.0	81.22	2241.6	560.0	81.23	-0.01
630.0	91.37	2154.2	630.0	91.37	0.00
700.0	101.53	2063.0	699.9	101.51	0.01

VW Piezometer Calibration Certificate

Serial #: 1404211
Range : 700 kPa
Cable Length: 60 m
Date of Calibration: 12/6/2014

Part #: 52611035
Cable Part # : 50613524
Calibrated by: KB
Note:

ABC Calibration Factors

	A	B	C
kPa	-1.907203E-4	1.371290E-2	1.537918E+3
psi	-2.766164E-5	1.988888E-3	2.230562E+2

Pressure in kPa/psi = $(A \times Hz^2) + (B \times Hz) + C$, where Hz is frequency in Hertz.

TI Calibration Factors

	C0	C1	C2	C3	C4	C5
kPa	1.534389E+3	1.389239E-2	2.046774E-1	-1.908957E-4	4.733165E-5	-2.816794E-3
psi	2.225365E+2	2.014850E-3	2.968490E-2	-2.768611E-5	6.864634E-6	-4.085270E-4

Pressure in kPa/psi = $C0 + (C1 \times Hz) + (C2 \times T) + (C3 \times Hz^2) + (C4 \times Hz \times T) + (C5 \times T^2)$

Where Hz is the frequency reading in Hertz and T is the Thermistor reading in degrees C.
TI factors are calculated from temperatures at 5.0, 15.0 and 25.0 degrees C.
Applied pressure and temperature are NIST traceable.

Summary of Test Results at 15°C

Thermistor reading is 14.9 °C.

Applied Pressure is referenced to 1 atm. Calculated Pressure uses ABC Calibration factors.

Applied (kPa)	Equivalent (psi)	Frequency (Hz)	Calculated (kPa)	Calculated (psi)	Error (%FS)
0.0	0.00	2875.7	0.2	0.02	-0.02
70.0	10.15	2810.6	69.9	10.13	0.02
140.0	20.31	2743.8	139.7	20.26	0.04
210.0	30.46	2674.9	210.0	30.46	0.00
280.0	40.61	2604.3	280.1	40.62	-0.01
350.0	50.76	2531.9	350.0	50.77	0.00
420.0	60.92	2457.3	420.0	60.91	0.00
490.0	71.07	2380.3	490.0	71.06	0.00
560.0	81.22	2300.6	560.0	81.23	0.00
630.0	91.37	2218.1	630.0	91.37	0.00
700.0	101.53	2132.4	699.9	101.52	0.01

VW Piezometer Calibration Certificate

Serial #: 1703868
Range : 350 kPa
Cable Length: 15 m
Date of Calibration: 11/29/2017

Part #: 52611028
Cable Part # : 50613824
Calibrated by: KB
Note:

ABC Calibration Factors

	A	B	C
kPa	-1.025703E-4	-9.502580E-2	1.178095E+3
psi	-1.487656E-5	-1.378233E-2	1.708682E+2

Pressure in kPa/psi = $(A \times Hz^2) + (B \times Hz) + C$, where Hz is frequency in Hertz.

TI Calibration Factors

	C0	C1	C2	C3	C4	C5
kPa	1.180625E+3	-9.910942E-2	1.777375E-1	-1.019542E-4	5.112740E-5	-2.451099E-3
psi	1.712292E+2	-1.437410E-2	2.577774E-2	-1.478669E-5	7.415141E-6	-3.554893E-4

Pressure in kPa/psi = $C0 + (C1 \times Hz) + (C2 \times T) + (C3 \times Hz^2) + (C4 \times Hz \times T) + (C5 \times T^2)$

Where Hz is the frequency reading in Hertz and T is the Thermistor reading in degrees C.
TI factors are calculated from temperatures at 5.0, 15.0 and 25.0 degrees C.
Applied pressure and temperature are NIST traceable.

Summary of Test Results at 15°C

Thermistor reading is 14.2 °C.

Applied Pressure is referenced to 1 atm. Calculated Pressure uses ABC Calibration factors.

Applied (kPa)	Equivalent (psi)	Frequency (Hz)	Calculated (kPa)	Calculated (psi)	Error (%FS)
0.0	0.00	2957.3	0.0	0.00	-0.01
35.0	5.08	2907.1	35.0	5.08	0.00
70.0	10.15	2856.2	69.9	10.14	0.02
105.0	15.23	2804.4	104.9	15.22	0.02
140.0	20.31	2751.6	140.0	20.31	-0.01
175.0	25.38	2698.1	175.0	25.38	-0.01
210.0	30.46	2643.7	210.0	30.46	0.00
245.0	35.53	2588.2	245.1	35.54	-0.02
280.0	40.61	2531.8	280.0	40.61	-0.01
315.0	45.69	2474.3	315.0	45.69	-0.01
350.0	50.76	2415.8	349.9	50.75	0.02

VW Piezometer Calibration Certificate

Serial #: 1703869
Range : 350 kPa
Cable Length: 15 m
Date of Calibration: 11/29/2017

Part #: 52611028
Cable Part # : 50613824
Calibrated by: KB
Note:

ABC Calibration Factors

	A	B	C
kPa	-8.300954E-5	-1.100186E-1	1.018480E+3
psi	-1.203952E-5	-1.595685E-2	1.477180E+2

Pressure in kPa/psi = $(A \times Hz^2) + (B \times Hz) + C$, where Hz is frequency in Hertz.

TI Calibration Factors

	C0	C1	C2	C3	C4	C5
kPa	1.018745E+3	-1.120039E-1	1.113888E-1	-8.277293E-5	5.133708E-5	-1.310842E-3
psi	1.477513E+2	-1.624422E-2	1.615501E-2	-1.200478E-5	7.445552E-6	-1.901149E-4

Pressure in kPa/psi = $C0 + (C1 \times Hz) + (C2 \times T) + (C3 \times Hz^2) + (C4 \times Hz \times T) + (C5 \times T^2)$

Where Hz is the frequency reading in Hertz and T is the Thermistor reading in degrees C.
TI factors are calculated from temperatures at 5.0, 15.0 and 25.0 degrees C.
Applied pressure and temperature are NIST traceable.

Summary of Test Results at 15°C

Thermistor reading is 14.6 °C.

Applied Pressure is referenced to 1 atm. Calculated Pressure uses ABC Calibration factors.

Applied (kPa)	Equivalent (psi)	Frequency (Hz)	Calculated (kPa)	Calculated (psi)	Error (%FS)
0.0	0.00	2902.1	0.1	0.01	-0.02
35.0	5.08	2842.5	35.0	5.08	-0.01
70.0	10.15	2782.0	70.0	10.15	0.01
105.0	15.23	2720.3	104.9	15.22	0.02
140.0	20.31	2657.5	139.9	20.29	0.04
175.0	25.38	2593.2	175.0	25.38	0.01
210.0	30.46	2527.7	210.0	30.46	0.00
245.0	35.53	2460.7	245.1	35.55	-0.04
280.0	40.61	2392.5	280.1	40.63	-0.03
315.0	45.69	2322.8	315.1	45.70	-0.02
350.0	50.76	2251.7	349.9	50.75	0.03

VW Piezometer Calibration Certificate

Serial #: 1800203
Range : 350 kPa
Cable Length: 30 m
Date of Calibration: 1/23/2018

Part #: 52611024
Cable Part # : 50613824
Calibrated by: KB
Note:

ABC Calibration Factors

	A	B	C
kPa	-9.102411E-5	-9.977853E-2	1.118942E+3
psi	-1.320193E-5	-1.447165E-2	1.622888E+2

Pressure in kPa/psi = $(A \times Hz^2) + (B \times Hz) + C$, where Hz is frequency in Hertz.

TI Calibration Factors

	C0	C1	C2	C3	C4	C5
kPa	1.120952E+3	-1.024100E-1	6.120593E-2	-9.063425E-5	3.676217E-5	-3.480763E-4
psi	1.625746E+2	-1.485279E-2	8.876857E-3	-1.314492E-5	5.331714E-6	-5.048242E-5

Pressure in kPa/psi = $C0 + (C1 \times Hz) + (C2 \times T) + (C3 \times Hz^2) + (C4 \times Hz \times T) + (C5 \times T^2)$

Where Hz is the frequency reading in Hertz and T is the Thermistor reading in degrees C.
TI factors are calculated from temperatures at 5.0, 15.0 and 25.0 degrees C.
Applied pressure and temperature are NIST traceable.

Summary of Test Results at 15°C

Thermistor reading is 14.4 °C.

Applied Pressure is referenced to 1 atm. Calculated Pressure uses ABC Calibration factors.

Applied (kPa)	Equivalent (psi)	Frequency (Hz)	Calculated (kPa)	Calculated (psi)	Error (%FS)
0.0	0.00	3000.5	0.1	0.01	-0.02
35.0	5.08	2946.0	35.0	5.08	0.00
70.0	10.15	2890.7	69.9	10.14	0.03
105.0	15.23	2834.3	104.9	15.22	0.02
140.0	20.31	2777.0	139.9	20.29	0.03
175.0	25.38	2718.6	174.9	25.37	0.02
210.0	30.46	2659.0	210.1	30.47	-0.02
245.0	35.53	2598.4	245.1	35.55	-0.03
280.0	40.61	2536.7	280.1	40.63	-0.03
315.0	45.69	2473.9	315.0	45.69	0.00
350.0	50.76	2409.9	349.9	50.74	0.04

VW Piezometer Calibration Certificate

Serial #: 1800204
Range : 350 kPa
Cable Length: 30 m
Date of Calibration: 1/23/2018

Part #: 52611024
Cable Part # : 50613824
Calibrated by: KB
Note:

ABC Calibration Factors

	A	B	C
kPa	-7.723072E-5	-1.517535E-1	1.108283E+3
psi	-1.120137E-5	-2.200999E-2	1.607429E+2

Pressure in kPa/psi = $(A \times Hz^2) + (B \times Hz) + C$, where Hz is frequency in Hertz.

TI Calibration Factors

	C0	C1	C2	C3	C4	C5
kPa	1.111302E+3	-1.551888E-1	4.906523E-2	-7.670203E-5	4.653373E-5	-6.609788E-4
psi	1.611751E+2	-2.250744E-2	7.116059E-3	-1.112430E-5	6.748909E-6	-9.586350E-5

Pressure in kPa/psi = $C0 + (C1 \times Hz) + (C2 \times T) + (C3 \times Hz^2) + (C4 \times Hz \times T) + (C5 \times T^2)$

Where Hz is the frequency reading in Hertz and T is the Thermistor reading in degrees C.
TI factors are calculated from temperatures at 5.0, 15.0 and 25.0 degrees C.
Applied pressure and temperature are NIST traceable.

Summary of Test Results at 15°C

Thermistor reading is 14.4 °C.

Applied Pressure is referenced to 1 atm. Calculated Pressure uses ABC Calibration factors.

Applied (kPa)	Equivalent (psi)	Frequency (Hz)	Calculated (kPa)	Calculated (psi)	Error (%FS)
0.0	0.00	2930.8	0.1	0.02	-0.04
35.0	5.08	2872.7	35.0	5.08	0.00
70.0	10.15	2813.7	69.9	10.13	0.04
105.0	15.23	2753.5	104.9	15.21	0.03
140.0	20.31	2692.4	139.8	20.28	0.04
175.0	25.38	2630.0	175.0	25.38	0.01
210.0	30.46	2566.5	210.1	30.47	-0.03
245.0	35.53	2502.0	245.1	35.55	-0.04
280.0	40.61	2436.4	280.1	40.63	-0.03
315.0	45.69	2369.6	315.0	45.69	-0.01
350.0	50.76	2301.7	349.8	50.74	0.05

VW Piezometer Calibration Certificate

Serial #: 1703302
Range : 700 kPa
Cable Length: 60 m
Date of Calibration: 10/20/2017

Part #: 52611035
Cable Part # : 50613824
Calibrated by: KB
Note:

ABC Calibration Factors

	A	B	C
kPa	-1.537654E-4	-7.290478E-2	1.610262E+3
psi	-2.230179E-5	-1.057394E-2	2.335488E+2

Pressure in kPa/psi $= (A \times Hz^2) + (B \times Hz) + C$, where Hz is frequency in Hertz.

TI Calibration Factors

	C0	C1	C2	C3	C4	C5
kPa	1.612713E+3	-7.643283E-2	1.233910E-1	-1.532562E-4	5.410520E-5	-2.269820E-3
psi	2.338960E+2	-1.108525E-2	1.789572E-2	-2.222715E-5	7.847020E-6	-3.291980E-4

Pressure in kPa/psi $= C0 + (C1 \times Hz) + (C2 \times T) + (C3 \times Hz^2) + (C4 \times Hz \times T) + (C5 \times T^2)$

Where Hz is the frequency reading in Hertz and T is the Thermistor reading in degrees C.
TI factors are calculated from temperatures at 5.0, 15.0 and 25.0 degrees C.
Applied pressure and temperature are NIST traceable.

Summary of Test Results at 15°C

Thermistor reading is 14.0 °C.

Applied Pressure is referenced to 1 atm. Calculated Pressure uses ABC Calibration factors.

Applied (kPa)	Equivalent (psi)	Frequency (Hz)	Calculated (kPa)	Calculated (psi)	Error (%FS)
0.0	0.00	3007.4	0.3	0.04	-0.04
70.0	10.15	2936.8	70.0	10.15	0.01
140.0	20.31	2864.5	139.7	20.27	0.04
210.0	30.46	2790.2	209.8	30.42	0.04
280.0	40.61	2713.9	279.9	40.59	0.02
350.0	50.76	2635.6	350.0	50.76	0.00
420.0	60.92	2555.1	420.1	60.93	-0.02
490.0	71.07	2472.2	490.2	71.10	-0.04
560.0	81.22	2386.9	560.2	81.25	-0.03
630.0	91.37	2298.8	630.1	91.39	-0.01
700.0	101.53	2207.9	699.7	101.49	0.04

APPENDIX D
Existing Explorations by Hart Crowser and Others

APPENDIX D
EXISTING EXPLORATIONS BY HART CROWSER AND OTHERS

In addition to the explorations and laboratory test results presented in Appendices A and B, respectively, previous soil explorations by Hart Crowser and others were used to gain an understanding of the subsurface conditions at the proposed development at Point Wells.

Borings previously performed by Hart Crowser and others at the Project site were consulted for the current report. These logs are included in this appendix, separated by location (slope, Upper Bench, and Lower Bench). Logs produced by others are presented for reference only and Hart Crowser is not responsible for the accuracy or completeness of the information presented in the logs. Approximate locations of these borings are shown on Figures 2 and 3; actual locations may differ from those shown.

SLOPE

Boring Log

Project Name: Point Wells				Sheet 1 of 3
Job No.: 10903	Logged by: SSR	Start Date: 2/9/04	Completion Date: 2/9/04	Boring No.: B-1
Drilling Contactor: Boretec		Drilling Method: HSA		Sampling Method: SPT
Ground Surface Elevation: ±236'		Hole Completion: ☐ Monitoring Well ☐ Piezometer ☒ Abandoned, sealed with bentonite		

General Notes	W (%)	No. Blows Ft.	Depth Ft.	USCS Symbol	Surface Conditions: Depth of Topsoil 6": grass
			0	SM	Brown silty fine to medium SAND with gravel, medium dense, moist
	8.9	38	5–6		-variable silt content
	18.9	19	10–11		-moist to wet -6" silt layer -wet -possible seepage at 10.5'
	8.3	57	15–16	SP-SM	Brown poorly graded SAND with silt, very dense, moist to wet -10.2% fines

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Boring Log
Point Wells
Snohomish County, Washington

Proj. No. 10903	Dwn. GLS	Date Mar. 2004	Checked RAC	Date 3/4/04	Plate A2

BORING LOG 10903.GPJ ECI.GDT 3/4/04

Subsurface conditions depicted represent our observations at the time and location of this exploratory hole, modified by engineering tests, analysis and judgment. They are not necessarily representative of other times and locations. We cannot accept responsibility for the use or interpretation by others of information presented on this log.

Boring Log

Project Name: Point Wells				Sheet 2 of 3
Job No.: 10903	Logged by: SSR	Start Date: 2/9/04	Completion Date: 2/9/04	Boring No.: B-1
Drilling Contactor: Boretec		Drilling Method: HSA		Sampling Method: SPT
Ground Surface Elevation: ±236'		Hole Completion: ☐ Monitoring Well ☐ Piezometer ☒ Abandoned, sealed with bentonite		

General Notes	W (%)	No. Blows Ft.	Graphic Symbol	Depth Ft.	Sample	USCS Symbol	Description
	12.8	55		21		SP-SM	Brown poorly graded SAND with silt, very dense, moist to wet
				22			
				23			
				24			
	10.3	48		25		SM	Bray silty fine to medium SAND with gravel, dense, moist
				26			
				27			
				28			
				29			
	7.6	45		30		SP-SM	Gray poorly graded fine SAND with silt, dense, moist
				31			
				32			
				33			
				34			
	4.7	64		35			-very dense
				36			
				37			
				38			
				39			

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Boring Log
Point Wells
Snohomish County, Washington

Proj. No. 10903	Dwn. GLS	Date Mar. 2004	Checked RAC	Date 3/4/04	Plate A3

Boring Log

Project Name: Point Wells				Sheet 3 of 3
Job No. 10903	Logged by: SSR	Start Date: 2/9/04	Completion Date: 2/9/04	Boring No.: B-1
Drilling Contactor: Boretec		Drilling Method: HSA		Sampling Method: SPT
Ground Surface Elevation: ±236'		Hole Completion: ☐ Monitoring Well ☐ Piezometer ☒ Abandoned, sealed with bentonite		

General Notes	W (%)	No. Blows Ft.	Graphic Symbol	Depth Ft.	Sample	USCS Symbol	Description
	17.7	49		41		SP-SM	Gray poorly graded SAND with silt, dense, wet
				42–44			-seepage at 40'
	21.0	41		45–46		CL	Gray lean CLAY, very stiff, moist
				47–49			LL=34 PL=22 PI=12
	28.8	70		50–54			
	31.9	62		55–56			
							Boring terminated at 56.5 feet below existing grade. Groundwater seepage encountered at 10.5 and 40.0 feet during drilling. Boring backfilled with bentonite and cuttings.

RB-8-00010285

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Boring Log
Point Wells
Snohomish County, Washington

Proj. No. 10903	Dwn. GLS	Date Mar. 2004	Checked RAC	Date 3/4/04	Plate A4

BORING 3 10903.GPJ ECI.GDT 3/4/04

Boring Log

Project Name: Point Wells				Sheet 1 of 2
Job No.: 10903	Logged by: SSR	Start Date: 2/9/04	Completion Date: 2/9/04	Boring No.: B-2
Drilling Contactor: Boretec		Drilling Method: HSA		Sampling Method: SPT
Ground Surface Elevation: ±246'		Hole Completion: ☐ Monitoring Well ☐ Piezometer ☒ Abandoned, sealed with bentonite		

Surface Conditions: Depth of Topsoil 6": grass

General Notes	W (%)	No. Blows Ft.	Graphic Symbol	Depth Ft.	Sample	USCS Symbol	Description
				0		SM	Brown silty SAND with gravel, medium dense, moist
				1			
				2			
				3			
				4			
	10.9			5			
		34		6			
				7			
				8			
				9			
	11.9			10			
		30		11			
				12			-seepage at 11.5'
				13			
				14			
	12.6			15			
		50/4"		16			
				17			
				18			
				19			

RB-8-00010287

BORING LOG 10903.GPJ ECI.GDT 3/4/04

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Boring Log
Point Wells
Snohomish County, Washington

Proj. No. 10903	Dwn. GLS	Date Mar. 2004	Checked RAC	Date 3/4/04	Plate A5

Boring Log

Project Name: Point Wells				Sheet 2 of 2
Job No. 10903	Logged by: SSR	Start Date: 2/9/04	Completion Date: 2/9/04	Boring No.: B-2
Drilling Contactor: Boretec		Drilling Method: HSA		Sampling Method: SPT
Ground Surface Elevation: ±246'		Hole Completion: ☐ Monitoring Well ☐ Piezometer ☒ Abandoned, sealed with bentonite		

General Notes	W (%)	No. Blows Ft.	Graphic Symbol	Depth Ft.	Sample	USCS Symbol	
	7.4	50/5"				SM	Gray silty SAND with gravel, very dense, moist
				21			Boring terminated at 21.0 feet below existing grade. Groundwater seepage encountered at 11.5 feet during drilling. Boring backfilled with bentonite and cuttings.

RB-8-00010288

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Boring Log
Point Wells
Snohomish County, Washington

Proj. No. 10903	Dwn. GLS	Date Mar. 2004	Checked RAC	Date 3/4/04	Plate A6

Subsurface conditions depicted represent our observations at the time and location of this exploratory hole, modified by engineering tests, analysis and judgment. They are not necessarily representative of other times and locations. We cannot accept responsibility for the use or interpretation by others of information presented on this log.

BORING 10903.GPJ ECI.GDT 3/4/04

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Boring Log

Project Name: Point Wells					Sheet 1 of 4
Job No.: 10903	Logged by: SSR	Start Date: 2/9/04	Completion Date: 2/9/04	Boring No.: B-3	
Drilling Contactor: Boretec		Drilling Method: HSA		Sampling Method: SPT	
Ground Surface Elevation: ±160'		Hole Completion: ☐ Monitoring Well ☐ Piezometer ☒ Abandoned, sealed with bentonite			

Surface Conditions: Depth of Forest Duff 6"

General Notes	W (%)	No. Blows Ft.	Depth Ft.	USCS Symbol	Description
			0	SM	Brown silty SAND with gravel, loose to medium dense, moist (Possible Fill)
	5.7	20	5–6		-iron oxide staining -variable silt content
			9	SM	Brown silty SAND with gravel, dense, moist
	13.2	44	10–11		
	22.2	73	15–16		-becomes wet, possible seepage

RB-8-00010289

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Boring Log
Point Wells
Snohomish County, Washington

Proj. No. 10903	Dwn. GLS	Date Mar. 2004	Checked RAC	Date 3/4/04	Plate A7

Subsurface conditions depicted represent our observations at the time and location of this exploratory hole, modified by engineering tests, analysis and judgment. They are not necessarily representative of other times and locations. We cannot accept responsibility for the use or interpretation by others of information presented on this log.

BORING LOG 10903.GPJ ECI.GDT 3/4/04

Boring Log

Project Name: Point Wells				Sheet 2 of 4
Job No. 10903	Logged by: SSR	Start Date: 2/9/04	Completion Date: 2/9/04	Boring No.: B-3
Drilling Contactor: Boretec		Drilling Method: HSA		Sampling Method: SPT
Ground Surface Elevation: ±160'		Hole Completion: ☐ Monitoring Well ☐ Piezometer ☒ Abandoned, sealed with bentonite		

General Notes	W (%)	No. Blows Ft.	Depth Ft.	USCS Symbol	Description
	13.7	50/5"	21	SM	Gray silty SAND with gravel, very dense, moist
			22		-contains thin layer of organic matter
			23		
			24		
	27.3	21	25		-iron oxide staining -becomes wet, possible seepage
			26	CL	Gray lean CLAY, stiff, moist
			27		
			28		
			29		
	24.7	20	30		
			31	ML	Gray fine sandy SILT, medium dense, wet
			32		-possible seepage at 31'
			33		
			34		
	31.4	16	35		-wet -seepage at 35.5'
			36	SM	Gray silty fine SAND, medium dense, moist
			37		
			38		
			39		

RB-8-00010290

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Boring Log
Point Wells
Snohomish County, Washington

Proj. No. 10903	Dwn. GLS	Date Mar. 2004	Checked RAC	Date 3/4/04	Plate A8

Subsurface conditions depicted represent our observations at the time and location of this exploratory hole, modified by engineering tests, analysis and judgment. They are not necessarily representative of other times and locations. We cannot accept responsibility for the use or interpretation by others of information presented on this log.

BORING LOG 10903.GPJ ECI.GDT 3/4/04

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Boring Log

Project Name: Point Wells					Sheet 3 of 4
Job No. 10903	Logged by: SSR	Start Date: 2/9/04	Completion Date: 2/9/04	Boring No.: B-3	
Drilling Contactor: Boretec		Drilling Method: HSA		Sampling Method: SPT	
Ground Surface Elevation: ±160'		Hole Completion: ☐ Monitoring Well ☐ Piezometer ☒ Abandoned, sealed with bentonite			

General Notes	W (%)	No. Blows Ft.	Depth Ft.	USCS Symbol	Description
	30.3	13		SM	Gray silty fine SAND, medium dense, moist
			41	ML	Gray SILT, medium dense, moist
			42		
			43		
			44		
	26.9	21	45	SM	Gray silty fine SAND, medium dense, moist to wet
			46		-possible seepage zone
			47		
			48		
			49		
	34.7	39	50		
			51	CL	Gray lean CLAY, stiff, moist
			52		
			53		LL=50 PL=23 PI=27
			54	SM	Gray silty fine SAND, medium dense, wet
	25.7	28	55		
				CL	Gray silty CLAY, stiff, moist
			56	ML	Gray SILT, stiff, wet
			57		
			58		
			59		

RB-8-00010291

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Boring Log
Point Wells
Snohomish County, Washington

Proj. No. 10903	Dwn. GLS	Date Mar. 2004	Checked RAC	Date 3/4/04	Plate A9

BORING LOG 10903.GPJ ECI.GDT 3/4/04

Subsurface conditions depicted represent our observations at the time and location of this exploratory hole, modified by engineering tests, analysis and judgment. They are not necessarily representative of other times and locations. We cannot accept responsibility for the use or interpretation by others of information presented on this log.

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Boring Log

Project Name: Point Wells				Sheet 4 of 4
Job No. 10903	Logged by: SSR	Start Date: 2/9/04	Completion Date: 2/9/04	Boring No.: B-3
Drilling Contactor: Boretec		Drilling Method: HSA		Sampling Method: SPT
Ground Surface Elevation: ±160'		Hole Completion: ☐ Monitoring Well ☐ Piezometer ☒ Abandoned, sealed with bentonite		

General Notes	W (%)	No. Blows Ft.	Graphic Symbol	Depth Ft.	Sample	USCS Symbol	Description
	33.7	59		61		ML	Gray SILT, very stiff / hard, moist
							Boring terminated at 61.5 feet below existing grade. Groundwater seepage encountered at 15.0, 26.0, 35.5, 46.0 and 55.0 feet during drilling. Boring backfilled with bentonite and cuttings.

RB-8-00010292

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Boring Log
Point Wells
Snohomish County, Washington

Proj. No. 10903	Dwn. GLS	Date Mar. 2004	Checked RAC	Date 3/4/04	Plate A10

BORING LOG 10903.GPJ ECI.GDT 3/4/04

Boring Log

Project Name: Point Wells				Sheet 1 of 2
Job No. 10903	Logged by: SSR	Start Date: 2/9/04	Completion Date: 2/9/04	Boring No.: B-4
Drilling Contactor: Boretec		Drilling Method: HSA		Sampling Method: SPT
Ground Surface Elevation: ±206'		Hole Completion: ☐ Monitoring Well ☐ Piezometer ☒ Abandoned, sealed with bentonite		

Surface Conditions: Depth of Topsoil 6": grass

General Notes	W (%)	No. Blows Ft.	Depth Ft.	USCS Symbol	Description
			0	SM	Brown silty SAND with gravel, medium dense, moist
	16.4	12	5		-becomes wet, possible seepage
			7		-gray
	28.2	30	10		-wet
	28.6	33	15		
			15.5	ML	Gray SILT, stiff, moist
			17		-sand layers

RB-8-00010293

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Boring Log
Point Wells
Snohomish County, Washington

Proj. No. 10903	Dwn. GLS	Date Mar. 2004	Checked RAC	Date 3/4/04	Plate A11

BORING LOG 10903.GPJ ECI.GDT 3/4/04

Boring Log

Project Name: Point Wells					Sheet 2 of 2
Job No.: 10903	Logged by: SSR	Start Date: 2/9/04	Completion Date: 2/9/04	Boring No.: B-4	
Drilling Contactor: Boretec		Drilling Method: HSA		Sampling Method: SPT	
Ground Surface Elevation: ±206'		Hole Completion: ☐ Monitoring Well ☐ Piezometer ☒ Abandoned, sealed with bentonite			

General Notes	W (%)	No. Blows Ft.	Graphic Symbol	Depth Ft.	Sample	USCS Symbol	Description
	28.3	39		21		CL	Gray lean CLAY, very stiff, moist
				22			
				23			
				24			
	27.0	32		25		ML	Gray SILT, stiff, moist
				26			-wet sand layers
				27			
				28			
				29			
	23.5			30		SP-SM	Gray poorly graded fine SAND with silt, very dense, wet
		61		31		ML	Gray SILT, hard, wet, possible seepage zone
							Boring terminated at 31.5 feet below existing grade. Groundwater seepage encountered at 5.0 and 30.0 feet during drilling. Boring backfilled with bentonite and cuttings.

RB-8-00010294

BORING LOG 10903.GPJ ECI.GDT 3/4/04

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Boring Log
Point Wells
Snohomish County, Washington

Proj. No. 10903	Dwn. GLS	Date Mar. 2004	Checked RAC	Date 3/4/04	Plate A12

Boring Log

Project Name: Point Wells				Sheet 1 of 2
Job No.: 10903	Logged by: SSR	Start Date: 2/9/04	Completion Date: 2/9/04	Boring No.: B-5
Drilling Contactor: Boretec		Drilling Method: HSA		Sampling Method: SPT
Ground Surface Elevation: ±218'		Hole Completion: ☐ Monitoring Well ☐ Piezometer ☒ Abandoned, sealed with bentonite		

Surface Conditions: Depth of Topsoil 6": grass

General Notes	W (%)	No. Blows Ft.	Depth Ft.	USCS Symbol	Description
			0	SM	Brown silty SAND with gravel, medium dense, moist to wet
	9.8	50/5"	5		-very dense
			8		-gray
	10.6	50/5"	10		
	26.5	71	15	SP-SM	Brown poorly graded SAND with silt, very dense, wet
			16		-seepage zone

RB-8-00010295

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Boring Log
Point Wells
Snohomish County, Washington

Proj. No. 10903	Dwn. GLS	Date Mar. 2004	Checked RAC	Date 3/4/04	Plate A13

BORING LOG 10903.GPJ ECI.GDT 3/4/04

Boring Log

Project Name: Point Wells				Sheet 2 of 2
Job No. 10903	Logged by: SSR	Start Date: 2/9/04	Completion Date: 2/9/04	Boring No.: B-5
Drilling Contactor: Boretec		Drilling Method: HSA		Sampling Method: SPT
Ground Surface Elevation: ±218'		Hole Completion: ☐ Monitoring Well	☐ Piezometer	☒ Abandoned, sealed with bentonite

General Notes	W (%)	No. Blows Ft.	Graphic Symbol	Depth Ft.	Sample	USCS Symbol	Description
	20.9	45		21		SP-SM	Brown poorly graded SAND with silt, dense, water bearing
							Boring terminated at 21.5 feet below existing grade. Groundwater seepage encountered at 15.0 and 20.0 feet during drilling. Boring backfilled with bentonite and cuttings.

RB-8-00010296

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Boring Log
Point Wells
Snohomish County, Washington

Proj. No. 10903	Dwn. GLS	Date Mar. 2004	Checked RAC	Date 3/4/04	Plate A14

BORING LOG 10903.GPJ ECI.GDT 3/4/04

Boring Log

Project Name: Point Wells			Sheet 1 of 3
Job No. 10903	Logged by: SSR	Start Date: 2/10/04	Completion Date: 2/10/04	Boring No.: B-6
Drilling Contactor: Boretec	Drilling Method: HSA	Sampling Method: SPT
Ground Surface Elevation: ±186'	Hole Completion: ☐ Monitoring Well ☒ Piezometer ☐ Abandoned, sealed with bentonite

Surface Conditions: Depth of Topsoil 6": grass

General Notes	W (%)	No. Blows Ft.	Depth Ft.	USCS Symbol	Description
			0	SM	Brown silty fine to medium SAND, medium dense, moist
			4		-contains gravel
	14.3	28	5–6		
			8		-variable silt content
	21.0	12	10–11		-wet -possible seepage zone -17.1% fines
			14		-gray
	27.5	14	15–16	CL	Gray lean CLAY, stiff, moist
			17		-sand lenses LL=33 PL=23 PI=10

RB-8-00010297

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Boring Log
Point Wells
Snohomish County, Washington

Proj. No. 10903	Dwn. GLS	Date Mar. 2004	Checked RAC	Date 3/4/04	Plate A15

BORING LOG 10903.GPJ ECI.GDT 3/4/04

Boring Log

Project Name: Point Wells				Sheet 2 of 3
Job No. 10903	Logged by: SSR	Start Date: 2/10/04	Completion Date: 2/10/04	Boring No.: B-6
Drilling Contactor: Boretec		Drilling Method: HSA		Sampling Method: SPT
Ground Surface Elevation: ±186'		Hole Completion: ☐ Monitoring Well ☒ Piezometer ☐ Abandoned, sealed with bentonite		

General Notes	W (%)	No. Blows Ft.	Graphic Symbol	Depth Ft.	Sample	USCS Symbol	Description
	28.8	21		21–24		ML	Gray SILT, stiff, moist
	28.5	29		25–29		CL	Gray lean CLAY, very stiff, moist -silt lenses
	27.8	44		30–34		ML	Gray SILT, very stiff / hard, wet -seepage zone
	32.0	25		35–39		CL	Gray lean CLAY, stiff, moist

RB-8-00010298

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Boring Log
Point Wells
Snohomish County, Washington

Proj. No. 10903	Dwn. GLS	Date Mar. 2004	Checked RAC	Date 3/4/04	Plate A16

BORING LOG 10903.GPJ ECI.GDT 3/4/04

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Boring Log

Project Name: Point Wells				Sheet 3 of 3
Job No.: 10903	Logged by: SSR	Start Date: 2/10/04	Completion Date: 2/10/04	Boring No.: B-6
Drilling Contactor: Boretec		Drilling Method: HSA		Sampling Method: SPT
Ground Surface Elevation: ±186'		Hole Completion: ☐ Monitoring Well ☒ Piezometer ☐ Abandoned, sealed with bentonite		

General Notes	W (%)	No. Blows Ft.	Graphic Symbol	Depth Ft.	Sample	USCS Symbol	
	28.0	23		41		CL	Gray lean CLAY, stiff, moist
							Boring terminated at 41.5 feet below existing grade. Groundwater seepage encountered at 11.0 and 31.0 feet during drilling. 1" PVC Standpipe installed to 41.5 feet. Lower 30.0 - 40.0 feet slotted. Boring backfilled with sand and bentonite. Concrete well cap.

RB-8-00010299

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Boring Log
Point Wells
Snohomish County, Washington

Proj. No. 10903	Dwn. GLS	Date Mar. 2004	Checked RAC	Date 3/4/04	Plate A17

Boring Log

Project Name: Point Wells				Sheet 1 of 3
Job No. 10903	Logged by: SSR	Start Date: 2/10/04	Completion Date: 2/10/04	Boring No.: B-7
Drilling Contactor: Boretec		Drilling Method: HSA		Sampling Method: SPT
Ground Surface Elevation: ±200'		Hole Completion: ☐ Monitoring Well ☒ Piezometer ☐ Abandoned, sealed with bentonite		

Surface Conditions: Depth of Topsoil 6": grass

General Notes	W (%)	No. Blows Ft.	Depth Ft.	USCS Symbol	Description
			0	SM	Brown silty fine to medium SAND. medium dense, moist
			2		-contains gravel
	26.5	14	5		
			5.5	ML	Gray brown SILT, stiff, moist
			6.5		-iron oxide staining
	27.4	22	10		
			11		-possible seepage zone at 11'
			12.5		LL=29 PL=24 PI=5
	31.0	25	15		
			15.5		-poorly graded wet sand layer, 4" thick

RB-8-00010300

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Boring Log
Point Wells
Snohomish County, Washington

Proj. No. 10903	Dwn. GLS	Date Mar. 2004	Checked RAC	Date 3/4/04	Plate A18

Subsurface conditions depicted represent our observations at the time and location of this exploratory hole, modified by engineering tests, analysis and judgment. They are not necessarily representative of other times and locations. We cannot accept responsibility for the use or interpretation by others of information presented on this log.

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Boring Log

Project Name: Point Wells				Sheet 2 of 3
Job No.: 10903	Logged by: SSR	Start Date: 2/10/04	Completion Date: 2/10/04	Boring No.: B-7
Drilling Contactor: Boretec		Drilling Method: HSA		Sampling Method: SPT
Ground Surface Elevation: ±200'		Hole Completion: ☐ Monitoring Well ☒ Piezometer ☐ Abandoned, sealed with bentonite		

General Notes	W (%)	No. Blows Ft.	Graphic Symbol	Depth Ft.	Sample	USCS Symbol	Description
	28.0	23		21		ML	Gray SILT, stiff, moist
				22			
				23			
				24			
	27.5	41		25			
				26			
				27			
				28			
				29			
	29.6	35		30			-wet -seepage zone
				31			
				32			
				33			
				34			
	27.6	39		35			-wet -with fine sand
				36			
				37			
				38			
				39			

RB-8-00010301

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Boring Log
Point Wells
Snohomish County, Washington

Proj. No. 10903	Dwn. GLS	Date Mar. 2004	Checked RAC	Date 3/4/04	Plate A19

Boring Log

Project Name: Point Wells				Sheet 3 of 3
Job No. 10903	Logged by: SSR	Start Date: 2/10/04	Completion Date: 2/10/04	Boring No.: B-7
Drilling Contactor: Boretec		Drilling Method: HSA		Sampling Method: SPT
Ground Surface Elevation: ±200'		Hole Completion: ☐ Monitoring Well ☒ Piezometer ☐ Abandoned, sealed with bentonite		

General Notes	W (%)	No. Blows Ft.	Graphic Symbol	Depth Ft.	Sample	USCS Symbol	Description
	29.1	28		41		CL	Gray lean CLAY, stiff, moist
				42			
				43			
				44			
	26.0	28		45			-massive texture
				46			
				47			
				48			
				49			
	28.2	25		50			
				51			
							Boring terminated at 51.5 feet below existing grade. Groundwater seepage encountered at 11.0 and 30.0 feet during drilling. 1" PVC standpipe installed to 51.5 feet. Lower 30.0 - 40.0 feet slotted. Boring backfilled with sand, bentonite. Concrete well cap.

RB-8-00010302

BORING LOG 10903.GPJ ECI.GDT 3/4/04

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Boring Log
Point Wells
Snohomish County, Washington

Proj. No. 10903	Dwn. GLS	Date Mar. 2004	Checked RAC	Date 3/4/04	Plate A20

Boring Log

Project Name: Point Wells			Sheet 1 of 2
Job No.: 10903	Logged by: SSR	Start Date: 2/10/04	Completion Date: 2/10/04	Boring No.: B-8
Drilling Contactor: Boretec	Drilling Method: HSA	Sampling Method: SPT		
Ground Surface Elevation: ±242'	Hole Completion: ☐ Monitoring Well ☒ Piezometer ☐ Abandoned, sealed with bentonite			

Surface Conditions: Depth of Topsoil 6": grass

General Notes	W (%)	No. Blows Ft.	Depth Ft.	USCS Symbol	Description
			0	SM	Brown silty fine to medium SAND with gravel, medium dense, moist
	11.8	21	5		-moist to wet
			10	SP-SM	Brown poorly graded SAND with silt, medium dense, moist
	9.0	27	11		-7.3% fines
			15	SM	Brown silty SAND with gravel, very dense, moist
	11.6	50/5"	16		

RB-8-00010303

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Boring Log
Point Wells
Snohomish County, Washington

Proj. No. 10903	Dwn. GLS	Date Mar. 2004	Checked RAC	Date 3/4/04	Plate A21

Subsurface conditions depicted represent our observations at the time and location of this exploratory hole, modified by engineering tests, analysis and judgment. They are not necessarily representative of other times and locations. We cannot accept responsibility for the use or interpretation by others of information presented on this log.

BORING_ 10903.GPJ ECI.GDT 3/4/04

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Boring Log

Project Name: Point Wells				Sheet 2 of 2
Job No. 10903	Logged by: SSR	Start Date: 2/10/04	Completion Date: 2/10/04	Boring No.: B-8
Drilling Contactor: Boretec		Drilling Method: HSA		Sampling Method: SPT
Ground Surface Elevation: ±242'		Hole Completion: ☐ Monitoring Well ☒ Piezometer ☐ Abandoned, sealed with bentonite		

General Notes	W (%)	No. Blows Ft.	Graphic Symbol	Depth Ft.	Sample	USCS Symbol	Description
	2.0	50/5"		21		SP-SM	Brown poorly graded SAND with silt, very dense, moist
				22			
				23			
				24			
	4.7	50/4"		25		SM	Brown silty SAND with gravel, very dense, moist
				26			
				27			
				28			
				29			
	17.8	60		30		SP-SM	Brown poorly graded SAND with silt, very dense, wet
				31			-seepage at 30'
							Boring terminated at 31.5 feet below existing grade. Groundwater seepage encountered at 30.0 feet during excavation. 1" PVC standpipe installed to 31.5 feet. Lower 10.0 feet slotted. Boring backfilled with sand and bentonite. Concrete well cap.

RB-8-00010304

BORING 10903.GPJ ECI.GDT 3/4/04

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Boring Log
Point Wells
Snohomish County, Washington

Proj. No. 10903	Dwn. GLS	Date Mar. 2004	Checked RAC	Date 3/4/04	Plate A22

Boring Log

Project Name: Point Wells				Sheet 1 of 4
Job No. 10903	Logged by: SSR	Start Date: 2/11/04	Completion Date: 2/11/04	Boring No.: B-9
Drilling Contactor: Boretec		Drilling Method: HSA		Sampling Method: SPT
Ground Surface Elevation: ±132'		Hole Completion: ☐ Monitoring Well ☐ Piezometer ☒ Abandoned, sealed with bentonite		

Surface Conditions: Heavy brush, saplings and blackberry brambles

General Notes	W (%)	No. Blows Ft.	Graphic Symbol	Depth Ft.	Sample	USCS Symbol	Description
				0		SM	Brown silty SAND with gravel, loose to medium dense, moist
	21.4	18		5–6.5	SPT		-gray -wet
				10		ML	Gray SILT, stiff, moist, with sand lenses
	31.3	13		10–11.5	SPT		
				11		CH	Gray fat CLAY, stiff, moist
	40.4	11		15–16.5	SPT		LL=64 PL=29 PI=35

RB-8-00010305

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Boring Log
Point Wells
Snohomish County, Washington

Proj. No. 10903	Dwn. GLS	Date Mar. 2004	Checked RAC	Date 3/4/04	Plate A23

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Boring Log

Project Name: Point Wells				Sheet 2 of 4
Job No.: 10903	Logged by: SSR	Start Date: 2/11/04	Completion Date: 2/11/04	Boring No.: B-9
Drilling Contactor: Boretec		Drilling Method: HSA		Sampling Method: SPT
Ground Surface Elevation: ±132'		Hole Completion: ☐ Monitoring Well ☐ Piezometer ☒ Abandoned, sealed with bentonite		

General Notes	W (%)	No. Blows Ft.	Depth Ft.	USCS Symbol	Description
	30.4	10	20–21	ML	Gray SILT, stiff, wet
	28.6	20	21–31	SP-SM	Gray poorly graded very fine SAND with silt, medium dense, wet -seepage at 21'
	29.0	22			
			31–35	ML	Gray fine sandy SILT, medium dense, moist to wet
	29.8	20	35–36	CL	Gray lean CLAY, stiff, moist
			36–40	SP-SM	Gray poorly graded fine SAND with silt, medium dense, wet -seepage at 36'

RB-8-00010306

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Boring Log
Point Wells
Snohomish County, Washington

Proj. No. 10903	Dwn. GLS	Date Mar. 2004	Checked RAC	Date 3/4/04	Plate A24

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Boring Log

Project Name: Point Wells					Sheet 3 of 4
Job No.: 10903	Logged by: SSR	Start Date: 2/11/04	Completion Date: 2/11/04	Boring No.: B-9	
Drilling Contactor: Boretec		Drilling Method: HSA		Sampling Method: SPT	
Ground Surface Elevation: ±132'		Hole Completion: ☐ Monitoring Well ☐ Piezometer ☒ Abandoned, sealed with bentonite			

General Notes	W (%)	No. Blows Ft.	Graphic Symbol	Depth Ft.	Sample	USCS Symbol	Description
	33.0	19				SM	Gray silty fine SAND, medium dense, wet
				41			
				42			-seepage zone, 62.2% fines
				43			
				44			
	30.4	24		45			-silt and clay layers
				46			-wet
				47			
				48			
				49			
	30.1	14		50			-wet
				51			-clay layer
				52			
				53			
				54			
	38.2	26		55			
				56		CL	Gray lean CLAY, stiff, moist, with silt and sand lenses
				57			
				58			
				59			

RB-8-00010307

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Boring Log
Point Wells
Snohomish County, Washington

Proj. No. 10903	Dwn. GLS	Date Mar. 2004	Checked RAC	Date 3/4/04	Plate A25

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Boring Log

Project Name: Point Wells				Sheet 4 of 4
Job No.: 10903	Logged by: SSR	Start Date: 2/11/04	Completion Date: 2/11/04	Boring No.: B-9
Drilling Contactor: Boretec		Drilling Method: HSA		Sampling Method: SPT
Ground Surface Elevation: ±132'		Hole Completion: ☐ Monitoring Well ☐ Piezometer ☒ Abandoned, sealed with bentonite		

General Notes	W (%)	No. Blows Ft.	Graphic Symbol	Depth Ft.	Sample	USCS Symbol	Description
	30.5	24		61		CL	Gray lean CLAY, stiff, moist, with sand lenses
							Boring terminated at 61.5 feet below existing grade. Groundwater seepage encountered at 21.0, 36.0 and 40.0 feet during drilling. Boring backfilled with bentonite and cuttings.

RB-8-00010308

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Boring Log
Point Wells
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Proj. No. 10903	Dwn. GLS	Date Mar. 2004	Checked RAC	Date 3/4/04	Plate A26

Boring Log

Project Name: Point Wells				Sheet 1 of 3
Job No.: 10903	Logged by: SSR	Start Date: 2/11/04	Completion Date: 2/11/04	Boring No.: B-10
Drilling Contactor: Boretec		Drilling Method: HSA		Sampling Method: SPT
Ground Surface Elevation: ±142'		Hole Completion: ☐ Monitoring Well ☒ Piezometer ☐ Abandoned, sealed with bentonite		

Surface Conditions: Heavy brush, saplings and blackberry brambles

General Notes	W (%)	No. Blows Ft.	Depth Ft.	USCS Symbol	Description
			0	SM	Brown silty fine SAND with gravel, medium dense, wet
	23.0	16	5–6.5		-gray -wet, seepage zone, 17.8% fines
	23.5	16	10–11.5	ML	Gray fine sandy SILT, medium dense, moist -sand lenses
	39.4	12	15–16.5	CL	Gray lean CLAY, stiff, moist -massive texture LL=35 PL=22 PI=13

RB-8-00010309

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Point Wells
Snohomish County, Washington

Proj. No. 10903	Dwn. GLS	Date Mar. 2004	Checked RAC	Date 3/4/04	Plate A27

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Boring Log

Project Name: Point Wells				Sheet 1 of 3
Job No.: 10903	Logged by: SSR	Start Date: 2/11/04	Completion Date: 2/11/04	Boring No.: B-10
Drilling Contactor: Boretec		Drilling Method: HSA		Sampling Method: SPT
Ground Surface Elevation: ±142'		Hole Completion: ☐ Monitoring Well ☒ Piezometer ☐ Abandoned, sealed with bentonite		

Surface Conditions: Heavy brush, saplings and blackberry brambles

General Notes	W (%)	No. Blows Ft.	Depth Ft.	USCS Symbol	Description
			0	SM	Brown silty fine SAND with gravel, medium dense, wet
	23.0	16	5		-gray -wet, seepage zone, 17.8% fines
	23.5	16	10		
			11	ML	Gray fine sandy SILT, medium dense, moist -sand lenses
	39.4	12	15	CL	Gray lean CLAY, stiff, moist -massive texture LL=35 PL=22 PI=13

RB-8-00010309

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Boring Log
Point Wells
Snohomish County, Washington

Proj. No. 10903	Dwn. GLS	Date Mar. 2004	Checked RAC	Date 3/4/04	Plate A27

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Boring Log

Project Name: Point Wells				Sheet 2 of 3
Job No.: 10903	Logged by: SSR	Start Date: 2/11/04	Completion Date: 2/11/04	Boring No.: B-10
Drilling Contactor: Boretec		Drilling Method: HSA		Sampling Method: SPT
Ground Surface Elevation: ±142'		Hole Completion: ☐ Monitoring Well ☒ Piezometer ☐ Abandoned, sealed with bentonite		

General Notes	W (%)	No. Blows Ft.	Graphic Symbol	Depth Ft.	Sample	USCS Symbol	Description
	41.1	11		21		ML	Gray fine sandy SILT, medium dense, moist
				22			
				23			
				24			
	31.5	31		25		SM	Gray silty fine SAND, dense, wet
				26			-seepage zone
				27			
				28			
				29			
	31.9	25		30			-wet
				31			
				32			
				33			
				34			
	23.8	50/6"		35			
				36			
				37			
				38			
				39			

RB-8-00010310

BORING 10903.GPJ ECI.GDT 3/4/04

Earth Consultants Inc.
Geotechnical Engineers, Geologists & Environmental Scientists

Boring Log
Point Wells
Snohomish County, Washington

Proj. No. 10903	Dwn. GLS	Date Mar. 2004	Checked RAC	Date 3/4/04	Plate A28

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Boring Log

Project Name: Point Wells				Sheet 3 of 3
Job No. 10903	Logged by: SSR	Start Date: 2/11/04	Completion Date: 2/11/04	Boring No.: B-10
Drilling Contactor: Boretec		Drilling Method: HSA		Sampling Method: SPT
Ground Surface Elevation: ±142'		Hole Completion: ☐ Monitoring Well ☒ Piezometer ☐ Abandoned, sealed with bentonite		

General Notes	W (%)	No. Blows Ft.	Graphic Symbol	Depth Ft.	Sample	USCS Symbol	
	38.1	20		41		CL	Gray lean CLAY, stiff, moist, massive, occasional sand lens
							Boring terminated at 41.5 feet below existing grade. Groundwater seepage encountered at 5.0 and 26.0 feet during drilling. 1" PVC standpipe installed to 41.5 feet. Lower 20.0 - 30.0 feet slotted. Boring backfilled with sand and bentonite. Concrete well cap.

RB-8-00010311

BORING 10903.GPJ ECI.GDT 3/4/04

Earth Consultants Inc.
Geotechnical Engineers, Geologists & Environmental Scientists

Boring Log
Point Wells
Snohomish County, Washington

Proj. No. 10903	Dwn. GLS	Date Mar. 2004	Checked RAC	Date 3/4/04	Plate A29

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Project: King County WTD / Brightwater Conveyance System **Project Location: King & Snohomish Counties, Washington** **Contract Number: E23007E**	**Log of Boring E-101** Sheet 1 of 5

Date(s) Drilled	**3/19/03 - 3/20/03**	Geotechnical Consultant	**Camp Dresser & McKee Inc.**	Logged By	**SHE/TCB**	Checked By	**VJP 02-03-04**
Drilling Method/Rig Type	**Roto-Sonic/Mud Rotary/ T3**	Drilling Contractor	**Cascade Drilling, Inc.**	Total Depth of Borehole	**140.0 feet**		
Casing Size/Type	**6"/4"**	Hammer Weight/Drop (lbs/in.)	**300# / 30"**	Ground Surface Elevation/Datum	**131.2 feet / Metro**		
Location	**NW Richmond Beach Dr and 205th St**	Coordinates	**N 287747 E 1256907**	Elevation Source	**Survey**		

Elevation, feet	Depth, feet	SAMPLES Type	Number	Blows / 6 in. (N)	Recovery, %	Graphic Log	USCS	MATERIAL DESCRIPTION	Piezometer Schematic	Lab Tests	Pocket Penetrometer (tsf)	REMARKS AND OTHER TESTS
	0						NA	10 Inches Asphaltic Concrete Pavement				
130							GW	Sandy GRAVEL (GW) and cobbles **(af)**				
	5											
125												
							SP-SM	Medium dense, olive gray, wet, slightly silty SAND (SP-SM), trace rounded gravel, poorly-graded, homogeneous **(Qpfnf)**				Logged from cuttings to 20 ft bgs
	10											
120												
	15											
115												
	20		1	10 - 17 - 19 (36)	67					M,SA		
110												
	25											

Groundwater Observation Data:

OW (FT BGS): 34.0 (Low) 26.8 (High)

Remarks: Negative Groundwater Data indicates measurements above Ground Surface
Recovery values > 100 indicate sample expansion during sampling.

CDM

Log of Boring E-101

Elevation, feet	Depth, feet	SAMPLES Type	Number	Blows / 6 in. (N)	Recovery, %	Graphic Log	USCS	MATERIAL DESCRIPTION	Piezometer Schematic	Lab Tests	Pocket Penetrometer (tsf)	REMARKS AND OTHER TESTS
	25											
105												
	30											
100												
	35											
95												
	40		2	7 - 24 - 30 (54)	78							
90												
	45											
85								Layers of brown, silty sand, occasional organics				
	50											
80												
							SM	Medium dense, olive gray, wet, very silty SAND (SM), fine sand, occasional organics **(Qpfnf)**				
	55		3	3 - 5 - 15 (20)	28					M,SA		
75												
								Scattered strata of dense sand and sandy silt up to 2 feet thick				
	60											

Project: King County WTD / Brightwater Conveyance System Project Location: King & Snohomish Counties, Washington Contract Number: E23007E	Log of Boring E-101 Sheet 3 of 5

Elevation, feet	Depth, feet	Type	Number	Blows / 6 in. (N)	Recovery, %	Graphic Log	USCS	MATERIAL DESCRIPTION	Piezometer Schematic	Lab Tests	Pocket Penetrometer (tsf)	REMARKS AND OTHER TESTS
70	60		4	10 - 22 - 30 (52)	67					M,SA DD		
65	65		5	25 - 18 - 24 (42)	89		ML	Hard, olive gray, moist, SILT (ML), nonplastic to low plasticity, rapid dilatancy, occasional organics as partings **(Qpfnl)**				Sample has organic odor
							SM	Very dense, olive gray, wet, silty SAND (SM), fine sand, scattered organics **(Qpfnf)**				
60	70		6	12 - 19 - 36 (55)	89					M,SA		Slight organic odor
							ML	Hard, olive gray, moist to wet, SILT (ML), trace clay, low plasticity, slow dilatancy, laminated to stratified, scattered organics **(Qpfnl)**				
55	75		7	9 - 15 - 20 (35)	100					MP		
							GW	Very dense, gray green, wet, very sandy GRAVEL (GW), well-graded fine to coarse gravel, subangular to rounded **(Qpfnf)**				
50	80		8	17 - 50 50	50					M,SA		
												Rough drilling; based on drilling behavior, cobble zone from 84 to 93 ft bgs
45	85		9	4 - 21 - 50/4" (100+)	50			Scattered cobbles				
40	90		10	5 - 38 - 50/5" (100+)	36							
	95							Transitions trace fine sand, trace silt, rounded				

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Elevation, feet	Depth, feet	Samples: Type	Samples: Number	Samples: Blows / 6 in. (N)	Samples: Recovery, %	USCS	MATERIAL DESCRIPTION	Lab Tests	Pocket Penetrometer (tsf)	REMARKS AND OTHER TESTS
	95		11	11 - 50/6" (100+)	50		gravel			
-35										
	100									
-30							Scattered cobbles and occasional thin sand layers			Cobble zone from 102 to 105 feet bgs
	105					SP-SM	Dense, gray green, moist, very gravelly SAND (SP-SM), trace silt, poorly-graded fine to coarse gravel, angular to subangular **(Qpfnf)**			
-25							Transitions very sandy grvel	M,SA		Switch to Roto-Sonic drilling at 107 ft bgs due to loss of circulation in mud rotary
	110					SW	Dense, gray green, moist, very gravelly SAND (SW), well-graded fine to coarse sand **(Qpfnf)**			
-20			12		80					
	115									
-15							Transitions slightly gravelly sand			
	120						Transitions fine gravelly sand, trace coarse gravel			
-10			13		50					
							Transitions very gravelly sand Transitions very fine to coarse sandy, fine gravel	BG		
	125									Drilling action indicates heave below 125 ft bgs, possibly due to tidal influences
-5							Layer fine to medium sand			
	130									

Project: King County WTD / Brightwater Conveyance System **Project Location: King & Snohomish Counties, Washington** **Contract Number: E23007E**	**Log of Boring E-101** Sheet 5 of 5

Elevation, feet	Depth, feet	Type	Number	Blows / 6 in. (N)	Recovery, %	USCS	MATERIAL DESCRIPTION	Lab Tests	Pocket Penetrometer (tsf)	REMARKS AND OTHER TESTS
	130		14		75					
0							Interbed of coarse gravel			
						SW-SM	Dense, gray green, moist, sightly gravelly SAND (SW-SM), trace silt, trace coarse sand, well-graded fine to medium sand **(Qpfnf)**			
	135						Transitions gravelly to very gravelly			
-5							Transitions trace gravel, occasional fine organics			
			15		98					
								M,SA		
	140						Terminated boring at 140 feet below ground surface			
-10										
	145									
-15										
	150									
-20										
	155									
-25										
	160									
-30										
	165									

CDM

Project: King County WTD / Brightwater Conveyance System
Project Location: King & Snohomish Counties, Washington
Contract Number: E23007E

Log of Boring E-102

Date(s) Drilled	3/3/03 - 3/6/03	Geotechnical Consultant	Camp Dresser & McKee Inc.	Logged By	SHE
Checked By	VJP 02-03-04				
Drilling Method/Rig Type	Mud Roatry/ Porta-drill	Drilling Contractor	Gregory Drilling, Inc.	Total Depth of Borehole	270.0 feet
Casing Size/Type	PQ (7"O.D.)	Hammer Weight/Drop (lbs/in.)	300# / 30"	Ground Surface Elevation/Datum	291.2 feet / Metro
Location	NE 205th St/50' W of 26th Ave W	Coordinates	N 287608 E 1258098	Elevation Source	Survey

Elevation, feet	Depth, feet	SAMPLES: Type	Number	Blows / 6 in. (N)	Recovery, %	Graphic Log	USCS	MATERIAL DESCRIPTION	Piezometer Schematic	Lab Tests	Pocket Penetrometer (tsf)	REMARKS AND OTHER TESTS
	0						NA	Crushed rock				
290							SM	Medium dense, brown, wet, silty SAND (SM), trace fine to coarse rounded gravel, fine to medium sand, homogeneous with gravel scattered at random **(Qvt)**				Soil description inferred from drill action and cuttings
							SP-SM	Medium dense, brown, saturated slightly silty SAND (SP-SM), poorly-graded trace gravel **(Qva)**				Flowing and caving sand
285	5											
280	10							Transitions to gravelly sand, fine to coarse grained, subrounded to rounded				
							GW	Dense, brown, wet GRAVEL (GW), trace clay (most matrix washed out), trace sand, well-graded medium plasticity, clay gravel fine to coarse, rounded to subangular, varied lithology-mostly volcanics and quartz **(Qva)**				Gravelly drilling last 5 to 7 feet
275	15											
270	20		1	1 - 7 - 23 (30)	67							
	25											

Groundwater Observation Data:

OW (FT BGS):	135.8 (Low)	134.6 (High)
VWP 1 (FT BGS):	189.5 (Low)	185.2 (High)

Remarks: Negative Groundwater Data indicates measurements above Ground Surface
Recovery values > 100 indicate sample expansion during sampling.

CDM

Log of Boring E-102

Elevation, feet	Depth, feet	Type	Number	Blows / 6 in. (N)	Recovery, %	Graphic Log	USCS	MATERIAL DESCRIPTION	Piezometer Schematic	Lab Tests	Pocket Penetrometer (tsf)	REMARKS AND OTHER TESTS
265	25											
							SP	Dense dark gray, wet, SAND (SP), fine beds laminated (<1 mm), coarser thin beds (1-3 mm), laminated beds folded-interbeds 3-5 cm **(Qva)**				Inferred from drill action and cuttings
260	30											
												Quiet, rapid drilling
255	35						SM	Silty SAND (SM), fine sand **(Qva)**				
												Washing hole for extended period-abundant silty fine sand
							ML	Very stiff to hard, dark gray, wet, SILT (ML), low plasticity, rapid dilatancy, laminated beds (1-3 mm), folded-interbeds 1 to 2 inch thick **(Qvlc)**				
250	40		2	8 - 13 - 25 (38)	72					MP		
245	45											
240	50											
							CL	Hard, olive gray, dry to moist, silty CLAY (CL), medium plasticity, laminated (<1 mm) to layered (10 mm), interbedded strata of silt to 2 feet thick **(Qvlc)**				Driller reports clayey bed from 52 to 57 feet
235	55											
	60											

CDM

Elevation, feet	Depth, feet	SAMPLES Type	Number	Blows / 6 in. (N)	Recovery, %	Graphic Log	USCS	MATERIAL DESCRIPTION	Piezometer Schematic	Lab Tests	Pocket Penetrometer (tsf)	REMARKS AND OTHER TESTS
	60		3	11 - 13 - 19 (32)	78			Slickensides, sand folds				
230												
	65											
225							SP	Dense, dark gray, wet SAND (SP), trace silt, poorly-graded indistinctly bedded to massive **(Qpfnf)**				Even, rapid to medium drilling, driller reports silty
	70											
220												
	75											
215												
	80		4	13 - 18 - 19 (37)	78					BG		Soil resistance to drilling is consistent
210												
	85											
205												
	90											
200												
	95											

Elevation, feet	Depth, feet	SAMPLES Type	Number	Blows / 6 in. (N)	Recovery, %	Graphic Log	USCS	MATERIAL DESCRIPTION	Piezometer Schematic	Lab Tests	Pocket Penetrometer (tsf)	REMARKS AND OTHER TESTS
	95											
195												
								Transitions to gray purple				
	100		5	13 - 13 - 14 (27)			CL	Very stiff, olive gray and gray purple, dry to moist, silty CLAY (CL), medium plasticity, no dilatancy, laminated and layered, with silt and silty sand **(Qpfnl)**		MP		
190												
	105											
185												
	110											
180												
	115						SP	Very dense, olive gray, moist SAND (SP), trace silt, poorly-graded fine sand, homogeneous, subangular to subround **(Qpfnf)**				30% quartz, 70% green and dark gray volcanics
175												
	120		6	21 - 33 - 44 (77)	100					BG		
170												
	125											
165												
	130											

Elevation, feet	Depth, feet	SAMPLES Type	Number	Blows / 6 in. (N)	Recovery, %	Graphic Log	USCS	MATERIAL DESCRIPTION	Piezometer Schematic	Lab Tests	Pocket Penetrometer (tsf)	REMARKS AND OTHER TESTS
	130											
160												
												Smooth, quiet, firm drilling, driller reports sandy
	135											
155												
							SM	Very dense, olive gray, dry to moist, SILTY SAND (SM) **(Qpfnf)**				
	140		7	17 - 26 - 34 (60)	100					BG		Quartz to 60 to 70%
150												
	145											
145												
												Consistant soil resistance to drilling
	150											
140												
												No sample taken, drilling action suggests sand
	155											
135												
							ML	Hard, olive gray, moist, sandy SILT (ML), fine sand **(Qpfnf)**				
	160		8	21 - 32 - 40 (72)	100					M,SA DD		Consistent soil resistance to drilling
130												
	165											

Project: King County WTD / Brightwater Conveyance System
Project Location: King & Snohomish Counties, Washington
Contract Number: E23007E

Log of Boring E-102

Elevation, feet	Depth, feet	Samples: Type	Samples: Number	Samples: Blows / 6 in. (N)	Samples: Recovery, %	Graphic Log	USCS	MATERIAL DESCRIPTION	Piezometer Schematic	Lab Tests	Pocket Penetrometer (tsf)	REMARKS AND OTHER TESTS
	165											
125												
	170		9	11 - 20 - 39 (59)	89		ML	Hard, gray olive, dry to moist, slightly clayey SILT (ML), medium plasticity, no dilatancy, homogeneous, with possible occasional parting along bedding, occasional small organics especially at top - one reed blade **(Qpfnl)**		AD,MP		170 ft bgs, conventional radiocarbon date 19,310 +/- 100 years B.P.
120												
							SW-SM	Very dense, olive gray to gray purple, moist, slightly silty SAND (SW-SM), well-graded fine to medium sand, with occasional clear laminate, grains dark gray volcanics and quartz, silt interbeds as partings to layers from 183 to 187 feet bgs, silt with greenish tint **(Qpfnf)**				
	175		10	30 - 41 - 50/5" (100+)	100					M,SA DD		
115												
	180		11	50/6"	83			Gray purple, clean, subrounded		M,SA		Irregular drilling resistance due to gravel
110												
								Occasional organics				
	185		12	25 - 36 - 34 (70)	100							
105												
							SP-SM	Very dense, gray purple, moist slightly silty SAND (SP-SM), poorly-graded fine to coarse, homogeneous, subangular to subrounded **(Qpfnf)**				Quartz 60%, volcanics 40%
	190		13	30 - 40 - 50 (90)	89					M,SA DD		Consistant soil resistance to drilling
100												
								Trace fine gravel				
	195		14	50/6"	100					M,DD BG		
95												
							SP	Very dense, olive gray, moist SAND (SP), trace silt, fine to medium, indistinctly laminated, trace fine rounded gravel in layers **(Qpfnf)**				
	200											

Project: King County WTD / Brightwater Conveyance System Project Location: King & Snohomish Counties, Washington Contract Number: E23007E	**Log of Boring E-102** Sheet 7 of 8

Elevation, feet	Depth, feet	SAMPLES Type	Number	Blows / 6 in. (N)	Recovery, %	Graphic Log	USCS	MATERIAL DESCRIPTION	Piezometer Schematic	Lab Tests	Pocket Penetrometer (tsf)	REMARKS AND OTHER TESTS
	200		15	50/6"	100							
90												
	205		16	29 - 23 - 34 (57)	100							
85								6-Inch layer of gray olive, moist silt at 206 feet bgs, contact sharp, with fibrous organics along contact				
							SW	Very dense, olive gray to gray purple, wet, gravelly SAND (SW), well-graded fine to coarse grained, subangular to subrounded, gravel fine, rounded, tabular, well graded **(Qpfnf)**				
	210		17	50/5" (100+)	67							
80												
							GW	Very dense, olive gray, wet, sandy GRAVEL (GW), well-graded fine to coarse gravel , subrounded **(Qpfnf)**				Gravel predominantly fine grained volcanics
	215		18	50/3" (100+)	67							
75												
												Irregular drilling resistance due to gravel
	220		19	30/0"								No penetration - 30-plus blows, stopped drive to save sampler
70												
							SP-SM	Very dense, gray green, moist, slightly silty SAND (SP-SM), poorly-graded fine to medium sand, trace gravels, parting along indistinct bedding planes **(Qpfnf)**				70% white to green subangular to subround quartz, 30% dark gray subrounded volcanics.
	225		20	50/6"	100					M,SA		
65												
							CL	Hard, olive gray, moist, silty CLAY (CL), medium plasticity, slow dilatancy, scattered fibrous organics **(Qpfnl)**				Inferred from drill action and cuttings
	230		21	20 - 38 - 50/4" (100+)	81		ML	Hard, gray green, moist, sandy SILT (ML), nonplastic, rapid dilatancy, laminated at contact, scattered organics **(Qpfnl)**				
60												
	235											

Elevation, feet	Depth, feet	Samples: Type	Samples: Number	Samples: Blows / 6 in. (N)	Samples: Recovery, %	Samples: Graphic Log	USCS	MATERIAL DESCRIPTION	Piezometer Schematic	Lab Tests	Pocket Penetrometer (tsf)	REMARKS AND OTHER TESTS
	235		22	50/6"	100					M,SA MP		
55												
	240		23	20 - 21 - 31 (52)	89							
50								Scattered fibrous organics in fine beds, abundant peaty organics in tip, trace clay				
	245		24	15 - 27 - 30 (57)	89			Red brown		MP,BG		
45												
	250		25	50/3" (100+)	100							Gravel causing sampler bounce At 250 ft bgs; Sharp oil layer contact, sandy silty, over gravel in smpler shoe
40							GW	Very dense, gray green, wet GRAVEL (GW), trace silt/sand matrix, well-graded clast supported fine to coarse gravel, rounded to subrounded, clay coating on clasts **(Qpfnf)**				Drilling resistance due to gravel
	255		26		0							6 inches of slough in ring
35												
	260		27	50/1" (100+)	104							Boirng sloughed approximately 9 inches
30												
	265											Continued drilling resistance to gravel
25												
	270							Boring terminated at 270 feet below ground surface				Hole stopped at 270 feet due to gravel slough and mud loss

Date(s) Drilled	4/17/03 - 4/22/03	Geotechnical Consultant	Camp Dresser & McKee Inc.	Logged By	JAP
Checked By	VJP 02-03-04				
Drilling Method/Rig Type	Roto-Sonic/	Drilling Contractor	Cascade/Boart-Longyear	Total Depth of Borehole	242.0 feet
Casing Size/Type	9"/6"/4"/Telescoping	Hammer Weight/Drop (lbs/in.)	N/A	Ground Surface Elevation/Datum	260.6 feet / Metro
Location	20425 25th Ave NW	Coordinates	N 287564 E 1257757	Elevation Source	Survey

Elevation, feet	Depth, feet	Samples: Type	Samples: Number	Blows / 6 in. (N)	Recovery, %	Graphic Log	USCS	MATERIAL DESCRIPTION	Piezometer Schematic	Lab Tests	Pocket Penetrometer (tsf)	REMARKS AND OTHER TESTS
260	0											0 to 6 ft bgs excavated with vacuum truck, not sampled
255	5						GM	Loose, brown, wet, silty, slightly sand GRAVEL (GM) poorly-graded **(af)**				
250	10		1		52		SP	Medium dense, olive gray, wet SAND (SP), trace gravel, trace silt, poorly-graded fine to medium sand **(Qva)**				
245	15							4-Inch thick silty sand layer				
240	20		2		95		ML	Very stiff, gray, moist SILT (ML), trace sand, trace organics, frequent partings, sandy seams **(Qvlc)**		M		
	25											

Groundwater Observation Data:

OW (FT BGS): 159.1 (Low) 155.9 (High)

Remarks: Negative Groundwater Data indicates measurements above Ground Surface
Recovery values > 100 indicate sample expansion during sampling.

Project: King County WTD / Brightwater Conveyance System Project Location: King & Snohomish Counties, Washington Contract Number: E23007E	**Log of Boring E-201** Sheet 2 of 8

Elevation, feet	Depth, feet	Type	Number	Blows / 6 in. (N)	Recovery, %	Graphic Log	USCS	MATERIAL DESCRIPTION	Piezometer Schematic	Lab Tests	Pocket Penetrometer (tsf)	REMARKS AND OTHER TESTS
235	25							Sand-filled vertical fractures 26 to 27.5 ft bgs, trace brown organics in sand seams		M		
230	30		3		105		ML	Hard, gray, moist SILT (ML), trace sand, horizontal laminations **(Qpfnl)**				
225	35							Grades very stiff, slickensides		M		
			4		73					M		
220	40							Grades hard				
215	45		5		99					M		
								Grades to clayey				
210	50						CL	Hard, gray, moist CLAY (CL), silt layers up to 3 inches thick, slickensides **(Qpfnl)**				
			6		105					M		
205	55						ML	Soft to very stiff, gray, wet, very sandy SILT (ML), trace clay, occasional organics, layered silty, fine sand layers **(Qpfnl)**				Sample disturbed
	60											

Elevation, feet	Depth, feet	Type	Number	Blows / 6 in. (N)	Recovery, %	Graphic Log	USCS	MATERIAL DESCRIPTION	Piezometer Schematic	Lab Tests	Pocket Penetrometer (tsf)	REMARKS AND OTHER TESTS
200	60											
195	65		7		102			Interbedded silt and clay 66 to 68 ft bgs with slickensides at boundaries				
								3-inch layer silty clay				
190	70							Grades hard, moist, slightly clayey				
								7-inch thick layer fine sand				
185	75									M		
							SM	Dense, gray, wet, silty SAND (SM), trace clay, fine sand **(Qpfnf)**				
			8		98		CL	Hard, gray, moist, silty CLAY (CL), trace sand, slickensides **(Qpfnl)**				
180	80							Frequent slickensides 80 to 90 ft bgs				
175	85		9		92							
170	90						ML	Very stiff, olive gray, wet, very sandy SILT (ML), rapid dilatancy, scattered organics **(Qpfnl)**				
			10		42					M		
	95											

Project: King County WTD / Brightwater Conveyance System	**Log of Boring E-201**
Project Location: King & Snohomish Counties, Washington	Sheet 4 of 8
Contract Number: E23007E	

Elevation, feet	Depth, feet	Samples: Number	Samples: Blows / 6 in. (N)	Samples: Recovery, %	USCS	MATERIAL DESCRIPTION	Lab Tests	Pocket Penetrometer (tsf)	REMARKS AND OTHER TESTS
165	95				CL	Hard, gray, moist, silty CLAY (CL), trace sand, slickensides **(Qpfnl)**	M		
160	100	11		88	SM	Dense, gray, wet, silty SAND (SM), trace clay, scattered organics **(Qpfnf)**			
					CL	Hard, gray, moist, slightly silty CLAY (CL), slickensides **(Qpfnl)**			
155	105						M		
						Grades silty clay			
150	110	12		110	SP-SM	Dense, gray, wet, slightly silty SAND (SP-SM), trace clay, poorly-graded fine to medium sand, micaceous **(Qpfnf)**			
145	115					1-foot layer of silty clay			
						Organic odor, trace organics			
					CL	Hard, gray, moist, silty CLAY (CL) **(Qpfnl)**	M		
140	120	13		112					
					SP	Dense, gray, moist SAND (SP), trace silt, poorly-graded fine to medium sand **(Qpfnf)**			
135	125					Trace fine gravel, subangular to subrounded			
						Trace clay, clay has black organic streaks, organic smell			
	130								

CDM

Elevation, feet	Depth, feet	Type	Number	Blows / 6 in. (N)	Recovery, %	Graphic Log	USCS	MATERIAL DESCRIPTION	Piezometer Schematic	Lab Tests	Pocket Penetrometer (tsf)	REMARKS AND OTHER TESTS
130	130		14		89							
125	135							136 to 146 ft bgs, sand cleaner, trace silt, fine to coarse gravel content increasing, gravel subrounded				
120	140		15		89					M,SA		
115	145							Grades gravelly sand 147 to 152 ft bgs, gravel subangular to subrounded, granitic matrix		M,SA		
110	150		16		96			Grades to trace gravel, 152 to 156 ft bgs				
105	155						SW-SM	Dense, gray, moist, gravelly, slightly silty to silty SAMD (SW-SM), well-graded fine to coarse sand **(Qpfnf)**		M,SA		
100	160		17		80							
	165											

Elevation, feet	Depth, feet	Samples: Type	Samples: Number	Samples: Blows / 6 in. (N)	Samples: Recovery, %	Samples: Graphic Log	USCS	MATERIAL DESCRIPTION	Piezometer Schematic	Lab Tests	Pocket Penetrometer (tsf)	REMARKS AND OTHER TESTS
	165											
95										M,SA		
								Grades to gravelly, wet				
	170											
90			18		34							
								Layers of brown, sandy silt up to 4 inches thick 173 to 176 ft bgs				
	175											
85							GP	Dense, gray, wet, very sandy GRAVEL (GP), trace silt, poorly-graded, fine to coarse gravel, fine to coarse sand **(Qpfnf)**				
							SP	Dense, gray, wet, slightly gravelly SAND (SP), trace silt, poorly-graded fine to medium sand **(Qpfnf)**				
	180											
80								Grades to slightly silty				
	185											
75			19		71			4-inch peat layer				
	190							Sand grades finer, siltier				
70												
							SM	Dense, gray, wet, silty SAND (SM), trace fine gravel, frequent organics **(Qpfnf)**		M		
							PT	Hard, dark brown, moist PEAT (PT), layers of hard, gray olive, moist, clayey SILT (ML) **(Qpfnw)**				
	195									M,OC		
65							ML	Very stiff, gray olive, wet, sandy, slightly clayey SILT (ML), nonplastic, fine sand, homogeneous, scattered organics **(Qpfnl)**				
										M		
	200											

Project: King County WTD / Brightwater Conveyance System
Project Location: King & Snohomish Counties, Washington
Contract Number: E23007E

Log of Boring E-201

Elevation, feet	Depth, feet	Samples: Type	Samples: Number	Samples: Blows / 6 in. (N)	Samples: Recovery, %	Samples: Graphic Log	USCS	MATERIAL DESCRIPTION	Piezometer Schematic	Lab Tests	Pocket Penetrometer (tsf)	REMARKS AND OTHER TESTS
-60	200		20		104		PT	Hard, brown, moist PEAT (PT) **(Qpfnw)**		M		
							ML	Stiff, brown, moist, slightly sandy SILT (ML), fine sand, homogeneous **(Qpfnl)**				
-55	205						SM	Dense, gray, moist, silty SAND (SM), fine to medium sand, faint laminations of sand **(Qpfnf)**				
							PT	Hard, brown, moist PEAT (PT) **(Qpfnw)**				
			21		122		ML	Stiff, gray, moist, slightly sandy SILT (ML), scattered black and brown organics **(Qpfnl)**		M		
-50	210							Grades to very sandy				
								Grades to wet				
-45	215							1-foot hard, brown peat layer		M		
			22		83							
-40	220						SP-SM	Dense, gray, moist, gravelly, slightly silty SAND (SP-SM), poorly-graded, fine to coarse sand, fine to coarse gravel **(Qpfnf)**				
							GP-GM	Dense, gray, wet, slightly silty, very sandy GRAVEL (GP-GM), subangular to subrounded gravel, fine to coarse sand, poorly-graded, clay coating gravel **(Qpfnf)**				
-35	225							Grades to sandy, coarser gravel				
-30	230		23		90					M,SA		
								Grades to trace silt				
	235											

CDM

Project: King County WTD / Brightwater Conveyance System Project Location: King & Snohomish Counties, Washington Contract Number: E23007E	**Log of Boring E-201** Sheet 8 of 8

Elevation, feet	Depth, feet	SAMPLES Type	Number	Blows / 6 in. (N)	Recovery, %	Graphic Log	USCS	MATERIAL DESCRIPTION	Piezometer Schematic	Lab Tests	Pocket Penetrometer (tsf)	REMARKS AND OTHER TESTS
-25	235							Clayey organics on gravel				
			24		90							
-20	240											
								Terminated boring at 242 feet below ground surface				
-15	245											
-10	250											
-5	255											
-0	260											
--5	265											
	270											

Project: King County WTD / Brightwater Conveyance System **Project Location: King & Snohomish Counties, Washington** **Contract Number: E23007E**	# Log of Boring E-401 Sheet 1 of 4

Date(s) Drilled	**10/16/03 - 10/17/03**	Geotechnical Consultant	**Camp Dresser & McKee Inc.**	Logged By **TCB**	Checked By **RWS 2/2/04**
Drilling Method/Rig Type	**Wireline Core/ Portadrill**	Drilling Contractor	**Gregory Drilling, Inc.**	Total Depth of Borehole	**121.0 feet**
Casing Size/Type	**PQ (7" OD)**	Hammer Weight/Drop (lbs/in.)	**N/A**	Ground Surface Elevation/Datum	**211.8 feet / Metro**
Location	**2621 NW 205th**	Coordinates	**N 287641 E 1257412**	Elevation Source	**Survey**

Elevation, feet	Depth, feet	SAMPLES Type	Number	Blows / 6 in. (N)	Recovery, %	Graphic Log	USCS	MATERIAL DESCRIPTION	Piezometer Schematic	Lab Tests	Pocket Penetrometer (tsf)	REMARKS AND OTHER TESTS
	0											0 to 6 feet excavated with vacuum truck, not sampled
210												
	5											
205							ML	Very stiff to hard, gray, moist, slightly clayey to clayey SILT (ML), low plasticity, frequent horizontal lamination **(Qpfnl)**			2.5 4.5	
			1		18			Grades silty, occasional organics, mica				
	10											
200								Frequent partings of light gray, silt				
			2		62							
	15											
195								2-inch layer of brown silt with red brown partings and seams Clayey SILT, gray, slow dilatancy				
			3		50							
	20							6-inch layer of silt, low plasticity, rapid dilatancy				6-inch layer of blocky fractures
190												
								Decreasing clay, no plasticity, trace fine sand, rapid dilatancy				
	25											

Groundwater Observation Data:

VWP 1 (FT BGS): 56.3 (Low) 49.2 (High)

Remarks: Negative Groundwater Data indicates measurements above Ground Surface
Recovery values > 100 indicate sample expansion during sampling.
Pocket Penetrometer shown as 4.6 indicates unconfined compressive strength > 4.5 tsf (penetrometer upper limit).

Project: King County WTD / Brightwater Conveyance System
Project Location: King & Snohomish Counties, Washington
Contract Number: E23007E

Log of Boring E-401

Elevation, feet	Depth, feet	SAMPLES: Type	SAMPLES: Number	SAMPLES: Blows / 6 in. (N)	SAMPLES: Recovery, %	SAMPLES: Graphic Log	USCS	MATERIAL DESCRIPTION	Piezometer Schematic	Lab Tests	Pocket Penetrometer (tsf)	REMARKS AND OTHER TESTS
	25											
			4		30							
185												
								Pockets of dark gray SILT				45 to 60 degree inclined bedding, jumbled texture
	30											
								Interbedded layers of clayey SILT and slightly sandy SILT, fine sand				
180												
												3-inch layer of highly fractured, gray clay
			5		67							
	35											
175												
								Pockets of silty, fine sand				
	40											
												4-inch layer highly fractured blocky texture and slickensides
170												
			6		67							
	45											
								Bedding inclined 30 degrees				
							CL	Hard, olive gray, moist, slightly silty to silty CLAY (CL-CH), medium to high plasticity, frequent silty SAND, fine sand layers, with mica **(Qpfnl)**				Frequent fractures and slickensides inclined 30 to 45 degrees
165												
			7		67							
	50											
160												
								Grades back and forth between clayey silt and clay				
	55											
											4	
155												
			8		67							
	60											

Project: King County WTD / Brightwater Conveyance System Project Location: King & Snohomish Counties, Washington Contract Number: E23007E	Log of Boring E-401 Sheet 3 of 4

Elevation, feet	Depth, feet	SAMPLES: Type	SAMPLES: Number	SAMPLES: Blows / 6 in. (N)	SAMPLES: Recovery, %	SAMPLES: Graphic Log	USCS	MATERIAL DESCRIPTION	Piezometer Schematic	Lab Tests	Pocket Penetrometer (tsf)	REMARKS AND OTHER TESTS
	60											
								Sandy SILT layer, rapid dilatancy				
150												
							SP-SM	Very dense, olive gray, moist, silty SAND (SM) grading to slightly silty SAND (SP-SM), fine to medium sand, poorly-graded, occasional organics, mica, homogeneous, with occasional interbedded layers of silty CLAY and clayey SILT **(Qpfnf)**				
	65		9		67							
145												
								Clay seam with blocky fractures and slickensides				Flows at 1 to 2 gpm
	70									M,SA		
140												
			10		67							
								Scattered pockets of laminated silty clay				
	75											Angular clasts of clay within sand matrix
135												
			11		66							
	80											
								Hard, gray olive to gray green, moist				Irregular bedding, dipping 30 to 45 degrees, sand-filled fractures, blocky fracture,
130								3-foot stratum of slightly clayey SILT, occasional organics				
											3.75	
	85		12		67							
125												
								Very heterogeneous silt rip-ups in clean sand and wavy irregular interbedded clay, silt, and sand seams				Very heterogeneous silt rip-ups in clean sand and wavy irregular interbedded clay, silt, and sand seams
	90									M,SA		
120												
			13		29			Irregular texture throughout, no structure				Irregular texture throughout, no structure
	95											

Project: King County WTD / Brightwater Conveyance System Project Location: King & Snohomish Counties, Washington Contract Number: E23007E	**Log of Boring E-401** Sheet 4 of 4

Elevation, feet	Depth, feet	SAMPLES Type	Number	Blows / 6 in. (N)	Recovery, %	Graphic Log	USCS	MATERIAL DESCRIPTION	Piezometer Schematic	Lab Tests	Pocket Penetrometer (tsf)	REMARKS AND OTHER TESTS
	95											
115												
	100		14		0							
110							SP	Very dense, gray, moist SAND (SP), fine to medium sand, trace coarse sand, trace silt, poorly-graded, scattered fine gravelly layer **(Qpfnf)**				102 to 114 ft bgs, sand has quartz and feldspar content estimated at 75%
	105											
105												Driller report: soils are medium dense, fine to coarse sand, with scattered fine gravel layers
	110		15		0							
100												
								Fine to medium sand, no gravel				
	115		16		60					M,SA		
95							ML	Hard, gray green, moist SILT (ML), nonplastic, interbedded with frequent brown organic silt seams, 1-inch red brown, moist organic SILT and fibrous PEAT (OL) layer at top of contact **(Qpfnl)**				SILT rip-ups
			17		38		SM	Very dense, gray, moist, silty SAND (SM), fine to medium sand **(Qpfnf)**			4.6	
	120											
90								Terminated boring at 121 feet below ground surface				
	125											
85												
	130											

CDM

Project: King County WTD / Brightwater Conveyance System Project Location: King & Snohomish Counties, Washington Contract Number: E23007E	# Log of Boring E-402 Sheet 1 of 7

Date(s) Drilled	9/30/03 - 10/7/03	Geotechnical Consultant	Camp Dresser & McKee Inc.	Logged By	MJB	Checked By	RWS 2/02/04
Drilling Method/Rig Type	Wireline/ CME 45C	Drilling Contractor	Gregory Drilling, Inc.	Total Depth of Borehole	206.5 feet		
Casing Size/Type	PQ (7"O.D.)	Hammer Weight/Drop (lbs/in.)	Canterra	Ground Surface Elevation/Datum	304.4 feet / Metro		
Location	2162 NW 204th St	Coordinates	N 287489 E 1258407	Elevation Source	Survey		

Elevation, feet	Depth, feet	Samples: Type	Samples: Number	Samples: Blows / 6 in. (N)	Samples: Recovery, %	Graphic Log	USCS	MATERIAL DESCRIPTION	Piezometer Schematic	Lab Tests	Pocket Penetrometer (tsf)	REMARKS AND OTHER TESTS
	0							Vegetation (sod), topsoil				
300	5											
							SP-SM	Medium dense to dense, gray, moist to wet, slightly silty, gravelly SAND (SP-SM), poorly-graded fine to coarse sand, fine to coarse subrounded to subangular gravel **(Qva)**				
295			1		0							
	10											Sand with scattered gravels inferred from drill action and cuttings
			2		17							
290							ML	Very stiff, dark gray, moist, slightly gravelly, slightly sandy to sandy SILT (ML), fine to medium sand, trace coarse sand, fine to coarse subrounded to subangular gravel, homogeneous **(Qvlc)** Grades wet, slightly sandy, clayey silt, scattered layers of fine sandy silt				
	15		3		0							
			4		40							
285	20										3.2	
			5		50							
280	25		6		100						4.5	

Groundwater Observation Data:

VWP 1 (FT BGS): 149.2 (Low) 147.7 (High)

Remarks: Negative Groundwater Data indicates measurements above Ground Surface

Recovery values > 100 indicate sample expansion during sampling.

Project: King County WTD / Brightwater Conveyance System
Project Location: King & Snohomish Counties, Washington
Contract Number: E23007E

Log of Boring E-402

Elevation, feet	Depth, feet	Sample Number	Blows / 6 in. (N)	Recovery, %	USCS	MATERIAL DESCRIPTION	Pocket Penetrometer (tsf)	REMARKS AND OTHER TESTS
	25							
		7		30				Sand inferred from drill action and cuttings
275						Rapid dilatancy		
	30							
		8		36				Sand inferred from drill action and cuttings
270	35							
		9		70	ML	Hard, dark gray, moist to wet, slightly sandy, clayey SILT (ML), fine to medium sand, laminations of gray silt **(Qpfnl)**		
265							4	
	40				SM	Medium dense, dark gray, wet, very silty SAND (SM), rapid dilatancy, scattered organics **(Qpfnf)**		
		10		40				
260	45							
		11		54				blocky structure
255	50							
		12		0				
250	55							
					ML	Hard, dark gray, moist, clayey SILT (ML), trace fine sand, medium plasticity, slow dilatancy **(Qpfnl)**		
		13		100			4.5	
245	60							

Project: King County WTD / Brightwater Conveyance System	Log of Boring E-402
Project Location: King & Snohomish Counties, Washington	
Contract Number: E23007E	

Elevation, feet	Depth, feet	SAMPLES: Type	SAMPLES: Number	SAMPLES: Blows / 6 in. (N)	SAMPLES: Recovery, %	USCS	MATERIAL DESCRIPTION	Lab Tests	Pocket Penetrometer (tsf)	REMARKS AND OTHER TESTS
	60						Scattered silty clay seams, silty sand layers with scattered organics			
240			14		64		Grades wet, low plasticity,			Blocky structure, bedding 0 to 5 degrees, high angle slickensides 60 degrees
	65									
235			15		100					
	70									Blocky structure
230			16		50					
	75									Paleosol
									3	Blocky structure, bedding 0 to 5 degrees, slickensides - high angle 45 degrees, slow HCl reaction
225			17		60	SP-SM	Dense, dark gray, wet, slightly silty to silty SAND (SP-SM), poorly-graded fine to medium sand, frequent layers of medium plasticity clayey silt, scattered partings of organics **(Qpfnf)**			
	80									
220			18		56					
	85								2	
215			19		64					
	90					SP	Dense, dark gray, wet SAND (SP) trace silt, poorly graded fine to medium sand, numerous organics **(Qpfnf)**			
210			20		60					
	95									

Elevation, feet	Depth, feet	Type	Number	Blows / 6 in. (N)	Recovery, %	Graphic Log	USCS	MATERIAL DESCRIPTION	Piezometer Schematic	Lab Tests	Pocket Penetrometer (tsf)	REMARKS AND OTHER TESTS
	95											Slight groundwater flowing conditions (1 to 2 gpm) through drill pipe
							ML	Hard, dark gray, wet, clayey SILT (ML), low plasticity, frequent seams of silty clay and sandy silt **(Qpfnl)**				Bedding 0 degrees, blocky structure and slickensides
205	100		21		60						3.5	PP for clay layers
							SP	Dense, dark gray, wet SAND (SP), trace silt, poorly-graded fine sand **(Qpfnf)**				Groundwater flowing approximately 2 gpm
200	105		22		50		CH	Hard, dark gray, moist CLAY (CH), trace fine subrounded to subangular gravel, high plasticity, high dry strength **(Qpfnl)**			3.2	
							ML	Hard, dark gray, wet, sandy SILT (ML), low plasticity, well-graded fine sand, scattered organics **(Qpfnl)**				
195	110		23		30							
							SM	Dense, dark gray, wet, silty SAND (SM), fine sand, scattered organics **(Qpfnf)**				
190	115		24		52							
185	120						CH	Very stiff, green gray to dark gray, moist CLAY (CH), medium to high plasticity, laminated **(Qpfnl)**				Blocky structue, numerous slickensides high angle 40 degrees, Paleosol?
							SM	Dense, green gray to dark gray, wet, very silty SAND (SM), trace fine gravel, fine sand, rapid dilatancy, seams of silty clay and layers of clayeysilt **(Qpfnf)**				
180	125		25		60							
175	130		26		2							

Project: King County WTD / Brightwater Conveyance System Project Location: King & Snohomish Counties, Washington Contract Number: E23007E	**Log of Boring E-402** Sheet 5 of 7

Elevation, feet	Depth, feet	SAMPLES: Type	SAMPLES: Number	SAMPLES: Blows / 6 in. (N)	SAMPLES: Recovery, %	SAMPLES: Graphic Log	USCS	MATERIAL DESCRIPTION	Piezometer Schematic	Lab Tests	Pocket Penetrometer (tsf)	REMARKS AND OTHER TESTS
	130											
								12-inch silty clay layer, medium plasticity			4.5	PP for clay layer
170			27		60							
	135							Grades coarser sand				Very blocky structure, stiff, 6-inch slickensided layer
							SM	Dense, dark gray, wet, silty SAND (SM), fine sand, scattered seams and layers of medium to high plasticity clay **(Qpfnf)**				
165			28		20							
	140											
160			29		5			Grades very silty				
	145											
155			30		50							Organic odor
	150							Grades very dense, silty, fine to medium sand, scattered mica				Trace weathered andesite, medium sand grains
150			31		0							
	155											
145			32		100							
	160											
140			33		100							
	165											

Elevation, feet	Depth, feet	Type	Number	Blows / 6 in. (N)	Recovery, %	USCS	MATERIAL DESCRIPTION	Lab Tests	Pocket Penetrometer (tsf)	REMARKS AND OTHER TESTS
	165									
								M,SA		
135	170		34		100					
130	175		35		100					
125	180		36		90					
						ML	Hard, dark gray to green gray, moist, slightly gravelly SILT (ML), trace sand, fine subrounded gravel, scattered organics **(Qpfnl)**			Paleosol Organic odor (CH_4)
						SM	Dense, light gray, wet, silty SAND (SM), well-graded fine to medium sand **(Qpfnf)**			
120	185		37		50			M,SA		
							Gravelly organic silt layer			
115	190		38		60		Scattered layers of hard, green gray, moist, Organic clayey, to clay, medium to high plasticity, high to very high dry strength,			Sand was observed to have high quartz content (est. 80% quartz)
110	195		39		100					
						SP	Very dense, dark gray, wet, SAND (SP) poorly-graded fine to medium sand, **(Qpfnf)**			Organic odor
105	200		40		70					

Project: King County WTD / Brightwater Conveyance System Project Location: King & Snohomish Counties, Washington Contract Number: E23007E	**Log of Boring E-402** Sheet 7 of 7

Elevation, feet	Depth, feet	SAMPLES: Type	Number	Blows / 6 in. (N)	Recovery, %	Graphic Log	USCS	MATERIAL DESCRIPTION	Piezometer Schematic	Lab Tests	Pocket Penetrometer (tsf)	REMARKS AND OTHER TESTS
	200									M,SA		Gravel inferred from drill action and cuttings
100	205		41		50			1-foot hard, green gray, organic silt, abundant wood particles and organics			4.25	Paleosol
								Terminated boring at 206.5 feet below ground surface				
95	210											
90	215											
85	220											
80	225											
75	230											
70	235											

CDM

UPPER BENCH

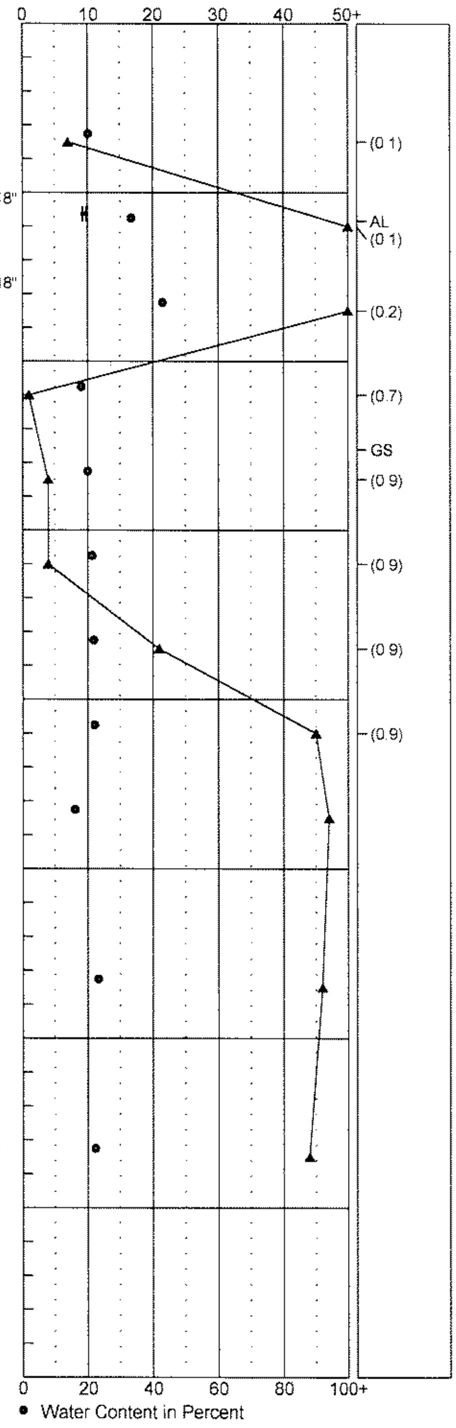
Boring Log B-09-1

Location: See Figure 3.
Approximate Ground Surface Elevation: 47 Feet
Horizontal Datum: NAD 83
Vertical Datum: NAVD 88

Drill Equipment: Modified B-61/Mud Rotory
Hammer Type: SPT w/140 lb. automatic hammer
Hole Diameter: 6 inches
Logged By: B. McDonald Reviewed By: K. Shah

USCS Class	Soil Descriptions	Depth in Feet
	2 inches of Asphalt over 10 inches of Sand over 3 inches of Concrete.	0
SM	Loose, wet, gray-brown, silty SAND with scattered gravel. (FILL)	∇ ATD
	Brown discharge with abundant gravel observed.	
ML	Very soft, wet, gray SILT and sandy SILT. (Colluvium)	5
	Trace of wood fragments observed to 11.5 feet.	
	Scattered organic material and zones of silty gravel observed.	10
SM/GM	Loose, wet, gray, slightly silty, very sandy GRAVEL with trace organic material to 15 feet. (Colluvium)	
	Grades to silty SAND with zones of sandy SILT and scattered gravel to 17.5 feet.	15
	Medium dense, with gravelly SAND zones.	
SP	Dense, wet, gray SAND. (Fluvial)	20
	Gravelly.	
	Slightly silty.	25
	Occasional silty SAND partings.	30
	Bottom of Boring at 34.0 Feet. Started 01/05/10. Completed 01/05/10.	35
		40

Sample	Blows	Lab Tests & (PID)
S-1	2 3 4	(0.1)
S-2	1/18"	AL (0.1)
S-3	1/18"	(0.2)
S-4	1 0 1	(0.7)
S-5	1 2 2	GS (0.9)
S-6	2 2 2	(0.9)
S-7	4 8 13	(0.9)
S-8	16 20 25	(0.9)
S-9	18 21 26	
S-10	16 20 26	
S-11	15 20 24	



1. Refer to Figure A-1 for explanation of descriptions and symbols.
2. Soil descriptions and stratum lines are interpretive and actual changes may be gradual.
3. USCS designations are based on visual manual classification (ASTM D 2488) unless otherwise supported by laboratory testing (ASTM D 2487).
4. Groundwater level, if indicated, is at time of drilling (ATD) or for date specified. Level may vary with time.

HARTCROWSER
17203-38 1/10
Figure A-2

SEE SITE MAP FIGURE 2

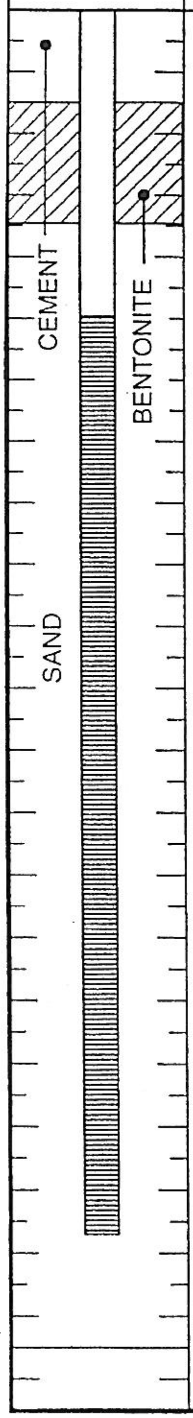
PACIFIC ENVIRONMENTAL GROUP, INC.

WELL NO. MW-95
PAGE 1 OF 1

PROJECT NO: 520-133.1G
LOGGED BY: B.A.
DRILLER: HAYES DRILLING
DRILLING METHOD: HSA
SAMPLING METHOD: SPLIT SPOON
CASING TYPE: SCHD. 40 PVC
SLOT SIZE: 0.020"
GRAVEL PACK: 2 x 12 SAND

CLIENT: CHEVRON
DATE DRILLED: 10-9-98
LOCATION: Point Wells, Richmond Beach
HOLE DIAMETER: 6"
HOLE DEPTH: 21.5'
WELL DIAMETER: 2"
WELL DEPTH: 19.8'
CASING STICKUP: NA

WELL COMPLETION

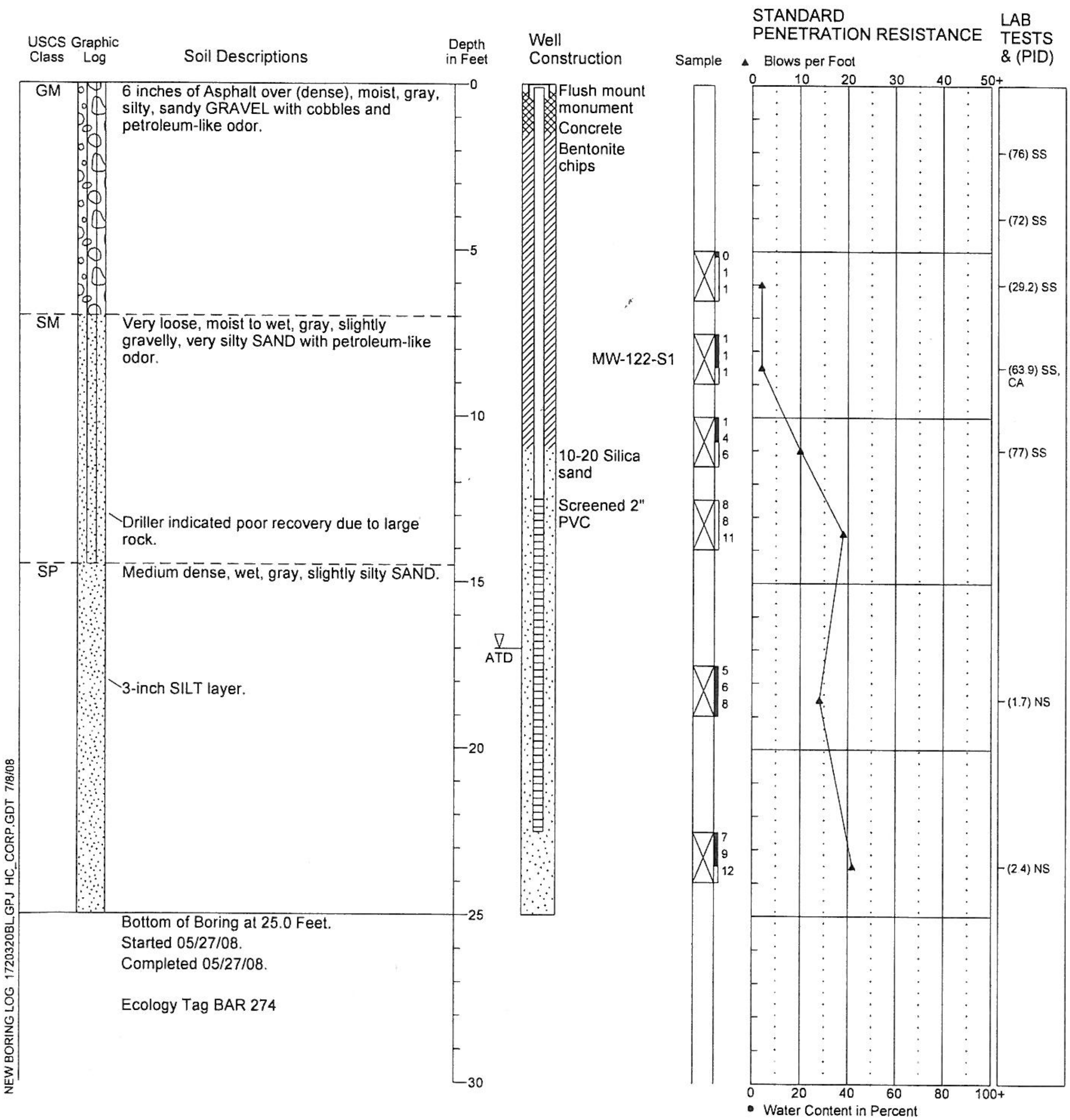


DEPTH (FEET)	MOISTURE CONTENT	PID (ppm)	PENETRATION (BLOWS/ 6")	SOIL TYPE	LITHOLOGY/REMARKS
0					GRAVEL COVER.
1				SM	SILTY SAND: light olive brown; 20% fines; 80% very fine to fine sand.
3.5	Dp	-			
5	Dp		67		
8				CL-ML	INTERBEDDED CLAY/SILT: dark olive brown to dark gray; low plasticity; 50% clay; 50% silt.
10	Dp		42		
11 (▽)		0		SM	SILTY SAND: dark gray; 15% fines; 85% fine to medium sand.
12	Wt				
14					@14': as above; 15% fines; 60% very fine to medium sand; 25% coarse sand; trace subangular gravel.
16	Wt		53	ML	SANDY SILT: dark gray; 80% silt; 20% very fine sand.
18	Mst				
21	Wt Sat		45	SM	SILTY SAND: 10 to 40% fines; 40 to 60% fine to medium sand.
22					BOTTOM OF BORING 21.5'

Boring Log & Construction Data for Monitoring Well MW-122

Location: See Figure 2.
Approximate Ground Surface Elevation: Feet
Horizontal Datum: Field located
Vertical Datum: NA

Drill Equipment: Hollow stem auger
Hammer Type: 140 lb. Auto hammer with 30" drop
Hole Diameter: 10 inches
Logged By: A. Inglish/A. Goodwin Reviewed By: A. Goodwin



1. Refer to Figure A-1 for explanation of descriptions and symbols.
2. Soil descriptions and stratum lines are interpretive and actual changes may be gradual.
3. USCS designations are based on visual manual classification (ASTM D 2488) unless otherwise supported by laboratory testing (ASTM D 2487).
4. Groundwater level, if indicated, is at time of drilling (ATD) or for date specified. Level may vary with time.
5. SS = Slight Sheen, NS = No Sheen, MS = Moderate Sheen, HS = Heavy Sheen
6. While trying to set well, hole was heaving and was unable to reach a depth of 25' (closest was 21'). Moved north 3' and drilled new borehole. Abandoned borehole's water level is 2 - 2.5' bgs showing confined conditions.
7. Analytical water content tabulated in Table 2.

HARTCROWSER

17203-20 *5/08*

Figure A-93

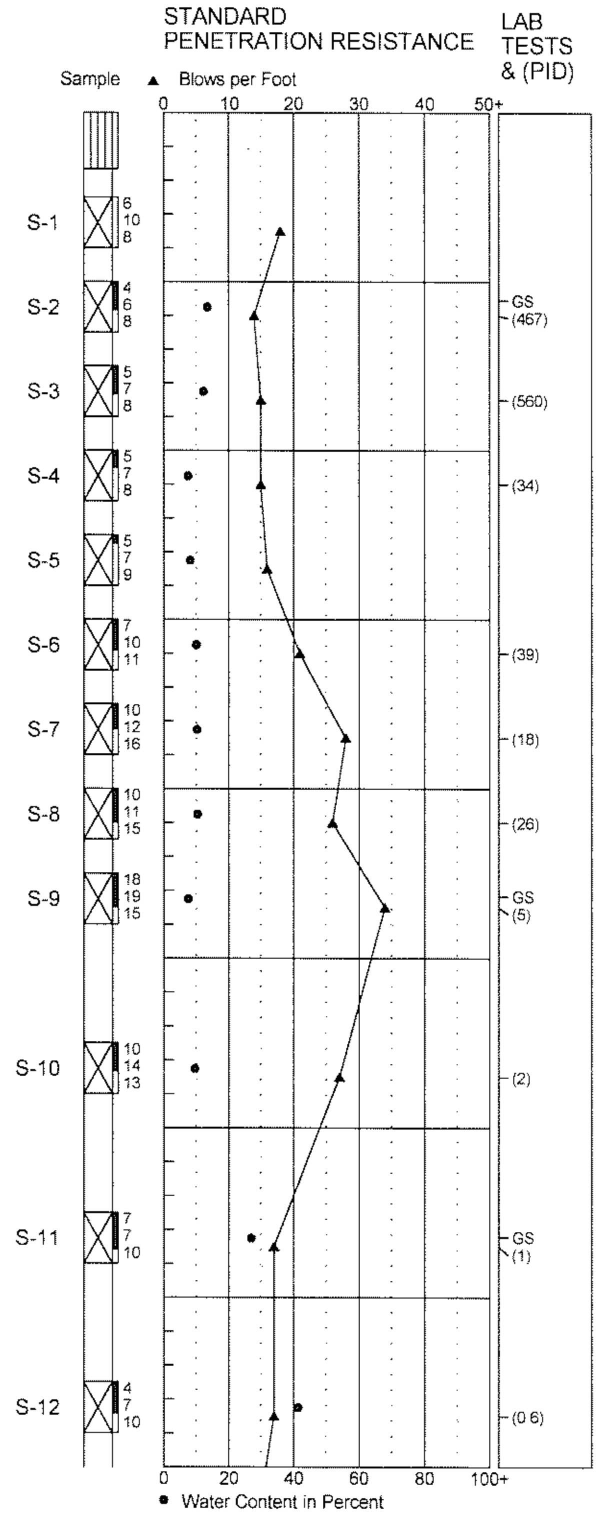
LOWER BENCH

Boring Log B-09-2

Location: See Figure 3.
Approximate Ground Surface Elevation: 7 Feet
Horizontal Datum: NAD 83
Vertical Datum: NAVD 88

Drill Equipment: Modified B-61/Mud Rotory
Hammer Type: SPT w/140 lb. automatic hammer
Hole Diameter: 6 inches
Logged By: B. McDonald Reviewed By: K. Shah

USCS Class	Soil Descriptions	Depth in Feet
SM/GM	Crushed GRAVEL over (medium dense), moist, brown, gravelly SAND to (medium dense), wet, gray, sandy GRAVEL. (FILL) Large gravel/cobbles observed with petroleum hydrocarbon-like odor to 5 feet.	0 (▽ ATD)
SP	Medium dense, wet, dark gray, very gravelly SAND to silty, gravelly SAND (TPH impacted). (Fluvial)	5
GP	Medium dense, wet, gray to dark gray, slightly silty, sandy GRAVEL. (Fluvial) 12 inches of slough observed. Slight petroleum hydrocarbon-like odor to 20 feet. Very sandy. Slightly silty, gravelly SAND to sandy GRAVEL.	10
SM/GM	Dense, wet, gray, slightly silty, very gravelly SAND to medium dense, sandy GRAVEL. (Fluvial)	22
SM	Medium dense, wet, olive-gray, silty SAND with wood fragments. (Lacustrine) Grades to very silty SAND to sandy SILT with scattered gravel and shells.	30–40



1. Refer to Figure A-1 for explanation of descriptions and symbols.
2. Soil descriptions and stratum lines are interpretive and actual changes may be gradual.
3. USCS designations are based on visual manual classification (ASTM D 2488) unless otherwise supported by laboratory testing (ASTM D 2487).
4. Groundwater level, if indicated, is at time of drilling (ATD) or for date specified. Level may vary with time.

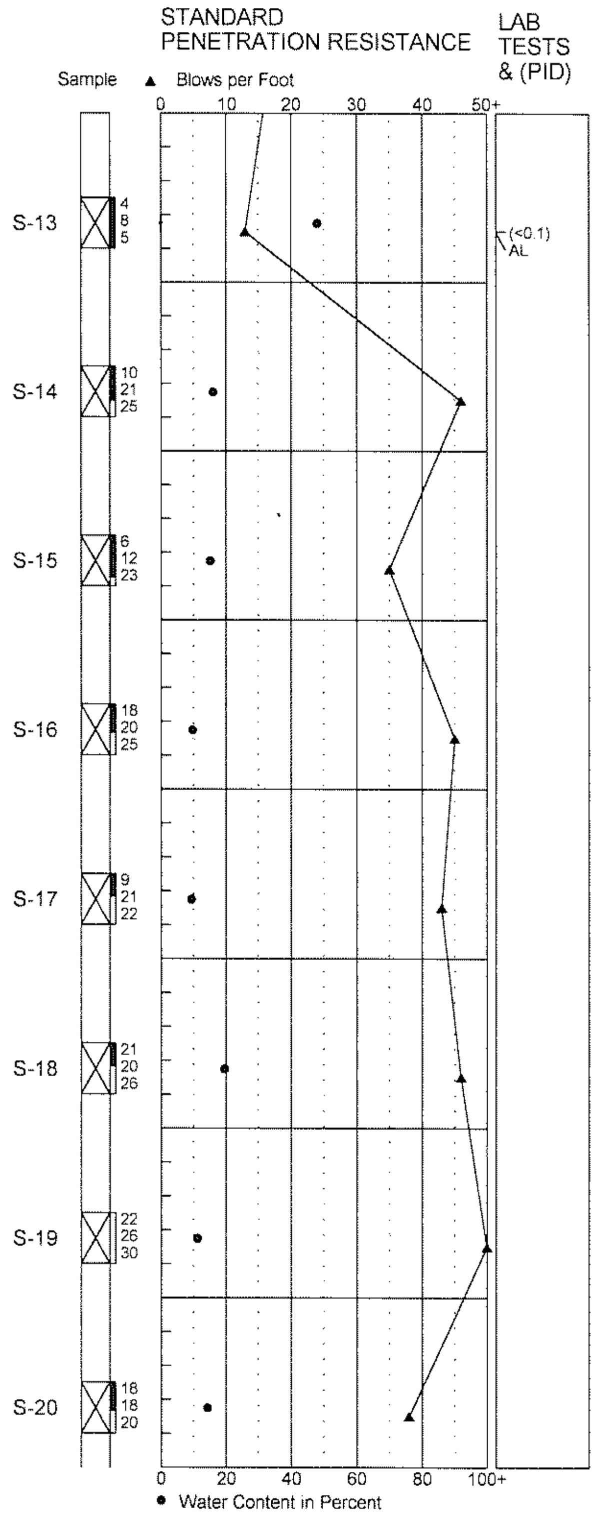
HARTCROWSER
17203-38 12/09
Figure A-3 1/2

Boring Log B-09-2

Location: See Figure 3.
Approximate Ground Surface Elevation: 7 Feet
Horizontal Datum: NAD 83
Vertical Datum: NAVD 88

Drill Equipment: Modified B-61/Mud Rotory
Hammer Type: SPT w/140 lb. automatic hammer
Hole Diameter: 6 inches
Logged By: B. McDonald Reviewed By: K. Shah

USCS Class	Soil Descriptions	Depth in Feet
SM	Medium dense, wet, olive-gray, silty SAND with wood fragments. (Lacustrine) (cont'd) Grades to stiff, wet, olive-gray, sandy SILT with scattered wood fragments, trace of shell, and hydrogen sulfide odor. (Non-plastic) Abundant wood fragments observed to 47 feet.	40–45
GP	Dense, wet, gray to dark gray, sandy GRAVEL with shell fragments to 59 feet. Silty. (Fluvial) Gravelly SAND. Drill action indicates possible large gravel/cobbles. Slightly silty, gravelly SAND. No recovery with 2-inch diameter SPT. Resampled with 3-inch diameter SPT. Abundant shell fragments to bottom of boring.	50–75
	Bottom of Boring at 79.0 Feet. Started 12/28/09. Completed 12/30/09.	80



NEW BORING LOG 1720338-BL.GPJ HC_CORP.GDT 1/22/10

1. Refer to Figure A-1 for explanation of descriptions and symbols.
2. Soil descriptions and stratum lines are interpretive and actual changes may be gradual.
3. USCS designations are based on visual manual classification (ASTM D 2488) unless otherwise supported by laboratory testing (ASTM D 2487).
4. Groundwater level, if indicated, is at time of drilling (ATD) or for date specified. Level may vary with time.

HARTCROWSER

17203-38 *12/09*

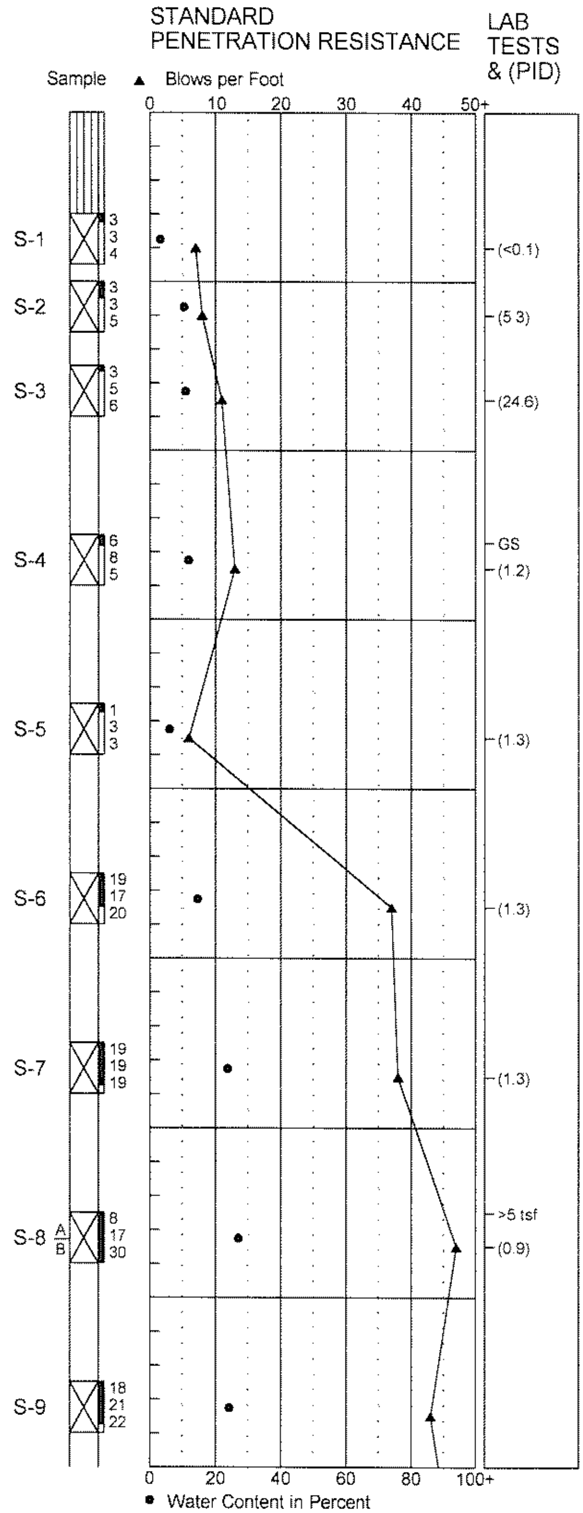
Figure A-3 *2/2*

Boring Log B-09-3

Location: See Figure 3.
Approximate Ground Surface Elevation: 11 Feet
Horizontal Datum: NAD 83
Vertical Datum: NAVD 88

Drill Equipment: Modified B-61/Mud Rotory
Hammer Type: SPT w/140 lb. automatic hammer
Hole Diameter: 6 inches
Logged By: B. McDonald   Reviewed By: K. Shah

USCS Class	Soil Descriptions	Depth in Feet
SP	(Loose), moist, brown to dark gray, silty, gravelly SAND to sandy GRAVEL. (FILL)	0
GW	Loose, moist to wet, gray to dark gray, sandy GRAVEL (TPH impacted). (Fluvial)	5
	Medium dense.	
	Drill action indicates possible scattered cobble.	10
	Abundant gravel to 17.5 feet.	15
	Slightly sandy GRAVEL.	
	Dense, gravelly SAND with scattered shell fragments.	20
SM	Dense, wet, gray, slightly silty SAND with scattered shell fragments. (Fluvial)	25
ML	Very stiff, wet, gray SILT. (Lacustrine)	30
SM	Dense, wet, gray, silty SAND with laminations. (Fluvial)	
	Trace organic material.	35
	Slightly silty.	40



NEW BORING LOG 1720338-BL.GPJ HC_CORP.GDT 1/22/10

1. Refer to Figure A-1 for explanation of descriptions and symbols.
2. Soil descriptions and stratum lines are interpretive and actual changes may be gradual.
3. USCS designations are based on visual manual classification (ASTM D 2488) unless otherwise supported by laboratory testing (ASTM D 2487).
4. Groundwater level, if indicated, is at time of drilling (ATD) or for date specified. Level may vary with time.

HARTCROWSER

17203-38   12/09

Figure A-4   1/2

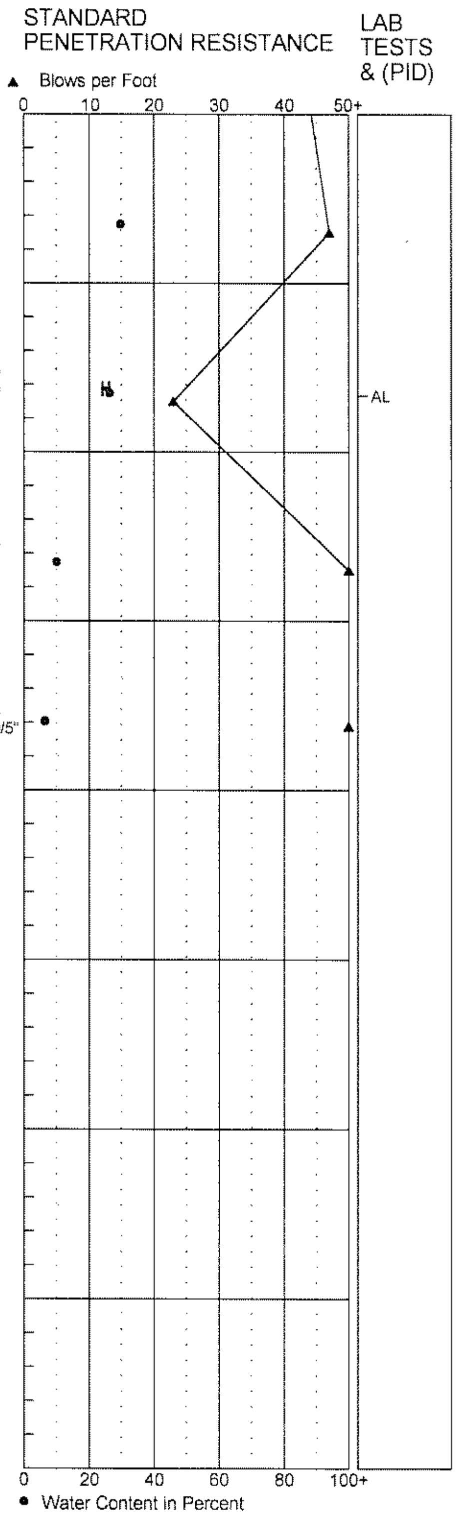
Boring Log B-09-3

Location: See Figure 3.
Approximate Ground Surface Elevation: 11 Feet
Horizontal Datum: NAD 83
Vertical Datum: NAVD 88

Drill Equipment: Modified B-61/Mud Rotory
Hammer Type: SPT w/140 lb. automatic hammer
Hole Diameter: 6 inches
Logged By: B. McDonald Reviewed By: K. Shah

USCS Class	Soil Descriptions	Depth in Feet
SM	Dense, wet, gray, silty SAND with laminations. (Fluvial) (cont'd)	40–46
SM/ML	Very stiff, wet, gray, sandy SILT and SILT with thin laminations. (Lacustrine)	46–50
GP	Very dense, wet, gray, sandy to slightly sandy GRAVEL. (Fluvial)	50–58.4
	Bottom of Boring at 58.4 Feet. Started 12/30/09. Completed 12/30/09.	

Sample	Blows
S-10	19, 23, 24
S-11	10, 10, 13
S-12	28, 27, 24
S-13	28, 50/5"



NEW BORING LOG 1720338-BL.GPJ HC_CORP.GDT 1/22/10

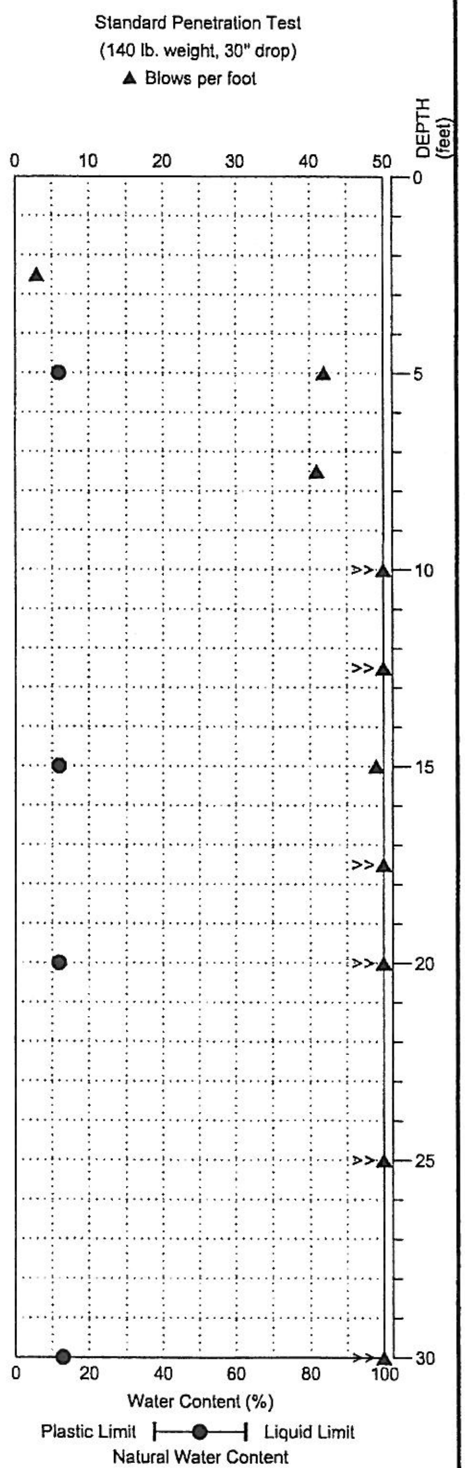
1. Refer to Figure A-1 for explanation of descriptions and symbols.
2. Soil descriptions and stratum lines are interpretive and actual changes may be gradual.
3. USCS designations are based on visual manual classification (ASTM D 2488) unless otherwise supported by laboratory testing (ASTM D 2487).
4. Groundwater level, if indicated, is at time of drilling (ATD) or for date specified. Level may vary with time.

HARTCROWSER
17203-38 12/09
Figure A-4 2/2

DRILLING COMPANY: Subterranean
DRILLING METHOD: Mud Rotary
SAMPLING METHOD: SPT w/safety hammer
SURFACE ELEVATION: 3 ± feet

LOCATION: N 288249.6, 1255930.7
DATE STARTED: 10/29/2007
DATE COMPLETED: 11/1/2007
LOGGED BY: D. Maloney + J. Gillie

DEPTH (feet)	USCS SOIL CLASS	DESCRIPTION	SAMPLE NUMBER	PEN. RESISTANCE (blows/6 inches)	OTHER TESTS
0	GP	Very loose to dense, dark gray, slightly silty, sandy, fine to coarse GRAVEL, moist.			
		Low recovery in S-1 at 2.5 feet. Gravel lodged in tip.	S-1	3-2-1	
5			S-2	20-20-22	GS
	SP SM	Dense, dark gray to dark olive gray, slightly silty to silty, fine gravelly, fine to coarse SAND, moist. **(PRE-FRASER NON-GLACIOFLUVIAL DEPOSITS)**			
			S-3	23-21-20	
10	GW	Very dense to dense, dark gray, slightly silty, sandy, well graded GRAVEL, moist. Low recovery in S-4. High blow count probably a result of pounding on a cobble or coarse gravel particle. Driller notes rough, cobbly drilling action.	S-4	27-32-48	
			S-5	32-50/5"	
15			S-6	39-27-22	GS
			S-7	38-37-42	
	SP	Very dense, dark gray, slightly silty, fine to coarse SAND, moist.			
20	GW GM	Very dense, dark gray, slightly silty to silty, sandy, well graded GRAVEL, moist.	S-8	39-37-45	GS
25	GP	Very dense, dark gray, medium to coarse sandy, fine to coarse GRAVEL, moist.	S-9	31-50-39	
30					



For a proper understanding of the nature of subsurface conditions, this exploration log should be read in conjunction with the text of the geotechnical report.

NOTE: This log of subsurface conditions applies only at the specified location and on the date indicated and therefore may not necessarily be indicative of other times and/or locations.

HWA GEOSCIENCES INC.

Brightwater Marine Outfall Design

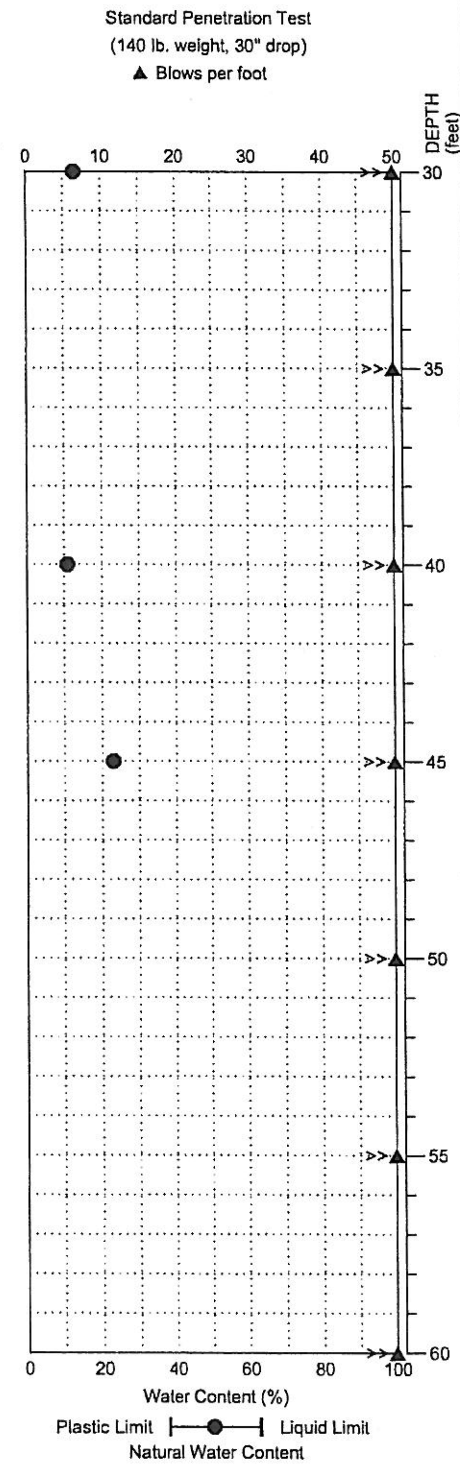
BORING:
B-490+36

PROJECT NO.: 2007-007-21 FIGURE: 12

DRILLING COMPANY: Subterranean
DRILLING METHOD: Mud Rotary
SAMPLING METHOD: SPT w/safety hammer
SURFACE ELEVATION: 3 ± feet

LOCATION: N 288249.6, 1255930.7
DATE STARTED: 10/29/2007
DATE COMPLETED: 11/1/2007
LOGGED BY: D. Maloney + J. Gillie

DEPTH (feet)	USCS SOIL CLASS	DESCRIPTION	SAMPLE NUMBER	PEN. RESISTANCE (blows/6 inches)	OTHER TESTS
30	SM	Very dense, dark gray, fine to coarse gravelly, silty, fine to coarse SAND, moist.	S-10	45-47-50	GS
		Driller notes sandy drilling, but very dense, slow, constant drilling.			
		Driller notes sandy drilling, but faster.			
35		Drilling and blows are consistent.	S-11	58-50/6"	
		Driller notes off and on gravelly drilling, mostly sand, slow.			
40	GW GM	Very dense, dark gray to dark olive gray, slightly silty, fine to coarse sandy, well-graded GRAVEL, moist.	S-12	38-36-31	GS
		Driller notes constant, smooth, faster drilling.			
45	SM	Very dense, dark gray to dark olive gray, slightly fine gravelly, silty, fine SAND, moist.	S-13	36-48-43	GS
50	GP	Very dense, dark gray, slightly silty, slightly sandy, fine to coarse GRAVEL, moist.	S-14	64-50/5"	
55		Very dense, dark gray, medium to coarse sandy GRAVEL, wet.	S-15	45-40-50/5.5"	
60					



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HWA GEOSCIENCES INC.

Brightwater Marine Outfall Design

BORING:
B-490+36

PROJECT NO.: 2007-007-21 FIGURE: 12

BORING 2007-007.GPJ 3/6/08

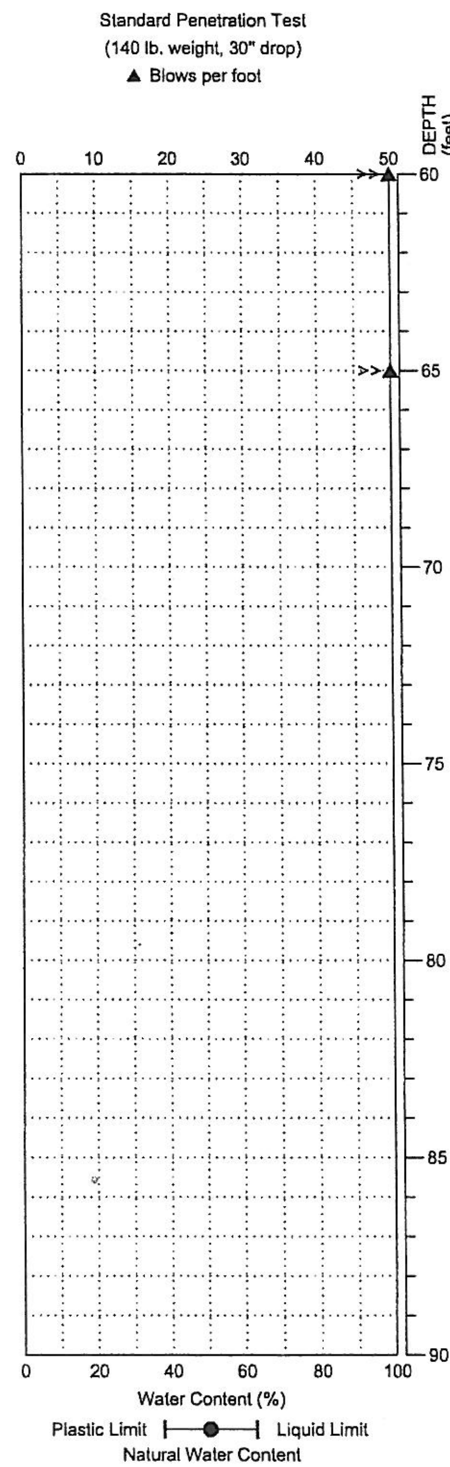
DRILLING COMPANY: Subterranean
DRILLING METHOD: Mud Rotary
SAMPLING METHOD: SPT w/safety hammer
SURFACE ELEVATION: 3 ± feet

LOCATION: N 288249.6, 1255930.7
DATE STARTED: 10/29/2007
DATE COMPLETED: 11/1/2007
LOGGED BY: D. Maloney + J. Gillie

DEPTH (feet)	SYMBOL	USCS SOIL CLASS	DESCRIPTION	SAMPLE TYPE	SAMPLE NUMBER	PEN. RESISTANCE (blows/6 inches)	OTHER TESTS	GROUNDWATER
60		SP	Very dense, dark gray, gravelly, medium to coarse SAND, wet.	☒	S-16	55-50/6"		
65		GP	Very dense, dark gray, medium to coarse sandy GRAVEL, wet. Some gravel particles fracturing like soft rock.	☒	S-17	46-50/5.5"		

Borehole terminated at 66.0 feet below the existing ground surface.

Depth scale (feet): 60, 65, 70, 75, 80, 85, 90



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HWA GEOSCIENCES INC.

Brightwater Marine Outfall Design

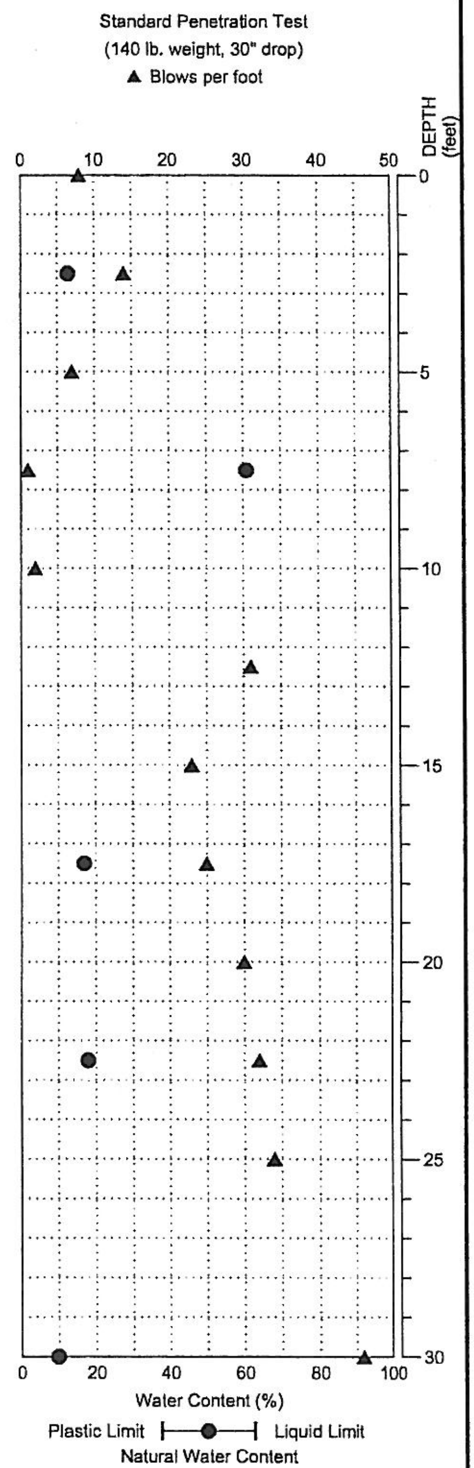
BORING:
B-490+36

PROJECT NO.: 2007-007-21 FIGURE: 12

DRILLING COMPANY: Gregory Drilling Inc.
DRILLING METHOD: HSA
SAMPLING METHOD: SPT w/autohammer
SURFACE ELEVATION: 8 ± feet

LOCATION: N 288202.2, E 1256046.4
DATE STARTED: 10/8/2007
DATE COMPLETED: 10/8/2007
LOGGED BY: J. Speck

DEPTH (feet)	USCS SOIL CLASS	DESCRIPTION	SAMPLE NUMBER	PEN. RESISTANCE (blows/6 inches)	OTHER TESTS	GROUNDWATER
0	SP	Loose, gray, fine to medium SAND, trace coarse sand and shell fragments, wet.	S-1	2-3-5		
		As above, brownish gray, medium dense, trace coarse sand, fine gravel, shell fragments.	S-2	4-8-6	GS	∇
5		Loose, olive gray, fine to coarse SAND, trace silt.	S-3	3-5-2		
	OL	Soft, olive brown to very dark brown, organic SILT, with decomposing wood, trace sand, hydrogen sulfide odor.	S-4	0-0-1	GS	
10	SP	Loose, olive gray, fine to medium SAND, trace gravel and silt, wet.	S-5	1-1-1		
		No recovery - coarse gravel or cobbles.	S-6	11-15-16		
15	SP	Medium dense, gray to dark gray, fine to medium SAND, with fine to coarse gravel, wet.	S-7	8-12-11		
			S-8	4-10-15	GS	
20		As above, dense.	S-9	11-13-17		
			S-10	14-13-19	GS	
25			S-11	12-14-20		
30						



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HWA GEOSCIENCES INC.

Brightwater Marine Outfall Design

BORING:
B-491+63

PAGE: 1 of 2

PROJECT NO.: 2007-007-21 FIGURE: 13

DRILLING COMPANY: Gregory Drilling Inc.
DRILLING METHOD: HSA
SAMPLING METHOD: SPT w/autohammer
SURFACE ELEVATION: 8 ± feet

LOCATION: N 288202.2, E 1256046.4
DATE STARTED: 10/8/2007
DATE COMPLETED: 10/8/2007
LOGGED BY: J. Speck

DEPTH (feet)	SYMBOL	USCS SOIL CLASS	DESCRIPTION	SAMPLE TYPE	SAMPLE NUMBER	PEN. RESISTANCE (blows/6 inches)	OTHER TESTS	GROUNDWATER
30		SW SM	Dense, gray to dark gray, well-graded SAND with silt and gravel, wet.	X	S-12	21-25-21	GS	

Boring terminated at 31.5 feet below surface.

Ground water observed at 3 feet at time of exploration (ground water tidally influenced).

Standard Penetration Test (140 lb. weight, 30" drop)
▲ Blows per foot

Blows per foot scale: 0 10 20 30 40 50
Depth scale: 30 35 40 45 50 55 60
Water Content (%): 0 20 40 60 80 100

Plastic Limit ├─●─┤ Liquid Limit
Natural Water Content

For a proper understanding of the nature of subsurface conditions, this exploration log should be read in conjunction with the text of the geotechnical report.

NOTE: This log of subsurface conditions applies only at the specified location and on the date indicated and therefore may not necessarily be indicative of other times and/or locations.

HWA GEOSCIENCES INC.

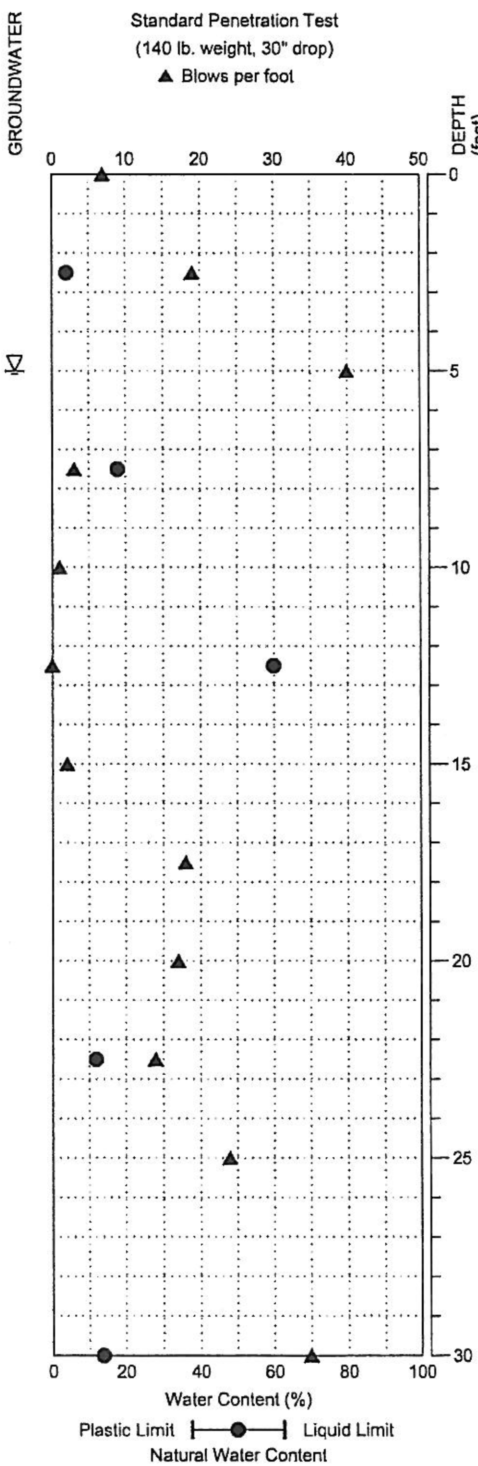
Brightwater Marine Outfall Design

BORING:
B-491+63

DRILLING COMPANY: Gregory Drilling Inc.
DRILLING METHOD: HSA
SAMPLING METHOD: SPT w/autohammer
SURFACE ELEVATION: 13 ± feet

LOCATION: N 288151.9, E 1256169.5
DATE STARTED: 10/8/2007
DATE COMPLETED: 10/8/2007
LOGGED BY: J. Speck

DEPTH (feet)	USCS SOIL CLASS	DESCRIPTION	SAMPLE NUMBER	PEN. RESISTANCE (blows/6 inches)	OTHER TESTS	GROUNDWATER
0	SP	Loose, olive gray, slightly fine to coarse gravelly, fine to medium SAND, with trace coarse sand, trace silt, moist.	S-1	2-2-5		
			S-2	6-8-11	GS	
5		As above, grayish brown, medium dense, trace shell fragments.	S-3	20-19-21		∇
	SP SM	Loose to dense, olive gray to dark olive gray, slightly silty to silty, fine to medium SAND, with trace coarse sand and gravel, wet.	S-4	5-2-1	GS	
	PT	Soft PEAT with sand interbeds, wet, hydrogen sulfide odor.				
10	OL	Soft, light yellow brown, SILT, decomposed wood fragments, fine to medium sand interbeds, moist.	S-5	0-0-1		
		Dark gray to black, wood and sand interbed, faint hydrocarbon odor.	S-6	0-0-0	GS	
15		Soft, olive gray SILT, decomposed wood fragments, fine to medium sand interbeds, moist, hydrogen sulfide odor.	S-7	0-0-2		
	SP	Medium dense, olive gray to dark gray, fine to medium, gravelly, SAND, trace silt, wet. Gravel is fine to coarse. Decreasing hydrogen sulfide odor.	S-8	6-8-10		
20		As above decreasing odor.	S-9	7-7-10		
	SP	Medium dense, dark gray, fine to medium SAND with fine to coarse gravel, trace coarse sand, wet. No hydrogen sulfide odor.	S-10	5-5-9	GS	
25		As above with increasing fine sands.	S-11	5-10-14		
30						



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NOTE: This log of subsurface conditions applies only at the specified location and on the date indicated and therefore may not necessarily be indicative of other times and/or locations.

HWA GEOSCIENCES INC.

Brightwater Marine Outfall Design

BORING:
B-492+94

PAGE: 1 of 2

PROJECT NO.: 2007-007-21 FIGURE: 14

DRILLING COMPANY: Gregory Drilling Inc.
DRILLING METHOD: HSA
SAMPLING METHOD: SPT w/autohammer
SURFACE ELEVATION: 13 ± feet

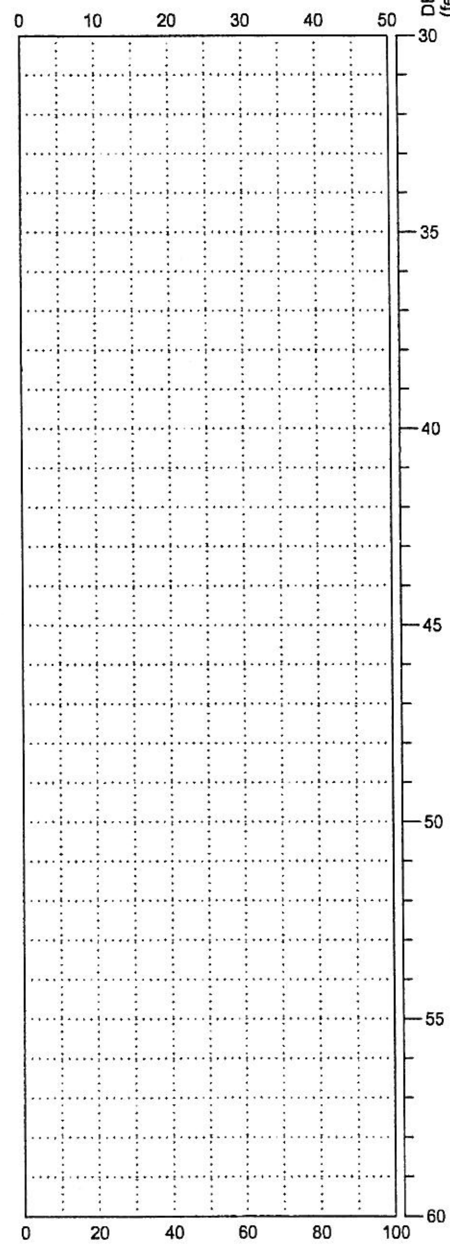
LOCATION: N 288151.9, E 1256169.5
DATE STARTED: 10/8/2007
DATE COMPLETED: 10/8/2007
LOGGED BY: J. Speck

DEPTH (feet)	SYMBOL	USCS SOIL CLASS	DESCRIPTION	SAMPLE TYPE	SAMPLE NUMBER	PEN. RESISTANCE (blows/6 inches)	OTHER TESTS	GROUNDWATER
30			As above, dense.		S-12	8-19-16	GS	

Boring terminated at 31.5 feet below surface.

Ground water observed at 5 feet at time of exploration (ground water tidally influenced).

Standard Penetration Test
(140 lb. weight, 30" drop)
▲ Blows per foot



Water Content (%)
Plastic Limit ├──●──┤ Liquid Limit
Natural Water Content

For a proper understanding of the nature of subsurface conditions, this exploration log should be read in conjunction with the text of the geotechnical report.

NOTE: This log of subsurface conditions applies only at the specified location and on the date indicated and therefore may not necessarily be indicative of other times and/or locations.

HWA GEOSCIENCES INC.

Brightwater Marine Outfall Design

BORING:
B-492+94

PROJECT NO.: 2007-007-21 FIGURE: 14

KHM
ENVIRONMENTAL MANAGEMENT INCORPORATED

PROJECT NO:	CG29291A	CLIENT:	Chevron
LOGGED BY:	E. Larsen	LOCATION:	Pt. Wells Terminal
DRILLER:	Cascade	DATE DRILLED:	10/31/01
DRILLING METHOD:	HS	HOLE DIAMETER:	12-Inches
SAMPLING METHOD:	D&M	HOLE DEPTH:	21.5 Feet
CASING TYPE:	Sch. 40 PVC	WELL DIAMETER:	8 Inches
SLOT SIZE:	0.040"	WELL DEPTH:	20 Feet
GRAVEL PACK:	Pea Gravel	CASING STICKUP:	N/A

ELEVATION	NORTHING	EASTING

BORING/WELL NO: AP-36
PAGE 1 OF 1

LOCATION MAP

SEE FIGURE 3

Well Completion: Backfill / Casing — BENT (0–~4 ft below fill), PEA GRAVEL (~4–21.5 ft)

Static Water Level: ▼ (approx. 7 ft)

Depth (feet)	Moisture Content	PID Reading (ppm)	Penetration (blows/6")	Soil Type	LITHOLOGY / DESCRIPTION
0					SAND & GRAVEL - FILL
2				SW	SAND: grayish brown; 5% fines; fine to coarse grained; 20-30% gravel; loose; no odor.
5	Dp	2.6	10 / 14 / 20		@ 5 Feet: as above; dense; faint hydrocarbon odor.
10	Wet	16	2 / 2 / 1		@ 10 feet: as above; increasing gravel; hydrocarbon odor (oil); medium dense; sheen.
15	Wet	8	7 / 14 / 20		@15 Feet: as above; 10-20% gravel; hydrocarbon odor; sheen.
18				SM	SILTY SAND: gray; 10-20% fines; fine to medium grained; medium dense; faint hydrocarbon odor.
20	Wet	4.1	9 / 10 / 17		
21.5					BOTTOM OF BORING AT 21.5 FEET

KHM
ENVIRONMENTAL MANAGEMENT INCORPORATED

PROJECT NO:	CG29291A	CLIENT:	Chevron
LOGGED BY:	E. Larsen	LOCATION:	Pt. Wells Terminal
DRILLER:	Cascade	DATE DRILLED:	11/8/01
DRILLING METHOD:	HS	HOLE DIAMETER:	12-Inches
SAMPLING METHOD:	D&M	HOLE DEPTH:	21.5 Feet
CASING TYPE:	Sch. 40 PVC	WELL DIAMETER:	8 Inches
SLOT SIZE:	0.040"	WELL DEPTH:	20 Feet
GRAVEL PACK:	Pea Gravel	CASING STICKUP:	N/A
ELEVATION		NORTHING	EASTING

BORING/WELL NO: AP-39
PAGE 1 OF 1

LOCATION MAP
SEE FIGURE 3

Well Completion (Backfill / Casing)	Static Water Level	Moisture Content	PID Reading (ppm)	Penetration (blows/6")	Depth (feet)	Sample (Recovery / Interval)	Soil Type	LITHOLOGY / DESCRIPTION
					0			SAND & GRAVEL - FILL
BENT					2–4			
PEA GRAVEL		Mst	39	5 7 6	5–6.5	■	GW	Sandy GRAVEL: dark gray; 5% fines; 20-30% sand; fine to medium gravel; medium dense; strong hydrocarbon odor; sheen.
	▼ (~7.2)							
		Wet	8.9	2 2 1	10–11.5	■		@ 10 feet: as above; very loose; strong hydrocarbon odor; sheen.
					14		SW	SAND: dark gray; 5% fines; fine to coarse grained; 10-20% gravel; loose; hydrocarbon odor; sheen.
		Wet	12.1	2 3 4	15–16.5	■		
					19		GW	Sandy GRAVEL: dark gray; 5% fines; 20-30% sand; fine to medium gravel; medium dense; hydrocarbon odor.
		Wet	5.8	8 12 15	20–21.5	■		BOTTOM OF BORING AT 21.5 FEET

Converse NW

Monitoring Well Geologic & Construction Log

Project Number	Well Number	Sheet
91-35101-06	MW-42	1 of 1

Project: Pt. Wells Monitoring Well Installations
Elevation (Top of Well Casing): 11.94
Water Level Elev.: 4.94
Drilling Contractor: McDonald Holt, Inc.
Drilling Method: B-61/HSA

Location: Pt. Wells Distribution Center
Surface Elevation:
Start Date: April 16, 1991
Finish Date: April 16, 1991

Depth feet	Well Construction	Lab Tests	ST	Blows/6"	OVM Reading	Description
0	locking flush-mounted aluminum monument; concrete					SILTY SAND (Fill); brown, some fine to coarse gravel; medium dense, very moist
	bentonite seal	C	Drive Barrel	9, 8, 9		
5	10/20 silica sand filter pack		Drive Barrel	2, 3, 2		grades to gray; loose, very moist
	ATD 4/16/91 (water level)					
			Drive Barrel	3, 5, 6		grades to black, hydrocarbon like staining and odor
10			Drive Barrel	7, 10, 15		
	well screen, 4.0" ID schedule 40 PVC with 0.010" slots					
15			Drive Barrel	3, 5, 12		SAND (Fill); gray, fine to medium, trace gravel; medium dense, wet; hydrocarbon like odor with sheen
20			Drive Barrel	5, 11, 12		little fine to medium gravel, trace shell fragments; medium dense, wet; hydrocarbon like odor and sheen
						Bottom of boring at depth 22.0 feet. Soil sampler driven using a 300-pound hammer falling 30 inches.

ST - Sampler Type:
- 2" OD Split Spoon
- Bulk Grab Sample
- Drive Barrel

Lab Tests:
- S - Soil Properties
- C - Chemical Properties
- ∇ Water Level

Logged by: BCP
Approved by: RAL

Figure No. A-10

Converse NW — Monitoring Well Geologic & Construction Log

Project Number	Well Number	Sheet
91-35101-06	MW-43	1 of 1

Project: Pt. Wells Monitoring Well Installations
Location: Pt. Wells Distribution Center
Elevation (Top of Well Casing): 10.04
Surface Elevation:
Water Level Elev.: 5.04
Start Date: April 16, 1991
Drilling Contractor: McDonald Holt, Inc.
Finish Date: April 16, 1991
Drilling Method: B-61/HSA

Depth feet	Well Construction	Lab Tests	ST	Blows/6"	OVM Reading	Description
0	locking flush-mounted aluminum monument; concrete					SILTY SAND (Fill); gray to brown, fine sand, trace fine to medium gravel, wood fragments; medium dense, wet; hydrocarbon like odor
	bentonite seal	C	Drive Barrel	3, 5, 7		
5	ATD 4/16/91 (water level)		Drive Barrel	5, 9, 6		increasing silt content, decreasing gravel content
	10/20 silica sand filter pack					
			Drive Barrel	3, 8, 12		
10	well screen, 4.0" ID schedule 40 PVC with 0.010" slots		Drive Barrel	3, 5, 7		grades to gray, fine to coarse sand, some fine to medium gravel
15			Drive Barrel	1, 2, 2		SILT (Fill); dark brown, trace sand, peat and wood fragments; very loose, very moist; hydrocarbon like odor and visible liquid hydrocarbons in sample
20			Drive Barrel	5, 9, 14		SILTY SAND (Fill); gray, fine to coarse, some fine to coarse gravel; medium dense, wet; hydrocarbon like odor
						Bottom of boring at depth 21.5 feet. Soil sampler driven using a 300-pound hammer falling 30 inches.

ST - Sampler Type:
- 2" OD Split Spoon
- Bulk Grab Sample
- Drive Barrel

Lab Tests:
- S - Soil Properties
- C - Chemical Properties
- ∇ Water Level

Logged by: BCP
Approved by: RAL

Figure No. A-11

Converse NW

Monitoring Well Geologic & Construction Log

Project Number	Well Number	Sheet
91-35101-11	MW-79	1 of 2

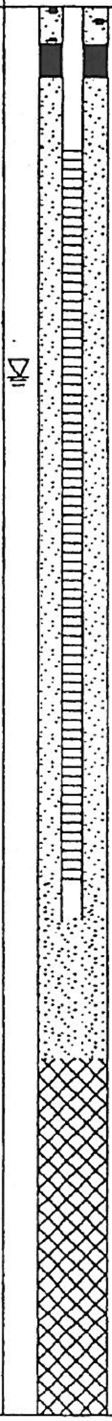
Project South Warehouse-Barrel Facility Environmental Assessment **Location** Chevron Point Wells Distribution Fa

Elevation (Top of Well Casing) 11.16 **Surface Elevation** 11.50

Water Level Elev. 6.25 **Start Date** January 21, 1992

Drilling Contractor Geoboring & Dev. Co. **Finish Date** January 22, 1992

Drilling Method Skid Mounted / HSA



Depth feet	Well Construction	Lab Tests	ST	Blows/ 6"	OVM Reading	Description
	locking flush-mounted steel monument				ppm	6 inches thick CONCRETE SLAB
	concrete annular seal bentonite seal	C		15 23 20	11	FILL SAND; gray, fine to medium, little coarse sand, trace fine gravel; medium dense, moist unidentified odor
	10/20 silica sand filter pack ATD 1/22/92			21 26 28	560	SILTY SAND; gray-brown, fine to medium, some lumps of hard yellow-brown silt, trace coarse sand and mica, trace fine gravel; dense, very moist; hydrocarbon-like odor
5	1/23/92	C		22 25 21	600	SANDY SILT; gray, fine sand, little coarse sand, trace wood fragments; very stiff, moist; hydrocarbon-like odor
10	well screen, 2" ID schedule 40 PVC with 0.010" slots			1 7 10	500	ESTUARINE DEPOSITS SAND; gray, some silt, medium to coarse, few fine gravel, trace plant fragments; medium dense, wet; hydrocarbon-like odor
	threaded end cap			1 2 2	30	ORGANIC SILT; yellow-brown to gray-brown, few plant fibers and fragments; soft, moist; organic-like odor
15	backfilled with bentonite chips			9 10 10	20	SAND; gray, medium to coarse, some fine sand and silt, trace fine gravel; medium dense, wet; organic-like odor

ST - Sampler Type:
- 2" OD Split Spoon
- Bulk Grab Sample
- Drive Barrel

Lab Tests:
- S - Soil Properties
- C - Chemical Properties
- ∇ Water Level

Logged by: ECR
Approved by: RAL
Figure No.

Converse NW

Monitoring Well Geologic & Construction Log

Project Number: 91-35101-11 | Well Number: MW-79 | Sheet 2 of 2

Project: South Warehouse-Barrel Facility Environmental Assessment
Location: Chevron Point Wells Distribution Fa
Elevation (Top of Well Casing): 11.16
Surface Elevation: 11.50
Water Level Elev.: 6.25
Drilling Contractor: Geoboring & Dev. Co.
Start Date: January 21, 1992
Drilling Method: Skid Mounted / HSA
Finish Date: January 22, 1992

Depth feet	Well Construction	Lab Tests	ST	Blows/ 6"	OVM Reading	Description
						trace wood fragments and lumps of organic silt
			Drive Barrel	1 9 19	15	
	backfilled with bentonite chips					grades coarser across sample with depth
25						
			Drive Barrel	12 15 22	45	
30						Bottom of boring at depth 29.0 feet Bore hole allowed to cave in to 15 feet Monitoring well installed to depth 12.5 feet Soil sampler driven using a 140-pound hammer falling 30 inches
35						

ST - Sampler Type:
- 2" OD Split Spoon
- Bulk Grab Sample
- Drive Barrel

Lab Tests:
- S - Soil Properties
- C - Chemical Properties
- Water Level

Logged by: ECR
Approved by: RAL

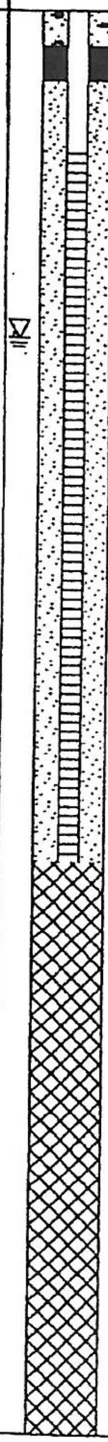
Figure No.

Converse NW

Monitoring Well Geologic & Construction Log

Project Number	Well Number	Sheet
91-35101-11	MW-83	1 of 2

Project: South Warehouse-Barrel Facility Environmental Assessment
Location: Chevron Point Wells Distribution Fa
Elevation (Top of Well Casing): 11.45
Surface Elevation: 11.66
Water Level Elev.: 7.04
Drilling Contractor: Geoboring & Dev. Co.
Start Date: January 27, 1992
Drilling Method: Skid Mounted / HSA
Finish Date: January 27, 1992



Depth feet	Well Construction	Lab Tests	Blows/6"	OVM Reading	Description
	locking flush-mounted steel monument			ppm	6 inches thick CONCRETE SLAB
	concrete annular seal bentonite seal riser, 2" ID schedule 40 PVC	C	11 16 23	8	FILL SAND; brown, fine to coarse, little fine gravel, trace silt; medium dense, moist
	10/20 silica sand filter pack	C	14 20 18	14	SILTY SAND WITH GRAVEL; brown, fine to coarse sand, fine gravel; medium dense, moist hydrocarbon-like odor and staining
5	2/13/92 (water level) well screen, 2" ID schedule 40 PVC, 0.010" slot size		10 11 13	45	SAND; brown to gray, fine to medium, trace silt; medium dense, wet; hydrocarbon-like odor, sheen on sampler
			1 0 0	120	BEACH DEPOSITS SAND; gray, fine to medium, trace silt and shell fragments; very loose, wet; hydrocarbon-like odor
10					
	threaded end cap		3 6 9		ESTUARINE DEPOSITS ORGANIC SILT; brown, fibrous, few fine to medium sand, trace shell fragments; stiff, moist; hydrocarbon-like odor
15	mixture of soil and bentonite chips				
			7 11 18		few plant fibers; soft, moist; hydrocarbon-like odor
					BEACH DEPOSITS SAND WITH GRAVEL; gray-brown, fine to coarse sand, fine gravel; medium dense, wet; hydrocarbon-like odor

ST - Sampler Type:
- 2" OD Split Spoon
- Bulk Grab Sample
- Drive Barrel

Lab Tests:
- S - Soil Properties
- C - Chemical Properties
- ∇ Water Level

Logged by: ECR
Approved by: RAL
Figure No.

Monitoring Well Geologic & Construction Log

Project Number	Well Number	Sheet
91-35101-11	MW-83	2 of 2

Project: South Warehouse-Barrel Facility Environmental Assessment
Location: Chevron Point Wells Distribution Fa
Elevation (Top of Well Casing): 11.45
Surface Elevation: 11.66
Water Level Elev.: 7.04
Start Date: January 27, 1992
Drilling Contractor: Geoboring & Dev. Co.
Finish Date: January 27, 1992
Drilling Method: Skid Mounted / HSA

Depth feet	Well Construction	Lab Tests	ST	Blows/6"	OVM Reading	Description
						ESTUARINE DEPOSITS ORGANIC SILT; brown, few fibers; soft, moist
			Drive Barrel	8 21 31		BEACH DEPOSITS SAND WITH GRAVEL; gray, fine to coarse sand, fine gravel, abundant quartz sand, trace silt; dense, wet
25						
			Drive Barrel	13 27 43		
						Bottom of boring at 29.0 feet Boring backfilled with bentonite chips Soil sampler driven using a 140-pound hammer falling 30 inches
30						
35						

ST - Sampler Type:
- 2" OD Split Spoon
- Bulk Grab Sample
- Drive Barrel

Lab Tests:
- S - Soil Properties
- C - Chemical Properties
- Water Level

Logged by: ECR
Approved by: RAL

Figure No.

KHM

ENVIRONMENTAL MANAGEMENT INCORPORATED

PROJECT NO:	CG29291A	CLIENT:	Chevron
LOGGED BY:	E. Larsen	LOCATION:	Pt. Wells Terminal
DRILLER:	Cascade	DATE DRILLED:	10/29/01
DRILLING METHOD:	HS	HOLE DIAMETER:	12-Inches
SAMPLING METHOD:	D&M	HOLE DEPTH:	21.5 Feet
CASING TYPE:	Sch. 40 PVC	WELL DIAMETER:	8 Inches
SLOT SIZE:	0.040"	WELL DEPTH:	20 Feet
GRAVEL PACK:	Pea Gravel	CASING STICKUP:	N/A

BORING/WELL NO: MW-97

PAGE 1 OF 1

LOCATION MAP

SEE FIGURE 2

ELEVATION	NORTHING	EASTING

Well Completion: Backfill, Casing — CONCRETE (0–1.5 ft), BENT (1.5–4 ft), PEA GRAVEL (4–21.5 ft)

Static Water Level	Moisture Content	PID Reading (ppm)	Penetration (blows/6")	Depth (feet)	Sample	Soil Type	LITHOLOGY / DESCRIPTION
				0			CONCRETE SLAB
				1		SW	SAND: brown; trace fines; fine to coarse grained; 10-20% fine gravel; dense; damp; no hydrocarbon odor.
	Mst	21	15 18 30	5–6.5	X	ML	SILT: gray; 15-20% fine sand; hard; organic odor.
▼ (approx. 7.7)							
				9		SW	SAND: gray; 5% fines; fine to coarse grained; 20-30% gravel; cobbles; very dense; strong hydrocarbon odor; sheen.
	Wet	647	50 (6)	10	X		
				14		PT	PEAT: brown; damp; strong hydrogen sulfide odor.
	Dp	227	5 6 7	15–16.5	X	OL	ORGANIC CLAY: dark gray; stiff; strong hydrogen sulfide odor.
				19		SW	SAND: dark gray; 5% fines; medium to coarse grained; 10-20% gravel; dense; hydrogen sulfide odor.
	Wet	217	6 17 30	20–21.5	X		
				21.5			BOTTOM OF BORING AT 21.5 FEET

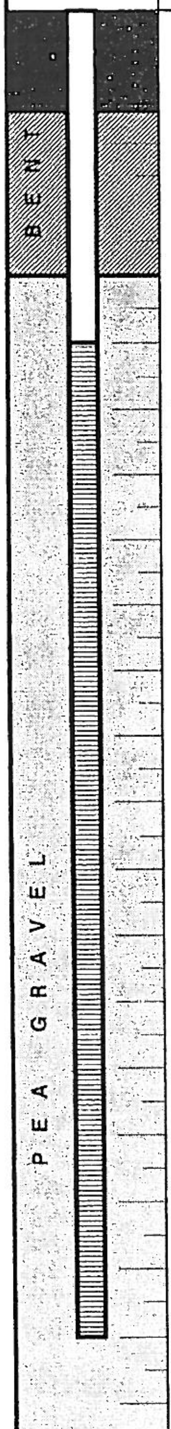
KHM
ENVIRONMENTAL MANAGEMENT INCORPORATED

PROJECT NO: CG29291A	CLIENT: Chevron	BORING/WELL NO: MW-98
LOGGED BY: E. Larsen	LOCATION: Pt. Wells Terminal	PAGE 1 OF 1
DRILLER: Cascade	DATE DRILLED: 10/29/01	LOCATION MAP
DRILLING METHOD: HS	HOLE DIAMETER: 12-Inches	
SAMPLING METHOD: D&M	HOLE DEPTH: 21.5 Feet	SEE FIGURE 2
CASING TYPE: Sch. 40 PVC	WELL DIAMETER: 8 Inches	
SLOT SIZE: 0.040"	WELL DEPTH: 20 Feet	
GRAVEL PACK: Pea Gravel	CASING STICKUP: N/A	
ELEVATION	NORTHING	EASTING

Well Completion (Backfill / Casing)	Static Water Level	Moisture Content	PID Reading (ppm)	Penetration (blows/6")	Depth (feet)	Sample (Recovery / Interval)	Soil Type	LITHOLOGY / DESCRIPTION
					0			CONCRETE SLAB
BENT					1–2		SW	SAND: brown; trace fines; fine to coarse grained; 10-20% gravel; medium dense; damp; faint hydrocarbon odor.
PEA GRAVEL	▼	Dp	77	8 14 17	5–6.5	■	ML	SILT: gray; 20-30% fine sand; hard; hydrocarbon odor.
					8.5–10		GW	GRAVEL: dark gray; trace fines; 10-20% fine to coarse sand; fine to coarse gravel; wood fragments; medium dense; strong hydrocarbon odor; sheen.
		Wet	202	8 12 7	10–11.5	■		
					13.5–14.5		SW	SAND: brown; trace fines; fine to coarse grained; 10% gravel; thin peat/organic clay interbed; medium dense; hydrocarbon odor.
		Wet	170	16 9 8	15–16.5	■		
		Wet	95	16 18 24	20–21.5	■		@20 Feet: dark gray; wood fragments; anoxic; dense; hydrocarbon odor.
					21.5			BOTTOM OF BORING AT 21.5 FEET

KHM ENVIRONMENTAL MANAGEMENT INCORPORATED

PROJECT NO: CG29291A	CLIENT: Chevron		BORING/WELL NO: MW-99	
LOGGED BY: E. Larsen	LOCATION: Pt. Wells Terminal		PAGE 1 OF 1	
DRILLER: Cascade	DATE DRILLED: 10/29/01		LOCATION MAP	
DRILLING METHOD: HS	HOLE DIAMETER: 12-Inches		SEE FIGURE 2	
SAMPLING METHOD: D&M	HOLE DEPTH: 21.5 Feet			
CASING TYPE: Sch. 40 PVC	WELL DIAMETER: 8 Inches			
SLOT SIZE: 0.040"	WELL DEPTH: 20 Feet			
GRAVEL PACK: Pea Gravel	CASING STICKUP: N/A			
ELEVATION	NORTHING	EASTING		



Static Water Level	Moisture Content	PID Reading (ppm)	Penetration (blows/6")	Depth (feet)	Soil Type	LITHOLOGY / DESCRIPTION
				0		CONCRETE SLAB
				1	SW	SAND: brown; trace fines; fine to coarse grained; 10-20% gravel; dense; damp; no odor.
▼	Dp	146	9 18 25	5–6.5	ML	SILT: gray; 20-30% fine sand; trace gravel; hard; hydrocarbon odor.
				9	GW	GRAVEL: gray; 5% fines; 20-30% fine to coarse sand; fine to medium gravel; medium dense; hydrocarbon odor; sheen; thin peat interbed.
	Wet	311	6 6 10	10–11.5		
	Wet	NR	3 3 4	15–16.5		@15 Feet: no recovery.
				19	SW	SAND: dark gray; trace fines; fine to coarse grained; 10% gravel; very dense; hydrogen sulfide odor.
	Wet	0	5 17 21	20–21.5		BOTTOM OF BORING AT 21.5 FEET

KHM
ENVIRONMENTAL MANAGEMENT INCORPORATED

PROJECT NO:	CG29291A	CLIENT:	Chevron	BORING/WELL NO: MW-103	
LOGGED BY:	E. Larsen	LOCATION:	Pt. Wells Terminal	PAGE 1 OF 1	
DRILLER:	Cascade	DATE DRILLED:	10/30/01	LOCATION MAP	
DRILLING METHOD:	HS	HOLE DIAMETER:	8-Inches	SEE FIGURE 2	
SAMPLING METHOD:	D&M	HOLE DEPTH:	21.5 Feet		
CASING TYPE:	Sch. 40 PVC	WELL DIAMETER:	4 Inches		
SLOT SIZE:	0.020"	WELL DEPTH:	19 Feet		
GRAVEL PACK:	2X12 Sand	CASING STICKUP:	N/A		
ELEVATION		NORTHING		EASTING	

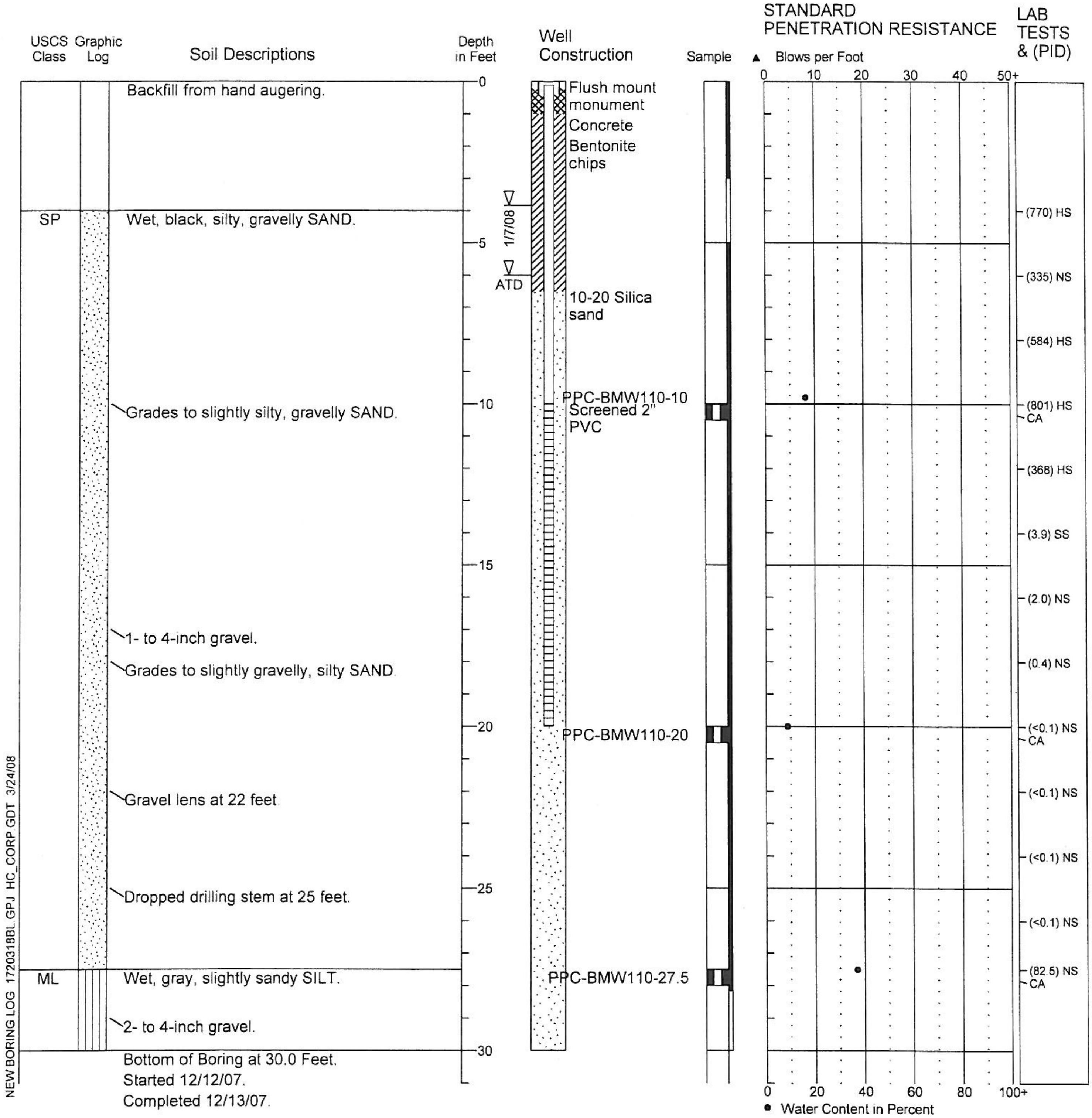
Well Completion: Backfill / Casing — B T; 2 X 1 2 S A N D

Static Water Level	Moisture Content	PID Reading (ppm)	Penetration (blows/6")	Depth (feet)	Sample Recovery / Interval	Soil Type	LITHOLOGY / DESCRIPTION
				0			CONCRETE SLAB
				1		SW	SAND - FILL: trace fines; fine to coarse grained; 20-30% gravel; cobbles; loose; damp; no odor.
▼	Wet	312	5 6 10	5–6.5	sample		@ 5 Feet: native sand; gray; 5% fines; fine to coarse grained; 5-10% gravel; medium dense; saturated with product (diesel odor).
				8–9		SP	SAND: gray; 5% fines; fine grained; loose; micaceous; hydrocarbon odor
	Wet	0	2 3 4	10–11.5	sample		
	Wet	0	6 17 18	15–16.5	sample		@15 Feet: as above; dense; hydrocarbon odor;
				18–19		GW	Sandy GRAVEL: dark gray; 5% fines; 20-30% fine to coarse sand; fine to coarse gravel; very dense; no odor.
	Wet	0	12 30 24	20–21.5	sample		BOTTOM OF BORING AT 21.5 FEET
				22			

Boring Log & Construction Data for Monitoring Well MW-110

Location: See Figure 1.
Approximate Ground Surface Elevation: 7.96 Feet
Horizontal Datum: Field Located
Vertical Datum: NA

Drill Equipment: Sonic Drill
Hammer Type: Plastic sleeve
Hole Diameter: 6 inches
Logged By: C. Rust   Reviewed By: G. Both



SS = Slight Sheen, MS = Moderate Sheen,
HS = Heavy Sheen, NS = No Sheen

1. Refer to Figure B-1 for explanation of descriptions and symbols.
2. Soil descriptions and stratum lines are interpretive and actual changes may be gradual.
3. USCS designations are based on visual manual classification (ASTM D 2488) unless otherwise supported by laboratory testing (ASTM D 2487).
4. Groundwater level, if indicated, is at time of drilling (ATD) or for date specified. Level may vary with time.
5. Water Content was not determined by Hart Crowser.

HARTCROWSER

17203-16   *12/07*

Figure B-3

Boring Log & Construction Data for Monitoring Well MW-119

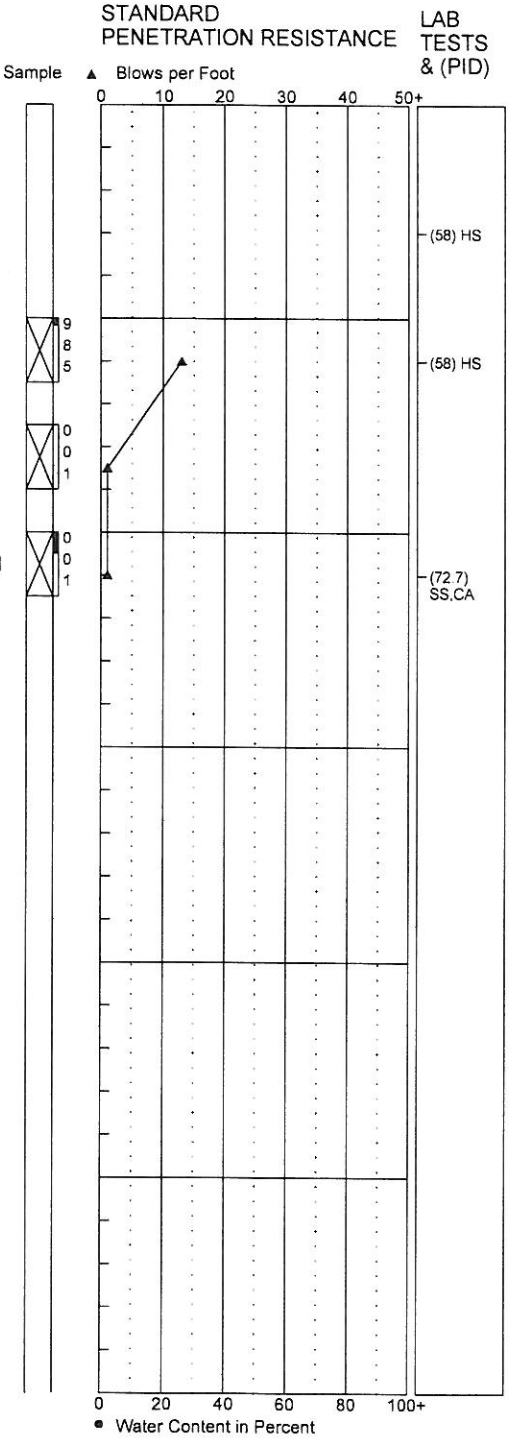
Location: See Figure 2.
Approximate Ground Surface Elevation: Feet
Horizontal Datum: Field located
Vertical Datum: NA

Drill Equipment: Hollow stem auger
Hammer Type: 140 lb. Auto hammer with 30" drop
Hole Diameter: 10 inches
Logged By: A. Inglish Reviewed By: A. Goodwin

USCS Class	Soil Descriptions	Depth in Feet
GW	(Loose), moist to wet, gray-brown, slightly silty, sandy GRAVEL with cobbles, petroleum-like odor, and free phase product.	0
SW	Medium dense, wet, gray, gravelly SAND. Poor recovery due to rock lodged in sampler.	5 (ATD)
GW	Very loose, wet, dark gray, slightly silty, sandy GRAVEL with petroleum-like odor.	10
	Bottom of Boring at 15.0 Feet. Started 05/28/08. Completed 05/28/08. Ecology Tag BAR 262	15

Well Construction: Stick-up monument; Concrete; Bentonite chips; 10-20 Silica sand; Screened 2" PVC

Sample: MW-119-S1



1. Refer to Figure A-1 for explanation of descriptions and symbols.
2. Soil descriptions and stratum lines are interpretive and actual changes may be gradual.
3. USCS designations are based on visual manual classification (ASTM D 2488) unless otherwise supported by laboratory testing (ASTM D 2487).
4. Groundwater level, if indicated, is at time of drilling (ATD) or for date specified. Level may vary with time.
5. SS = Slight Sheen, NS = No Sheen, MS = Moderate Sheen, HS = Heavy Sheen
6. Analytical water content tabulated in Table 2.

NEW BORING LOG 1720320BL.GPJ HC_CORP.GDT 7/8/08

HARTCROWSER

17203-20 **5/08**

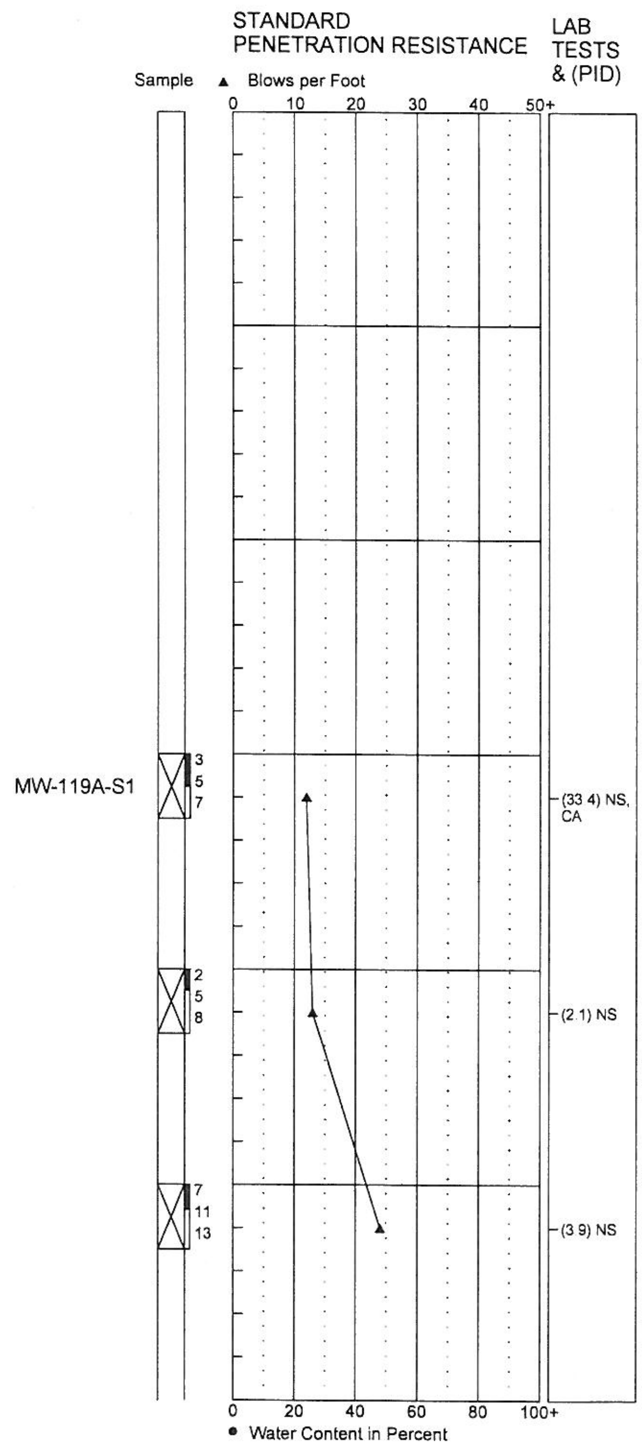
Figure A-89

Boring Log B-119A

Location: See Figure 2.
Approximate Ground Surface Elevation: Feet
Horizontal Datum: Field located
Vertical Datum: NA

Drill Equipment: Hollow stem auger
Sample Type: 140 lb. Auto hammer with 30" drop
Hole Diameter: 10 inches
Logged By: A. Inglish Reviewed By: A. Goodwin

USCS Class	Graphic Log	Soil Descriptions	Depth in Feet
		Drilled unsampled to 15 feet. Refer to Boring Log MW-119 for soil classification.	0
			5
		▽ ATD	
			10
SW		Medium dense, wet, gray, slightly gravelly, coarse SAND.	15
		Grading very gravelly	20
			25
		Bottom of Boring at 30.0 Feet. Started 05/30/08. Completed 05/30/08.	30



B-119A was originally named MW-119A.

1. Refer to Figure A-1 for explanation of descriptions and symbols.
2. Soil descriptions and stratum lines are interpretive and actual changes may be gradual.
3. USCS designations are based on visual manual classification (ASTM D 2488) unless otherwise supported by laboratory testing (ASTM D 2487).
4. Groundwater level, if indicated, is at time of drilling (ATD) or for date specified. Level may vary with time.
5. SS = Slight Sheen, NS = No Sheen, MS = Moderate Sheen, HS = Heavy Sheen
6. Analytical water content tabulated in Table 2.

HARTCROWSER

17203-20 5/08

Figure A-90

Project: King County WTD / Brightwater Conveyance System **Project Location:** King & Snohomish Counties, Washington **Contract Number:** E23007E	# Log of Boring P19-02

Date(s) Drilled	**8/18/03 - 8/25/03**	Geotechnical Consultant	**Camp Dresser & McKee Inc.** Logged By **MJB**	Checked By	**VJP 02-03-04**
Drilling Method/Rig Type	**Wireline/ CME 85**	Drilling Contractor	**Cascade Drilling, Inc.**	Total Depth of Borehole	**107.0 feet**
Casing Size/Type	**PQ (7"O.D.)**	Hammer Weight/Drop (lbs/in.)	**300# / 30"**	Ground Surface Elevation/Datum	**109.0 feet / Metro**
Location	**Pt. Wells**	Coordinates	**N 288005 E 1256501**	Elevation Source	**Survey**

Elevation, feet	Depth, feet	Samples: Type	Samples: Number	Samples: Blows / 6 in. (N)	Samples: Recovery, %	USCS	MATERIAL DESCRIPTION	Piezometer Schematic	Lab Tests	Pocket Penetrometer (tsf)	REMARKS AND OTHER TESTS
	0					SP-SM	Medium dense to dense, dark gray to light brown, dry to moist, slightly silty, gravelly SAND (SP-SM), poorly-graded, fine to coarse sand, fine to coarse gravel, subrounded to subangular, slight odor **(af)**				
		■	1	10 - 11 - 11 (22)	100						
105		■	2	12 - 19 - 19 (38)	100						
	5										
		■	3	10 - 13 - 20 (33)	67	SP	Dense, dark gray and black, wet, trace silt to slightly silty SAND (SP), trace gravel, poorly-graded, fine to coarse sand, fine to coarse gravel, subrounded and wood debris **(Qb)**				
						PT	Medium stiff, brown, moist PEAT,(PT), wood debris **(Qw)**				
100	10	■	4	3 - 2 - 3 (5)							
		■	5	1 - 2 - 3 (5)	100						
95	15	■	6	1 - 3 - 2 (5)	100	OL	Medium stiff, gray, moist ot wet, slightly sandy, organic SILT (OL), low plasticity, scattered to abundant organics/woody material, layers of peat, sandy silt, silty sand **(Qw)**				
		■	7	17 - 10 - 7 (17)		SM	Dense, brown, wet, silty to very silty SAND (SM), trace fine gravel, fine to coarse sand, numerous organics, organic odor **(Qpfnf)**				
		■	8	9 - 14 - 24 (38)	100						
90	20					GP	Very dense, dark gray, wet, very sandy GRAVEL (GP), trace silt, poorly-graded fine to coarse sand, fine to coarse gravel, angular to subrounded **(Qpfnf)**				
		■	9	75/6" (100+)	4						
85	25										

Groundwater Observation Data:

OW (FT BGS):	11.4 (Low)	3.5 (High)
VWP 1 (FT BGS):	7.7 (Low)	-4.9 (High)

Remarks: Negative Groundwater Data indicates measurements above Ground Surface
Recovery values > 100 indicate sample expansion during sampling.

Elevation, feet	Depth, feet	Sample Type	Sample Number	Blows / 6 in. (N)	Recovery, %	USCS	MATERIAL DESCRIPTION	REMARKS AND OTHER TESTS
	25					ML	Very dense, gray green, moist, slightly gravelly, sandy SILT (ML), fine to coarse sand, fine gravel, subrounded to subangular, homogeneous **(Qpfnl)**	
			10	50/6" (100+)	3			
						GP	Very dense, gray, wet, sandy GRAVEL to gravelly SAND (GP-SP) **(Qpfnf)**	Soil description inferred from drill action and cuttings
80								
	30							
			11	70/6" (100+)	0			
75								Gravelly drilling, sand in cuttings
	35							
			12	100/4" (100+)	0			
70								
	40							Gravelly drilling (4-inch gravels/cobbles), sand in cuttings
			13	100/3" (100+)	0			
65								
	45							
			14	100/4" (100+)	49			Coarse gravel in sampling shoe
60								
	50					ML	Hard, dark brown, moist, gravelly SILT (ML), laminated, numerous organics **(Qpfnl)**	
			15	100/6" (100+)	17			
55								
	55					GM	Very dense, dark gray, wet, silty to very silty, sandy GRAVEL (GM), fine to coarse sand, fine to coarse gravel, subrounded, occasional organics **(Qpfnf)**	Most fines washed from sample
			16	100/5" (100+)	60			
50								
	60							

Project: King County WTD / Brightwater Conveyance System
Project Location: King & Snohomish Counties, Washington
Contract Number: E23007E

Log of Boring P19-02

Elevation, feet	Depth, feet	Samples: Type / Number	Blows / 6 in. (N)	Recovery, %	USCS	MATERIAL DESCRIPTION	Piezometer Schematic	Lab Tests	Pocket Penetrometer (tsf)	REMARKS AND OTHER TESTS
	60									
		17	100/5" (100+)	40						Coarse gravel/cobble in shoe, 14 ft of heave, hole cave overnight 65 to 51 ft, case to 53 ft
45										
	65				GW	Dense, green gray, wet, sandy, GRAVEL (GW), well-graded, fine to coarse sand, subangular to subrounded fine to coarse gravel, with cobbles, possible boulders **(Qpfnf)**				Gravelly drilling, sand in cuttings
										Wood in cuttiings
40										
	70									
										4-inch cobbles, clean SW in cuttings, wood fragments
35										
	75									Cobbles, medium sand, cuttings - cobble/boulder
						Layer of fine to coarse sand, well-graded				12 feet of heave to 66 ft
30										
	80									
										High tide, mud mix thinning
25										
	85									
						Grades green gray, fine to coarse sand, gravel with cobbles				
20										
	90									
						Grades coarser, gravel/cobble/boulder				
						Medium to coarse sand				Cuttings from cobble/boulder
15										
	95									

Project: King County WTD / Brightwater Conveyance System Project Location: King & Snohomish Counties, Washington Contract Number: E23007E	**Log of Boring P19-02** Sheet 4 of 4

Elevation, feet	Depth, feet	SAMPLES: Type	Number	Blows / 6 in. (N)	Recovery, %	Graphic Log	USCS	MATERIAL DESCRIPTION	Piezometer Schematic	Lab Tests	Pocket Penetrometer (tsf)	REMARKS AND OTHER TESTS
	95											Organics in cuttings
-10												16 ft of heave
	100											
-5								Green gray, fine to coarse sand and fine gravel, angular to subangular				
	105											Shell fragments
								Terminated boring at 107 feet below ground surface				
0												
	110											
-5												
	115											
-10												
	120											
-15												
	125											
-20												
	130											

Log of Boring P19-03

Project: King County WTD / Brightwater Conveyance System
Project Location: King & Snohomish Counties, Washington
Contract Number: E23007E

Date(s) Drilled	8/26/03 - 8/29/03	Geotechnical Consultant	Camp Dresser & McKee Inc.	Logged By	SWC/MJB
Checked By	VJP 02-03-04				
Drilling Method/Rig Type	Wireline/ CME 85	Drilling Contractor	Cascade Drilling, Inc.	Total Depth of Borehole	76.0 feet
Casing Size/Type	PQ (7"O.D.)	Hammer Weight/Drop (lbs/in.)	300# / 30"	Ground Surface Elevation/Datum	108.8 feet / Metro
Location	Pt. Wells	Coordinates	N 288365 E 1256276	Elevation Source	Survey

Elevation, feet	Depth, feet	Samples: Type	Samples: Number	Samples: Blows / 6 in. (N)	Samples: Recovery, %	Graphic Log	USCS	MATERIAL DESCRIPTION	Piezometer Schematic	Lab Tests	Pocket Penetrometer (tsf)	REMARKS AND OTHER TESTS
	0						SM	Medium dense, gray, moist, silty SAND (SM), trace fine gravel, fine to medium sand **(af)**				
			1	6 - 9 - 12 (21)	100							
105			2	6 - 6 - 5 (11)	100							
	5		3	6 - 5 - 5 (10)	100							
							PT	Medium stiff, brown, moist PEAT (PT), fibrous, and gray olive SILT (ML), low plasticity, slow dilatancy **(Qw)**				
100			4	1 - 2 - 2 (4)	100							
	10		5	1 - 2 - 2 (4)	100		OL	Soft to medium stiff, brown to dark gray, moist, organic SILT (OL), low to medium plasticity varying to slightly clayey SILT (MH), numerous organics, medium to high plasticity, slow dilatancy **(Qw)**				
95			6	1 - 2 - 2 (4)	100							
	15		7	4 - 4 - 8 (12)	100		SP-SM	Medium dense, dark gray, wet, slightly silty SAND (SP-SM), poorly-graded fine to medium sand **(Qb)**				
90												
	20											
85												
	25											

Groundwater Observation Data:

OW (FT BGS):	7.9 (Low)	4.3 (High)
VWP 1 (FT BGS):	16.0 (Low)	5.6 (High)

Remarks: Negative Groundwater Data indicates measurements above Ground Surface
Recovery values > 100 indicate sample expansion during sampling.

Project: King County WTD / Brightwater Conveyance System	Log of Boring P19-03
Project Location: King & Snohomish Counties, Washington	Sheet 3 of 3
Contract Number: E23007E	

Elevation, feet	Depth, feet	Type	Number	Blows / 6 in. (N)	Recovery, %	Graphic Log	USCS	MATERIAL DESCRIPTION	Piezometer Schematic	Lab Tests	Pocket Penetrometer (tsf)	REMARKS AND OTHER TESTS
	60		15	50/4" (100+)	0							Fine to coarse sand in cuttings, gravelly drilling
45												
	65		16	44 - 50/6" (100+)	25							
40												
	70		14	12 - 14 - 19 (33)	11							Fine to coarse sand in cuttings, gravelly drilling, coarse gravel in sampler tip
35	75											
								Terminated boring at 76 feet below ground surface.				
30	80											
25	85											
20	90											
15	95											

APPENDIX E
Brightwater EIS, Appendix 4-C: Outfall Geophysical Surveys

4-C
OUTFALL GEOPHYSICAL SURVEYS

FINAL
ENVIRONMENTAL
IMPACT STATEMENT

Brightwater
Regional Wastewater
Treatment System

APPENDICES

Brightwater
King County TREATMENT SYSTEM

Final

Appendix 4-C
Outfall Geophysical Surveys

August 2003

Prepared for King County by

Williamson & Associates
Seattle, WA

CDM
Bellevue, WA

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by calling 206-684-1280 or 711 (TTY)

King County
Department of Natural Resources and Parks
Wastewater Treatment Division

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1.0 BACKGROUND / INTRODUCTION

1.1 Project Description

King County has prepared a Draft Environmental Impact Statement (Draft EIS) and Final Environmental Impact Statement (Final EIS) on the Brightwater Regional Wastewater Treatment System. The Final EIS is intended to provide decision-makers, regulatory agencies and the public with information regarding the probable significant adverse impacts of the Brightwater proposal and identify alternatives and reasonable mitigation measures.

King County Executive Ron Sims has identified a preferred alternative, which is outlined in the Final EIS. This preferred alternative is for public information only, and is not intended in any way to prejudge the County's final decision, which will be made following the issuance of the Final EIS with accompanying technical appendices, comments on the Draft EIS and responses from King County, and additional supporting information. After issuance of the Final EIS, the King County Executive will select final locations for a treatment plant, marine outfall and associated conveyances.

The County Executive authorized the preparation of a set of Technical Reports, in support of the Final EIS. These reports represent a substantial volume of additional investigation on the identified Brightwater alternatives, as appropriate, to identify probable significant adverse environmental impacts as required by the State Environmental Policy Act (SEPA). The collection of pertinent information and evaluation of impacts and mitigation measures on the Brightwater proposal is an ongoing process. The Final EIS incorporates this updated information and additional analysis of the probable significant adverse environmental impacts of the Brightwater alternatives, along with identification of reasonable mitigation measures. Additional evaluation will continue as part of meeting federal, state and local permitting requirements.

Thus, the readers of this Technical Report should take into account the preliminary nature of the data contained herein, as well as the fact that new information relating to Brightwater may become available as the permit process gets underway. It is released at this time as part of King County's commitment to share information with the public as it is being developed.

1.2 Objective

Geophysical surveys were performed by Williamson & Associates, Inc., a subcontractor for CDM under King County Contract No. E23007E, Geotechnical Services for the Brightwater Conveyance System. CDM's role related to the Brightwater outfall is to support pre-design activities related to the preferred alternative outfall location (Zone 7S near Point Wells). These surveys were intended to supplement the prior studies (King County, 2001 and King County 2002a) with additional site specific data on bathymetry, bottom conditions, and sediments.

The geophysical surveys were performed in two separate phases: 1) an AMS-120 Geophysical Survey to obtain data over a broad area of potential outfall alignments and 2) a Sub-Bottom Profile Geophysical Survey to obtain more detailed sub-bottom and shallow seismic profiles along a specific target alignment identified based on the first survey results.

Specific objectives of the AMS-120 geophysical surveys were to:

- Characterize the lateral and vertical extent of the surficial sediment and subsurface geology.
- Identify possible surficial and subsurface geohazards or geologic conditions that might impact the construction or operation of the outfall and diffuser.
- Identify an outfall corridor and diffuser locations for further investigation.

The second, high-resolution survey augmented the bathymetric and sub-bottom information collected earlier with the AMS 120 sonar mapping system. This second survey was conducted to provide greater detail related to geology and slope morphology in an area of the survey region identified as a potential outfall pipe route.

1.3 Datum

1.3.1 Horizontal Datum

The project geodetic datum is the North American Datum of 1983, adjusted for HPGN in 1991 (NAD83/91). All coordinates are based on the Washington North Zone of the State Plane Coordinate System (SPCS83) and are in U.S. Survey Feet.

1.3.2 Vertical Datum

The project vertical datum is METRO Datum and all elevations are in feet. METRO Datum = North American Vertical Datum of 1988 (NAVD88) + 96.28 feet.

The bathymetric vertical datum is Mean Lower Low Water (MLLW) and all water depths are in feet. MLLW = NAVD88 + 2.29 feet. MLLW = Metro Datum - 93.99 feet.

2.0 EQUIPMENT AND METHODS

2.1 AMS-120 Geophysical Survey

The AMS-120 Geophysical Survey phase commenced on February 24, 2003 with the mobilization of the equipment on the vessel *Point Lavinia*, a 90-foot converted crew boat.

The AMS-120 is a deep seafloor mapping system capable of generating co-registered sonar imagery and interferometric bathymetry across a swath of up to 3,300 feet. The AMS-120 is a general purpose system with an emphasis on high resolution imagery. The bathymetric mapping capability allows cost-effective seafloor bathymetry maps to be made at 2 foot or better contour intervals.

The following equipment was mobilized:

- AMS-120 swath bathymetric sidescan sonar with integrated 4.5 kHz Sub-Bottom Profiler (SBP)
- ISIS Sonar Image Processing System
- SOSI oceanographic winch with 6500 feet of 0.45 inch oceanographic coax cable
- Trimble AgGPS Receiver with USCG differential signal input for horizontal positioning
- Coastal Oceanographics' HYPACK MAX trackline control and data logging software
- Knudsen 320M 28 and 200kHz depth sounder for "look ahead" towfish safety
- Trackpoint II ultrashort baseline (USBL) system for towfish positioning
- Overside pole for mounting Trackpoint transceiver and Knudsen transducer
- 2000-pound depressor and 24 inch sheave for AMS towing system.
- 60kW Deck Generator
- SeaBird 911 CTD Sound Velocity Profiler
- Pilothouse monitor for the helmsman

The area surveyed was a rectangle extending from a depth of 50 feet, 7,500 feet seaward from Point Wells at Richmond Beach and extending along the shore for 7,000 feet. This is the Zone 7S area from previous surveys. The survey was performed along 15 primary tracklines spaced 400 feet apart and several supplementary and ties lines as shown on Figure 1, AMS-120 Survey Tracklines.

Data was acquired simultaneously with the echosounder, sidescan sonar, and subbottom systems along each trackline to measure water depths and to obtain information on the seabed features and stratigraphy beneath the seabed. The sidescan data is also used to identify possible obstructions along the route. Pseudo range corrections were obtained from USCG beacon stations. The system provided real-time helmsman steering information, logged all position data, and also allowed generation of pre- and post-plot trackline displays for review of survey plan, data coverage and for field plotting of data.

Vessel control and positioning provided navigation and horizontal position accuracy to better than 3 feet. The navigation system was configured to operate at a 1-second data rate to yield an extremely high-density data set.

Calibration of all systems was conducted at the beginning of the survey. Frequent comparison of the single beam echosounder and the first return of the sidescan were made and data from tie lines were cross-checked during post processing to assure accuracy in data acquisition.

It was intended to use the Geopulse Boomer to get additional lower frequency subbottom data but equipment problems and necessity to stay in deeper water to protect the overside pole (which extended 6 feet below the keel) prevented its optimum use. A decision was made to perform the additional sub-bottom survey at a later date when specific outfall alignments had been identified.

2.2 Sub-Bottom Profile Geophysical Survey

Data collection for this portion of the project commenced April 21, 2003 with mobilization of all geophysical survey equipment aboard a privately-owned, 25-foot, jet-powered, survey and fishing charter.

The survey system deployed in this second phase consisted of a high-resolution echo sounder, a 3.5 kHz sub-bottom profiler system, a shallow seismic profiler system, and an integrated navigation and positioning system. The specific systems used were:

- GeoAcoustics GeoPulse Shallow Seismic Profiling System
- Datasonics 3.5kHz Sub-Bottom Profiler System
- Triton-Elics ISIS Sonar Data Acquisition System
- Odom 34kHz Echo Sounder System
- Trimble Ag132 DGPS System for horizontal positioning
- Hypack Max Integrated Navigation System for logging navigation data
- EPC 1086 Thermal Graphic Recorder
- SeaBird 911 CTD Sound Velocity Profiler

The high-resolution survey consisted of a centerline that was axially co-incident to the target pipeline alignment, 2 parallel "wing" lines to the north and 2 parallel wing lines to the south of this line, as shown on Figure 5, Sub-Bottom Survey Tracklines. The line spacing between each of these lines was 50 feet. In order to provide redundant coverage and to remove any echo sounder bias, the centerline was run twice, once in each direction. So as to highlight the regional geology, two additional lines were run: one approximately1,800 feet further to the north of the centerline, roughly parallel to Line 3 of AMS-120 survey and one approximately 800 feet south of the centerline, roughly parallel to Line 9 of the AMS-120 survey. Additionally, seven 'tie' lines were run, two in deep water, one at the slope toe, two mid-slope, one at the slope break and one in shallow water.

The transducers for both the 3.5 kHz and the echo sounder were deployed off the port side of the vessel nearest the transom, with the echo sounder being mounted on a separate pole approximately 2 feet forward of the 3.5 kHz transducer. The GeoPulse transducer was deployed to starboard and in line with the Datasonics transducer. The receiver array was towed inline to the transducer with the array center approximately 16 feet aft. The draft to the faces of all three transducers was approximately 2 feet. The DGPS antenna was located atop the pole where the Datasonics transducer was mounted. Given the close proximity of all the geophysical elements, no offsets other than transducer depths were applied.

The Trimble Ag132 provided pseudo-range corrected positions using the differential correction service operated by the USCG; with differential GPS lock being maintained throughout all survey operations. All navigation data were logged to the Hypack integrated navigation system.

The Hypack Max system was set up to output navigation data to the ISIS sonar data acquisition system, permitting the logging of navigation data into the ISIS sonar record. Both the Datasonics 3.5 kHz system and the GeoPulse shallow seismic system were integrated into the ISIS data acquisition system; with the data from each system being a separate sub-bottom/seismic channel in a single Triton-Elics (XTF) file.

The Odom echo sounder was installed with the 34 kHz transducer option and integrated into the Hypack navigation system. The auto ping rate was selected.

3.0 RESULTS

3.1 AMS-120 Geophysical Survey

Data collected during this geophysical survey are presented as Figure 2, AM-120 Survey Bathymetry, Figure 3, AMS-120 Survey 3-D Bathymetric Perspective, and Figure 4, AMS-120 Survey Sidescan Mosaic. The regional setting and man-made considerations are described in the Brightwater background documentation (King County 2001, 2002a, 2002b, and 2002c).

3.1.1 Positioning and Tracklines

All survey tracklines, described previously, are shown on Figure 1. Position data was reduced and checked for accuracy confirming the planned horizontal position accuracy of 3 feet or better.

3.1.2 Bathymetry

Bathymetric data obtained with the deep-towed AMS-120 interferometric swath bathymetry system provides higher resolution and more detail in deeper water than narrow-beam surface transducers. After adjustment for tidal and position, the bathymetric data at a water depth of 50 feet or more is estimated to have an absolute accuracy of better than 3 feet and a repeatability of about 1 foot. Bathymetric contours of the bottom are shown as depth in feet below Mean Lower Low Water (MLLW) on Figure 2.

A three-dimensional perspective view of the bottom surface is shown on Figure 3. The gaps in the data collected, appearing as faint geometric shapes in Figure 3, are visible in the northeast and southeast corners of the study area.

The bathymetry indicates a relatively narrow, shallow near-shore region with a slope break occurring at about 90-110 feet water depth. North of Line 8, the slope is steep and unbroken to the 660 feet contour where beyond the slope base the bathymetry becomes relatively flat. In contrast, in the region of Lines 9, 10, 11 and 12, the slope becomes much more complex with a second break occurring mid-slope and an approximately 600-foot wide, 30-foot deep trench occurring at the slope base.

In addition, three natural ravines occur. The first, a small ravine south of line 5, the second, much more pronounced ravine occurring approximately coincident to Line 11 and a third ravine occurring north of Line 13. The origin of the ravines and of the complex slope morphology is uncertain from the bathymetric data and may warrant further geophysical investigation if the final alignment should encounter these features.

3.1.3 Sidescan

A mosaic of all the sidescan swaths is presented on Figure 4. The higher resolution original records were reviewed to identify slope and bottom features. The sidescan imagery show the steep gradient relatively near shore incised with ravines, a deeper channel at the base of the slope and a relatively flat, featureless deeper floor at depths of 600-700 feet.

Several sidescan targets are noted and are listed in Table 1. Causal inspection of Target 1 suggests that it has the outline of a wreck but closer inspection indicates that this feature is more likely geologic in origin. Targets 2, 3 and 4 are all relatively large features, with hard returns, but show little evidence that they stand proud of the seafloor. Target 5, seen on three separate images, is a hard return that stands well proud of the sea floor; the feature is approximately 35 feet long, relatively thin (about 3 feet) and casts a significant shadow. Preliminary interpretation is that this feature is metal debris, possibly a hatch cover or trawl door that has fallen overboard and knifed into the sediments. Preliminary examination revealed no cables.

Table 1: Sidescan Sonar Target List

Target Number	Line	Location		Size	Evaluation
		Northing	Easting		
1	BW01	290,606	1,253,754	60' x 19'	Geology
2	BW01	290,515	1,253,415	20' x 3'	Debris
3	BW09	287,134	1,252,752	32' x 4'	Debris
4	BW14	284,508	1,252,457	14' x 3'	Debris
5	BW15a BW15 Cal2	283,582	1,251,658	35' x 3' Est. height 6'	Debris, hard return, casts a shadow

3.1.4 Sub-Bottom Survey

As is to be expected, the sub bottom record is limited by the relatively low acoustic penetration of 4.5 kHz system in the sediment types occurring in the region. However, the system is not without merit, as the 4.5 kHz record clearly reveals a relatively thin layer of younger, presumably re-worked material mantling much of the topography. South of Line 9, the sub bottom record hints at further geologic complexity occurring at the toe of the slope. Copies of all the subbottom records were provided to CDM for further interpretation and evaluation.

3.2 Sub-Bottom Profile Geophysical Survey

3.2.1 Positioning and Tracklines

All survey tracklines, described previously, are shown on Figure 5. The navigation data were high quality differential GPS, accurate to within 3 feet and required very little post-processing to produce survey track lines. The boat handling also proved to be quite good, resulting in relatively little cross-track error from the intended survey line. Event marks were recorded every 200 feet along track and are plotted on the track line map, the water depth profiles were recorded in the ISIS file and are displayed on the analog sub-bottom and seismic records.

3.2.2 Bathymetry

Echo sounder data was collected with the Odom set to its auto ranging mode. In auto mode, the Odom worked unattended to approximately 450 feet water depth; however, below this depth the system required occasional transmit power and receive gain adjustments to maintain bottom track. In general, the bathymetric data are of very high quality.

The echo sounder data were edited using the Single Beam Editor Utility in the Hypack Max system and depth corrected using 1,488m/s for the speed of sound in water as calculated from a CTD profile. Editing amounted to de-spiking the raw data and clipping out the areas where bottom track was lost for more than a few successive pings. The edited bathymetric data were tide corrected in Hypack Max using the verified NOAA tide-curve as referenced to the Seattle (9447130) tide-station and zonally corrected to Edmonds, Washington.

Where survey lines intersect, the tide-corrected bathymetry agrees to better than a foot. It is further noteworthy, that in water depths greater than about 70 feet, the bathymetry inferred from the 6 lines (2 centerlines and 4 wing lines) which run the length of the preferred route tied to the bathymetry derived from the February 2003 AMS-120 survey within about one foot.

3.2.3 Sub-Bottom Survey

The Datasonics 3.5 kHz and the GeoPulse profiler systems were operated concurrently and timed via a single trigger pulse initiated by the EPC 1086 recorder. The data from both systems were digitally logged as independent sub-bottom channels to the ISIS sonar data acquisition system while, the navigation string provided by Hypack was logged to the header of each ping. The ping rate of 450 μs was selected to maximize the data coverage across the widely varying water depth. An 8 bit, 4 Kb sample was taken for each channel and for each ping.

As is expected, the 3.5 kHz Datasonics system produced a record similar to the AMS 120's 4.5 kHz sub-bottom profiler; and as with the 4.5 kHz, the acoustic penetration of the 3.5 kHz, was typically 10-15 feet and occasionally as much as 30-40 feet. On both 4.5 kHz and the 3.5 kHz records, indications of bedding were typically indistinct so that relationships between geologic units were most often indeterminate.

The GeoPulse system, with a center frequency of ~700 Hz, was selected as an acoustic source because it is capable of greater acoustic penetration than the 3.5 kHz while providing better resolution than a bubble pulser. On the slope and in shallow water, the acoustic penetration of this system was typically 80 feet or more and often in excess of 150 feet. In the deep-water flats, the acoustic resolution was much less, likely due to thick, weakly layered homogeneous sediments. The GeoPulse record, in general, was good at revealing bedding and highlighting the stratigraphic relationships between geologic units. The GeoPulse system proved particularly useful at delineating the thickness of the postglacial sediment drape.

Synthesizing the available geophysical data from the GeoPulse, the 3.5 kHz and from the AMS-120 survey and summarizing this information, six informal geologic units and a regional unconformity are recognized as shown on Figure 6, Sub-Bottom Centerline Profile:

- **Upper Stratified Unit** – This unit is horizontally stratified to slightly westward dipping and occurs from approximately 35 feet to 330 feet water depths. The base of the unit is sub-horizontal with perhaps 15 feet of topography.

- **Unstratified Unit** - This unit is massively bedded, approximately 100 feet to 165 feet thick. The basal contact of the unit dips eastward and cuts the lower stratified unit. The unit is probably a glacial till.

- **Lower Stratified Unit** - This unit is horizontally stratified with the base of the unit at 575 feet water depth. Compared to the upper stratified unit, acoustic penetration is relatively low. Some evidence for (active?) soft-sediment deformation and down-slope sediment transport, particularly near the basal contact of the unit.

- **Acoustically Opaque Sediments** – This unit has very low acoustic penetration on either the 4.5 kHz, 3.5 kHz or GeoPulse records. The basal contact was not observed but the unit is interpreted to be well indurated glacial till at greater than 575 foot water depth beneath the slope.

- **Regional Unconformity** - This feature is a glacial erosional surface that cuts the Upper Stratified, Unstratified, Lower Stratified units, and Acoustically Opaque Sediments.

- **Deepwater Sediments** – These weakly layered, horizontal bedded, homogeneous sediments occur stratigraphically above the regional unconformity. Low acoustic penetration was achieved on the 4.5 kHz, 3.5 kHz or GeoPulse records. The unit is most likely post-glacial infill of the Puget Sound.

- **Post-Glacial Sediment Drape** – This is the surficial unit in the survey area that mantles the postglacial topography. On the slope, the unit is variable in thickness from less than about 5 feet to occasionally more than 20 feet, tending to be thickest nearest shore and at the slope toe. In deepwater, the unit grades into a thick, weakly layered homogenous sediment.

4.0 SUMMARY

The AMS-120 and Sub-Bottom geophysical surveys, conducted in the vicinity of the proposed outfall pipe alignment, were successful in identifying the subsurface bathymetric and geologic conditions. Key information gained from the surveys included:

- **Sidescan Targets** – Generally the bottom is free of ship wrecks or other man-made features. Five targets were evaluated with the sidescan sonar. Of the five, one appeared to be geologic in nature, three were evaluated to be flat-lying debris, and one was evaluated to be debris standing about 6 feet above the sediment surface.

- **Bathymetry** - The bathymetry indicates a relatively narrow, shallow near-shore region with a steeper slope break occurring at about 90-110 feet water depth. In the northern portion of the survey area the steeper slope is unbroken to about the 660 feet contour becoming relatively flat further to the west. In the southern portion of the survey area the slope becomes much more complex with a second break occurring mid-slope. An approximately 30 feet deep trench occurs at the base of the slope. An area near Tracklines 7 and 8 has the flattest slope (about 15 degrees), a more uniform slope, a less abrupt transition at the base of the slope, and no significant, unusual bathymetric or sub-bottom features that are evident. This is the area selected for further study. Other locations have a more irregular slope; the slopes are much steeper towards their toe (on the order of 26 – 35 degrees in some areas).

- **Ravines** – Three natural ravines occur within the survey area. The origins of the ravines and of the slope break are uncertain from the bathymetric data. The ravines have irregular features and are considered to have a potential for continuing down slope movement of the post-glacial sediment.

- **Sub-Bottom Profile** – The sub-bottom profile encountered a veneer of more recent sediments (Holocene drape) over topography of denser, stratified and unstratified sediments probably of glacial origin. The sediment drape is variable in thickness from less than about 5 feet to occasionally more than 20 feet, but tending to be thickest nearest shore and at the slope toe and beyond. The sub-bottom data implies potential movement of these surficial soils on the slope.

Using the bathymetry, side-scan sonar and sub-bottom profile data, the CDM Team examined alternate alignment configurations and recommended an outfall alignment for further study centered in the area where the second phase Sub-Bottom Survey was performed. This alignment crosses the seabed with the least gradient and the least irregular centerline profile as compared to other potential alternatives. The recommended alignment avoids the three ravines disclosed in the bathymetric and sidescan sonar data, and none of the identified sidescan targets surveys are near the alignment. The recommended route alignment also revealed the minimum thickness of potentially weaker Holocene drape (the surficial veneer of more recent sediments), which would lessen the risk for earthquake-induced liquefaction or slope failure. The side-scan sonar data also confirmed that the recommended route alignment avoids slope areas that may have experienced deeper slope failures in the geologic past.

5.0 REFERENCES

King County, 2001. *Marine Geophysical Investigation, Marine Outfall Siting Study.* Seattle, Washington.

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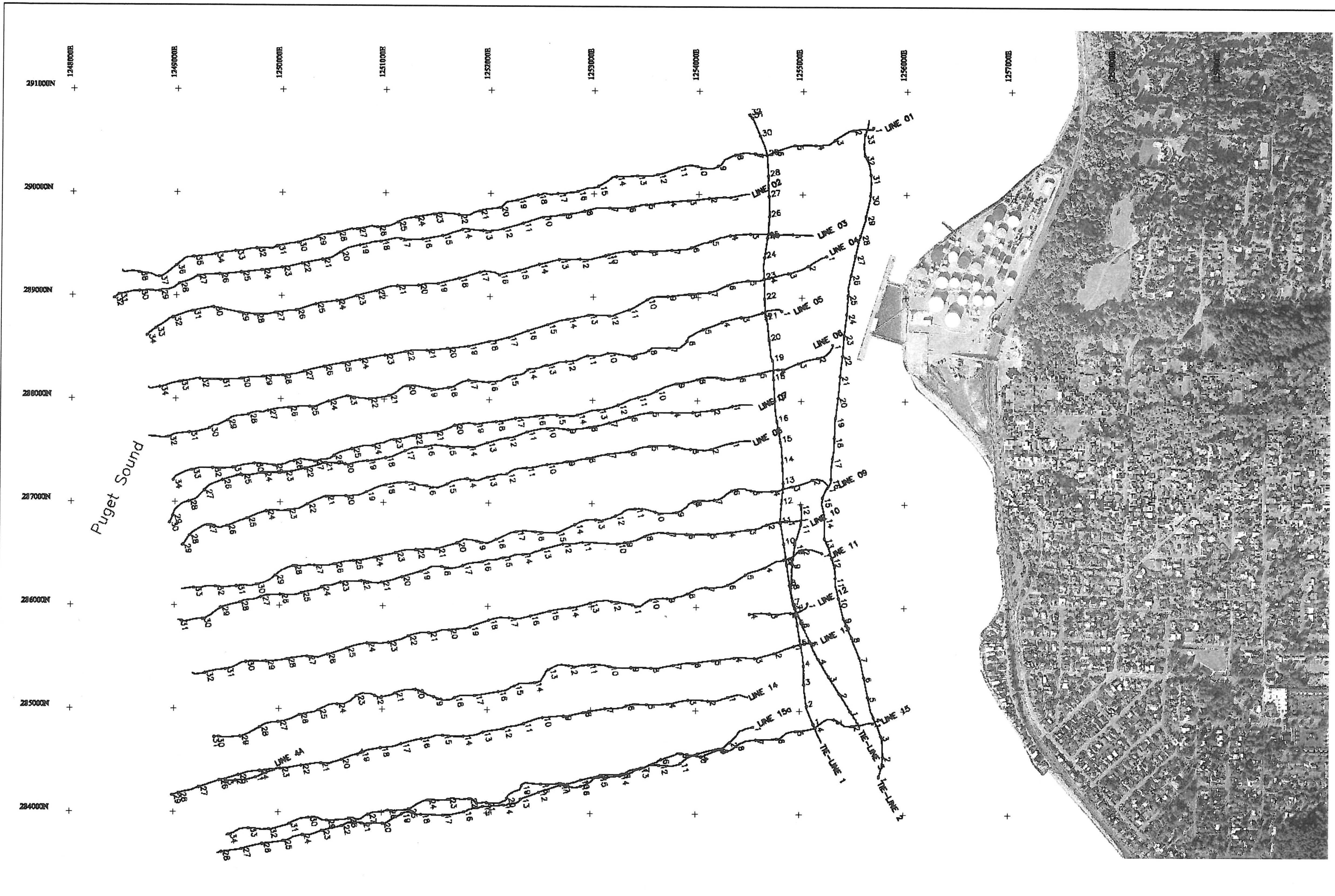
King County, 2002b. *Brightwater Regional Wastewater Treatment System Draft Environmental Impact Statement.* Seattle, Washington.

King County, 2002c. *Brightwater Marine Outfall Conceptual Design Report.* Seattle, Washington.



Notes:

System: AMS-120 Deep Seafloor Mapping System

Navigation: Trimble AG132 DGPS and Trackpoint II, Hypack Integration

Swath Width: 1,000 feet

Geodetic Parameters:

Horizontal Datum: NAD83/91

SPSC Zone: Washington North

Grid Units: U.S. Survey Feet

LEGEND

TRACKLINE WITH TIMING MARKS

N

0 500 1000 Feet

June 2003

King County
Department of Natural Resources and Parks
Wastewater Treatment Division

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Data Sources: Williamson and Associates, March 2003

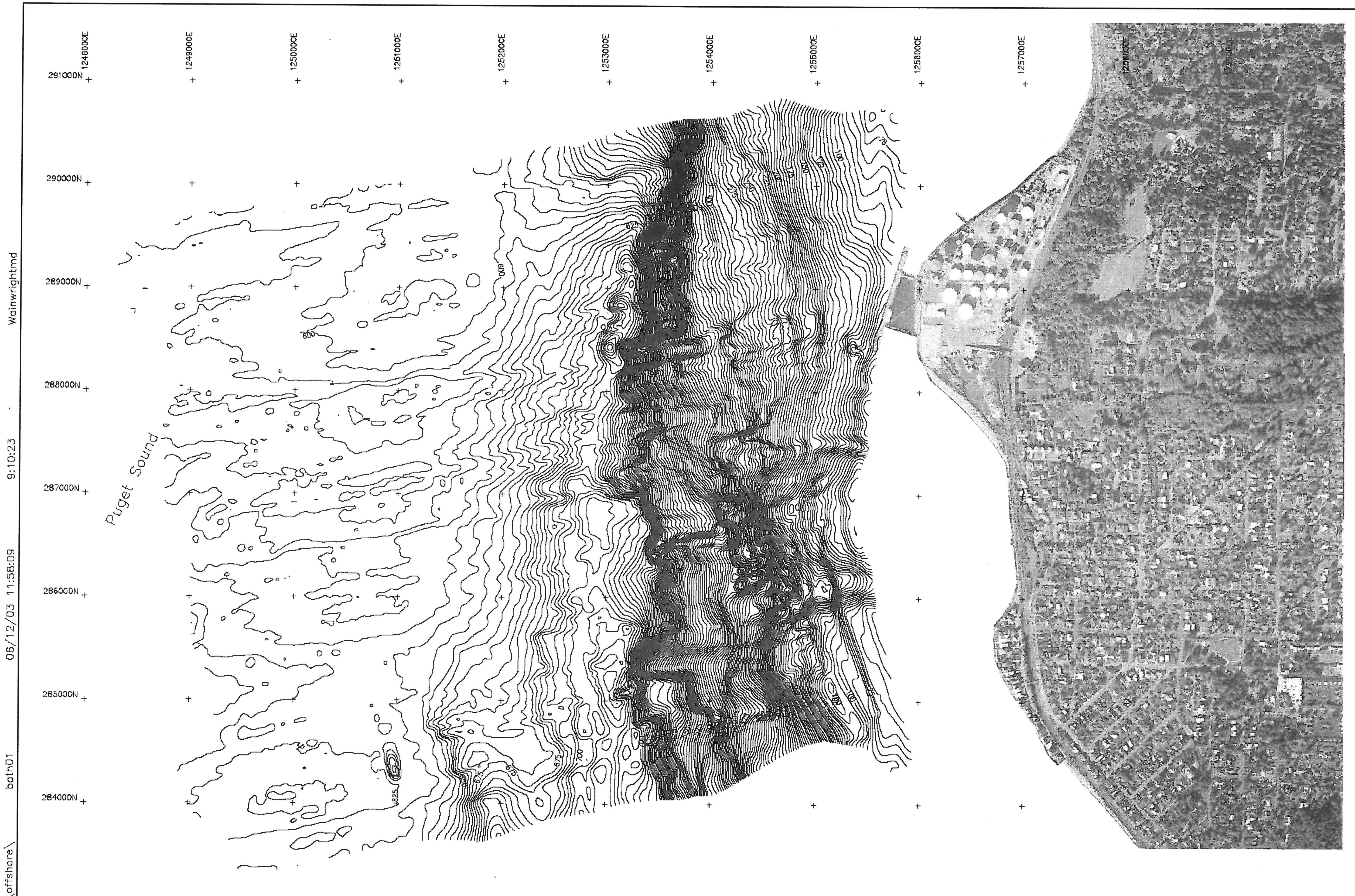
File Name: tm06cf01.dwg

Figure 1

AMS-120 Survey Tracklines

BRIGHTWATER REGIONAL WASTEWATER TREATMENT SYSTEM

P:\19897\37576\offshore\ track01 06/12/03 10:28:21 7:52:38 Wainwrightmd



Notes:

System: AMS-120 Deep Seafloor Mapping System

Navigation: Trimble AG132 DGPS and Trackpoint II, Hypack Integration

Swath Width: 1,000 feet

Geodetic Parameters:

Horizontal Datum: NAD88/91

SPSC Zone: Washington North

Grid Units: U.S. Survey Feet

Vertical Datum: MLLW

Conversions: MLLW = NAVD88 + 2.32 feet;
MLLW = Metro Datum - 93.96 feet

LEGEND

250 / 225 Bathymetric Contours (Depth)
Contour Interval = 5 feet

N

0 500 1000 Feet

June 2003

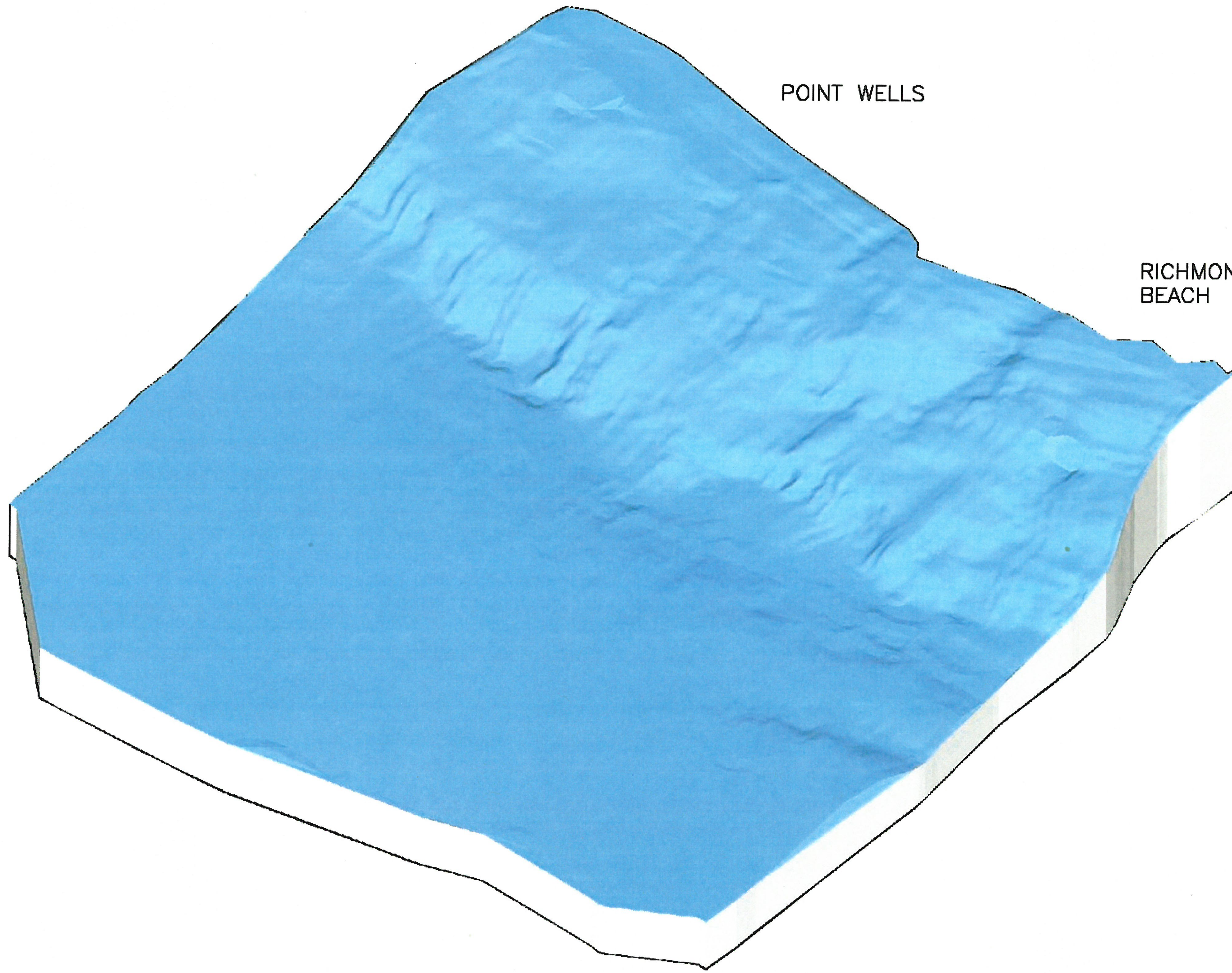
King County
Department of
Natural Resources and Parks
Wastewater Treatment Division

Data Sources: Williamson and Associates, March 2003

File Name: bath01.dwg

Figure 2
AMS-120 Survey Bathymetry
BRIGHTWATER REGIONAL
WASTEWATER TREATMENT SYSTEM

P:\19897\37576\offshore\ bath01 06/12/03 11:58:09 9:10:23 Wainwrightmd



Notes:

System: AMS-120 Deep Seafloor Mapping System

Navigation: Trimble AG132 DGPS and Trackpoint II, Hypack Integration

Swath Width: 1,000 feet

Geodetic Parameters:

Horizontal Datum: NAD83/91

SPSC Zone: Washington North

Grid Units: U.S. Survey Feet

King County
Department of Natural Resources and Parks
Wastewater Treatment Division

Data Sources: Williamson and Associates, March [illegible]

File Name: [illegible]

Figure 3

AMS-120 Survey 3-D Bathymetric Perspective

BRIGHTWATER REGIONAL WASTEWATER TREATMENT SYSTEM

P:\19897\37576\offshore\ 3d 06/12/03 11:06:35 11:33:46 Wainwrightmd

Notes:

System: AMS 120 Deep Seafloor Mapping System

Navigation: Trimble AG132 DGPS and Trackpoint II, Hypack Integration

Swath Width: 1,000 feet

Geodetic Parameters:

Horizontal Datum: NAD88/91

SPSC Zone: Washington North

Grid Units: U.S. Survey Feet

N

0 500 1000 Feet

June 2003

King County
Department of Natural Resources and Parks
Wastewater Treatment Division

Data Sources: Williamson and Associates, March 2003

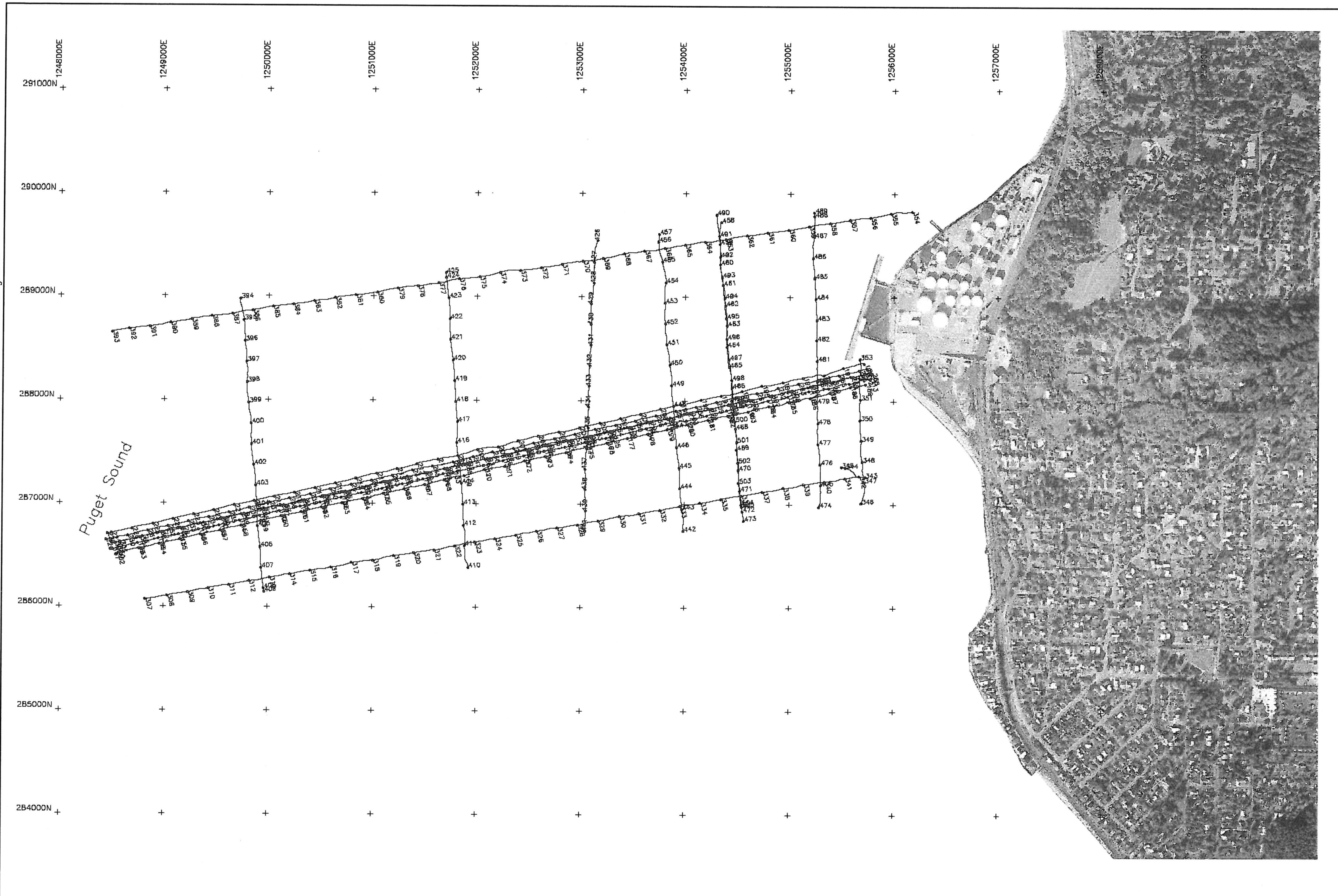
File Name: tm85af04.dwg

Figure 4

AMS-120 Survey Sidescan Mosaic

BRIGHTWATER REGIONAL WASTEWATER TREATMENT SYSTEM

P:\19597\37576\offshore\ CDM BWMosaic 06/12/03 10:57:13 6:07:23 Wainwrightmd



Notes:

System: Odem Echo Sounder System, Datasonics Sub-Bottom Profiler System, GeoAcoustics GeoPulse Shallow Seismic Profiling System

Navigation: Trimble AG132 DGPS and Trackpoint II, Hypack Integration

Geodetic Parameters:

Horizontal Datum: NAD88/91

SPSC Zone: Washington North

Grid Units: U.S. Survey Feet

LEGEND

Trackline with Timing Marks

N

0 500 1000 Feet

June 2003

King County
Department of
Natural Resources and Parks
Wastewater Treatment Division

Data Sources: Williamson and Associates, March 2003

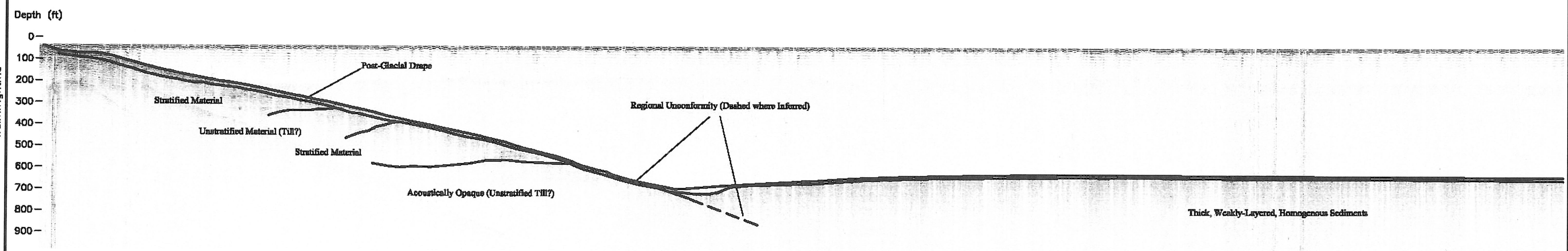
File Name: track02.dwg

Figure 5

Sub-Bottom Survey Tracklines

BRIGHTWATER REGIONAL WASTEWATER TREATMENT SYSTEM

P:\19897\37576\offshore\ sub-bottom 06/12/03 11:30:25 13:28:06 Wainwrightmd



Notes:

System: GeoAcoustics GeoPulse Shallow Seismic Profiling System

Navigation: Trimble AG132 DGPS and Trackpoint II, Hypack Integration

Vertical Exaggeration ~ 1.15x

0 250 500 Feet

June 2003

King County
Department of
Natural Resources and Parks
Wastewater Treatment
Division

Data Sources: Williamson and Associates, May 2003

File Name: [illegible]

Figure 6

Sub-Bottom Survey Centerline Profile

BRIGHTWATER REGIONAL WASTEWATER TREATMENT SYSTEM